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Unilateral primary breast edema: Can T2-weighted images meet the diagnostic challenge?

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Abstract

Background: Unilateral primary breast edema may pose a diagnostic challenge. Excluding malignant etiologies is of utmost importance and may require the use of dynamic MRI examination as a problem solver. Yet, the enhancement pattern of benign and malignant disorders associated with edematous breasts may overlap, and this may add to the dilemma. So, our aim in the current study was to assess the role of T2-weighted MR imaging as a problem-solving sequence in differentiating benign from malignant causes of the edematous breast.

Results: In the current prospective study, 65/96 cases were benign and 31/96 cases were malignant. By the individual analysis of the signal intensity in T2-weighted imaging of MRI examination, there was a significant correlation between low T2 signal intensity lesion and malignant etiology of breast edema with a resultant higher sensitivity of 83.87% and a higher specificity of 98.46% as compared to the contrast-enhanced series, which achieved a sensitivity of 80.65% and a specificity of 20.00%. The combined assessment of T2 WI and the contrast-enhanced series yielded a higher sensitivity of 100% and a specificity of 98.46%.

Conclusions: T2WI is a problem-solving sequence in the evaluation of the primary edematous breast, yielding a significant added value in the diagnostic approach and improving the overall diagnostic performance of dynamic contrast-enhanced MRI.

Keywords: Edematous breast, T2WI, DCE-MRI, Inflammatory breast carcinoma, Mastitis

Background

Unilateral breast edema is a sign of breast inflammation. It can present with variable clinical findings, and these often include enlargement of the breast, redness, and thickening of the skin with dimpling, along with an associated variable degree of tenderness. Unilateral breast edema may be the presentation of a broad spectrum of many disorders, ranging from primary mammary to systemic causes and from benign to malignant processes [1]. Thus, achieving an accurate diagnosis poses a real diagnostic challenge.

Differentiation between the many diseases potentially involved in the edematous breast is essential before proper management. Obtaining a detailed patient's clinical history, previous procedures, and detailed knowledge of unilateral breast edema etiologies can help radiologists achieve an accurate diagnosis [2].

Mammography and an ultrasound examination should be performed as the initial methods of investigation. Mammographic findings are non-specific, and they include skin thickening, global asymmetry, and coarsened trabeculae, while ultrasound findings include skin thickening, interstitial edema, hyperechoic fat lobules, and dilated subdermal lymphatics. Though ultrasound may yield more specific signs, sometimes it does not permit an etiological diagnosis to be made with certainty [3].

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MRI is an examination to be used in problematic cases when sono-mammographic findings are equivocal. It should be performed in cases with primary breast edema with unidentified underlying etiology and in cases who are resistant to well-managed anti-inflammatory and/or antibiotic treatment [3]. There is a paucity of literature discussing the added value of MRI in assessing the edematous breast. The few conducted studies have accused MRI of having a low specificity and a low accuracy in assessing the edematous breast, especially when associated with inflammatory signs. Most of these studies concluded that MRI should not be used to differentiate between benign and malignant causes of breast edema due to the overlap in the enhancement patterns [4]. These studies mainly assessed the post-contrast MRI sequences with no consideration given to the added value of the T2-weighted imaging. T2WIs are considered a problem-solving tool in breast MRI. The normal parenchymal architecture and lesion morphology are better delineated on T2WIs. Being fluid sensitive, edema, collections, and abscess cavities can be easily identified on the T2WIs [5].

In reference to the underestimation of the impact of adding the T2WI on the contrast images assessment, the current study aimed to assess the added role of T2-weighted MR imaging in differentiating benign from malignant causes of unilateral primary breast edema.

Methods

This study was a prospective analysis, approved by the ethics committee at our institute, during the period from December 2018 to December 2021.

Patient population

The study included 96 patients referred for an MRI examination from the "Multidisciplinary Breast Cancer Tumor Board" to investigate the underlying cause of breast edema. They were subjected to a primary ultrasound and/or mammography evaluation according to the patient's age. Inclusion criteria included patients with persistent edematous breasts after adequate medical management and patients with inconclusive ultrasound and mammography findings.

Exclusion criteria included patients with unilateral or bilateral breast edema secondary to systemic disorders (e.g., cardiac and renal failure) and patients who responded to medical treatment and have achieved complete resolution of the breast edema. Patients who had a contraindication to MRI examination and/or intravenous contrast (renal impairment, allergic patients, or pregnant patients) or those who lacked pathological confirmation were also excluded from the study.

Mammography and ultrasound examination and image analysis

Ultrasound examination was performed for all cases. Mammography examination was not performed in young and lactating females and was only reserved for patients above 40 years and younger ones with suspected malignant etiology.

Magnetic resonance imaging acquisition

MRI was performed for the breasts using a 1.5 Tesla magnet scanner (Gyroscan Intera, Philips Medical System). All patients were examined in the prone position using a dedicated phased-array breast coil with eight channels. Total study time ranged from 30 to 45 min. No sedation was used.

