Journal of Carcinogenesis
Covering Genesis to Therapeutics

Journal of Carcinogenesis, ISSN: 1477-3163
2025; Vol 24: Issue10s, https://carcinogenesis.com/

Comparative Analysis of Contrast-Enhanced Mammography and Breast Magnetic Resonance Imaging in Diagnosing and Characterizing Breast Lesions

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ABSTRACT

Background: Breast cancer remains the most common malignancy among women worldwide and a major cause of cancer-related mortality.

Objective: This study aimed to compare the diagnostic performance of contrast-enhanced mammography and breast MRI in detecting and characterizing breast lesions, using histopathology as the reference standard.

Methods: A cross-sectional comparative study was conducted at KMU hospital and Research center Peshawar from May 2024 to May 2025. A total of 235 female patients aged 20 years and above with clinically or radiologically detected breast lesions were included. All participants underwent both CEM and breast MRI within a two-week interval, followed by histopathological confirmation through biopsy or surgical excision.

Results: The mean age of patients was 48.2 ± 10.6 years. Among the 235 lesions, 164 (69.8%) were malignant and 71 (30.2%) were benign. CEM demonstrated a sensitivity of 95.7% and specificity of 85.9%, while MRI showed a sensitivity of 98.8% and specificity of 83.1% ($p > 0.05$). The overall diagnostic accuracy was 92.8% for CEM and 94.0% for MRI. There was excellent agreement between BI-RADS categories of both modalities ($\kappa = 0.82$). MRI detected additional multifocal or multicentric lesions in 6% of patients, while CEM provided better visualization of lesion margins and microcalcifications.

Conclusion: It is concluded that both contrast-enhanced mammography and breast MRI demonstrate high diagnostic accuracy in detecting and characterizing breast lesions. Although MRI remains slightly superior for identifying multifocal disease and assessing lesion extent, CEM offers nearly equivalent diagnostic performance with lower cost, shorter procedure time, and wider availability.

Keywords: *Contrast-enhanced mammography, breast MRI, BI-RADS, breast cancer, diagnostic accuracy*

How to Cite: Shaista Khan, Sanam Nusrat, Amjad Ali, Shumaila Khero, Asadullah, Muhammad Imran Farid, Asma Nadeem, (2025) Comparative Analysis of Contrast-Enhanced Mammography and Breast Magnetic Resonance Imaging in Diagnosing and Characterizing Breast Lesions., *Journal of Carcinogenesis, Vol.24, No.10s,* 359-365.

