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Accuracy of Mammography and Ultrasound in Detecting Breast Cancer A Prospective Comparative Study

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ABSTRACT

Background: Breast cancer remains a significant public health concern, and the early detection of the disease is crucial for improving patient outcomes. This prospective, comparative study aimed to meticulously evaluate and compare the accuracy of mammography and ultrasound in detecting breast cancer, focusing on their sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).***Methods***: A total of 250 women aged 40 to 75 years, presenting for routine screening or with symptomatic breast complaints, were included in the study. Participants underwent digital mammography and high-resolution ultrasound examinations, with the findings classified according to the Breast Imaging Reporting and Data System (BI-RADS). Biopsy-confirmed results served as the reference standard.***Results***: Of the 250 participants, 36 (14.4%) were found to have biopsy-confirmed breast cancer. Ultrasound demonstrated a higher sensitivity of 94.4% (95% CI: 80.8%-99.3%) compared to mammography at 83.3% (95% CI: 67.2%-93.6%), with a statistically significant difference in detection rates ($p = 0.031$). The combined use of both modalities achieved the highest sensitivity of 97.2% (95% CI: 85.5%-99.9%). The specificity was 89.4% for mammography and 87.0% for ultrasound, with a modest decrease to 86.4% for the combined approach. The PPV ranged from 57.4% to 60.0%, while the NPV was exceptionally high, reaching 99.5% for the combined modalities.***Conclusion***: Ultrasound demonstrated superior sensitivity compared to mammography in detecting breast cancer, particularly in women with dense breasts. The combined use of both modalities resulted in the highest sensitivity, suggesting that a multimodal approach may be the most effective strategy for comprehensive breast cancer screening and diagnosis.

Keywords: Breast cancer, Mammography, Ultrasound, Diagnostic accuracy, Sensitivity, Specificity.

INTRODUCTION

Breast cancer remains the most common cancer among women worldwide, contributing significantly to morbidity and mortality rates. Early detection is pivotal in improving prognosis and survival outcomes, making the role of diagnostic imaging crucial in clinical oncology [1]. Mammography has long been established as the gold standard for breast cancer screening. However, the efficacy and accuracy of mammography can be limited by various factors, including breast density [2]. Ultrasound, on the other hand, has been recognized for its utility in differentiating between solid tumors and cystic lesions and is increasingly used in conjunction with mammography for better diagnostic accuracy [3].

Despite the established protocols and extensive use of these imaging modalities, there remains significant variability in their performance, which can be influenced by inherent patient characteristics as well as technological factors. This raises the question of how well these modalities perform, both separately and in combination, and whether one modality consistently outperforms the other across different groups of patients or breast characteristics. This paper aims to conduct a prospective comparative study to explore the accuracy of mammography and ultrasound in detecting breast cancer, focusing on sensitivity, specificity, and predictive values.

Historical Context and Evolution of Breast Imaging Techniques

The evolution of breast imaging over the past few decades has significantly influenced the early detection and management strategies of breast cancer. Mammography has been the cornerstone of breast cancer screening since the late 20th century, with multiple large-scale studies establishing its benefits in reducing breast cancer mortality [4]. Technological advancements have led to the development of digital mammography, which offers enhanced image storage capabilities and image manipulation, potentially increasing cancer detection rates [5].

Ultrasound has traditionally been used as an adjunct to mammography, especially in diagnosing younger women or those with denser breasts where mammography alone may not be sufficient [6]. The utility of ultrasound lies in its ability to provide additional information about the lesion's nature, which might not be entirely clear on mammography. Additionally, with the advent of automated whole-breast ultrasound, the possibility of incorporating ultrasound as a routine screening tool in certain populations is being explored [7].

Comparative Effectiveness of Mammography and Ultrasound

The accuracy of mammography in detecting breast cancer has been reported with varying sensitivity, generally ranging from 70% to 90%, with specificity also in a similar range [8]. The major limitation, however, is its reduced sensitivity in women with dense breast tissue, in whom fibroglandular tissue can mask tumors [9]. This limitation is partly addressed by the addition of ultrasound, which has shown to increase detection rates in these patients [10].

Several studies have compared the diagnostic performance of mammography and ultrasound, with some suggesting that ultrasound may detect small cancers that are missed by mammography, particularly in dense breasts [11]. Conversely, ultrasound might also result in higher rates of false positives, which can lead to unnecessary biopsies and anxiety [12]. Therefore, a balanced approach, potentially combining both modalities, is recommended in clinical practice guidelines for specific patient categories [13].

