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ARAŞTIRMA YAZISI / RESEARCH ARTICLE

# KONTRASTLI SPEKTRAL MAMOGRAFİNİN TANISAL PERFORMANSI: MEME KANSERİNDEN ŞÜPHELENİLEN HASTALARDA KONTRASTLI DİNAMİK MR GÖRÜNTÜLEME İLE KARŞILAŞTIRMA

# DIAGNOSTIC PERFORMANCE OF CONTRAST-ENHANCED SPECTRAL MAMMOGRAPHY: COMPARISON WITH CONTRAST-ENHANCED DYNAMIC MR IMAGING IN PATIENTS WITH SUSPECTED BREAST CANCER

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**ÖZET**

**AMAÇ:** Meme Kanseri şüphesi bulunan BI-RADS 4 ve 5 lezyonların tespiti açısından, kontrastlı spektral mamografinin (KSM) tanısal performansını, dinamik kontrastlı manyetik rezonans (MR) görüntüleme ile karşılaştırmaktır.

**GEREÇ VE YÖNTEM:** ACR BI-RADS 4 ve 5 lezyonları olan 92 hastaya KSM, MR Görüntüleme ve ardından kor biyopsi uygulandı. Kitlesel lezyonlar, kitlesel olmayan lezyonlar ve mikrokalsifikasyonlar olarak sınıflandırılan lezyonlar iki radyolog tarafından incelendi ve 7 puanlık bir puanlama sistemi kullanılarak değerlendirildi.

**BULGULAR:** Altı hastada bilateral olmak üzere toplam 98 lezyon saptandı. Histopatolojik incelemede lezyonların 56'sı benign (56/98, %57) ve 42'si malign (42/98, %43) idi. Lezyonların 55'i kitle lezyonu, 18'i kitle dışı lezyon ve 25'i mikrokalsifikasyon olarak sınıflandırıldı. KSM lezyonların 28'ini (%28,6) benign, 70'ini (%71,4) malign olarak skorlarken, bu sonuçlar MR Görüntüleme ile değerlendirmede sırasıyla 30 (%30,6) ve 68 (%69,4) idi. Var olan kanseri göstermek için hem KSM hem de MR görüntülemenin duyarlılığı her iki modalite için %95 idi. ROC (Receiver Operating Characteristic) analizinde AUC (Area Under the Curve), KSM için 0,93 (%95 CI:0,870-0,977) ve MR Görüntüleme için 0,94 (%95 CI:0,882-0,982) idi. KSM ve MR Görüntüleme arasında AUC değerlerinde istatistiksel olarak anlamlı bir fark yoktu (p=0,332; p>0,05).

**SONUÇ:** KSM'nin tanısal performansı, BI-RADS 4 ve 5 lezyonları olan hastalarda indeks kanserlerin saptanmasında MR görüntüleme ile karşılaştırıldığında benzerdir. KSM bu konuda güvenilir bir tanı aracı olarak kullanılabilir.

**ANAHTAR KELİMELER:** Kontrastlı mamografi, Spektral mamografi, Dijital mamografi, Meme MRG, Meme kanseri.

**ABSTRACT**

**OBJECTIVE:** To compare the diagnostic performance of contrast-enhanced spectral mammography (CESM) with dynamic contrast-enhanced magnetic resonance (MR) imaging in terms of the detection of BI-RADS 4 and 5 lesions suspected of breast cancer.

**MATERIAL AND METHODS:** 92 patients with ACR BI-RADS 4 and 5 lesions underwent CESM, MR Imaging, and consequent core biopsy. Two readers assessed the index lesions which were classified as mass lesions, non-mass lesions, and microcalcifications, and scored using a 7-point scoring system.

**RESULTS:** A total of 98 index lesions were detected, including bilateral lesions in six patients. In histopathological analysis, 56 of the lesions were benign (56/98, 57%,) and 42 of the lesions were malignant (42/98, 43%). 55 of the lesions were classified as mass lesions, 18 as non-mass lesions, and 25 as microcalcifications. CESM scored 28 of the lesions (28,6%) as benign, and 70 (71,4%) of the lesions were malignant whereas these results were 30 (30,6%) and 68 (69,4%) for MR Imaging examinations, respectively. The sensitivity of both CESM and MR imaging for depicting the index cancer was 95 % for both modalities. In ROC (Receiver Operating Characteristic) analysis, AUC (Area Under the Curve) was 0.93 (%95 CI:0.870-0.977) for CESM and 0.94 (%95 CI:0.882-0.982) for MR Imaging. There was no statistically significant difference in AUC values between CESM and MR Imaging (p=0.332; p>0.05).

