

Role of Diffusion MRI in Diagnosis of Inflammatory Breast Lesions

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Abstract: Background: Mastitis is inflammation of the breast that may or may not be accompanied by infection. The term mastitis is often used synonymous with breast infection, but strictly speaking mastitis is inflammation of the breast irrespective of the cause. Having mastitis does not raise the woman's risk of developing breast cancer. **Aim of the Work:** To elucidate the role of Diffusion MRI in evaluating patients with inflammatory breast lesions. **Patients and Methods:** This is a prospective study that included 42 clinically or pathologically diagnosed patients as having inflammatory breast lesions, who were referred to MRI unit from Ain shams hospital and outpatient breast clinics. This study was carried out during the period between August 2017 and April 2019. **Results:** The results from the present study and previous studies provide consistent evidence that DWI is a good diagnostic non invasive tool for breast lesions characterization and when added to the standard breast MRI protocols, it aids the diagnosis of different inflammatory breast lesions. **Conclusion:** The present study supports the usefulness and the role of DWI, with the calculation of the ADC values, in differentiation between infectious, non infectious benign inflammatory and malignant inflammatory breast lesions.

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Keywords: Magnetic Resonance Imaging, Breast Lesions.

1. Introduction

In the great majority of cases, breast inflammation is caused by an inflammatory or infectious disease of breast tissue; however sometimes it can be due to inflammatory cancer. Although inflammatory breast cancer is clinically quite rare, radiologists specializing in breast disease must be familiar with its signs and be able to diagnose it without delay. Inflammatory cancer is an aggressive form of invasive cancer characterized by diffuse infiltration of breast tissue and the sudden onset of symptoms ⁽¹⁾.

Mastitis was classified by *Kamal et al.* ⁽²⁾ into three main types; the infectious, noninfectious and malignant mastitis.

Infectious mastitis encompasses breast specific and nonspecific forms of infections whether primary or complicating already present breast pathologies. This form of mastitis is more common during the child bearing period especially during lactation. Patients in this group usually present with fulminant inflammatory manifestations and are usually treated with antibiotics, hot fomentations and various breast drainage procedures. *Non-infectious mastitis* encompasses another group of aseptic or chemical inflammatory breast disorders that do not necessarily occur during lactation, are not usually present with fulminant inflammatory signs and do not usually resolve with antibiotics. Microbial infection may trigger some forms as peri-ductal mastitis or

complicate others as diabetic Mastopathy. The third group of mastitis, which is the most serious form of mastitis, is the *Malignant Mastitis (MM)* usually accompanying the inflammatory breast carcinoma or the very rare form of malignant breast abscess ⁽²⁾.

Complete resolution is usually the rule in most cases of mastitis. If after 10 days of antibiotics, symptoms of mastitis do not dissipate, inflammatory carcinoma should be ruled out and punch skin biopsy (that includes skin and dermal lymphatics) should be performed.

If after biopsy the diagnosis remains unclear, breast MRI may help to demonstrate the success of the antibiotic treatment and diagnose coexisting or confounding inflammatory carcinoma ⁽³⁾.

Radiologists who practice breast imaging have long known that the field provides observational and interpretative challenges second to no other area of radiology. The discipline of breast imaging is changing rapidly; the updates on the state-of-the-art technology as well as fortifying the basic concepts of breast imaging have been refined and improved over the prior 10-15 years ⁽⁴⁾.

Researches on new MRI techniques are being conducted to further increase the specificity of breast MRI. Diffusion weighted imaging (**DWI**) was recently integrated into the standard breast MRI examination for this purpose ⁽⁵⁾.

According to BIRADS MRI lexicon, morphological evaluation of breast lesions is done by

evaluating its shape, margins, and enhancement characteristics, enhancement distribution, and internal enhancement pattern. Kinetic evaluation is done by detecting the initial and post-initial enhancement of the breast lesion. In order to increase breast MRI specificity, diffusion weighted imaging (DWI) was added ⁽⁶⁾.

Diffusion weighted MR imaging detects early changes in the morphology and physiology of tissues, such as changes in the permeability of (cell membranes, cell swelling and/or cell lysis. Since 2002 many studies revealed the usefulness of DWI in differentiation of malignant from benign tumor of the breast ⁽⁶⁾.

DWI assessment includes both qualitative interpretation for lesion detection and quantitative measures of ADC for lesion characterization. Qualitatively, areas of restricted diffusion will be of higher signal intensity on diffusion weighted images and lower signal intensity on ADC map images ⁽⁷⁾.

Pathologic findings have indicated that there can be inflamed dilated ducts, inflammatory cysts, and abscesses in inflammatory breast diseases. Therefore, as to the inflammatory breast diseases, inflammatory cells and debris inside the cysts, dilated ducts and abscesses likely contribute to the central hyperintensity on DWI. In contrast, as to breast cancer, the high cellularity of tumor cells in the wall likely contributes to the peripheral hyperintensity on DWI. The differences in DWI findings and ADC values between breast cancer and inflammatory breast diseases could help differentiate these conditions for more accurate diagnosis. The combination of multiple MRI features may thus provide the valuable information for differential diagnosis ⁽⁸⁾.

Aim of the Work

The aim of this study is to elucidate the role of Diffusion MRI in evaluating patients with inflammatory breast lesions.

2. Patients and Methods

Study Population

This is a prospective study that included 42 clinically or pathologically diagnosed patients as having inflammatory breast lesions, who were referred to MRI unit from Ain shams hospital and outpatient breast clinics. This study was carried out during the period between August 2017 and April 2019.

Patients were subjected to a multi-parametric MRI study performed using a 1.5 Tesla superconductive MR scanner at Ain Shams university hospitals (philips).