Cases were examined first by pre-contrast sequences: Axial T1-weighted sequence spin-echo (SE) (TR/TE 500/5.3 ms), sagittal and axial T2-weighted sequences SE (TR/TE 120/ 4.9 ms) and axial T2-weighted inversion recovery (IR) (TR/ TE 80/6.5 ms). For all the aforementioned sequences, slice thickness = 4 mm, matrix = 512 · 192, flip angle = 90_, and FVO = 34–37 cm. Six dynamic 3D "T1 High-Resolution Isotropic Volumetric Examination" THRIVE acquisition was used; 1 before and 5 after power injection of 0.1 mmol/kg BW of contrast (Gd-DTPA), with the parameters (TR/TE 2.8/9 ms) and slice thickness = 1.5 mm. Post-processing subtraction images were used to highlight the enhancing features in the image.

Image analysis

MRI findings were analyzed and reported both for the contrast uptake pattern and for the corresponding T2 WI signal (once independently and once combined) by two different readers with 10–15 years of experience in the field of breast imaging (kappa 0.63). They were blinded to the mammography and ultrasound findings. In case of disagreement, the final diagnosis was reached in consensus.

Analysis of contrast-enhanced sequences was done and accordingly, lesions were classified according to their contrast uptake as enhancing or non-enhancing. Based on the enhancement pattern, further classification of the enhancing lesions was performed into mass and non-mass enhancement. The enhancing mass lesions displayed either homogeneous, heterogeneous or rim enhancement with the latter two being the most concerning enhancement patterns favoring a malignant etiology. Non-mass lesions' enhancement patterns included homogeneous, heterogeneous, or clustered rings with the latter two being the most concerning

Table 1 Main discriminating descriptors between benign and malignant etiology of unilateral primary breast edema

	Benign descriptors	Malignant descriptors
MRI dynamic sequences	Non-enhancement Homogenous enhancement	Rim enhancement Heterogeneous
T2-weighted sequence	Collections or abscess cavities Bright/intermediate T2 signal	Dark T2 signal

enhancement patterns favoring a malignant etiology. That is emphasized in Table 1.

Analysis of the T2-weighted images included reporting: the presence of any lesion, interstitial edema, or the presence of collections or abscess cavities. On T2-weighted images, the signal pattern of any identified lesion was compared to the signal of the fibroglandular parenchyma and accordingly, a bright, intermediate or a low signal was assigned. Lesions of a bright or intermediate signal were considered benign, while lesions of a low signal were considered suspicious, as shown in Table 1.

The diagnostic indices of the enhancement pattern and the T2WI were calculated individually in reference to the core and surgical biopsy results.

Pathological analysis

The diagnosis was established through a core needle biopsy or cytology of fluid aspirates (considered the standard reference). To confirm a benign pathology, patients with biopsy-proven benign edematous breasts were followed up until complete resolution was achieved, while to confirm a malignant pathology, reference to the surgical pathology was accomplished.

Statistical analysis

Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Sciences) version 22. The statistical measure of the strength of the relationship between the benign and malignant descriptors of the identified lesions and the pathology results was measured using the correlation coefficient. The values range between − 1.0 and 1.0. A calculated number greater than 1.0 or less than − 1.0 means that there was an error in the correlation measurement. A correlation of − 1.0 shows a perfect negative correlation, while a correlation of 1.0 shows a perfect positive correlation. A correlation of 0.0 shows no linear relationship between the movement of the two variables. The *P* value less than or equal to 0.05 was considered significant, and that less than 0.01 was considered highly significant. A comparison between categorical data was made using the chi-square test. Standard diagnostic indices including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated.

Results

This prospective study included 96 patients with unilateral breast edema who were referred for an MRI examination from the "Multidisciplinary Breast Cancer Tumor Board." An initial ultrasound (in 96/96 cases, 100%) ± mammography examination (65/96 cases, 67.7%) was performed according to the age of the patients and their lactational status. Both studies were either inconclusive and mismatched the clinical presentation or were not responsive to medical treatment. Their age ranged from 21 to 64 years (mean age 37.2 ± SD). Unilateral breast edema was the sole sign in 67/96 (69.8%) patients. Additional intramammary mass was palpable in 26/96 patients (27.1%), and another 3/96 patients (3.1%) had a palpable axillary mass.

Among the studied cases and according to the histopathological results, underlying benign etiology was detected in 65/96 cases (67.7%), while underlying malignant etiology was detected in 31/96 cases (32.3%). The most common pathologies associated with benign edema were granulomatous mastitis (20/65, 30.8%), while the most common encountered malignancy was invasive duct carcinoma (26/31, 83.9%). This is illustrated in Table 2.

Dynamic contrast-enhanced MRI findings

In the current study, there were 7/96 (7.3%) cases that showed no enhancement, while 89/96 (92.7%) cases

Table 2 Different pathologies encountered among the studied population

Final diagnosis	Count	%
Lactational mastitis	14/96	14.58%
Granulomatous mastitis	20/96	20.83%
Abscess cavity	16/96	16.67%
Postoperative/therapy changes	8/96	8.33%
Fat necrosis	5/96	5.21%
Specific mastitis	2/96	2.08%
IDC	26/96	27.08%
ILC	4/96	4.17%
NHL	1/96	1.04%

IDC Invasive duct carcinoma, *ILC* Invasive lobular carcinoma, *NHL* Non-Hodgkin lymphoma

showed enhancement either as mass or as non-mass enhancement. A significant correlation between the absence of enhancement and benign nature was found (*P* value < 0.001, r:0.1937) (Table 3).

