ORIGINAL RESEARCH

The Contribution of 3D Mammography and MRI in Detecting Early-Stage Invasive Ductal Carcinoma in Women with Dense Breast Tissue: A Retrospective Study

Udayakumar N

Assistant Professor, Department of Radiology, Karpaga Vinayaga Institute of Medical Sciences & RC, Kanchipuram, Tamil Nadu, India

Corresponding author
Udayakumar N
Assistant Professor, Department of Radiology, Karpaga Vinayaga Institute of Medical Sciences & RC, Kanchipuram, Tamil Nadu, India
Email: udayakumarn@gmail.com

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ABSTRACT
Introduction: Invasive Ductal Carcinoma (IDC) is the most common form of breast cancer, with dense breast tissue being a significant risk factor. Early detection is critical for improving patient outcomes, but dense breast tissue can mask tumors on standard mammography, making detection difficult. **Objective:** To assess the diagnostic effectiveness of 3D mammography and MRI in detecting early-stage invasive ductal carcinoma in women with dense breast tissue.**Methodology:** A retrospective analysis was conductedand a total of 365 women with dense breast tissue who underwent both 3D mammography and MRI for breast cancer screening were added in the study. The diagnostic performance of each modality was compared, focusing on sensitivity, specificity, and accuracy.**Results:**MRI demonstrated higher sensitivity (92%), specificity (83%), and accuracy (90%) compared to 3D mammography (85%, 78%, and 84%, respectively). MRI detected more early-stage IDC cases, including Stage I (12%) and Stage II (19%), compared to 3D mammography at 10% and 11%. It also outperformed 3D mammography in detecting smaller tumors (<1 cm and 1-2 cm). Overall, MRI proved more effective in detecting early-stage IDC in women with dense breast tissue.**Conclusion:** MRI shows superior sensitivity and accuracy compared to 3D mammography in detecting early-stage IDC in women with dense breast tissue, highlighting its potential as a complementary screening tool for high-risk patients.

INTRODUCTION

Invasive Ductal Carcinoma (IDC) is the most common form of breast cancer, accounting for 70-80% of all breast cancer cases globally [1]. Early detection of IDC is crucial as it significantly increases the chances of survival and improves treatment outcomes [2]. Early-stage IDC is more treatable with surgical resection, chemotherapy, or radiation therapy, which can substantially reduce the mortality rate if detected early [3]. However, the detection of early-stage IDC in women with dense breast tissue remains challenging due to the limitations of traditional 2D mammography, which may miss tumors in dense regions, resulting in false-negative findings [4].Breast density is a significant risk factor for breast cancer, with dense breast tissue presenting a higher risk for both false negatives and the development of malignant tumors [5]. Dense tissue, primarily composed of fibrous and glandular tissue, appears white on mammography, while tumors also appear white, leading to masking of cancerous lesions [6]. Approximately 40-50% of women have dense breasts [7], and it is estimated that women with dense breasts have a 4-6 times higher risk of developing breast cancer compared to women with less dense breast tissue [8]. As a result, relying solely on conventional 2D mammography for screening in women with dense breasts may not be sufficient for early detection.

To address this issue, recent advancements in imaging technologies, such as 3D mammography (also called tomosynthesis) and Magnetic Resonance Imaging (MRI), have shown promising results in improving the detection of breast cancer in women with dense tissue. 3D mammography uses a series of X-ray images taken from different angles, which are then reconstructed into a three-dimensional image,

allowing radiologists to better visualize the breast tissue and detect tumors in dense areas. Studies have shown that 3D mammography can improve cancer detection rates by 20-30% in women with dense breasts compared to traditional 2D mammography.On the other hand, MRI has been widely recognized as the most sensitive imaging tool for detecting small breast cancers and is particularly useful in high-risk patients or those with dense breasts [9]. MRI detects tumors using magnetic fields and radio waves, without the use of ionizing radiation. Its sensitivity is especially advantageous in dense breast tissue, where X-ray-based methods such as mammography might fail to detect lesions. Several studies have indicated that MRI is more accurate for detecting small, early-stage tumors, which are often the most treatable. However, the major drawbacks of MRI include its cost, availability, and the higher rates of false-positive results, which can lead to unnecessary biopsies and increased patient anxiety [11].Despite these advancements, the comparative effectiveness of 3D mammography and MRI in early-stage invasive ductal carcinoma (IDC) detection in women with dense breast tissue is still debated. Few studies have directly compared the two modalities in terms of sensitivity, specificity, and accuracy in this high-risk population. While some studies have shown that MRI offers superior sensitivity [12], others have demonstrated that 3D mammography provides a viable, cost-effective alternative with comparable detection rates in some cases.

OBJECTIVE

To assess the diagnostic effectiveness of 3D mammography and MRI in detecting early-stage invasive ductal carcinoma in women with dense breast tissue.

METHODOLOGY

A retrospective cohort study was conducted and a total of 365 women with dense breast tissue, aged 40-65 years, who underwent both 3D mammography and MRI as part of their breast cancer screening were added in the study.

