VOLUME 10 | ISSUE2

Breast Imaging ORIGINAL ARTICLE

Role of automated breast 3D ultrasound in detection and characterization of Different breast lesions referral to post contrast MRI and pathological results

Maysa Abd El Aziz Ali M. Sc.[1], Fatma Saber M.D.[1]; Maha Hussein Helal M.D.[1]; Omnia Mokhtar Nada M .D.[1] Emad El Din El Gameae M.D[2]

[1]The Department of Diagnostic Radiology, National Cancer Institute, Cairo University, Egypt

[2]The Department of pathology, National Cancer Institute, Cairo University, Egypt

[1]Dr.Maysa Abd El Aziz Ali ,Radiology Department , National Cancer Institute, Cairo University
Maysaabdo84@yahoo.com

[2]DR .Fatma Saber. Radiology Department , National Cancer Institute, Cairo University
fatmasabersinger@hotmail.com

[3]Prof. Dr. Maha Hussein Helal, Radiology Department, National Cancer Institute, Cairo University
Dr.mahahelal@yahoo.com

[4]Prof. Dr. Omnia Mokhtar Nada, Radiology Department, National Cancer Institute, Cairo University
Omnian44@yahoo.com

5 .Dr. Emad El –Din El-Gamea, Pathology Department, National Cancer Institute, Cairo University

SUBMISSION: 06/06/2024 - ACCEPTANCE: 09/02/2025

ABSTRACT

Aim: To assess the agreement between automated breast 3D ultrasound (ABUS) and post contrast MRI in detection and characterization of breast lesions, using the pathological result as a gold standard.

Methods: This prospective study included 30 female patients presenting with palpable breast masses detected through clinical or mammographic examination. All patients underwent automated breast ultrasound (ABUS)

CORRESPONDING AUTHOR, GUARANTOR

Dr.Maysa Abd El Aziz Ali
Email: Maysaabdo84@yahoo.com

and contrast enhanced magnetic resonance imaging (CE-MRI). Images from both modalities were analyzed by two experienced radiologists, and results were compared with each other and with pathological findings.

Result: 60 lesions were statistically evaluated in this study, among which 25 were benign and 35 were malignant. The sensitivity and specificity of ABUS in characterization of breast lesions were 91.4 and 83.3, respectively while for MRI were 100 and 84 respectively.

Conclusions: Automated breast ultrasound and CE-MRI are two promising modalities in breast imaging. Their diagnostic indices in this study were very close to each other. Due to high cost of MRI and its contraindication for certain patients, ABUS can be used as an adjunct modality to mammography for detection and characterization of breast lesions especially in dense breasts.

keywords

ABUS (automated breast ultrasound).

CE-MRI (contrast enhanced magnetic resonance imaging).

KEY WORDS

carotid artery stenosis, stroke, internal carotid artery, Doppler Ultrasound, NIH stroke scale

Background

The topic of breast cancer screening is still hotly contested. The only screening test that has been shown to lower mortality is mammography, which has long been the cornerstone of breast cancer detection. Breast ultrasonography (US) has been utilized as a supplementary method to mammography for screening and diagnostic purposes (1).

although mammography is still the gold standard for screening breast cancer, there is increase in the awareness of subpopulations of women for whom mammography has reduced sensitivity. Additionally, Mammography also has increased the false positives result and unnecessary biopsies, which raise radiation exposure, cost, and patient worry (2).

New technologies such as (ABUS) and (MRI) have been developed for early detection of breast cancer in response to such challenges (1).

Excellent results in diagnostic settings have been documented with the development of automated breast ultrasound (ABUS) systems in recent times (3). Minimizing examination duration and decreasing the operator dependence are two benefits of the modern ABUS devices, which contain high-frequency broadband transducers, in order to cover the entire breast. ABUS system generates hundreds of pictures, that radiologists must review it (3).

Contrast-enhanced MRI of the breast is the most sensitive method for detection of invasive breast cancer, especially non-calcified lesions (4). By Incorporating functional perfusion and morphological criteria in MRI, this algorithm may improve inexperienced reader performance to the level of experienced radiologists (5). Furthermore, there is a chance that the same formal algorithm can reduce the number of needless biopsies by over 25% (6).

