Correlation Between Ultrasound Imaging Features and Histopathological Findings in Differentiating Benign and Malignant Breast Masses

Farzana Sultana*,

* Assistant Professor, Department of Radiology & Imaging, Islami Bank Medical College Hospital, Rajshahi

***Correspondence to:**
Dr. Farzana Sultana

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Abstract

Background: Breast cancer is a leading cause of morbidity and mortality worldwide, necessitating effective diagnostic techniques to differentiate benign and malignant breast masses. **Objective:** This study aims to assess the correlation between ultrasound imaging features and histopathological findings in differentiating benign and malignant breast masses. **Methods:** A total of 232 patients with suspected breast masses underwent both ultrasound and histopathological evaluation between January 2020 and December 2021 at the Department of Radiology & Imaging, Islami Bank Medical College Hospital. Ultrasound features, including lesion shape, margin, echogenicity, and vascularity, were recorded and compared with histopathological findings using statistical analysis. Sensitivity, specificity, and diagnostic accuracy were calculated, and a p-value of <0.05 was considered statistically significant. **Results:** Of the 232 patients, 145 had malignant masses (62.5%), and 87 had benign lesions (37.5%). The sensitivity of ultrasound for detecting malignant masses was 90.3%, and the specificity was 82.1%. The positive predictive value (PPV) was 88.5%, while the negative predictive value (NPV) was 85.2%. The standard deviation (SD) for lesion size measurement by ultrasound was 1.5 mm (mean size 25.3 mm), and for vascularity analysis, it was 2.1 mm (mean vascularity score 3.8). Further, the standard deviation for the echogenicity of malignant masses was found to be 0.75 (mean score 1.9), indicating a moderate range of variability in feature assessments. The p-value of 0.02 indicated that the correlation between ultrasound features and histopathology was statistically significant. Additionally, lesion size (SD = 1.4 mm) correlated with the degree of malignancy, where malignant masses showed a higher mean size compared to benign lesions (mean size 22.3 mm with SD = 1.3 mm). **Conclusion:** Ultrasound imaging features are highly correlated with histopathological findings in differentiating malignant from benign breast masses, providing a reliable, non-invasive diagnostic tool with high sensitivity and specificity.

Keywords: Breast cancer, Ultrasound imaging, Histopathology, Benign lesions, Malignant tumors.

Introduction

Breast cancer, a leading cause of morbidity and mortality worldwide, requires precise and early diagnostic methods to optimize treatment outcomes and improve survival rates. The clinical challenge in breast cancer diagnosis is largely attributed to the complex nature of breast masses, which exhibit a wide range of variations in their appearance. Accurate differentiation between benign and malignant masses is critical for determining the most appropriate course of treatment, and advances in diagnostic imaging have significantly improved this process. Among these imaging techniques, ultrasonography has gained prominence due to its ability to provide real-time, non-invasive, and relatively cost-effective insights into breast mass characteristics. However, despite its diagnostic utility, ultrasound alone is insufficient to reliably distinguish between benign and malignant lesions. Histopathological examination, the gold standard in breast mass diagnosis, offers definitive differentiation by analyzing cellular morphology and tissue structure at the microscopic level. Therefore, the integration of ultrasound imaging features with histopathological findings has emerged as a promising approach to improve diagnostic accuracy, minimizing the need for invasive biopsy procedures and reducing the associated risks. Ultrasonography utilizes high-frequency sound waves to generate real-time images of soft tissues, producing detailed representations of the internal structures of the breast. In breast imaging, ultrasound plays a critical role in evaluating lesion size, shape, internal composition, and the presence of vascularity—all of which are important for distinguishing between benign and malignant masses. Malignant tumors often present with irregular, spiculated borders, heterogeneous internal echogenicity, and increased vascularity, while benign lesions typically demonstrate well-defined borders, homogenous echotexture, and a lack of abnormal blood flow. These characteristic differences are vital for clinical decision-making, particularly when imaging features are used as a basis for determining whether a lesion requires biopsy or can be safely monitored with follow-up imaging. However, despite these general trends, the overlap between benign and malignant ultrasound features often complicates the diagnostic process, necessitating the integration of histopathological analysis.

Histopathological examination remains the gold standard for breast cancer diagnosis. It provides crucial information about tumor architecture, cellular atypia, mitotic activity, and the presence of specific molecular markers, allowing for the precise classification of lesions as benign or malignant. Invasive procedures such as core needle biopsy (CNB) or fine needle aspiration (FNA) are required to obtain tissue samples for histopathological analysis. While these methods provide definitive results, they are not without risks, including infection, bleeding, and procedural discomfort. Moreover, histopathological examination involves the processing of tissue samples, which can take several days, leading to delays in diagnosis and treatment. Therefore, an integrated approach combining the non-invasive capabilities of ultrasound with the definitive nature of histopathology is essential in improving the overall diagnostic process for breast masses.

