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Original Article

Differential diagnostic value of ultrasound elasticity score and strain ratio in breast cancer

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Abstract: This study aimed to evaluate the value variance of ultrasound elasticity score (ES) and strain ratio (SR) in the diagnosis of benign and malignant of breast masses. 302 breast nodules were from 283 patients receiving ultrasonography of the breast. They were divided into two groups according to the mass size: > 10 mm group and ≤ 10 mm group in the second step. The diagnostic value was compared between ES and SR in these lesions. Results showed that ES and SR were significantly different between patients with benign and malignant masses ($P < 0.05$), but were similar between patients with benign and malignant microlesions ($P > 0.05$). In > 10 mm group, there was significant difference between ES and SR in the diagnosis of benign and malignant masses, but no difference was observed in ≤ 10 mm group. SR has better sensitivity, specificity and accuracy in the diagnosis of breast masses as compared to ES. It is concluded that the strain ratio yielded better results than the elasticity score, especially in > 10 mm group. Ultrasound elastography is an easy and feasible method in the differentiation of benign breast masses from malignant masses and also has a favorable efficiency in the diagnosis of breast microlesions.

Keywords: Breast cancer, ultrasound, elastography

Introduction

Breast cancer (BC) is a common malignancy in women and has been the leading cause of cancer related death in women [1]. Clinically, BC is diagnosed through palpitation firstly, but palpitation is subjective and has a poor sensitivity to small and deep masses [2]. Real time elastography (RTE) is a new technique that is used for palpitation under ultrasound and has been used for the non-invasive detection of hardness of a mass in soft tissues and superficial organs. Generally, cancer tissue is harder than the adjacent normal breast tissue. This property serves as the basis for some examinations, such as palpation, that are currently being used in the clinical assessment of breast abnormalities, as well for elastography [3-6]. By using the spatial correlation method, the phase-shift tracking method and the combined autocorrelation method (CAM), we can measure tissue strain at elastography. The principle of strain elastography is that tissue compression produces strain within the tissue and that the strain is smaller in harder tissue than in softer tissue. Therefore, by measuring the tissue strain induced by compression, we can estimate tissue hardness, which may be useful in diagnosing breast cancer. At the same time, elastography can be used to qualitatively or semi-quantitatively diagnose breast masses, which may increase the diagnostic accuracy [3, 5, 7, 8]. In 1991, Ophir et al [9] for the first time reported the use of elastography. To date, numerous studies have been conducted to investigate elastography. There are two kinds of elastography that include strain elastography and shear wave elastography. Shear wave elastography (SWE) uses a radiation force produced by an ultrasonic beam to stress tissues

and ultrafast sonographic tracking techniques to measure the speed of shear waves. SWE mostly is used in the in-depth organs such as liver. The hardness was measured by strain elastography through manual pressurization, which can be described with the measurement of elasticity score (ES) or strain ratio (SR). It is used mostly in superficial organs such as mammary gland or thyroid. It has been reported that elastography can increase the diagnostic accuracy, which may reduce the use of breast biopsy or surgery in typical patients whose masses with scores at 4-5 or higher ER [10-16]. This study aimed to evaluate the efficiency of SR and ES in the diagnosis of breast tumors.

Methods

Subjects

This study was approved by the Ethics Committee of our hospital, all the patients were informed of the sensitivity, accuracy and limitations of the detections, and informed consent was obtained before study from each patient.

A total of 288 female patients with breast tumor were recruited from the Cancer Hospital of Hunan Province between February 2009 and December 2014, and 308 breast lesions were studied in these patients. Of these patients, 6 nodules of 5 patients had no pathological support and thus excluded from this study. Thus, 302 breast lesions from 283 patients were finally analyzed. Among those, 269 patients were with only one mass, 10 patients were with two masses, 3 patients were with three masses, and 1 patient was with four masses. All the breast nodules were solid or mixed cystic and solid, and had the BI-RADS [17] grades of 3-5. All the patients received pathological examination after biopsy under guidance with ultrasound or surgery. The mean age was 45 ± 12 years (range: 17-70 years) in patients with benign masses and 45 ± 10 years (range: 12-78 years) in those with malignant masses.

Ultrasound equipment

Routine ultrasound examination, elastography and color Doppler ultrasound examination were performed by the same ultrasound physician with 10-year experience in the ultrasound examination, and images were blindly analyzed by two physicians. In each patient, bilateral whole-breast sonography was performed in the transverse and longitudinal places using a Hitachi EUB-8500 (Hitachi Medical, Tokyo, Japan) ultrasound scanner equipped with a 6-MHz to 13.0-MHz linear-array transducer. The equipment has the characteristics of harmonic wave production, focal amplification, and video replay, and the images may be automatically optimized. Thus, the best images were obtained for further analysis.