Methods

Patient population

This study conducted in national cancer institute (NCI) in CAIRO University between July 2022 and September 2023. The study was approved by the ethical committee of the NCI, Cairo University.

This study enrolled 30 female patients (ages 31-74, mean age: 51.5 years) undergoing both contrast-enhanced MRI (CE-MRI) and automated breast ultrasound (ABUS). Patients were asked to expose their upper body for both examinations.

Inclusion criteria: female patients with breast lesions.

Exclusion criteria: patient with severe renal dysfunction contraindicated to administrate the contrast. Patient contraindicated to do MRI like patients with heart pacemaker, insulin pump, intracranial metal clips, neurostimulator and metallic bodies in the eyes or severe claustrophobia.

Examination protocol

Automated breast examination protocol:

Images were acquired with using a GE Invenia ABUS system (GE Healthcare). During scanning, the patient laid down on a standard exam table in supine position, a layer of lotion was applied to the breast to ensure good contact between the 3D ABUS device and the skin a curved panel was placed over the breast and gently flattened the tissue against the body. A disposable mesh membrane was used to stabilize the breast in place while the transducer automatically moves across it. For average-sized and smaller breasts, three acquisition anteroposterior (AP), lateral (LAT), and medial (MED) were sufficient to cover the entire breast. For larger breasts, we performed additional scans to cover the superior (SUP) or inferior (INF) parts of the breast. Then images were taken to offline workstation for interpretation by radiologist.

MRI protocol design:

The study was performed with a 1.5- T (Philips acheieva healthcare) MRI unit with using breast coil. Images of both breasts were obtained in the axial plane with the patient laid in the prone position. In this study, the following sequences were used: axial, turbo spin-echo T2- weighted imaging and Pre-contrast axial T1-weighted flash three-dimensional (3D) weighted image, injection of gadolinium was given in a dose of 0.1 mmol/kg and a flow rate of 1-2 ml/sec flushed at 20 ml of saline. The automatic injector was used. For dynamic study a T1 weighted gradient echo pulse sequence is repeated as rapidly as possible for 5 to 7 minutes after contrast injection.. Subtraction images were obtained by subtraction of unenhanced images from the first contrast enhanced image on a pixel by pixel. The images were reformatted in the sagittal and coronal planes with additional maximum intensity projection representation. Then, data exported to a PACS workstation.

Image Analysis:

The MRI and ABUS data were evaluated by two experienced radiologists in consensus, both observers were unaware of the pathological data of each patient.

Automated ultrasound images:

We assessed: breast composition, mass characterization including (location, shape, margin, orientation, echo pattern and posterior feature) and non-mass lesion distribution. Then BIRADS classification was done.

MRI images:

We assessed: mass characterization including (location, shape, margin and pattern of enhancement) and non-mass characterization including (distribution and internal enhancement). Then BIRADS classification was done. All breast lesions included in this study were interpreted as described above and then the accuracy in reaching the final diagnosis was calculated for both MRI and ABUS.

Pathological results were used as the gold standard reference apart from 19 lesions which were proven by its radio-logical criteria to be benign. Samples were obtained with fine needle aspiration cytology (FNAC), core biopsy, surgical excision and radical surgery. Analysis of the samples was performed in the pathology department of the Egyptian national cancer institute by a group of well-trained expert pathologists.

Statistical analysis

All analysis was done using the statistical package of social science (SPSS, version 25). Cleaning of data as a first step was done to detect missing values and invalid responses. Normality of data distribution was done by using shapiro-wilk test. Descriptive statistics, such as percentage, frequencies, mean and standard deviation, were used to measure the demographic variables, clinical and laboratory data. Analytical statistic was applied to investigate the association between ABUS, MRI and pathology. Quantitative data were presented by mean (standard deviation), while qualitative data were presented by frequency distribution. The independent sample t- test used for comparison of means and the chi- square test was used to compare between proportions. The probability of less than 0.05 was used as a cut off point for all significant tests and all statistical were 2 tailed.

Sample size

The number of study participants was calculated using EPI- info (statistical; software for epidemiology) depend on population number and percentage of disease.

