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Original Article

Diagnostic utility of two-dimensional shear wave elastography to differentiate benign and malignant breast lesions

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Abstract

Aim: The aim of this study was to evaluate the diagnostic performance of two-dimensional shear wave elastography in the differentiation of malignant and benign breast lesions.

Material and Methods: A total of 83 breast lesions in 76 patients were prospectively investigated with B-mode ultrasonography and two-dimensional shear wave elastography techniques. B-mode ultrasonography findings were classified based on BI-RADS lexicon 5th edition. The mean elasticity and the standard deviation of speed mode (m/s) and elasticity mode (kPa) were calculated for all breast lesions. Diagnostic performances of each quantitative parameters were compared.

Results: Of 83 breast lesions, 45 (54.2%) were benign and 38 (45.7%) were malignant. Among the all shear wave elastography parameters, the standard deviation (E_{SD}) of the shear wave speed (m/s) had the highest AUROC (0.953) value. When a cut-off value of 0.85 m/s was used for E_{SD} of speed mode, sensitivity, specificity, accuracy, PPV, and NPV were detected as 94.7%, 88.8%, 91.5%, 87.8%, and 95.2%, respectively.

Conclusions: Two-dimensional shear wave elastography has excellent diagnostic performance in the differentiation of benign and malignant breast lesions. The standard deviation (E_{SD}) of speed modehad the best diagnostic performance when compared other quantitative parameters.

Keywords: Shear Wave Elastography; Ultrasound; Breast Lesions.

INTRODUCTION

Breast cancer is the most common cancer type among the women and the incidence is increasing in the last decades (1,2). Physical examination has an important role to detect breast lesions, however it is limited in patients with deep and small lesions (3). Mammography has been widely preferred method in breast cancer screening. Nevertheless, it has several limitations, such as radiation exposure and evaluate dense breast tissue (4). Ultrasonography (US) has become a complementary method to mammography to avoid this restriction (5).

US elastography is a method used to measure the stiffness of a tissue (6). This imaging technique can be divided into some groups according to their methods. (7). One of them, strain elastography can evaluate the breast lesions as qualitative and semi-quantitative (8). However, this method lacks quantitative information and is highly examiner-dependent (9). Another technique is acoustic radiation force impulse (ARFI) that evaluates tissue displacement induced using acoustic impulses from the transducer and it has less operator-dependence. Nevertheless, ARFI still cannot provide the adequate quantitative data about the lesion stiffness (10).

As a result of these limitations, shear wave elastography (SWE) has gained increasing attention in recent years. Toshiba SWE (T-SWE; Canon Medical Systems,USA) has developed a new SWE technique for clinical practice which is based on two-dimensional elastography imaging. Moreover, T-SWE provides information about the tissue

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stiffness both in kilopascals (kPa) and in meters per second (m/s) (10).

The aim of this study was to determine the diagnostic performance of T-SWE in the differentiation of benign and malignant breast lesions.

MATERIAL and METHODS

Patients

This prospective study was approved by local ethic committee and informed oral and written consents were obtained from all patients. From March 2017 to July 2018, a total of 76 patients with 83 breast lesions were included the study. The inclusion criteria were the visibility of the lesion in B-mode US and no history of breast surgery, radiotherapy or chemotherapy.

B-mode US and T-SWE Imaging

All patients were examined by using a Toshiba Aplio 500 (Toshiba Aplio 500, Canon Medical Systems,USA) with a 7.2 to 14 MHz high-frequency linear-array transducer. B-mode US and T-SWE were performed by a radiologist with 8 years of experience in breast radiology and 2 years of experience in T-SWE.

All patients were evaluated in the supine position with the arms elevated. Longitudinal and transverse B-mode US images were acquired of the breast lesions. B-mode US findings were classified using American College of Radiology Breast Imaging report and Data System (BI-RADS) lexicon 5th edition. Subsequently, T-SWE were performed in order to evaluate the stiffness of the breast lesions. T-SWE images were obtained in “One Shot Scan” mode. Propagation mode, speed mode, and elasticity mode were switched respectively after image frozen.

In the propagation mode, the contour lines display the quality and reliability of the images. Homogeneous images had parallel contour lines, whereas the wider contour intervals was detected in the stiffer lesions (Figure 1).

