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ORIGINAL ARTICLE

Comparison of SWE (Shear Wave Elastography) and ADC (Apparent Diffusion Coefficient) Values in the Evaluation of Breast Lesions

Tevfik Güzelbey[1], Ezgi Kartal[2], Arda Kayhan[3]

[1]Department of Radiology, Istanbul Basaksehir Cam and Sakura City Hospital, Istanbul, Türkiye
[2]Department of Radiology, Rize Public Hospital, Rize, Türkiye
[3]Department of Radiology, Koc University Hospital, Istanbul, Türkiye

Abstract

Introduction: Values obtained by shear wave elastography (SWE) in breast lesions were compared with Apparent Diffusion Coefficient (ADC) values. This study aimed to demonstrate the usability of SWE, which is an easy-to-apply, cost-effective, quantitative data-providing and user-independent method, to distinguish benign and malignant lesions.

Methods: In the retrospective study, SWE measurements were made by placing the smallest region of interest (ROI) obtained in 24 lesions, in the areas where the red color was most intense on the color map. The obtained values were compared with the ADC values determined using the ROI drawn freely from the entire lesion in ADC mapping and the round ROI drawn from the darkest area.

Results: A high level of correlation (p=0.001, r=0.790) was detected between the kPa values measured in SWE and the minimum ADC values measured in diffusion, and a moderate correlation (p=0.001, r=0.670) was found between the ADC values measured from the entire lesion. A significant difference was detected between SWE, minimum ADC and mean ADC values of benign and malignant lesions (p=0.001).

Discussion and Conclusion: There is a high correlation between ADC values obtained in diffusion-weighted imaging (DWI) and SWE values in breast lesions. SWE, which is easy to apply, cost-effective and provides quantitative data, can be used instead of ADC mapping to distinguish benign and malignant breast lesions.

Keywords: Apparent diffusion coefficient; breast lesions; magnetic resonance imaging; shear wave elastography.

Today, conventional B-mode ultrasonography (USG) and magnetic resonance imaging (MRI) are very important in the evaluation of breast lesions and to distinguish benign-malignant lesions with high accuracy. In addition to conventional USG, shear wave elastography (SWE) significantly increases diagnostic accuracy[1–4]. Likewise, diffusion-weighted imaging (DWI) added to MRI is also beneficial in distinguishing between benign and malignant lesions[5–7].

Ultrasound elastography is a method used in addition to conventional B-mode evaluation and evaluates the stiffness of the lesion. Since malignant lesions are significantly stiffer than benign lesions, elastography provides significant benefit in the distinction between malignant and benign. Two techniques are used in ultrasound elastography: strain elastography and shear wave elastography (SWE). In strain elastography, pressure is applied on the tissue with the transducer, and the elasticity of the tissue with the resulting stress is displayed in real time with a color map on gray scale. However, with this technique, the absolute elasticity of the tissue cannot be measured. In addition, there is

Correspondence: Ezgi Kartal, M.D. Department of Radiology, Rize Public Hospital, Rize, Türkiye
Phone: +90 506 232 51 55 **E-mail:** ezgikartal91@gmail.com
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a significant difference in evaluation between observers in this technique[8,9]. In SWE, the radiation rate of the acoustic sound power sent by USG in the tissue is calculated[10]. SWE is more advantageous because it provides quantitative values, does not require compression, is user-independent, and has high reproducibility[11].

Breast MRI is superior to mammography and USG in terms of accuracy in the diagnosis and characterization of breast cancer, with sensitivity ranging from 98-100% and specificity of approximately 88%[12,13]. Diffusion-weighted imaging (DWI), which is a sequence that does not require the use of intravenous (IV) contrast and takes a short time to perform, is a sequence that is sensitive to the Brownian motion of protons and provides information about the biological character of the tissue. Apparent diffusion coefficient (ADC) is used to measure this movement. Due to high cellularity in malignant tumors, the movement of protons in water decreases and ADC values are measured lower than in benign lesions[5,12,13]. Additionally, since changes in ADC values are monitored earlier than changes in tumor size or vascularization, it may be used in the evaluation of response to treatment[14].

The aim of the study is to compare the values obtained with SWE with ADC values and thus to demonstrate the usability of SWE, which is an easy-to-apply, cost-effective, quantitative data-providing and user-independent method.