Results

General information

Thirty patients (60 breasts) underwent CE-MRI and ABUS scans. CE-MRI detected 60 lesions while ABUS missed three lesions of them. Of the whole detected le-

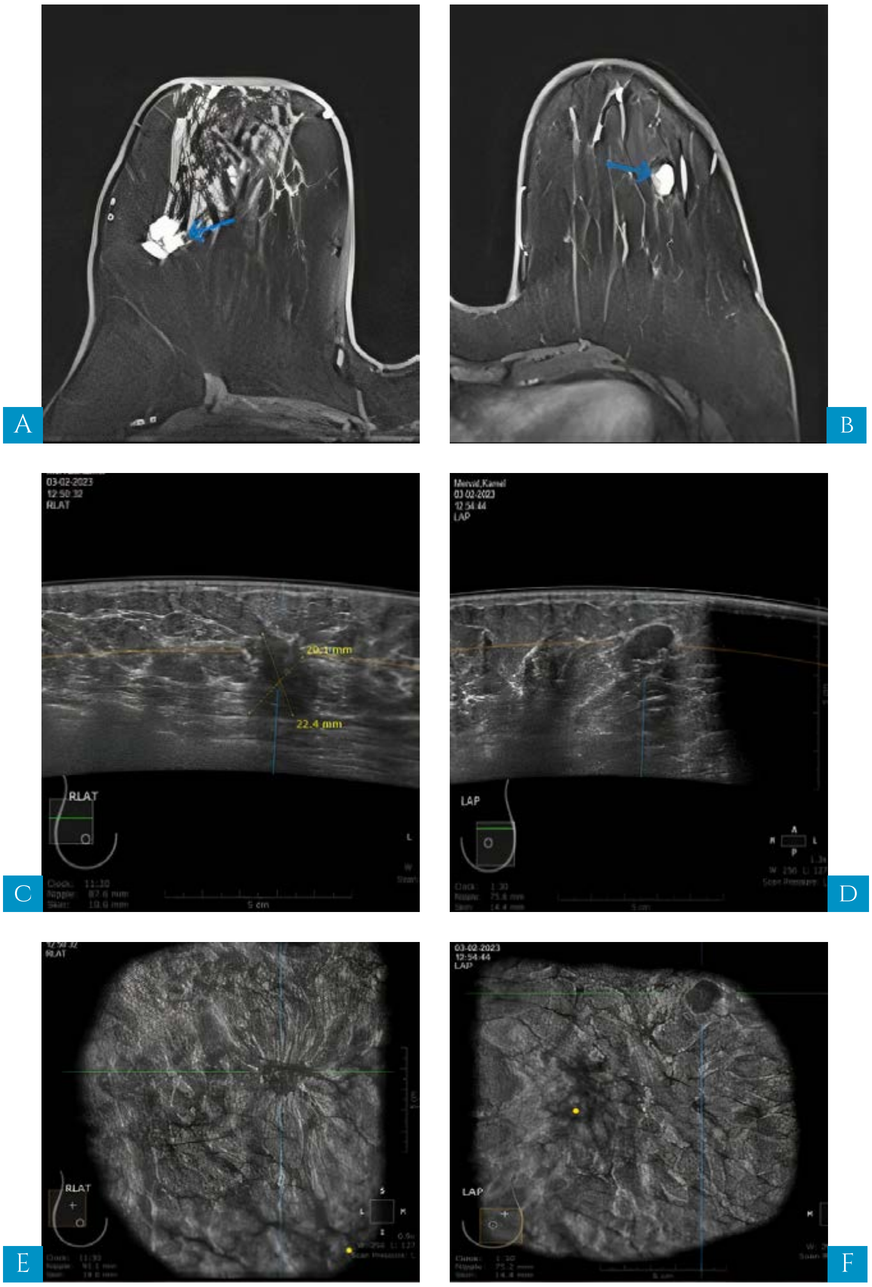

Fig.1: *A 61-year-old female patient presenting to us by a clinically palpable right breast lump by doing ABUS and MRI left breast lesion is detected A & B: MRI post contrast with fat sat image axial view of both breast show: A. Right UOQ speculated mass lesion with anterior ductal extension reaching to the nipple (BIRAD V). B. Left oval shaped lesion with circumscribed margin BIRAD III. C. right lateral view axial image show irregular shape mass lesion with speculated margin (BIRAD V). D. left antroposterior axial image show mass lesion of indistinct margin and non-parallel orientation (BIRAD IV). E. left antroposerior coronal image show a defect with micro lobulated margin (BIRAD IV). F. Right coronal view shows a defect with retraction phenomena (BIRAD V).*