**CONCLUSIONS:** The diagnostic performance of CESM is similar when compared to MR imaging in the detection of index cancers in patients with BI-RADS 4 and 5 lesions. CESM may be used as a confidential diagnostic tool in this regard.

**KEYWORDS:** Contrast-enhanced mammography, Spectral mammography, Digital mammography, Breast MRI, Breast cancer.

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## INTRODUCTION

Mammography (MG) is the standard technique both for screening and diagnostic purposes in the early detection of breast cancer which also reduces mortality rates (1). However, well-known limitations of MG due to reduced contrast between tumor and dense fibro glandular tissues lead to additional imaging modalities to increase sensitivity (2). Dynamic contrast-enhanced MR Imaging for breast cancer evaluation has emerged as the most sensitive technique in breast cancer detection (3). Beyond this, MR Imaging has the advantage of lesion characterization by demonstrating excellent morphologic detail with its highest soft tissue resolution compared to other breast imaging modalities and contrast enhancement characteristics (4). Nevertheless, the specificity of MR Imaging is lower than MG (5). In addition, it still has limitations due to being an expensive, uncomfortable, and time-consuming modality (6). Also of concern are the side effects and unknown long-term effects of gadolinium. Therefore, alternative imaging modalities using different contrast agents should be considered. Recently, contrast-enhanced spectral mammography (CESM) came into prominence taking advantage of both MG with radiographic demonstration of lesions and microcalcifications and MR Imaging with contrast enhancement status of the lesions (7 - 9).

The aim of this study was to compare the additional diagnostic performance of CESM and MR Imaging to conventional digital MG regarding the detection of malignant lesions in patients with suspicious breast cancer.

## MATERIAL AND METHODS

### Study Patients

Ninety-two patients who had ACR BI-RADS 4 and 5 lesions at digital MG between February 2015 and November 2018 were included in the study. All patients accepted to undergo CESM, MR Imaging, and consequent core biopsy. CESM and MR Imaging were performed with at least a 48-hour interval to prevent any contrast agent interaction and to provide renal elimination. Core biopsies were performed after CESM and MR Imaging with a 14 or 16-gauge automated tru-cut needle. Patients with breast implants, a history of allergy to contrast agents, previous breast surgery or receipt of radiation or neoadjuvant chemotherapy for breast malignancy, and pregnant or breastfeeding women were excluded from the study. The mean age of the patients was 51 years (range, 32–76 years).

### Mammography

Full-field digital MG was performed with Senographe DS (GE Healthcare, Chalfont St. Giles, UK), at least two standard views as cranio-caudal (CC) and medio-lateral-oblique (MLO) as part of the routine clinical workup.

### CESM

CESM studies were performed with the Senographe DS (GE Healthcare, Chalfont St. Giles, UK), a full-field digital MG unit that allows dual-energy exposures. Contrast material was injected intravenously to the patients in the sitting position. Contrast medium (300 mg iodine/mL, 1.5 mL/kg, Xenetix® 300, Guerbet, France) was injected via an automatic injector at a flow rate of 2 ml/s. 2 minutes after contrast medium administration, low and high energy images were acquired with a special software program. Low energy images were obtained with peak kilo-voltage (kVp) values varying between 26-31 kVp and high energy images 45-49 kVp. A kVp and mAs values are automatically determined by the device according to the breast thickness. As positioning, images were taken first in CC and then in MLO projections. Examination of both breasts was completed in approximately 5 minutes. Late images were taken for suspicious lesions at the seventh minute. Subtracted images were obtained with the software program that deleted background parenchymal structures and non-contrast lesions.

### MR Imaging

MR Imaging was performed using a 1,5-T system (Optima MR450w, GE Healthcare) with a dedicated 8-channel breast coil in a prone position. Multiparametric MR images of the breast, including T1 and T2-weighted, diffusion-weighted, and dynamic contrast-enhanced images, were obtained. The typical MR Imaging parameters that were used are described in detail in **Table 1**. The contrast agent gadoterate meglumine (Dotarem, Guerbet) was automatically

injected at a rate of 2.0 mL/s. The contrast dose (0.1 mmol/kg) was based on the patient's weight. The slice thickness was 2 mm without an intersection gap.