Routine ultrasound examination

Patients were placed in a supine position, and bilateral breasts were completely exposed. The location, number, size, shape, borderline, echoes, calcified foci, characteristics of calcification and acoustic halo were determined at gray scale mode. Then, the real time blood flow was measured at CDFI and CDE for the Bi-RADS classification of the breast. Images and videos from routine ultrasound examination and color Doppler ultrasound examination were stored. The images from color Doppler ultrasound examination covered the mass and normal breast tissues 1-2 cm away from the mass. The breast masses were classified according to the Breast imaging reporting and data system (BI-RADS) developed by the American College of Radiology in 2003. Patients diagnosed with level 3 or higher breast mass through ultrasound were subjected to elastography.

Elastography

After routine ultrasound examination, strain elastography was performed. The scanner was equipped with a sonoelastographic unit for measuring the level of elasticity of a lesion, which is represented by a color type. In B mode, we first examined the target lesion and then moved the region of interest (ROI) around the lesion. We took care to ensure that there was sufficient surrounding breast tissue in the region of interest, because the stiffness of a lesion in this system is displayed relative to the average strain inside the region of interest. Two-dimensional image and elastography image were presented in the same screen simultaneously. The probe was vertical to the skin surface and manipulated with relatively slight pressure to obtain images that were suitable for analysis and high levels of pressure were avoided, as they could result in nonlinear elasticity parameters; in such circumstances, the

