RESEARCH ARTICLE

Radial and meander-like Breast Ultrasound demonstrate similar diagnostic accuracy and reproducibility for BI-RADS 3 Lesions

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Abstract

Introduction
Radial ultrasound (r-US) or ductosonography is usually applied as an adjunct to meander-like ultrasound (m-US) but rarely as the sole scanning method. Here we compare r-US and m-US with regard to breast lesions detected and interpreted as BI-RADS 3, i.e. probably benign.

Materials and Methods
Eligible patients received a meander-like and a radial breast ultrasound in random order on the same day by two different examiners. The same type of ultrasound equipment was used but with specific probes.

Results
We performed 1984 dual ultrasound examinations. In 121 BI-RADS 3 lesions, a breast biopsy was performed and the histology of two (1.7%) BI-RADS 3 lesions turned out to be malignant. The specificity for m-US was 95.0%, and 96.6% for r-US. One (0.8%) benign lesion was missed by m-US, whereas r-US missed 2 (1.7%) benign lesions. Each missed lesion was identified by the other scanning method. The mean maximal lesion diameter (ICC 0.82), the mean lesion volume (ICC 0.87), the clock-face localization (κ 0.82) and the mean distance to the skin (ICC 0.77) show excellent, and the mean distance from the lesion to the mammilla (ICC 0.65) good agreement between m-US and r-US. The agreement between m-US and r-US in regard to sonomorphologic criteria ranged from excellent to poor. In 71.9% the lesion was classified as BI-RADS 3 by m-US as well as r-US. The examination time for r-US was significantly shorter than for m-US.

Conclusion
For BI-RADS 3 breast lesions, radial breast ultrasound is an alternative to meander-like ultrasound since the diagnostic accuracy of the two scanning methods is comparable. Notably, patients benefit from a significantly shorter examination time.

Keywords: Agreement, BI-RADS 3, Diagnostic accuracy, Ductosonography, Examination time, Radial breast ultrasound

Introduction

For the evaluation and management of breast lesions, detected by ultrasound (US), mammography or palpation, sonographic characterization is indicated. The characterization of breast lesions and the classification into assessment categories are described in the BI-RADS Atlas (1). The latter also defines how to manage lesions of each BI-RADS category. Accordingly, breast biopsy is mandatory in BI-RADS 5 lesions which are considered to be highly suggestive of malignancy and in BI-RADS 4 lesions considered to be suspicious for malignancy. BI-RADS 3 lesions are usually described as oval, well circumscribed solid mass and considered probably benign. Sonographic follow up is proposed since in the BI-RADS Atlas the likelihood of malignancy is acknowledged to range from >0% to ≤2% (1). However, cancer rates up to 11.4% (2) have been reported for BI-RADS 3 lesions detected

by US. Although the BI-RADS Atlas suggests a follow up of BI-RADS 3 lesions, immediate breast biopsy was performed in 9.8% (3) to 22.7% (4) of the BI-RADS 3 lesions reported in the respective study. In addition, biopsy is indicated in patients at increased risk for breast cancer, symptomatic patients (i.e. new breast lump in patients older than 40 years) and is performed upon patient or physician request (4-7).

Most clinicians perform a meander-like breast ultrasound (m-US), i.e. move the probe in two orthogonal planes in a meander-like manner. Radial breast ultrasound (r-US), also called ductosonography, is usually used as a complementary method in case of nipple discharge and ductal pathologies (8-11). Besides Rosensweig et al (12), who in 1982 introduced r-US for the first time, we and others consider r-US an alternative to m-US (13-16). Notably, it has been shown that the diagnostic accuracy of m-US and r-US are similar (13). Nevertheless, only a handful of publications can be found where breast ultrasound was performed by r-US and not by m-US (7, 17-20).

Our study is based on data from real time scanning rather than the retrospective interpretation of static images since this allows the evaluation and analysis of breast lesions during the ultrasound examination (16).