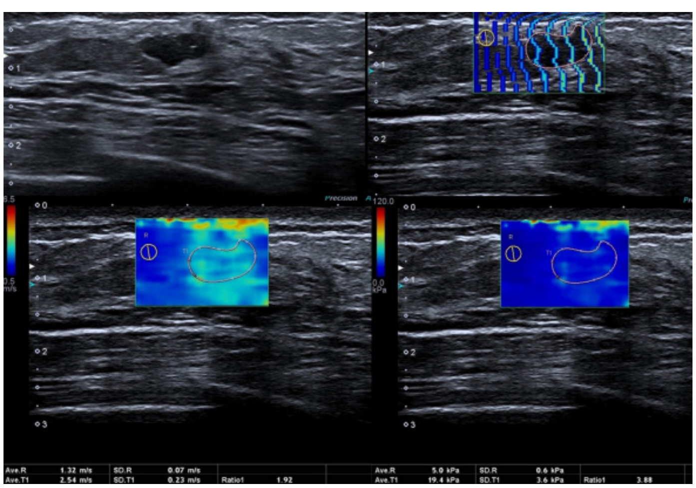

Figure 1. 36-year-old woman with fibroadenoma. B-mode ultrasonography showing a well-circumscribed round mass. Propagation mode showing regularly parallel contour lines. Speed mode showing the E_{mean} and E_{SD} of the lesion are 2.54 m/s and 0.23 m/s, respectively. Elasticity mode showing the E_{mean} and E_{SD} of the lesion are 19.4 kPa and 3.6 kPa, respectively

Distribution of the lesion stiffness was obtained both with speed mode in m/s and with elasticity mode in kPa. Then, one region of interest (ROI) was drawn by hand and adjusted to the lesion contour to include the maximum lesion area to get the mean elasticity (E_{mean}) and the standard deviation (E_{SD}) values in kPa and m/s.

Histopathology

US-guided core needle biopsies applied all breast lesions with a 14G biopsy needle (Geotek Medical, Ankara, Turkey). BI-RADS 3 lesions underwent biopsy because of the clinician's or patient's request, or because the patients were at high risk. All pathologic diagnoses were made by a single pathologist with 14 years' experience in breast pathology. The final diagnosis was based on histopathological results.

Statistical Analysis

Statistical analyses were performed with the Statistical Package for Social Sciences 22.0 (SPSS Inc., Chicago, IL, USA). Categorical variables were presented in percentages and frequencies. The proportions were compared using Fisher exact tests. Continuous variables were compared using the independent samples t-test. Receiver operating characteristic (ROC) curves were constructed to evaluate the diagnostic performance of the T-SWE. Using optimal cut-off values, the sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) were calculated. A p value less than 0.05 was accepted as statistically significant.

RESULTS

Total of 83 breast lesions (mean size, 19.4 mm ± 10.6; range 6 – 50 mm) in 76 patients (mean age, 47.6 years ± 11.9; range 18–86 years) were histopathologically diagnosed as malignant (n = 38) and benign breast lesions (n = 45). The histopathologic diagnoses are summarized in Table 1.

Table 1. Histopathologic types of the breast lesions

	Number of lesions	%
Malignant Lesions		
Invasive ductal carcinoma	33	39.7
Invasive lobular carcinoma	3	3.6
Medullary carcinoma	1	1.2
Ductal carcinoma in situ	1	1.2
Benign lesions		
Fibroadenoma	17	20.4
Fibrocystic changes	10	12
Sclerosing adenosis	7	8.4
Ductal hyperplasia	4	4.8
Intraductal papilloma	2	2.4
Fibrosis	3	3.6
Granulomatous mastitis	1	1.2
Hamartoma	1	1.2

Seventy women had a single breast mass, whereas six women had dsouble breast masses. The most frequent clinical finding was a palpable breast mass (48.1%).

Of all breast lesions, an oval shape and circumscribed margin were the most common B- mode US findings in benign lesions, whereas irregular shape and not circumscribed margin were the most frequent B-mode US findings in malignant lesions. Hypoechogenicity was the most common echo pattern in all breast lesions. There were statistically differences between malignant and benign breast lesions in the shape, margin and posterior features. The main features of the patients and the breast lesions are presented in Table 2.