**Table 1:** Imaging Parameters for Breast MR Examination

| Parameter | T1-weighted MR Imaging | T2-weighted MR Imaging | DW MR Imaging | DCE MR Imaging |
|---|---|---|---|---|
| Repetition time (msec)/ Echo time (msec) | 8.3/4.7 | 3200–3500/90–100 | 7000-8000/80-90 | 3.9/1.9 |
| Matrix | 420x440 mm | 204x256 | 128x128 | 320x320 |
| Flip angle (degrees) | 25 | 90 | 90 | 15 |
| Section thickness (mm) | 5 | 5 | 2,4 | 2,4 |
| Field of view (mm) | 360 | 360 | 320 | 320 |
| No. of signals acquired | 2 | 2 | 2 | NA |
| *b* value (sec/mm2) | NA | NA | 0/800 | NA |
| Temporal resolution (sec) | NA | NA | NA | 60 |

### Image Interpretation

Anonymised images were sent to a dedicated MG workstation (Seno Iris, GE Healthcare) for MG and CESM cases and a dedicated MR Imaging workstation (ADW 4.5, GE Healthcare) for MR Imaging cases. All images were reviewed by two radiologists independently (Radiologist A, 19 years of breast imaging experience, and Radiologist B (16 years of breast imaging experience), each reading half of the images. The radiologists were blinded to clinical findings and previous reports but they were aware that the study included only patients with a suspicion of breast cancer. They interpreted the MG, CESM, and MR images at four different viewing sessions in a random order.

Readers were asked to assess the index lesions. Index lesions were classified as mass lesions, non-mass lesions, and microcalcifications. MG and MR images were interpreted in accordance with the BI-RADS® lexicon of the American College of Radiology (ACR) (10). A BI-RADS score was dedicated for each index lesion for MG and MR images. A 7-point scoring system from 1-7 was used to compare the diagnostic performance of each modality indicating BI-RADS scores from 1 to 7 (including 4A, 4B, and 4C). Interpretation and scoring of CESM images were simulated to the BI-RADS system regarding the morphology and the existence of contrast enhancement of the lesions similar to MG and MR Imaging criteria respectively. Lesions having scores ranging from 1 to 3 (BI-RADS 1-3) were accepted as benign, and 4-7 (BI-RADS 4-5) were accepted as malignant. The lesion size was measured by each radiologist at the largest dimension. Images and histology results were cross-referenced by the corresponding author. Invasive carcinoma and ductal carcinoma in situ (DCIS) were considered as malignant lesions. Benign and premalignant lesions (e.g. atypical ductal hyperplasia) were defined as nonmalignant lesions.

### Ethical Committee

Our study is a prospective research study and was conducted according to the ethical standards of the Declaration of Helsinki, and approved by the Institutional Ethics Committee (Fatih Sultan Mehmet Training and Research Hospital) (2021/67).

### Statistical Analysis

All statistical analyses were performed using the IBM SPSS Statistics 22. Shapiro-Wilk test was used for the convenience of normal distribution of the parameters. Specificity, sensitivity, negative predictive value, and positive predictive value in the diagnosis of index cancer were calculated. Images of cases diagnosed histopathologically as breast cancer were evaluated by a radiologist, and cases rated as 4 or higher on a 7-point scale were considered true positive diagnosis. Cases rated as 3 or less on the same scale were accepted as true negative diagnosis. Binormal receiver operating characteristic curves for maximum probability were estimated to evaluate the diagnostic performance of radiologists in the four image display settings, and the area under the receiver operating characteristic curve (AUC) was used as a summary performance index. All p-values were two-sided, and a p-value less than 0.05 was considered to indicate a statistically significant difference.

## RESULTS

### Histopathological Outcome

In 92 patients, 98 index lesions were detected, including bilateral lesions in 6 patients. In histopathological analysis, 56 of the lesions were benign (56/98, 57%,) and 42 of the lesions were malignant (42/98, 43%). Histopathological subtypes of the lesions were demonstrated in **Table 2**.

