# Diagnostic value of MR spectroscopy in suspicious breast lesions

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**Abstract**

**Background:** MRI has an essential role in breast imaging, along with mammography and ultrasonography. DCE- MRI is not 100% accurate in discriminating benign from malignant lesions. In attempt to improve the specificity of DCE-MRI, multiparametric MRI (mp-MRI) with additional functional parameters had been introduced.

**Objectives:** To assess the added diagnostic value of MR spectroscopy in evaluation of suspicious breast lesions.

**Patients and methods**: This prospective study included 60 females, their mean age was 42.1 ± 12 SD with 75 breast lesions categorized as BI-RADS 3 or BI-RADS 4 based on sonomamography. They were subjected to multiparametric breast MRI (T2WI, dynamic contrast-enhanced MR imaging, diffusion-weighted images, and MR spectroscopy). ROC-analysis was employed for comparison between the diagnostic accuracy of mp-MRI and mp-MRI combined with MRS to predict the malignant lesions using the histopathological results as a standard of reference.

**Results:** 33 (55 %) patients had histopathologically diagnosed 43 (58%) benign breast lesions and 27 (45%) patients had 32 (42%) malignant lesions. Using mp-MRI (dynamic contrast-enhanced MR imaging, T2-weighted images and diffusion-weighted images) had 98% accuracy of with 97.8%, sensitivity and 98.6%, specificity in differentiating malignant from benign lesions. A higher diagnostic 99.2% accuracy was obtained from combined mp-MRI and MRS with 99.5% sensitivity, 98.6% specificity.

**Conclusion:** Despite of its limitations, MRS is a promising functional MRI technique thus improves the diagnostic accuracy of MRI for characterization of suspicious breast lesions when combined to mp-MRI to avoid unnecessary biopsy.

**Keywords: Breast lesions, mp-MRI, MR Spectroscopy.**

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## Introduction

Variable benign and malignant breast lesions can affect the women. Breast cancer is the most common women malignancy. In 2018, worldwide approximately 2.1 million newly diagnosed cancer breast were estimated with 627.000 deaths **(Bray et al, 2018)**

Currently, breast Dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) has an integral role in breast imaging. It has the highest sensitivity for breast cancer detection, with 89 to 99% negative predictive value **(Fardanesh et al., 2019).**

However, there is overlap of enhancement characteristics between benign and malignant breast lesions witha wide range of specificity has been reported ranged from 47% to 97%. In addition, morphology assessment based on conventional MRI is prone to experience-related variation and interobserver bias **(Pinker-Domenig et al., 2012; Sardanelli et al., 2010; Morrow et al., 2011; D'Orsi et al., 2013).**

In attempt to improve the specificity of DCE-MRI and to overcome the bias of morphology assessment, multiparametric MRI (mp-MRI) with additional functional parameters had been introduced. Diffusion-weighted imaging (DWI) and MR spectroscopy (MRS) are considered as established non-invasive functional techniques combined with DCE-MRI in mp-MRI to obtain a higher diagnostic accuracy of breast cancer**(Bunovic et al., 2021).**

MRS provides valuable information about the biochemical tissue properties. Total choline (tCho) is used to refer to different choline metabolites such as choline, phosphocholine, and glycerophosphocholine that resonant at around 3.23 ppm **(Baltzer and Dietzel , 2013).**

Based on the reported association of elevated tCho levels with malignancy, in

vivo qualitative and quantitative tCho measurements have been used to differentiate malignant from benign breast lesions **(Fardanesh et al., 2019).**

High specificity rates ranged between 85–100% had been reported for MRS in breast lesion diagnosis, however its sensitivity is still variable ranged between 44-82% **(Bolan et al., 2005).** In spite of the valuable data obtained from MRS, its clinical value in breast lesions diagnosis is still controversial. The aim of this study was to assess the added diagnostic value of MR spectroscopy to multiparametric breast MRI in evaluation of suspicious breast lesions by sono-mammographic examinations.

## Patients and Methods

### *Study design*

This prospective study of 2-years enrollment duration included 60 women with breast lesions, their mean age was 42.1 ± 12 SD years, ranged from 19 to 78 years. All of them were referred to MRI unit in Diagnostic Radiology and Intervention Department, at a university hospital from the surgical breast clinic and surgical outpatient's clinics. They had indeterminate suspicious breast lesions; categorized as BI-RADS 3 or BI-RADS 4 by sono-mammographic examinations according to the Breast Imaging Reporting and Data System (BI-RADS). Exclusion criteria included patients with BI-RADS 2 or BI-RADS 5and lesions smaller than 1 cm. In addition; general contraindications to MRI (claustrophobia, any metallic prosthesis), or to the contrast media (elevated renal function tests, pregnancy, lactation). The gold standard reference for MRI results were verified either by biopsy (fine needle, core needle or open surgical biopsies) and correlated with the histopathological proven results, or by 6 months clinical and imaging follow-up for cases classified as BIRADS 3.

The study was approved by the institutional review board (IRB) and all patients gave their informed oral consent to participate in the study.

***MRI Technique***

All MRI examinations had been obtained by using 1.5 Tesla machine (Philips-Acheiva), Netherlands. The patients were examined in prone position using a bilateral, dedicated, phased array breast coil with both breasts were entirely fitted within in the cups of the coil.

The following sequences were obtained;T1-weighted sequences (TR 6.1, TE 2.6, TI 600, NEX 1, flip angle 15 and 4 mm slice thickness). T2- weighted axial sequences (TR 4500, TE 70, NEX 1,flip angle 120 and 4 mm slice thickness), and STIR images (TR 8.75, TE 4.33, NEX 1, flip angle 15 and 0.9 mm slice thickness).