1. INTRODUCTION

Breast cancer remains one of the most prevalent malignancies among women worldwide and continues to pose a major public health concern due to its high morbidity and mortality [1]. According to the World Health Organization, it is now the most frequently diagnosed cancer globally, surpassing lung cancer. In low- and middle-income countries such as Pakistan, breast cancer is often detected at advanced stages because of limited screening access, lack of awareness, and economic constraints [2]. This delayed diagnosis significantly affects survival outcomes, emphasizing the need for accessible, accurate, and cost-effective imaging tools to enable early detection and appropriate management [3]. Conventional full-field digital mammography has long been the primary screening method for breast cancer. However, its diagnostic accuracy declines in women with dense breast tissue, where overlapping parenchyma can obscure lesions [4]. Ultrasound is often used as an adjunct to mammography but has its own drawbacks, including operator dependency and limited specificity. These limitations have encouraged the development of advanced imaging modalities that not only provide anatomical information but also offer insights into tumor vascularity and metabolic activity [5]. Among these, contrast-enhanced mammography (CEM) and breast magnetic resonance imaging (MRI) have gained significant attention for their ability to detect and characterize breast lesions more effectively. Contrast-enhanced mammography utilizes intravenous iodinated contrast and dual-energy acquisition to generate images highlighting areas of neovascularization [6]. The technique combines low-energy mammograms resembling standard mammography with high-energy recombined images that display contrast enhancement patterns indicative of malignancy. It operates on the principle that cancerous lesions demonstrate higher vascular permeability and contrast uptake due to angiogenesis. CEM offers several advantages: it is relatively quick, affordable, and compatible with existing mammography systems [7]. Studies have shown that the sensitivity of CEM can reach up to 97 percent, comparable to that of MRI, with some reports suggesting higher specificity in certain clinical scenarios. Breast MRI, especially dynamic contrast-enhanced MRI, remains the gold standard for advanced breast imaging [8]. It provides superior soft-tissue contrast, allowing accurate assessment of lesion size, morphology, and multifocality. It is particularly valuable for staging, evaluating treatment response, and screening high-risk populations [9]. MRI, however, is associated with certain drawbacks, including high cost, longer scan times, limited availability, and contraindications in patients with renal dysfunction, pacemakers, or severe claustrophobia. In resource-limited settings, these factors significantly restrict its widespread use, highlighting the need for alternative imaging techniques that maintain comparable diagnostic accuracy [10]. Comparative studies have consistently demonstrated that both CEM and MRI exhibit high sensitivity in detecting breast cancer. Meta-analyses indicate that the pooled sensitivity for both modalities is around 96 percent, while CEM may offer slightly higher specificity [11]. CEM also provides better visualization of microcalcifications than MRI, which can aid in detecting ductal carcinoma in situ. The shorter procedural time of CEM typically under 10 minutes also enhances workflow efficiency and patient comfort, in contrast to MRI's 30–45-minute acquisition period. Furthermore, CEM can be easily integrated into existing mammographic setups, making it a practical and cost-effective option in many hospitals [12].

2. OBJECTIVE

This study aimed to compare the diagnostic performance of contrast-enhanced mammography and breast MRI in detecting and characterizing breast lesions, using histopathology as the reference standard.

3. METHODOLOGY

This was a cross-sectional comparative study conducted at KMU hospital and Research center Peshawar from May 2024 to May 2025. A total of 235 female patients were enrolled in the study. Non-probability consecutive sampling was used to recruit participants meeting the inclusion criteria during the study period.

Inclusion Criteria

Female patients aged 20 years and above presenting with palpable breast lumps or radiologically detected breast lesions requiring further evaluation.

Patients who underwent both contrast-enhanced mammography and breast MRI for the same lesion within a two-week interval.

Patients who consented to undergo biopsy or surgical excision for histopathological confirmation.

Exclusion Criteria

Pregnant or lactating women.

Patients with contraindications to contrast media (e.g., renal insufficiency, allergy to iodine or gadolinium-based agents).

Patients with prior breast surgery, radiotherapy, or biopsy within six weeks before imaging.

Patients with incomplete imaging or unavailable histopathological results.

Imaging Technique

All patients first underwent contrast-enhanced mammography (CEM) using a dual-energy digital mammography system. An intravenous injection of non-ionic iodinated contrast medium (1.5 mL/kg at a rate of 3 mL/s) was administered, followed by saline flush. Dual-energy images were acquired in standard craniocaudal (CC) and mediolateral oblique (MLO) projections for both breasts. The recombined images displaying contrast enhancement were generated automatically by the system software. Within two weeks of CEM, each patient underwent breast MRI on either a 1.5 Tesla or 3 Tesla scanners using a dedicated bilateral breast coil. The MRI protocol included T1-weighted, T2-weighted, diffusion-weighted imaging (DWI), and dynamic contrast-enhanced (DCE) sequences following intravenous administration of a gadolinium-based contrast agent (0.1 mmol/kg). Subtraction images and kinetic enhancement curves were generated to evaluate enhancement patterns. All CEM and MRI images were independently reviewed by two consultant radiologists with a minimum of five years of experience in breast imaging. The radiologists were blinded to each other's findings and to histopathology results. Lesions were analyzed based on morphology, enhancement pattern, and distribution, and classified according to the Breast Imaging-Reporting and Data System (BI-RADS) categories for both modalities. The final diagnosis was established based on histopathological examination of core needle biopsy or surgical excision specimens. Histopathology served as the gold standard against which imaging findings were compared.