**Table 2:** Histopatholocigal subtypes of benign and malignant lesions

| Benign lesions | n (56) | Malignant lesions | n (42) |
|---|---|---|---|
| Adenosis/fibrosis | 33 | Infiltrative ductal carcinoma | 30 |
| Fibroadenoma | 6 | In situ ductal carcinoma | 6 |
| Focal fibrocystic changes | 5 | Infiltrative lobular carcinoma | 4 |
| Intraductal papilloma | 3 | Medullary carcinoma | 1 |
| Chronic inflammation | 3 | Mucinous carcinoma | 1 |
| Fat necrosis | 2 | | |
| Apocrin metaplasia | 2 | | |
| Granulomatous mastitis | 2 | | |

## Lesion Outcome

Fifty-five of the lesions were classified as mass lesions, 18 as non-mass lesions, and 25 as microcalcifications at mammography **(Table 3)**.

**Table 3:** Classification of the lesions according to lesion types

| Lesion type | n (98) | % |
|---|---|---|
| Mass lesion | 55 | 56,1 |
| Non-mass lesion | 18 | 18,4 |
| Microcalcification | 25 | 25,5 |

All index lesions were detected in both CESM and MR Imaging **(Figure 1)**. The range for maximum diameter of the lesions was 3-81 (mean 23.43±16.45, median 18) for CESM and 3-67 (mean 20.46±13.66, median 16) for MR Imaging.

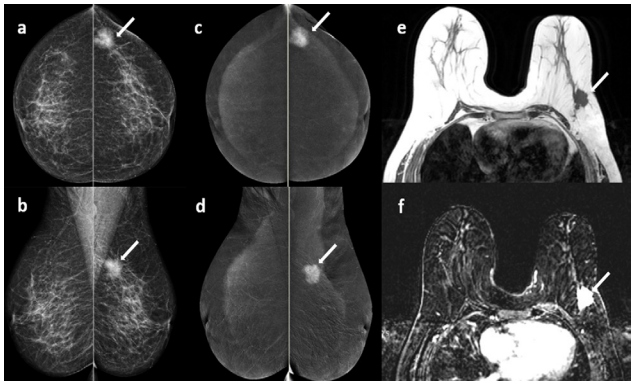


**Figure 1:** Images in 42-year-old woman who presented with left breast lump. Bilateral craniocaudal and mediolateraloblique (a,b) mammography show a mass with irregular border in upper outer quadrant of left breast (arrows), which was scored as 6 in mammography (c,d) CESM images show the prominent enhancement in the mass lesion with a score of 7. Patient also underwent contrast-enhanced breast MR imaging to demonstrate the relations with deep structures. T1 weighted MR image (e) showed that a clear space between the lesion and pectoral muscle. Dynamic subtraction MR image (f) shows the marked enhancement of the lesion. The MR imaging score of the lesion was also 7. Invasive ductal carcinoma was diagnosed in histopathological analysis performed with core biopsy.

## Diagnostic performance of CESM and MR Imaging

CESM scored 28 of the lesions (28,6%) as benign and 70 (71,4%) of the lesions were malignant whereas these results were 30 (30,6%) and 68 (69,4%) for MR Imaging examinations, respectively **(Table 4)**.

**Table 4:** Lesion characterisation as benign or malignant according to CESM, MR Imaging and histopathological results

| Lesion characterisation | CESM | MR Imaging | Histopathology |
|---|---|---|---|
| Benign | 28 (28,6) | 30 (30,6) | 56 (57,1) |
| Malign | 70 (71,4) | 68 (69,4) | 42 (42,9) |

Note.— Numbers in parentheses are percentages

Most of the lesions detected in MG were scored as 4 in MG (63/98), however, most of them were downstaged to benign categories in CESM and MR imaging examinations **(Table 5)**. In 24 patients, the lesions scored as malignant both with CESM and MR Imaging, had been proven to have benign results in histopathology (20 of 24 scored as 4 and 4 of 24 scored as 5, with CESM and 22 of 24 scored as 4 and 2 of 24 scored as 5 with MR Imaging). Additionally, CESM scored 6 patients and MR Imaging scored 4 patients as malignant which were histopathologically benign **(Figure 2)**. There were no patients scored as 6 or 7 with CESM and MR Imaging and had benign results histopathologically. The sensitivity of both CESM and MR Imaging for depicting the index cancer was 95 % for both modalities (40/42 of index cancer) **(Table 6)**. In two patients who had microcalcifications at MG, CESM and MR Imaging failed to show DCIS and scored as 3 in both contrast-enhanced modalities **(Figure 3)**.