▪ **Inclusion Criteria:**

1. Female gender.
2. Age more than 18 years old.

3. Patients presenting with symptoms suggestive of inflammatory breast lesions.

▪ **Exclusion Criteria:**

1. Male gender.
2. Patients known to have contraindications for MRI, e.g. an implanted magnetizable device, and pacemakers.
3. Patients with renal problems (serum creatinine level more than 1.8 or GFR less than 30 mL/min/1.73m²).

Sampling Method: convenience sampling method.

Ethical Considerations:

- Official permissions obtained from the radiodiagnosis department, faculty of medicine, Ain shams university.
- The scientific ethical committee of the patients was respected.
- Official permissions obtained from the dean of Ain shams university hospitals.
- The included patients were informed about the nature and the purpose of the study and a verbal consent was taken before performing the MRI study.
- Ensuring confidentiality.

Patients were subjected to the following:

The routine MR procedure used for breast imaging included the following:

- History taking & full clinical examination by referring clinician.
- Asking about previously done mammography and/or sono-mammography.
- Detailed explanation of imaging procedure.
- Laboratory: renal function including (serum creatinine level).
- All metallic objects were removed from the patient's body prior to the study.
- A cannula was inserted (for contrast media injection) before starting the examination.
- Appropriate IV anesthetic agents were given to some patients who feared the MRI machine (claustrophobia) when needed.

Patient position:

Patients were placed in the prone position to allow breasts to naturally hang inside the loops of the coil and to ensure that breasts fit entirely within the coil, positioning pads and cushions were used to eliminate skin folds within the coil near the axilla and under the breast. The arms were raised beside the patient head comfortably rested.

MRI Sequence:

The routine protocol used for breast imaging that includes:

1. Axial T1W and T2WIs.
2. Axial T2 fat suppressed, **STIR (Short Tau Inversion Recovery)**.

3. Dynamic post-contrast MRI: Using a 3D fat-suppressed dynamic thrive sequence with parallel acquisition performed every minute for seven minutes after injection of a bolus of Gadopentate dimeglumine (0.1 mmol/kg; Magnevist, Bayer HealthCare) at a rate of 2 mL/s, followed by a 20-mL saline flush administered using an automatic injector. Both breasts were examined in the axial plane at 30 s, 1 min, 2 min, 3 min, 4 min, 5 min and 6 min after contrast injection, respectively.

4. Axial delayed Post-contrast fat suppressed T1 WI ± Sagittal Post- contrast T1 WI.

5. Diffusion weighted imaging with ADC maps.

▪ Diffusion study was performed prior to contrast administration not only to negate any possible effects of the presence of contrast agent on water diffusivity within the tumor tissue but also to nullify any T2 shortening resulting from the contrast agent. EPI (echo-planar imaging) DW imaging was performed in the transverse plane with tri-directional diffusion gradients by using b values 0, 400 and 800 sec/mm² to increase sensitivity to cellular packing. The ADC maps created automatically and the ADC values calculated through selected ROIs. The other parameters were as follows: (TR) 10036 ms, (TE) = 80 ms, (NEX)= 2, matrix 256x256 with (FOV): 421, ST= 3mm, slice gap 0mm.

Image Interpretation:

All lesions in both breasts were evaluated, as regards:

1) Lesion assessment:

1- Mass, non mass or cystic lesions and collections.

2- Non mass like enhancement was evaluated as the following:

Its pattern (focal, linear or ductal) and distribution (segmental, regional, multiple, patchy or diffuse).

3- Diffusion study: whether the lesion showed (homogenous, heterogeneous or no) diffusion restriction and mean ADC value was measured.

2) Other findings:

- Diffuse of focal skin thickening
- Subcutaneous edema
- Retro-areolar involvement.
- Nipple retraction or invasion
- Axillary lymphadenopathy with evaluation of its fatty hilum and shape.
- Pectoralis muscle invasion
- Chest wall invasion
- Pre contrast high ductal signal

Statistical Analysis:

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 23. The quantitative data were presented as mean, standard deviations and ranges when parametric. Also qualitative variables were presented as number and percentages.

The comparison between groups regarding qualitative data was done by using *Chi-square test* and/or *Fisher exact test* when the expected count in any cell found less than 5.

The comparison between more than two groups regarding quantitative data and parametric distribution was done by using *One Way ANOVA test*.

Receiver operating characteristic curve (ROC) was used to assess the best cut off point with its sensitivity, specificity, positive predictive value, negative predictive value and area under curve (AUC) of the studied marker.

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following:

P-value > 0.05: Non significant (NS)

P-value < 0.05: Significant (S)

P-value < 0.01: Highly significant (HS).

3. Results

Table (1): Showing relation between different inflammatory breast lesions and age of patients

History		Infectious mastitis	Non infectious mastitis	Malignant	Test value*	P-value	Sig.
		No. = 21	No. = 18	No. = 3			
Age	Mean±SD	37.81 ± 11.75	41.17 ± 12.89	59.00 ± 3.46	4.115	0.024	S
	Range	25 – 68	21 – 64	57 – 63			

P-value > 0.05: Non significant (NS); P-value < 0.05: Significant (S); P-value < 0.01: highly significant (HS)

•: Independent t-test

The current study included 42 patients that were clinically or pathologically diagnosed as having inflammatory breast lesions with an age range of 21-68 years and mean age of 40.76±12.8]. The frequency and relative frequencies (percentage) of cases

included under each pathological entity listed in (Table 1).

In our study the patients are grouped as Group 1 & 2 (benign mastitis) where Group 1: represent infectious entity of mastitis (21/42 cases-50%) group 2: represent non-infectious entity of mastitis (18/42

cases- 42.9 %) and while group 3: represented malignant mastitis in the form of IBC (3/42 cases-7.1 %).