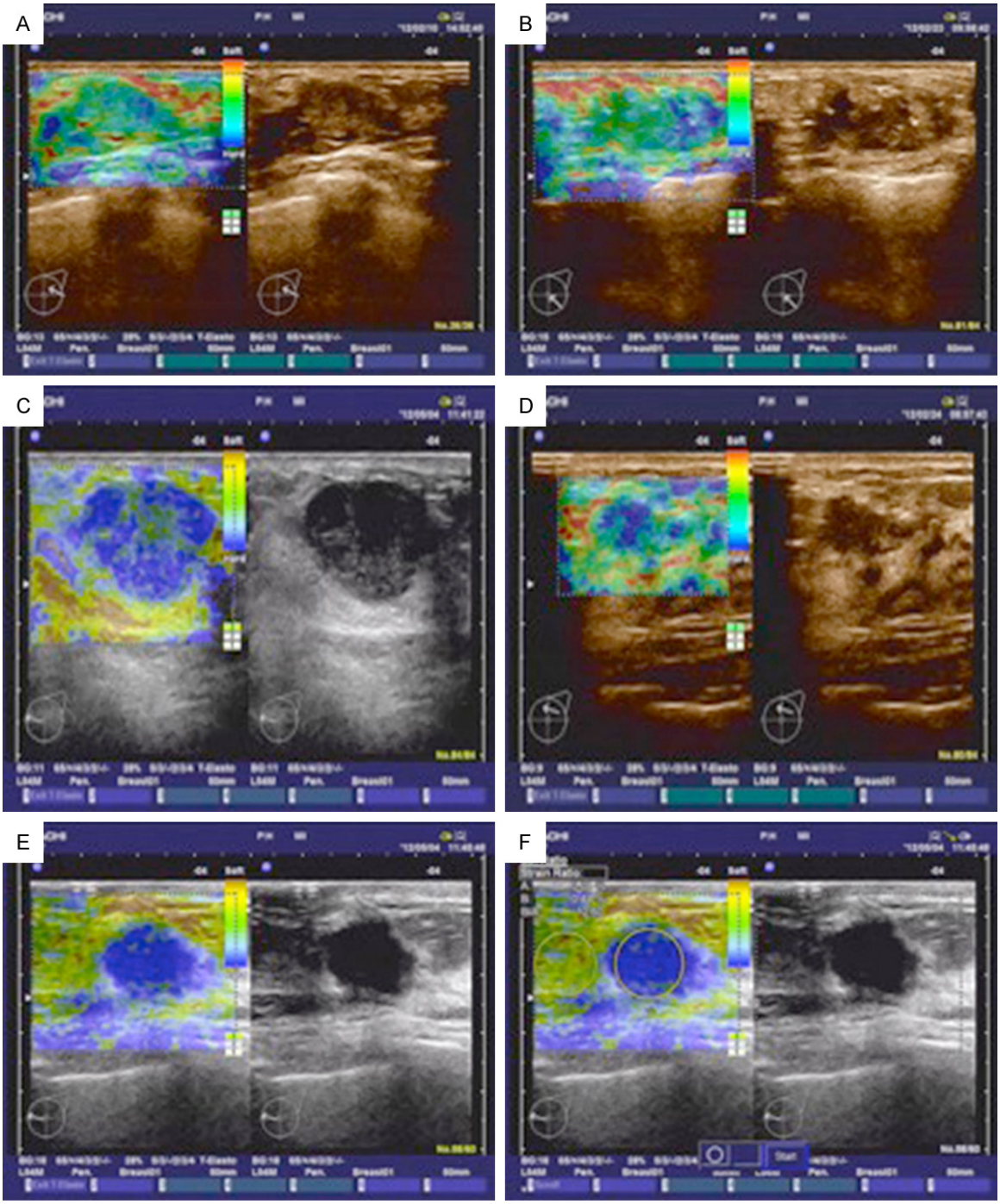

Figure 1. ES 5 points scoring method of ultrasonic elasticity and SR measurement. A: A score of 1 indicated there evenly shaded in green in entire lesion. B: A score of 2 indicated that had a mosaic pattern of green and blue) in the lesion. C: A score of 3 showed the peripheral part of lesion was green, and the central part was blue. D: A score of 4 indicated that the entire lesion was blue, but its surrounding area was not included. E: A score of 5 indicated the entire lesion and its surrounding area were blue. F: SR: Strain ratio = B/A. The average strain of the lesion was determined by selecting a representative region of interest from lesion and was expressed as A. A corresponding region of interest of adjacent breast tissue of the same depth was then selected, and the average strain was expressed as B. The resultant strain ratio was calculated according to the equation strain ratio = B/A, which reflected the property of stiffness of the lesion.

pressure values are no longer proportional to the strain values.

According to the illustration on the ultrasound machine, red, green, and blue represent soft,

Table 1. Pathology results and ultrasound elasticity score of 302 breast lesions (n)

Pathology	N (total)	ES				
		1	2	3	4	5
Benign	94	40	21	21	12	0
Fibrocystic breast disease	14	7	6	1	0	0
Fibroadenoma	47	28	2	9	8	0
Intraductal papilloma	10	0	5	3	2	0
Inflammatory lesion	9	2	3	3	1	0
Galactocele	5	0	1	3	1	0
Benign cystosarcoma phyllodes	4	0	2	2	0	0
Lipoma	3	3	0	0	0	0
Mucinous adenomas	1	0	1	0	0	0
Hemangioma	1	0	1	0	0	0
Malignant	208	0	2	13	146	47
Invasive ductal carcinoma	165	1	0	5	118	41
Invasive lobular carcinoma	22	0	0	2	15	5
Mucinous carcinoma	2	0	0	1	1	0
Adenocarcinoma	2	0	0	0	2	0
Intraductal carcinoma	11	0	0	2	8	1
Medullary carcinoma	4	0	0	3	1	0
Eczema-like cancer	2	0	2	0	0	0
		0.05%	0.96%	6.25%	69.71%	22.60%

Notes: N = number of mass.

medium, and hard lesions, respectively. 2-3 indicators used to evaluate the integrated frequency with and without oppression were selected [18]. After obtaining a strain image, we scored the lesion using the five-point scoring system [5, 16]. A score of 1 indicated even strain for the entire hypoechoic lesion (ie, the entire lesion was evenly shaded in green). A score of 2 indicated strain in most of the hypoechoic lesion, with some areas of no strain (for example: the hypoechoic lesion had a mosaic pattern of green and blue). A score of 3 indicated strain at periphery of the hypoechoic lesion, with sparing of the center of the lesion (for example: the peripheral part of lesion was green, and the central part was blue). A score of 4 indicated no strain in the entire hypoechoic lesion (for example: the entire lesion was blue, but its surrounding area was not included). A score of 5 indicated no strain in the entire hypoechoic lesion of in the surrounding area (for example: the entire hypoechoic lesion and its surrounding area were blue; **Figure 1A-E**). If ES of a lesion was between 1 and 3, the lesion was categorized as benign. If ES of a lesion was assigned a score of 4 or 5, the lesion was categorized as malignant. Calculation of the strain ratio was based on the comparison of the average strain measured in the lesion with the adjacent breast tissue of the same depth. Using proprietary software on the ultrasound machine, the average strain of the lesion was determined by selecting a representative region of interest from lesion and was expressed as A. A corresponding region of interest of adjacent breast tissue of the same depth was then selected, and the average strain was expressed as B. The resultant strain ratio (SR) was calculated with equation SR = B/A, which reflected the stiffness of the lesion (**Figure 1F**).

SR may semi-quantitatively reflect the elastic characteristics of the mass and is a relatively objective method in the evaluation of tissue hardness [19, 20]. In several studies, adipose tissues were used as a reference with the lesions. However, the depths of adipose tissues in different patients are not same, thus, in the present study, the mass and ROI were compared with surrounding gland tissues [21].