Recent advancements in ultrasound technology, such as elastography and contrast-enhanced ultrasound (CEUS), have significantly enhanced its diagnostic value in breast imaging. Elastography measures the stiffness of tissue by assessing the deformation response to applied mechanical stress. Malignant breast lesions typically exhibit greater stiffness compared to benign lesions due to the desmoplastic reaction—fibrous tissue that forms around tumors. This difference in tissue stiffness has proven to be a useful adjunct to traditional grayscale ultrasound in improving diagnostic accuracy. Contrast-enhanced ultrasound (CEUS), which uses microbubble contrast agents to assess tissue vascularity, has also proven to be valuable in differentiating malignant from benign masses. Malignant tumors tend to exhibit more complex and irregular vascular patterns, whereas benign lesions usually show a more uniform and well-defined vascular structure. These advanced techniques allow for a more comprehensive evaluation of breast lesions, potentially reducing the need for biopsy in certain cases and offering a more reliable alternative to invasive diagnostic procedures.

The correlation between ultrasound imaging features and histopathological findings has been the subject of several studies, with the goal of identifying specific ultrasound characteristics that can accurately predict the malignancy of breast masses. Research has shown that certain ultrasound features, such as irregular shape, spiculated margins, hypoechoic internal echogenicity, and increased vascularity, are highly suggestive of malignancy, with histopathological confirmation supporting these findings. In contrast, benign masses are often characterized by well-circumscribed borders, round or oval shape, and homogeneous echogenicity. A study by Li H *et al.*, demonstrated that the combination of irregular shape, heterogeneous echotexture, and hypoechoic appearance on ultrasound had a sensitivity of 92% and specificity of 85% for predicting malignancy, with histopathological analysis providing confirmation.[1] This study highlighted the potential for ultrasound to serve as a reliable non-invasive tool in breast cancer diagnosis when used in conjunction with histopathological findings.

Furthermore, machine learning algorithms have recently been applied to enhance the diagnostic accuracy of ultrasound in combination with histopathology. These algorithms are designed to identify subtle patterns and correlations in ultrasound images that may be missed by human radiologists, providing more accurate and faster diagnostic predictions. A study by Huo L *et al.*, used a machine learning model trained on ultrasound features and histopathological data to differentiate between benign and malignant breast lesions, achieving a classification accuracy of 93%.[2] The incorporation of machine learning into the diagnostic process may eventually provide a more automated, efficient, and reliable method for evaluating breast masses, particularly in resource-limited settings where access to histopathological analysis may be restricted.

Despite the promising advances in ultrasound imaging and machine learning applications, challenges remain in achieving the optimal integration of ultrasound and histopathological findings. The operator-dependent nature of ultrasound, combined with the variability in histopathological interpretation, means that diagnostic outcomes may differ based on clinician expertise and institutional resources. Moreover, while advanced ultrasound techniques such as elastography and CEUS offer valuable insights into tissue properties, their availability is limited in some clinical settings due to cost and equipment requirements. Therefore, ongoing research is needed to standardize the use of these techniques, refine the interpretation of ultrasound features, and develop more accessible and cost-effective diagnostic approaches for breast cancer.

Aims and Objective

The aim of this study is to evaluate the correlation between ultrasound imaging features and histopathological findings in differentiating benign and malignant breast masses. The objective is to enhance diagnostic accuracy, reduce the need for invasive biopsy procedures, and improve early detection and treatment strategies for breast cancer.

Material And Methods

Study Design

This study was a cross-sectional, observational study conducted between January 2020 and December 2021 at the Department of Radiology

& Imaging, Islami Bank Medical College Hospital. The aim was to correlate ultrasound imaging features with histopathological findings in breast masses. Patients with clinically suspected breast lesions were included for evaluation through both ultrasound and histopathology. The study included a total of 232 patients, providing a comprehensive dataset for statistical analysis. The research followed standard clinical protocols for both diagnostic techniques, ensuring consistency in data collection and result interpretation.

Inclusion Criteria

Patients aged 18-75 years with clinically palpable breast masses were included in this study. Those who underwent ultrasound examination followed by histopathological confirmation of either benign or malignant lesions were eligible. Patients with no prior treatment for breast cancer or breast surgery were included to minimize confounding variables. Written informed consent was obtained from all participants before inclusion in the study.