Based on the analysis of the enhancement pattern, homogeneous enhancement was equally distributed among the benign and malignant cases. Heterogeneous enhancement was found in 36/89 (40.45%) cases, out of which only 19/36 (52.78%) cases were verified as malignant by pathology, while 17/36 (47.22%) cases were benign. Rim or clustered ring enhancement was found in 41/96 (42.70%) cases, out of which only 6/41 (14.63%) cases were verified as malignant by pathology, while the remaining 35/41 (85.37%) cases were benign, as shown in Table 4.

An insignificant negative correlation was found between the enhancement pattern and the benign or malignant pathology (*P* value 0.237, r -0.1257).

In reference to the enhancement pattern, 6/96 (6.25%) malignant cases were false negative as they showed homogeneous enhancement, while 52/96 (54.2%) benign cases were false positive as they displayed heterogeneous non-mass or rim/clustered ring enhancement (Fig. 1). That is emphasized in Table 5.

T2-weighted MRI findings

Signs of focal or diffuse inflammatory changes were identified in all cases (96/96, 100%). Based on the T2 WI signal pattern, 69/96 (71.88%) lesions elicited a bright or an intermediate signal intensity and were considered benign (Fig. 2), while 27/96 (28.12%) lesions elicited a T2 WI low signal intensity and were considered malignant. A significant correlation was found between the T2 WI signal pattern and the outcome after biopsy ($r = 0.9743$, *P* Value is < 0.00001). Their relation to final pathology is emphasized in Table 6.

In reference to signal intensity in T2 WI, 64/69 (92.75%) cases were true negative (Fig. 3), while 5/69 (5.21%) cases were false negative and malignant pathology was verified by final pathology (3/4 cases were invasive lobular carcinoma, 1/5 case was IDC, and 1/5 case was non-Hodgkin lymphoma) (Fig. 4). Conversely, there were 26/27 (96.30%) true positive cases (Fig. 5) with only 1/27 (3.70%) false positive cases as verified by final pathology (Table 7).

Combined T2 WI and contrast-enhanced series analysis

Based on the combined analysis of the findings noted in both T2 WI and contrast-enhanced series, there were 64/96 (66.67%) true negative cases with only 1/96 (1.04%) false positive case that elicited low signal in T2 WI and heterogeneous non-mass enhancement in the contrast-enhanced series. By combined analysis, the most suspicious finding, either on T2 WI or contrast-enhanced series, was taken into consideration. Accordingly, there were no false negative cases in this study (Table 8).

In the current study, analysis of the signal intensity in T2 WI has achieved a higher sensitivity, as well as a much higher specificity and overall diagnostic accuracy as compared to the contrast-enhanced series. However, the best sensitivity was achieved on combined analysis of both T2 WI and contrast-enhanced series, yet with equivalent specificity as that achieved by T2 WI (Fig. 6). That is emphasized in Table 9.

Table 3 Distribution of the presence/absence of enhancement among the studied population

Presence or absence of enhancement	Pathology				Correlation
	Benign		Malignant		
	Count	%	Count	%	
Non-enhancing	7	100%	0	0%	P value < 0.001*
Enhancing (mass/non-mass)	58	69.17%	31	34.83%	P value < 0.058 r: 0.1937

Table 4 Correlation between the pattern of enhancement and final pathology

Pattern of enhancement		Pathology				Correlation
		Benign		Malignant		
		Count	%	Count	%	
Mass/non-mass	Homogeneous	6	50.0%	6	50.0%	P value 0.237 r − 0.1257
	Heterogeneous	17	47.22%	19	52.78%	
	Rim/clustered ring	35	85.37%	6	14.63%	

