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Original Article

Radiology Section

Distribution of CEM BI-RADS Recombined Image Descriptors in Malignant and Non-malignant Breast Lesions: A Prospective Observational Study

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ABSTRACT

Introduction: Contrast-Enhanced Mammography (CEM) is an emerging functional breast imaging technique that integrates digital mammography with intravenous iodinated contrast administration. Following the introduction of a dedicated Breast Imaging-Reporting and Data System (BI-RADS) lexicon for CEM in 2022, validation of individual Recombined (RC) image descriptors has become essential for standardised interpretation.

Aim: To evaluate the distribution of CEM BI-RADS recombined image descriptors in malignant and non-malignant breast lesions.

Materials and Methods: The present prospective observational study was conducted between July 2019 and March 2023 at the Institute of Radiodiagnosis, Government Kilpauk Medical College and hospital, Chennai, Tamil Nadu, India, and evaluated 802 breast lesions (327 malignant and 475 non-malignant) from 769 participants using CEM. RC image descriptors- including enhancement presence, morphology, margins, internal enhancement characteristics, distribution patterns, lesion conspicuity, and contrast kinetics- were assessed according to the 2022 American College of Radiology Breast Imaging-Reporting and Data System (ACR CEM BI-RADS) lexicon. Statistical analysis was performed using the Chi-square test, with $p<0.05$ considered statistically significant.

Results: The study population comprised women, with malignant lesions predominantly observed in patients aged over 40 years (mean age: 52.68±10.61 years), while non-malignant lesions were more common in younger patients (mean age: 48.78±9.64 years). Absent enhancement was identified exclusively in non-malignant lesions (57.9%). A higher frequency of mass enhancement was observed in malignant lesions (83.5%) compared with non-malignant lesions (36.2%). With respect to mass enhancement patterns, non-circumscribed margins (86.4% vs. 12.2%), heterogeneous internal enhancement (74.7% vs. 25.6%) were observed in a significantly higher proportion of malignant lesions than non-malignant lesions. Similarly, malignant lesions demonstrated higher lesion conspicuity and predominantly washout (82.4%) or plateau (16%) contrast kinetics.

Conclusion: According to the findings of the present study, distinct CEM BI-RADS recombined image descriptors demonstrate significant associations with malignant and non-malignant breast lesions.

Keywords: Breast imaging-reporting and data system, Contrast-enhanced mammography, Histopathology, Recombined images

INTRODUCTION

The CEM integrates digital mammography with intravenous iodinated contrast to provide a functional assessment of breast lesions by highlighting tumour-related neoangiogenesis. This approach improves lesion detection and characterisation beyond conventional mammography and ultrasonography [1-3]. Dual-energy acquisition produces low-energy images comparable to standard mammography and recombined images that highlight iodine uptake. Earlier BI-RADS editions lacked a dedicated lexicon for CEM [2,4,5]; however, a supplementary CEM BI-RADS lexicon was introduced by the American College of Radiology in 2022 to standardise interpretation of RC images [5].

Despite increasing clinical use of CEM, limited studies have systematically evaluated individual BI-RADS RC image descriptors and their correlation with histopathology [6-11]. Most published literature focuses on diagnostic performance rather than descriptor-level validation [12-15]. The present study aimed to address this gap by evaluating the distribution of CEM BI-RADS recombined image descriptors in malignant and non-malignant breast lesions.

MATERIALS AND METHODS

The present prospective observational study was conducted between July 2019 and March 2023 at the Institute of Radiodiagnosis, Government Kilpauk Medical College and hospital, Chennai, Tamil Nadu, India, after obtaining Institutional Ethics Committee approval (IEC protocol ID No.166/2019). Written informed consent was obtained from all participants prior to their inclusion in this study.

