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Research Article

Shear Wave Elastography Characterization of Breast Lumps by using Quantitative and Qualitative Definition a Learning Curve

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Abstract

Objective: The study aimed to describe shear wave elastographic characteristics differentiating benign and malignant breast lumps and to establish a combined scoring system to make a diagnosis.

Material & methods: All patients over 15 years of age presented with breast lumps were included. Shear wave elastography was done by using Aixpslorer Ultrasound System Multiwave version 8.2.0 (Supersonic Imagine S.A. Aix-en-Provence, France) with Superlinear TM (SL15-4* 50 mm Super Linear Array) probe. Qualitative assessment was done on color code (ie blue, yellow, orange, red and dark red) and presence of signal void dark area. Quantitative assessment was taken in Kilopascals (KPA), where KPA mean was taken from the darkest area. All patients underwent biopsy to confirm histopathology. Each parameter was individually correlated with histopathological diagnosis; broadly categorized into benign and malignant lesions. Finally the parameters were combined to see if combination further improves diagnostic accuracy.

Results: A total of 109 patients with breast lumps were included. The dark red color code, presence of signal void area and the mean KPA >250 were independent predictors of malignant histopathology. The benign lesions showed low mean KPA and blue color code without any signal void area with exception of breast abscess. Combine score system has potential to accurately define nature of breast lumps, where score 1 defines benign and 3 defines malignant lesions, while in score 2 a great majority was malignant but a few benign lesions also fall into this category.

Conclusion: Breast lumps undergoing shear wave elastography if scored 1 having blue to orange color code, KPA <200 and no signal void area can be safely avoided biopsy. However those scored 2 and 3 need to have histopathological diagnosis.

Introduction

Breast pain and lump are the most common complaints seen in the general practice as well as at specialist breast centers [1]. A great majority of patients come with the complaint of breast lumps. Ultrasound and mammograms are the basic breast related investigations, followed by Fine Needle Aspiration Cytology (FNAC) or tissue biopsy [2,3]. Among the patients present with breast lumps only 5-10% come up with the diagnosis of cancer, the rest have negative biopsies (ie benign lesions) [4,5]. Those patients undergoing screening mammograms have recalls and biopsies for findings which then prove as benign. These negative biopsies account for patients stress and also economic burden on the system and patients [6].

Shear Wave Elastography (SWE) is a relatively new emerging technique being investigated for its utilization in characterizing the nature of the lesions by measuring tissue stiffness [7]. Assessment of the tissue architecture and the stiffness is one of the oldest modes of diagnosis in medical science, given the reason that the pathological manifestations alter both. This analysis is based on the concept that the cancers tend to be harder as compared to benign lesions. It used to be done manually during clinical examination, however recently the advancements in the conventional ultrasound system have added a tool which has potential to assess tissue stiffness and presenting its results in qualitative as well as in quantitative measurements. For quantitative assessment the results are presented in Kilopascals (KPA) with its mean, maximum, minimum and standard deviation, by measuring the velocity of shear wave propagation in the lesion [8]. The qualitative assessment is presented in the color scale ranging from blue, yellow, orange, red to dark red where blue suggests soft tissue elasticity (ie normal or benign) to dark red suggestive of stiff lesion (ie malignancy) [9]. Standing alone the qualitative and quantitative measurements have lacking of definite cut-offs to firmly define the nature of the lesion.

There are studies available suggesting the role of shear wave elastography in characterizing the lesions of breast [10], liver [11], thyroid [12] etc. All these studies suggest higher sensitivity and specificity of ultrasound system when it is complemented with shear wave. B-mode ultrasound has its scoring system in terms of Breast Imaging Reporting and Data System (BI-RADS) to define the nature of the lesion [13,14]. However till date shear wave has been used to complement BI-RADS but there is no strong evidence to define characteristics of the benign and malignant lesions on elastography.

Some studies suggest color code others have given numerical cut-offs but there is lot of overlap and numerical readings were set low to define malignancy resulting in benign lesions again fall into the category of suspicious [9,15,16].

This study therefore aimed to understand shear wave elastographic description of the lesions without taking mammogram findings into account and B-mode ultrasound findings. Although B-mode ultrasound was used as the basic identification tool for the presence of the lump and a guide for application of shear wave. In this study we used color code, presence of punched out lesion (dark area-with no shear wave signals/signal void area) and the quantitative measurements (ie mean KPA) and correlated with the histopathological diagnosis. We also attempted to establish a combine score system to increase diagnostic yield.