Materials and Methods

This is a retrospective study and approval was received from the relevant ethics committee (Ethics committee approval number: 2019/10/41). Between October 2016 and January 2017, a total of 91 Breast Imaging-Reporting and Data System (BI-RADS) category 3, 4 and 5 solid lesions were evaluated with SWE in 87 female cases referred to our clinic for USG-guided biopsy. Among these cases, 3 lesions that were superficial and protruded beyond the skin were excluded from the study because it was thought that they would affect elastography measurements. Among these cases with elastography measurements, 29 cases with previous MRI examination were included in the study. Six of these cases were excluded from the study because there were artifacts on DWI and the lesions could not be clearly distinguished. A total of 24 lesions in 23 cases (mean age: 46.95±12.75) were included in the study.

All lesions were evaluated with B-mode USG and SWE before biopsy. The evaluation was performed by a radiologist (T.G.) with 7 years of USG experience, using the TOSHIBA Aplio 500 (Toshiba Medical System Corporation, Tokyo, Japan) device and a high-frequency (14 Mhz) linear transducer. Two-dimensional (2D) SWE examination was performed in B-mode examination by holding the probe vertically and without significant compression in two different locations where the lesion was best observed. The image was recorded after waiting approximately 5 seconds for the real-time color map to form and the artifacts to disappear. In all measurements, the smallest ROI obtainable (2 mm in diameter) was placed in the areas where the red color was most intense in the color map. The highest value obtained from three measurements was used for analysis.

Breast MRI was performed using a 1.5 Tesla MRI device (Magnetom Aera; Siemens Medical Systems, Erlangen, Germany). An 8-channel dedicated breast coil was used during imaging in the prone position. DWI was obtained using fat-suppressed two-dimensional echo-planar imaging (EPI) sequences taken in the axial plane. For DWI, the relevant values were obtained as follows: TR: 6900 msec, TE: 81 msec, matrix: 132x220, slice thickness: 4.4 mm, FOV: 276 mm; b value:50, 400 and 800 s/mm2. ADC mapping was performed from images with a b value of 800 s/mm2 using DWI. The obtained images were evaluated by a radiologist (T.G.) with five years of breast MRI experience. With the help of other sequences obtained, the ADC equivalent of the lesions detected on DWI was determined. ADC measurements were evaluated on Siemens syngoMR D13 version workstation. ADC measurements were performed with the help of a ROI drawn freely by hand from the entire lesion and a round ROI with an area of 0.14 cm2 drawn at least 3 pixels from the darkest area. The lowest ADC value detected after three measurements for each lesion was recorded as the minimum, maximum and mean value.

Statistical Analysis

Statistical analysis was performed using SPSS v.21 (SPSS Inc, Chicago, IL, USA). The data obtained were categorized as mean and standard deviation (SD), or median and interquartile range (IQR: 75^{th} and 25^{th} percentile). The suitability of the data according to normal distribution was evaluated with the Kolmogorov-Smirnov test. In abnormal distribution, Spearman's Rho test was used to analyze the correlation between two variables. To compare two independent groups, the independent Mann-Whitney U test was used. Results with a p value <0.05 were considered statistically significant.

Results

Histological findings, ADC and SWE values observed in benign and malignant lesions are shown in Table 1. Pathological diagnoses of benign and malignant lesions, maximum kPa values measured in SWE and minimum and mean ADC values measured in ADC mapping are shown separately for each lesion in Table 1.

Table 1. Histological findings, SWE and ADC values in benign and malignant lesions

	Pathology	Maximum SWE (kPa)	Minimum ADC (x 10^{-3} mm^2/sec)	Mean ADC (x 10^{-3} mm^2/sec)
Benign	FA	11.5	1.559	1.594
	IP	12	1.248	1.274
	FA	15.8	1.016	1.117
	FA	16	1.002	1.301
	FA	16.3	1.020	1.105
	FA	16.7	1.170	1.330
	FA	19	1.379	1.998
	FA	22.2	1.458	1.813
	FA	23.3	0.906	1.205
	FA	34.7	1.404	1.529
	IP	88.5	0.868	1.177
	SA	93	0.691	0.998
	ADH	117	0.583	0.845
Malign	IDC	87.3	0.609	0.868
	IDC	91	0.493	0.820
	IDC	99	0.655	0.959
	IDC	103.3	0.602	0.863
	ILC	104	0.183	0.332
	IDC	106.9	0.462	0.939
	DCIS	114	0.504	0.967
	IDC	116	0.200	0.526
	IDC	118	0.604	0.916
	IDC	131	0.345	0.905
	IDC	141	0.742	1.123

SWE: Shear wave elastography; ADC: Apparent diffusion coefficient; FA: Fibroadenoma; IP: Intraductal papilloma; SA: Sclerosing adenosis; ADH: Atypical ductal hyperplasia; IDC: Invasive ductal carcinoma; ILC: Invasive lobular carcinoma; DCIS: Ductal carcinoma in situ.

