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Role of magnetic resonance imaging (MRI) in evaluating the Indeterminate Breast Lesions

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ORIGINAL STUDY

Role of MRI in evaluating the indeterminate breast lesions

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Abstract

Background: **The number of women who are diagnosed with breast cancer (BC) continues to rise, making it the utmost public cause of cancer death among ladies globally. It has been proposed that high-risk individuals get breast MRIs, which are the most sensitive BC screening method that does not use ionizing radiation.**

Aim and objectives: **This research effort assesses breast MRI to clarify the Breast Imaging Reporting and Data System (BIRADS) categorization of indeterminate mammography or ultrasonography examines as well as evaluate the diagnostic reliability of MRI in assessing lesions discovered on screening or diagnostic mammography or ultrasonography that are BIRADS 3 or 4. The goal of the research is to minimize the mortality rate associated with BC.**

Patients and methods: **This Diagnostic accuracy observational analytical cross-sectional trial was done on 38 patients presented with BIRADS 3 and 4 lesions by conventional ultrasound and mammography at Department of Radiology, Armed Forces College of Medicine, Cairo, Egypt. The duration of the study was from January 1 to October 31, 2023.**

Result: **Regarding the time of maximum enhancement as detected in MRI, considering that absence enhancement and late enhancement at10,7, and 4 min are signs of Benign lesions and maximum enhancement at 2 and 1 min are signs of malignant lesions, sensitivity was 95%, specificity was 77.78% and accuracy was 86.84%. Regarding Threshold of enhancement as detected in MRI, considering that absence of enhancement and threshold enhancement less than 60 are signs of Benign lesions and threshold of enhancement more than 60 are signs of Malignant lesions, the sensitivity was 69.70%, specificity was 100% and accuracy was 73.68%. Essential imaging tool breast MRI is increasingly employed in daily practice.**

Conclusion: **Stellate shape, nondefined lesion margins, skin thickening, earlier time to enhancement, earlier peak, earlier washout, type II and III enhancement curves, maximum enhancement at 2 and 1 min, apparent diffusion coefficient and MRS were identified as significant predictors for BC malignancy.**

Keywords: American College of Radiology (ACR), Breast imaging-reporting and breast cancer (BC), Database system (BIRADS), Magnetic resonance imaging, Radiography mammography

1. Introduction

Breast cancer (BC) is the most prevalent cause of cancer death among women worldwide. Egypt in 2008 had 37.7% of new cancer cases and 29.1% of cancer deaths from carcinoma of the breast [1].

X-ray mammography is the suggested screening process for women over 40, decreasing breast cancer mortality by 30–70%. However, its specificity, and sensitivity, in addition to predictive values vary, affecting confidence. Ultrasound is also employed for screening, especially in nursing, young, or pregnant females, also as a supplement to mammography in women with heterogeneously or highly thick breasts. This method is user-dependent and hard to notice minor lesions and then

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distinguish cysts with dense contents from solid lesions [2].

Therefore, elastography, contrast ultrasonography, tomosynthesis, and magnetic resonance imaging have been recommended as alternatives to mammography and ultrasonography for the purpose of population screening [3].

The American College of Radiology (ACR) designed the Breast Imaging-Reporting and Database System (BIRADS) to standardize breast lesion descriptions, improve clinician communication, reduce inter-observer variability, and improve patient care. The accuracy of these descriptions affects cancer prognosis and treatment. Short-term follow-up imaging or biopsies are recommended for BIRADS 3 in addition to 4 lesions, which are likely benign with malignancy risk of under 2 and 10%, respectively, and can increase health system costs, morbidity, and patient worry [4].

Individuals with indeterminate mammographic and ultrasonographic observations (BIRADS 3 or 4 lesions) have been proposed to use various imaging modalities as a 'problem-solving' method. When other diagnostic imaging investigations or physical examinations are unable to confirm the existence of BC as well as a biopsy is not possible, the ACR's published practice recommendations may recommend a breast MRI. However, some research suggests that MRI imaging can help physicians manage BIRADS stages 3 and 4 lesions and prevent unnecessary biopsies [5].

Therefore, the tenacity of this research was to assess MRI's capability to detect and evaluate BIRAD grade 3 and 4 lesions in the breast.

1.1. Staging in women with known breast cancer

Local staging of a known BC before to surgery is a frequent but contentious rationale for preoperative magnetic resonance imaging. More disease has been detected at MRI, but this has not led to better outcomes. Therefore, guidelines for breast preoperative Wide variations exist in BC diagnostic MRIs amongst women [5].

Younger women, those with hormone receptor-negative tumors, and those with thick breasts are at an increased likelihood for developing invasive interval cancers in the postoperative duration, as well as those who opted for breast conservation surgery without radiation therapy. Therefore, MRI preoperative examination is recommended for women with any of these risk factors. Additionally, while most recommendations recommend MRI for the staging of invasive lobular cancers, the effectiveness of conventional modalities and clinical breast examinations is limited [6].

Management of lesions detected at MRI. Mammographically obscure lesions in the afflicted breast are often discovered using preoperative magnetic resonance imaging. Therefore, pathologic evaluation should validate results that affect the intended surgical operation before treatment is administered. Conversion of breast-conserving surgery (BCS) for benign lesions to mastectomy was documented in early research; this ought to be avoided. The great prevalence of incidental lesions makes the adoption of a multiparametric technique highly important, since it could enable the designation of lesions as certainly benign as well as obviate biopsy. Occult lesions detected by MRI-directed US are nonetheless cause for concern and should be biopsied using MRI guidance [7].

Detection of contralateral BC In 5.5–9.3% of women with a history of unilateral BC, MRI will reveal latent contralateral disease; of these, 37–48% are malignant. About a third of the tumors found are DCIS, and all of them are tiny (1 cm). There are currently no predictors of contralateral cancer detection, and this includes breast density.