The study is formed of 17 patients (40.47%) presented with first time breast symptoms, 16 patients (38%) presented with known mastitis either clinically

or pathologically. The remaining 9 patients (21.4 %) are known cases of breast cancer (either inflammatory breast carcinoma or other entity of breast carcinoma with management related likely inflammatory changes).

Table (2): Showing number and percent of patients with inflammatory breast lesions

Diagnosis	No.	%
I- Infectious mastitis	21 (50.0%)	
*Simple		
- Non lactation	3	14.3%
- Lactation	2	9.5%
* Complicated		
• Abscess	9	42.9%
• Infected cysts	2	9.5%
• Infected post intervention collections	3	14.3%
• Draining sinus tract	2	9.5%
II- Non infectious mastitis	18 (42.9%)	
* Periductal mastitis / ductectasia	3	16.7%
* Granulomatous mastitis	5	27.8%
* Plasma cell mastitis	2	11.1%
* Zary mastitis		
• Post operative changes	3	16.7%
• Post chemotherapy/Post irradiation changes	2	11.1%
• Fat necrosis	3	16.7%
III- Malignant	3 (7.1%)	
* Inflammatory breast carcinoma	3	100.0%
* Malignant Abscess	0	0.0%

Table (3): Showing the clinical characteristics for patients with inflammatory breast diseases

Clinical signs and symptoms indicative of inflammation		Infectious mastitis		Non infectious mastitis		Malignant		Test value*	P-value	Sig.
		No.	%	No.	%	No.	%			
Laterality	Right	7	33.3%	6	33.3%	0	0.0%	4.311	0.365	NS
	Left	8	38.1%	7	38.9%	3	100.0%			
	Bilateral	6	28.6%	5	27.8%	0	0.0%			
Pain (Mastalgia)	No	2	9.5%	5	27.8%	1	33.3%	2.522	0.283	NS
	Yes	19	90.5%	13	72.2%	2	66.7%			
Lump sensation	No	10	47.6%	12	66.7%	3	100.0%	3.656	0.161	NS
	Yes	11	52.4%	6	33.3%	0	0.0%			
Fever	No	14	66.7%	18	100.0%	3	100.0%	8.400	0.015	S
	Yes	7	33.3%	0	0.0%	0	0.0%			
Breast discharges	No	12	57.1%	18	100.0%	3	100.0%	11.455	0.003	HS
	Yes	9	42.9%	0	0.0%	0	0.0%			
Hotness	No	14	66.7%	18	100.0%	3	100.0%	8.400	0.015	S
	Yes	7	33.3%	0	0.0%	0	0.0%			

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value < 0.01: highly significant (HS)

*: Chi-square test

The previous table shows no significant differences regarding inflammatory symptoms between infectious, non infectious and malignant inflammatory breast lesions.

Table (4): MRI morphological features of inflammatory breast lesions in correlation with clinical data, follow up and histopathology using Chi-square test

MRI Analysis		Infectious mastitis		Non infectious mastitis		Malignant		Test value*	P-value	Sig.
		No.	%	No.	%	No.	%			
Diffuse or focal skin thickening	No	13	61.9%	7	38.9%	0	0.0%	4.995	0.082	NS
	Yes	8	38.1%	11	61.1%	3	100.0%			
Diffuse or sectional interstitial edema (high T2 signal intensity)	No	4	19.0%	2	11.1%	0	0.0%	1.037	0.595	NS
	Yes	17	81.0%	16	88.9%	3	100.0%			
Focal collections /cystic lesions	No	4	19.0%	11	61.1%	3	100.0%	11.310	0.003	HS
	Yes	17	81.0%	7	38.9%	0	0.0%			
Focal mass lesion	No	21	100.0%	15	83.3%	3	100.0%	4.308	0.116	NS
	Yes	0	0.0%	3	16.7%	0	0.0%			
Retroareolar involvement/ductectasia	No	11	52.4%	8	44.4%	3	100.0%	3.182	0.204	NS
	Yes	10	47.6%	10	55.6%	0	0.0%			
Lymph nodes enlargement	No	2	9.5%	6	33.3%	1	33.3%	3.535	0.171	NS
	Yes	19	90.5%	12	66.7%	2	66.7%			

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value < 0.01: highly significant (HS)

*: Chi-square test

There is no significant statistical difference regarding MRI morphological analysis of different entities of infectious, non infectious and malignant inflammatory breast lesions. The only significant difference is seen regarding the focal collection/cystic

lesions representing 81 % in infectious inflammatory breast conditions, 38.9 % in non infectious inflammatory breast conditions and no focal collection/cystic lesions is seen in malignant inflammatory breast conditions.

Table (5): MRI Enhancement patterns of different inflammatory breast lesions using Chi-square test

Patterns of enhancement		Infectious mastitis		Non infectious mastitis		Malignant		Test value*	P-value	Sig.
		No.	%	No.	%	No.	%			
Marginal /peripheral	No	1	4.8%	9	50.0%	3	100.0%	16.488	0.000	HS
	Yes	20	95.2%	9	50.0%	0	0.0%			
Discrete patchy/heterogeneous	No	16	76.2%	15	83.3%	2	66.7%	0.566	0.754	NS
	Yes	5	23.8%	3	16.7%	1	33.3%			
Focal mass enhancement	No	21	100.0%	18	100.0%	3	100.0%	--	--	--
	Yes	0	0.0%	0	0.0%	0	0.0%			
Non mass enhancement	No	15	71.4%	9	50.0%	3	100.0%	3.733	0.155	NS
	Yes	6	28.6%	9	50.0%	0	0.0%			
Diffuse parenchymal enhancement	No	16	76.2%	18	100.0%	0	0.0%	17.294	0.000	HS
	Yes	5	23.8%	0	0.0%	3	100.0%			
Combined	No	14	66.7%	16	88.9%	3	100.0%	3.724	0.155	NS
	Yes	7	33.3%	2	11.1%	0	0.0%			

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value < 0.01: highly significant (HS)

*: Chi-square test

We observed benign mastitis (non infectious and infectious mastitis) had shown rather comparable presentation of marginal (74.4%), discrete patchy (20.5%), non mass like enhancement (38.5%) and combined pattern of enhancement (23.1%). The least presentable was the diffuse enhancement (12.8 %). On the other side, malignant mastitis had shown mostly diffuse enhancement pattern.