Statistical analysis

Data were analyzed with the software SAS (Statistical Analysis System). P values < 0.05 were considered statistically significant. Pathological examination after biopsy or surgery served as a golden standard. Measurement data are expressed as mean ± standard deviation X ± S). First, t test was used to compare the SR and ES between all malignant masses and benign masses. The efficiency of SR and

Table 2. Pathological characteristics and ES of 87 small lesions (n)

Pathology	N (total)	ES				
		1	2	3	4	5
Benign	62	39	14	7	2	0
Fibrocystic breast disease	14	7	6	1	0	0
Fibroadenoma	33	28	2	3	0	0
Intraductal papilloma	6	0	4	0	2	0
Inflammatory lesion	6	2	1	3	0	0
Lipoma	2	2	0	0	0	0
Hemangioma	1	0	1	0	0	0
Malignant	25	0	0	4	14	7
Invasive ductal carcinoma	16	1	0	0	10	5
Invasive lobular carcinoma	4	0	0	2	1	1
Mucinous carcinoma	1	0	0	0	1	0
Adenocarcinoma	2	0	0	0	2	0
Intraductal carcinoma	2	0	0	1	0	1
		0%	0%	16%	56%	28%

Notes: N = number of mass.

ES differentiating malignant masses from benign ones was evaluated by ROC. Second, Z test was used to compare the AUC, aiming to evaluate the difference of SR and ES in the diagnosis of malignant and benign masses, and McNemar's test was employed to compare the sensitivity, specificity and accuracy. The sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of ES and SR in the diagnosis of malignant and benign masses were recorded. Finally, all patients were divided into two groups according to the mass size: ≤ 10 mm group and > 10 mm group, and the diagnostic efficiency of SR and ES was compared between two groups The *P* value, odds ratios (ORs) and 95% confidence intervals (CIs) for malignant masses versus benign masses were calculated on the basis of the logistic regression model with adjustments for age.

Results

Pathological findings

Of 302 masses, 94 were benign and 208 were malignant. The mean diameter was 23.63 ± 10.12 mm (range: 5.1-83.3 mm) in benign group and 18.35 ± 17.84 mm (range: 5.1-88.6 mm) in malignant group (**Table 1**). Of benign masses, fibroadenoma was the most common (47/94; 50%). In malignant masses, invasive ductal carcinoma was the most common (165/208; 79.3%). Of 302 masses, there were 87 small lesions (benign: n = 62; malignant: n = 25). Of small lesions, the median diameter was 8.51 ± 1.0 mm (range: 5.1-10 mm) in malignant group and 8.10 ± 1.28 mm (range: 3.3-10.0 mm) in benign group (**Table 2**). Of small benign lesions, fibroadenoma was the most common (33/62; 53.2%); of small malignant lesions, invasive ductal carcinoma was the most common (16/25; 64%). The pathological characteristics and ES of 215 bigger lesions are show in **Table 3**.

Elasticity scores and strain ratios in the differential diagnosis

ES of 302 masses: The mean ES was 1.79 ± 0.84 in 94 benign masses and 4.16 ± 0.55 in 208 malignant masses, showing significant difference ($P < 0.05$). Of 208 malignant masses, 93% had a ES of ≥ 4. However, 15 had a ES of ≤ 3 which were misdiagnosed as benign masses. Of 94 benign masses, 87% had a ES of ≤3. However, 12 had a ES of ≥ 4 and were misdiagnosed as malignant masses.

SR of 302 masses: The mean SR was 2.03 ± 1.08 in 94 benign masses and 4.89 ± 1.77 in 208 malignant masses, showing significant difference ($P < 0.05$). ROC was delineated to evaluate the diagnostic efficiency of SR in breast masses. When the cut-off value of SR was 3.13, the sensitivity and specificity of SR were the highest. Of 208 malignant masses, 190 had SR of ≥ 3.13 and 18 had SR of < 3.13 and thus were misdiagnosed as benign masses. Of 94 benign masses, 87 had SR of < 3.13 and 7 had SR of ≥ 3.13 and thus misdiagnosed as malignant masses.