1.2. Screening breast MRI

Multiple studies have shown that combining MRI with mammography increases survival rates and that MRI can detect disease at an earlier stage than mammography alone, leading to this general agreement. It is important to remember that the research on screening MRI focuses on high-risk women, in whom the incidence of BC is greater, and the sensitivity of mammography is lower [7].

High-risk women The American Cancer Society and ACR suggest annual screening magnetic resonance imaging and mammography for high-risk women with a lifetime hazard of more than 20% the high-risk group has multiple genetic alterations, including *BRCA2, BRCA1, TP53, PALPB2, CHECK2, PTEN, ATM, CDH1,* and *STK11*.

The majority of high-risk screening literature focuses on *BRCA1/2* carriers, who have sensitivities amongst 75.2–100% in addition specificities amongst 83–98.4%. BRCA1/2 carriers had a cancer detection rate of 26.2/1000, compared with 5.4/1000 for high-risk nonmutation carriers. Recently, screening magnetic resonance imaging and mammography have essentially no incremental cancer identification rate in high-risk patients under 40 [7].

Abbreviated MRI Screening MRI is not frequently utilized because to its great price and the scarcity of available MRI machines. Breast MRI may become

more widely available and less expensive if the MRI process were streamlined so that images could be acquired and interpreted more quickly. In a study involving 443 women and 606 MRI scans, Kuhl *et al.* introduced the idea of a shortened protocol consisting of a single pre and postcontrast T1-weighted acquisition and they found that it was precisely as precise as the full protocol [8].

1.3. Breast imaging reporting and data system

The ACR proposed the BI- RADS categorization system in 1986, with the initial report appearing in 1993. In the 1980s, when annual screening mammograms were first introduced, there was an explosion in the number of mammograms performed, despite massive inconsistency in the results reported by radiologists. Risk evaluation and quality control for MG were standardized with the introduction of BI-RADS, as were the reports available to those who are not radiologists [8].

2. Patients and methods

This Diagnostic accuracy observational analytical cross-sectional research was performed on 38 cases presented with BIRADS 3 and 4 lesions by conventional mammography and ultrasound at Department of Radiology, Armed Forces College of Medicine, Cairo, Egypt from January 1 to October 31, 2023.

2.1. Inclusion criteria

(a) Female patients.
(b) Adult (age: >18 years).
(c) Cases presented with BIRADS 3 and 4 lesions by conventional mammography and ultrasound, in the screening or diagnostic contexts.

2.2. Exclusion criteria

(a) Lesions as isolated cluster of microcalcifications.
(b) History of allergy to contrast agents.
(c) Patients with renal impairment being considered as a contraindication to contrast injection.
(d) Patients with bad general condition.
(e) Contraindications that are absolute for breast MRI encompass the following: renal function impairment or allergy to gadolinium-based contrast media (eGFR <30 ml/min/1.73 m^2); incapability to lie prone; significant obesity; excessively large breasts; and implantable devices that do not support MRI activities.

2.3. Method

(i) Detailed history taking including:
  (a) Personal data: Name, address, sex, age, occupation.
  (b) Complaint.
  (c) Previous medical history (including but not limited to surgical complications, type of procedure, reconstructive surgery, hormonal replacement, and so forth).
  (d) Family history of any disease.
(ii) Careful clinical examination.
(iii) Laboratory investigations:
  (a) Serum creatinine.
  (b) GFR.
(iv) The purpose of the mammography was to identify any architectural distortion, asymmetry in breast density, microcalcification, or masses.
(v) Every ultrasonography case was performed at the Women Imaging Unit, which is part of the department of radio diagnosis at Military Hospitals. The procedure aimed to identify both benign and malignant conditions, in addition to classify breast lesions according to the BIRADS system.
(vi) Magnetic Resonance Imaging: (All cases with BIRAD 3 and 4 were investigated on ACHIVA PHILIPS 1.5 T Machine at MRI unit in Military Hospitals) done as following:

2.4. Imaging technique

(i) All patients were scanned using the standard protocols using dedicated coils in prone position using multiplanar MRI sequences:
  (a) Axial T1W/T2WIs.
  (b) STIR suppresses axial T2 fat.
  (c) Fat suppression in axial and sagittal postcontrast T1 WI.
  (d) Dynamic post-contrast MRI, a 2 ml/s bolus of Gadopentate dimeglumine (0.1 mmol/kg; Magnevist, Bayer HealthCare) followed by a 20 ml saline flush. Both breasts were examined in the axial plane 90 s, 1, 2, 3, 4, 5, and 6 min following contrast administration.
  (e) Time intensity curves: After administering contrast to the preselected ROI, signal intensity measurements were conducted at the point of maximal enhancement, which was typically marked on the curve.
  (f) Diffusion weighted imaging.
  (g) Proton MR Spectroscopy.
(ii) Image Interpretation:

Four expert radiology consultants with 15–25 years of experience reviewed the MRIs independently (all were blinded to the final diagnosis). Regarding the following, every lesion or area of aberrant enhancement identified by MRI that may have been indicative of malignancies in both breasts was assessed:

(i) Lesion assessment:
  (a) Dynamic postcontrast.
    (i) Mass was assessed for its Site, Size, Shape, Margin, Enhancement pattern.
  (b) The signal intensity of the mass on T2WI and STIR images and on T1WI.
  (c) Diffusion study: the mean apparent diffusion coefficient (ADC) value and whether the lesion exhibited diffusion restriction.
  (d) Kinetic Curve Assessment.
  (e) Proton MR Spectroscopy: the presence of a choline peak was assessed using the choline signal-to-noise ratio to identify the lesion. This research employed a semi-quantitative approach, with a choline threshold SNR of 2. Positive results were observed when the signal-to-noise ratio was equal to or above 2, and negative results were observed in all other scenarios.

