VOLUME 11 | ISSUE 2

ORIGINAL ARTICLE | Diagnostic imaging

Role of Automated Breast 3D Ultrasound and Post-Contrast Mammography in Detection and Characterization of Different Breast Lesions Referred to Pathological Results

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SUBMISSION: 21/10/2025 | ACCEPTANCE: 02/06/2026

ABSTRACT

Purpose: To evaluate and compare the diagnostic performance of Automated Breast Ultrasound (ABUS) and Contrast-Enhanced Digital Mammography (CEDM) in the detection and characterization of breast lesions, using histopathological findings as the reference standard, and to assess their complementary roles—particularly in patients with dense breast tissue or non-mass enhancement patterns.

Material and Methods: In this prospective study, 42 women with clinically or radiologically suspicious breast lesions underwent both ABUS and CEDM, between September 2022 and April 2024. Histopatholog-

KEY WORDS

Automated breast ultrasound, Contrast-enhanced digital mammography, Breast cancer, Dense breast, Diagnostic imaging.

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ical diagnosis was used as the reference standard. Diagnostic performance metrics, including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), were calculated for both modalities.

Results: Among 53 detected lesions, 38 (72%) were malignant and 15 (28%) benign. ABUS achieved 100% sensitivity, 73.33% specificity, 90.48% PPV, and 100% NPV, with an overall accuracy of 92.45%. CEDM demonstrated 100% sensitivity, 60% specificity, 86.36% PPV, and 100% NPV, with an accuracy of 88.68%. ABUS was particularly effective in identifying key morphological features such as lesion orientation, retraction phenomena, and ductal extension. CEDM provided enhanced detection of non-mass enhancement patterns often linked to early-stage malignancies.

Conclusion: Both ABUS and CEDM exhibit high diagnostic accuracy and sensitivity in breast lesion evaluation. ABUS offers higher specificity and structural detail, while CEDM enhances vascular visualization. Their combined use may significantly improve diagnostic confidence, especially in patients with dense breast tissue.

Introduction

Breast cancer remains a global health burden, affecting over one million women annually. The lifetime risk for developing breast cancer was approximately 12.3% between 2010 and 2012, translating to about one in eight women. Encouragingly, the 5-year relative survival rate between 2005 and 2011 reached 89%, largely attributed to the widespread adoption of screening programs and advancements in treatment modalities [1].

Mammography is a cornerstone of breast cancer screening and has been proven to reduce mortality. However, its sensitivity is significantly reduced in women with dense breast tissue, detecting only 30–48% of non-palpable cancers in such cases. Women with extremely dense breasts have up to an 18-fold increase in interval cancers compared to those with fatty breasts [2]. Supplementary screening with handheld ultrasound has demonstrated improved detection rates in dense-breasted women [3].

Automated breast ultrasound (ABUS) represents a promising technological advancement in breast imaging. Unlike handheld ultrasound, ABUS offers standardized image acquisition, minimizes operator dependency, and provides three-dimensional reconstruction for coronal plane interpretation, enhancing cancer detection accuracy [4,5]. Additionally, ABUS is time-efficient, with each image taking approximately 1.5 minutes, markedly shorter than the 20-minute duration required for handheld scans [4].

Contrast-enhanced imaging techniques offer further diagnostic value, especially in assessing tumor vascularity. Contrast-enhanced digital mammography (CEDM) uses iodinated contrast agents with digital mammography and shows potential for higher diagnostic accuracy compared to conventional mammography and ultrasound combinations [6,7]. While MRI remains the most sensitive modality, its limitations include high costs, limited availability, contraindications in certain patients, and increased false positives [8,9].

Our study aims to evaluate and compare the diagnostic performance of ABUS and CEDM in the detection and characterization of breast lesions, using histopathological findings as the reference standard, and to assess their complementary roles—particularly in patients with dense breast tissue or non-mass enhancement patterns.

Material and Methods

Design and population:

This prospective observational study was conducted on 42 female patients who presented with either palpable breast masses or suspicious clinical findings warranting further radiological evaluation at the Female Imaging Unit of the National Cancer Institute (NCI), Cairo University, from September 2022 to April 2024.