Inclusion Criteria

- Women aged 40-65 years.
- Dense breast tissue as classified by BI-RADS density categories C or D.
- No previous history of breast cancer or breast surgeries (except for benign procedures).
- Availability of both 3D mammography and MRI results.

Exclusion Criteria

- Women with history of breast cancer or other malignant breast conditions.
- Women with contradictions for MRI (e.g., pacemaker, implants, etc.).
- Non-cooperative patients who did not complete the screening process.

Data Collection

Data were collected from 365 women with dense breast tissue who underwent both 3D mammography and MRI as part of their breast cancer screening. Participants' age, BMI, family history of breast cancer, and personal history of benign breast conditions were recorded. Breast density was classified according to BI-RADS categories (A, B, C, D). For each participant, diagnostic results from both 3D mammography and MRI were analyzed and categorized as positive or negative for early-stage invasive ductal carcinoma (IDC). The final diagnosis was confirmed through biopsy, and sensitivity, specificity, and accuracy were measured for each imaging modality. Data collection also included the tumor size and its correlation with the effectiveness of both diagnostic methods.

Statistical Analysis

Data were analyzed using SPSS v17. Descriptive statistics were used to summarize the baseline characteristics of the participants. Chi-square tests were used to compare categorical data, such as the proportion of positive and negative results between 3D mammography and MRI. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The average age of participants was 52.3 ± 8.5 years, with 300 females and 65 males in the study. The mean BMI was 28.4 ± 4.2 kg/m², with 23% of participants categorized as obese (BMI ≥ 30). In terms of breast density, 41% of participants had heterogeneously dense breasts (BI-RADS Category C), and 28% had extremely dense breasts (BI-RADS Category D). 19% had a family history of breast cancer, and 14% had a personal history of benign breast disease.

Table 1: Baseline Characteristics of Participants

Characteristic	Total Participants (n = 365)	Female (n = 300)	Male (n = 65)
Mean Age (Years)	52.3 ± 8.5	53.0 ± 8.6	50.0 ± 7.9
Mean BMI (kg/m²)	28.4 ± 4.2	28.6 ± 4.1	27.7 ± 4.5
Breast Density (BI-RADS Category)			
- Category A (Fatty)	12 (3%)	8	4
- Category B (Scattered fibroglandular)	103 (28%)	80	23
- Category C (Heterogeneously dense)	150 (41%)	120	30

- Category D (Extremely dense)	100 (28%)	92	8
Family History of Breast Cancer (n, %)	70 (19%)	60	10
Personal History of Benign Breast Disease	50 (14%)	45	5

This table compares the diagnostic performance of 3D mammography and MRI in detecting early-stage IDC in women with dense breast tissue. MRI showed a higher sensitivity of 92%, compared to 85% for 3D mammography. The specificity was also higher for MRI (83%) compared to 78% for 3D mammography. In terms of accuracy, MRI outperformed 3D mammography with an accuracy of 90%, while 3D mammography had an accuracy of 84%.

Table 2: Diagnostic Performance of 3D Mammography and MRI

Test Modality	Sensitivity (%)	Specificity (%)	Accuracy (%)
3D Mammography	85%	78%	84%
MRI	92%	83%	90%

For Stage I (localized) tumors, 3D mammography detected 35 cases (10%) while MRI detected 45 cases (12%). For Stage II (regional) tumors, 3D mammography detected 40 cases (11%) while MRI detected 70 cases (19%). Overall, MRI demonstrated a significantly higher detection rate for IDC, with a total detection of 115 cases (31%) compared to 75 cases (21%) for 3D mammography, showing a clear advantage of MRI in early detection.

Table 3: Incidence of Early-Stage IDC Detection Using 3D Mammography and MRI

Stage of Cancer	3D Mammography	MRI	P-value
Stage I (Localized)	35 (10%)	45 (12%)	0.04
Stage II (Regional)	40 (11%)	70 (19%)	< 0.001
Total Detection Rate	75 (21%)	115 (31%)	< 0.001

3D mammography had a false positive rate of 18% and a false negative rate of 15%, while MRI had a false positive rate of 10% and a false negative rate of 8%.

Table 4: Comparison of False Positive and False Negative Rates for 3D Mammography and MRI

Test Modality	False Positive (%)	False Negative (%)
3D Mammography	18%	15%
MRI	10%	8%

For tumors < 1 cm, MRI detected 40 cases (11%) compared to 20 cases (5%) detected by 3D mammography. For tumors 1-2 cm, MRI detected 60 cases (16%) while 3D mammography detected 40 cases (11%). For tumors > 2 cm, MRI detected 30 cases (8%), while 3D mammography detected 15 cases (4%).For dense breasts (Categories C & D), 3D mammography showed a sensitivity of 85%, while MRI showed a higher sensitivity of 92%. For non-dense breasts (Categories A & B), the sensitivity of 3D mammography was 80%, and MRI had a sensitivity of 85%.

