



Magnetic resonance imaging and shear wave elastography comparison in the evaluation of breast lesions

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Abstract

This study aims to compare the Magnetic Resonance Imaging (MRI) and Shear Wave Elastography (SWE) data and investigate their contribution to diagnosis when both are individually used and combined. This study included the consent of 46 diagnostic biopsy patients after their breast MRI examination was performed. Mass appearance patients in the sonographic evaluation were SWE examined before the biopsy. In MR examination, lesion localization, size, contrast curves, contrast enhancement features, intensity in the fat-suppressed T2A sequence, Emean value in SWE examination, and histopathological results were examined. Individual and combined use of MRI and SWE findings were evaluated with histopathological results. The diagnosis consistency was compared according to the histopathological results of the malignant-benign defined lesions. Higher sensitivity in MRI; higher specificity and accuracy in SWE were acquired when both methods were compared. The accuracy of MRI improved when MRI use is combined with SWE. The combined use of SWE with MRI increases the diagnostic accuracy in breast lesion characterization. We observed that lesions showing a type 3 enhancement curve and iso-hypointense on the T2W sequence in breast MRI could be predicted to show a stiff elasticity pattern on SWE due to higher elastography values.

Keywords: Breast lesions, magnetic resonance imaging, shear wave elastography

Introduction

Magnetic Resonance Imaging (MRI) is a high-sensitivity imaging method that has some limitations for breast imaging to differentiate benign and malignant lesions correctly. Breast MRI sensitivity is as high as 90-95% for breast malignant lesions detection; however, its specificity varies between 37 to 97% [1,2]. Thus, breast MRI is mostly used with auxiliary imaging methods such as mammography and ultrasonography (US).

Information about both dynamic (enhancement pattern, enhancement type) and morphological features (mass shape, edge features, size) can be obtained with breast MRI. In the dynamic evaluation of breast lesions, the enhancement and pattern help in the lesion characterization [3,4]. The lesions are classified according to the BIRADS (Breast Imaging-Reporting and Data System) atlas in breast MRI [5].

Breast elastography is a new technique that contributes to mammography and the US in the characterization of breast lesions. This technique gives information about the lesion tension (elasticity) and stiffness, just like in clinical palpation. Clinical studies reveal that elastography is a useful technique in differentiating benign-malignant breast lesions. There are two methods in the clinical use of elastography, strain, and shear wave elastography [6,7]. The disadvantage of Strain Elastography (SE) is being user-dependent. In SE, the practitioner gently applies compression with the SE probe, and information about tissue stiffness is provided by calculating the displacement in the tissue after compression. Due to the lack of probe standard in terms of applied pressure by a practitioner, there might be wide variations between image and elasticity values. As a result, the variation within the individual's findings and interpersonal variability can be high [8]. In shear wave elastography (SWE), a short duration (0.03-0.4 ms), high power (frequency 2.67 MHz) acoustic repulsive radiation force is applied to the tissue with a US probe instead of an external compression; thus, user-dependent variations are eliminated. In this way, more objective elasticity values are obtained. In SWE studies, it was concluded that SWE is an effective imaging method that contributes to the differentiation of benign and malignant

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lesions and complements other methods [9,10,11].

In this study, we aim to compare both MRI and SWE data and investigate the contribution of these imaging techniques to diagnosis when they are combined or individually used. In this way, we aim to understand the main contribution of SWE in combinatory use with MRI in the differentiation of benign and malignant breast masses. Therefore, false positive MRI findings and excessive biopsy rates would be reduced in combinatory use of SWE and MRI.

Materials and Methods

This prospective study was approved by the Firat University Non-Interventional Research Ethics Committee (20.12.2018-21-21). In this study, we performed a prospective SWE examination before percutaneous biopsy in 46 patients who were requested clinical and radiological diagnostic biopsy after breast MRI in our clinic. Written informed consent forms were obtained from each patient included in the study. Lesions that could not be clearly seen or deeply located (over 4cm) were excluded from the US examinations' evaluation. Besides, patients who had undergone previous surgical or interventional procedures in their breasts with lesions and had other known systemic diseases and those whose breast MRI images were of insufficient quality were excluded from the study.