**Table 5:** BI-RADS score of the lesions regarding MG, CESM and MR Imaging

| Score | MG | CESM | MR Imaging |
|---|---|---|---|
| 1 (1) | - | - | - |
| 2 (2) | - | 1 (1) | 6 (6,1) |
| 3(3) | - | 27 (27,6) | 24 (24,5) |
| 4(4A) | 63 (64,3) | 29 (29,6) | 26 (26,5) |
| 5(4B) | 7 (7,2) | 9 (9,2) | 8 (8,2) |
| 6 (4C) | 12 (12,2) | 6 (6,1) | 7 (7,1) |
| 7(5) | 16 (16,3) | 26 (26,5) | 27 (27,6) |

Note—Numbers in parentheses are percentage

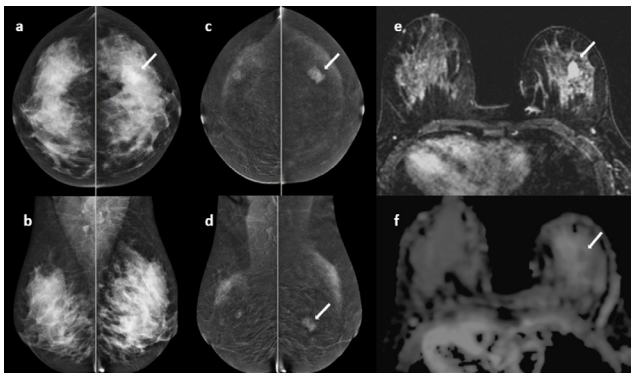


**Figure 2:** Images in 44-year-old woman who attended for routine follow-up. Bilateral craniocaudal and mediolateraloblique (a,b) mammography show an ill-defined mass in dense breast parenchyma (arrows) in lower outer quadrant of left breast (arrows), which was scored as 5. CESM (c,d) images clearly show the lesion with irregular borders and prominent enhancement with a score of 6. Dynamic subtraction MR image (e) demonstrates also marked enhancement in the lesion. Diffusion weighted image (f) shows a mild restricted diffusion. The MR imaging score of the lesion was also 6. Fibroadenoma was diagnosed in histopathological analysis performed with core biopsy.

**Table 6:** Sensitivity, specificity, positive predictive value, and negative predictive value and accuracy levels for CESM and MR Imaging.

| | | | | | | |
|---|---|---|---|---|---|---|
| **CESM score** | ≥4 | 95,2 | 46,4 | 57,1 | 92,8 | 67,3 |
| | ≥5 | 88,1 | 92,9 | 90,2 | 91,2 | 90,8 |
| | ≥6 | 76,2 | 100,0 | 100,0 | 84,8 | 89,8 |
| | ≥7 | 61,9 | 100,0 | 100,0 | 77,8 | 83,7 |
| **MR Imaging score** | ≥4 | 95,2 | 50,0 | 58,8 | 93,3 | 69,3 |
| | ≥5 | 90,5 | 92,9 | 90,5 | 92,9 | 91,8 |
| | ≥6 | 78,6 | 100,0 | 100,0 | 85,9 | 89,8 |
| | ≥7 | 64,3 | 100,0 | 100,0 | 78,9 | 84,7 |

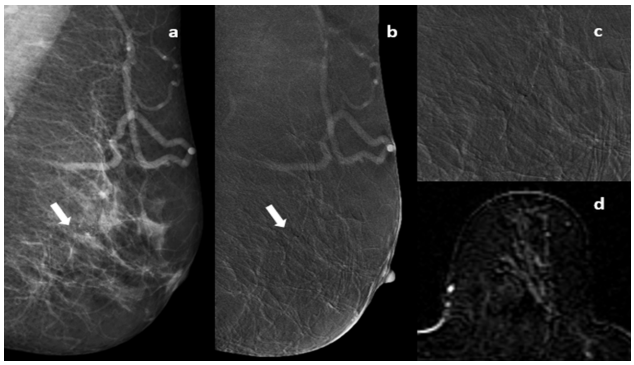


**Figure 3:** Images in 51-year-old woman who attended for routine follow-up. Left mediolateraloblique (a) mammography shows amorphous-grouped microcalcifications (arrow) in upper part of left breast, which was scored as 4. Subtracted CESM (b) image shows no prominent enhancement, the score was 3. Dynamic subtraction MR image (e) demonstrates also no enhancement in the same location. The MR imaging score of the lesion was also 3. Low-grade DCIS was diagnosed in histopathological analysis with stereotactic core needle biopsy.