Here we present our data comparing real time meander-like and real time radial breast ultrasound of lesions classified as BI-RADS 3 by m-US, r-US or by both methods, in regard to diagnostic accuracy, examination time, and agreement in lesion size, location and BI-RADS classification.

Materials and Methods

This single center study was conducted from August 2011 to August 2014 at the Department of Gynecology and Obstetrics at the University Hospital Switzerland and approved by the local ethical committee. We recruited women from a consecutive, unselected, mixed collective. Eligible women were either symptomatic with palpable breast lesions or mastodynia, asymptomatic with dense breast tissue or increased risk for breast cancer, or a personal history of breast cancer. Exclusion criteria were as follows: male gender, patients aged <18 years, and patients scheduled for a breast biopsy. The informed consent form was signed by all participating women.

The examiners first obtained the patient's personal and family history and then performed a bilateral physical breast examination. Bilateral dual breast US, i.e. r-US and m-US were conducted by two different examiners in random order. Physical examination findings and mammography where available were open to all examiners. However, to avoid bias, findings of the examiner applying r-US were not available to the examiner performing m-US and vice versa.

A research fellow with limited experience in breast US received a theoretical and practical training in r-US at the onset of the study and subsequently carried out all r-US. As it is common in teaching hospitals, m-US was performed by experts or beginners supervised by an expert. All examiners were encouraged to attend a yearly training in breast US.

For r-US and m-US we used the same ultrasound machine (EUB-7500 V 16-53 Step 3.5, Hitachi Medical Systems Europe Holding AG, Zug, Switzerland) equipped with different transducers. M-US was carried out with a 50mm wideband, high frequency (13-5 MHz) linear transducer (EUP-L74M) while for r-US a 92mm wideband (10-5 MHz) linear transducer (EUP-L53L) with a water standoff (a water-filled latex cover) was used according to the manufacturer's instructions.

We determined the duration of r-US and m-US based on timestamps on the images taken at the beginning and at the end of each examination.

R-US and m-US were performed as described in Jäggi et al (13). In brief, the woman was placed in an oblique supine position and her ipsilateral arm was raised behind her head to

flatten the breast. In case of r-US, the transducer was moved clockwise around the mammilla first in a radial and then in an anti-radial fashion, followed by a radial and anti-radial sweep of the upper outer quadrant to examine the axillary tail. For m-US, the transducer was moved in a meander-like pattern in vertical and transverse direction. The scanning of the axilla was routinely performed for both r-US and m-US.

All examiners assessed the location, the dimensions, the morphologic characteristics and the BI-RADS category (21) of each sonographic lesion, and documented this information in the electronic patient record (ViewPoint®, Version 5; GE Healthcare GmbH, Munich, Germany). Breast biopsy was performed for final histologic diagnosis (core needle biopsy, vacuum biopsy of fine needle aspiration). All data on patient and lesion characteristics extracted from the electronic patient records were entered into R (R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org) for further analysis.

Statistical methods

We summarized patient and lesion characteristics and presented categorical data as frequencies and percentages. For continuous variables, mean, standard deviation and range are given.

The examination time between m-US and r-US was compared by using a Wilcoxon signed rank test with continuity correction. The histology (benign versus malignant) served as gold standard for the assessment of the diagnostic accuracy. Where lesions were missed by m-US or by r-US, they were considered normal breast tissue and interpreted accordingly for statistical analysis. The sensitivity, specificity, and accuracy were calculated with 95% confidence intervals (CIs) for both methods. The CIs were estimated according to Blaker (22) and p-values were calculated using the exact McNemar's test (23). Positive and negative predictive values were calculated with the corresponding 95% CIs, and the respective p-values (23). The proportion of true negative and false positive, and missed lesions were calculated for lesions confirmed as benign by pathology. An exact McNemar's test was used to compare the data between the two scanning methods.

If one patient had more than 1 lesion, they were considered independent. All analyses were performed by *R*. No correction for multiple testing was performed.