Ultrasonography Evaluation

In our clinic, the US examination was performed with a digital US device which included SWE software (GE Logiq S8 XDclear 2.0, Korea), in the supine position. SWE examination was performed after the B-Mode US examination using a 9-12 MHz linear probe. Manual compression was not used as SWE since it is a dynamic sonoelastography technique. Patients were asked to hold their breath to keep the image stable during the examination. The lesion was centralized, and the field of view (FOV), which included the lesion and the adjacent breast tissue at the same depth, was determined, and the stiffness was shown as a color scale within this area.

B-mode image corresponding to the lesion was also shown to see the borders of the lesion. The ROI cursor was placed on the hardest part of the lesion in the FOV according to the color scale, and SW velocity was measured. Most of the lesions were measured with a single ROI after seeing that there was no significant difference in the comparison of ROI measurements taken at least three times and a single ROI. The same procedures were repeated at least three times, and their highest values were included in the study. The SWE velocity of the lesions was converted into Emean kiloPascals (kPa) and recorded. Acquired images and measurements were digitally recorded (Figure 1 and Figure 2 a,b).

Magnetic Resonance Imaging

Breast imaging was performed using a 7-channel breast coil with a 1.5 Tesla magnetic resonance device (GE 1.5T EXCITE TO 16 CH) in our hospital. The patients were placed in the prone position with their breasts inside the coils. Simultaneous bilateral breast imaging was performed. After localizer and calibration images were taken in axial, coronal, and sagittal planes, T2 IDEAL, 3D T1 VIBRANT, fat-suppressed T2, DWI ALL 35-400-800 axial images were taken. After fat-suppressed 3D T1 weighted VIBRANT sequence images are acquired, contrast agents containing gadoteric acid or

gadobutrol were administered through the antecubital vein at a dose of 0.2 mmol/kg with an automatic injector at a rate of 2ml/s, followed by a 20ml saline solution injected. Immediately after saline injection, dynamic postcontrast images were obtained by using all parameters of pre-contrast T1-weighted images exactly. The lesions' dynamic contrast curves were created by transferring the images to the workstation in our department via digital media (Figure 1 and Figure 2 c-f).

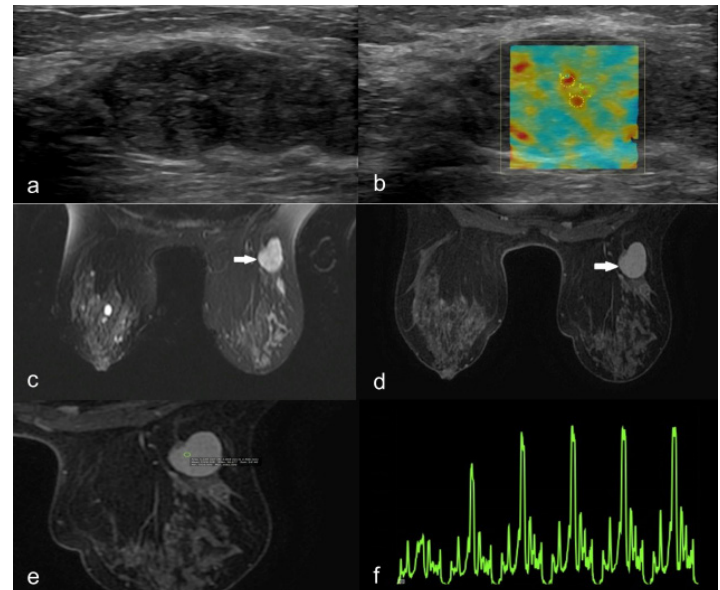


Figure 1. 41-year-old female patient: (a) ultrasonography B-mode image; (b) stiff elasticity pattern in the SWE (Emean: 78.53 kPa); (c) hyperintense lesion in the axial fat-suppressed T2W sequence; (d) homogeneous contrast enhancement in the axial contrast-enhanced T1W sequence; (e,f) ROI application in axial contrast-enhanced T1W sequence and type 2 enhancement curve in time-signal intensity curve. The histopathologic diagnosis is fibroadenoma