Diagnosis:

- *Core biopsy was done and revealed invasive ductal with focal lobular differentiation in the right and invasive ductal carcinoma in the left.*
- *Automated ultrasound was superior to MRI in characterization of left lesion by detection of partial indistinct margin and its non-parallel orientation.*

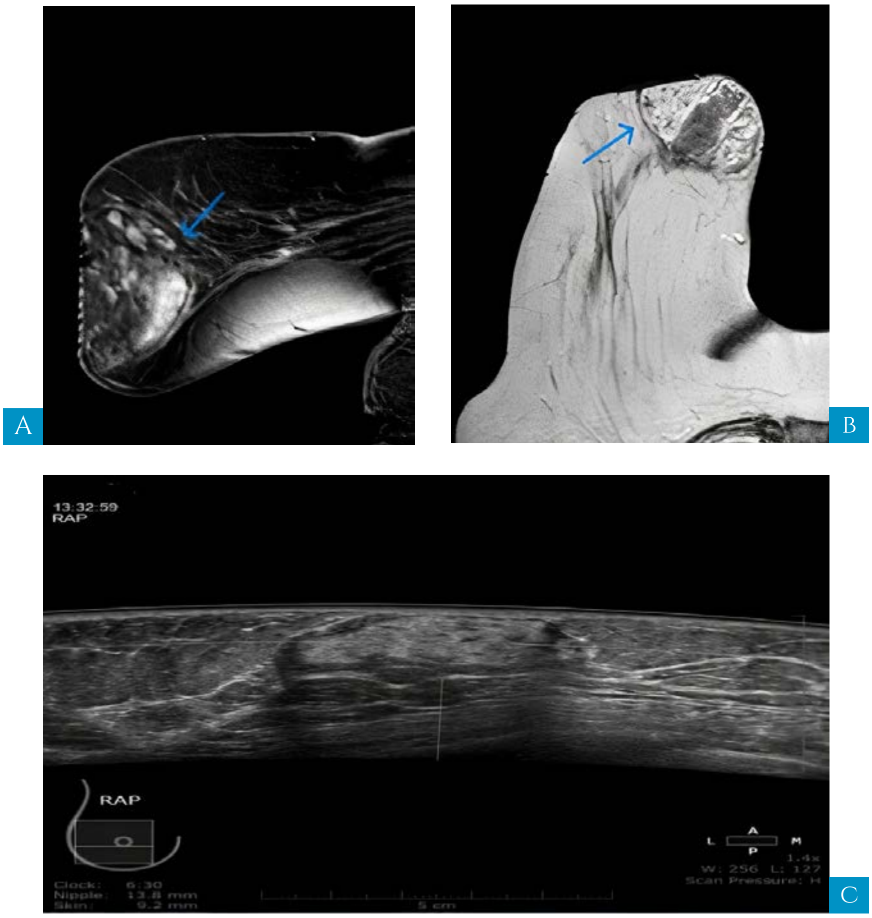

Fig. 2: *49-year-old female patient presenting to us by a clinically palpable right retro areolar breast lump A. MRI Post contrast with fat sat image sagittal view of the right breast. B. MRI T1 weight image axial view of the right breast. A&B show encapsulated mass with heterogeneous signal intensity within confirmed to the fatty and fibro glandular element and the fibro glandular element exhibited contrast enhancement similar to normal glandular tissue (BIRADS II). C: Automated ultrasound right AP axial image shows oval shape mass with circumscribed margins, parallel orientation and heterogeneous echo pattern (BIRADS II).*

Diagnosis:

The lesions diagnosed to be:

- *Hamartoma by its specific criteria.*
- *Both automated and MRI were equal in detection and characterization of the masses.*