Data Analysis

Data were entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 26. Continuous variables such as patient age and lesion size were expressed as mean ± standard deviation (SD), while categorical variables such as BI-RADS category, lesion type, and histopathological diagnosis were presented as frequencies and percentages. The diagnostic performance of CEM and MRI was evaluated in terms of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy, taking histopathology as the reference standard. A p-value of less than 0.05 was considered statistically significant.

4. RESULTS

Data were collected from 235 patients, with a mean age of 48.2 ± 10.6 years, ranging from 23 to 72 years. The majority of participants (58.7%) were between 40 and 60 years of age, while 19.6% were younger than 40 years and 21.7% were older than 60 years. More than half of the patients (54.0%) had heterogeneously dense breasts, followed by 29.4% with extremely dense tissue and 16.6% with fatty parenchyma, indicating that a large proportion of the study population had dense breasts an important factor that can limit the sensitivity of conventional mammography. Clinically, the most common presenting symptom was a palpable lump, observed in 60.4% of cases, followed by nipple discharge in 13.6%, pain or tenderness in 7.7%, and incidental or screening-detected findings in 18.3%. Histopathological evaluation revealed that out of the 235 lesions, 164 (69.8%) were malignant and 71 (30.2%) were benign. Among the benign lesions, fibroadenoma was the most frequent (57.7%), followed by fibrocystic disease (23.9%), duct ectasia (8.5%), and other benign pathologies such as adenosis and papilloma (9.9%). Among malignant lesions, invasive ductal carcinoma was predominant, accounting for 72.0% of cases, while invasive lobular carcinoma and ductal carcinoma in situ comprised 14.0% and 6.7%, respectively.

Table 1. Baseline Demographic and Clinical Characteristics of Patients (n = 235)

Variable	**n (%) / Mean ± SD**
Age (years)	48.2 ± 10.6
Age group	
20–39 years	46 (19.6%)
40–60 years	138 (58.7%)
>60 years	51 (21.7%)
Breast density	
Fatty	39 (16.6%)
Heterogeneously dense	127 (54.0%)
Extremely dense	69 (29.4%)
Clinical presentation	

Palpable lump	142 (60.4%)
Nipple discharge	32 (13.6%)
Pain/tenderness	18 (7.7%)
Incidental/screening finding	43 (18.3%)
Lesion Type	
Benign (n = 71)	
Fibroadenoma	41 (57.7%)
Fibrocystic disease	17 (23.9%)
Duct ectasia	6 (8.5%)
Others (adenosis, papilloma)	7 (9.9%)
Malignant (n = 164)	
Invasive ductal carcinoma	118 (72.0%)
Invasive lobular carcinoma	23 (14.0%)
Ductal carcinoma in situ	11 (6.7%)
Others (mucinous, medullary, metaplastic)	12 (7.3%)

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Histopathological evaluation revealed that out of the 235 lesions, 164 (69.8%) were malignant and 71 (30.2%) were benign. Among the benign lesions, fibroadenoma was the most frequent (57.7%), followed by fibrocystic disease (23.9%), duct ectasia (8.5%), and other benign pathologies such as adenosis and papilloma (9.9%). Among malignant lesions, invasive ductal carcinoma was predominant, accounting for 72.0% of cases, while invasive lobular carcinoma and ductal carcinoma in situ comprised 14.0% and 6.7%, respectively. Other less common subtypes such as mucinous, medullary, and metaplastic carcinoma constituted 7.3% of the total malignant group. These results align with the known epidemiological trend where invasive ductal carcinoma represents the majority of breast cancers.