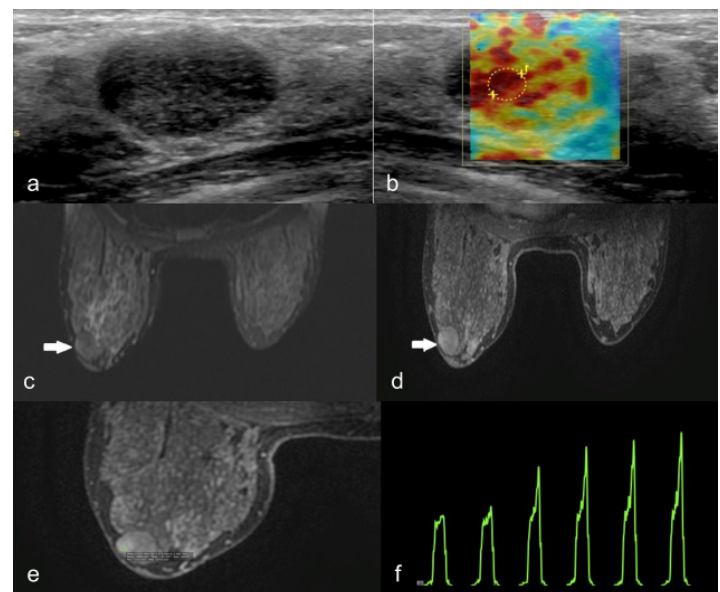


Figure 2. 20-year-old female patient: (a) ultrasonography B-mode image; (b) Stiff elasticity pattern in the SWE (Emean: 89.17 kPa); (c) Iso-hypointense lesion in the axial fat-suppressed T2W sequence; (d) Heterogeneous contrast enhancement in the axial contrast-enhanced T1W sequence; (e,f) ROI application in axial contrast-enhanced T1W sequence and type 1 enhancement curve in time-signal intensity curve. The histopathologic diagnosis is intraductal papilloma

Radiological Image Evaluation

Breast MRI was evaluated by a radiologist experienced in breast

radiology, and elastography was performed by a radiologist with 3 years of experience in the field. The clinical trial was performed as double-blind; neither the radiologists for MRI nor the radiologist for elastography examination were influenced by each other until the clinical trial is over.

Breast MRI findings were evaluated based on the fifth version of the ACR BI-RADS 2013 data dictionary [12]. According to the BI-RADS classification, malignancy probability evaluation was classified into five subgroups: 1-negative findings, 2-benign, 3-possibly benign, but need for follow-up, 4-potentially malignant, and 5-malignant tumor. In general, tumors classified as BI-RADS 3 were considered benign, and tumors classified as 4 and 5 were considered malignant tumors. BI-RADS 3 refers to tumors that are 98% benign, but still, need to be followed up, and the classification of these tumors as benign did not affect the study. BIRADS 1,2,3 is considered a benign group, and BIRADS 4,5, as a malign group.

The location of the lesions was defined according to the quadrants in the right or left breast. The enhancement kinetic curve assessment in the BI-RADS data dictionary was obtained as time-signal intensity curves in dynamic contrast-enhanced sequences. These kinetic curves show the signal intensity changes of contrast enhancement over time in the tissue, and to obtain these curves, ROIs of 5mm² were placed in the most contrast-enhancing lesion parts. Three high-contrast enhanced measurements were taken from different areas of the tumor, and the ROI showing the highest enhancement among these measurements was selected for further analysis.

After the post-contrast early phase, the kinetic curve types of the lesions in the late phase were defined as persistent (Type 1), plateau (Type 2), or wash-out (Type 3). The persistent curve was defined as the progressive increase in enhancement over time, and the plateau curve was defined as the curve that remained constant at the maximum signal intensity level after contrast agent injection. The wash-out curve was determined as the curve with decreasing signal intensity after the maximum signal intensity level. The enhancement pattern found in the BI-RADS data dictionary was categorized as homogeneous, heterogeneous, circular, and non-enhancing internal septa in contrast-enhanced images. The comparative appearances of the lesions, which are not included in the BI-RADS data dictionary, were evaluated according to the pectoralis major muscle in the fat-suppressed T2W sequence in subgroups hyperintense, iso-hypointense, and heterogeneous.

Lesions, according to Emean values measured in SWE evaluated based on the referenced data from Bayat et al. [11] on the same brand and similar version US device. Lesions with 30.18±27.81 kPa values were benign, and 90.66±35 lesions with a value of 55 kPa were considered malignant. Later, the lesions were biopsied.