According to above findings, the sensitivity, specificity, accuracy, positive predictive value, negative predictive value and Youden's index (YI) of ER and SR in the diagnosis of breast masses were determined (**Tables 4** and **5**) with pathological examination as a golden standard. The ROC of ES and SR delineated independently (**Figure 2A**). The AUC was 0.903 (95% CI: 0.859-0.946) for ES and 0.968 (95% CI: 0.945-0.991) for SR, showing significant different between them (Z = 2.59, *P* = 0.0096

Table 3. Pathological characteristics and ES of 215 bigger lesions (n)

Pathology	N (total)	ES				
		1	2	3	4	5
Benign	32	1	7	14	10	0
Fibroadenoma	14	0	0	6	8	0
Intraductal papilloma	4	0	1	3	0	0
Inflammatory lesion	3	0	2	0	1	0
Galactocele	5	0	1	3	1	0
Benign cystosarcoma phyllodes	4	0	2	2	0	0
Lipoma	1	1	0	0	0	0
Mucinous adenomas	1	0	1	0	0	0
		3.13%	21.88%	43.75%	31.25%	0%
Malignant	183	0	2	9	132	40
Invasive ductal carcinoma	149	0	0	5	108	36
Invasive lobular carcinoma	18	0	0	0	14	4
Mucinous carcinoma	1	0	0	1	0	0
Intraductal carcinoma	9	0	0	1	8	0
Medullary carcinoma	4	0	0	3	1	0
Eczema-like cancer	2	0	2	0	0	0
		0%	1.09%	4.92%	72.13%	21.86%

Notes: N = number of mass.

Table 4. Diagnostic efficiency of SR and ES in breast lesions

Method	Sensitivity	Specificity	Accuracy	PPV	NPV	Youden Index
ES (n = 302)	92.7% (193/208)	87.2% (82/94)	91.06% (275/302)	94.1% (193/205)	84.5% (82/97)	0.799
SR (n = 302)	91.3 (190/208)	92.5% (87/94)	91.7% (277/302)	96.4% (190/197)	93.5% (87/93)	0.838
ES (n = 87)	84.0% (21/25)	96.7% (60/62)	93.1% (81/87)	91.3% (21/23)	93.7% (60/64)	0.81
SR (n = 87)	88% (22/25)	98.4% (61/62)	95.4% (83/87)	95.6% (22/23)	95.3% (61/64)	0.86
ES (n = 215)	94.5% (173/183)	68.8% (22/32)	90.7% (195/215)	94.5% (173/183)	68.7% (22/32)	0.63
SR (n = 215)	90.7% (166/183)	84.4% (27/32)	89.8% (193/215)	97.1% (166/171)	95.3% (27/44)	0.75

Table 5. McNemar's test of ES

ES (n)	SR (n)		*P* valve
	Negative	Positive	
Negative (84+15 = 97)	86	10	0.136
Positive (12+193 = 205)	19	187	

< 0.05). It was identified that both ES (adjusted OR = 12.789, 95% CI = 6.858-23.850, P < 0.001) and SR (adjusted OR = 12.605, 95% CI = 6.684-23.770, P < 0.001) showed a significant increased risk of breast cancer.

ES of 87 small lesions: Mean ES was 1.55 ± 0.82 in small benign lesions and 4.12 ± 0.67 in small malignant lesions, showing significant difference (P < 0.05). Of 25 malignant lesions, 21 had ES of ≥ 4 of which 4 were misdiagnosed as benign lesions. Of 62 benign lesions, 60 had ES of < 3 of which 2 were misdiagnosed as malignant lesions.

SR of 87 small lesions: Mean SR was 1.68 ± 0.65 in benign lesions and 4.64 ± 1.51 in malignant lesions, showing significant difference (P < 0.05). ROC was delineated to evaluate the diagnostic efficiency of SR. When the SR was 3.10, the sensitivity and specificity were the highest. Of 25 malignant lesions, 22 had SR of ≥ 3.10 and 3 had SR of < 3.10 and thus mis-diagnosed as benign lesions.

The pathological examination served as a gold standard, and the sensitivity, specificity, accuracy, positive predictive value, negative predictive value and Youden's index were calculated (**Table 4**). The ROCs of SR and ES were in-