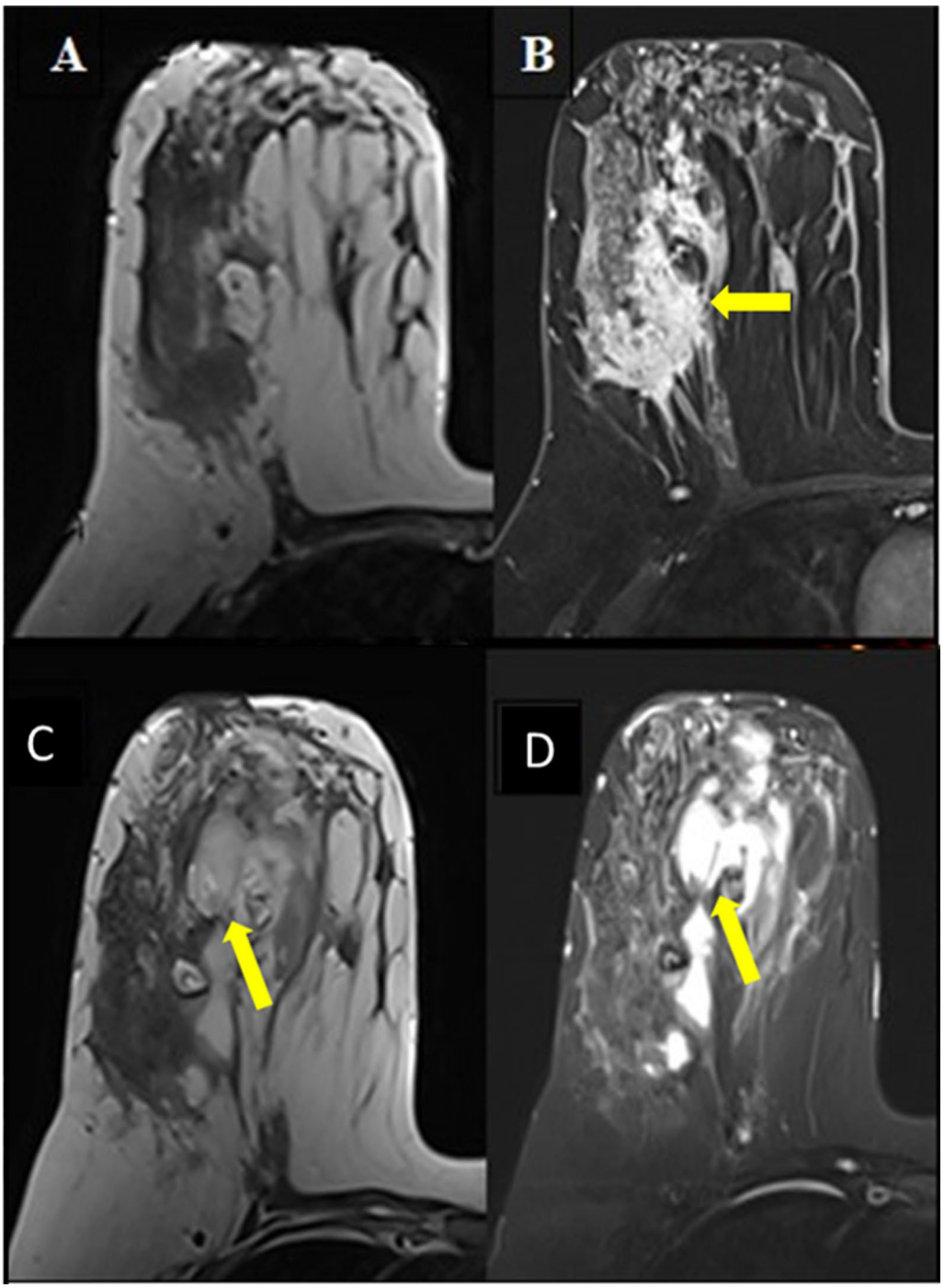

Fig. 1 A 35-year-old female with right breast swelling and tenderness. Pathology revealed benign pathology; non-specific granulomatous mastitis. MRI examination was done at an early stage of the disease process after resistance to antibiotic treatment. **A** Axial T2-weighted image shows regional area of low signal intensity with corresponding intense heterogeneous non-mass enhancement (arrow) in the post-contrast dynamic series (**B**) and was considered suspicious (false positive). Follow-up non-contrast MRI examination by axial T2- and STIR-weighted images (**C** and **D**) shows the development of ill-defined fluid collections (arrows), consistent with a benign inflammatory process (true negative)

Table 5 Correlation between the diagnosis by contrast-enhanced series and final pathology

Diagnosis	Pathology			
Dynamic contrast-enhanced series	TP	FP	TN	FN
	25	52	13	6

TP true positive; FP false positive; TN true negative; FN false negative

Discussion

Unilateral primary breast edema poses a diagnostic dilemma as they are the presenting clinical imaging feature in variable breast disorders that range from benign to malignant forms, especially inflammatory breast carcinoma (IBC) [6]. Distinguishing IBC from other causes of mastitis is of utmost importance, as this alters the treatment strategy and the overall prognosis [7].

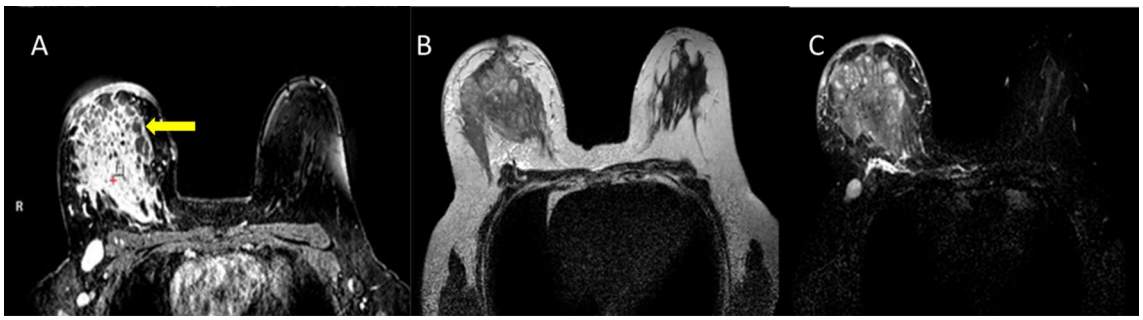

Fig. 2 A 43-year-old female with right breast induration and tenderness, under antibiotic treatment for one month with no apparent amelioration of the condition. Pathology revealed benign pathology; non-specific granulomatous mastitis with multifocal suppuration and chronic abscess formations. **A** Axial post-contrast dynamic MRI series reveals suspicious intense heterogeneous and clustered ring (arrow) non-mass enhancement (false positive). **B** and **C** Axial T2 weighted and STIR MRI images show diffuse breast involvement by an ill-defined complex process with bright to intermediate signal intensity with multiple tiny abscess cavities (true negative)