When MRI and SWE were evaluated together the lesion was considered malignant (i) if BIRADS 5 in MRI (independent from SWE results), (ii) BIRADS 4 in MRI and hard elasticity in SWE, and (iii) BIRADS 3 in MRI and hard elasticity in SWE. Also, the lesion was considered benign, if BIRADS 3 or 4 in MRI and soft elasticity in SWE.

Histopathological examinations of the lesions were performed by experienced pathologists. Lesions were divided into two groups benign and malignant according to their histopathological

diagnosis.

Statistical analysis

IBM SPSS Statistics v25.0 was used for statistical data analysis. Categorical measurements were expressed as numbers and percentages, and numerical measurements were given as mean ± standard deviation for normally distributed data and median, interquartile range (25-75) percentile values for non-normally distributed data. Chi-square and Fisher Exact test statistics were used for the comparison of categorical measurements between groups. The distribution normality was evaluated with the Kolmogorov-Smirnov test and, according to the test results, the Independent T and the Mann-Whitney U tests were used in the comparisons of the two groups. One-way analysis of variance was used to compare normally distributed numerical measurements of three groups and above, and the Tukey test was used to determine the difference between groups. Receiver Operating Characteristic (ROC) curves were plotted to measure the diagnostic value of pathology results and MRI when used alone or together. The result of p<0.05 was considered statistically significant in all analyzes.

Results

All patients were women, and ages ranged from 19 to 69 (mean 45.6±1.9). The sizes of the lesions ranged from 8 mm to 54mm (mean 18.3±1.4). Among 46 patients, the lesions observed in 21 (46%) were located in the right breast, and 25 (54%) were located in the left breast. Lesions were most frequently in the upper outer quadrant (24 lesions, 52%) and least frequently in the lower inner quadrant (5 lesions, 11%).

Histopathologically, the lesions were evaluated as benign 32 (70%) and as malignant 14 (30%) (Table 1). The percentage distribution of benign and malignant lesions is shown in Figure 3.

Table 1. According to MRI, SWE, MRI-SWE evaluations, and histopathological results, the classification of lesions are benign and malign

	MRI	SWE	MRI-SWE	Histopathological results
Benign	11(24%)	23(50%)	22(48%)	32(70%)
Malign	35(76%)	23(50%)	24(52%)	14(30%)

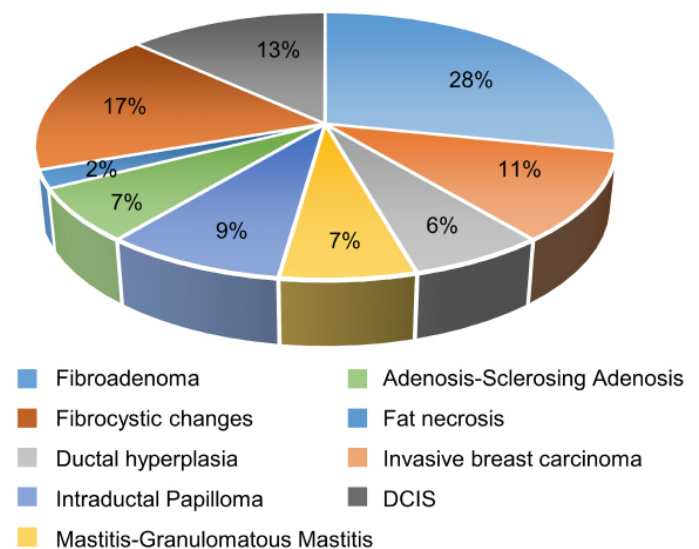


Figure 3. Percentage representation of the histopathological diagnosis distribution

Based on the MRI results, 11 (24%) of the lesions were evaluated as benign and 35 (76%) as malign according to BIRADS classification (Table 1). The number of 11 lesions as BIRADS 3, 30 lesions were BIRADS 4, and 5 lesions were BIRADS 5. The kinetic contrast enhancement curve was type 1 (persistent) in 25 (54%) of 46 cases, type 2 (plateau) in 14 (30%), type 3 (wash-out) in 7 (15%). Thirty-six (78%) of the lesions were heterogeneous, 5 (11%) were homogeneous, 2 (4%) were annular enhancement, and 3 (7%) had non-enhancing internal septation. Lesions were seen as 28 (61%) heterogeneous, 10 (22%) iso-hypointense, and 8 (17%) hyperintense in the T2W sequence.