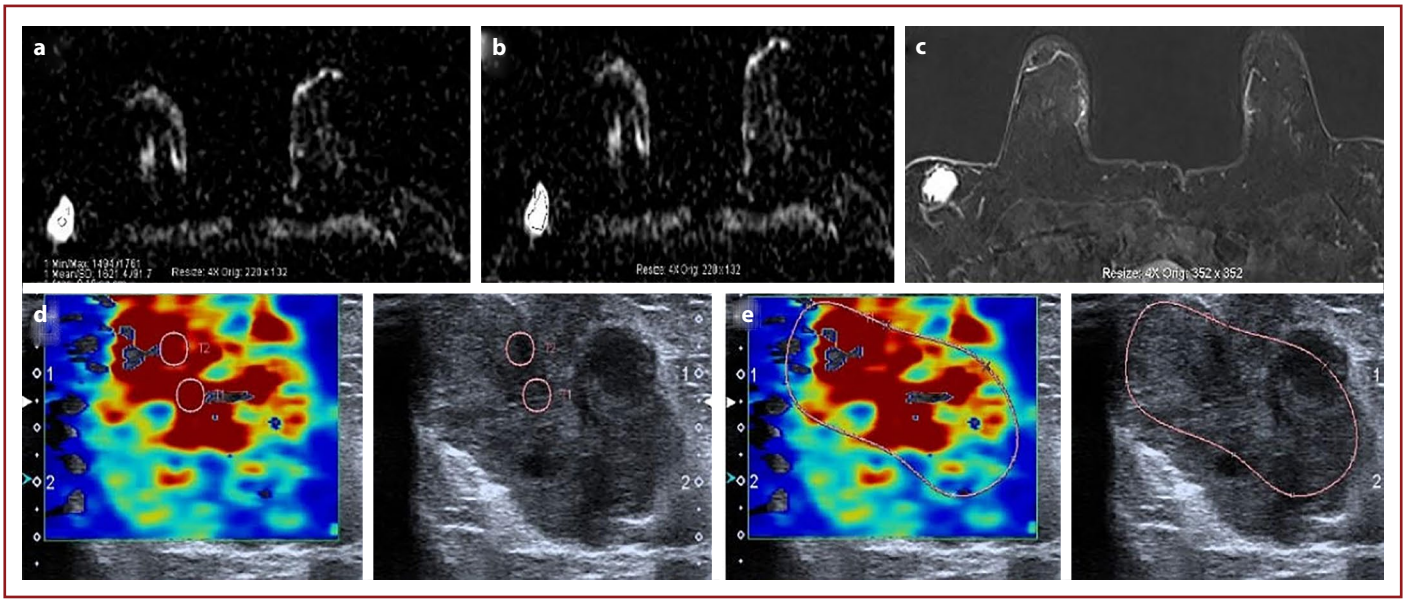

Figure 1. A lesion located in the axillary tail of the right breast in a 41-year-old female patient, with a histopathological diagnosis of fibroadenoma. **(a)** The measurement image made with a round ROI and the lesion does not show hypointensity in ADC mapping; **(b)** The measurement made from the entire lesion; **(c)** The lesion contrast enhancement pattern in postcontrast subtraction images; **(d and e)** SWE measurement technique.

The mean SWE value of benign lesions was measured as 37.38±19 kPa, the minimum ADC value as 1.097±0.299x10^{-3} mm^2/sec, and the mean ADC value of the lesion was measured as 1.329±0.325x10^{-3} mm^2/sec (Fig. 1) (Table 2). The mean SWE value detected in cases with malignancy was 110.13±16.14 kPa, the minimum ADC value was 0.490±0.181x10^{-3} mm^2/sec, and the mean ADC value of the lesion was measured as 0.838±0.221x10^{-3} mm^2/sec (Fig. 2) (Table 2). As seen in Table 2, kPa values measured in SWE in benign lesions were lower than in malignant lesions. This indicates that malignant lesions are stiffer. As seen in Table 2, the minimum and mean ADC values measured in benign lesions are higher than in malignant lesions, indicating that malignant lesions have dense cells. When SWE, minimum ADC and mean ADC values of the lesion were compared, a significant difference was found between benign and malignant lesions for all three variables (p<0.001 for all three analyzes) (Table 2).

The mean age of women with benign lesions was 43.46±710.8, and the mean age of women with malignant lesions was 51.09±9.94. Considering the mean age, no statistically significant difference was observed between women with benign and malignant lesions (p=0.80). According to the measurement made on the longest axis, the mean size was found to be 15.54±7.04 mm in benign lesions and 25.90±16.71 mm in malignant lesions. No statistically significant difference was observed between the sizes of benign and malignant lesions (p=0.80) (Table 2).