Eligibility criteria

Eligible participants were adult females without prior breast surgery or implants. Patients with contraindications to contrast administration—such as a known allergy to iodinated contrast agents, impaired renal function, pregnancy, or lactation—were excluded.

Assessments

All patients underwent both Automated Breast Ultrasound (ABUS) and Contrast-Enhanced Digital Mammography (CEDM) as part of their diagnostic workup. Histopathological examination via core needle biopsy, excisional biopsy, or radical surgery served as the reference standard for radiological-pathological correlation.

Automated Breast Ultrasound

This was performed using the GE Invenia ABUS system (GE Healthcare). Patients were scanned in the supine position following the application of contact lotion. A curved compression panel and disposable mesh membrane were used to stabilize the breast during automated scanning. Standard views included anteroposterior, medial, and lateral acquisitions; additional superior or inferior views were obtained for larger breasts. Each view required approximately 1.5 minutes, and 3D reconstruction allowed coronal-plane visualization.

Contrast-Enhanced Digital Mammography

A non-ionic iodinated contrast agent (1.5 mL/kg body weight) was manually injected via an antecubital vein contralateral to the affected breast. Two minutes post-injection, bilateral craniocaudal and mediolateral oblique mammographic views were obtained using dual-energy acquisition. Low-energy images were captured at 26–31 kVp, while high-energy images were acquired at 45–49 kVp to enable post-processing subtraction, enhancing lesion conspicuity while minimizing background parenchymal signal.

Image analysis

Image analysis for both modalities was independently performed by two experienced radiologists blinded to pathological outcomes. ABUS interpretation included assessment of breast composition, lesion number, location, morphology, echogenicity, posterior acoustic features, and BI-RADS categorization. Similarly, CEDM analysis focused on mass and non-mass enhancement patterns, distribution, margins, and final BI-RADS classification.

Outcomes

The primary outcome was the diagnostic accuracy of each imaging modality in identifying malignant lesions. Secondary outcomes included lesion characterization concordance and BI-RADS categorization agreement. All imaging results were correlated with histopathological diagnoses obtained within one to three weeks of imaging.

Sample size

The number of study participants was calculated using EPI- info (statistical; software for epidemiology) depend on population number and percentage of disease.

Statistical methods

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 29 (IBM Corp., Armonk, NY). Qualitative variables were presented as frequencies and percentages, while quantitative variables were expressed as mean ± standard deviation (SD). Comparisons between categorical variables were performed using the Chi-square test. Agreement between imaging modalities and pathological findings was assessed using the Kappa (κ) statistic, interpreted as follows: $\kappa < 0.20$, poor; 0.21–0.40, weak; 0.41–0.60, moderate; 0.61–0.80, good; and 0.81–1.00, very good agreement. Diagnostic performance was evaluated using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Results

This study included 42 female patients presented to the NCI screening unit, their mean age was 47.6±12.65.

Among the 53 evaluated breast lesions, 15 (28%) were benign and 38 (72%) were malignant. Invasive ductal carcinoma (IDC) was the most common malignancy, accounting for 32 cases (84%), followed by ductal carcinoma in situ in 2 cases (5%) and invasive lobular carcinoma in 4 cases (11%). Laterality analysis revealed that 23 lesions (43%) were located in the right breast and 30 (57%) in the left breast. **Table 1**

Table 1: Histological diagnosis in the patients included in our study

Pathology	Subcategory	n (%)
Benign (n = 15)	Nonspecific granulomatous mastitis	1 (6.7%)
	Simple cyst	3 (20.0%)
	Complicated cyst	1 (6.7%)
	Intra-ductal papilloma	1 (6.7%)
	Peri-ductal mastitis / negative malignancy	1 (6.7%)
	Fibroadenoma	1 (6.7%)
	Sclerosing adenosis	1 (6.7%)