(ii) Other findings:
  (a) Subcutaneous edema, Nipple retraction/ Nipple invasion
  (b) Suspicious Axillary lymphadenopathy with evaluation of its fatty hilum (loss/preserved), shape (oval/round), its dimensions showing diffusion restriction with ADC value 3 mm^2/s and appreciable postcontrast enhancement with time-intensity curve type [] keeping with benign/malignant/ suspicious nature.
  (c) Chest wall invasion.
  (d) Skin invasion focal or diffuse skin thickening.
  (e) Hematoma/blood, Cysts, Abnormal signal void.

(iii) Gold standard:

Initially, we conducted a prospective evaluation of conventional contrast-enhanced MR images and interpreted them diagnostically using the BI-RADS MRI lexicon. We then reviewed the spectroscopic investigation to determine the focal breast lesions' final radiological characteristics. Thirdly, the result is compared with the histopathology and biopsy results.

2.5. Ethical considerations

Informed written consent was obtained from all cases before enrolment. Study details, the nature of the investigations was explained to all patients.

Approval of the Research Ethics Committee of AFCM, Egypt, was obtained. The study was carried out in a manner that was consistent with the principles outlined in the Declaration of Helsinki.

2.5.1. Right to refuse or withdraw

Individuals were not obligated to participate in this study if they so choose. Additionally, individuals could withdraw their involvement at any given moment. Their medical treatment was not impacted by their choice to participate or not in this study. The confidentiality of individual information was upheld in all written and published data that emerged from the research.

2.6. Data management and statistical analysis

Data entry, processing, and statistical analysis was carried out using IBM Corp. Released 2011. IBM SPSS Statistics for windows, version 20.0 Armonk, NY:IBM Corp. (Statistical Package for the Social Sciences). Utilized were significant tests including Spearman's correlation, Kruskal–Wallis, Wilcoxon's, and χ^2; logistic regression analysis was also employed. The data were presented and analyzed in accordance with the type of data obtained for each variable (parametric or nonparametric). *P* values below 0.05 (5%) were deemed to indicate statistical significance.

2.7. Descriptive statistics

(a) Parametric numerical data includes mean, standard deviation (±SD), and range, while non-parametric data provides median and inter-quartile range (IQR).
(b) Prevalence and proportion of non-numerical data.

2.8. Analytical statistics

(a) Kruskal–Wallis test was used to assess the statistical significance for variations in nonparametric variables between multiple research groups.
(b) The one-way analysis of variance for variables that are continuous and normally distributed.

The Tukey test was used to conduct post hoc analysis following analysis of variance, while the Mann–Whitney *U* test was employed for post hoc results.

3. Results

3.1. Study population

The current study enrolled 38 females with mean age of = 45.16 ± 11.4 years. Age varied from 20 to 67 with mean ± SD = 45.16 ± 11.4. The least number of patients was in the age group 60–70 years (7.89%) then 20–29 years (10.53%). The greatest number of patients was in the age group 40–49 years (36.84%).

The number of cases with Right Breast Lesions was 21 (55.26%). The number of patients with RUOQ Lesion in the study population was 10 (26.32%).

The number of cases with True Positive Mammography tests results in the study population was 17 (44.74%) while number of cases with True Positive Ultrasonography tests results in the study population was 19 (50%) Figs. 1 and 2, Tables 1–8.

4. Discussion

Universally, BC is the primary cause of cancer-related fatalities and the most prevalent cancer among women. Considered by Ref. [1]. Radiography mammography screening continues to be the benchmark for detecting the disease in women aged 40 and above; it has been demonstrated to lessen death from breast cancer by 30–70%. However, its predictive values, sensitivity, and specificity vary, which impacts its dependability [9]. Ultrasonography is also utilized as a screening method, and is particularly recommended for young women, those who are breastfeeding or pregnant, and those who have heterogeneously or highly thick breasts who cannot undergo mammography alone [2]. In light of the drawbacks of mammography and ultrasonography as a population screening tool, several imaging modalities have been recommended as replacements [3,10]. Breast MRI has been advocated as a useful screening option in the high-risk group since it is the most sensitive tool for identifying BC devoid of the utilizing of ionizing radiation [7,8]. Radiologist management of lesions identified on mammography or ultrasound that are inconclusive has been shown to benefit from MRI imaging in several trials [5,11,12].

The primary objective of this trial was to evaluate the diagnostic precision of magnetic resonance imaging in determining the severity of indeterminate breast lesions in BIRAD grades 3 and 4.

In the current study, histopathological diagnosis showed that number of patients with invasive duct carcinoma was 20 (52.63%). Number of patients with True positive mammography tests results was 17 (44.74%). Receiver operating characteristic (ROC) curve analysis showed that mammography test sensitivity was 73.91%, Specificity 80%, and Accuracy 76.32%, in detecting malignant lesions (Fig. 3).

According to Chen *et al.* DCIS and other malignant calcifications can be detected by MG. However, MG is not a perfect test, and its general sensitivity is 75–85%, which lowers rapidly for dense breast parenchyma, for tiny breast cancer, its diagnostic effectiveness is still disputable. The study also, showed that mammography correctly detected 344/475 (72.4%) malignant lesions.

