

Original Article

Role of multi-mode ultrasound in the diagnosis of level 4 BI-RADS breast lesions and Logistic regression model

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Received June 11, 2015; Accepted September 12, 2015; Epub September 15, 2015; Published September 30, 2015

Abstract: Objective: This study is to investigate the diagnostic role of multi-mode ultrasound in level 4 BI-RADS breast lesions and to establish a Logistic regression model. Methods: Totally 179 patients with 182 sites of breast lesions were enrolled in this study. Preoperatively, the examinations of routine ultrasonography, elastography, contrast-enhanced ultrasonography and three-dimensional color Doppler were performed. Postoperatively, the breast lesions were diagnosed as benign and malignant lesions according to pathological results. Diagnostic indicators of each ultrasound analysis were determined and compared. The relationship between these diagnostic indicators and the benign and malignant features of breast lesions was analyzed by single factor analysis. Logistic regression model was established. Results: The diagnostic indicators with high sensitivity and specificity were tumor edge, enhanced range and score of elastography. Four factors of tumor edge, enhanced order, contrast mode and score of elastography were related with the benign and malignant features of breast lesions. The prediction model was $\text{Logit}(P) = 0.636 + 4.471X_1 + 4.337X_2 + 3.753X_3 + 3.014X_4 + 2.525X_5 + 2.105X_6$. Likelihood ratio test showed that the model was statistically significant ($\chi^2 = 161.876$, $P < 0.0001$). This model could effectively distinguish between benign and malignant tumors ($R^2 = 0.813$, prediction accuracy 92.3%). The differences in sensitivity and specificity between multi-mode ultrasound diagnosis and routine ultrasound diagnosis were statistically significant ($P < 0.001$). However, there was no significant difference between Logistic regression model and multi-mode ultrasound diagnosis. Conclusion: Multi-mode ultrasound and Logistic regression model are more effective in diagnosing level 4 BI-RADS breast lesions.

Keywords: Breast neoplasms, BI-RADS 4 level, multi-mode ultrasound diagnosis

Introduction

The incidence rate of breast cancer in China was 2.55/100,000 in 2009, accounting for 16.81% of female malignancies, while the five-year disease-free survival in patients with breast cancer has increased from 70% in 1980 to 85% in 2011 [1]. In 2003, the breast imaging report and data system (BI-RADS) was issued by the American College of Radiology [2] to standardize mammographic reporting. Five levels are included in BI-RADS. And, level 4 is divided into three sublevels of 4a, 4b and 4c. Lesion less than 4a is considered as a benign lesion while lesion more than 4a is considered as malignant lesions. The routine sonographic manifestations of level 4 BI-RAD breast lesions

tend to have a certain degree of overlapping and are sometimes difficult to judge [3, 4]. Thus, it is difficult to identify the nature of such lesions in clinic. Elastography, contrast-enhanced ultrasonography and three-dimensional color Doppler may help the diagnosis of such lesions. However, the comprehensive application of these methods has not yet formed a unified diagnostic criterion [5].

In this study, the diagnostic value of multi-mode ultrasound was investigated. The level 4 BI-RADS breast lesions detected by routine ultrasound were used. The manifestations of these breast lesions by multi-mode ultrasound were used as explanatory variable. The regression coefficient of each variable was used to evalu-

ate the risk of malignancy contributed by each variable. The malignancy indicators for breast lesions were identified.

Materials and methods

Clinical data of patients

A total of 179 cases breast cancer patients treated in Xinjiang Tumor Hospital from August 2013 to December 2014 were enrolled in this study. They were all female and were aged from 23 to 80 years old, with a mean age of (32 ± 3.6) years. These 179 cases had 182 sites of lesions which were surgically resected. The diameter of lesions ranged from 0.5 cm to 6 cm, with an average diameter of (2.5 ± 1.4) cm. Among them, 119 lesions were malignant and 63 lesions were benign, as confirmed by post-operative pathological examinations. According to the BI-RADS [6], 72 lesions of the 119 malignant lesions were level 4c BI-RADS breast lesions, 45 were level 4b, and 2 were level 4a. Among the 63 benign lesions, 40 lesions were level 4c BI-RADS breast lesions, 11 were level 4b, and 12 were level 4a. Prior written and informed consent were obtained from every patient and the study was approved by the ethics review board of Xinjiang Medical University.