Fig. 3: *A 55 year-old female patient with a left clinically palpable lump.A & B MRI of the left breast post fat sat image axial view show two interconnecting upper central irregular speculated mass with heterogeneous enhancement (BIRAD V). C&D Automated ultrasound of the left breast coronal view show two adjacent defect with retraction phenomena with distant 74 &75 from the nipple (BIRAD V). F&G Automated ultrasound of the left breast superior and medial view axial image show two left irregular shaped hypo-echoic mass with speculated margins, non- parallel orientation and posterior acoustic shadowing at 11 &12 o clock.*

Diagnosis:

- *Extensional biopsy done and revealed invasive lobular carcinoma tubolobular type*
- *Both automated and MRI were equal in detection and characterization of the masses.*

sions, 25 lesions were benign while the remaining 35 were malignant.

Pathological confirmation was obtained for 41 lesions (n=41/60) through core biopsy (n=30), fine-needle aspiration cytology (FNAC; n=7), and excisional biopsy (n=4). The remaining 19 lesions (n=19/60) were proven by their radiological criteria in both ABUS and CE-MRI to be benign including the following: fibroadenomas (follow up) (n=9), intra mammary lymph node (n=2), fat containing lesion (hamartoma) (n=1) and simple cysts (n=7). The histological diagnosis included in our study was shown in Table 1.

ABUS identified 57 lesions (48 masses, 9 non-mass). CE-MRI detected all 60 lesions (49 masses, 11 non-mass). Specific criteria for lesions detected in ABUS are shown in Tables 2. Table 3 shows lesions criteria detected in CE-MRI.

Table (1): The histological diagnosis in the patients included in our study

Pathology (n=60)		Count	%
Benign (n=25)	Fibroadenoma	9	34.6
	intramammary lymph node	2	7.7
	retro areolar intraductal papilloma	1	3.8
	Non-specific granulomatous inflammation	2	7.7
	Multiple cysts	7	27
	Phyloid	1	3.8
	periductal mastitis	2	11.6
	Hamartoma	1	3.8
Malignant (n=35) Pathology details	invasive ductal carcinoma	21	60
	metastatic adenocarcinoma of axillary lymph node	1	2.9
	invasive lobular carcinoma	10	28.5
	ductal carcinoma in situ	2	5.7
	Lobular carcinoma in situ	1	2.9

Table (2): Characterizations of lesions in (ABUS)

		Count	%
Composition	homogenous fat	10	16.6
	homogenous fibro glandular	15	26.8
	Heterogenous	35	62.5
Mass lesion (n=48) Shape	Oval	12	25
	Round	20	41.6
	Irregular	16	33.3

Table (2): Characterizations of lesions in (ABUS)

		Count	%
Margin	Circumscribed	24	48.9
	Indistinct	7	12.2
	Angular	5	10.2
	micro lobulated	2	4
	Speculated	10	20.4
Orientation	Parallel	22	45.8
	Not parallel	26	54.1
Eco pattern	An-echoic	8	14.3
	Hyper echoic	1	1.8
Eco pattern	iso echoic	0	0
	Hypo echoic	30	62.5
	Heterogeneous	9	16
Posterior feature	no features	26	46.4
	Enhancement	8	14.3
	Shadowing	16	28.6
	combined pattern	6	10.7
Lesion nature	Solid	45	78.6
	Cystic	7	12.5
	Solid with cystic	5	8.9
Coronal view	retraction phenomena	15	26.8
	Irregular hyper echoic rim	17	30.4
	Smooth hyper echoic rim	24	42.8
Non mass lesions(n=9) Distributions	Focal	2	22.2
	Linear to segmental	5	55.5
	Regional	2	22.2
BIRADS	BIRADS I	3	5
	BIRADS II	10	16.9
	BIRADS III	11	18.6
	BIRADS IV	17	28.3
	BIRADS V	18	30
	BIRADS VI	1	1.6
Lesion type according to BIRAD	Benign	24	40
	Malignant	36	60