There is significant difference regarding the marginal/ peripheral enhancement (20 of 21 infectious lesions representing 95.2%, 9 of 18 non infectious lesions, representing 50%) and There is also significant difference regarding diffuse parenchymal enhancement between different groups of the inflammatory breast lesions.

No significant difference regarding discrete mass enhancement or combined patterns of patchy/ heterogeneous, focal mass enhancement, non enhancement.

Table (6): Inflammatory breast lesions according to Dynamic post contrast behavior and BIRADs in correlation to clinical data, follow up and histopathology

		Infectious mastitis	Non infectious mastitis	Malignant	Test value	P-value	Sig.
		No.=21	No.=18	No. = 3			
Dynamic behavior of the lesion with evaluation of the initial enhancement as well as the shape of time/signal intensity curves	Type I	17 (81.0%)	15 (83.3%)	0 (0.0%)	28.844*	0.000	HS
	Type II	4 (19%)	3(16.7%)	1 (33.3%)			
	Type III	0(0.0%)	0(0.0%)	2 (66.7%)			
BIRADs	II	0 (0.0%)	3 (16.7%)	0 (0.0%)	49.781*	0.000	HS
	III	20 (95.2%)	11 (61.1%)	0 (0.0%)			
	IV	1 (4.8%)	4 (22.2%)	0 (0.0%)			
	V	0 (0.0%)	0 (0.0%)	3(100.0%)			

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value< 0.01: highly significant (HS)

*: Chi-square test; •: Independent t-test

There is significant difference regarding dynamic behavior of different groups of inflammatory breast lesions. Type I (steady curve) appeared in 71.4% of the infectious mastitis, 83.3% of non infectious mastitis. Type II (plateau curve) was detected in 28.6% of the infectious mastitis, 16.7% of

the non infectious mastitis, in case of malignant mastitis. Type III (washout curve) in our study is seen in 2 cases of the included malignant mastitis lesions and not seen in benign lesions (infectious and non infectious groups).

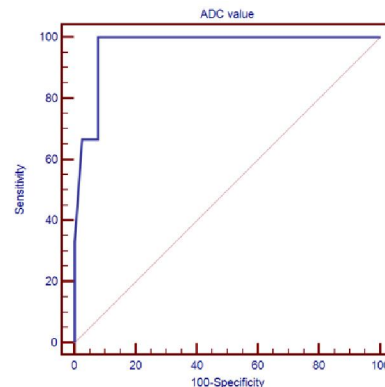
Table (7): Inflammatory breast lesions according to their MRI DW features and mean ADC values in correlation to clinical data, follow up and histopathology

		Infectious mastitis	Non infectious mastitis	Malignant	Test value	P-value	Sig.
		No.=21	No.=18	No. = 3			
MRI DWI features	No restriction	3 (14.3%)	15 (83.3%)	0 (0.0%)	21.292*	0.000	HS
	Restriction	18 (85.7%)	3 (16.7%)	3(100.0%)			
ADC Values	Mean±SD	1.50 ± 0.19	1.48 ± 0.23	1.07± 0.26	5.735	0.007	HS
	Range	1.28 – 2.15	.85 – 1.75	0.85 – 1.35			

Regarding the lesion signal which was seen in DWI, no diffusion restriction was seen in 14.3 % of infectious inflammatory breast lesions, while diffusion restriction was seen in about 85.7% of infectious inflammatory breast lesions, no diffusion restriction was seen in 83.3 % of non infectious inflammatory breast lesions while diffusion restriction was seen in about 16.7% of non infectious inflammatory breast lesions. Diffusion restriction was noticed in the 3 included malignant inflammatory breast lesions.

In all 42 lesions, several ROIs were placed and ADC values were extrapolated. The mean ADC values of infectious mastitis was $1.50 \pm 0.19 \times 10^{-3}$ mm²/s (range 1.28- 2.15 $\times 10^{-3}$ mm²/s), the median ADC of non infectious mastitis was $1.48 \pm 0.23 \times 10^{-3}$ mm²/s (range.85- 1.75 $\times 10^{-3}$ mm²/s), and that of

malignant lesions was $1.07 \pm 0.26 \times 10^{-3}$ mm²/s (range 0.85- 1.35 $\times 10^{-3}$ mm²/s).



Parameter	AUC	Cut of Point	Sensitivity	Specificity	PPV	NPV
ADC value	1.000	≤ 1	100.0	92.31	50.0	100.0

Fig. (1): Roc curve between Diagnosis groups regarding ADC value.

Regarding ADC values there was a significant statistical difference between malignant inflammatory breast lesions compared to benign inflammatory breast lesions (infectious and non infectious) ($p < 0.007$) (Fig 1).

ROC curves of the ADC values are represented in (Fig. 1). The cut off value for ADC derived from the ROC analysis was ($1 \times 10^{-3} \text{mm}^2/\text{s}$).

Sensitivity at this level was 100% and specificity 92.3%.

Illustrative CASES

Case 1:

MRI study of a 42-year-old female patient, A history of pathologically proven case of chronic granulomatous mastitis at left LIQ breast.

The patient is known to have long standing left sided nipple retraction since many years.