For dynamic protocol, an unenhanced coronal 3D THRIVE T1-weighted sequence was done followed by intravenous injection of gadolinium containing contrast (0.1mmol/kg) at 3 ml /sec using a power injector followed by a bolus of 30 ml of isotonic solution. Subsequently, 5 consecutive series were performed at 90-second intervals (TR 8, TE 4, flip angle 20 and FOV 310). ROI was placed within the area of maximum enhancement, and kinetic curves were elicited to analyze amount of contrast uptake at the DCE-MRI.

DWI was obtained before contrast administration at multiple b value (0, 800, 1500 s/mm) with the following parameters ; TR 8500, TE 70, matrix 192 × 192, FOV of 330 mm, NEX:1, sectional thickness 4.5 mm with a 1 mm intersection gap. ADC maps were reconstructed on the workstation and mean ADC value was automatically calculated for each lesion using focused ROI (Small ROI placed on the darkest area of the lesion on the ADC map corresponding to the most suspicious area).

MRS was performed for each individual lesion using single-voxel and point-resolved spectroscopy (PRESS) pulse sequence with the following parameters; TR/TE 2000 / 272 ms, spectral width 1000 Hz, vector size 1024, with an acquisition time of 4:16 min). Volume of interest VOI (average of 12 × 12 × 12 mm) was placed on the solid component of the lesion using either T2WI or post contrast subtracted images. The MRS time was 10 minutes average.

***Image analysis***

According to BIRADS-MRI lexicon, the lesions were classified into mass or non-mass-like enhancement. For mass lesions; the size, shape (round, oval, lobulated, irregular), margins (smooth, speculated, irregular), T1WI, T2WIintratumoral signal intensity were reported, while distribution modifiers and internal enhancement pattern were reported for non-mass-like-enhancement. In addition; Skin thickening, skin invasion, nipple invasion, lymph node status and their number if enlarged were assessed for both mass lesions and non-mass-like-enhancement.

For dynamic contrast enhanced images; visual analyses of the enhancement kinetic curves were performed. According to the MRI BI-RADS lexicon, type I curve (persistent or progressive enhancement pattern) was highly suggestive of benign lesions, Type II curve (plateau pattern) was considered concerning for malignancy and Type III curve (washout pattern) was strongly suggestive of malignancy.

On DWI, High signal intensity at high b value and low ADC values were suggestive of malignancy rather than benign tumors and normal breast parenchyma.

Then, MR spectroscopy interpretation was performed for Cho peak at 3.2 ppm qualitatively by the absence or presence of chol peak and its shape and quantitatively by the automatically calculated tchol signal to

noise ratio (SNR). Lesions with elevated chol peak and SNR $\geq$ 2 were considered as malignant lesions while absent peak or short broad peak with SNR < 2 were reported as benign lesion.

Finally, DCE-MRI, MRS, combined DCE-MRI and DWI, combined DCE-MRI and MRS and DCE-MRI combined with both DWI and MRS diagnoses were reported and compared with the histopathology results.

***Statistical analysis***

SPSS program (version 21) was used for descriptive analyses of the demographic, clinical, radiological, and pathological characteristics. The quantitative variables were described with mean ± standard deviation and range, while qualitative variables were represented with numbers and percentages. T-student test was applied to test the presence of significant differences between two independent comparable quantitative variables, while Chi square was applied to test the presence of significant differences between two independent comparable qualitative variables (benign versus malignant), depending on the features assessed. The P-value < 0.05 was considered statistically significant.

The diagnostic performance of mp-MRI with and without MRS was assessed by the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy.

**Results**

***Patients***

60 females included in the current study, their ages ranged between 19 and 78 years old (mean 42.1 ± 12 SD) with75 breast lesions were categorized as BI-RADS 3 or BI-RADS 4 based on sonomamography, their clinical presentations included palpable mass, pain, inflammatory symptoms, nipple discharge, skin retraction, nipple retraction and post-operative or post-neoadjuvant chemotherapy or radiotherapy follow up.

***Histopathological findings***

33 (55 %) patients had 43 (58%) benign breast lesions, 6of them had multiple lesions (4 had fibroadenomas&2 had fibrocystic changes) and 27 (45%) patients had 32 (42%) malignant lesions, 4 of them had multiple lesions (3 had multicentric invasive ductal carcinoma [IDC]and 1 had lymphoma).

Fibroadenoma was found to be the most common benign breast lesion(37%), while IDC was the most common malignancy(72%), (**Table .1).**

**Table 1. Classification and histopathology of the studied patients**

| Variables | Benign breast lesions | Malignant breast lesions |
|---|---|---|
| **Patient's no. (%)** | 33 (55) | 27(45) |
| **Lesion's no. (%)** | 43 (58) | 32 (42%) |
| **Age mean (range)** | 39 ± 0.23 (19 -78) | 47 ± 0.45 (28 -75) |
| **Multiplicity no. (%)** | 6 (18) | 4 (15) |
| **Bilaterally** | 3 (9) | 2 (7) |
| **Histopathology no. (%)** | - Fibroadenoma: 16 (37)<br>- Post-operative changes; 10 (23)<br>- Mastitis: 6 (14)<br>- Abscess: 5 (12)<br>- Intraductal papilloma: 2 (5)<br>- Fibrocystic disease:3 (7)<br>- Complicated cyst : 1 (2) | - Invasive ductal carcinoma : 23 (72)<br>- Invasive lobular carcinoma: 5 (16).<br>- Ductal carcinoma in situ:3 (9).<br>- Lymphoma: 1 (3) |

***DCE-MRI and DWI assessment results***

By DCE-MRI, the lesions were classified into 51 mass lesions and 24 non-mass lesions. The malignant mass size ranged from 1.5 to 9.5 cm (mean, 4.2 cm), and benign mass size ranged from 1.7 to 5.5 cm (mean, 2.8 cm).