Methodology

Patients

This study included all female patients' ≥15 years of age coming to the department of surgery with a breast lump and planned to have tru-cut or excisional biopsy. The study was conducted during a period from March 2014 to March 2016. Patients with known diagnosis of cancer were excluded. In patients having more than one lesion the lesion from which biopsy was taken was considered. All patients were scanned and biopsied by the same team of elastography and the surgery department. Histopathology was done by the same team of pathologists. All patients were informed of the scan and consent was taken.

Elastographic methods and parameters

Shear wave elastography was performed by using SuperSonic Imagine, Aix-en-Provence, France (v8.20) with a linear-array probe (maximum frequency=12-14MHz). The site of the lesion was recorded as provided in Figure (1a). At each area of the lesion the probe was placed still for at least 10 seconds to allow supersonic to produce and display the image. At least five images were taken from each lesion. For these 10 seconds patients were asked to hold their breath.

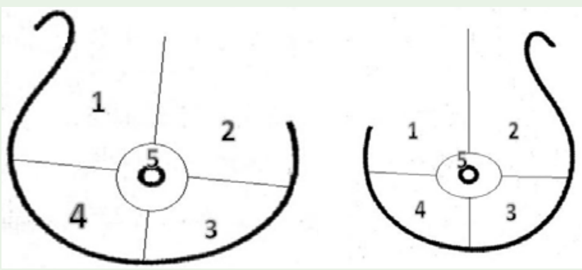

Figure 1a: Breast diagram used for recording the site of the lump on shearwave elastography.

Figure1b: default setting of qualitative and quantitative assessment of breast lumps on SuperSonic Imagine, Aix-en-Provence, France (v8.20) with a linear-array probe (maximum frequency=12-14MHz).

Based on the available literature mean of the stiffness showed the highest accuracy among all the features including mean, maximum, minimum and standard deviation, therefore mean of the ORI was taken as the final reading of the lesion [17]. The lesions were measured at different sites, only mean KPA of the lesion from the area of maximum stiffness was recorded (Figure 1b). The default maximum display setting was 180 KPA. The qualitative assessment was done by the color code. The homogenous blue was considered one color; however in tumors with heterogeneous pattern the darkest color was noted. In addition, presence of the signal void area was noted (Figure 1c).

Statistical methods

Data was recorded in Statistical Package for Social Sciences (SPSS version 18.0, Chicago, Illinois, USA). The quantitative data was recorded as continuous variable, while color code and presence of signal void area as categorical variables. The histopathological

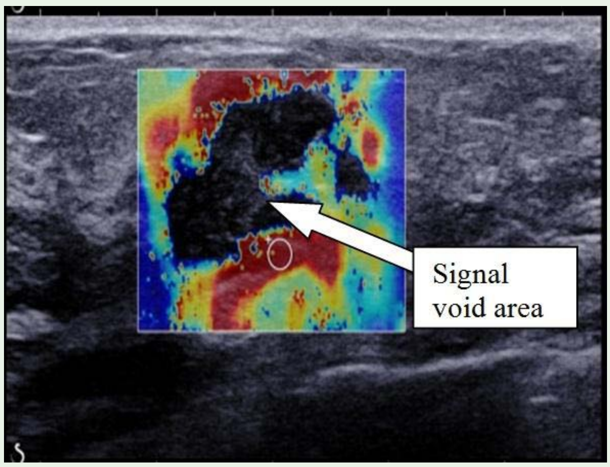

Figure 1c: presence of signal void area within a breast tumour on shear wave elastography using Super Sonic Imagine, Aix-en-Provence, France (v8.20) with a linear-array probe (maximum frequency=12-14MHz).

Table 1: Summary of the quantitative and qualitative parameters of the breast lumps on shear wave elastpgraphy.