Ultrasound elastography Emean values varied between 12.43 kPa and 169.60 kPa. According to these values, 23 (50%) of the lesions were evaluated as benign and 23 (50%) as malign in the light of the data obtained from the study conducted by Bayat et al. (15) on a similar US device (Table 1).

In the evaluation performed together with MRI and ultrasound SWE, 22 (48%) lesions were evaluated as benign and 24 (52%) lesions were as malignant (Table 1).

Histopathologically, it was observed that the probability of malignancy increased as the lesion size increased, although it was not statistically significant ($p=0.051$).

It is seen in Figure 4 that as the size of the lesion increased, the elastography value increased. The relationship between elastography Emean value and lesion size was examined, and a positive correlation was found ($R=0.49$, $p<0.001$). In addition, when the relationship between age and elastography Emean value was investigated, a weak positive correlation was found, but it was not statistically significant. When the relationship between age and size was examined, it was found that there was a negative correlation, but it was not statistically significant.

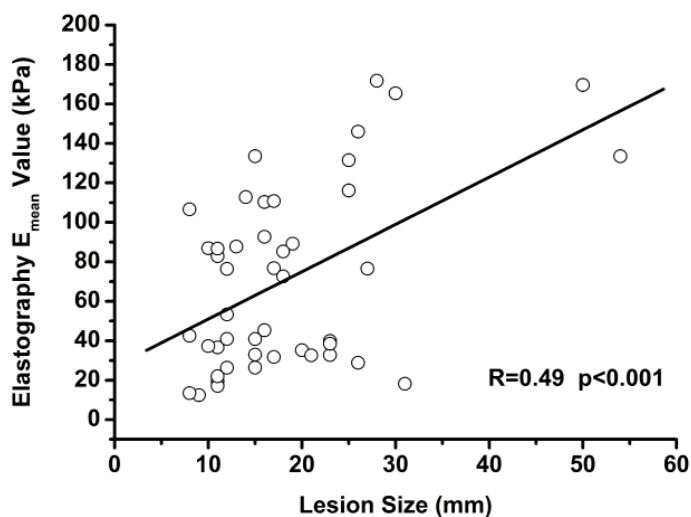


Figure 4. The comparison of lesion sizes and elastography Emean values

The elastography values were found statistically significantly higher in malignant cases when the mean SWE value of the lesions was evaluated as benign and malignant according to the BIRADS classification in MRI. ($p<0.05$, Figure 5). In this evaluation, the mean Emean value of benign lesions was 39.90 kPa, and malignant lesions were 80.49 kPa.

A statistically significant positive correlation was observed in the comparison of elastography Emean values, and lesions diagnosed histopathologically in benign and malignant categories ($p<0.05$, Figure 6) Emean value was found to be 31.51 kPa for benign lesions and 110.06 kPa for malignant lesions.

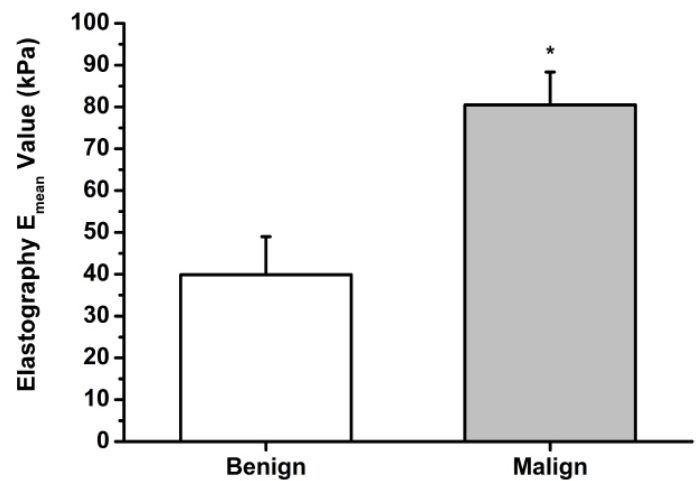


Figure 5. The evaluation of patients with MRI distinguishing between benign and malignant according to elastography Emean values (* $p<0.05$)