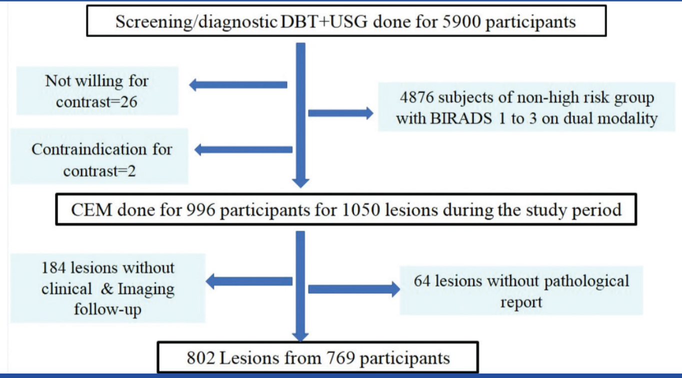
Inclusion and Exclusion criteria: Lesions were included if CEM was performed before biopsy or surgery and histopathological confirmation was available, or if benign lesions demonstrated stability on imaging follow-up for a minimum of 24 months. Lesions lacking pathological confirmation or adequate follow-up were excluded.

After applying the inclusion and exclusion criteria, 802 lesions met the study requirements [Table/Fig-1].

Study Procedure

CEM acquisition protocol: CEM was performed using a dual-energy mammography system (Hologic-Selenia Dimensions Three-dimensional (3D) Tomosynthesis unit). Intravenous non-ionic iodinated contrast was administered at a dose of 1.5 mL/kg, followed by standard craniocaudal and mediolateral oblique views. Delayed imaging was obtained for qualitative assessment of contrast kinetics [1,3,16].

Image analysis: Recombined images were independently evaluated by two experienced breast radiologists using the 2022 ACR CEM BI-RADS lexicon. Lesions were categorised as absent enhancement,



[Table/Fig-1]: Patient selection flow chart.

mass enhancement, or non-mass enhancement. Margins, internal enhancement characteristics, distribution patterns, lesion conspicuity, and qualitative contrast kinetics were assessed [5]. All malignant lesions were confirmed by histopathological examination. Non-malignant lesions were classified based on histopathology or cytology, and documented stability on imaging follow-up.

STATISTICAL ANALYSIS

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software version 26. Qualitative variables were expressed as frequencies and percentages. Categorical variables were analysed using the Chi-square test. Comparisons between malignant and non-malignant lesions were performed using the Chi-square test. Continuous variables were compared using the independent t-test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 802 breast lesions were included in the final analysis, comprising 327 malignant and 475 non-malignant lesions. Malignant lesions were observed in older patients and demonstrated significantly larger mean lesion size compared with non-malignant lesions (p<0.001) [Table/Fig-2].

Absent enhancement on RC images was observed exclusively in non-malignant lesions. Mass enhancement and non-mass enhancement were significantly more common in malignant lesions [Table/Fig-3].

Within the subgroup of mass-enhancing lesions, non-circumscribed margins, heterogeneous internal enhancement, irregular or thick rim enhancement, enhancing septae, and mural nodules

Characteristics		Malignant (n=327)		Non malignant (n=475)		χ^2	p-value
		n	%	n	%		
Indication	Screening	31	9.5	219	46.1	121.08	0.001
	Diagnostic/ staging	296	90.5	256	53.9		
Laterality	Left breast	179	54.7	255	53.7	0.087	0.768
	Right breast	148	45.3	220	46.3		
Family history of malignancy	Present	11	3.4	44	9.3	10.55	0.001
	Absent	316	96.6	431	90.7		
Breast density assessed by DBT /LE image in CEM	Type A	6	1.8	5	1.1	11.40	0.010
	Type B	127	38.9	134	28.2		
	Type C	175	53.5	303	63.8		
	Type D	19	5.8	33	6.9		
Background Parenchymal Enhancement (BPE	Minimal	178	54.4	230	48.4	7.39	0.06
	Mild	75	22.9	114	24		
	Moderate	63	19.3	95	20		
	Marked	11	3.4	36	7.6		

Character		Malignant	Non-malignant	t-value	p-value
Age in years	Mean	52.68	48.78	5.39	0.001
	Standard deviation	10.61	9.64		
Tumour size in cms	Mean	2.57	1.55	9.59	0.001
	Standard deviation	1.32	1.37		

[Table/Fig-2]: Demographic profile and baseline features of study population.