There was a high significant difference in the types of enhancement kinetic curves between benign and malignant lesions (P-value< 0.001). 37 (86%) benign lesions had type I curve of enhancement, while 5(12%) lesions showed type II curve (3mastitis, 1post-operative fat

necrosis and 1 post-operative scar) and 1(2%) had type III curve in a case of post-operative left retroareolar sinus tracks with inspissated contents. On the other hand, 24 (75%) malignant lesions had type III curve, while 7 (22%) had type II curve and 1 lesion (3%) had type I curve, that was diagnosed histopathologically as ILC. Diagnostic accuracy of DCE- MR was 88.7 % with 96.8 % sensitivity and 85.7 % specificity.

DWI assessment revealed high significant difference between benign and malignant lesions (P-value< 0.004), that nearly half of benign lesions (52%) were not restricted, 32% were intermediately restricted and high restriction was reported in 16%(4mastitis, 2fibroadenomas and 1papilloma), while 76% of malignant lesions were highly restricted, 14 % intermediately restricted and only 3 (10%) were not restricted, 2 IDC and 1 ILC.

ADC signal of most benign lesions were high and iso to high (42% and 34% respectively), while 17 % of lesions were isointense, and only 7% were low and iso to low (2abscess and 1fibroadenomas). For malignant lesions, 71% were low, 22% for iso to low and iso and 3.5% for each of iso to high and high signal.

The mean ADC value of benign lesions was 1.08 x $10^{-3}$ $mm^2/s$, and for malignant lesions was 0.72 x $10^{-3}$ $mm^2/s$ with high significant difference (P < 0.001). ADC cutoff value was 0.95 x $10^{-3}$ $mm^2/s$.The reported diagnostic accuracy of DCE- MR combined with DWI and ADC was 98 % with 97.8 % sensitivity and 98.6 % specificity.

***MR Spectroscopy assessment findings***

On MR spectroscopy, Cho peak level at 3.2 ppm was significantly different in benign and malignant lesions (P-value< 0.04). Elevated tall choline peak with SNR $\geq$ 2 was detected in 27 (84%) malignant lesions **(Fig.1& 2).**