Table 1: Histological diagnosis in the patients included in our study

Pathology	Subcategory	n (%)
Benign (n = 15)	Ductal hyperplasia	1 (6.7%)
	Chronic inflammatory seroma	1 (6.7%)
	Fibrocystic changes	2 (13.3%)
	Intramammary lymph node	2 (13.3%)
Malignant (n = 38)	Invasive ductal carcinoma	32 (84.2%)
	Ductal carcinoma in situ	2 (5.3%)
	Invasive lobular carcinoma	4 (10.5%)
Side	Right breast	23 (43.4%)
	Left breast	30 (56.6%)
Breast Density (ACR)	A: Fatty	3 (5.7%)
	B: Scattered fibroglandular	20 (37.7%)
	C: Heterogeneous fibroglandular	21 (39.6%)
	D: Extremely dense	9 (17.0%)

ACR: American College of Radiology, n: number of lesions

Out of 42 patients, a total of 53 lesions were identified, including 49 mass lesions and 4 non-mass lesions presenting as parenchymal distortion.

Homogeneous fibroglandular breast composition was observed in 33 cases (62%), heterogeneous fibroglandular in 17 cases (32%), and homogeneous fatty tissue in 3 cases (6%).

Ductal extension was noted in 28 lesions (53%), while 25 lesions (47%) showed no extension. Lesion orientation was non-parallel to the skin in 41 cases (77%) and parallel in 12 cases (23%).

Among the 49 mass lesions, 22 (45%) were single and 27 (55%) were multiple. Irregular shape predominated in 36 lesions (74%), followed by round (14%) and oval (12%) shapes.

Regarding margins, spiculated edges were most common (53%), followed by circumscribed (22%), microlobulated (16%), and indistinct (8%) margins.

Additionally, ABUS detected 4 non-mass lesions with parenchymal distortion, of which 3 were malignant (2 IDCs and 1 ductal carcinoma in situ) and 1 was benign (periductal mastitis). **Table 2**

Table 2: Characterizations of lesions in ABUS

Feature	Category	n (%)
Lesion Type	Mass lesions	49 (92.5%)
	Parenchymal distortion (non-mass)	4 (7.5%)
Mass Shape (n = 49)	Irregular	36 (73.5%)
	Oval	6 (12.2%)
	Round	7 (14.3%)
Mass Margins (n = 49)	Spiculated	26 (53.1%)
	Circumscribed	11 (22.4%)
	Microlobulated	8 (16.3%)
	Indistinct	4 (8.2%)

Table 2: Characterizations of lesions in ABUS

Feature	Category	n (%)
Mass Number (Axial View)	Single	22 (44.9%)
	Multiple	27 (55.1%)
Coronal View Features	Retraction phenomenon	18 (34.0%)
	Complete hyperechoic rim	13 (24.5%)
	Incomplete hyperechoic rim	18 (34.0%)
	No mass (parenchymal distortion)	4 (7.5%)
Ductal Extension (n = 53)	Present	28 (52.8%)
	Absent	25 (47.2%)
Breast Composition (n = 53)	Homogeneous fatty tissue	3 (5.7%)
	Homogeneous fibroglandular tissue	33 (62.3%)
	Heterogeneous fibroglandular tissue	17 (32.0%)
Echo Pattern (n = 53)	Hypoechoic	38 (71.7%)
	Anechoic	8 (15.1%)
	Isoechoic	3 (5.7%)
	Hyperechoic	0 (0.0%)
Lesion Orientation (n = 53)	Parallel to skin	12 (22.6%)
	Non-parallel to skin	41 (77.4%)
Posterior Features (n = 53)	No posterior feature	34 (64.2%)
	Posterior shadowing	13 (24.5%)
	Posterior enhancement	6 (11.3%)
Parenchymal Distortion (n = 53)	Present	5 (9.4%)
	Absent	48 (90.6%)
BI-RADS Category (n = 53)	BI-RADS II	8 (15.1%)
	BI-RADS III	3 (5.7%)
	BI-RADS IV	11 (20.8%)
	BI-RADS V	31 (58.4%)