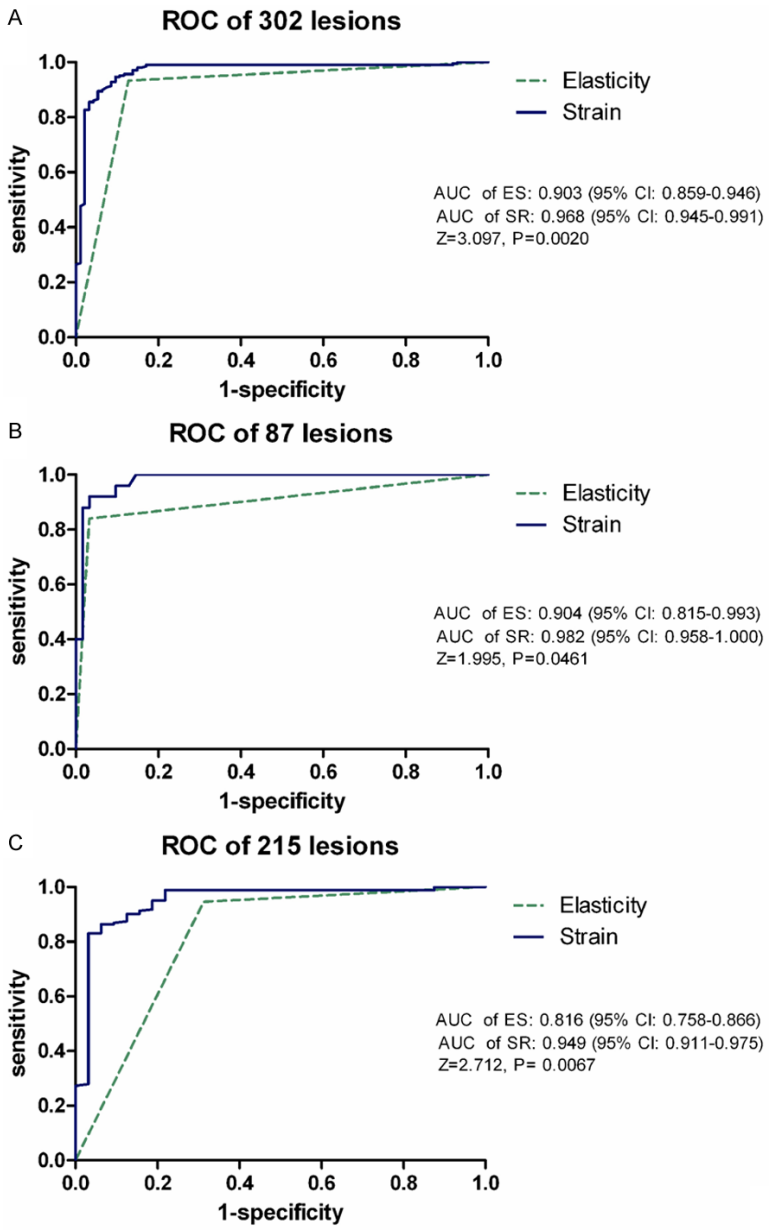

Figure 2. ROC curve. A: ROC curves for the elasticity score and strain ratio for differentiating malignant from benign breast lesions in 302 lesions. Diagonal segments are produced by ties. The AUC was 0.903 (95% CI: 0.859-0.946) for ES and 0.968 (95% CI: 0.945-0.991) for SR. B: ROC curves for the elasticity score and strain ratio for differentiating malignant from benign breast lesions in 87 small lesions. Diagonal segments are produced by ties. The AUC was 0.904 (95% CI: 0.815-0.993) for ES and 0.982 (95% CI: 0.958-1.000) for SR. C: ROC curves for the elasticity score and strain ratio for differentiating malignant from benign breast lesions in 215 small lesions. Diagonal segments are produced by ties. The AUC was 0.816 (95% CI: 0.758-0.866) for ES and 0.949 (95% CI: 0.911-0.975) for SR.

dependently delineated. The AUC was 0.904 (95% CI: 0.815-0.993) for ES and 0.982 (95% CI: 0.958-1.0) for SR (**Figure 2B**), showing no significant difference (Z = 1.674, *P* = 0.094 > 0.05).

Discussion

Krouskop et al [22] found that the hardness of malignant breast tumors was 2-3 times more than that of benign tumors. On the basis of the fact that the deformation was smaller and the coefficient of elasticity was larger in malignant lesions as well as the coefficient of elasticity of invasive ductal carcinoma was significantly larger than that of benign lesions, it is feasible to differentiate malignant breast tumors from benign ones according to ES [5, 23].

Analysis of ES

In the present study, ES was determined in 302 breast masses. Of 208 malignant masses, 15 had ES of 2 or 3 and thus were misdiagnosed as benign masses. This may be explained as follows: (1) The mass volume was large (n = 7). In 4 masses, hemorrhage and necrosis at the mass center reduced the hardness of mass center, the deformation of the mass was obvious, and thus the ES was lower, resulting in misdiagnosis. Another 2 masses were diffuse and accounted for almost 1/2 of the unilateral breast, softness was present on palpitation, and thus the ES was lower. One case was too big to set up the ROI so it couldn't be accurately measured. (2) The pathological type was different. 2 patients with eczema-like cancer presented tissue bulge at the affected breast which was mass like, ulcer was observed at the nipple area, and the mass localized at the mammary areola with unclear borderline. The examination was inconvenient due to the ulcer; elastography showed a lower hardness at the soft tissues, and thus the score was only 2. In 3 patients with medul-