Table 6 Correlation between assessment of signal intensity in T2-weighted MRI and final pathology

		Pathology				Correlation
		Benign		Malignant		
		Count	%	Count	%	
(T2-weighted MRI)	Benign	64	92.75%	5	7.24%	r = 0.9743 P value is < .00001*
	Malignant	1	3.7%	26	96.30%	

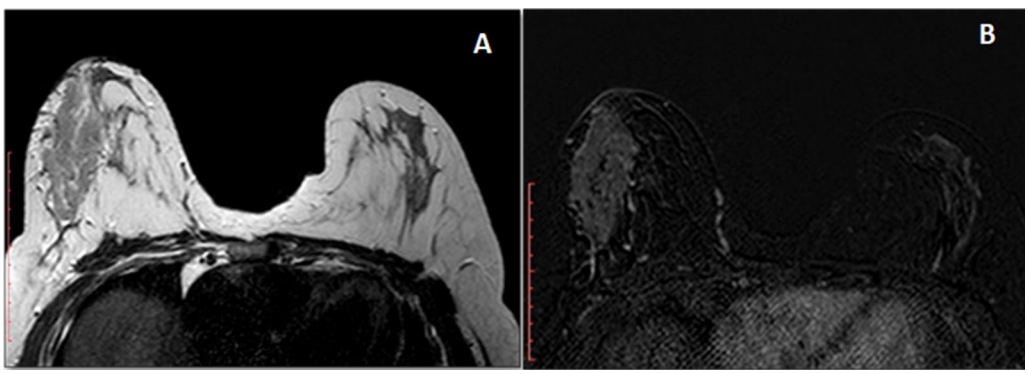

Fig. 3 A 38-year-old female presenting with right breast lump, skin redness, and tenderness. She was resistant to proper medical treatment. Pathology revealed benign pathology; non-specific granulomatous mastitis. **A** Axial T2-weighted MRI image shows segmental area of intermediate to bright signal intensity (true negative). **B** Axial post-contrast dynamic series shows segmental non-mass enhancement (false positive)

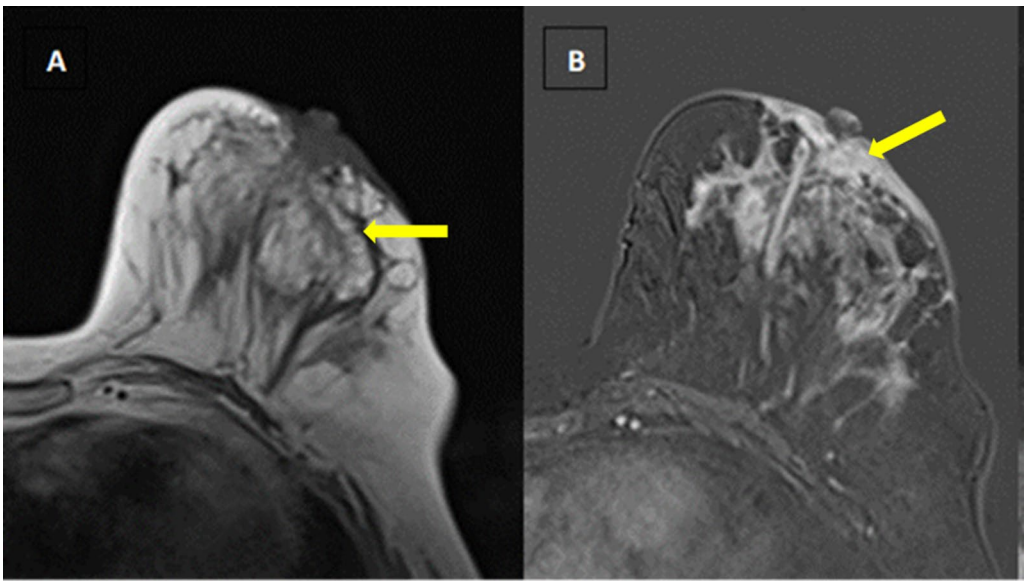

Fig. 4 A 65-year-old female with left breast induration. Pathology revealed malignant pathology; invasive lobular carcinoma. **A** Axial T2-weighted MRI image shows regional area of high signal intensity (arrow) (false negative). **B** Axial post-contrast dynamic MRI series shows corresponding suspicious intense heterogeneous non-mass enhancement extending to the nipple/areola complex (arrow) (true positive)

In this study, we discussed the role of the T2 WI in the evaluation and discrimination between benign and malignant disorders associated with unilateral primary breast edema. Results were compared with the final diagnosis which was reached after revision of core biopsy/surgical specimens or cytology of fluid aspirates.

The age of the patients included in the study ranged from 21 to 64 years (mean age 37.2 ± SD). Mammography is of limited ability in the evaluation of edematous breasts because of the associated increased breast density that may obscure underlying lesions, also the possible associated tenderness that may interfere with proper breast compression. Le-Petross et al. [8] stated that MRI has higher diagnostic accuracy compared with conventional mammography because of their high capability to the depiction of obscured lesions in conventional mammography.