n: number of lesions

A significant association was found between lesion morphology and pathology. Approximately 94.2% of malignant lesions were irregular, whereas 43% of benign lesions were round and 36% were oval ($P < 0.001$). Circumscribed margins were observed in 79% of benign lesions, while 72% of malignant lesions had spiculated margins ($P < 0.001$). Ductal extension was present in 66% of malignant lesions compared to only 20% of benign lesions ($P < 0.05$). Lesion orientation also differed significantly, with 100% of malignant lesions being non-parallel to the skin, versus 80% of benign lesions which were parallel ($P < 0.001$). BI-RADS classification showed that 79% of malignant lesions were BI-RADS V and 21.1% were BI-RADS IV, whereas benign lesions were mainly BI-RADS II (53.3%), with smaller proportions classified as BI-RADS III (20%), IV (20%), and V (6.7%) ($P < 0.001$). On ABUS-specific coronal views, the retraction phenomenon was seen in 51.4% of lesions, all of which were malignant, yielding a sensitivity of 100% for malignancy. Conversely, complete hyperechoic rim

was detected in 92.9% of benign lesions with 100% sensitivity, while incomplete hyperechoic rim was observed in 48.6% of malignant lesions, showing 94.4% sensitivity for malignancy. **Table 3**

Table 3: Correlation between ABUS imaging features and histopathological diagnosis of breast lesions

		Pathology lesion		P value
		Malignant (35)	Benign (14)	
Shape (n=49)	rounded	1(2.9)	6(43)	<0.001*
	Oval	1(2.9)	5(36)	
	Irregular	33(94.2)	3 (21)	
Margin (n=49)	Circumscribed	0(0)	11(79)	<0.001*
	Indistinct	4(11)	0(0)	
	Micro-lobulated	6(17)	2(14)	
	Spiculated	25(72)	1(7)	
Ductal extension	Yes	0(0)	12(80)	0.003*
	No	38(100)	3(20)	
Orientation	Parallel to skin	0(0)	12(80)	<0.001*
	Non-parallel to skin	38(100)	3(20)	
BIRADS (n=53)	II	0(0)	8(53.3)	<0.001*
	III	0(0)	3(20)	
	IV	8(21.1)	3(20)	
	V	30(78.9)	1(6.7)	
Shape (n=49)	Retraction phenomena	18(51.4)	0 (0)	<0.001*
	Complete hyperechoic rim	0 (0)	13(92.9)	
	Incomplete hyperechoic rim	17(48.6)	1 (7.1)	

**: significant p-value <0.05*

Out of 42 cases, 53 lesions were identified on CEDM. Ten lesions showed no enhancement—9 of which were benign and one was ductal carcinoma in situ (DCIS). Among 34 enhancing mass lesions, 24 demonstrated isolated mass enhancement, while 10 showed both mass and associated non-mass enhancement. The remaining 9 lesions revealed non-mass enhancement only. Irregular shape was predominant among enhancing masses (94%), while spiculated or irregular margins were observed in 91.1% of cases.

Masses were equally distributed between single and multiple lesions (50% each). Ductal extension was present in 53% of all lesions. Of the 10 non-enhancing lesions, all were benign except one DCIS. Among the 9 non-mass enhancement lesions, 7 (77.8%) were malignant (all IDC) and 2 were benign (non-specific granulomatous mastitis and periductal mastitis). Regional distribution was seen in 5 cases (4 malignant, 1 benign), and segmental distribution in 4 cases (3 malignant, 1 benign), supporting a strong association between enhancement patterns and malignancy. **Table 4**

There was a statistically significant correlation between CEDM features and lesion pathology. All malignant mass lesions exhibited an irregular shape, while 50% of benign lesions were rounded ($P < 0.001$). Regarding lesion margins on mammography, 75% of benign lesions were circumscribed, whereas 56.7% of malignant lesions had indistinct margins ($P < 0.001$).

Ductal extension was present in 66% of malignant lesions compared to only 20% of benign ones ($P < 0.05$). BI-RADS classification also differed significantly, with 55.3% of malignant lesions categorized as BI-RADS V