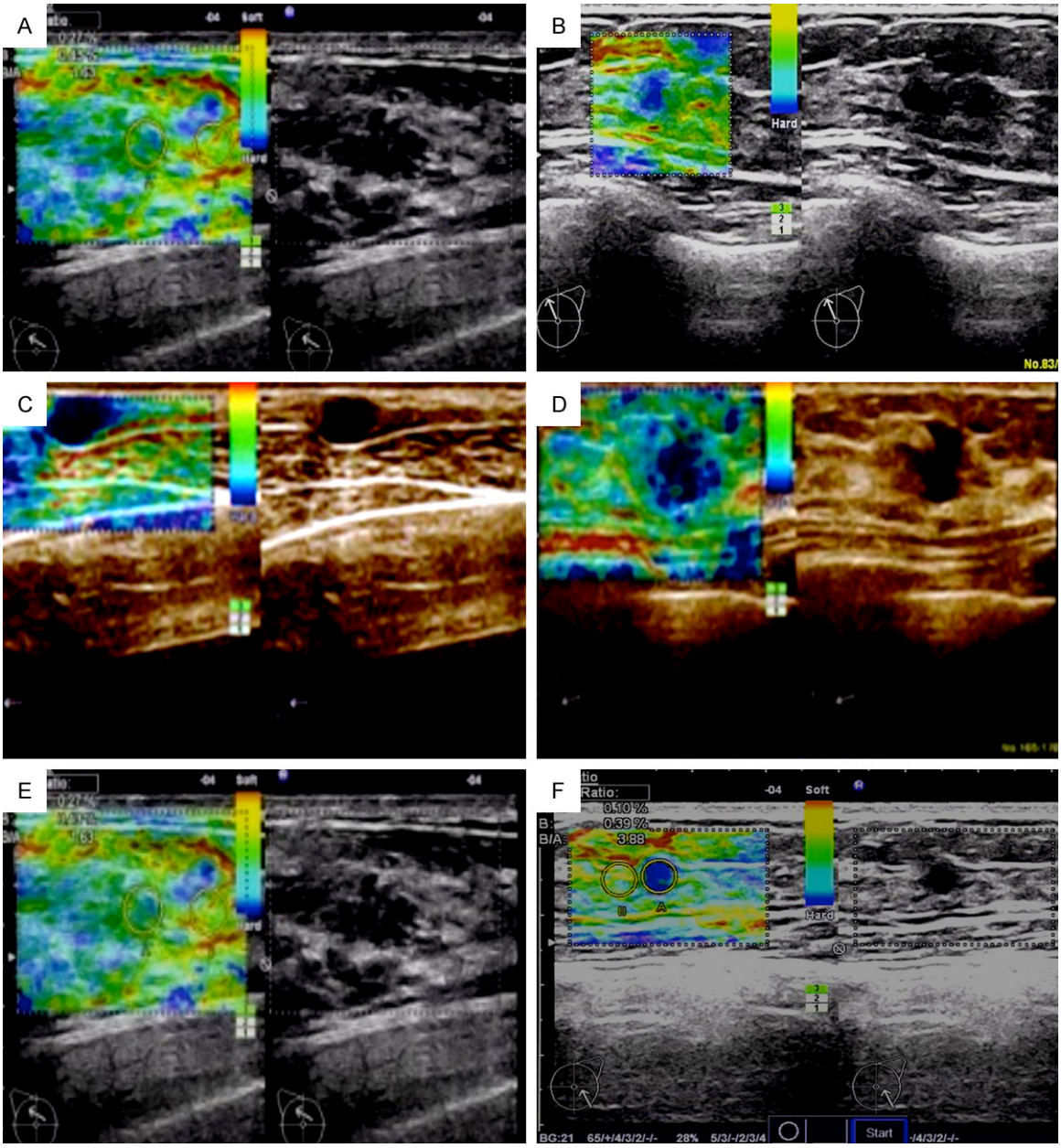

Figure 3. There were different elastography scores and different SR in all kinds of lesions. A: Invasive lobular carcinoma. Elastography showed red-green in most area and the ES was 2, SR was 1.63. B: Intraductal carcinoma. Elastography showed blue at the center and green at the periphery, and the ES was 3, SR was 1.53. C: Invasive ductal carcinoma. The mass and surround tissues were evenly blue and the ES was 5, SR was 4.35. D: Invasive ductal carcinoma. The mass center was blue, the mass periphery was green, and the ES was 3, SR was 3.32. E: Invasive lobular carcinoma. SR was 1.61 and ES was 2. F: Invasive ductal carcinoma. SR was 3.88 and ES was 4.