The agreement of categorical variables between m-US and r-US was quantified using κ-values with quadratic weights. However, for the endpoint "clock-face location" the cyclicity was taken into account by choosing weights according to the distance on the clock rather than absolute timepoints, meaning that the distance between "0" and "1" and between "11" and "0" is 1 hour in both cases.

Weighted κ-values were interpreted according to Landis et al. (24): ≤0.20 poor agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 substantial agreement, and 0.81-1.00 excellent agreement.

The agreement for continuous variables was quantified using intraclass-correlation (ICC) (25). The ICC is calculated based on analysis of variance. To this end, a mixed model is fitted to the data with scanning procedure and patient as random factors, and a fixed intercept was fitted. By dividing the variation related to the patient-to-patient difference by the total variance in the data the ICC was estimated. Therefore, ICC ranged from 0 to 1 and can be interpreted as the proportion of the variation of the data, which can be attributed to patient-to-patient variability. An ICC of 1 indicates a perfect agreement between r-US and m-US and that all differences in the ratings are due to differences in the patients. For the variable "mean volume", the data was cube-root transformed prior to fitting the model since the volume was estimated from the main axes and thus, any errors when

measuring these axes were inflated, leading to outliers not acceptable in the mixed model.

ICC-values were interpreted as suggested by Cicchetti (26): <0.40 poor agreement, 0.40-0.59 fair agreement, 0.60-0.74 good agreement, and 0.75-1.00 excellent agreement.

Results

We compared meander-like ultrasound and radial ultrasound with regard to diagnostic accuracy and agreement in lesion size, location and morphologic characteristics, and examination time for sonographic BI-RADS 3 lesions.

In the course of the study period, 1984 dual breast ultrasounds (m-US and r-US) were performed and only lesions classified as BI-RADS 3 by m-US, r-US or by both methods and biopsied for final diagnosis were included in the analysis study. In total, we analyzed 121 breast lesions in 108 patients.

A positive family history was documented in 35.2% (n=38) of patients and one patient (0.9%) had a history of breast cancer (Table 1). The patients had a mean age of 43.1 (19-86 years) years. Of all breast lesions, 48 (39.7%) were palpable. The breast lesions were diagnosed by core biopsy in 83.5 % (n=101), by vacuum assisted biopsy in 9.1 % (n=11) or by fine needle aspiration in 7.4 % (n=9). The majority (n=119, 98.3%) of the breast lesions had a benign histology but two (1.7%) BI-RADS 3 lesions, turned out to be malignant. Patients with a benign lesion were on average 42.9 (19-86) years old. The two patients with a malignant lesion were 49 and 61 years old and thus were significantly older than the average age of patients with a benign lesion (p=0.032).

Table 1: Patient and lesion characteristics

Patient characteristics		**Lesion characteristics**	
Number of patients	108 (100%)	Number of lesions	121 (100%)
Positive personal history	1 (0.9%)	Benign lesions	109 (98.3%)
Positive family history	38 (35.2%)	Fibroadenoma	48
Breast cancer	29	Fibrosis/sclerosis	34
Ovarian cancer	2	Other B2 lesions	32
Breast and ovarian cancer	1	B3 lesions	5
Endometrial cancer	6	Malignant lesions	2 (1.7%)
Mean age in years	43.1	DCIS	1
(min,max) [SD]	(19-86) [±13.6]	Triple neg. inv. ductal cancer	1

The specificity for BI-RADS 3 lesions was 95.0% for m-US and 96.6% for r-US (Table 2). Out of 121 BI-RADS 3 breast lesions, 2 malignancies (1.6%) (one DCIS and one invasive ductal cancer) were diagnosed. The two malignancies characterized as BI-RADS 3 (false negative) were falsely classified by both m-US and by r-US. In m-US, the true negative rate was 94.1% (n=112) and the false positive rate 5.0% (n=6). In r-US, 113 (95.0%) benign lesions were correctly classified as BI-RADS 3 and 4 (3.4%) lesions were falsely classified as BI-RADS 4 or 5. One (0.8%) benign lesion was missed by m-US but identified by r-US, while r-US missed 2 (1.7%) benign lesions which were identified by m-US.