Findings	Malignant on HPE (n=327)		Non-malignant on HPE/Cytology/Follow-up (n=475)		χ^2	p-value
	n	%	n	%		
Absent enhancement	0	0	275	57.9	288.6	0.001
Mass enhancement	273	83.5	172	36.2		
Non-Mass Enhancement (NME)	54	16.5	28	5.9		
Enhancing asymmetry	0	0	0	0		

[Table/Fig-3]: Distribution according to CEM morphological findings between malignant and non-malignant lesions.

were significantly associated with malignancy [Table/Fig-4]. Circumscribed masses with thin smooth rim enhancement or dark internal septations were observed only in benign lesions and are described under BI-RADS 2 entities.

Mass enhancement		Malignant on HPE (n=273)		Non-malignant on HPE/ Cytology/ Follow-up (n=172)		χ^2	p-value
		n	%	n	%		
Margin	Circumscribed	37	13.6	151	87.8	238.3	0.001
	Not circumscribed	236	86.4	21	12.2		
	Spiculated	51	21.6	0	0	5.66	0.001
	Non-spiculated	185	78.4	21	100		
Internal enhancement	Circumscribed lesion with thin smooth rim of adjacent enhancement with internal negative enhancement*	0	0	48	27.9	192.38	0.001
	Circumscribed lesion with non-enhancing dark internal septations#	0	0	6	3.5		
	Homogenous	16	5.9	60	34.9		
	Heterogenous	204	74.7	44	25.6		
	Irregular or thick rim enhancement/ enhancing septae/ enhancing mural nodule	53	19.4	14	8.1		

[Table/Fig-4]: Distribution according to subset of CEM morphological findings: Mass enhancement between malignant and non-malignant lesions.
*,#Certain benign imaging features (thin smooth rim enhancement and dark internal septations) are not explicit BI-RADS internal enhancement descriptors but are described under BI-RADS 2 benign entities such as cysts and fibroadenomas

For non-mass enhancement, segmental and regional distribution patterns and clumped internal enhancement were significantly more frequent in malignant lesions [Table/Fig-5].

Among the 802 lesions studied, 275 showed no enhancement, while 527 demonstrated contrast enhancement. Of these 527 enhancing lesions, delayed images were either not acquired or were deleted before the assessment of contrast kinetics and lesion conspicuity in 30 cases. Consequently, lesion conspicuity and contrast kinetics could be evaluated in 497 contrast-enhancing lesions. Malignant lesions demonstrated significantly higher lesion conspicuity and predominantly washout or plateau contrast kinetics, whereas non-

Non-Mass Enhancement (NME)		Malignant on HPE (n=54)		Non-malignant on HPE/ Cytology/ Follow-up (n=28)			
		n	%	n	%	χ^2	p-value
Internal enhancement	Homogenous	1	1.9	0	0	1.33	0.384
	Heterogenous	41	75.9	24	85.7		
	Clumped	12	22.1	4	14.3		
Distribution	Diffuse	10	18.5	4	14.3	32.1	0.001
	Multiple regions	2	3.7	0	0		
	Regional	18	33.3	4	14.3		
	Focal	1	1.9	10	35.7		
	Linear	0	0	5	17.9		
	Segmental	23	42.6	5	17.9		

[Table/Fig-5]: Distribution according to subset of CEM morphological findings: Non-mass enhancement between malignant and non-malignant lesions.

malignant lesions most commonly showed persistent enhancement patterns [Table/Fig-6].