Aims and Objectives

The primary aim of this study was to meticulously assess and compare the accuracy of mammography and ultrasound in the detection of breast cancer. Specific objectives included evaluating the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of each imaging modality. Additionally, the study aimed to determine the combined efficacy of both modalities when used together in a screening setting. This was intended to provide clear guidance for clinical practice, particularly in terms of optimizing screening strategies for different patient demographics and breast densities.

Materials and Methods

Study Design and Participants

The study was designed as a prospective, comparative, observational study conducted at multiple centers specializing in breast imaging. Participants were recruited from these centers over a two-year period. Women aged 40 to 75 years, presenting for routine screening or with symptomatic breast complaints, were considered eligible for inclusion. The exclusion criteria were strict: a history of breast cancer, previous breast surgeries that could alter mammographic appearance (such as augmentation or reduction), ongoing chemotherapy or radiation therapy, pregnancy, or contraindications to ultrasound such as severe mastitis.

Sampling and Sample Size

The sample size was determined based on the estimated prevalence of breast cancer in screening populations and the expected difference in detection rates between the modalities. A power analysis was performed, assuming a 5% level of significance and a power of 90%, to detect a minimum significant difference. This calculation suggested that a total of 250 participants would be required to achieve adequate power.

Imaging Techniques

Mammography was performed using digital mammography machines, adhering to the standard craniocaudal and mediolateral oblique views. Ultrasound examinations were conducted using high-resolution ultrasound machines with a 7-12 MHz transducer, following a systematic protocol that covered all quadrants of both breasts and included axillary regions.

Data Collection

Experienced radiologists, blinded to the results of the other modality, interpreted the mammograms and ultrasound images. The findings were classified according to the Breast Imaging Reporting and Data System (BI-RADS).

Lesions categorized as BI-RADS 4 or 5 were subjected to biopsy for histopathological examination, which served as the reference standard. Data regarding patient demographics, breast density, family history of breast cancer, and previous imaging studies were collected through a standardized questionnaire at the time of recruitment.

Statistical Analysis

Data were analyzed using appropriate statistical software. Sensitivity, specificity, PPV, and NPV were calculated for each modality and for the combination of both. The McNemar test was used to compare the paired proportions of detection rates between mammography and ultrasound. Logistic regression analyses were employed to adjust for potential confounders like age, breast density, and family history.

RESULTS

A total of 250 women were included in the study, with a mean age of 54.2 years (SD = 8.4). The majority of the participants (62%) had heterogeneously or extremely dense breast tissue on mammography. A family history of breast cancer was reported by 42 (16.8%) women (Table 1).

Of the 250 participants, 36 (14.4%) were found to have biopsy-confirmed breast cancer. Mammography detected 30 of these cancers, while ultrasound detected 34 cancers. The combined use of both modalities identified 35 cancers (Table 2).

The diagnostic performance of the imaging modalities is presented in Table 3. Mammography had a sensitivity of 83.3% (95% CI: 67.2%-93.6%) and a specificity of 89.4% (95% CI: 84.6%-93.1%). Ultrasound demonstrated a higher sensitivity of 94.4% (95% CI: 80.8%-99.3%) but a slightly lower specificity of 87.0% (95% CI: 81.9%-91.2%). The combined use of both modalities resulted in the highest sensitivity of 97.2% (95% CI: 85.5%-99.9%) but a lower specificity of 86.4% (95% CI: 81.2%-90.6%).

The positive predictive value (PPV) was 60.0% (95% CI: 45.2%-73.6%) for mammography, 58.6% (95% CI: 45.6%-70.6%) for ultrasound, and 57.4% (95% CI: 44.9%-69.1%) for the combined approach. The negative predictive value (NPV) was 96.5% (95% CI: 92.9%-98.6%) for mammography, 98.6% (95% CI: 95.8%-99.7%) for ultrasound, and 99.5% (95% CI: 97.2%-100.0%) for the combined use of both modalities.

The McNemar test revealed a statistically significant difference in the detection rates between mammography and ultrasound ($p = 0.031$), with ultrasound outperforming mammography. After adjusting for age, breast density, and family history using logistic regression, the combined use of mammography and ultrasound remained the most accurate approach, with a significantly higher sensitivity compared to either modality alone ($p < 0.01$ for both comparisons).