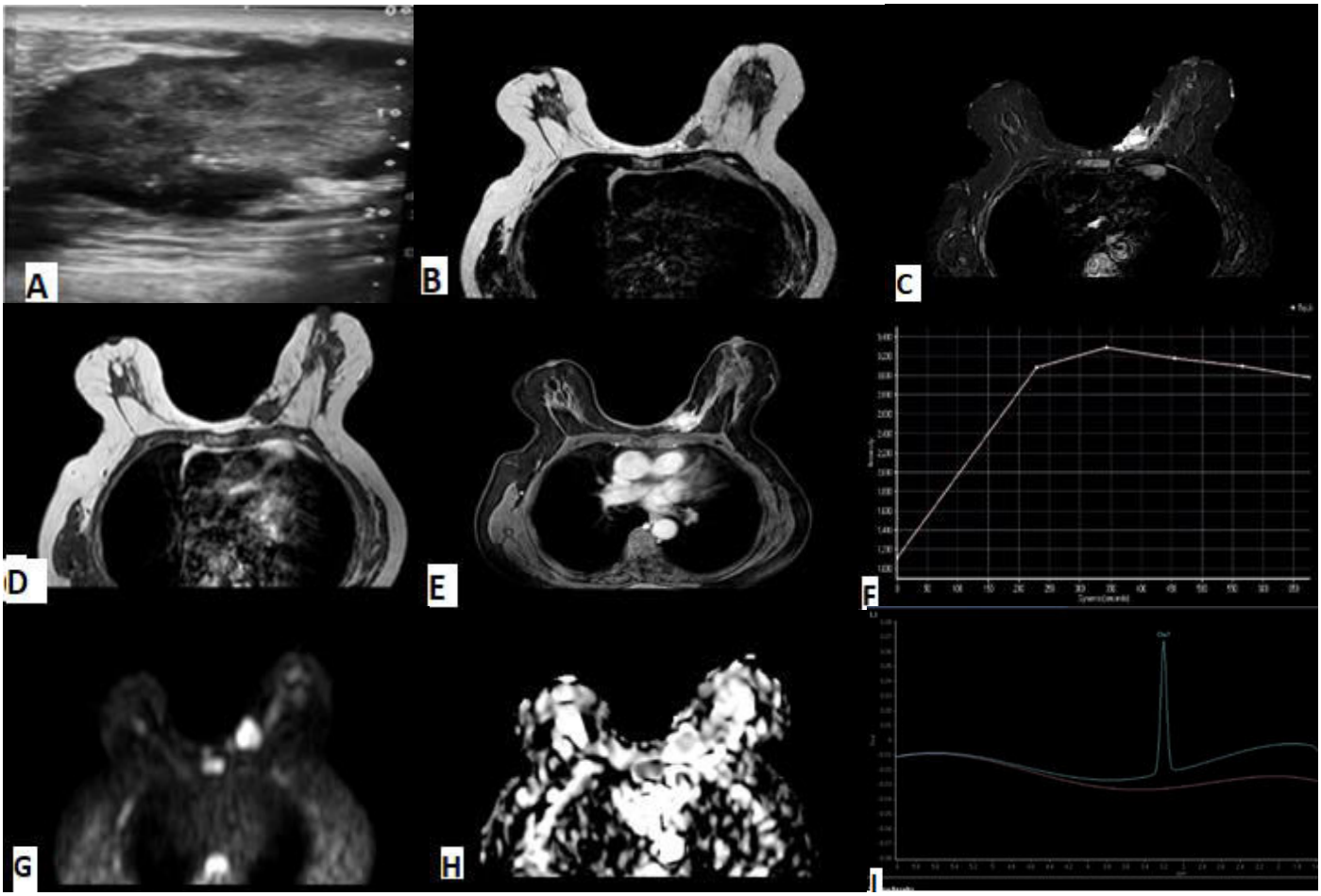


**Fig. 1.** 75 years old female patient with left breast invasive ducal carcinoma grade II: (A) US: Lt breast solid heterogeneous irregular mass with tiny flecks of calcifications. MRI: An ill-defined spiculated abnormal non-homogenous signal intensity lesion, isointense signal on T2WI (B), hyperintense on STIR (C), and hypointense on T1WI (D), of marked heterogeneous T1 post Gd enhancement (E) with type III curve of enhancement (F). It is restricted DWI (G), of iso to low signal on ADC map (H) with mean AD value of 0.8 x $10^{-3}$ $mm^2/s$. MRS (I) curve and values show malignant spectral pattern elevated choline peak at 3.2 ppm with choline SNR of 2.5.

One of them was residual ILC that had type I curve of enhancement, as well it was detected in 9 (21%) benign lesions;6 fibroadenoma(**Fig.3**), 2intraductal papilloma and 1 post-radiotherapy skin thickening and interstitial edema). Absent or short broad peak with SNR < 2 were detected in 5 (16%) malignant cases **(Fig.4)**, and 34 (79%)

benign lesions.MRS correctly diagnosed the post-operative case with left retroareolar sinus tracks with inspissated contents that had a false positive DCE-MRI result with type III curve enhancement **(Fig. 5).**The reported diagnostic accuracy of MRS was 82% with 85.7% sensitivity and 79.3% specificity.