Findings	Malignant on HPE (n=313)		Non-malignant on HPE/ Cytology/Follow-up (n=184)			
	n	%	n	%	χ^2	p-value
Lesion conspicuity						
Low	29	9.3	107	58.2	170.51	0.001
Moderate	144	46.0	71	38.6		
High	140	44.7	6	3.3		
Contrast kinetics						
Persistent	5	1.6	151	85.3	385.74	0.001
Plateau	50	16	22	12.4		
Washout	258	82.4	4	2.3		

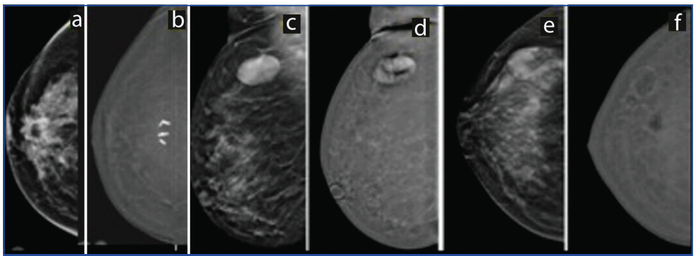
[Table/Fig-6]: Distribution according to lesion conspicuity and contrast kinetics in CEM between malignant and non-malignant lesions.

[Table/Fig-7] summarises the histopathological distribution of the 802 breast lesions. Invasive ductal carcinoma was the most prevalent diagnosis, observed in 293 lesions (36.5%), followed by fibrocystic disease spectrum in 151 lesions (18.8%) and fibroadenoma in 146 lesions (18.2%).

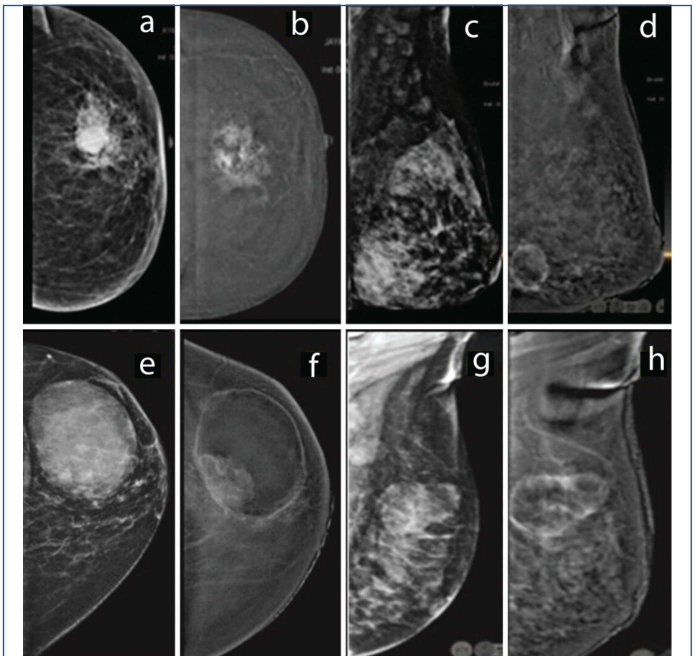
Malignant lesions	n=327 (40.8%)	Non-malignant lesions	n=475 (59.2%)
Invasive breast carcinoma-NST(ductal)	293	Fibrocystic change	151
DCIS	9	Fibroadenoma	146
Invasive lobular carcinoma	7	Papilloma	37
Papillary carcinoma	6	Inflammatory/ granulomatous mastitis	33
Malignant phyllodes	4	Post-op & post RT changes	22
Mucinous carcinoma	2	Usual ductal hyperplasia	14
Mucinous carcinoma with DCIS	1	Benign phyllodes	9
ILC with DCIS	1	Fibroadenolipoma	5
Tubular carcinoma	1	Fibroadenomatoid change	3
Poorly differentiated malignancy	2	Periducal mastitis	3
Mixed carcinoma	1	Benign adenomyoepithelioma	1
		Lipoma	2
		Intramammary lymph node	9
		Post-op seroma	4
		Sclerosing adenosis	2
		Benign breast tissue	10
		Miscellaneous benign lesions	24

[Table/Fig-7]: Distribution of 802 breast lesions based on histology.