Table 4: Characterizations of lesions in CEDM

Feature	Category	n (%)
Enhancement Type	Mass enhancement	24 (45.2%)
	Non-mass enhancement	9 (16.9%)
	Both (mass & non-mass)	10 (18.9%)
	No enhancement	10 (18.9%)
Number of Masses	Single	17 (50.0%)
	Multiple	17 (50.0%)
Mass Shape	Round	2 (6.0%)
	Oval	1 (3.0%)
	Irregular	31 (91.0%)
Mass Margin	Circumscribed	3 (8.9%)
	Irregular	18 (52.9%)
	Spiculated	13 (38.2%)
Enhancement Pattern	Homogeneous	2 (4.0%)
	Heterogeneous	33 (62.3%)
	Clumped	10 (18.9%)
	Marginal	3 (5.7%)
Enhancement Distribution	Focal	1 (1.9%)
	Linear	0 (0.0%)
	Segmental	6 (11.3%)
	Regional	9 (17.0%)
	Multiregional	3 (5.7%)
Ductal Extension	Present	28 (52.8%)
	Absent	25 (47.2%)

n: number of lesions

and 44.7% as BI-RADS IV. In contrast, benign lesions were classified as BI-RADS II in 33%, BI-RADS III in 27%, and BI-RADS IV in 40% of cases (P < 0.001). **Table 5**, **Fig. 1**

Table 5: CEDM according to pathology lesion

		Pathology lesion		P value
		Malignant (30)	Benign (4)	
Shape (n=34)	Rounded	0(0)	2(50)	<0.001*
	Oval	0(0)	1(25)	
	Irregular	30(100)	1(25)	
Margin (n=34)	Circumscribed	0(0)	3(75)	<0.001*
	Indistinct	17(56.7)	1(25)	
	Obscured	13(39.4)	0(0)	

Table 5: CEDM according to pathology lesion				
		Pathology lesion		P value
		Malignant (30)	Benign (4)	
Ductal extension	Yes	25 (66)	3 (20)	0.001*
	No	13 (34)	12 (80)	
BIRADS (n=53)	II	0(0)	5(33)	<0.001*
	III	0(0)	4(27)	
	IV	17(44.7)	6(40)	
	V	21(55.3)	0(0)	

**: significant p-value <0.05*

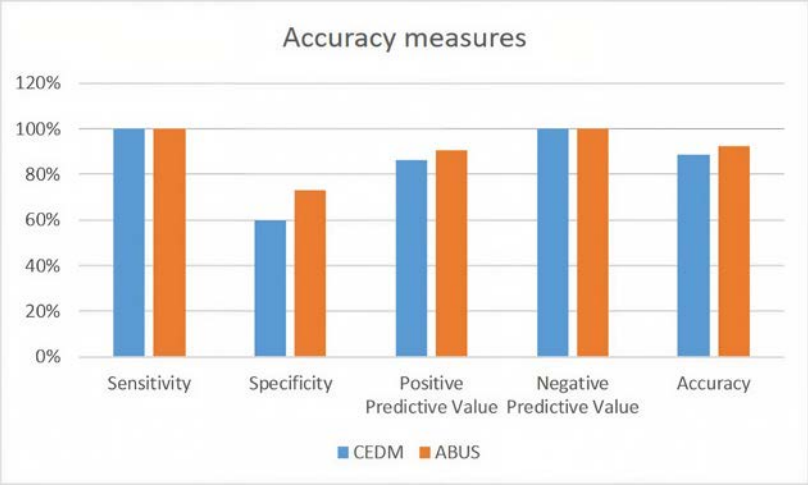

Fig. 1 *Comparison between accuracy measures of CEDM, and ABUS.*

Table 6: Comparison between accuracy measures of CEDM and ABUS		
Measure	**CEDM**	**ABUS**
Sensitivity	100%	100%
Specificity	60%	73.33%
Positive Predictive Value	86.36%	90.48%
Negative Predictive Value	100%	100%
Accuracy	88.68%	92.45%

CEDM: Contrast-enhanced digital mammography, ABUS: Automated breast ultrasound

Discussion

Breast cancer is the most common malignancy among women globally and remains a leading cause of cancer-related mortality. Early detection and precise characterization of breast lesions are essential for improving prognosis, as early-stage cancers have significantly higher survival rates [10]. While mammography is the cornerstone of breast cancer screening, its diagnostic sensitivity is notably reduced in women with dense breast tissue [11].