Table (3): Characterizations of lesions in MRI				
Type	**Character**		**Count**	**%**
Mass lesion(N= 49)	Shape	Oval	8	16.3
		Round	24	49
		Irregular	17	34.7
Mass lesion(N= 49)	Margin	Circumscribed	24	49
		Irregular	15	30.7
		Speculated	10	20.4
Non mass lesion(n=11)	Distribution	Focal	2	18.2
		Linear	5	45.4
		Segmental	2	18.2
		Regional	2	18.2
		Diffuse	0	0
	Internal enhancement	Homogenous	2	18.2
		Heterogeneous	7	63.6
		Clumped	2	18.2
	BIRADS	BIRADS I	0	0
		BIRADS II	10	16.7
		BIRADS III	11	18.3
		BIRADS IV	18	30
		BIRADS V	20	33.3
		BIRADS VI	1	1.7
	Lesion type according to BIRAD	Benign	21	35
		Malignant	39	65

For mass lesion characterization in both modalities, Regarding the shape of the mass lesion 12 were oval, 20 were rounded and 16 irregular in ABUS. On the other hand, 17 masses appeared irregular in CE-MRI. One mass couldn't be detected by ABUS but was detected by CE-MRI images as irregular small mass (Table 4).

Table (4): Relation between both modalities regarding the shape						
		ABUS		**MRI**		**P value**
		Count %		**Count %**		
Shape	Oval	12	19.6	8	16.3	0.2
	Round	20	33.9	24	49	
	Irregular	16	46.5	17	34.7	
	No mass	1	4.3	0	0	

Regarding The lesion's margins in coronal view (which is unique for ABUS), 15 lesions showed retraction phenomenon (all were malignant 100%), however, (88.4%) of the benign lesions showed complete smooth hyper echoic rim. 46.6% of the malignant lesions showed irregular hyper echoic rim (Table 5).

Table (5): Automated coronal view

		Pathology				P value
		Benign		Malignant		
		Count	%	Count %	%	
AUTOMATED coronal view	Retraction phenomena	0	0%	15	50%	< 0.001
	smooth hyper echoic rim	23	88.4%	2	3.3%	
	Irregular hyper echoic rim	3	11.5%	14	46.6%	

3.3 For non-mass characterization, eleven non-mass lesions detected by MRI (n=11/11) while only nine could be detected by ABUS (n=9/11).

Regarding Internal enhancement (unique for MRI), 66.6% showed homogenous enhancement were benign while 75% of malignant lesions showed heterogeneous enhancement, however, all lesions showed clumped enhancement were malignant (Table 6).

Regarding the distribution of non-mass lesions, Two cases with linear distribution were only detected by CE-MRI not by ABUS and were proven to be DCIS by pathology.

Table (6): Internal enhancement (unique for MRI) for non mass lesion in MRI

		Pathology				P value
		Benign		Malignant		
		Count	%	Count %	%	
MRI non mass internal enhancement	Homogenous	2	66.6%	0	0%	< 0.001
	Heterogeneous	1	33.3%	6	75%	
	Clumped	0	0%	2	25%	

The results for BI-RADS classification by ABUS and CE-MRI showed 100% agreement in BIRADS II & III for benign lesions, while, it showed 95% agreement in BIRADS V for malignant lesion. Three lesions were given BIRADS I by ABUS images (not detected) and given BIRADS V by MRI (all were DCIS two of them were non-mass lesions and one was mass lesion). Only one lesion given BIRADS IV in ABUS images and V in MRI images (Table 7).

Table (7): Relation between both modalities regarding BIRADS scoring system

		ABUS		MRI		P VALUE
BIRADS	BIRADS I	3	5%	0	0%	0.8
	BIRADS II	10	16.9%	10	16.7%	
	BIRADS III	11	18.6%	11	18.3%	
	BIRADS IV	17	28.3%	18	30%	

Table (7): Relation between both modalities regarding BIRADS scoring system						
		ABUS		MRI		P VALUE
BIRADS	BIRADS V	18	30%	20	33.3%	0.8
	BIRADS VI	1	1.6%	1	1.7%	
	Clumped	0	0%	2	25%	

ABUS was comparable to CE-MRI in terms of sensitivity (91% vs.100%), specificity (83.3% vs. 84%), diagnostic accuracy (88.1% vs. 93.3%), positive predictive value (88.9% vs. 89.7%), and negative predictive value (86.9% vs. 100%) (Table 8).