As for ultrasound, it was revealed that the number of cases with true positive ultrasonography tests

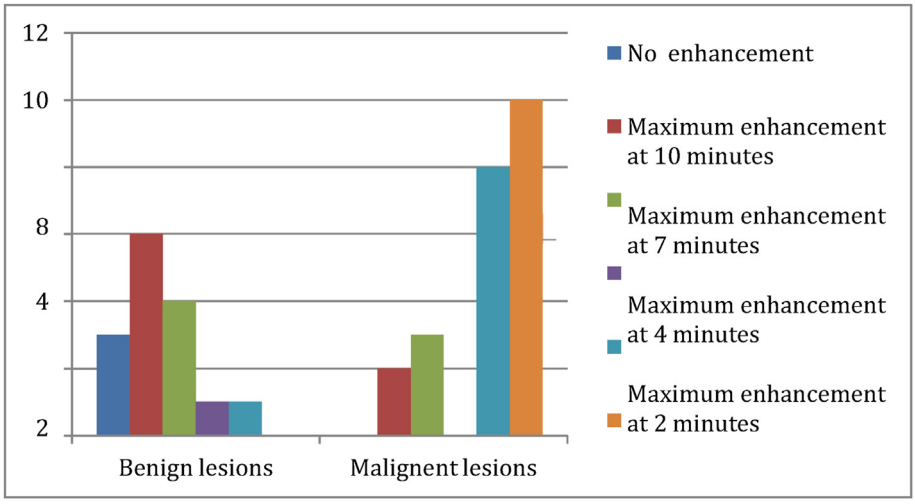

Fig. 1. Bar chart displaying comparison among the study groups concerning time of maximum enhancement.

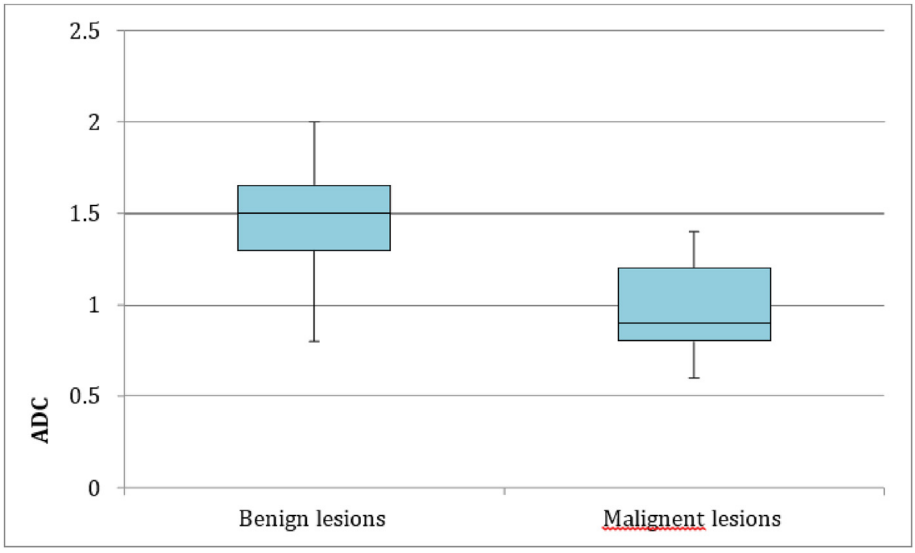

Fig. 2. Box-plot displaying variance among the study groups concerning apparent diffusion coefficient.

results was 19 (50%). ROC curve analysis showed that Ultrasonography test sensitivity was 82.61%, Specificity 73.33% and Accuracy 78.95% in detecting malignant lesions.

Higher than the current study, Gharekhanloo *et al.*, revealed that ultrasonography had a sensitivity of 93.9% and a specificity of 86.5% for the recognition of malignant in addition to benign lesions; its positive and negative predictive values were 86.9% and 93.8%, correspondingly [13]. Among the studied patients there were 99 (48.8) have malignant lesions

Table 2. Age distribution among the study population.

	Study population (n = 38)
Age	
Mean ± SD	45.16 ± 11.4
Median (IQR)	46 (39–52.75)
Range (minimum–maximum)	47 (20–67)
Age distribution, *n* (%)	
20–29 years	4 (10.53)
30–39 years	7 (18.42)
40–49 years	14 (36.84)
50–59 years	10 (26.32)
60–70 years	3 (7.89)

Table 1. BI-RADS assessment categories.

Final assessment categories		
Category	Management	Likelihood of cancer
0 Need additional imaging or prior examinations	Recall for additional imaging and/or await prior examinations	N/A
1 Negative	Routine screening	Essentially 0%
2 Benign	Routine screening	Essentially 0%
3 Probably benign	Short interval follow-up (6 months or continued)	>0% but ≤2%
4 Suspicious	Tissue diagnosis	4 a: low suspicion for malignancy ≥2% to ≤10% 4 b: moderate suspicion of malignancy (≥10% to ≤50%) 4 c: high suspicion for malignancy (≥50% to ≤95%)
5 Highly suggestive of malignancy	Tissue diagnosis	≥95%
6 Known biopsy-proven	Surgical excision when clinically appropriate	N/A

Table 3. Histopathological diagnosis among the study population.

Study population ($N = 38$) [n (%)]	
Histopathological diagnosis	
Invasive duct carcinoma	20 (52.63)
DIC	1 (2.63)
Malignant phyllodes tumor	1 (2.63)
Recurrence	1 (2.63)
Fibro adenoma	7 (18.42)
Proliferative fibrocystic changes	2 (5.26)
Benign phyllodes tumor	1 (2.63)
Papilloma	1 (2.63)
No recurrence	1 (2.63)
Duct ectasia	1 (2.63%)
Abscess	1 (2.63%)
Post radiation changes	1 (2.63)

with ultrasound. The higher accuracy than our study may be due to the difference in radiologist experience. Also, Chen *et al.*, showed that ultrasound correctly detected 421/475 (88.6%) malignant lesions [14].

To assess breast lesions, magnetic resonance imaging can employ both morphology and enhancement kinetics. Not only does this aid to discriminate between malignant and benign tumors, but also gives a physiological basis for more precise measurement of tumor size than feasible with mammography or ultrasonography.