Quantitative measurements of breast lesions in correlation with histopathological diagnosis					
Histopathological diagnosis (N)	**Minimum mean KPA**		**Maximum Mean KPA**		**Median KPA**
Fibroadnoma (37)	26.30		151.40		63.0
Fibrocystic disease (35)	28.30		248.30		127.0
Abscess (5)	70.70		155.30		155.0
Carcinoma breast (32)	203.0		300.0		260.0
Quantitative characteristics of breast lesions in correlation with histopathological diagnosis					
Histopathological diagnosis (N)	**Blue (N=37)**	**Yellow/green (N=26)**	**Orange (N=12)**	**Red (N=5)**	**Dark red (N=29)**
Fibroadnoma (37)	33	4	0	0	0
Fibrocystic disease (35)	2	17	12	2	0
Abscess (5)	0	5	0	0	0
Carcinoma breast (32)	0	0	0	3	29
Pattern of presence of signal void area within the lesion in correlation with histopathology					
Histopathological diagnosis (N)	**Signal void area present**			**Signal void area abscent**	
Fibroadnoma (37)	0			37	
Fibrocystic disease (35)	0			35	
Abscess (5)	5			0	
Carcinoma breast (32)	27			5	

diagnosis was correlated with the mean KPA, color code and the presence of signal void area. Chi-square test was applied for categorical variables. Logistic regression analysis was carried out to see the independent predictors of the diagnosis. A p-value <0.05 was considered significant.

Results

A total of 109 patients were included with breast lumps, there were four types of pathological diagnosis came up including benign lesion ie fibroadenoma, fibrocystic disease (including simple cysts), abscess and carcinoma breast. Median age of study patients was 40 years (range 15-78), 64.2% (N=70) were ≤45 years and 35.8% (N=39) were >45 years of age. Median size of the masses on grey scale was 1.3 cm (range 0.9-8.2 cm). There was no significant correlation between the size of the mass with the age of the patients (p>0.05).

Quantitative characteristics of benign and malignant lesions

Fibroadenomas show low readings in KPA, while malignant lesions show highest reading. Fibrocystic lesions and the abscess show relatively high readings, however lower than the malignant lesions. A summary of the readings is presented in Table 1 and Figure 2.

Qualitative characteristics of the benign and malignant lesions

Color code: Dark red color was significantly associated with malignant histopathology, none of the benign lesions adopted dark red color on elastography, however two cases of fibrocystic disease show red color on elastography (p<0.001). All benign lesions range from blue to orange color. Benign lesions showed more or less homogenous pattern with exception of fibrocystic disease in peri-menopausal women where there was relatively more heterogeneous pattern (Table 1).

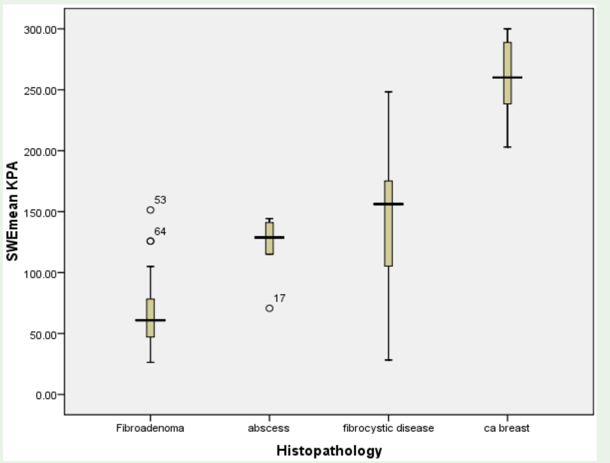

Figure 2: Box plot presents the pattern of quantitative measurements of breast lesion in correlation with the histopathological diagnosis by using SuperSonic Imagine, Aix-en-Provence, France (v8.20) with a linear-array probe (maximum frequency=12-14MHz).

Signal void area within the lesion

Presence of signal void area within the lesion was highly significantly associated with the malignant histopathology (p<0.001). A summary is given in Table 1.

Combined score system for shear wave elastography interpretation

Logistic regression analysis suggests that all the variables including dark red color code, signal void area and the mean KPA >250 are independent predictors of malignant histopathology. For combined analysis the patients were grouped into three categories

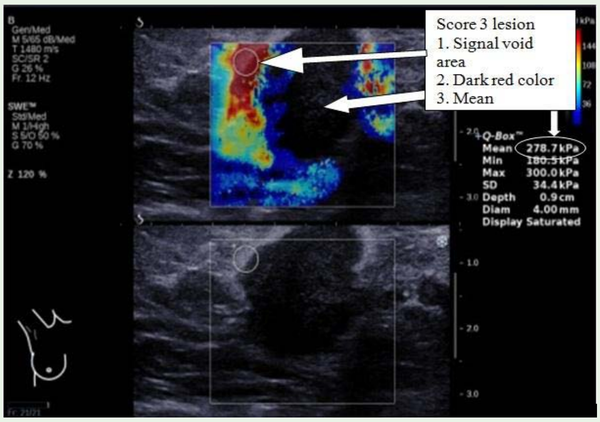

Figure 3a: Infiltrating ductal carcinoma in right breast, score 3 on shear wave elastography.