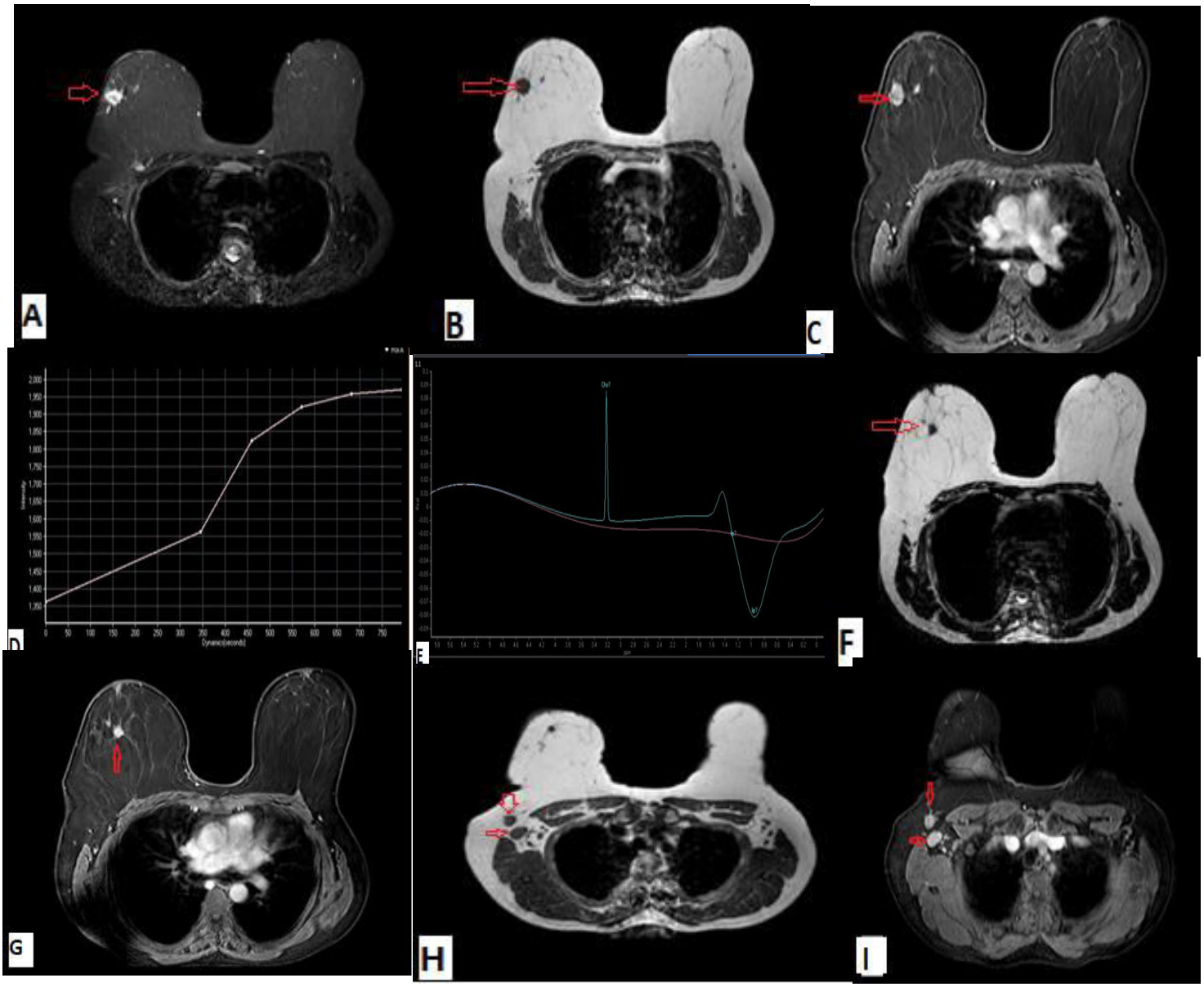


**Fig.2.** 40 years old female patient with Rt mammary multi-centric IDC and right axillary lymph nodes: An abnormal signal intensity lesion at 10 o'clock position about 2.5x1.5 cm, of bright signal on STIR (A) and low signal on T1 (B), of marked T1 post Gd enhancement (C) with type II curve (plateau pattern) of enhancement (D). MRS (E) curve and values show malignant

spectral pattern elevated choline peak at 3.2 ppm with choline SNR of 2.9. Other multiple enhanced small focal lesions are also detected at outer upper and inner quadrants about (3-8mm in size), of low T1 signal (F), highly enhanced post Gd injection (G). Associated multiple Rt axillary enhanced LNs, the largest about 1.5 cm (H&I).

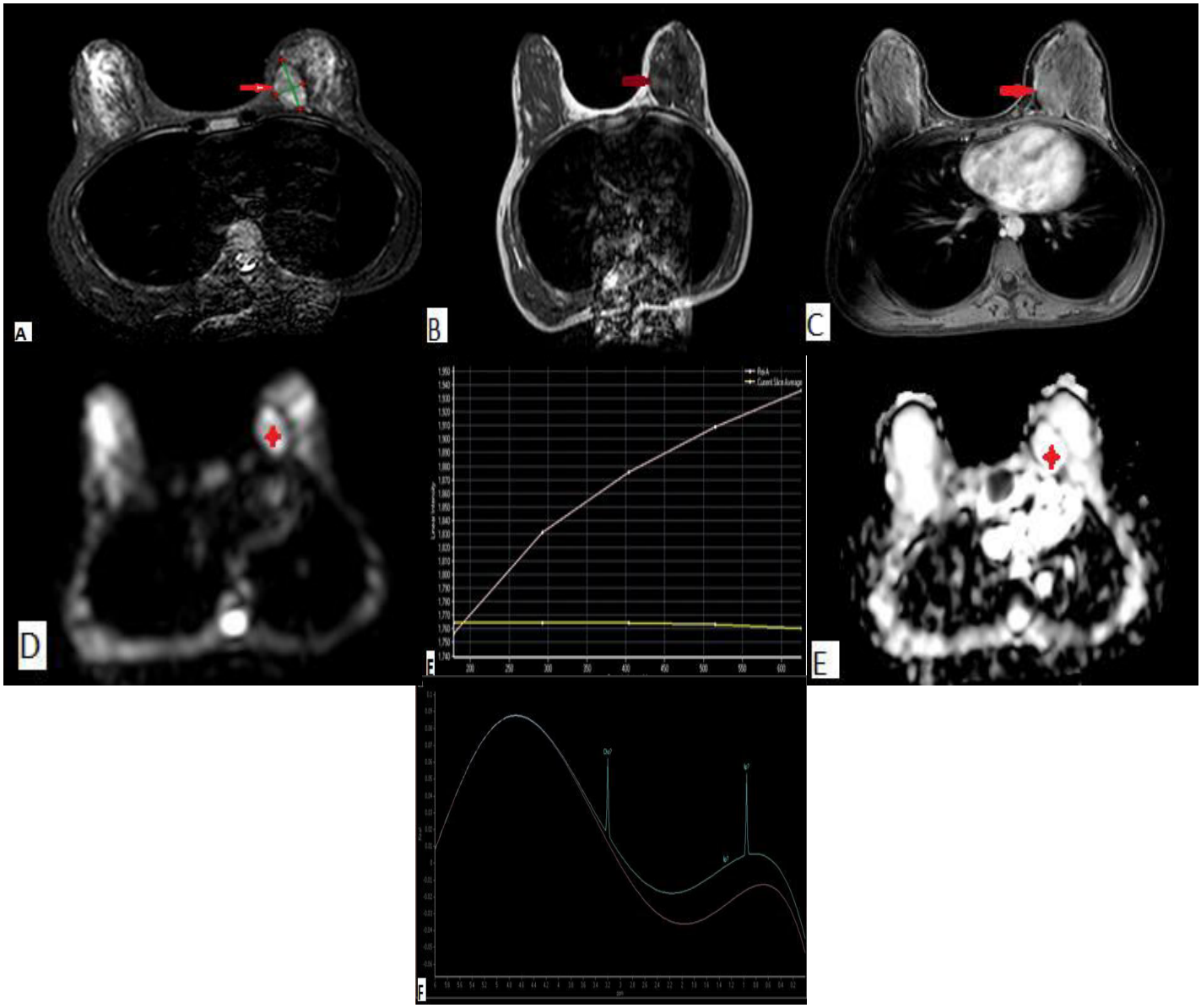


***Fig. 3.*** 25 years old female patient with left breast fibroadenoma: left lower inner quadrant homogenous mass with regular outline of intermediate signal on STIR (A), low on T1 (B), of Faint T1 post Gd enhancement (C) with type I curve of enhancement (F). MRS (E) curve and values show elevated choline peak at 3.2 ppm with choline SNR of 2.2. It is not restricted on DWI (D), of bright signal on ADC map (E) with mean AD value of 1.5 x $10^{-3}$ $mm^2/s$.