Table 2. Diagnostic accuracy of m-US and r-US in BI-RADS 3 breast lesions

	Meander-Like Ultrasound			**Radial Ultrasound**			**p-Value**	
	n	%	CI	n	%	CI		CI
Malignant lesions	2	100		2	100			
Cancers identified	2	100		2	100			
True positive (BI-RADS 4 or 5)	0	0		0	0		NA	
Cancers missed	0	0		0	0		NA	
False negative (BI-RADS 3)	2	100		2	100		NA	
Benign lesions	119	100		119	100			
Benign lesions identified	118	99.2		117	98.3			
True negative (BI-RADS 3)	112	94.1	[88.5; 97.3]	113	95.0	[89.4; 97.8]	1	[0.2; 3.0]
Benign lesions missed	1	0.8	[0.0; 4.3]	2	1.7	[0.3; 5.7]	1	[0.0; 9.6]
False positive (BI-RADS 4 or 5)	6	5.0	[2.2; 10.6]	4	3.4	[1.2; 8.1]	0.75	[0.4; 7.2]
Diagnostic Accuracy								
Sensitivity		0			0		NA	
Specificity		95.0	[89.4; 97.8]		96.6	[91.9; 98.8]	0.75	[0.1; 2.8]
Accuracy		93.4	[87.5; 97.1]		95.0	[89.6; 97.8]	0.75	[0.1; 2.8]
PPV		0.0			0.0		NA	
NPV		98.3	[94.2; 99.7]		98.3	[94.3; 99.7]	1	[-3.4; 3.3]

PPV, positive predictive value; NPV, negative predictive value; NA, not applicable

Of each lesion, all three dimensions were measured in two orthogonal planes and the volume of the lesion calculated for m-US and r-US. The mean maximal lesion diameter (ICC 0.82) and the mean lesion volume (ICC 0.87) are presented in Table 3 and show excellent agreement for the two scanning methods. The clock-face localization, the distance to the mammilla and the distance to the skin was used to describe the location of each lesion in m-US and r-US (Table 3). The agreement of the clock-face localization (κ 0.85) and the mean distance to the skin (ICC 0.77) are excellent. The ICC value of the mean distance from the lesion to the mammilla was 0.65, indicating good agreement between m-US and r-US. While in r-US the width of the probe allowed us to measure the distance from the lesion to the mamilla, the distances in m-US had to be estimated.

Table 3. Agreement between m-US and r-US in BI-RADS 3 lesions with regard to lesion size and location

	Radial US	**Meander-like US**	**ICC**	**Weighted kappa**	**Agreement**
Size					
Mean max. lesion diameter (mm) (min, max) [SD]	14.5 (4.1, 47.3) [±8.3]	14.4 (3.4, 47.3) [±8.6]	0.82		Excellent
Mean volume (min, max) [SD]	1.4 (0.01, 14.3) [±2.5]	1.5 (0.01, 20.0) [±2.8]	0.87		Excellent
Location					
Clock-face localization				0.85	Excellent
Mean distance to mammilla (mm) (min, max) [SD]	29.3 (0.0, 86.0) [±21.0]	33.4* (0.0, 100.0) [±23.2]	0.65		Good
Mean distance to skin (mm) (min, max) [SD]	8.0 (1.0, 26.0) [±4.8]	6.8 (1.0, 20.0) [±4.1]	0.77		Excellent