Multi-mode ultrasound

Routine ultrasonography, elastography, contrast-enhanced ultrasonography and three-dimensional color Doppler were performed. The Philips IU22 Ultrasound system (Philips Ultrasound, Inc., Bothell, WA, USA) with probe frequency 5-12MHZ was used.

The indicators of routine ultrasonography included: hyperechoic halo (without hyperechoic halo, benign; with hyperechoic halo, malignant), edges (with clear structure, benign; without clear structure, malignant), microcalcifications (without microcalcifications, benign; with microcalcifications, malignant), and, vascular distribution in two-dimensional ultrasound (without blood flow or with spot-like and strip-like blood flow, benign; net-like blood flow, malignant).

The 5-point scoring system was used for evaluation in elastography [7]. Score 1: all the lesion was deformed and was green; Score 2: part of the lesion was deformed; the center of the lesion was blue and the surrounding area of the lesion was green; Score 3: the proportion of

green and blue was similar in the lesion; Score 4: there was no obvious deformation in the lesion and the whole lesion was blue; Score 5: there was no obvious deformation in the lesion or in the surrounding area of the lesion; the lesion and the surrounding area of the lesion was blue. Scores 1-3 were defined as benign lesions and scores 4-5 were defined as malignant lesions.

The indicators of contrast-enhanced ultrasonography included [8]: enhanced range (\leq the range of two-dimensional ultrasound, benign; $>$ the range of two-dimensional ultrasound, malignant), enhanced mode (slow rise rapid drop or slow rise slow drop, benign; rapid rise rapid drop or rapid rise slow drop, malignant), enhanced order (overall enhancement or centrifugal enhancement, benign; centripetal enhancement, malignant), and enhanced strength (no, low or equal enhancement, benign; high enhancement, malignant).

The types of blood supply were used for evaluation in three-dimensional color Doppler [9]. No blood supply, wrap-around blood supply, or embracing blood supply was defined as benign. Penetrating blood supply or irregular type blood supply was defined as malignant.

Statistical analysis

Data was analyzed by SPSS19.0 software. Analysis of count data used χ^2 test, corrected χ^2 test or Fisher exact test. $P < 0.05$ was considered as statistically significant. The indicators of multi-model ultrasound were analyzed by Logistic regression analysis and a mathematical model (inclusion criteria: $P < 0.05$, exclusion criteria: $P > 0.05$) was established. The regression parameter estimates were analyzed using Wald χ^2 test. The fitting of the Logistic regression model was analyzed using the likelihood ratio test. $P < 0.05$ was considered statistically significant. The three-dimensional χ^2 test was used to compare the sensitivity and specificity of different diagnostic modes. $P < 0.05$ was considered statistically significant.

Results

Assessment of the indicators of multi-mode ultrasound and their diagnostic values

The indicators of multi-mode ultrasound and their diagnostic values were analyzed, respectively. As shown in **Table 1**, the indicators of

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Table 1. Assessment of the indicators of multi-mode ultrasound and their diagnostic values