Table 5: Correlation Between Tumor Size and Detection Method

Tumor Size (cm)	Detected by 3D Mammography	Detected by MRI	P-value
< 1 cm	20 (5%)	40 (11%)	0.01
1-2 cm	40 (11%)	60 (16%)	0.03
> 2 cm	15 (4%)	30 (8%)	0.02
Breast Density			
Dense (C & D)	85%	92%	< 0.001
Non-Dense (A & B)	80%	85%	0.04

DISCUSSION

This study aimed to evaluate and compare the diagnostic performance of 3D mammography and MRI in detecting early-stage invasive ductal carcinoma (IDC) in women with dense breast tissue. The results demonstrated that MRI exhibited superior sensitivity, specificity, and accuracy compared to 3D mammography, supporting its role as a more effective tool for the detection of early-stage IDC in this high-risk population.The sensitivity of MRI was found to be 92%, which is significantly higher than the 85% sensitivity observed for 3D mammography. These findings are consistent with previous studies that have highlighted the superior sensitivity of MRI for detecting small tumors, particularly in dense breast tissue. MRI's ability to detect small, early-stage tumors that may be hidden in dense tissue has been well documented, and it plays an essential role in the

early diagnosis of IDC[13].3D mammography, while more effective than traditional 2D mammography, is still dependent on X-ray technology and may miss smaller tumors, especially in dense breasts. The increased sensitivity of MRI observed in this study reinforces its value as a complementary screening tool for women with dense breast tissue.In terms of specificity, MRI also showed a higher value of 83%, compared to 3D mammography's specificity of 78%. This indicates that MRI is more effective at correctly identifying patients without cancer, which is crucial in preventing unnecessary procedures, such as biopsies, and reducing patient anxiety. The specificity of both modalities is acceptable; however, the slightly higher specificity of MRI further supports its role in accurately diagnosingIDC and minimizing the occurrence of false positives.

The accuracy of MRI was also higher at 90%, compared to 3D mammography's accuracy of 84%. Accuracy, which considers both sensitivity and specificity, is a crucial measure in evaluating the overall effectiveness of a diagnostic test. The higher accuracy of MRI suggests that it is a more reliable imaging modality for the detection of early-stage IDC in women with dense breast tissue. These findings are consistent with earlier studies that emphasized the diagnostic advantage of MRI for women with dense breasts[14].In terms of tumor size, MRI demonstrated a higher detection rate for smaller tumors compared to 3D mammography, especially for tumors measuring <1 cm and 1-2 cm in size. These smaller tumors, which are often more treatable, are difficult to detect on traditional mammography and 3D mammography, especially in dense tissue. In this study, 40% of tumors < 1 cm were detected by MRI, compared to only 20% detected by 3D mammography. This underscores the sensitivity of MRI for detecting early-stage IDC, providing a crucial diagnostic advantage in women with dense breast tissue.Moreover, our study also examined the diagnostic performance of both modalities in heterogeneously dense and extremely dense breasts. The sensitivity of 3D mammography was significantly lower in women with extremely dense breasts, highlighting the challenges of using mammography in this subset of women. On the other hand, MRI maintained high sensitivity across both categories of dense breast tissue (heterogeneously dense and extremely dense), further emphasizing its superiority in this context [15].This suggests that MRI may be the preferred choice for women with extremely dense breasts, who are at a higher risk of undetected IDC due to the limitations of 3D mammography.

While MRI demonstrated superior diagnostic performance, it is important to acknowledge its limitations, including cost, availability, and the higher rates of false positives. MRI is considerably more expensive than 3D mammography and may not be available in all settings, which limits its widespread use in routine screening programs [16]. Furthermore, the higher false-positive rate of MRI can lead to additional biopsy procedures, which could result in unnecessary patient anxiety and over-diagnosis. Despite these drawbacks, the high sensitivity of MRI for detecting early-stage IDC in dense breast tissue makes it a valuable supplemental screening tool, particularly for high-risk populations.The results of this study suggest that MRI should be considered for women with dense breast tissue, particularly those at high risk of breast cancer, such as those with a family history of the disease, BRCA mutations, or extremely dense breasts[17]. However, due to its cost and availability, 3D mammography remains a viable option for routine screening in women with heterogeneously dense breasts, as it provides a good balance between detection rates and cost-effectiveness.

CONCLUSION

This study highlights the superior performance of MRI compared to 3D mammography in detecting early-stage invasive ductal carcinoma (IDC) in women with dense breast tissue. MRI demonstrated higher sensitivity (92%), specificity (83%), and accuracy (90%) than 3D mammography, particularly in detecting smaller tumors that are often missed by traditional imaging methods. These results suggest that MRI should be considered a valuable supplementary screening tool for women with dense breasts, especially those at high risk of developing breast cancer. However, 3D mammography remains a viable and cost-effective option for routine screening in women with heterogeneously dense breasts. Despite its higher false-positive rate, MRI offers a more detailed and accurate assessment, especially for small, early-stage tumors, which are more treatable. Future studies should focus on the long-term impact of these screening modalities on breast cancer detection and survival outcomes, while considering the cost-effectiveness and accessibility of these imaging technologies.

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