Advances in imaging, such as ABUS and CEDM, have emerged to address these limitations. ABUS provides radiation-free, three-dimensional imaging that enhances lesion visualization, particularly in dense

breasts, whereas CEDM improves anatomical detail and highlights vascularized lesions using iodinated contrast agents [12,13]. The aims to evaluate the diagnostic accuracy, sensitivity, and specificity of ABUS in comparison with CEDM, and to clarify their complementary roles in the detection and characterization of both mass and non-mass breast lesions.

The predominance of IDC in breast cancer cohorts has been well established in previous literature. IDC, along with invasive lobular carcinoma, represents the most frequent histological subtypes globally, together accounting for the majority of breast cancer cases [14,15]. Their high incidence across diverse populations underscores the importance of refining diagnostic strategies for accurate identification and classification of these subtypes.

Lateral asymmetry in breast cancer incidence has also been a subject of ongoing investigation. Multiple epidemiological studies have reported a modest but consistent left-sided predominance. Similarly, Cheng et al. [16] identified a higher incidence of left-sided breast cancer, with reported ratios ranging from 1.05 to 1.26. This pattern is further supported by Surveillance, Epidemiology, and End Results (SEER) data, which suggest not only a higher prevalence on the left side but also an association with more aggressive tumor biology and worse clinical outcomes [17].

Several hypotheses have been proposed to explain this phenomenon, including anatomical differences such as the generally larger volume of the left breast, behavioral factors like preferential right-sided breastfeeding, and potential detection biases related to patient handedness and self-examination tendencies [18]. Despite these theories, no single explanation has gained universal acceptance, and the underlying mechanisms remain poorly understood. Continued investigation into laterality patterns may yield insights into both breast cancer pathophysiology and opportunities for optimizing screening strategies.

ABUS has increasingly been recognized as a reliable tool in the characterization of breast lesions, particularly in women with dense breast tissue. Multiple studies have established strong correlations between specific ABUS morphological features and malignancy risk. Irregular shape and non-circumscribed or spiculated margins are widely accepted as hallmarks of malignant lesions, as highlighted by Bhatia et al. [19] and further supported by Yun et al. [20], who demonstrated that these descriptors on ABUS are highly predictive of malignancy. In contrast, benign lesions such as fibroadenomas and cysts typically present with round or oval shapes and well-circumscribed margins, aiding in their non-invasive differentiation from suspicious findings [21].

Lesion orientation relative to the skin surface has also proven to be a critical diagnostic feature. The presence of a non-parallel orientation is consistently associated with malignancy, as reported by Ali et al. [22], who found that non-parallel lesions were more likely to represent malignant pathology. This feature enhances the radiologist's confidence when recommending biopsy and plays a pivotal role in lesion risk stratification.

A unique strength of ABUS lies in its ability to generate coronal images, offering a "surgical" perspective that is not achievable with handheld ultrasound. The retraction phenomenon, characterized by a stellate pattern radiating from a lesion, is highly specific for malignancy and has been highlighted in the literature as a reliable indicator of invasive disease [23,24]. Conversely, a complete hyperechoic rim visualized on coronal imaging has been linked to benignity, improving diagnostic confidence and potentially reducing unnecessary interventions. These coronal-plane features, unique to ABUS, serve as powerful adjuncts in routine diagnostic workflows.

Furthermore, ABUS enhances the visualization of ductal architecture, making it particularly useful in detecting DCIS and assessing the extent of ductal spread. This capability is essential for surgical planning, as it contributes to more accurate margin assessment and may help reduce recurrence rates post-resection [25]. The ability of ABUS to detect extracorporeal ductal extension offers a significant advantage over handheld ultrasound by enabling comprehensive preoperative mapping of disease extent [26]. Such information is invaluable for optimizing surgical outcomes and tailoring individualized treatment strategies.

Recent literature also underscores the superiority of ABUS over handheld ultrasound in delineating multifocality and architectural distortion, particularly in preoperative staging. In comparative evaluations, ABUS demonstrated improved lesion conspicuity and reproducibility, especially in the context of dense breast parenchyma [25].

These benefits are particularly relevant as breast imaging continues to evolve toward more standardized and automated solutions.