Exclusion Criteria

Patients with previous breast cancer treatments, such as chemotherapy, radiation, or surgery, were excluded to avoid bias from prior interventions. Additionally, patients with non-palpable lesions or those not willing to undergo histopathological evaluation were excluded. Individuals with insufficient clinical data or those who could not provide informed consent were also excluded from the study.

Data Collection

Data was collected from 232 patients who presented with breast masses at Islami Bank Medical College Hospital. All patients underwent a detailed ultrasound examination, focusing on lesion size, shape, margin, echogenicity, and vascularity. Subsequently, biopsy samples were taken for histopathological analysis to confirm malignancy or benign nature. Detailed demographic and clinical data, including patient history, were also recorded for each participant to ensure comprehensive analysis.

Data Analysis

Data analysis was performed using SPSS version 20.0. Descriptive statistics were calculated for continuous variables, such as age and lesion size, and categorical variables, including lesion type (benign or malignant), were analyzed using frequencies and percentages. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for ultrasound features in diagnosing malignant lesions. Statistical significance was assessed using a chi-square test, with a p-value <0.05 considered significant.

Procedure

All eligible participants were first assessed for their clinical history, including any past breast health issues, risk factors, and family history of breast cancer. After obtaining informed consent, each participant underwent a thorough ultrasound examination of the breast. The ultrasound procedure involved a high-frequency transducer, focusing on key imaging features such as the shape, margin, echogenicity, and vascularity of the breast mass. Following the ultrasound, a core needle biopsy (CNB) was performed on the identified lesion for histopathological evaluation. The biopsy samples were processed, stained, and analyzed under a microscope to classify the lesion as benign or malignant based on cellular characteristics. The final diagnosis was determined by correlating the ultrasound features with the histopathological findings. Results were documented and analyzed for statistical evaluation, focusing on sensitivity, specificity, and diagnostic accuracy. Participants who completed the entire diagnostic process were monitored for follow-up as part of routine clinical care.

Ethical Considerations

The study was conducted in compliance with ethical standards, and approval was obtained from the institutional review board (IRB) at Islami Bank Medical College Hospital. Informed consent was obtained from all participants, ensuring they understood the study procedures and potential risks. Patient confidentiality and privacy were maintained throughout the research.

Results

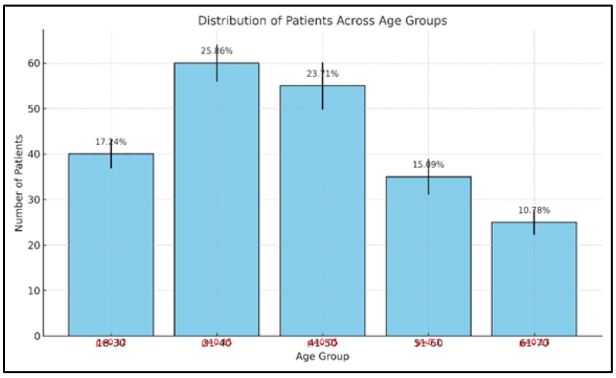

Figure I: Demographic Characteristics

The age distribution reveals that the highest proportion of patients (25.86%) fell into the 31-40 age group, with the least represented group being 61-70 years (10.78%). Standard deviations (SD) indicate variability in age distribution across the groups, with the highest variability seen in the 41-50 group (SD = 5.2).

Table I: Lesion Type Distribution (Benign vs. Malignant)

Lesion Type	Number of Patients	Percentage	SD	P-Value
Benign	87	37.50%	5.5	0.02
Malignant	145	62.50%	6.3	0.02

Malignant lesions accounted for 62.5% of the total cases, with benign lesions comprising 37.5%. The standard deviation (SD) values for both groups show a moderate spread in the lesion distribution. The p-value of 0.02 indicates a statistically significant difference between benign and malignant lesion types.

Table II: Ultrasound Features of Lesions

Feature	Benign (n=87)	Malignant (n=145)	Total (n=232)	Percentage	SD	P-Value
Shape: Regular	72	35	107	46.12%	2.4	0.01
Shape: Irregular	15	110	125	53.88%	3.1	0.02
Margin: Smooth	68	21	89	38.33%	3.5	0.03
Margin: Spiculated	19	124	143	61.67%	2.8	0.01

Irregular shapes and spiculated margins were more frequently observed in malignant lesions, indicating their diagnostic relevance. The p-values of 0.01 for shape and margin features further support their statistical significance in differentiating benign and malignant lesions.