It is well agreed that the primary method of investigation in the edematous breasts is ultrasound examination, but the reliance on operator experience and the possibility of missing lesions, particularly in cases presenting with extensive breast edema, may reduce the sensitivity of ultrasound [8].

MRI may act as a problem solver in edematous breast as it can confirm or exclude the presence of associated mass lesions when extensive inflammatory reactions constituted a barrier to an efficient ultrasound diagnosis. The real challenge of MRI was with the atypical forms of mastitis (e.g., tuberculous and pseudomonas infections), and chronic non-specific granulomatous mastitis that may mimic malignant etiologies of breast edema.

Dynamic contrast-enhanced series is an important part of the multiparametric MRI approach used for the assessment of breast lesions, yet it is accused of low specificity while evaluating edematous or inflammatory breast disorders. In the current study, the absence of enhancement was significantly correlated with benign disorders (P value < 0.001), while the individual analysis of the enhancement pattern was not indicative of the underlying etiology of breast edema and this is due to the overlap of the enhancement patterns of benign and malignant disorders. To be more precise, a negative correlation was even calculated and this added more to the diagnostic challenge (P value < 0.237, r -0.1257).

Based on the pattern of enhancement, there were 36/89 (40.45%) lesions that showed heterogeneous mass or non-mass enhancement, out of which 19/36 (52.78%) lesions were verified pathologically as malignant, while 17/36 (47.22%) lesions were verified pathologically as benign. That was in accordance with Ferron et al. [3], who stated that non-mass enhancement is not a specific criterion directing diagnosis toward a benign or malignant etiology. This may explain the evident low specificity (20%) that was achieved by the individual analysis of contrast-enhanced series in our study. Conversely, the achieved relatively high sensitivity (80.7%) was attributed to the fact that almost all malignant lesions show contrast

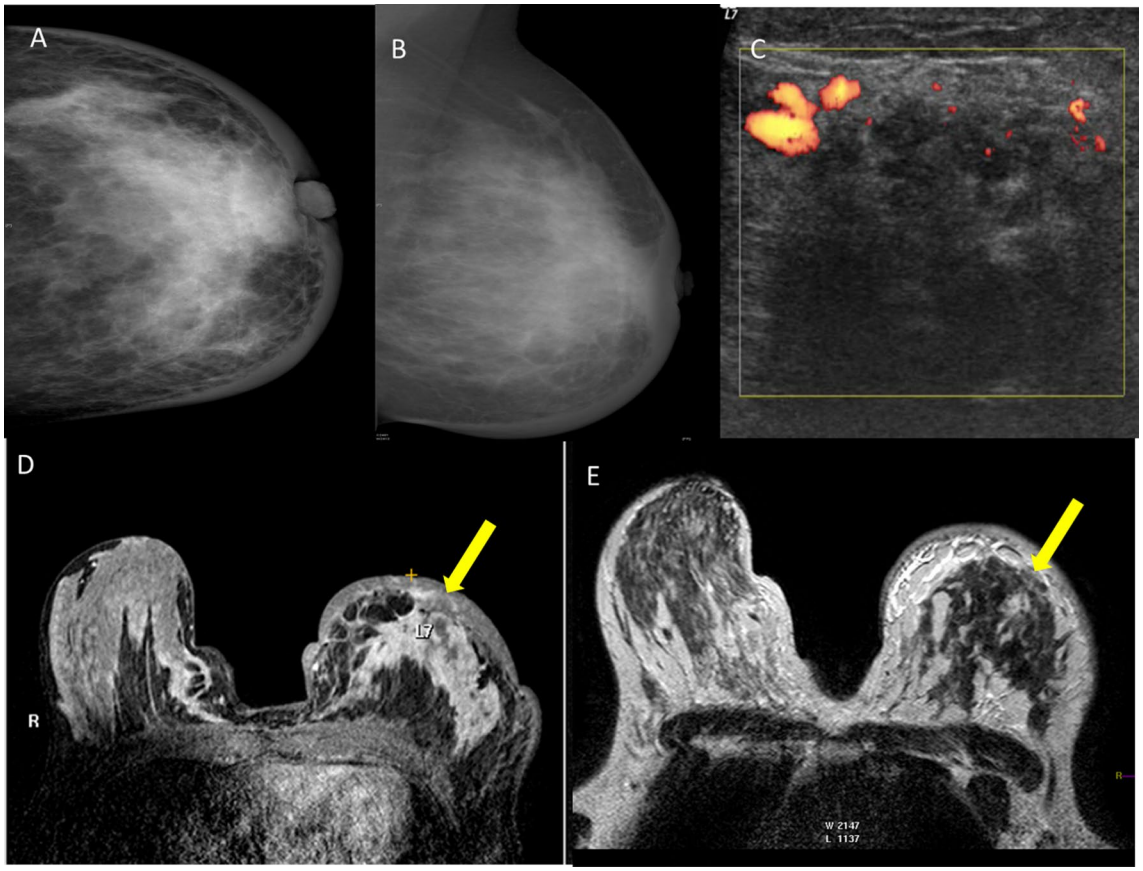

Fig. 5 A 35-year-old female with left indurated tender breast, pathology revealed invasive lobular carcinoma. **A**, **B** FFDM CC and MLO views show dense breast with diffuse skin thickening and coarsened trabeculae. **C** Ultrasound findings were equivocal with just increased parenchymal vascularity. **D** Axial post-contrast dynamic MRI series shows left breast suspicious intense heterogeneous non-mass enhancement extending to the nipple/areola complex (true positive). **E** Axial T2-weighted MRI image shows corresponding regional area of low signal intensity (true positive) FFDM; full-field digital mammography; CC, craniocaudal view; MLO, mediolateral oblique view.