Table (8): Comparison between accuracy measures of ABUS and MRI

Statistics	MRI	ABUS
Specificity	84%	83.3%
Sensitivity	100%	91.4%
Negative Predictive Value	100%	86.9%
Positive Predictive Value	89.7 %	88.9 %
Accuracy	93.3%	88.1%

4-Discussion:

In Shin, H. J et al. 2015 study state that HHUS is still a little challenging and time-consuming for radiologists. ABUS may be able to get around these problems by providing high-resolution 3D views and dramatically reducing the operator dependence (7).

Another study retrospectively evaluated the detection performance of benign and malignant breast masses using ABUS, results showed higher performance of ABUS in the detection of malignant, large, irregular shaped masses with surrounding changes, than benign, small, or round/oval masses without surrounding changes (8).

Although breast MRI has the highest sensitivity for detecting of breast cancer (9), it has variable specificity (10). Currently, second-look HHUS is typically performed to determine whether an MRI detected lesion can be visualized on US, making it suitable for US guided biopsy especially lesions with median sized of approximately 1 cm (11).

The results of a second look ultrasound typically enable the lesion to be identified as either certainly or probably benign, in which case follow-up is advised, or as suspicious, in which case ultrasound guided biopsy, which has numerous advantages over MRI-guided biopsy, can be carried out (12, 13).

In our study, we evaluated the characterization of different breast lesions and detection accuracy of ABUS compared to CE-MRI using pathology as a gold standard.

According to the newest BIRADS lexicon criteria for describing malignant masses and as regard the shape, 16 masses were irregular in both modalities and were proved to be malignant, yet MRI underestimated one case since it gave the appearance of a rounded mass (known as a benign descriptor) however indistinct margin was identified by automated ultrasound images and core biopsy proved the malignant nature of this lesion. We found out that the sensitivity of ABUS regarding characterization of the shape of malignant masses was 92% while it was 90% for CE-MRI.

Regarding the margins, as expected, all cases which had circumscribed margin were considered benign by both ABUS and MRI, however pathological examination proved malignant nature in one lesion detected by ABUS and two lesions detected by MRI. This confirms the idea that a single criterion is not enough for radiologists to reach a correct diagnosis. in our study sensitivity of ABUS regarding characterization of the shape of benign lesion was (95.8%) while it was (94.6%) in MRI. However, it was 100% regarding for the speculated masses (malignant lesions) in both modalities.

As regarding lesion margins in coronal view (which is unique for ABUS), Sensitivity of retraction phenomenon for malignancy in our study was 100%, however, Sensitivity of smooth hyper echoic rim for benign lesions was 92%, and, sensitivity of irregular hyper echoic rim for malignant lesion detection was 82.3%.

As regards, the final BIRADS score given for both modalities, MRI showed accuracy of 100 % for characterization of malignant lesions, compared to accuracy of 84% for benign lesions, on the other hand, ABUS showed 91.4% accuracy for characterization of malignant lesions compared to 83.3% accuracy in benign lesions.

As known, the performance of mammography is reduced for cancer detection in dense-breast due to breast tissue summation, ABUS is an effective modality to detect mammographically occult breast cancers in women with dense breasts, also, it has high sensitivity and as accurate as CE-MRI for detection of small lesions especially, in coronal view which is unique for ABUS where the architecture distortion appears very clear.

In our study we found that the sensitivity of MRI in detection and characterization of breast masses was 100%, the specificity was 84%, the positive predictive value was 89.7% and the negative predictive value was 100 %. On the other hand, the sensitivity of ABUS was 91.4%, the specificity was 83.3%, the positive predictive value was 88.9% and the negative predictive value was 86.9%. (Fig. 1, 2 and 3). The limitation for this study was the small sample size which we hope to overcome in the following thesis.