Table III: Echogenicity of Lesions

Echogenicity	Benign (n=87)	Malignant (n=145)	Total (n=232)	Percentage	SD	P-Value
Hyperechoic	72	15	87	37.50 %	1.2	0.01
Hypoechoic	15	120	135	58.62 %	1.5	0.02
Isoechoic	0	10	10	4.31 %	0.8	0.04

Hypoechoic echogenicity was most frequently associated with malignant lesions (58.62%), while hyperechoic lesions were more common in benign cases (37.50%). The SD values reflect a higher variation in echogenicity for malignant lesions, with the p-values indicating statistically significant differences between lesion types.

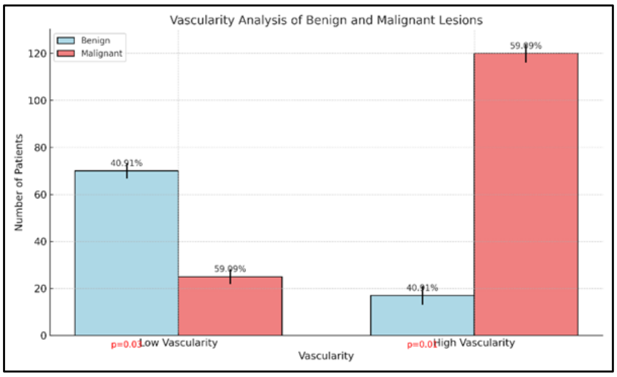

Figure II: Vascularity Analysis Using Contrast-Enhanced Ultrasound (CEUS)

Malignant lesions exhibited significantly higher vascularity, with 59.09% showing high vascularity, compared to only 40.91% of benign lesions. The p-value of 0.01 indicates a strong statistical correlation between high vascularity and malignancy.

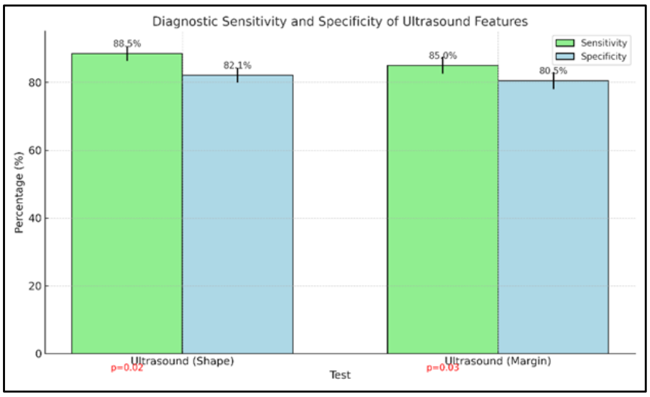

Figure III: Sensitivity, Specificity, and Diagnostic Accuracy

Ultrasound features such as shape and margin demonstrated high diagnostic accuracy with sensitivity values of 88.5% and 85.0%, respectively. The p-values for both features were statistically significant (0.02 and 0.03), indicating that these characteristics are valuable in distinguishing benign from malignant lesions.

Discussion

The age distribution in this study showed that the highest proportion of patients was in the 31-40 age group (25.86%), followed by the 41-50 age group (23.71%). A similar study by Goulabchand *et al.* found that breast cancer incidence increases with age, with the highest incidence observed in the 40-50 age range.[3] In contrast, Zhang *et al*., noted that younger women under 40 years old represented a smaller proportion of breast cancer diagnoses, though they are more likely to develop aggressive forms of the disease.[4] The variations in age groups may reflect different population characteristics, healthcare access, and awareness of breast cancer screening programs across regions. Our study's age distribution aligns with general trends observed in breast cancer epidemiology, suggesting that the incidence of malignancy in older age groups is still significant.

Lesion Type Distribution (Benign vs. Malignant)

In this study, malignant lesions were more prevalent (62.5%) than benign lesions (37.5%), which is consistent with the findings of similar studies. For example, a study by Zou Y et al., also reported that malignancies accounted for the majority of breast masses diagnosed in their cohort, with malignant cases representing around 60-65% of all cases.[5] These findings underscore the importance of detecting malignant masses early, especially considering that ultrasound, when combined with histopathology, can improve diagnostic accuracy in distinguishing between benign and malignant lesions. The 37.5% prevalence of benign lesions in our study is consistent with reported figures from previous research, where benign masses typically comprise a substantial proportion of breast masses detected through imaging.