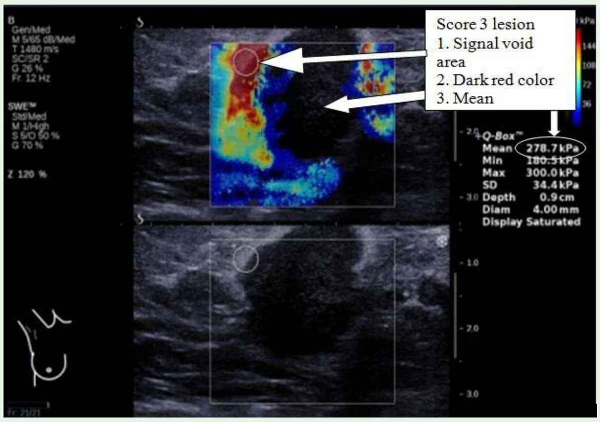

Figure 3b: Breast abscess in right breast, score 1 on shear wave elastography.

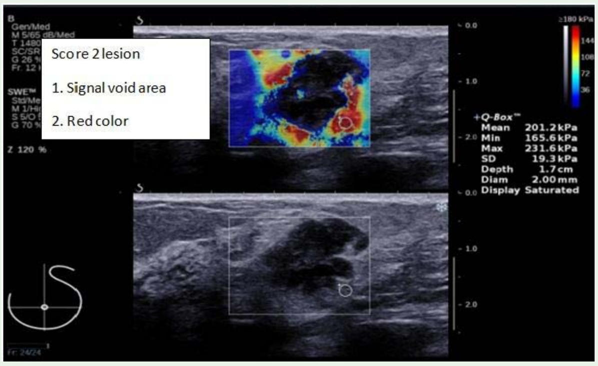

Figure 3c: Infiltrating ductal carcinoma in right breast, score 2 on shearwave elastography.

based on their characteristics on quantitative and qualitative findings (Table 2). Based on the scoring system our results showed that score 1 were all benign lesions, within score 2 a great majority were malignant a few were benign and all score 3 were malignant (Table 3). Shear wave elastography images of the breast lesions are given in Figure 3.

Table 2: Breast Shear wave Elastography Scoring system.

Category	1	2	3
Color code	Blue, yellow, orange	Red, Dark red	Dark red
Mean KPA range	<200	>200	>250
Punched out lesion status	Absent (breast abscess is an exception)	Present	May be present
Interpretation	Benign	Most likely malignant	Highly suspicious of malignancy

Table 3: Breast Shear wave Elastography Scoring system based pattern of diagnosis.

Score category	Histopathology			
	Fibroadenoma	Fibrocystic disease	Abscess	Carcinoma breast
1	100% (37)	94.3(33)	100(5)	0
2	0	5.7 (2)	0	31.2(10)
3	0	0	0	68.8(22)

Discussion

Shear wave elastography findings have potential to characterize the nature of breast lesions. However, grouped categories in the form of scale show high accuracy to differentiate benign from malignant lesions.

Elastography is a technique to measure elasticity of the tissue, where pathological processes tend to alter tissue architecture resulting in change in stiffness. Malignant lesions tend to be harder as compared to surrounding normal tissues. The tissue mapping system used by elastography helps in making a diagnosis. This technique is currently in use to assess liver fibrosis in cases of chronic liver disease [11,18], where it has largely replaced biopsy. This technique has remarkable acceptance on the part of patients due to noninvasive nature. For breast, shear wave elastography was introduced at some point in last decade. A number of studies were conducted to analyse the role of shear wave elastography in the diagnosis of breast masses. The studies showed that the elastography is highly reproducible mode of investigation [19]. A large multicenter trial "BE1" including 939 breast lumps showed that addition of shear wave elastography significantly improved diagnostic accuracy of ultrasound [20]. The study also showed that shear wave was superior to ultrasound in assessing BI-RADs category 3 and 4.