When lesions were accepted as malignant with a score of 4 or more, both CESM and MR Imaging had high sensitivity and negative predictive value (NPV) (95,2% and 92,8% for CESM and 95,2 and 93,3 for MR Imaging respectively). When the lesions were accepted as malignant with a score of 5 or more, CESM and MR Imaging had still high sensitivity and NPV levels (88,1% and 91,2% for CESM and 90,5 and 92,9 for MR Imaging), however specificity, PPV, and accuracy were significantly improved (from 46,4% to 92,9 %, from 57,1% to 90,2% and from 67,3% to 90,8% for CESM and from 50% to 92,9%, from 58,8% to 90,5% and 69,3% to 91,8 for MR Imaging respectively). In ROC analysis AUC was 0.93 (%95 CI:0.870-0.977) for CESM and 0.94 (%95 CI:0.882-0.982) for MR Imaging **(Figure 4)**. There was no statistically significant difference in AUC values **(Table 7)** between CESM and MR Imaging (p=0.332; p>0.05).

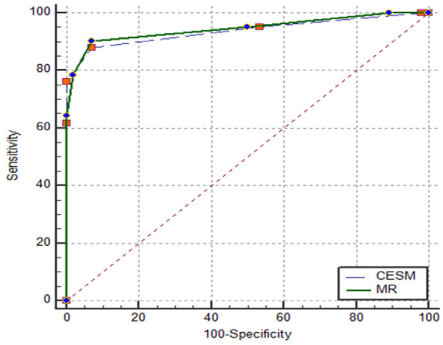


**Figure 4:** ROC curves for CESM and MR Imaging scores.

**Table 7:** The comparison of AUC results between CESM and MR Imaging

| | AUC | SE | 95% Confidence Interval | p |
|---|---|---|---|---|
| **CESM** | 0,938 | 0,028 | 0,870 to 0,977 | 0,332 |
| **MR Imaging** | 0,947 | 0,025 | 0,882 to 0,982 | |

There were no major reactions to the intravenous iodinated or gadolinium-based contrast agents during and after CESM and MR Imaging examinations, respectively.

## DISCUSSION

Our results showed that; the sensitivity and NPV of both CESM and MR Imaging for depicting the index cancer were very high for both modalities in patients with BI-RADS 4 and 5 lesions. Each modality identified 40/42 index cancer (95,2%). This result is comparable to the results reported in previous studies (11 - 13). Jochelson et al. (2013) reported a sensitivity of 96% both for CESM and MR Imaging which depicted 50/52 of index lesions (11). Another study including 178 patients with breast cancer indicated sensitivity levels for the detection of index lesions were 94% and 95% for CESM and MR Imaging, respe-

ctively (12). In our study, two patients with suspect microcalcifications at MG were missed by CESM and MR Imaging since there was no prominent enhancement in both modalities. The final diagnosis of these lesions was low-grade DCIS in histopathological analysis. Fallenberg et al claimed that CESM may catch the DCIS cases which MR Imaging missed because of the contrast uptake mechanism of the DCIS which is less from neoangiogenesis but mostly by diffusion (14). The time delay of imaging after IV contrast administration between CESM and MR Imaging may explain this difference according to this report. However, in that study including 80 index cancers, authors reported only one case of DCIS missed by MR Imaging. Similarly, in another study, which included 81 malignant lesions, MR Imaging missed 6 cases of DCIS, but they did not explain if there were any missed cases with CESM and they interpreted CESM images with associating tomosynthesis images (15).