Table 2. Diagnostic Performance of Contrast-Enhanced Mammography (CEM) and Breast MRI (n = 235)

Parameter	CEM (%)	MRI (%)	p-value
Sensitivity	95.7	98.8	0.12
Specificity	85.9	83.1	0.31
Positive Predictive Value (PPV)	93.2	91.8	—
Negative Predictive Value (NPV)	90.3	95.5	—
Overall Accuracy	92.8	94.0	0.18

On CEM, 20.0% of cases were classified as BI-RADS 2 (benign), 10.2% as BI-RADS 3 (probably benign), 27.2% as BI-RADS 4 (suspicious), and 42.6% as BI-RADS 5 (highly suggestive of malignancy). MRI demonstrated a similar distribution: 17.9% BI-RADS 2, 11.9% BI-RADS 3, 25.1% BI-RADS 4, and 45.1% BI-RADS 5.

Table 3. Comparison of BI-RADS Assessment Categories between CEM and MRI

BI-RADS Category	CEM n (%)	MRI n (%)
2 (Benign)	47 (20.0%)	42 (17.9%)
3 (Probably benign)	24 (10.2%)	28 (11.9%)
4 (Suspicious)	64 (27.2%)	59 (25.1%)
5 (Highly suggestive of malignancy)	100 (42.6%)	106 (45.1%)

Agreement between BI-RADS categories on CEM and MRI was excellent (Cohen's $\kappa = 0.82$).

MRI detected a higher number of multifocal or multicentric disease cases (13.6%) compared to CEM (7.7%), which was statistically significant ($p = 0.03$), highlighting MRI's advantage in identifying additional tumor foci. MRI also provided more accurate lesion size estimation within ±5 mm of histopathology in 90.6% of cases compared to 83.8% for CEM ($p = 0.04$). However, the rate of false positives was low and comparable for both modalities (CEM 4.3% vs. MRI 5.1%, $p = 0.67$).

Table 4. Comparison of Lesion Detection and Characterization between CEM and MRI

Parameter	CEM (n = 235)	MRI (n = 235)	p-value
Total lesions detected	228	233	0.24
Multifocal / multicentric disease	18 (7.7%)	32 (13.6%)	0.03*
Accurate size estimation (±5 mm)	197 (83.8%)	213 (90.6%)	0.04*
False positives	10 (4.3%)	12 (5.1%)	0.67

Significant at $p < 0.05$.

5. DISCUSSION

This study compared the diagnostic performance of contrast-enhanced mammography (CEM) and breast magnetic resonance imaging (MRI) in the detection and characterization of breast lesions among 235 female patients. The results demonstrated that both modalities showed excellent sensitivity and accuracy for identifying malignant breast lesions, with MRI showing slightly higher sensitivity while CEM achieved better specificity. These findings align closely with previous international studies, suggesting that CEM can serve as a practical and cost-effective alternative to MRI in most diagnostic settings. The mean age of patients in this study was 48.2 years, which corresponds with the common age range for breast cancer presentation reported in Asian populations. Dense breast tissue was observed in more than half of the participants, consistent with the demographic trend in premenopausal women, where conventional mammography tends to have reduced diagnostic performance. In this context, the role of functional imaging such as CEM and MRI becomes critical, as both techniques rely on vascular enhancement rather than tissue density, improving lesion conspicuity and diagnostic confidence [13].

Our results revealed that CEM achieved a sensitivity of 95.7% and specificity of 85.9%, compared with MRI, which demonstrated 98.8% sensitivity and 83.1% specificity. This difference, though statistically insignificant, highlights the diagnostic equivalence of the two modalities. Similar findings have been reported in a meta-analysis by Jochelson et al. (2022), where pooled sensitivity for CEM and MRI was 96% and 97% respectively, and specificity was slightly higher for CEM [14]. This can be attributed to the improved ability of CEM to display lesion morphology and associated calcifications, features that are sometimes missed or less conspicuous on MRI. In the present study, invasive ductal carcinoma was the most frequent histopathological subtype, accounting for 72% of malignant cases. Both CEM and MRI were effective in identifying the characteristic enhancement patterns associated with malignancy, such as irregular margins, heterogeneous internal enhancement, and rapid contrast washout kinetics [15]. However, MRI remained superior in detecting small sub-centimeter lesions and multifocal or multicentric disease, identifying additional lesions in 14 patients that were not visualized on CEM. This difference can be explained by MRI's higher contrast resolution and the advantage of multiplanar imaging, which allows for better evaluation of the entire breast parenchyma and chest wall [16].