By default setting shear wave elastography gives qualitative and quantitative details of the lesion by measuring speed of propagation of the shear waves through the tissue. There is a define range of colors and the default numbers to give a clue and supplement BI-RADs system. However in our study we did not considered BI-RADs system and grey scale B-mode ultrasound was only used to locate and measure the size of the lesion. This was done in order to provide evidence for the utilization of the shear wave technology as a mode of investigation in breast lumps. The quantitative readings were much higher in malignant lesion than the default setting, where 180 are perceived as the cut-off. In our study some of the benign lesions especially those with fibrocystic histopathology showed much higher mean KPA. Previously reported retrospective study showed that using cut-off value of 50 KPA 8% of lesions fell into the category of suspicious lesions which were labeled as benign on conventional radiology [21]. The study suggested sensitivity of shear wave in diagnosing lobular carcinomas superior to other modalities [21]. The study used a cut-off of 50 which is much lower than the default reading that probably has given a chance to lobular carcinoma to fall under the category of the suspicious lesion. The interesting finding we observed was the high elasticity of the peri-tumoral tissue. In our study most of the malignant lesions showed signal void area in the tumour while the surround area was very stiff. This finding was also reported in previous studies [22]. Lee et al reported signal void area in 43% of cancers in their study [23] while in our data 83% (N=27 out of 32 showed signal void area. The abscesses also showed signal void area. The signal void area in the malignant lesion was produced by very stiff central tissue while in the abscess it was the cavity. The difference between the pattern of the signal void area of cancer and abscess was the color scheme and the quantitative measurement of the surrounding area. The abscesses showed color ranging from blue to orange while the malignant lesions showed red and dark red surrounding area.

The color scheme to differentiate benign and malignant breast lesions has been studied previously [24-26]. In our study we used default color scheme where blue was benign and red was malignant. Our results are comparable in defining malignant lesions based on the color. However some of the fibrocystic lesions present with red color and their quantitative reading was higher. There is limited literature available to comment on shear wave elastographic features of fibrocystic disease.

Combination of the parameters always shows superiority than the single parameter. Therefore we attempted to combine all the independent parameters to accurately make a note of diagnosis. This type of scoring system for shear wave has not been reported before. This system has shown high accuracy in making a diagnosis of benign lesions and malignant lesions by categorizing them in score and 1 and 3. However there was a little overlap of some fibrocystic disease in score 2. Although majority of score 2 lesions were malignant. Based on these results we can safely avoid biopsy in score 1 cases.

We are aware of the limitation of small sample size in the study, so we consider this as a pilot study for construction of the score system; our unit is on way to prospectively validate this system.

Conclusion

Shear wave elastography appears highly reliable mode of imaging in breast lesion. Individual parameters including quantitative measurement and qualitative characteristics including color scheme and the presence of signal void area show significant correlation with the histopathological diagnosis. The combine score has potential to clearly differentiate benign from malignant lesions. Where score 1 labeled lesions can be safely spared from biopsy. Further prospective validation studies are required to confirm the results.