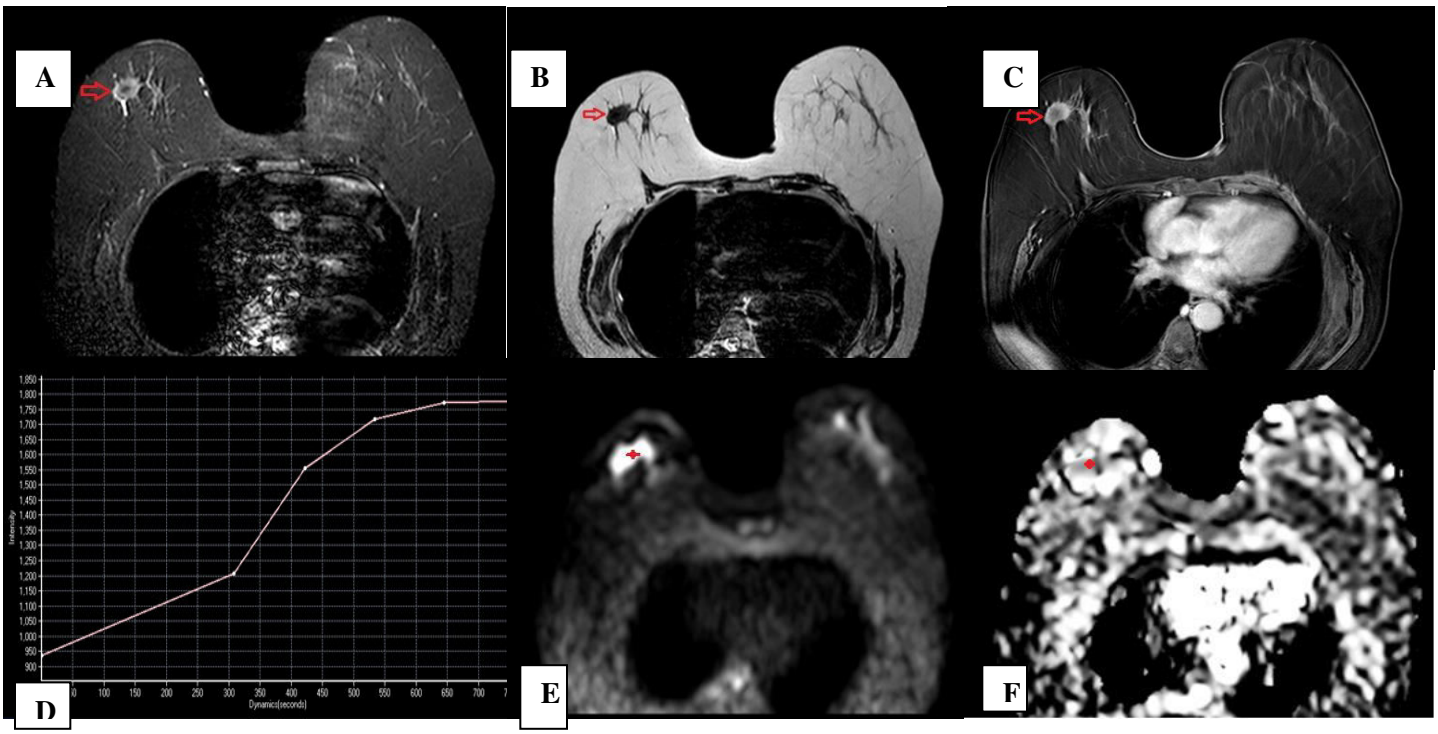


**Fig. 4.** 55 years old female patient with right breast IDC grade II: Right breast spiculated abnormal non-homogenous signal intensity lesion, intermediate signal on STIR (A), hypointense on T1WI (B), of marked non-homogenous T1 post Gd enhancement (C) with type II curve (plateau pattern) of enhancement (D). It is restricted DWI (E), of iso to low signal on ADC map (F) with mean AD value of 0.8 x $10^{-3}$ $mm^2/s$. MRS (G) low choline peak at 3.2 ppm with choline SNR of 0.5.

***Combined DCE-MRI, DWI and MR Spectroscopy assessment findings:***

MRS combined with DCE-MR accuracy was 97.5 % with 97.5 % sensitivity and 98 % specificity, and combined DCE-MRI, DWI and MRS had the highest sensitivity, specificity and accuracy in differentiating benign from malignant breast lesions of 99.5 %, 98.6% and 99.2% respectively (**Table. 2).**

Finally BIRADS classification of the lesions were done according to combined DCE-MRI, DWI and MRS diagnosis and compared with that obtained from combined DCE-MRI and DWI according to the histopathology, (**Table. 3).**

**Table 2. Diagnostic accuracy of DCE-MRI, DWI and MRS for breast lesions**

| Imaging modality | Sensitivity | Specificity | PPV | NPV | Accuracy |
|---|---|---|---|---|---|
| **DCE- MR** | 96.8 % | 85.7 % | 97.4 % | 82.4 % | 88.7 % |
| **DCE- MR &DWI** | 97.8 % | 98.6% | 98.1% | 98.4 % | 98 % |
| **MRS** | 85.7% | 79.3% | 75% | 88.5% | 82% |
| **DCE- MR &MRS** | 97.5 % | 98 % | 97.2 % | 98.2 % | 97.5 % |
| **DCE- MR &DWI & MRS** | 99.5 % | 98.6% | 98.1% | 99.6% | 99.2% |