4.1. Lesion morphology

Regarding lesion shape as detected by MRI in our research there was a highly significant variance among the two groups ($P = <0.001$). ROC curve analysis was performed for lesion shape as detected in magnetic resonance imaging in the assessment of malignant and benign lesions. Considering that regular shapes are signs of benign lesions and irregular shapes is a sign of malignant lesions, sensitivity was 90.48%, specificity was 76.47% and accuracy was 84.21%.

Also, regarding lesion margin as detected by MRI in our study, considering that circumscribed margins is a sign of benign lesions and not-circumscribed margins is a sign of malignant lesions, sensitivity was 85.19%, specificity was 100% and accuracy was 89.47%. Amitai *et al.* stated that most of the malignant tumors revealed irregular form and are noncircumscribed masses [11].

In accordance with the current research Almola *et al.*, revealed that a highly significant variance amongst malignant and benign lesions concerning magnetic resonance imaging morphological criteria (shape and margin) of the lesions ($P < 0.001$) [15].

Similar to Singh *et al.*, and Hashem *et al.*, who stated that speculated margin of the lesion in MRI has a high predictive value for malignancy [16,17].

As well, Tezcan *et al.*, revealed that magnetic resonance imaging results, involving lesion size over 20 mm, and shape for masses were significantly correlated with malignant lesions. Nevertheless, smooth margins and oval or round shape, were significantly more common in benign lesions [18].

Higher than the current study Seifeldein *et al.*, reported that morphological analysis by MRI demonstrations a high overall sensitivity of 97.5% and 85% specificity [19].

Table 4. Sensitivity, specificity, and accuracy of mammography, ultrasonography, and MRI test results in the assessment of benign and malignant lesions.

Diagnostic parameters	Sensitivity	Specificity	PPV	NPV	Accuracy
Mammography test, n (%)	73.91	80	85	66.67	76.32
Ultrasonography test, n (%)	82.61	73.33	82.61	73.33	78.95
Lesion shape as detected in MRI, n (%)	90.48	76.47	82.61	86.67	84.21
Early Peak as detected in MRI, n (%)	95.65	93.33	95.65	93.33	94.74
Early Washout as detected in MRI, n (%)	93.75	63.64	65.22	93.33	76.32
The enhancement curve as detected in MRI, n (%)	95.24	82.35	86.96	93.33	89.47
Time of maximum enhancement as detected in MRI, n (%)	95	77.78	82.61	93.33	86.84

Table 5. Type of the enhancement curve as detected in MRI among the study population.

	Benign lesions ($n = 15$)	Malignant lesions ($n = 23$)	Test of Significance	P
Type of the enhancement curve, n (%)			X2 = 26.978	<0.001
No	3 (21.43)	0		
Type I	11 (78.57)	3 (13.04)		
Type II	0	3 (13.04)		
Type III	0	17 (73.91)		

Table 6. Shows the time of maximum enhancement as detected in MRI among the study population. Regarding time of maximum enhancement, there was a significant variance among the two studied groups (P = 0.001).

	Benign lesions (n = 15)	Malignant lesions (n = 23)	Test of Significance	P
Time of maximum enhancement, n (%)			X2 = 20.826	0.001
No enhancement	3 (20)	0		
Maximum enhancement at 10 min	6 (40)	2 (8.70)		
Maximum enhancement at 7 min	4 (26.67)	3 (13.04)		
Maximum enhancement at 4 min	1 (6.67)	0		
Maximum enhancement at 2 min	1 (6.67%)	8 (34.78)		
Maximum enhancement at 1 min	0	10 (43.48)		

These findings corroborate the conclusion reached by Ebrahim and colleagues that there is a strong link between lesion form and margin and histological correlation. With an overall accuracy of 93.3%, the spiculated margin of malignant lesions provides the foundation for evaluating malignant nature in morphological characterization [20].

In addition, Alaref *et al.* done a systematic review and meta-analysis that demonstrated irregular margins in ILC and IDC were the most common morphologic descriptors in the majority of invasive breast cancers (sensitivity 87.0% and 89.9%, respectively) [21].

4.2. Pattern of enhancement

Regarding pattern of enhancement in our study, considering that no enhancement & homogeneous enhancement are signs of benign lesions and heterogeneous enhancement is a sign of malignant lesions, ROC curve analysis of pattern of enhancement showed poor diagnostic accuracy with sensitivity was 66.67%, specificity was 43.48% and accuracy was 52.63%.

In contrast to the current study Almola *et al.*, revealed that there was a highly significant variation amongst benign and malignant intraductal breast lesions regarding their internal pattern of enhancement. ($P < 0.001$) [15].

Also, in contradiction of the present research Ahluwalia *et al.* stated that Strong indicators of malignancy are heterogeneous increase on MRI enhancement [22].

As well, Tezcan and colleagues revealed that magnetic resonance imaging findings, the presence of atypical enhancement patterns, such as ductal or segmental enhancement in the absence of a mass, and heterogeneous enhancement in the case of masses, were strongly correlated with malignant lesions. However, benign lesions were far more likely to have homogenous enhancement. The most common morphological feature of malignant tumors is an enlarged mass, yet this feature is also commonly seen in benign lesions [18].

4.3. Time of enhancement

Regarding the time of enhancement, the current research displayed that there was a highly significant variance between the two studied groups (P = <0.001). Considering that no enhancement and late enhancement after 4 min are signs of benign lesions and early enhancement within 2 min is a sign of malignant lesions, ROC curve analysis showed that the sensitivity was 95%, specificity was 77.78% and accuracy was 86.84%.

Also, regarding early peak, the research presented that there was a highly significant variance amongst

Table 8. Receiver operating characteristic curve analysis with cut-off value, sensitivity, and specificity of apparent diffusion coefficient.