The accuracy of size estimation was slightly better with MRI (90.6%) than CEM (83.8%). MRI's three-dimensional acquisition and higher soft-tissue contrast facilitate more accurate assessment of lesion dimensions and local invasion. These results correspond with previous work by Patel et al. (2021), which reported that MRI provides more precise lesion size estimation, particularly in tumors larger than 2 cm. Nonetheless, the difference observed in our study was small and may not be clinically significant in many cases. CEM demonstrated an advantage in terms of accessibility, cost-

effectiveness, and procedural efficiency. The average CEM procedure took less than 10 minutes, compared to 30–45 minutes for MRI [17]. Furthermore, CEM can be performed on existing digital mammography platforms with minimal modification, eliminating the need for specialized MRI equipment and trained personnel. This makes CEM particularly advantageous in low- and middle-income countries, where MRI availability is limited and waiting times are long. Several studies from developing countries have emphasized that CEM's lower cost and faster workflow can substantially improve access to advanced breast imaging and facilitate earlier diagnosis [18].

Another notable finding of this study was the strong agreement between BI-RADS assessments on CEM and MRI (κ = 0.82), indicating that radiologists can achieve consistent lesion characterization across both modalities. This high concordance is consistent with the findings of Luczyńska et al. (2020), who reported a similar kappa value (0.81) in their comparison of CEM and MRI in breast cancer diagnosis. The present study reinforces that CEM can reliably assign BI-RADS categories and provide diagnostic confidence comparable to MRI in most clinical contexts [19]. Despite its benefits, CEM does have certain limitations. It cannot provide functional information such as diffusion-weighted imaging or evaluate implant integrity, both of which are possible with MRI. Additionally, CEM involves exposure to ionizing radiation and the use of iodinated contrast, which carries a small risk of allergic reactions or nephrotoxicity. MRI, on the other hand, uses non-ionizing radiation and gadolinium-based agents, which are generally safer for renal function but contraindicated in certain patients. Therefore, the choice between CEM and MRI should be individualized based on patient profile, indication, and institutional resources [20].

The findings of this study have important implications for breast cancer imaging protocols, especially in developing countries. The nearly equivalent diagnostic accuracy of CEM and MRI suggests that CEM can be incorporated into diagnostic algorithms as a first-line or alternative modality when MRI is unavailable or impractical. CEM could also serve as a triage tool to identify patients who would benefit most from MRI, thus optimizing resource allocation. Furthermore, its superior visualization of microcalcifications makes it particularly valuable in cases of ductal carcinoma in situ (DCIS), where MRI often falls short. The study's limitations include its single-center design, which may limit generalizability, and the absence of long-term follow-up data on recurrence or treatment response. Additionally, all imaging interpretations were performed by experienced radiologists; hence, results may vary with different expertise levels. Future multicenter studies with larger and more diverse populations are needed to validate these findings and assess inter-observer variability.

6. CONCLUSION

It is concluded that both contrast-enhanced mammography (CEM) and breast magnetic resonance imaging (MRI) provide high diagnostic accuracy in the detection and characterization of breast lesions. While MRI demonstrated slightly higher sensitivity and better detection of small or multifocal lesions, CEM achieved comparable overall performance with higher specificity, faster acquisition time, and significantly lower cos. These findings highlight that CEM can serve as a reliable and efficient alternative to MRI, especially in healthcare environments where MRI availability is limited or unaffordable

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