[Table/Fig-8] illustrates representative CEM findings observed in non-malignant breast lesions, including absent enhancement on recombined images, circumscribed masses with benign internal enhancement patterns. [Table/Fig-9] demonstrates CEM features significantly associated with malignant breast lesions,



[Table/Fig-8]: CEM features that were found exclusively among non-malignant lesions. Case 1: a,b) Findings seen only in LE image: a) Focal architectural distortion in LE; b) Absent enhancement image with post-op clips in RC image. Follow-up: post-op scar. Case 2: c,d) c) Circumscribed oval mass lesion in LE image; d) RC image shows non-enhancing septae. . Case 3: e,f) e) Multiple circumscribed round lesions in LE; f) Thin smooth rim of enhancement with internal negative enhancement. Correlative USG: multiple simple cysts.
HPE: Fibroadenoma; LE: Low energy; RC: Recombinant

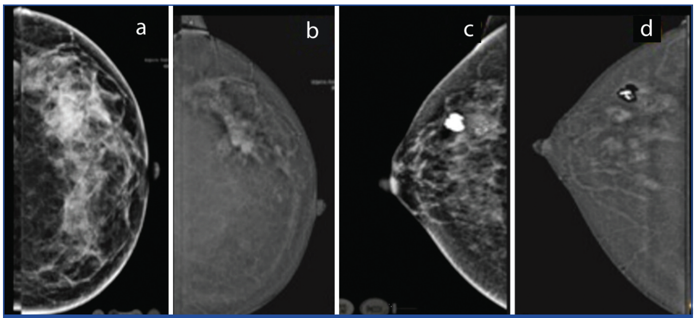


[Table/Fig-9]: CEM features that were found in a significantly high proportion among malignant lesions with mass enhancement. Case 1: a,b) LE & RC images; mass enhancement with non-circumscribed (spiculated margins). HPE: Invasive ductal carcinoma (IDC). Case 2: c,d) LE & RC images; mass enhancement with irregular rim enhancement. HPE: IDC. Case 3: e,f) LE & RC images; Circumscribed rim enhancing mass with enhancing mural nodule. HPE: Encapsulated papillary carcinoma with invasion. Case 4: g,h) LE & RC images; Rim-enhancing mass lesion with enhancing septae. HPE: IDC.

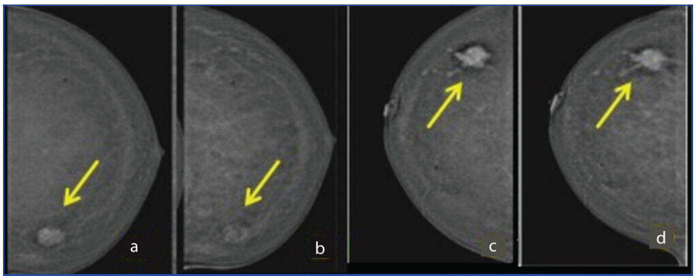
including mass enhancement with non-circumscribed margins, heterogeneous internal enhancement, irregular or thick rim enhancement, enhancing septae, and mural nodules. [Table/Fig-10] depicts non-mass enhancement patterns on CEM, showing segmental and regional distribution with clumped internal enhancement. [Table/Fig-11] illustrates qualitative contrast kinetic patterns on CEM, highlighting washout and plateau kinetics predominantly observed in malignant lesions. [Table/Fig-12] demonstrates persistent contrast kinetics, and low lesion conspicuity in non-malignant lesions.

DISCUSSION

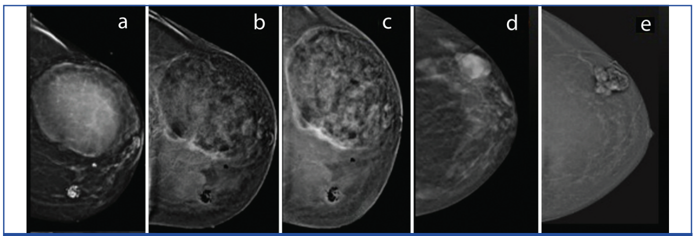
The findings of the present study demonstrate that individual CEM BI-RADS recombined image descriptors show significant associations with malignant and non-malignant breast lesions.



[Table/Fig-10]: CEM features that were found in a significantly high proportion among malignant lesions with Non-Mass Enhancement (NME). Case 1: a,b) LE & RC images; NME with segmental distribution. HPE: IDC. Case 2. C,d) LE & RC images; NME with clumped internal enhancement. HPE: IDC.