Table 7 Correlation between the diagnosis by T2 WI and final pathology

Diagnosis	Pathology			
T2-weighted images	TP	FP	TN	FN
	26	1	64	5

TP true positive; FP false positive; TN true negative; FN false negative

Table 8 Correlation between the diagnosis by combined analysis and final pathology

Diagnosis	Pathology			
Combined analysis	TP	FP	TN	FN
	31	1	64	0

TP true positive; FP false positive; TN true negative; FN false negative

uptake which is responsible for the low false negative results.

In the current study, we found that the low T2 signal intensity lesions were significantly correlated with malignant etiologies of breast edema, while the bright or intermediate T2 signal intensity lesions were significantly correlated with benign etiologies of breast edema ($r = 0.9743$, P value is < 0.00001). This was in accordance with Ferron et al., Mansour & Abolfotooh, and Malich et al. [3, 7, 9] who stated that T2-weighted sequences should be carefully analyzed as they found that a benign nature can be inferred from a T2 intermediate signal or bright signal.

Khalil et al. [10] had performed a detailed analysis of unenhanced MRI in the characterization of breast lesions, and they found that most malignant lesions were hypointense in T2 WI, contrary to benign breast

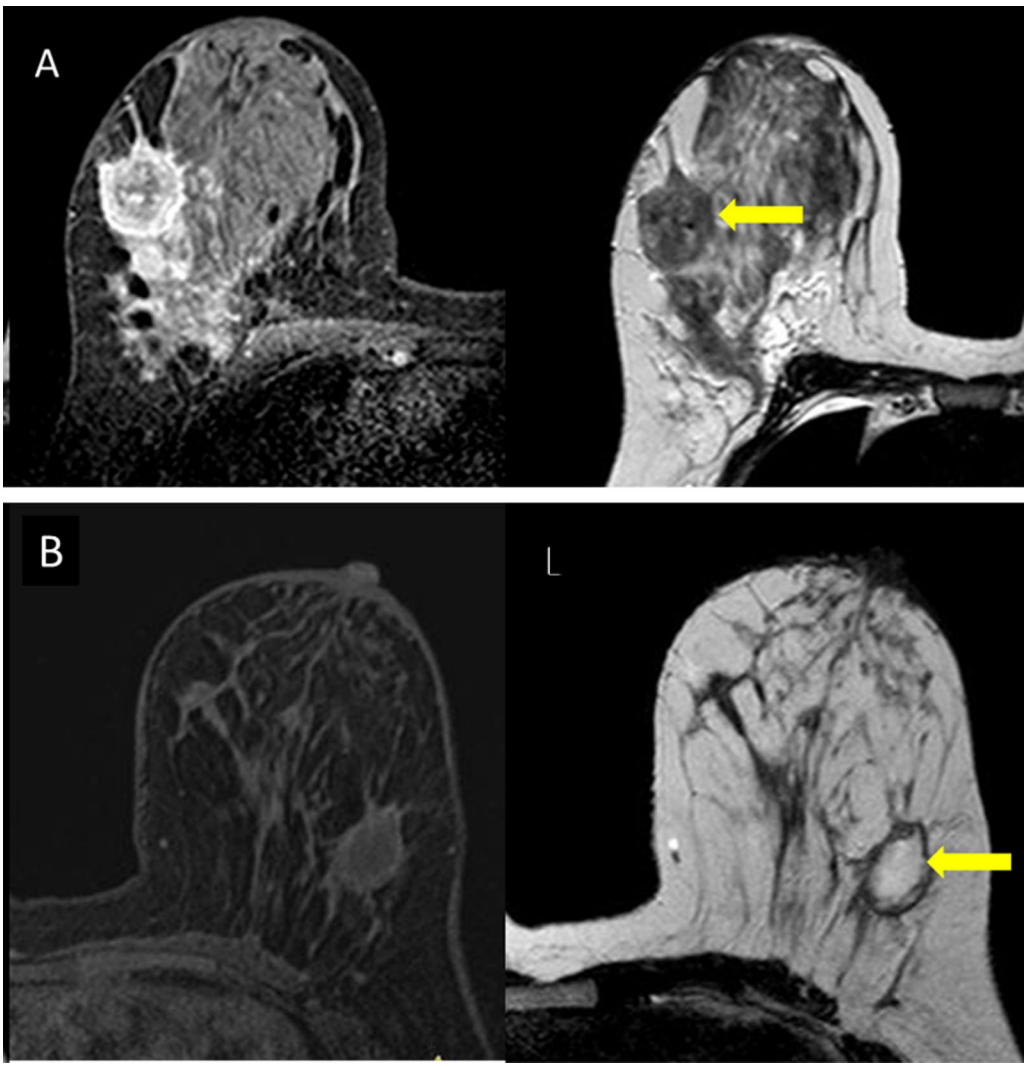

Fig. 6 Two different cases showing rim-enhancing lesions. **Case A**: Axial T2-weighted MRI image shows corresponding low signal intensity (arrow) suggestive of malignant process. Pathology revealed invasive duct carcinoma. **Case B**: Axial T2-weighted MRI image shows corresponding bright signal intensity (arrow) suggestive of benign inflammatory process. Pathology revealed abscess cavity in a case of granulomatous mastitis