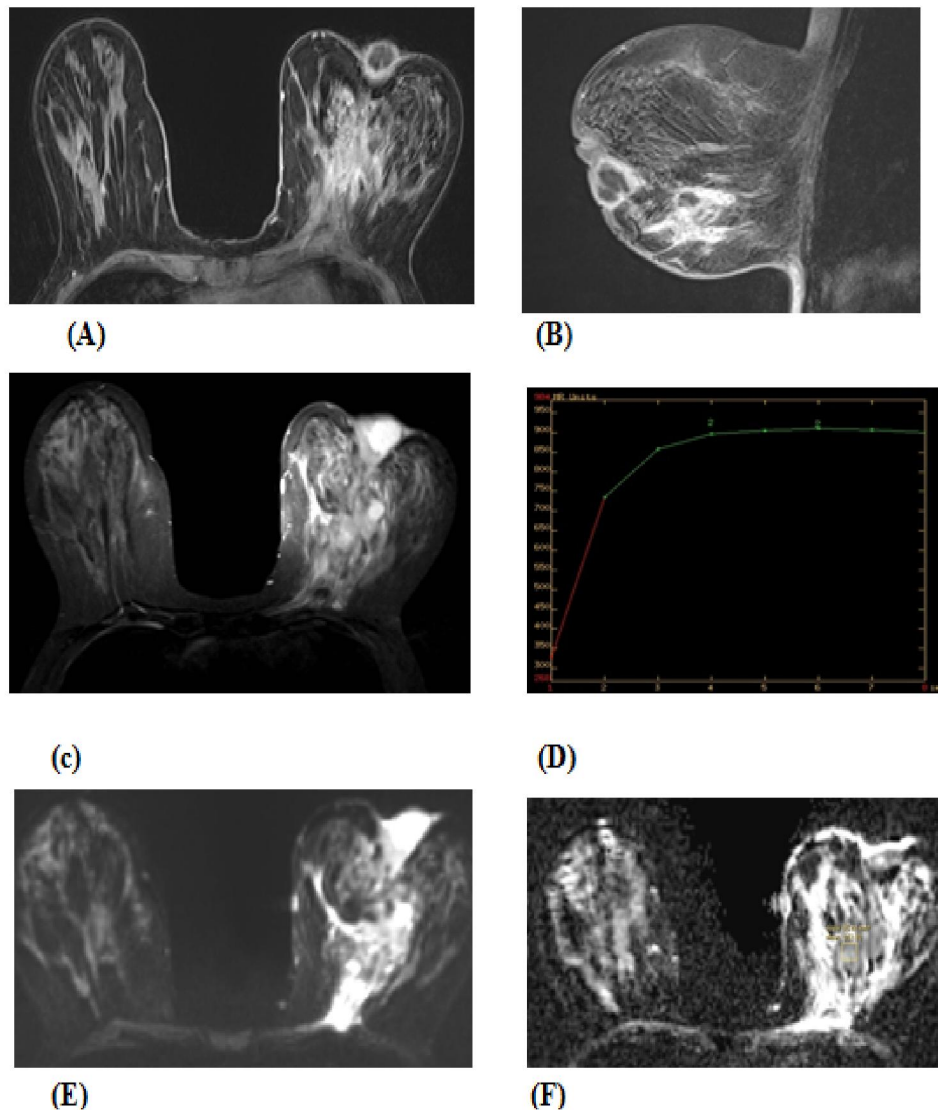


Fig. (2): A & B left breast showing non mass area of signal alteration and enhancement with intervening inflamed cystic changes. (C) This area is showing edematous changes on fat suppressed images. (D) Time signal intensity curve (TIC) showing type II pattern. (E) showing corresponding heterogeneous diffusion restriction on DWI. (F) The corresponding ADC map shows mottled appearance of relative diffusion restriction and diffusion facilitation mean ADC value of $1.35 \times 10^{-3} \text{mm}^2/\text{s}$.

Case 2: MRI study of a 33- year- old female patient presenting with bilateral mastalgia, lumps and breast discharge.