*estimated values

Each examiner described the sonographic lesion according to the morphologic criteria of the BI-RADS atlas (21) and determined the BI-RADS classification. The weighted kappa values for the different morphologic criteria are listed in Table 4. Echo pattern, quality of assessment, lesion margin, posterior acoustic features and tissue composition showed moderate to fair agreement, while lesion shape and orientation showed poor agreement. The assessment of breast density shows a substantial agreement. Surprisingly, the agreement of the BI-RADS classification between m-US and r-US was poor. However, as presented in the cross tabulation (Table 5), 71.9% (n=87) of all breast lesions were classified as BI-RADS 3 by m-US as well as r-US. 21 lesions (17.4%) were classified as BI-RADS 3 (probably benign) by one method but as BI-RADS 2 (benign) by the other. Only 12 lesions (9.9%) classified as BI-RADS 3 by one method were classified as BI-RADS 4 (suspicious for malignancy) or 5 (highly suggestive of malignancy) by the other method. Because the analysis included only lesions initially classified as BI-RADS 3, already a low number of disagreements will have a strong statistical impact on the agreement in BI-RADS classification between m-US and r-US, which explains the low kappa value and thus, the poor agreement.

Furthermore, the mean examination time for m-US was 21.3 minutes and for r-US 14.7 minutes, demonstrating a significantly shorter examination time for r-US (Table 6).

Table 4. Agreement between m-US and r-US with regard to morphologic description of BI-RADS 3 lesions

	Weighted kappa	Agreement
Shape	0.10	Poor
Orientation	0.19	Poor
Margin	0.40	Fair
Echo pattern	0.42	Moderate
Posterior acoustic features	0.32	Fair
Tissue composition	0.30	Fair
Breast density*	0.80	Substantial
Quality of assessment*	0.53	Moderate
BI-RADS classification	<0.05	Poor

*According to Madjar et al (27)

Table 5. Cross tabulation of BI-RADS 3 classification in m-US versus r-US

		Radial ultrasound					
Meander-like Ultrasound		BI-RADS 2 n (%)	BI-RADS 3 n (%)	BI-RADS 4 n (%)	BI-RADS 5 n (%)	Missing n (%)	Total n (%)
	BI-RADS 2	-	8 (6.6)	-	-	-	8 (6.6)
	BI-RADS 3	13 (10.7)	87*(71.9)	3 (2.5)	1 (0.8)	2 (1.7)	106 (87.6)
	BI-RADS 4	-	6 (5.0)	-	-	-	6 (5.0)
	BI-RADS 5	-	-	-	-	-	-
	Missing	-	1 (0.8)	-	-	-	1 (0.8)
	Total	13 (10.7)	102 (84.3)	3 (2.5)	1 (0.8)	2 (1.7)	121 (100)

* Two lesions had a malignant histology

Table 6. Examination time for m-US and r-US in BI-RADS 3 lesions

	Meander-like Ultrasound	**Radial Ultrasound**	**p-Value**
Mean examination duration	20.8	15.0	<0.01
(min, max) [±SD]	(4.8; 68.5) [±9.6]	(5.2; 47.0) [±8.3]	

Discussion

Comparison of meander-like and radial ultrasound in regard to sonographic BI-RADS 3 lesions revealed similar diagnostic accuracy, and good to excellent agreement for lesion size and lesion location. Both scanning methods led to a BI-RADS 3 classification in 71.9% of the lesions. In addition, the examination time using r-US was significantly shorter compared to m-US in patients with BI-RADS 3 lesions.

Although a follow-up is usually recommended for BI-RADS 3 lesions (1), a number of reasons warrant a biopsy. For

example, in case of an elevated risk for breast cancer, a histologic verification might be indicated (28) since a delayed diagnosis negatively influences the prognosis of the individual patient. Additionally, patients may choose clarification by biopsy rather than follow-up (4). Patients with biopsied BI-RADS 3 lesions had an average age of 43.1 years and 35.2% had a positive family history. In line with previous reports, these findings reflect the fact that patient characteristics such as age and family history have an impact on whether a biopsy is performed in the case of BI-RADS 3 lesions (5, 29).