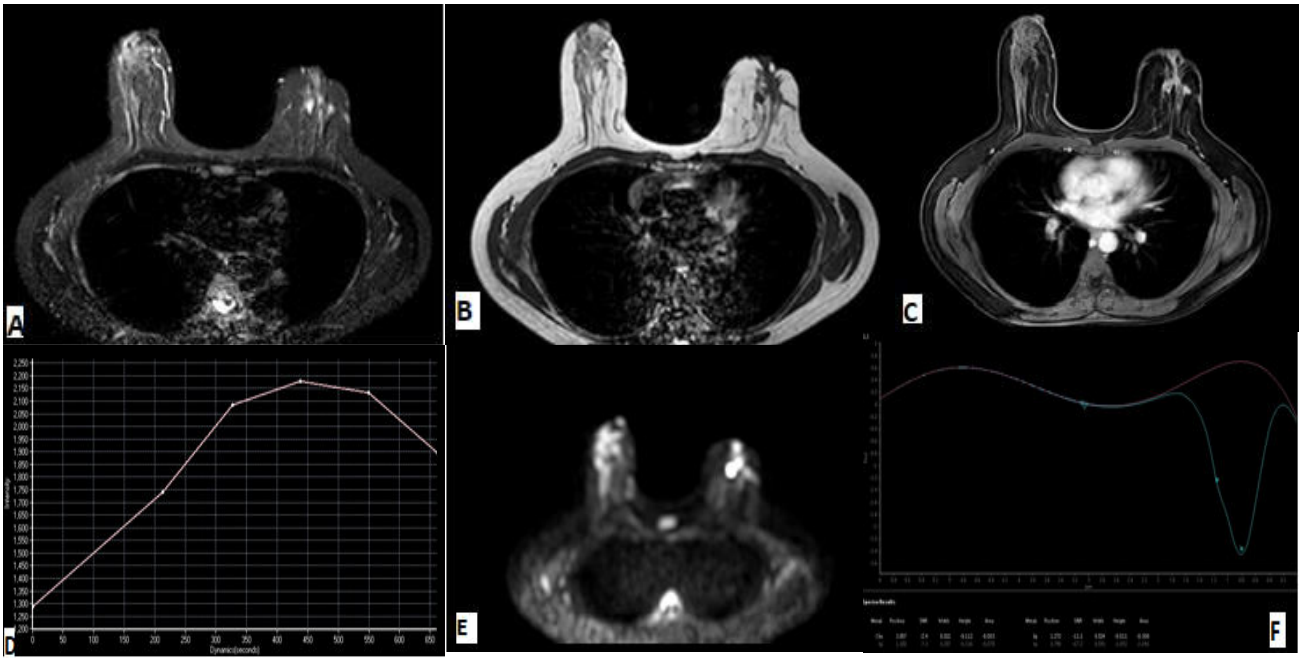


**Fig. 5.** 37 years old female patient with history of left lumpectomy of benign mass lesion with left retroareolar sinus tracks with inspissated contents: At the site of incision, retroareolar dilated tubular structures with intraductal contents displaying high signal at STIR (A), low signal at T1WI (B), with mild enhanced after Gd injection (C) and had type III curve of enhancement (D). It is restricted diffusion (E) with mean ADC value 0.2 x $10^{-3}$ $mm^2/s$. MRS revealed no choline peak (F)

**Table 3. PI-RADS score of the breast lesions on combined DCE-MRI and DWI and combined DCE-MRI, DWI and MRS according to histopathological results**

| Pathology | DCE-MRI +DWI | | | DCE-MRI +DWI+ MRS | | |
|---|---|---|---|---|---|---|
| | PI-RADS score | | | PI-RADS score | | |
| | 2 | 3 + 4 | 5 | 2 | 3 + 4 | 5 |
| **Benign lesions (no. = 43)** | 34 (79%) | 9 (21%) | 0 | 34 (79%) | 9 (21%) | 0 |
| **Malignant lesions (no. = 32)** | 0 | 3 (9%) | 29 (91%) | 0 | 1 (3%) | 31 (97%) |
| **Total (no. = 75)** | **34 (45%)** | **12 (16%)** | **29 (39%)** | **34 (45%)** | **10 (14%)** | **31 (41%)** |

## Discussion

MRI has essential role in breast imaging, along with mammography and ultrasonography. Its main indications for cancer breast are staging, screening in high risk women and evaluation of the response to neoadjuvant chemotherapy **(Mann et al., 2019)**.DCE- MRI is not 100% accurate in discriminating benign from malignant lesions, with subsequently large number of breast biopsies are recommended on the basis of imaging findings. Adding DWI and MRS can improve the diagnostic accuracy. On clinical aspect, DWI has been established in the standard protocols of breast MRI, while MRS is still a research tool with significant limitations, including relatively long acquisition times, frequent low quality spectra, difficult standardization, and quantification of tCho tissue concentration**(Luca et al., 2016).**

Suspicious breast lesions (BIRADS 3 & 4) are considered a diagnostic challenge with high percentage needs biopsy. We aimed to assess the added value of MR spectroscopy to DCE-MRI and DWI in characterization of these categories.

In this study, accuracy of DCE- MR for differentiating benign from malignant breast lesions was 88.7 % with 96.8 % sensitivity and 85.7 % specificity, while MRS had a lower accuracy of 82% with 85.7 % sensitivity and79.3 % specificity. Added MRS to DCE- MR increased the accuracy to 97.5 % with 97.5 % sensitivity and 98% specificity. The highest accuracy(99.2%) was reported when MRS added to combined DCE-MRI and DWI with sensitivity and specificity of 99.5% and 98.5% respectively.