Table 2. Features of the patients and breast lesions

	Benign (45)	Malignant (38)	p
Patients			
Mean age, y (range)	44.6 ± 9.9 (18 – 63)	51.7 ± 12.8 (30 – 86)	0.12
Symptoms			0.01
Palpable mass, n (%)	17 (20.4%)	23 (27.7%)	
Breast pain, n (%)	19 (22.8%)	13 (15.6%)	
Nipple change, n (%)	0 (0%)	6 (7.2%)	
Erythema, n (%)	1 (1.2%)	3 (3.6%)	
Screening/ symptomatic, n (%)	20 (24%)	10 (12%)	
Location of lesion			
Right, n (%)	23 (27.7%)	22 (26.5%)	0.65
Left, n (%)	22 (26.5%)	16 (19.2%)	
Lesions			
Mean size, mm (range)	17.1 ± 10.6 (6 – 44)	22.2 ± 10 (6 – 50)	0.93
Shape			
Oval/round, n (%)	41 (49.3%)	8 (9.6%)	<.0001
Irregular, n (%)	4 (4.8%)	30 (36.1%)	
Margin			
Circumscribed, n (%)	41 (49.3%)	3 (3.6%)	<.0001
Not circumscribed, n (%)	4 (4.8%)	35 (42.1%)	
Echo pattern			
Hyperechoic, n (%)	5 (6%)	2 (2.4%)	
Hypoechoic, n (%)	38 (45.7%)	35 (42.1%)	0.58
Mixed echoic, n (%)	2 (2.4%)	1 (1.2%)	
Posterior features			
Shadowing, n (%)	4 (4.8%)	25 (30.1%)	
Enhancement, n (%)	5 (6%)	1 (1.2%)	<.0001
No posterior features, n (%)	36 (43.3%)	12 (14.4%)	
Calcifications			
Present, n (%)	3 (3.6%)	7 (8.4%)	0.17
Absent, n (%)	42 (50.6%)	31 (37.3%)	

Most of the benign breast lesions were classifed as BI-RADS category 4a (33 of 45). Seven and five benign breast lesions were classifed as BI-RADS category 3 and 4b, respectively. None of benign lesions were classifed as BI-RADS category 4c or 5. Twenty one malignant breast lesions were classifed as BI-RADS category 5. Nine, five and three malignant breast lesions were classifed as BI-RADS category 4c, 4b and 4a, respectively.

All T-SWE quantitative results were higher in malignant lesions than benign ones in both speed and elasticity mode (Figure 2). T-SWE quantitaive results of malignant and benign breast lesions are summarized in Table 3.

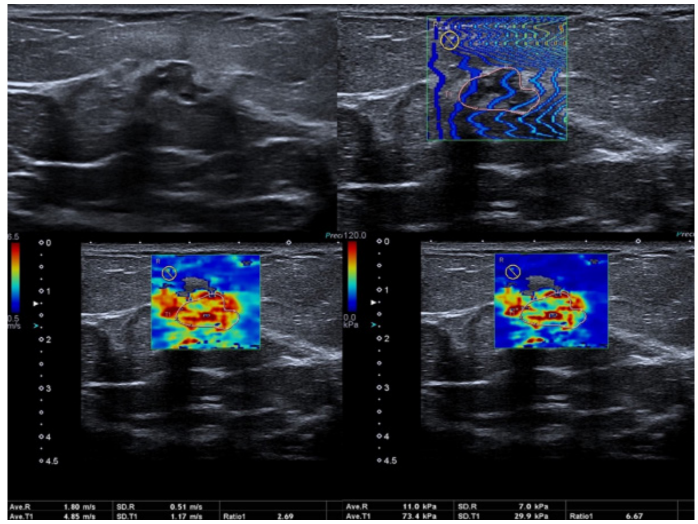

Figure 2. 54-year-old woman with invasive ductal carcinoma. B-mode ultrasonography showing a hypoechoic mass with irregular margin. Propagation mode showing irregularly distorted contour lines. Speed mode showing the E_{mean} and E_{SD} of the lesion are 4.85 m/s and 1.17 m/s, respectively. Elasticity mode showing the E_{mean} and E_{SD} of the lesion are 73.4 kPa and 29.9 kPa, respectively

Table 3. Comparison of T-SWE quantitative parameters between malignant and benign breast lesions

	Benign (45)	Malignant (38)	p
E_{mean} kPa	19 ± 7.8 (10.4 – 46.8)	50.1 ± 16.3 (13.6 – 80.3)	0.000
E_{mean} m/s	2.3 ± 0.5 (1.2 – 3.8)	3.7 ± 0.7 (1.9 – 4.9)	0.030
E_{SD} kPa	8.5 ± 7.8 (2.1 – 47)	32.6 ± 11.6 (4.9 – 52.8)	0.000
E_{SD} m/s	0.5 ± 0.3 (0.4 – 2.2)	1.5 ± 0.5 (0.5 – 2.4)	0.001

E_{mean} : the mean elasticity, E_{SD} : standard deviation of the elasticity

E_{SD} showed the best diagnostic performance in speed mode to differentiate of breast lesions. When a cut-off value of 0.85 m/s was used for E_{SD} of speed mode, the sensitivity and specificity detected as 94.7% and 88.8%, respectively.Sensitivity, specificity, accuracy, PPV and NPV values of all quantitative parameters are summarized in Table 4.