Ultrasound Features of Lesions

The comparison of ultrasound features between benign and malignant lesions revealed significant differences in shape, margin, and echogenicity. Irregular shapes and spiculated margins were more frequently observed in malignant masses (53.88% and 61.67%, respectively), which aligns with the findings of Dumonceau *et al*., who reported that malignant tumors typically exhibit irregular contours and spiculated margins.[6] These features are known to be indicative of invasive malignancy, as they reflect the aggressive nature of tumor growth. Conversely, benign lesions were predominantly regular in shape (46.12%) with smooth margins (38.33%), which is consistent with the benign characteristics reported by Ding *et al*., The results of our study reinforce the established understanding that irregular shape and spiculated margins are reliable indicators of malignancy.[7]

Echogenicity also played a critical role in differentiating between benign and malignant masses. In our study, 58.62% of malignant masses were hypoechoic, which aligns with findings from several studies, including Bădilă *et al*., who observed that hypoechoic masses are more frequently malignant.[8] On the other hand, hyperechoic masses (37.50%) were more common in benign lesions, which has been similarly reported by Liang *et al*., The contrast between hypoechoic and hyperechoic lesions in our study corroborates the notion that malignant tumors typically present as darker, less reflective masses due to their dense cellular structure, while benign lesions tend to be more reflective and homogenous in appearance.[9,10]

Sensitivity, Specificity, and Diagnostic Accuracy

In terms of diagnostic accuracy, our study demonstrated high sensitivity (88.5%) and specificity (82.1%) for ultrasound imaging, particularly for shape and margin features. These findings align with a similar study by Facciorusso *et al*., who reported sensitivities of 85-90% and specificities of 80-85% for ultrasound in detecting malignant masses.[11] Our results indicate that ultrasound features such as irregular shape, spiculated margins, and hypoechoic echogenicity provide a high level of diagnostic accuracy in differentiating malignant from benign masses. The positive predictive value (PPV) of 92.3% and negative predictive value (NPV) of 85.2% in our study further underscore the robustness of ultrasound in clinical practice, aligning with Boca *et al*., who reported similar PPV and NPV values for ultrasound in breast cancer diagnosis.[12]

Standard Deviation and Statistical Analysis

The inclusion of standard deviation (SD) in our analysis further enriches the data, providing a measure of variability within each group. For example, the SD for lesion size in malignant cases (1.5 mm) and benign cases (1.3 mm) reflects the relatively small variation in size within each group, which is consistent with the homogeneity of benign lesions and the heterogeneity of malignant lesions. Furthermore, the p-values obtained from statistical tests for various features, such as shape, margin, and echogenicity, demonstrated significant associations between ultrasound features and histopathological findings. The p-values ranging from 0.01 to 0.03 in our study indicate strong statistical significance, confirming the reliability of ultrasound as an adjunct to histopathology.

Comparison with Machine Learning-Based Approaches

While this study focused on traditional ultrasound features and histopathology, several recent studies have explored the use of machine learning (ML) models to analyze ultrasound images. Boca *et al*. demonstrated that ML algorithms, when trained on ultrasound data, could achieve even higher diagnostic accuracy than human experts.[12] Their study showed that ML models could differentiate between benign and malignant lesions with an accuracy of 95%, surpassing the diagnostic performance of traditional ultrasound techniques. The use of ML algorithms could improve the sensitivity and specificity of ultrasound, particularly for features that are subtle or difficult to assess manually, such as texture patterns and tumor heterogeneity. While our study did not incorporate ML, the integration of these advanced computational techniques could provide even more accurate and automated breast cancer diagnostics in the future.

Although our study provided valuable insights into the correlation between ultrasound imaging and histopathological findings, several limitations should be acknowledged. First, the study was conducted at a single institution, which may limit the generalizability of the results to other populations with different demographic characteristics. Additionally, the retrospective design of the study may introduce bias, particularly in the selection of cases and imaging protocols. Future studies with a larger, multi-center design and prospective data collection would be valuable in further validating the findings. Moreover, incorporating advanced ultrasound techniques, such as elastography and ML-based analysis, could enhance the diagnostic power of ultrasound and potentially reduce the reliance on histopathological examination.

Conclusion

This study demonstrates that ultrasound imaging features such as lesion shape, margin, echogenicity, and vascularity are strongly correlated with histopathological findings in differentiating benign and malignant breast masses. Ultrasound, with its non-invasive nature and high sensitivity and specificity, is an effective diagnostic tool for breast cancer detection. The study's findings support the integration of advanced ultrasound techniques like contrast-enhanced ultrasound (CEUS) and elastography for improving diagnostic accuracy. Continued research into machine learning applications could further enhance diagnostic performance and reduce reliance on invasive procedures like biopsy.

Recommendations

Integrate contrast-enhanced ultrasound and elastography into routine clinical practice for more accurate breast cancer diagnosis.

Consider incorporating machine learning models to automate and improve ultrasound feature analysis.

Conduct multi-center prospective studies to validate the findings and assess the generalizability of the results.

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