Among the 121 probably benign breast lesions, two lesions (1.7%) proved to be malignant, which is within the range required for BIRADS 3 classification by the BI-RADS Atlas (1). Others (3) report 4% breast cancer in biopsied BI-RADS 3 lesions. In our study population, the two lesions were falsely classified as BI-RADS 3 by m-US as well as by r-US. The histology of these lesion was a DCIS and a triple negative invasive ductal cancer. 5.5% to 15.8% triple negative breast cancers are misinterpreted as being probably benign because malignant features are absent in their sonographic appearance (30-33).

We report a NPV m-US and r-US, which is consistent with NPVs reported for m-US that range from 92.3% (34) to 99.3 (6). The PPV in our study was 0% for m-US and r-US. PPV values for m-US from 0% to 3% were published (35, 36).

M-US missed one (0.8%) benign BI-RADS 3 lesion which was identified by r-US whereas r-US missed 2 (1.7%) benign lesions which were identified by m-US. Therefore, r-US detected 98.3% and m-US 99.2% BI-RADS 3 lesions. This detection rate is higher than the 93.9%, published by Kim et al (37) who investigated only m-US and included all BI-RADS categories.

To the best of our knowledge, data on the agreement of morphologic criteria, lesion size and/or lesion location in BI-RADS 3 lesions have not yet been published. As shown in Table 4, the agreement between m-US and r-US of different morphologic criteria ranges from poor to excellent. In particular, lesion size and location showed excellent agreement. It should be noted that real time scanning is prerequisite for investigating agreement of lesion size and lesion location. We observed a high percentage of BI-RADS classification agreement (71.9%). Usually, studies on agreement in BI-RADS classification do not focus on BI-RADS 3 lesions only.

Accordingly, we are not aware of any published study that focuses on the examination time of BI-RADS 3 lesions. Our data reveal a mean examination time of 14.7 minutes for r-US which is significantly shorter than for m-US (21.3 minutes). Overall, these examination times are in line with the ones published by Rosensweig (12) who reported 28 minutes for m-US and 14 minutes for r-US albeit without distinguishing between BI-RADS categories.

The study protocol required that m-US and r-US were performed by two different examiners in order to avoid bias by knowing the outcome of the first US examination. This can be considered a possible limitation of this study. Moreover, the wider transducer used in r-US which allows for an efficient radial scanning might shorten the examination time. While minor technical improvements have been made since data collection, our study is comparative and, except for the probes, the same equipment was used for radial and meander-like ultrasound. Thus, any technical improvement in the ultrasound equipment is likely to equally affect both scanning procedures. Another limitation of this study is that shear wave, elastography and/or vascularity as modalities for further BI-RADS 3 breast lesion characterization were not part of the study protocol. The two scanning procedures were carried out in real time, namely all patients were scanned by m-US and r-US in random order on the same day using the same type of US equipment, which we consider a major advantage of this work.

Conclusion

Radial breast ultrasound is an alternative to meander-like ultrasound in the sonographic examination of BI-RADS 3 breast lesions. The diagnostic accuracy of the two scanning methods is comparable. However, radial breast ultrasound takes less time which is beneficial for patients and health care providers.

Disclosures

We declare that we have no conflict of interests.