Table 9 Diagnostic indices of T2-weighted MRI, contrast-enhanced MRI and combined MRI assessment in the detection of malignancy

	T2 WI (95% CI)	**DCE-MRI (95% CI)**	**Combined assessment (95% CI)**
Sensitivity	83.9% (66.3–94.6%)	80.7% (62.5–92.6%)	100% (88.8–100%)
Specificity	98.5% (91.7–100%)	20.0% (11.1–31.8%)	98.5% (91.7–100%)
Positive predictive value	96.3% (78.7–99.5%)	32.3% (23.1–42.6%)	97% (81.6–99.5%)
Negative predictive value	92.8% (85.2–96.6%)	68.4% (47.6–83.8%)	100%
Accuracy	93.8% (86.9–97.7%)	39.6% (29.8–50.1%)	99.0% (94.3–100%)

lesions that were usually hyperintense. However, this is not the case with specific pathologic types of breast cancer (e.g., mucinous or metaplastic carcinomas) and in the case of central necrosis or hemorrhage [11].

In our study, the sensitivity and specificity of T2-weighted images were 83.9% and 98.5%, respectively, with an overall accuracy of 93.8%. Among the 5 false negative cases, there were 3/5 (60%) cases (proved to be ILC) that presented with bright or intermediate signal intensity (3 out of 4 ILC) cases. De Lima Docema et al. [12] studied the MR imaging features of invasive lobular carcinoma and stated that lesions of intermediate signal intensity were relatively more noted in invasive lobular carcinoma than those of low signal intensity. Also, there was 1/5 (20%) case (proved to be non-Hodgkin lymphoma) that presented with bright signal intensity. In their study about the MRI features of breast lymphoma, Liu et al. [13] stated that all the included cases in their study were hyperintense in T2-weighted images.

Despite being displayed by benign inflammatory and malignant breast lesions, rim enhancement by itself is an established characteristic of suspicious lesions [14]. In this study, a rim/clustered ring enhancement was displayed by 41/96 (42.70%) lesions and they were all considered suspicious, yet in correlation with pathology, only 6/41(14.63%) lesions were malignant and 35/41 (85.37%) lesions were benign. By analysis of the T2 WI signal intensity of these lesions, underlying suspicious etiology was correctly excluded in 35/41 cases (true negative). Low T2 signal intensity was elicited in 5/6 (83.33%) malignant lesions (true positive), while only 1/6 (16.67%) lesion elicited bright signal intensity (false negative) and was pathologically proved as IDC.

By analyzing both T2-weighted images and the dynamic contrast-enhanced series, we attained a sensitivity of 100% and a higher overall diagnostic accuracy of 99%. That was in agreement with Kamal et al. [15], who stated that the internal enhancement pattern of a lesion is not a reliable sign in predicting malignancy, specifically rim-enhancing lesions, and that reviewing T2-weighted images can confirm benign inflammatory lesions like abscesses or infected cysts. Also, Baltzer et al. [16] stated that non-mass enhancement was found equally in both benign and malignant breast diseases, yet much improvement in sensitivity and specificity was achieved by analyzing the signal intensity in T2 WI.

The main limitation of this study was the small sample size, which was attributed to the selection of cases. MRI examination was only reserved for challenging cases who are resistant to adequate management, and inconclusive cases on sono-mammography examination.

Conclusions

Putting into consideration the overlap of the enhancement pattern of benign and malignant etiologies of the unilateral primary edematous breast, analysis of the signal intensity in T2WI may increase our confidence in discriminating benign from malignant etiologies. T2-weighted imaging may oppose the low specificity associated with contrast-enhanced series in the evaluation of edematous breast and thus alter the overall diagnostic performance.

Abbreviations

MRI: Magnetic resonance imaging; T2 WI: T2-weighted image; BI-RADS: Breast Imaging Reporting and Data System; DCE-MRI: Dynamic contrast-enhanced magnetic resonance imaging; THRIVE: T1 high-resolution isotropic volumetric examination; STIR: Short tau inversion recovery; ILC: Invasive lobular carcinoma; IDC: Invasive duct carcinoma; IBC: Inflammatory breast carcinoma.

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None.

Author contributions

RMK designed the work. SF wrote the manuscript and was responsible for correspondence to journal. EFK helped in writing the manuscript and worked on data collection and interpretation. RMK and YMT contributed in reviewing the manuscript and interpretation. All authors have read and approved the final manuscript.

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Availability of data and materials

All are available with the authors upon request.

Declarations

Ethics approval and consent to participate

The protocol was reviewed and approved by the Ethics Committee of Cairo University.

Consent for publication

A written consent for publication was obtained for these cases.

Competing interests

The authors declare that they have no competing interests.

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