lary carcinoma who were misdiagnosed as having benign masses, cancer cells became degenerated and necrotic and formed mucus, leading to the reduction in hardness. (3) The masses were small and the outline was unclear: Of 11 masses diagnosed as ductal carcinoma, 2 had ES of 3 because the outline was unclear, shape was irregular, the size was small, color Doppler ultrasound showed abundant blood flow signals, hypoechoes in surrounding tissues with anechoic dilated ducts, ultrasound elastography showed red-green, and thus the score was lower. Of 94 benign masses, 12 were misdiagnosed as malignant masses, which may be explained as follows: (1) There was fibrosis or calcification in the mass:

Fibroma accounted for 66.7% of masses misdiagnosed, which might be ascribed to fibrous components in the fibroma because the fibrous interstitium is dense, some masses are rich in stromal cells or calcified lesions, leading to the increase in hardness, which is similar to the features of carcinoma durum [24]. (2) Acute inflammatory edema: 1 patient with acute mastitis presented redness and swelling at the affected breast, the breast tissues were hard, the movement of the mass and surrounding tissues was small, and thus the probe oppression was poor, leading to the ES of 4; (3) The long course of disease: in 2 patients with ES of 4 who were finally diagnosed as having intraductal papilloma, the course of disease was relatively long, and repeated hyperplasia significantly increased the fibrous components in the mass, leading to the increase in the hardness. In 1 patient with cystic breast disease and galactocele, the milk stays in the cystic lesions, which increases the tissue tension, leads to secondary infection and fibrosis, and hard tissues were felt on palpitation, leading to the increase in ES.

The diagnosis of small breast lesions is a challenge in clinical practice, especially for the breast lesions smaller than 10 mm in diameter in routine ultrasound examination. In the present study, subgroup analysis was performed in small breast lesions. Although the movement of small breast nodules is favorable on palpitation, or ultrasound examination shows a clear borderline, regular shape, small size and even echoes, and CDFI shows absence of blood flow in the mass, it may not be diagnosed as a benign one if the ES is high. Of small breast lesions in the present study, 2 showed good movement on palpitation, repeated routine ultrasound examinations were suggestive of fibroadenoma, but ES was 4 and 5, respectively, with higher elastic ratio and the post-operative pathological examination confirmed it was invasive ductal carcinoma (**Figure 3C**). This implies that ES of ≥ 4 is specifically indicative of malignant lesions although the lesions are small. Of small breast lesions, false positive was found in 4, which might be ascribed to the invasive growth of the tumor and mix of the normal tissues and the tumor, leading to a reduced ES. Although the ES was lower than 4, the hardness of the lesion and normal tissues was different and elastography showed blue lump at the central hard region and blue-green soft tissues at the periphery, which are special "cobblestone sign" (**Figure 3D**).

Analysis of SR

Under the external pressure, the soft tissues with larger coefficient of elasticity show higher hardness and smaller strain, leading to a larger SR. On the contrary, tissues with smaller coefficient of elasticity display larger strain. There is evidence showing that SR is objective to reflect the difference in elasticity between mass and surrounding tissues and has a higher sensitivity in the diagnosis as compared to ES [11, 12, 20, 25].

In the present study, the SR was determined in 302 breast lesions. Results showed the SR of malignant masses was significantly larger than that of benign masses. In 208 malignant masses, the diagnostic efficiency of SR was similar to that of ES in invasive ductal carcinoma, but the possibility of misdiagnosis of SR was higher than that of ES in invasive lobular carcinoma due to the diffuse invasion and the poor contrast to surrounding normal tissues. The misdiagnosis of invasive malignancies might be ascribed to the mix of malignant tumor and normal tissues, leading to the reduced hardness and the decreased SR. For intraductal carcinoma, the SR had a better diagnostic efficiency as compared to ES (**Figure 3**). Of 94 benign masses, 7 had SR of ≥ 3.13 and 6 were fibroadenoma of which 3 had calcification, 3 showed severe dysplasia and 1 displayed repeated hyperplasia in galactocele. Misdiagnosis of SR was mainly found in fibroadenoma (85.7%, 6/7), which might be attributed to the large calcified foci in the mass, leading to the increase in absolute hardness and simultaneous increase in SR. Thus, we speculate that concomitant routine ultrasound examination may avoid the measurement of SR of large classified foci in the mass.

Diagnostic value of SR and ES

Breast masses were classified > 10 mm group and ≤ 10 mm group. In > 10 mm group, both SR and ES could differentiate malignant breast masses from benign ones. In ≤ 10 mm group, SR was superior to ES in the differential diagnosis of small breast lesions although there

was no significant difference, which might be ascribed to the small number of malignant lesions (**Figure 2B**).

On the basis of our findings ultrasound elastography with a new imaging principle is a simple and non-invasive method for the differential diagnosis of breast masses.

Disclosure of conflict of interest

None.

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