Similar to our results, **Bunovic et al.(2021)** reported a higher sensitivity and specificity of DCE-MRI than MRS of 100%, 91% and 80%, 74% respectively. In a meta-analysis of fourteen studies, which included 1140 patients with 1276 breast lesions, the reported pooled sensitivity and specificity of DCE-MRI were 93.2% and 71.1% respectively **(Zhang et al., 2016)** and in other previous meta-analysis and systematic reviews, the reported pooled sensitivity of MRS for breast lesions ranged from 71% to 74% and pooled specificity ranged from 76% to 88% **(Baltzer and Dietzel, 2013; Cen and Xu , 2014; Wang et al .,2015; Tan et al., 2015**).

The most common benign lesion in our series was fibroadenoma (37%) while invasive ductal carcinoma was the most common malignancy (72%), which is coincides with results reported by **Tsougos et al. (2014)** and **Fonseca et al .(2009)** respectively.

The mean size of the included malignant lesions was 4.2 and 2.8 for benign lesions with the minimum diameter for all lesions was 1.5 cm because of the poor performance of MRS in characterization of small lesions less than 1 cm. According to previous literatures **(Bunovic et al., 2021; Sharma and Jagannathan , 2019; Sardanelli et al., 2016**). MRS is limited in lesions smaller than 2 cm, and subsequently

its unreliability in the early stage of the disease. **Katz-Brull et al. (2002)** reported increased the sensitivity for detecting tCho with increased tumor size.

Both qualitative and quantitative approach of tcho assessment was used in this study for differentiating benign from malignant lesions. We used signal to noise ratio (SNR) as one of the most widely used quantitative biomarker representing the ratio of the choline peak to the noise amplitude. Variable cut-off values of tcho SNR to differentiate between benign and malignant breast lesions were previously reported ranged from $\geq$ 2 to $\geq$ 5, most of them used $\geq$ 2 to obtain the highest sensitivity and specificity for breast lesions characterization, however a wide range of sensitivity and specificity of 44-100% and 67-100% were reported respectively(**Danishad et al., 2010; Bathen et al.,2011; Ozaki and Fukuma, 2009; Bartella et al., 2006; Begley et al., 2012).**This wide variation in sensitivity and specificity could be caused by multiple factors that effect on the noise amplitude like patient movement, strength of the magnet, field homogeneity, coil loading etc.

In this study, based on MRS, 27 (84%) malignant lesion and 34 (79%) benign lesions were correctly diagnosed while9 (21%) benign lesions had elevated tChol peak; 6 fibroadenomas, and 2papilloma and 1post-radiotherapy interstitial edema with subsequent reported relatively low specificity (79.3%) and positive predictive value (75%) compared with those of DCE-MRI (97.4 % and 85.7 % respectively) or DCE-MRI combined with DWI (98.1% and 98.6% respectively). Similar false positive elevated choline peak was previously reported in fibroadenoma and fibroadenomatoid changes(**Bartella and Huang , 2007; Kvistad et al., 1999**; **Yeung et al., 2001). Mackinnon et al.(1997)** in an ex vivo MRS study of fine-

needle breast biopsy specimens, found that 25% of included fibroadenomashad detectable levels of Cho. Fibrocystic disease and tubular adenoma were also previously reported with elevated chol peak **(Kvistad, 1999; Roebuck et al., 1998),** respectively. Such benign lesions could be considered as causative elements of low MRS specificity in breast cancer diagnoses, so their MRS findings should be interpreted with caution.

In the current study, MRS correctly diagnosed the malignant lesion of false negative result on DCE-MRI with type 1 curve enhancement and was proved histopathologically as ILC. The slow pattern and continuous enhancement in ILC could be the cause of false negative result on DCE-MRI and its classification as benign lesions **(Mann et al., 2011).**On the other hand, MRS correctly diagnosed the benign post-operative lesion with false positive DCE-MRI result showed type III curve enhancement.

We found that the strength of MRS was its higher negative predictive value(88.5%) than that of DCE-MRI (82.4 %) which increased to 98.2 % when both were combined, so unnecessary biopsy could be avoided.

**Limitations**

The first limitation in this study was including the MRS analysis of choline peak only in differentiating benign from malignant breast lesions while other metabolites especially lipid were not included that might increase the MRS specificity. The second limitation was the relatively small number of included cases.

**Conclusions**

Despite of its limitations, MRS is a promising functional MRI technique that can provide beneficial additional information about the tissue metabolic activity thus improves the diagnostic accuracy of MRI for characterization of

suspicious breast lesions when combined to DCE-MRI to avoid unnecessary biopsy.

## Declarations

***Ethical approval and consent to participate***

-The study was done according to the clinical research ethics of Sohag university hospital. The committee's reference number is not applicable not available.

Verbal consent was obtained from all included patients in the study because data and figures used in this study didn't include specific personal data or individual details refer to the person.

***Consent for Publication***

- Consent for publication was obtained.

***Competing interests***

- The authors declare that they have no competing interests.

***Availability of data and material***

- The datasets used during the current study are available from the corresponding author on reasonable request.

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- This work was not funded from any source.

***Authors' contributions***

NMAH: Contributed in the design of the work, analysis and interpretation of data, writing the manuscript and have drafted the work and substantively revised it. MMNH: Contributed in the design of the work and data collection. NMA: Contributed in the design of the work, and interpretation of data, and revised it. MTMS: Contributed in the design of the work, and revised it. All authors have read and approved the manuscript.

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