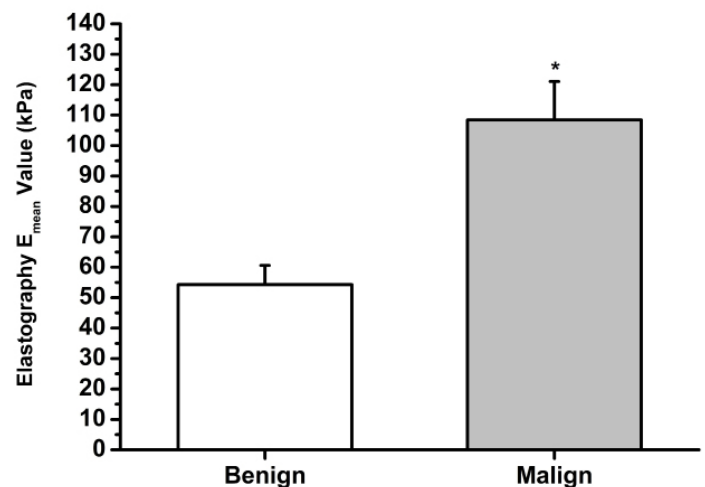


Figure 6. The comparison of elastography Emean values and lesions diagnosed histopathologically in benign and malignant categories (* $p<0.05$)

The average Emean value of those with type 3 enhancement curves was higher than those with type 1 when the enhancement curve types in MRI were compared with the elastography value. This difference was statistically significant ($p<0.05$). Although there was no statistically significant difference in other comparisons within the other groups, it was observed that those with type 3 contrast enhancement curves were higher than those with type 2 enhancement curves, and those with type 2 enhancement curves had higher Emean values than those with type 1 enhancement curves (Table 2).

It was found that those with heterogeneous and annular enhancement showed higher elastography values than those with homogeneous and non-enhancing internal septation when contrast enhancement type and elastography values were compared in MRI (Table 3).

malignant MRI results show high elastography values and subgroup types with mostly benign results show low elastography values. Such findings were observed for the first time in the literature to the best of our knowledge. In our breast MRI findings, when contrast enhancement curve types and SWE elastography values were compared, it was determined that the average elastography Emean value was statistically significantly higher for those with type 3 enhancement curves compared to those with type 1 enhancement curves. The average elastography Emean value of those with type 3 contrast enhancement curves was higher than those with type 2 contrast enhancement curves, and those with type 2 enhancement curves also had a higher average elastography Emean value compared to those with type 1 contrast enhancement curves. It was determined that when breast MRI contrast enhancement type and elastography values were compared, those showing heterogeneous and annular enhancement showed higher elastography values compared to those with homogeneous and non-enhancing internal septation. The mean value of iso-hypointense cases was higher than hyperintense cases when the intensity of the lesions in the T2W sequence and elastography values were compared in MRI. It was observed that those with heterogeneous intensity were higher than hyperintense cases, and iso-hypointense cases were higher than those with heterogeneous intensity.

In the US elastography and MRI study of fibrotic changes in the breast by Matsubayashi et al. [22]; it was observed that there was a decrease in signal intensity in lesions with fibrous changes compared to the pectoralis major muscle in the T2W sequence, and an increase in the elasticity score in SE, due to fibrous changes in malignant lesions compared to benign lesions. Our study similarly observed that the Emean value in SWE was higher in iso-hypointense cases compared to hyperintense cases in the fat-suppressed T2W sequence.

The number of patients was relatively small in our study compared to the literature. The main reason for the low number of patients was the difficulty in accepting additional examinations for study purposes from the patients who decided to have a biopsy. Also, not all malignant and benign lesions could be represented histopathologically. Therefore, multicenter prospective studies are necessarily required to overcome these limitations.

Conclusion

In conclusion, SWE and MRI are two effective imaging methods to be used in the evaluation of breast lesions. However, breast MRI causes false-positive results, and therefore, there is an inevitable need for biopsy. The use of SWE together with MRI increases diagnostic consistency and may reduce the number of unnecessary biopsies. In suspicious cases with the biopsy decision made with MRI, if the SWE value shows a soft character, can be categorized as BIRADS 3 and followed up at short intervals instead of biopsy. The results of our study are useful for the combined use of SWE and MRI in clinical practice. We also predicted that those with type3 enhancement curves and iso-hypointense in T2W sequence in breast MRI would show a stiff elasticity pattern in SWE. However, more studies are required to confirm this prediction..

Conflict of interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical approval

Ethics committee approval received from the Institutional Ethics Committee of University (20.12.2018-21-21).

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