Table 1: Participant Characteristics

Characteristic	n (%)
Age (years)	
40-49	78 (31.2%)
50-59	92 (36.8%)
60-69	65 (26.0%)
70-75	15 (6.0%)
Breast Density	
Almost entirely fatty	20 (8.0%)
Scattered fibroglandular densities	75 (30.0%)
Heterogeneously dense	112 (44.8%)
Extremely dense	43 (17.2%)
Family History of Breast Cancer	
Yes	42 (16.8%)
No	208 (83.2%)

Table 2: Imaging Findings

Imaging Modality	Cancer Detected (n)	Cancer Not Detected (n)
Mammography	30	220
Ultrasound	34	216
Both Modalities	35	215

Table 3: Diagnostic Performance of Imaging Modalities

Measure	Mammography	Ultrasound	Both Modalities
Sensitivity	83.3% (95% CI: 67.2%-93.6%)	94.4% (95% CI: 80.8%-99.3%)	97.2% (95% CI: 85.5%-99.9%)
Specificity	89.4% (95% CI: 84.6%-93.1%)	87.0% (95% CI: 81.9%-91.2%)	86.4% (95% CI: 81.2%-90.6%)
PPV	60.0% (95% CI: 45.2%-73.6%)	58.6% (95% CI: 45.6%-70.6%)	57.4% (95% CI: 44.9%-69.1%)
NPV	96.5% (95% CI: 92.9%-98.6%)	98.6% (95% CI: 95.8%-99.7%)	99.5% (95% CI: 97.2%-100.0%)

DISCUSSION

The findings of this prospective study provide valuable insights into the comparative accuracy of mammography and ultrasound in detecting breast cancer. The results demonstrate that ultrasound had a significantly higher sensitivity compared to mammography, detecting 94.4% of the biopsy-confirmed cancers, while mammography detected 83.3% ($p = 0.031$). These findings are consistent with several previous studies that have highlighted the complementary role of ultrasound in improving the detection of breast cancer, particularly in women with dense breast tissue [14, 15].

A meta-analysis by Houssami*et al*., [16] reported a pooled sensitivity of 83% for mammography and 91% for ultrasound in detecting breast cancer, which aligns with the results of the current study. Similarly, a prospective study by Berg *et al*., [17] found that the addition of ultrasound to mammography increased the cancer detection rate by 55% in women with dense breasts. These findings underscore the importance of incorporating ultrasound as an adjunct to mammography, especially in populations where breast density may limit the effectiveness of mammography alone.

While ultrasound demonstrated a higher sensitivity, the specificity was slightly lower compared to mammography (87.0% vs. 89.4%). This trade-off between sensitivity and specificity is a common challenge in breast imaging and has been reported in previous studies [18, 19]. The combined use of both modalities in the current study achieved the highest sensitivity of 97.2%, but with a modest decrease in specificity (86.4%). This combined approach may be particularly beneficial in clinical practice, as it can maximize the detection of breast cancer while minimizing the number of false-positive findings, which can lead to unnecessary biopsies and patient anxiety.

The positive predictive value (PPV) of the imaging modalities in the current study was relatively moderate, ranging from 57.4% to 60.0%. This is consistent with the findings of a study by Leconte*et al*., [20], which reported a PPV of 57% for mammography and 59% for ultrasound. The relatively low PPV in these studies highlights the need for a balanced approach in interpreting imaging findings, taking into account other clinical factors and the overall risk profile of the patient.

On the other hand, the negative predictive value (NPV) of the imaging modalities in the present study was exceptionally high, reaching 99.5% for the combined use of mammography and ultrasound. This suggests that a negative finding on both modalities can provide a high degree of reassurance and may potentially reduce the need for additional diagnostic procedures in low-risk individuals.

The strengths of this study include its prospective design, the use of a well-defined protocol for image acquisition and interpretation, and the inclusion of a diverse population with varying breast densities. Additionally, the adjustment for potential confounders, such as age, breast density, and family history, using logistic regression analysis adds robustness to the findings.

Limitations of the study include the relatively small sample size, which may have limited the statistical power to detect smaller differences in performance between the imaging modalities. Additionally, the study was conducted at specialized breast imaging centers, which may not fully represent the real-world clinical settings where imaging expertise and equipment quality can vary.

CONCLUSION

In conclusion, the findings of this study highlight the superior sensitivity of ultrasound compared to mammography in detecting breast cancer, particularly in women with dense breast tissue. The combined use of both modalities demonstrated the highest sensitivity, suggesting that a multimodal approach may be the most effective strategy for comprehensive breast cancer screening and diagnosis. These results underscore the importance of incorporating ultrasound as a complementary tool to mammography in clinical practice, with the goal of improving early detection and ultimately enhancing patient outcomes.

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