References

1. Olawaiye A, Alexander O, Matthew WL, George D, Kenneth K. Mastalgia: a review of management. J Reprod Med. 2005; 50: 933-939.
2. Lister D, Evans AJ, Burrell HC, Blamey RW, Wilson AR, Pinder SE, et al. The accuracy of breast ultrasound in the evaluation of clinically benign discrete, symptomatic breast lumps. Clin Radiol. 1998; 53: 490-492.
3. Ahmed I, Nazir R, Chaudhary MY, Kundi S. Triple assessment of breast lump. J Coll Physicians Surg Pak. 2007; 17: 535-538.
4. Khatun H, Enam S, Hussain M, Begum M. Correlation of fine needle aspiration cytology and its histopathology in diagnosis of breast lumps. Bangladesh Med Res Counc Bull. 2002; 28: 77-81.
5. Tiwari M. Role of fine needle aspiration cytology in diagnosis of breast lumps. Kathmandu Univ Med J (KUMJ). 2007; 5: 215-217.
6. Ando N, Iwamitsu Y, Kuranami M, Okazaki S, Wada M, Yamamoto K, et al. Psychological characteristics and subjective symptoms as determinants of psychological distress in patients prior to breast cancer diagnosis. Support Care Cancer. 2009; 17: 1361-1370.
7. Shiina T, Nightingale KR, Palmeri ML, Hall TJ, Bamber JC, Barr RG, et al. WFUMB guidelines and recommendations for clinical use of ultrasound elastography: Part 1: basic principles and terminology. Ultrasound Med Biol. 2015; 41: 1126-1147.
8. Chang JM, Won JK, Lee KB, Park IA, Yi A, Moon WK. Comparison of shear-wave and strain ultrasound elastography in the differentiation of benign and malignant breast lesions. AJR Am J Roentgenol. 2013; 201: 347-356.
9. Barr RG, Nakashima K, Amy D, Cosgrove D, Farrokh A, Schafer F, et al. WFUMB guidelines and recommendations for clinical use of ultrasound elastography: Part 2: breast. Ultrasound Med Biol. 2015; 41: 1148-1160.
10. Klotz T, Boussiona V, Kwiatkowskib F, Dieu-de Fraissinettea V, Bailly-Glatrea A, Lemery S, et al. Shear wave elastography contribution in ultrasound diagnosis management of breast lesions. Diagn Interv Imaging. 2014; 95: 813-824.
11. Li N, Luo YK, Tang WB. Roles of acoustic radiation force impulse and two-dimensional shearwave elastography in grading liver fibrosis in rabbits. Acta Academiae Med S. 2015; 37: 157-162.
12. Kim I, Eun-Kyung K, Jung HY, Kyung HH, Eun JS, Hee JM, et al. Diagnostic role of conventional ultrasonography and shearwave elastography in asymptomatic patients with diffuse thyroid disease: initial experience with 57 patients. Yonsei Med J. 2014; 55: 247-253.
13. Heinig J, Witteler R, Schmitz R, Kiesel L, Steinhard J. Accuracy of classification of breast ultrasound findings based on criteria used for BI-RADS. Ultrasound Obstet Gynecol. 2008; 32: 573-578.
14. Youk JH, Eun JS, Jeong-Ah K, Hee JM, Min JK, Chung HC, et al. Scoring system based on BI-RADS lexicon to predict probability of malignancy in suspicious microcalcifications. Ann Surg Oncol. 2012; 19: 1491-1498.
15. Shi XQ, Jun LL, Wen BW, Yan H. A set of shear wave elastography quantitative parameters combined with ultrasound BI-RADS to assess benign and malignant breast lesions. Ultrasound Med Biol. 2015; 41: 960-966.
16. Ganau S, Andreu FJ, Escribano F, Martín A, Tortajada L, Villajos M, et al. Shear-wave elastography and immune his to chemical profiles in invasive breast cancer: evaluation of maximum and mean elasticity values. Eur J Radiol. 2015; 84: 617-622.
17. Zhang Q, Xiao Y, Chen S, Wang C, Zheng H. Quantification of elastic heterogeneity using contourlet-based texture analysis in shear-wave elastography for breast tumor classification. Ultrasound Med Biol. 2015; 41: 588-600.
18. Barr RG. Elastography in clinical practice. Radiol Clin North Am. 2014; 52: 1145-1162.
19. Mun HS, Choi SH, Kook SH, Choi Y, Jeong WK, Kim Y. Validation of intra and inter observer reproducibility of shearwave elastography: Phantom study. Ultrasonics. 2013; 53: 1039-1043.
20. Schafer FK. Shear Wave Elastography BE1 multinational breast study: additional SWE features support potential to downgrade BI-RADS(R)-3 lesions. Ultraschall Med. 2013; 34: 254-259.
21. Sim YT, Vinnicombe S, Whelehan P, Thomson K, Evans A. Value of shear-wave elastography in the diagnosis of symptomatic invasive lobular breast cancer. Clin Radiol. 2015; 70: 604-609.
22. Xiao Y. Quantitative analysis of peri-tumor tissue elasticity based on shear-wave elastography for breast tumor classification. Conf Proc IEEE Eng Med Biol Soc. 2013; 2013: 1128-1131.
23. Lee SH, Jung MC, Won HK, Min SB, Mirinae S, Hye RK, et al. Added Value of Shear-Wave Elastography for Evaluation of Breast Masses Detected with Screening US Imaging. Radiology. 2014; 273: 61-69.

24. Kim S, Choi S, Choi Y, Kook SH, Park HJ, Chung EC. Diagnostic performance of shear wave elastography of the breast according to scanning orientation. J Ultrasound Med. 2014; 33: 1797-1804.

25. Youk JH, Hye MG, Eun JS, Kyung HH, Jeong-Ah K. Diagnostic value of commercially available shear-wave elastography for breast cancers: integration into BI-RADS classification with subcategories of category 4. Eur Radiol. 2013; 23: 2695-2704.

26. Youk JH, Son EJ, Gweon HM, Kim H, Park YJ, Kim JA. Comparison of strain and shear wave elastography for the differentiation of benign from malignant breast lesions, combined with B-mode ultrasonography: qualitative and quantitative assessments. Ultrasound Med Biol. 2014; 40: 2336-2344.