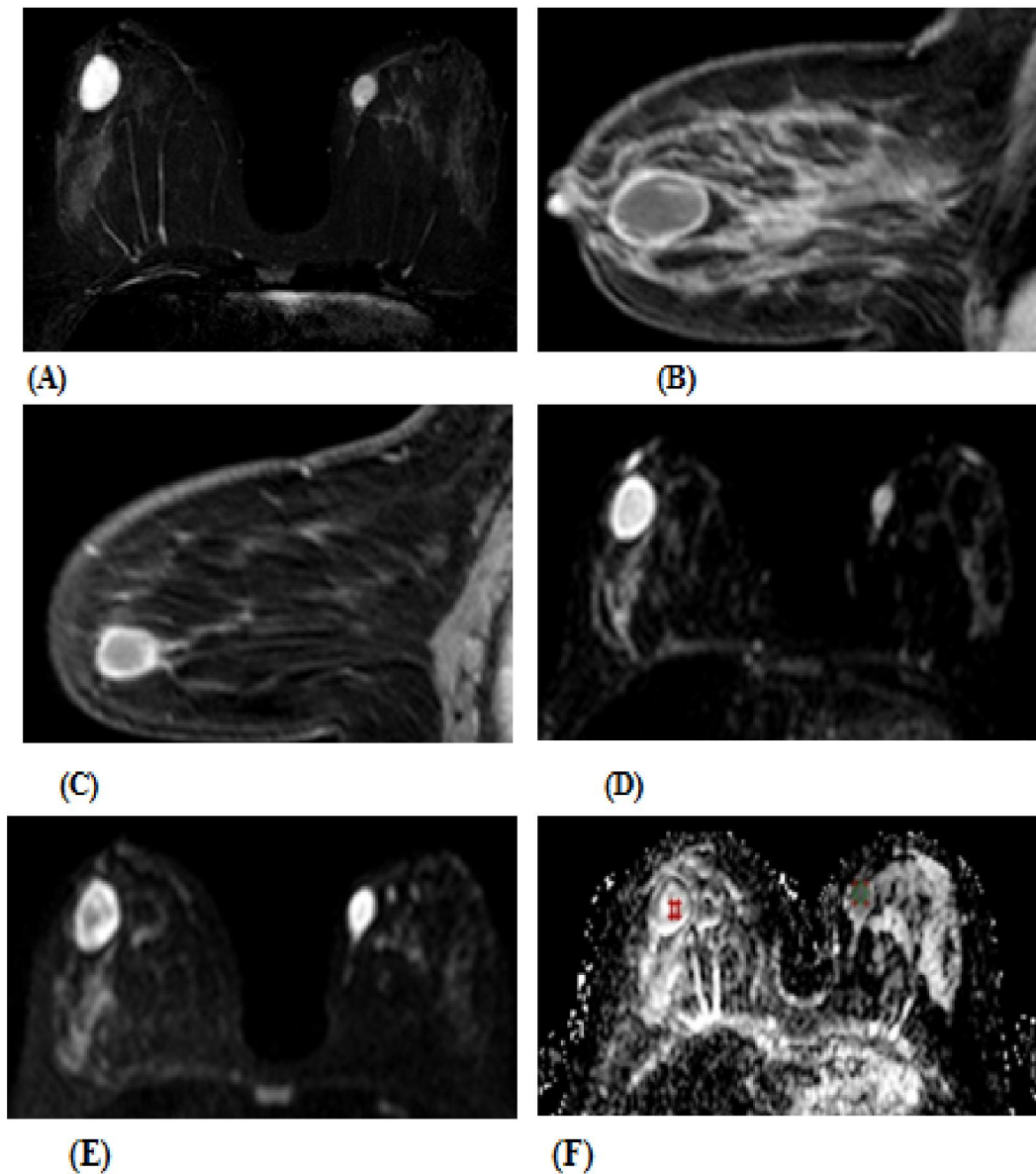


Fig. (3): (A) Bilateral breast cystic lesions on fat suppressed images. (B) The right breast is accommodating cystic lesion at 10 O'clock location, measuring 3.2x2.5 cm, appearance with thick mural confines showing circumferential mural enhancement on post contrast images. (C) The left breast is accommodating a cystic lesion acquiring similar MR features of the right breast cystic lesion. with central diffusion restriction. (D) & (E) showing corresponding central diffusion restriction on DWI. (F) The corresponding ADC map shows mean ADC value of 1.38×10^{-3} mm²/s.

Case 3: MRI study of a 57- year-old female patient with left breast recently diagnosed inflammatory carcinoma (pathologically proven).