	Diagnostic parameters			
	AUC	Cutoff value	Sensitivity	Specificity
ADC	0.909	1.25	80.0%	91.3%

Table 7. Apparent diffusion coefficient and MR spectroscopy among the study population.

	Benign lesions (n = 15)	Malignant lesions (n = 23)	Test of Significance	P
ADC				
Mean ± SD	1.5 ± 0.33	0.99 ± 0.24	t = 5.25	<0.001
Median (IQR)	1.5 (1.3–1.65)	0.9 (0.8–1.2)		
Range (Minimum –maximum)	1.2 (0.8–2)	0.8 (0.6–1.4)		
MR spectroscopy, n (%)				
Negative	13 (86.67)	0	X2 = 30.299	<0.001
Positive	2 (13.33)	23 (100)		

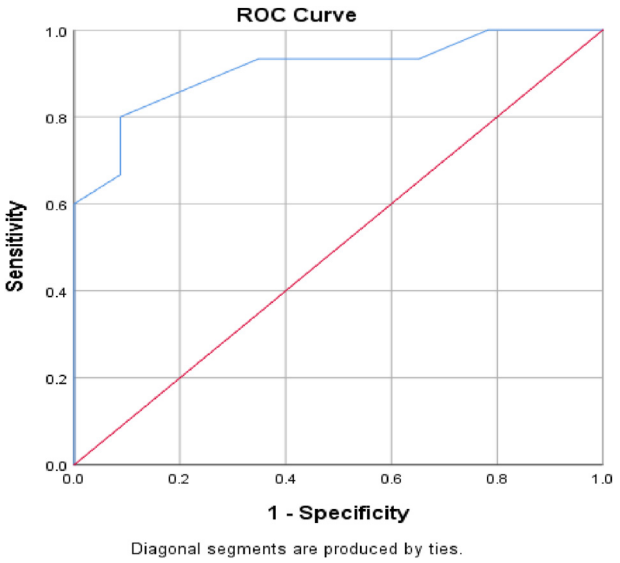

Fig. 3. Receiver operating characteristic curve for apparent diffusion coefficient.

the two studied groups ($P = <0.001$). Considering that early peak is a sign of malignant lesions, ROC curve analysis showed that the specificity was 93.33%, sensitivity was 95.65%, besides accuracy was 94.74%.

4.4. Maximum enhancement

As well, regarding time of maximum enhancement, the research indicated that there was a significant variance amongst the two studied groups ($P = 0.001$). Considering that absence enhancement and late enhancement at 10, 7, and 4 min are signs of benign lesions and maximum enhancement at 2 and 1 min are signs of malignant lesions, ROC curve analysis showed that the Specificity was 77.78%, Sensitivity was 95%, and Accuracy was 86.84%.

Also, in agreement with the current study Gao and Heller which concluded that In comparison to benign breast lesions, a steeper maximum slope, malignant breast lesions have a shorter time to enhancement, also a bigger initial enhancement rate. These are all hallmarks of malignant breast lesions [23].

Abe *et al.* found that tumors with characteristics such as rapid contrast material wash- in, maximum slopes of 13–29%/s, and strong, brilliant enhancement with an initial enhancement rate of 183% or more had a greater probability to be malignant than benign [24].

4.5. Contrast washout

Regarding early washout, the research presented a highly significant variance between the two studied groups ($P = <0.001$). Considering that early washout is a sign of malignant lesions, ROC curve analysis showed that the sensitivity was 93.75%, specificity was 63.64% and accuracy was 76.32%.

Regarding type of the enhancement curve, the existing research showed that there was a highly significant variance amongst the two studied groups ($P = <0.001$). Considering that no enhancement and Type I enhancement curve are signs of benign lesions and type II and III enhancement curves are signs of malignant lesions, ROC curve analysis showed that the specificity was 82.35%, sensitivity was 95.24% and accuracy was 89.47%.

Consistent with the present research Almola and colleagues displayed that there was a highly significant variance amongst benign and malignant lesions regarding type of the development curve ($P < 0.001$). As type III curve was significantly associated with malignancy [15].

Moreover, in concordance to the present research Ahluwalia *et al.* stated that type III curve was found to be a strong indicator of malignancy [22].

As well, Hegazy *et al.* revealed that invasive duct carcinoma mostly shows type III dynamic curve [25].

4.6. Diffusion and ADC

Regarding ADC among the study population. The ADC in Benign lesions varied from 0.8 to 2 with mean ± SD = 1.5 ± 0.33 while in Malignant lesions the ADC ranged from 0.6 to 1.4 with mean ± SD = 0.99 ± 0.24 with highly statistically significant variance ($P = <0.001$) amongst the two groups.

Consistent with the current study Almola and colleagues showed that the mean ADC value of benign ductal breast lesions was (1.34×10^{-3} mm^2/s ± 0.33 SD), while the mean ADC value of

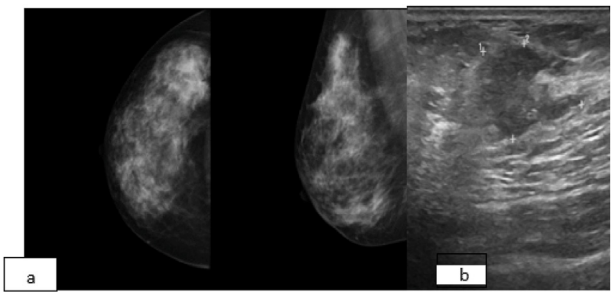

Fig. 4. Infiltrating ductal carcinoma a female patient 33-year-old. A history of right breast lump. (a) Craniocaudal and mediolateral views of the right breast mammographic study display heterogeneously dense parenchyma which may obscure small lesions associated with irregular shaped hyperdense lesion with partially obscured margin seen in UOQ (ACR C) (b): ultrasound study. The UOQ shows an 11 o'clock irregular shaped hypo- echoic lesion measuring (1.3 × 1) cm.