Performance metrics reported in previous large-scale studies support the clinical reliability of ABUS. Lin et al. [27], in a Chinese screening population, reported excellent diagnostic values with sensitivity and specificity approaching 93%, reinforcing the consistency of ABUS performance across diverse populations. These findings, taken together, further validate ABUS as a powerful diagnostic tool that complements existing modalities, particularly for accurate lesion characterization and surgical decision-making.

CEDM has emerged as a valuable adjunct in breast imaging, particularly for its ability to highlight tumor vascularity and enhance the visualization of malignant features. Consistent with prior studies, CEDM demonstrates high sensitivity for detecting mass lesions, with irregular shape and non-circumscribed margins—especially spiculated or irregular edges—serving as strong morphological indicators of malignancy [28-30]. These features, readily appreciated on maximum intensity projection (MIP) images, improve diagnostic confidence and help distinguish invasive tumors from benign masses.

In addition to mass lesions, CEDM also proved effective in identifying non-mass enhancement (NME), a radiologic pattern frequently associated with DCIS and other pre-invasive pathologies. The ability of CEDM to depict subtle regional or segmental enhancement—patterns classically linked to intraductal spread—enhances early cancer detection, particularly in patients with dense breasts, where conventional mammography may be less effective [31,32].

This capability underscores CEDM's utility in visualizing biologically significant but morphologically inconspicuous disease, offering potential benefit in screening and staging settings.

While CEDM successfully demonstrated ductal extension in over half of the cases, its performance in detecting detailed intraductal spread may be somewhat limited when compared to three-dimensional modalities such as ABUS. Prior comparative studies have suggested that 3D ultrasound techniques may offer superior accuracy in delineating ductal involvement, which is critical for surgical margin assessment and therapeutic planning [33].

From a performance standpoint, CEDM maintains high sensitivity, consistent with findings from meta-analyses reporting pooled sensitivity values nearing 97% [34]. However, its lower specificity—resulting in a higher rate of false positives—is a recognized limitation, often attributable to enhancement in benign entities. This limitation highlights the need for multimodal imaging strategies. When used in combination with ABUS, CEDM's diagnostic precision may be enhanced, as ABUS contributes additional morphologic detail and spatial resolution that can aid in reducing false-positive rates and improving lesion characterization.

The diagnostic performance of both ABUS and CEDM in this study was notably high, with each modality demonstrating 100% sensitivity and negative predictive value (NPV). These results reinforce their reliability in excluding malignancy when imaging findings are negative—an essential criterion for any screening or diagnostic tool. While both modalities performed well, ABUS showed a modest advantage in overall diagnostic accuracy (92.45% vs. 88.68%) due to its higher specificity (73.33% vs. 60%). These findings are consistent with prior reports, including Lin et al. [27], who demonstrated that ABUS maintains a strong balance between sensitivity and specificity, supporting its role as a complementary imaging modality alongside CEDM and mammography.

The slightly lower specificity observed with CEDM may reflect its high sensitivity to vascularized lesions, leading to enhancement in some benign cases and resulting in a higher false-positive rate. However, when used in conjunction with ABUS and mammography, CEDM contributes critical functional information—particularly in characterizing lesion vascularity and identifying non-mass enhancement patterns often associated with in situ or early invasive disease.

The integration of ABUS, CEDM, and mammography into a multimodal diagnostic approach holds particular promise for women with dense breast tissue, where the limitations of conventional imaging are most pronounced. Together, these modalities provide a complementary set of structural and functional data, enhancing lesion detection, characterization, and diagnostic confidence. This integrated imaging strategy may lead to more accurate early diagnoses, better-informed treatment planning, and ultimately improved patient outcomes.

Conclusion

ABUS and CEDM both demonstrate excellent sensitivity and overall diagnostic accuracy in the assessment of breast lesions. While ABUS provides superior specificity and detailed morphological evaluation, CEDM offers enhanced visualization of lesion vascularity. When used in combination, these modalities can substantially enhance diagnostic confidence, particularly in women with dense breast tissue. **R**

Acknowledgments: There were none to declare.

Declaration of interest statement:
None to be declared.

Ethical approval:
Ethical approval was obtained from the institutional Research and Ethics Committee, and informed consent was secured from all participants.

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