Conclusions:

This study underscores the importance of employing multiple imaging modalities for accurate detection and characterization of breast lesions. We confirmed the well-known superiority of MRI, which represents the most accurate imaging technique for evaluation of breast cancer, however, it has some drawbacks like, high cost, risks of hypersensitivity reactions to contrast media. On the other hand, ABUS was found to be a useful tool, and nearly accurate as CE-MRI, with potential advantages like, better accessibility, less cost, non-operator dependent, and, offers enhanced sensitivity for specific lesion characterization especially in dense breast. **R**

List of abbreviations:

ABUS: automated breast ultrasound, AP: ante posterior, BIRAD: breast imaging reporting and data system, CE-MRI: contrast enhanced magnetic resonance imaging, FNAC: fine needle aspiration cytology, INF: inferior, LAT: lateral, LOQ: lower outer quadrant, LIQ: lower inner quadrant, MED: medial, SPSS: statistical package of social science, SUP: superior, US: ultrasound, UOQ: upper outer quadrant.

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee (REC), NCI , Cairo University. Written and informed consent was obtained for all participants.

Funding

This research didn't receive any specific gran from funding agencies in the public, commercial, or not-for-profit

References

1. Drukteinis, J. S., Mooney, B. P., Flowers, C. I., Gatenby, R. A., Smith, B., & Johnson, L. (2013). Beyond mammography: new frontiers in breast cancer screening. The American Journal of Medicine, 126(6), 472-479
2. Berg, W. A., Blume, J. D., Cormack, J. B., Patel, N., Turner, A., & Young, S. (2008). Combined screening with ultrasound and mammography vs mammography alone in women at elevated risk of breast cancer. JAMA, 299(18), 2151–2163.
3. Chang, J. M., Moon, W. K., Cho, N., Park, J. S., & Kim, S. J. (2011). Breast cancers initially detected by hand-held ultrasound: detection performance of radiologists using automated breast ultrasound data. Acta Radiologica, 52(1), 8-14.
4. Bennani-Baiti, B., & Baltzer, P. A. (2017). MR imaging for diagnosis of malignancy in mammographic microcalcifications: a systematic review and meta-analysis. Radiology, 283(3), 692-701.
5. Marino, M. A., Clauser, P., Woitek, R., Wengert, G.

J., Kapetas, P., Bernathova, M.,... & Baltzer, P. A. (2016). A simple scoring system for breast MRI interpretation: does it compensate for reader experience? European radiology, 26, 2529-2537

6. Woitek, R., Spick, C., Schernthaner, M., Rudas, M., Kapetas, P., Bernathova, M.& Baltzer, P. A. (2017). A simple classification system (the Tree flowchart) for breast MRI can reduce the number of unnecessary biopsies in MRI-only lesions. European radiology, 27, 3799-3809
7. Shin, H. J., Kim, H. H., & Cha, J. H. (2015). Current status of automated breast ultrasonography. Ultrasonography, 34(3), 165.
8. Chang JM, Moon WK, Cho N, Park JS, Kim SJ. Radiologists' performance in the detection of benign and malignant masses with 3D automated breast ultrasound (ABUS). Eur J Radiol 2011;78:99-103
9. Kuhl C. The current status of breast MR imaging. Part I. Choice of technique, image interpretation, diagnostic accuracy, and transfer to clinical practice. Radiology 2007; 244:356–378
10. Smetherman DH. Screening, imaging, and image-guided biopsy techniques for breast cancer. Surg Clin North Am 2013; 93:309–327.
11. Abe H, Schmidt RA, Shah RN, et al. MR-directed (“Second-Look”) ultrasound examination for breast lesions detected initially on MRI: MR and sonographic findings. AJR Am J Roentgenol 2010; 194:370–377.
12. Vandromme MJ, Umphrey H, Kontrias H. Image-guided methods for biopsy of suspicious breast lesions. J Surg Oncol 2011; 103:299–305.
13. Schueller G, Jaromi S, Ponhold L, et al. US-guided 14-gauge core needle breast biopsy: results of a validation study in 1352 cases. Radiology 2008; 248:406–413.

Ready - Made Citation

Maysa Abd El Aziz Ali M. Sc., Fatma Saber M.D.; Maha Hussein Helal M.D.; Omnia Mokhtar Nada M.D.; Emad El Din El Gameae M.D. Role of automated breast 3D ultrasound in detection and characterization of Different breast lesions referral to post contrast MRI and pathological results, *Hell J Radiol 2025*; 10(2):11-23.