[Table/Fig-11]: CEM features that were found in a significantly high proportion among malignant lesions. Case 1: a,b) 2-min & 8-min RC images; washout kinetics. HPE: IDC. Case 2: c,d) 2-min & 8-min RC images; plateau kinetics in an irregular enhancing mass lesion with spiculated margins. HPE: IDC.



[Table/Fig-12]: CEM features that were found in a significantly high proportion among non-malignant lesions. Case 1: a-c) LE, 2-min RC & 8-min RC images; Persistent contrast kinetics. Excision biopsy: Benign phyllodes. Case 2: d,e) LE & RC images; Low conspicuity mass lesion. HPE: Fibroadenoma.

Absent enhancement was exclusively observed in benign lesions, supporting its role as a strong indicator of benignity. These findings are consistent with studies by Grażyńska A et al., and Amir T et al., which similarly reported a high prevalence of non-enhancing benign lesions [6,7]. Notably, Grażyńska A et al., demonstrated that recognition of absent enhancement on CEM contributed to a reduction of approximately 60% in unnecessary core needle biopsies [6].

In the present study, both mass enhancement and non-mass enhancement were observed in significantly higher proportions among malignant lesions compared with non-malignant lesions, findings comparable to those reported by Kim G et al., who observed mass enhancement in 71% and non-mass enhancement in 27.3% of enhancing malignant lesions [8].

Among participants with mass enhancement, non-circumscribed margins (86.4% vs. 12.2%), heterogeneous internal enhancement (74.7% vs. 25.6%), irregular rim enhancement, and enhancing septae/mural nodules (19.4% vs. 8.1%) were found in higher proportions among malignant lesions than in non-malignant lesions. In addition, clumped internal enhancement was more frequently observed in malignant lesions; however, the association was not statistically significant (p=0.384). A higher proportion of segmental and regional distribution patterns of NME was observed in malignant lesions, and this association was statistically significant (p=0.001) than in non-malignant lesions. These results are consistent with the study by Kamal RM et al., which identified irregular or non-circumscribed masses (true positivity: 76.8% vs. 14.2% in malignant and non-malignant lesions, respectively), non-mass enhancement with ductal or segmental distribution (56.8% vs. 19.8%), and heterogeneous or clumped internal enhancement (53.1% vs. 27.2%) as the most predictive descriptors of malignancy [9].

Regarding lesion conspicuity, the proportion of participants with highly conspicuous lesions was greater among those with malignant lesions than among those with non-malignant lesions. Specifically, 46% of malignant lesions demonstrated moderate conspicuity, 44.7% demonstrated high conspicuity, and the remaining lesions demonstrated low conspicuity. The findings of the current study are consistent with those of Nicosia L et al., who reported that lesion conspicuity on CEM showed satisfactory performance in predicting malignancy, with a sensitivity of 91.9% and a specificity of 67.2% [10].

With regard to contrast kinetics in CEM, the proportions of washout and plateau kinetics (82.4% and 16%, respectively) were higher among those with malignant lesions than non-malignant lesions. These results are comparable to the study by Subramaniam P et al., which found that among malignant lesions, 75% showed washout kinetics and 23% showed plateau kinetics [11].

Overall, descriptor-based interpretation using the 2022 CEM BI-RADS lexicon provides a structured framework for lesion characterisation and supports standardised reporting in routine clinical practice.

Limitation(s)

The present study was conducted at a single centre, which may limit generalisability. Lesion conspicuity and contrast kinetics were assessed qualitatively, and inter-observer variability was not evaluated. Quantitative enhancement analysis and multicentre validation were beyond the scope of this study.

CONCLUSION(S)

According to the findings of the present study, distinct CEM BI-RADS recombined image descriptors demonstrate significant associations with malignant and non-malignant breast lesions when correlated with histopathology. Descriptor-based interpretation supports standardised reporting using the CEM BI-RADS lexicon and may assist in informed clinical decision-making.

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