A high level of correlation (p=0.001, r=0.790) was found between the kPa values measured in SWE and the ADC val-

Table 2. Correlation between mean age and lesion sizes in benign-malignant lesions, mean values detected in SWE, and minimum and mean ADC values

	Benign	Malign	p
Mean age	43.46±10.8	51.09±9.94	0.48
Mean lesion size	15.54 ±7.04	25.90±16.71	0.80
Mean SWE (kPa)	37.38±19	110.13±16.14	<0.001
Mean Minimum ADC (x10^{-3} mm^2/sec)	1.097±0.299	0.490±0.181	<0.001
Mean value of mean ADC (x10^{-3} mm^2/sec)	1.329±0.325	0.838±0.221	<0.001

SWE: Shear wave elastography; ADC: Apparent diffusion coefficient.

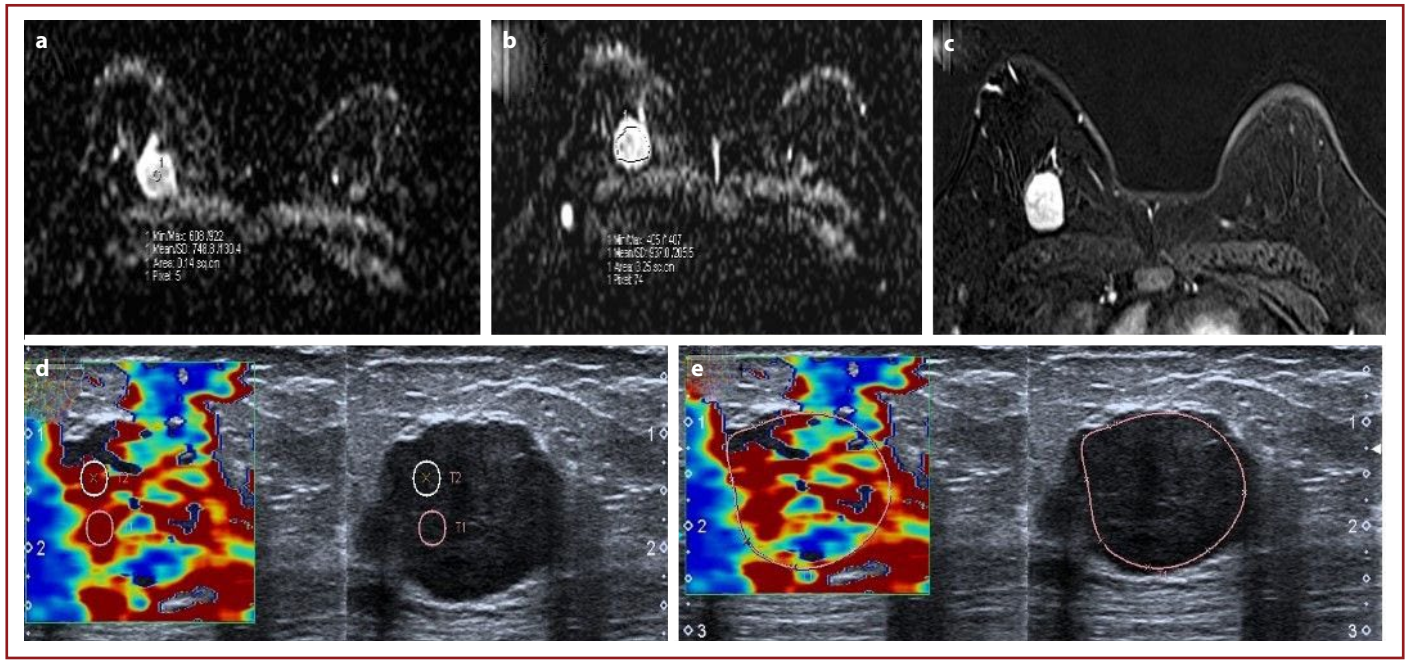

Figure 2. A lesion located in the upper inner quadrant of the right breast in a 47-year-old female patient, whose histopathological diagnosis was invasive ductal carcinoma. **(a)** Measurement image made with a round ROI from the most hypointense area of the lesion in ADC mapping; **(b)** Measurement made from the entire lesion; **(c)** Lesion contrast enhancement pattern and morphological features in postcontrast subtraction images; **(d and e)** SWE measurement technique.

ues measured from the most hypointense area in diffusion, and a moderate correlation (p=0.001, r=0.670) was found between the ADC values measured from the entire lesion.