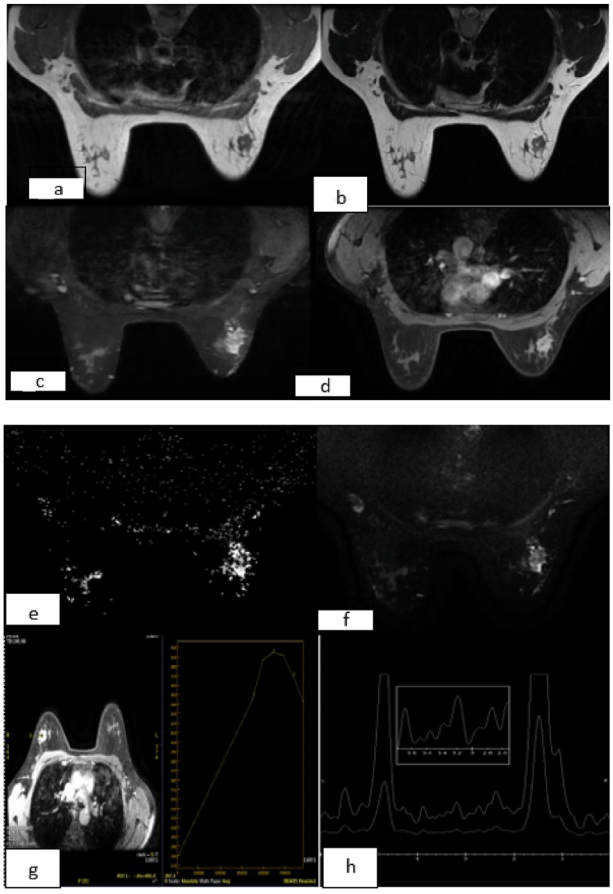

Fig. 5. Infiltrating ductal carcinoma MRI findings an irregular lesion is detected in the upper outer quadrant of the right breast measuring (2 × 1) cm with spiculated margins. Hypointense on Axial T1WI (a), hypointense on Axial T2WI (b), hyperintense on Axial STIR (c), Homogenous enhancement (d), heterogenous diffusion restriction, mean apparent diffusion coefficient value 1.1 × 10-3 mm^2/sec on DWI and apparent diffusion coefficient images (e,f), Positive MRS (g), type 3 kinetic curve (h).

malignant ductal breast lesions (0.69 × 10^{-3} mm^2/s ± 0.24 SD). There was a significant variance among malignant and benign ductal breast lesions concerning ADC value using a cut off ADC value at 1 × 10^{-3} mm^2/s [15].

Also, similar to our study Ebrahim and colleagues research stated that their recommended ADC cut-off value was (1.063 × 10^{-3} mm^2/s), and this cut-off value exhibited (96.9%) sensitivity and (66.7%) specificity. The mean ADC value of benign breast lesions was (1.23 × 10^{-3} mm^2/s ± 0.26 SD), but the mean ADC value of malignant breast lesions was (0.74 × 10^{-3} mm^2/s ± 0.23 SD) [20].

Also, Yang *et al.* study found a sharp variance amongst malignant and benign breast masses in terms of ADC, utilizing a cut-off ADC value at (1.061 × 10^{-3} mm^2/s) [2].

4.7. MR spectroscopy

Regarding MR spectroscopy the current study showed that the malignant group showed markedly elevated choline peak however in patients with benign lesion no choline peak was detected, there was a highly significant variance amongst the two studied groups (P = <0.001).

In concordance with the current study Elkafas and colleagues revealed a highly significant variance amongst the malignant and benign breast masses regarding MRS (P = <0.001). Based on the existence of a significant choline peak in the spectrum, 30 (62.5%) of the cases were malignant, whereas 18 (37.5%) were benign. El Fiki *et al.* reported similar findings; they found that MRS had a sensitivity of 90%, a specificity of 78.6%, an accuracy of 85%, a PPV of 85.7%, and an NPV of 84.6% [26], Figs. 4–7.

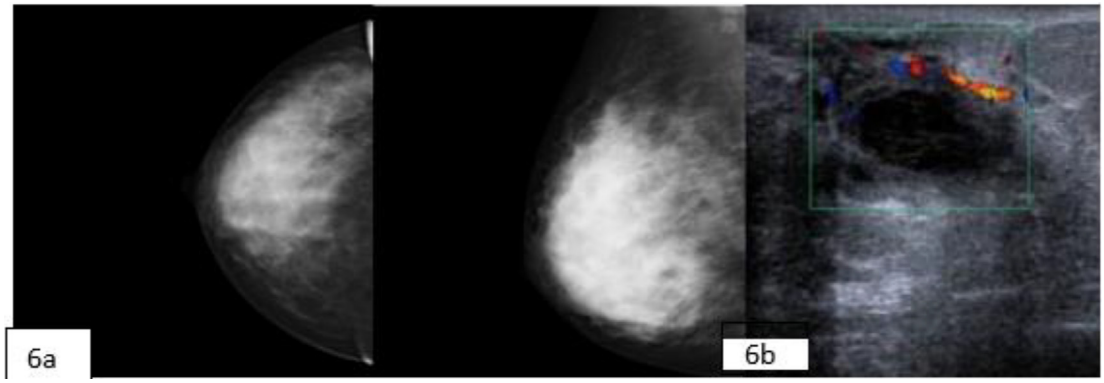

Fig. 6. Breast cyst: A female patient 41 years old. A history of right breast lump. (a) Craniocaudal and mediolateral views of the right breast display heterogeneously dense parenchyma which may obscure small lesions (ACR C), (b): ultrasound of the right breast revealed retroareolar complex cystic lesion with posterior enhancement, thick wall and peripheral vascularity.