Table 4. Comparison of diagnostic performances among groups with different quantitative parameters

	Cut-off value	SEN (%)	SPE (%)	ACC (%)	PPV (%)	NPV (%)	AUROC
E_{mean} kPa	29.5	86.8	93.3	90.3	91.6	89.3	0.952
E_{mean} m/s	2.92	86.8	93.3	90.3	91.6	89.3	0.924
E_{SD} kPa	16.5	92.1	91.1	91.5	89.7	93.1	0.947
E_{SD} m/s	0.85	94.7	88.8	91.5	87.8	95.2	0.953

E_{mean} : the mean elasticity, E_{SD} : standard deviation of the elasticity, SEN: Sensitivity, SPE: Specificity, ACC: Accuracy, PPV: positive predictive value, NPV: negative predictive value, AUROC: area under the receiver operating characteristic curve

DISCUSSION

US is the first step imaging method which is noninvasive and useful technique todistinguish breast lesions. High-frequency probes are the most frequently preferred device in the assessment of breast lesions. Thanks to high-frequency probes, the target lesion features such as echo pattern, shape, margin and calcifications can be evaluated more easily (11). However, breast lesions can be appeared many different form and they can mimic both benign and malignant breast lesions. Therefore, B-mode US cannot always provide adequate diagnostic performance in differentiating benign breast lesions from malignant (12).

US elastography is an imaging method that can detect tissue stiffness, which has developed in recent years (13). T-SWE provides quantitative data of the target tissue, including the mean elasticity and the standard deviation of elastic values in kPa and m/s. In this study, we performed T-SWE technique to obtain the highest sensitivity, specificity, and accuracy values todistinguish malignant and benign breast lesions. All breast lesions stiffness were evaluated via two-dimensional shear wave elastography. Thus, optimal elastography values were achieved in all breast lesions.

T-SWE provides objective tissue stiffness data using E_{mean} and E_{SD}. E_{mean} shows the general stiffness of the lesions and E_{SD} measures the internal heterogeneity of the target tissue. Hence, higher E_{mean} and E_{SD} values are related to a higher risk of malignancy. In this study, E_{mean} and E_{SD} values of malignant breast lesions were higher than benign breast lesions statistically which was compatible with previous reports (12,13).

Among the all elasticity parameters of T-SWE, highest AUROC value detected in E_{SD} with corresponding cut-off value of 0.85 m/s. Different reports had concordant optimal cut-off values using ESD(10,14). Yang et al. detected optimal cut-off values for E_{SD} as 0.91 m/s and for E_{mean} as 3.30 m/s. In the study, they reached 93.6% sensitivity and 95.5% specificity using E_{SD} and 85.1% sensitivity and 95.5% specificity using E_{mean} (14). In our study, we achieved 94.7% sensitivity and 88.8% specificity rates using E_{SD} and 86.8% sensitivity and 93.3% specificity rates using $E_{mean.}$

Tissue stiffness can also be calculated in elasticity mode as kPa by a physical quantity called Young's modulus. Ren et al. reported the optimal cut-off value of E_{mean} was 25.2 kPa and E_{SD} was 18.5 kPa in T-SWE (10). In their study, the sensitivity, specificity, and AUROC of E_{mean} was 92.7%, 81.3%, and 0.892, respectively. Additionally, all quantitative parameters show different diagnostic performance in various machines, it is challenging for clinicians to choose an appropriate parameter among them. Lee et al.recommended to use optimal cut-off value of E_{mean} as 68.40 kPa. In another study was conducted with Evans et al. recommended to useE_{mean} cut-off value as 50 kPa and Chang et al.recommended to useE_{mean} of 80.17 kPa (12,15-17). In our study, E_{mean} and E_{SD} showed excellent diagnostic performance to exhibit the tissue stiffness of the breast lesions. The Sensitivity, specificity, and AUROC of E_{mean} was 86.8%, 93.3%, and 0.952 and E_{SD} was 97.4%, 88.8%, and 0.947, respectively.

There were some false positive and negative results in our study. False positive results were detected in only fibroadenomas, while false negative results were detected in invasive ductal carcinoma, medullar carcinoma and ductal carcinoma in situ (DCIS). Some benign breast masses such as fibroadenoma and sclerosing adenosis might be seen stiffer in elastography images due to calcification or dense fibroblastic proliferations. Other side, malignant lesions such as DCIS and mucinous carcinoma might be detect softer in elastography images due to hemorrhage, necrosis or the soft nature of tumors. Several studies have shown similar false positive and negative results in the literature(6,14,18).

This study had some limitations. The sample size was relatively small. The lack of intraobserver or interobserver variability was another limitation. Last, the variation of histopathologic types was limited. Additional prospective studies with largerparticipants are needed.

CONCLUSION

T-SWE is a helpful, easy to use and noninvasive diagnostic imaging method to distinguish malignant and benign breast lesions. Speed mode and elasticity mode have excellent diagnostic performance with high sensitivity and specificity values.

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