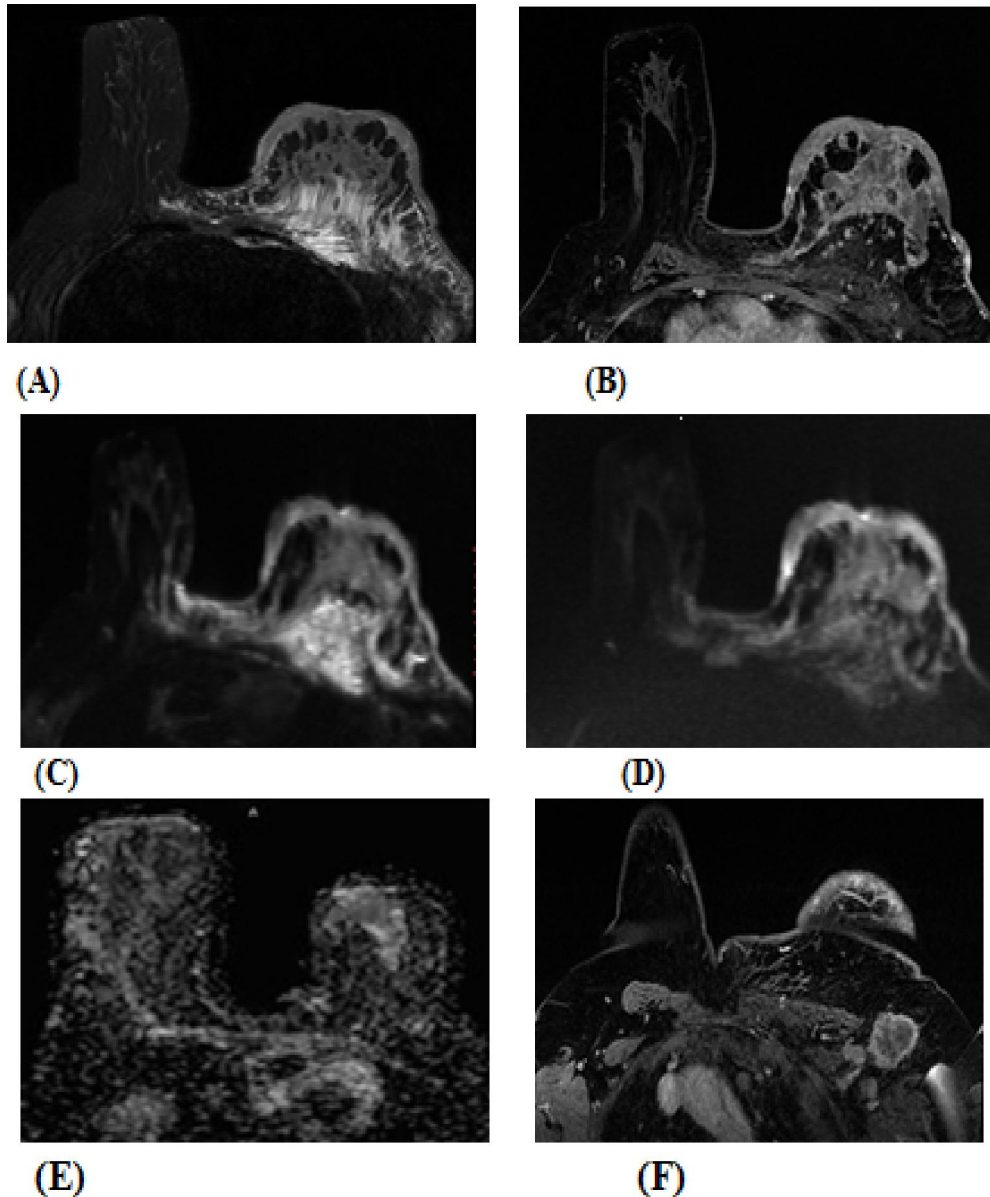


Fig. (4): Left breast shows a diffuse infiltrative process extending from the nipple areolar complex deep within the left breast parenchyma mainly implicating its superior aspect. (A) This area is showing edematous changes (fluid streaking) on fat suppressed images. (B) It shows heterogeneous enhancement. (C) & (D) showing diffuse corresponding heterogeneous diffusion restriction on DWI (b value 400 & 800) not only involving the breast parenchyma but also the overlying skin. (E) The corresponding ADC map shows mean ADC value of 0.8×10^{-3} mm²/s. (F) left axillary pathological lymph nodes.

4. Discussion

Inflammatory breast diseases consist of a wide array of conditions ranging from the benign simple infective mastitis to breast malignancy. Imaging features of benign and malignant inflammatory conditions often overlap which may cause diagnostic confusion and possibly delay proper treatment. In

some cases, correlation with clinical history and risk factors may be useful. For example, in a case of a lactating female, with signs of inflammation, benign mastitis is the most probable diagnosis and treatment can be initiated with follow-up imaging to look for resolution. Complications of breast infection, such as abscess formation should also be sought after. The

radiologist should be familiar with the range of common inflammatory breast conditions, Mastitis that does not resolve or respond to antibiotic therapy should always be furtherly evaluated with biopsy to rule out presence of malignancy⁽⁹⁾.

Breast infection can occur in healthy, non-lactating women of all ages. It remains a challenge to distinguish acute mastitis from malignancy, especially form inflammatory breast carcinoma (IBC), by clinical or imaging features⁽¹⁰⁾.

Unfortunately, there is a paucity of references discussing the role of MRI in evaluating inflammatory breast disorders.

As breast MRI is used as a beneficial diagnostic tool in association to mammography and ultrasonography, so it has become a major concern to improve its performance⁽¹¹⁾.

Although MRI has high sensitivity (up to 100%) in detecting the breast lesions, it lacks specificity for characterizing them⁽¹²⁾ because there is an overlap regarding the MRI description of both benign and malignant breast lesions⁽¹³⁾. So that, conventional DCE-MRI features only cannot clearly discriminate the nature of the lesions⁽¹⁴⁾.

In order to increase the MRI specificity we used diffusion-weighted imaging (DWI) which is known to be a non-contrast sequence that gives complementary information to the DCE-MRI⁽¹⁵⁾.

DWI provides important biological information about the composition of tissues and their physical properties⁽¹⁶⁾. The information is obtained noninvasively and without the need for contrast administration. DWI reflects some tissue characteristics and is mainly affected by cellularity, presence of edema, fibrosis and necrosis of the tissue necrosis⁽¹⁷⁾.

DWI is quantified by ADC values, which calculates the amount of water diffusivity through the tissues. ADC values vary between benign and malignant breast lesions, where by the ADC values of malignant breast lesions are usually lower than those of benign lesions, indicating restricted water diffusion and increased cellularity. The ADC values of benign lesions are higher, reflecting normal cellularity with no restriction of water movement. However, there is overlap between both entities as benign breast changes can give low ADC values and mimic malignancies. Abscess has low ADC values similar to malignant tumors. The area of low ADC value within an abscess usually gives high signal intensity on T2-weighted images, which indicates the high water content and high viscosity of the abscess. In clinical practice, physical examination findings should be considered when assessing these entities, there by simplifying the radiologic diagnosis⁽¹⁸⁾.

In our study there were 9 cases of abscesses, all showed central restricted diffusion with low ADC values. This diffusion restriction led to false positive results but when correlated with rim enhancement, diagnosis of an abscess becomes more logic because with malignant lesions areas of enhancement corresponds to area of DWI⁽¹⁹⁾. Previous papers that did not include MRI showed that the percentage of IGM breast lesions containing abscesses were 30–50%^(20, 21). But the studies that include MRI^(22, 23, 24) and our study showed that the percentage of IGM containing abscesses were approximately 80%. These results are probably because MRI has a high sensitivity of detecting abscess components within IGMs.

In our study to evaluate benign and malignant inflammatory lesions, there is no significant difference regarding clinical features and MRI morphological analysis between different groups of inflammatory breast lesions. It is important to elucidate the high T2 signal intensity regions of the different inflammatory breast lesions, areas of focal or cystic collections, enhancing parts of the lesion and regions of non mass like enhancement for ADC mapping. Our results were similar to *Kanaoa et al.*⁽²⁴⁾ who reviewed the ADC values of 17 benign inflammatory breast lesions and 16 malignant inflammatory breast lesions where the benign inflammatory lesions differentiated from benign non-inflammatory lesions and malignancies using the cutoff value of ADC (1.2×10^{-3} mm²/s) *Yilmaz et al.*⁽²³⁾ conducted a study evaluating ADC values of 37 cases of idiopathic granulomatous mastitis (IGM), 42 mastitis cases and 42 invasive breast cancers showing no significant difference, however their ADC values were calculated over the enhancing part of the lesions, and not over regions of high T2 weighted signal intensity. *Aslan et al.*⁽²⁵⁾ concluded that IGM lesions showed significantly lower mean ADC values compared to normal contralateral breast parenchyma, but did not compare IGM to breast cancer.