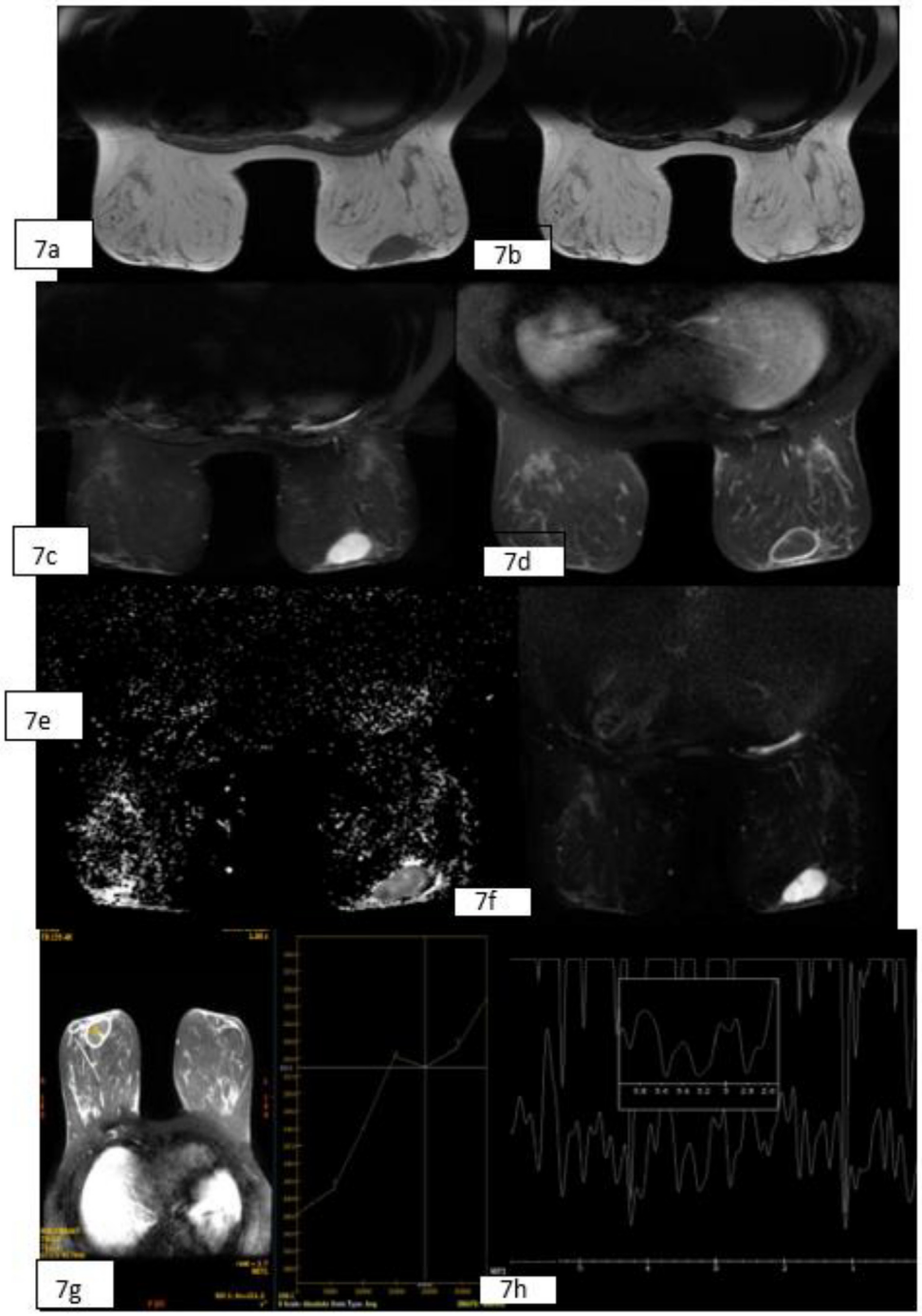

Fig. 7. MRI of the same patient: A lesion is observed retroareolar position measuring (4 × 2.5) cm, oval in shape, smooth margins, (a) hypointense on Axial T1WI, (b): hyperintense on Axial T2WI, (c): hyperintense on Axial STIR (d), Rim enhancement, (e,f) DWI and apparent diffusion coefficient images with homogenous diffusion restriction, mean apparent diffusion coefficient value 1.5 × 10^{-3} mm^2/s, (g) Negative MRS, (h): Kinetic Curve with slow initial rise and persistent delayed rise (type 1 kinetic curve).

4.8. Limitations

The current study was limited by a minor sample size, being a single center Trial and relatively short follow-up period.

Ethical considerations

Informed written consent was obtained from all cases before enrolment. Study details, the nature of the investigations was explained to all patients.

Approval of the Research Ethics Committee of AFCM, Egypt, was obtained. The study was carried out in a manner that was consistent with the principles outlined in the Declaration of Helsinki.

Right to refuse or withdraw

Individuals were not obligated to participate in this study if they so choose. Additionally, individuals could withdraw their involvement at any given moment. Their medical treatment was not impacted by their choice to participate or not in this study. The confidentiality of individual information was upheld in all written and published data that emerged from the research.

Limitations

The current study was limited by a minor sample size, being a single center Trial and relatively short follow-up period.

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Nil.

Author contribution

Jehan I. AlTohamy and Shrouk M. Awadallah: Data collection, scientific writing and radiological interpretation. Nivine A. M. Chalabi and Mohamed A. Farouk: radiological interpretation and supervision. Mina A. Moawad: Data collection and statistical analysis.

Institutional review board (IRB) approval number

The institutional committee's ethical criteria were followed during all proceedings. Armed forces collage of medicine institutional review board (IRB) approved the study (no. 210-2023) on 25.02.2023 (IORG0008659).

Conflicts of interest

There are no conflicts of interest.

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