Discussion

SWE, a newer elastography technique, provides quantitative assessment of tissue stiffness. The absence of the need to apply compression eliminates the operator-dependence limitation of strain elastography and allows for repeatable evaluations that do not differ between practitioners. For this reason, it is a technique that can be easily performed in daily use by performing it simultaneously with ultrasonography in centers where clinical application is possible. However, even if ultrasonography devices have this feature, it cannot be used in every center in our country due to the need to install new software.

In our study, a high level of correlation was detected between SWE, which measures the stiffness of the tissue, and ADC values, which is in parallel with increased cellularity. There are few studies comparing these parameters in the literature, and most of them were conducted using strain elastography. Matsubayashi et al.[15] found a significant correlation between elastography findings and ADC values of the fibrosis component in fibrocystic changes detected in the breast (p=0.0256). Satake et al.[13] compared the elastography and ADC values of BI-RADS category 4 and 5 lesions and found the sensitivity, specificity and accuracy threshold values in distinguishing between benign and malignant lesions as 81.8%, 70.4% and 79.1% in elastography and as 69.3%, 70.4% and 70.0% in ADC. However, since strain elastography was used in both studies, comparisons were made based on color maps instead of quantitative values. Studies have reported that the SWE technique applied in addition to conventional B-mode USG increases the diagnostic performance of breast lesions[16]. In our study, we used SWE because it does not require compression and is a quantitative method. Kapetas et al.[17] also compared ADC values with Acoustic Radiation Force Impulse (ARFI), a SWE technique, in their study and found a significant correlation, similar to our study.

It has been reported that ADC values, in comparison to SWE values, show higher specificity than contrast-enhanced MRI in distinguishing malignant-benign lesions[6]. There are studies reporting that DWI accompanied contrast-enhanced MRI is superior to contrast-enhanced MRI alone in terms of diagnostic accuracy[7]. Although DWI is included in the routine breast MRI protocol, its use as an independent parameter is still not in use[14,18]. On the other hand, the disadvantages of MRI are that it is expensive, not easily accessible, and has contraindications such as claustrophobia or carrying metallic implants. There are also DWI limitations such as not using common b values, varying Tesla values of the devices, and detecting changes in ADC threshold values due to changes in the sequence parameters caused by the devices.

In one of the two intraductal papilloma cases detected in our study, SWE and ADC values were similar to those of malignant lesions, while in the other they were similar to those of benign lesions. In the study of Satake et al.[13], values similar to those in benign lesions were found in papillomas with histopathological microcystic changes. However, in some papillomas, due to secondary changes such as hemorrhage, infarct or fibrosis, values similar to measurements in malignant lesions were detected. In addition, in two cases diagnosed with sclerosing adenosis and atypical ductal hyperplasia, where fibrosis and cellularity are high, SWE and ADC values were measured similar to malignant lesions.

Studies have reported that the best parameter among the mean, maximum, minimum and standard deviation parameters used in measurements made with SWE in the diagnosis of breast lesions is "maximum"[1-3,19–21]. Measuring these parameters from the entire lesion is not recommended because data cannot be obtained in some parts of the lesion, such as the central part. It has been found more reliable to make measurements from the location where the most accurate data can be obtained with as small ROI as possible[19]. For this reason, in our study, we measured with the smallest ROI and the maximum SWE value was used.

In the literature, the maximum kPa threshold value in SWE measurements for distinguishing benign-malignant breast lesions is stated to be between 46.7-93.8 kPa[19,20,22–24]. In our study, the lowest maximum SWE measurement in malignant lesions was 87.3 kPa and it is compatible with the literature.

The most important limitation of our study is that the number of patients is small and the histopathological diversity of benign-malignant lesions does not show a wide range. Another limitation is that the evaluations were made by the same radiologist and there were no dual readers. However, it should be noted that ADC measurements performed with both SWE and DAG are reproducible techniques[11,24,25]. Additionally, the stiffness of breast masses varies depending on the time of the menstrual cycle and may have affected SWE measurements.

As a result, there is a high correlation between ADC and SWE values in the differential diagnosis of breast lesions. There is a statistically significant correlation between SWE values, which measure the stiffness of the examined tissue, and ADC values, which is in parallel with increased cellularity. This result shows that SWE can be used instead of ADC mapping in the evaluation of breast lesions. We think that these results can be supported by multicenter studies with a large patient population.

Ethics Committee Approval: This is a retrospective study and approval was received from the relevant ethics committee (Ethics committee approval number: 2019/10/41).

Peer-review: Externally peer-reviewed.

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Conflict of Interest: None declared.

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