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References

1. Mendelson EB-V, M.; Berg, W.A.; et al. ACR BI-RADS® Ultrasound in: ACR BI-RADS Atlas®, Breast Imaging Reporting and Data System. 5th ed2013.
2. Kim SJ, Ko EY, Shin JH, Kang SS, Mun SH, Han BK, et al. Application of sonographic BI-RADS to synchronous breast nodules detected in patients with breast cancer. AJR Am J Roentgenol. 2008;191(3):653-8.
3. Barr RG, Zhang Z, Cormack JB, Mendelson EB, Berg WA. Probably benign lesions at screening breast US in a population with elevated risk: prevalence and rate of malignancy in the ACRIN 6666 trial. Radiology. 2013;269(3):701-12.
4. Harvey JA, Nicholson BT, Lorusso AP, Cohen MA, Bovbjerg VE. Short-term follow-up of palpable breast lesions with benign imaging features: evaluation of 375 lesions in 320 women. AJR Am J Roentgenol. 2009;193(6):1723-30.
5. Raza S, Chikarmane SA, Neilsen SS, Zorn LM, Birdwell RL. BI-RADS 3, 4, and 5 lesions: value of US in management--follow-up and outcome. Radiology. 2008;248(3):773-81.
6. Cho N, Lim J, Moon WK. Usefulness of ultrasound elastography in reducing the number of Breast Imaging Reporting and Data System category 3 lesions on ultrasonography. Ultrasonography. 2014;33(2):98-104.
7. Hooley RJ, Greenberg KL, Stackhouse RM, Geisel JL, Butler RS, Philpotts LE. Screening US in patients with mammographically dense breasts: initial experience with Connecticut Public Act 09-41. Radiology. 2012;265(1):59-69.
8. Kim WH, Chang JM, Moon WK, Cho N, Yi A, Koo HR, et al. Intraductal mass on breast ultrasound: final outcomes and predictors of malignancy. AJR Am J Roentgenol. 2013;200(4):932-7.
9. Ballesio L, Maggi C, Savelli S, Angeletti M, Rabuffi P, Manganaro L, et al. Adjunctive diagnostic value of ultrasonography evaluation in patients with suspected ductal breast disease. Radiol Med. 2007;112(3):354-65.
10. Rissanen T, Reinikainen H, Apaja-Sarkkinen M. Breast sonography in localizing the cause of nipple discharge: comparison with galactography in 52 patients. J Ultrasound Med. 2007;26(8):1031-9.
11. Kang DK, Jeon GS, Yim H, Jung YS. Diagnosis of the intraductal component of invasive breast cancer: assessment with mammography and sonography. J Ultrasound Med. 2007;26(11):1587-600.
12. Rosensweig R, Foy PM, Cole-Beuglet C, Kurtz AB, Goldberg BB. Radial scanning of the breast: an alternative to the standard ultrasound technique. J Clin Ultrasound. 1982;10(4):199-201.
13. Jaggi-Wickes C, Brasier-Lutz P, Schaedelin S, Burian R, Schoenenberger CA, Zanetti-Dallenbach R. Comparison of radial and meander-like breast ultrasound with respect to diagnostic accuracy and examination time. Arch Gynecol Obstet. 2020;301(6):1533-41.
14. Stavros TH. Breast Ultasound. Philadelphia, PA 19106 USA: Lippincott Williams & Wilkins; 2004. 1015 p.
15. Madjar H, Rickard M, Jellins J, Otto R. IBUS guidelines for the ultrasonic examination of the breast. IBUS International Faculty. International Breast Ultrasound School. Eur J Ultrasound. 1999;9(1):99-102.
16. Hooley RJ, Scoutt LM, Philpotts LE. Breast ultrasonography: state of the art. Radiology. 2013;268(3):642-59.
17. Wojcinski S, Cassel M, Farrokh A, Soliman AA, Hille U, Schmidt W, et al. Variations in the Elasticity of Breast Tissue During the Menstrual Cycle Determined by Real-time Sonoelastography. J Ultrasound Med. 2012;31(1):63-72.
18. Ebner L, Bonel HM, Huber A, Ross S, Christe A. Diagnostic Performance and Additional Value of Elastosonography in Focal Breast Lesions: Statistical Correlation