Our study shows that ADC cut off value (1×10^{-3} mm²/s) differentiates infectious and non infectious benign inflammatory breast lesions from malignant inflammatory breast lesions with Sensitivity was 100% and specificity 92.3%. This result suggests diffusion-weighted imaging (DWI) could be a useful non-invasive tool in diagnosing inflammatory breast lesions as benign or malignant. Our results were similar to those of *Wang et al.*⁽⁸⁾ where breast cancers had a lower ADC value than benign inflammatory lesions within the central part of the lesion. Their patient population was comprised of rim-enhancing masses with central cystic changes whereas our population consisted of benign and malignant

inflammatory lesions, which is much broader population.

The cut-off ADC value for benign and malignant lesions was as $1.25 \times 10^{-3} \text{ mm}^2/\text{s}$, giving 100% sensitivity and 77.3% specificity⁽¹⁸⁾.

Rieber et al.⁽²⁷⁾ reported MRI breast to show no significant difference between mastitis and inflammatory carcinoma, and *Al-Khawari and Athyal*⁽²⁸⁾ stated that the inclusion of chronic inflammatory lesions in their study was the main reason for a reduced MRI accuracy since such modality is not a good tool for the differentiation of benign from malignant lesions in such a clinical situation.

Mansour et al.⁽³⁾ stated dynamic post contrast MRI had displayed sensitivity, specificity, accuracy, positive predictive value and negative predictive value of 87.5%, 72.3%, 75.4%, 44% and 96% respectively in the evaluation of inflammatory breast disorders.

Performed MRI examination in our work was able to: (1) Estimate the actual extent of the breast inflammatory disease by making use of the multiplanar capability of the MRI, especially in large lesions that could not be accurately assessed by ultrasound. (2) Confirm the nature of the lesion of concern whether being purely cystic, purely solid or complex as sometimes complicated cystic masses may mimic solid lesions on ultrasound examination.

Qualitative criteria especially T2-weighted SI and presence of contrast uptake were the items that helped during the evaluation in significant number of cases. Through analyzing the different patterns of contrast uptake elicited in the study, we could observe that: benign mastitis (non infectious and infectious mastitis) had shown rather comparable presentation of marginal (74.4%), discrete patchy (20.5%), non mass like enhancement (38.5%) and combined pattern of enhancement (23.1%). The least presentable was the diffuse enhancement (12.8 %). On the other side, malignant mastitis had shown mostly diffuse enhancement pattern.

Skin thickening and edema in an untreated breast on MR images, as on mammograms, may be signs of malignancy, especially of inflammatory carcinoma. In a treated breast, these features are frequently observed after radiation therapy. Skin thickening was noted in more than half of the current study cases ($n = 22/42 - 52\%$). Being seen in 38.1 % of infectious mastitis, 61.1 % of non infectious mastitis and in 100% of the 3 included malignant mastitis.

During our work, there were some benign examples of mastitis that is likely to be confused with malignancy among those are: fat necrosis, granulomatous mastitis (GM). Fat necrosis resulting from injury to breast fat and granulomatous mastitis are an example of a chronic inflammatory processes considered the great mimicker of breast cancer. When

multiple signs typical of fat necrosis, (GM) and other entities of benign inflammatory breast lesions mimicking malignant mastitis are present, Biopsy may be deferred and routine or short-term follow-up may be selected on the basis of the degree of confidence in the imaging diagnosis⁽²⁹⁾.

The previously mentioned findings may be attributed to the fact that mastitis is a very vascular breast condition whether benign or malignant that displays different variables and overlapping patterns of angiogenesis.

We had to admit that in spite of the ability of MRI was able to differentiate between benign mastitis and malignant entities yet in certain circumstances of overlapping features, biopsy was still mandatory⁽²⁴⁾.

There are some limitations of this study. One limitation is that we have no cases where malignancy and infection (abscess) co-exist. So, in a possible rare case, high T2 signal intensity, or non mass enhancement or cystic collection inside a cancer may show variable diffusion behavior and hence variable ADC values.

Another limitation is that not all inflammatory lesions have a high T2 signal intensity, mass or non mass enhancement or cystic collection. Together with the fact that few lesions were relatively small and had no skin edema rendering them difficult to verify.

Quantitative analysis has been a recognizable limitation in the MRI assessment of inflammatory breast disorders. Attributed to overlap between different entities of inflammatory breast lesions. Such condition had resulted in upgrading of some benign conditions and consequently had subjected some patients to unnecessary interventional procedures.

Imaging of chronic benign mastitis is often nonspecific and must be monitored over the long term since it frequently recurs. Differentiating between benign and carcinomatous mastitis can be difficult as the Infectious mastitis is the principle differential diagnosis for inflammatory breast cancer. Differentiating between these two conditions is essentially based on the clinical history and ultrasound. MRI is not indicated as a first course of action, it is worth and mentioning that DWI plays an important role in the differentiation of breast cancer from benign lesions, the characterization of malignancy, the detection of lesions in unexpected sites, and evaluating tumor extension.

The present study did not establish a significant correlation when comparing tumor grades, tumor size to ADC values. The poor correlation of ADC values with the prognostic factors of the malignant tumors in this study is likely due to the small sample size.

5. Conclusion

The present study supports the usefulness of DWI as a good diagnostic non invasive tool for breast lesions characterization, with the calculation of the ADC values, in differentiation between infectious, non infectious benign inflammatory and malignant inflammatory breast lesions.

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