Other diagnostic performance rates regarding specificity and accuracy were moderate in our study (46,4%, 67,3 % for CESM, and 50%, 69,3% for MR Imaging, respectively). However, these values were higher when we used the score of 5 (corresponding to BI-RADS 4B) or more as a cut-off for both modalities (92,9%, 90,8%; 92,9%, 91,8% for CESM and MR Imaging, respectively). However, minimal loss was observed in sensitivity levels in CESM (95,2% to 88,1%) and MR Imaging (95,2% to 90,5%) in that case. Xing et al investigated 263 suspected breast lesions in 235 patients and reported comparable results regarding specificity and accuracy for CESM and MR Imaging which were 81%, 89,5% vs 80,2%, 71,7%, respectively (16). CESM has emerged as a promising tool to detect breast cancer with a higher specificity than MR Imaging, although specificity for CESM was slightly lower in our study in contrast to the literature. A recent meta-analysis showed that there were 13 publications investigating the diagnostic performance of CESM with a comparison of MR Imaging which identified the pooled specificity of CESM and MR Imaging were 0.66 and 0.52 with a range of 11-94% and 1-78% respectively (17). Some of these studies were retrospective while some were prospective in nature. Also, there were differences in the inclusion criteria of patients and the included lesions. Some studies included patients with newly diagnosed breast cancer while some of them investigated suspicious lesions for breast cancer similar to our study (18 - 20). This may explain the differences in diagnostic performance of these papers. Furthermore, it is well known that low specificity levels originate mostly from false positive rates which leads to unnecessary further procedures. Our PPV levels were 57,1% and 58,8 for CESM and MR Imaging while accuracy was 67,3% and 69,3% for CESM and MR Imaging respectively when the score of ≥4 (BI-RADS 4A) was used as a cut-off. We achieved 90% and above values for PPV and accuracy levels when the score of ≥5 (BI-RADS 4B) was used as a cut-off. This may be interpreted as when categorizing lesions in BI-RADS 4A, which needs histopathological analysis, every center may consider their own results for sensitivity and other performance rates to ensure a balance between over and underdiagnosis. The false positive cases of CESM (30/56) and MR Imaging (28/56) mostly originated from enhancing fibrocystic or inflammatory changes of the breast which mimicked malignant lesions in both contrast-enhanced studies. This may indicate similar behavior of contrast materials in breast tissues whether they are iodinated contrast media or gadolinium chelates. In our study, a scoring system was used to demonstrate the diagnostic values of CESM and MR Imaging regarding BI-RADS categories. This scoring system was used in a prior study, but the results of diagnostic performance per each score have not been reported (15).

The characterization of the lesions as mass lesions, non-mass lesions, and microcalcifications showed that there was no statistical significance in AUC levels between CESM and MR Imaging in each group. However, the AUC was highest for both modalities in mass lesions (0,99 for CESM and MR Imaging), followed by non-mass lesions and microcalcifications (0,94 and 0,99; 0,80 and 0,83 for CESM and MR Imaging respectively). This result showed that CESM is similar to MR Imaging to detect breast cancer presenting as non-mass lesions like asymmetries or architectural distortions and cancers presenting only with microcalcifications.

Our study has some limitations. First, we include only BI-RADS 4 and 5 lesions, since ethical reasons prevent us from obtaining CESM for be-

nign lesions as it is a contrast-enhanced study using ionizing radiation. Further studies would be performed for suspected cases of breast cancer who had first CESM examination instead of MG which will show the exact diagnostic values of CESM. Second, this study was constructed only to detect index cancers, but multifocal lesions would be included in the study. Since our study included only index cancers and was limited to BI-RADS 4 and 5 lesions, the number of subjects was small. Studies with larger numbers of subjects and including multifocal lesions will provide useful additional information.

In line with this study, it has been shown in the literature that CESM is equal to MR Imaging regarding diagnostic performance in detecting breast cancer. Knowing the advantages and challenges, radiologists may prefer to perform CESM instead of MR Imaging in selected cases. Beyond the major limitations of CESM like probable allergic reactions due to administration of iodinated contrast material, it has also the limitation of demonstrating axillary regions, the lesions located deep in the breast or the relations of these lesions to pectoral muscle and thoracic wall. The patients imaged with CESM may have a careful axillary imaging with ultrasound or if there is a suspect of deep lesions, further imaging studies should be applied.

In summary, our results suggest that CESM can accurately detect index cancers in patients with BI-RADS 4 and 5 lesions. In this regard, the diagnostic performance of CESM is similar when compared to MR Imaging.

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