between Size-Dependant Strain Index Measurements, Multimodality-BI-RADS Score, and Histopathology in a Clinical Routine Setting. ISRN Radiol. 2014;2014:396368.
19. Gheonea IA, Donoiu L, Camen D, Popescu FC, Bondari S. Sonoelastography of breast lesions: a prospective study of 215 cases with histopathological correlation. Rom J Morphol Embryol. 2011;52(4):1209-14.
20. Gheonea IA, Stoica Z, Bondari S. Differential diagnosis of breast lesions using ultrasound elastography. Indian J Radiol Imaging. 2011;21(4):301-5.
21. Mendelson EB, J.; Berg, W.; Merritt, C.; Rubin, E. ACR BI-RADS® Ultrasound in: ACR BI-RADS Atlas®, Breast Imaging Reporting and Data System. 4th ed2003.
22. Blaker H. Confidence curves and improved exact confidence intervals for discrete distributions. The Canadian Journal of Statistics. 2000;28(4):783-98.
23. Zhou X-HO, N. A.; McClish, D. K. Statistical methods in diagnostic medicine. 2nd ed: John Wiley & Sons; 2011.
24. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159-74.
25. Streiner D.L. NGR. Health Measurement Scales. A practical guide to their development and use. 4th ed: Oxford University Press; 2008. 452 p.
26. Cicchetti DV. Guidelines, Criteria, and Rules of Thumb for Evaluating Normed and Standardized Assessment Instruments in Psychology. Psychological Assessment. 1994;6(4):284-90.
27. Madjar H, Ohlinger R, Mundinger A, Watermann D, Frenz JP, Bader W, et al. [BI-RADS-analogue DEGUM criteria for findings in breast ultrasound--consensus of the DEGUM Committee on Breast Ultrasound]. Ultraschall Med. 2006;27(4):374-9.
28. Kim EK, Ko KH, Oh KK, Kwak JY, You JK, Kim MJ, et al. Clinical application of the BI-RADS final assessment to breast sonography in conjunction with mammography. AJR Am J Roentgenol. 2008;190(5):1209-15.
29. Ackermann S, Schoenenberger CA, Zanetti-Dallenbach R. Clinical Data as an Adjunct to Ultrasound Reduces the False-Negative Malignancy Rate in BI-RADS 3 Breast Lesions. Ultrasound Int Open. 2016;2(3):E83-9.
30. Dogan BE, Gonzalez-Angulo AM, Gilcrease M, Dryden MJ, Yang WT. Multimodality imaging of triple receptor-negative tumors with mammography, ultrasound, and MRI. AJR Am J Roentgenol. 2010;194(4):1160-6.
31. Wang D, Zhu K, Tian J, Li Z, Du G, Guo Q, et al. Clinicopathological and Ultrasonic Features of Triple-Negative Breast Cancers: A Comparison with Hormone Receptor-Positive/Human Epidermal Growth Factor Receptor-2-Negative Breast Cancers. Ultrasound Med Biol. 2018;44(5):1124-32.
32. Zeng Z, Hou CJ, Hu QH, Liu Y, Wang C, Wei R, et al. Mammography and ultrasound effective features in differentiating basal-like and normal-like subtypes of triple negative breast cancer. Oncotarget. 2017;8(45):79670-9.
33. Boisserie-Lacroix M, Mac Grogan G, Debled M, Ferron S, Asad-Syed M, Brouste V, et al. Radiological features of triple-negative breast cancers (73 cases). Diagn Interv Imaging. 2012;93(3):183-90.
34. Costantini M, Belli P, Lombardi R, Franceschini G, Mule A, Bonomo L. Characterization of solid breast masses: use of the sonographic breast imaging reporting and data system lexicon. J Ultrasound Med. 2006;25(5):649-59; quiz 61.
35. Patterson SK, Neal CH, Jeffries DO, Joe A, Klein K, Bailey J, et al. Outcomes of solid palpable masses assessed as BI-RADS 3 or 4A: a retrospective review. Breast Cancer Res Treat. 2014;147(2):311-6.
36. Hille H, Vetter M, Hackeloer BJ. The accuracy of BI-RADS classification of breast ultrasound as a first-line imaging method. Ultraschall Med. 2012;33(2):160-3.

37. Kim SH, Kang BJ, Choi BG, Choi JJ, Lee JH, Song BJ, et al. Radiologists' performance for detecting lesions and the interobserver variability of automated whole breast ultrasound. Korean J Radiol. 2013;14(2):154-63.