Indicators			Pathological results		Sensitivity (%)	Specificity (%)	The positive likelihood ratio	The negative likelihood ratio	The positive predictive value	The negative predictive value	Accuracy	Youden index	The area under the ROC curve
			Malignant	benign									
Routine ultrasonography	Hyperechoic halo	No	59	48	0.5	0.76	2.08	0.66	0.8	0.45	0.59	0.26	0.63
		Yes	60	15									
	Tumor edge	Clear and intact	11	42	0.91	0.67	2.76	0.13	0.84	0.79	0.82	0.58	0.76
		Not clear or intact	108	21									
	Microcalcifications	No	65	42	0.45	0.67	1.36	0.82	0.72	0.39	0.52	0.12	0.65
		Yes	54	21									
Vascular distribution in two-dimensional ultrasound	Without blood flow or with spot-like and strip-like blood flow	51	24	0.57	0.38	0.92	1.13	0.64	0.32	0.51	-0.05	0.48	
	Net-like blood flow	68	39										
Contrast-enhanced ultrasonography	Enhanced range	≤ the range of two-dimensional ultrasound	28	48	0.76	0.76	3.17	0.32	0.86	0.63	0.76	0.52	0.76
		> the range of two-dimensional ultrasound	91	15									
	Enhanced mode	Slow rise rapid drop or slow rise slow drop	24	18	0.8	0.29	1.13	0.69	0.68	0.42	0.62	0.09	0.55
		Rapid rise rapid drop or rapid rise slow drop	95	45									
	Enhanced order	Overall enhancement or centrifugal enhancement	38	60	0.68	0.95	13.6	0.34	0.96	0.61	0.77	0.63	0.82
		Centripetal enhancement	81	3									
Enhanced strength	No, low or equal enhancement	31	21	0.74	0.33	1.49	0.79	0.68	0.4	0.6	0.07	0.54	
	high enhancement	88	42										
Elastography	Scores of elastography	Scores 1-3	20	33	0.83	0.52	1.73	0.33	0.78	0.62	0.72	0.35	0.68
		Scores 4-5	99	30									
Three-dimensional color Doppler	Blood supply type in three-dimensional ultrasound	No, wrap-around, or embracing blood supply	53	42	0.55	0.67	1.67	0.67	0.76	0.44	0.59	0.22	0.61
		Penetrating or irregular type blood supply	66	21									

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Table 2. Single factor analysis of the indicators of multi-mode ultrasound

Indicators		Tumor feature				χ^2	P
		Malignant		Benign			
		Cases	Column percentage	Cases	Column percentage		
Hyperechoic halo	No	59	49.58	48	76.19	12.04	0.0005
	Yes	60	50.42	15	23.81		
Tumor edge	Not clear	81	68.07	11	17.46	68.454	< 0.0001
	Not intact	27	22.69	10	15.87		
	Clear and intact	11	9.24	42	66.67		
Microcalcifications	No	65	54.62	42	66.67	2.467	0.1163
	Yes	54	45.38	21	33.33		
Vascular distribution in two-dimensional ultrasound	Spot-like	23	19.33	13	20.64	0.903	0.6368
	Strip-like	28	23.53	11	17.46		
	Net-like	68	57.14	39	61.91		
Enhanced range	> the range of two-dimensional ultrasound	91	76.47	15	23.81	46.97	< 0.0001
	≤ the range of two-dimensional ultrasound	28	23.53	48	76.19		
Enhanced mode	Slow rise slow drop	24	20.17	18	28.57	9.525	0.0085
	Rapid rise slow drop	27	22.69	24	38.1		
	Rapid rise rapid drop	68	57.14	21	33.33		
Enhanced order	Centripetal enhancement	81	68.07	3	4.76	66.425	< 0.0001
	Overall enhancement or centrifugal enhancement	38	31.93	60	95.24		
Enhanced strength	Equal enhancement	15	12.61	8	12.7	1.642	0.4399
	Low enhancement	16	13.45	13	20.64		
	High enhancement	88	73.95	42	66.67		
Scores of elastography	Score 4	61	51.26	20	31.75	25.454	< 0.0001
	Score 5	38	31.93	10	15.87		
	Score ≤ 3	20	16.81	33	52.38		
Blood supply type in three-dimensional ultrasound	Penetrating type	50	42.02	15	23.81	37.81	< 0.0001
	Embracing type	19	15.97	30	47.62		
	Wrap-around type	16	13.45	6	9.52		
	No blood supply	0	0	6	9.52		
	Irregular type	34	28.57	6	9.52		

tumor edge, enhanced range, and the scores of elastography had relatively high sensitivity and specificity. The sensitivity and specificity of enhanced strength and enhanced model were relatively low. Similarly, the indicators of blood supply type in three-dimensional ultrasound, vascular distribution in two-dimensional ultrasound and microcalcifications had relative low sensitivity and specificity. The indicators of enhanced order and hyperechoic halo had high sensitivity and low specificity. To comprehensively compare the diagnostic value of different indicators, the receiver operation characteristic (ROC) curve was generated (data not shown) and the area under ROC curve was calculated (Table 1). The area under the ROC curve of tumor edge, enhanced range and enhanced order was all over 0.7, suggesting that these indicators have high diagnostic value. Collectively, this result indicates that the ultrasound indicators of tumor boundary have

diagnostic value than those of tumor internal features and tumor blood supply.

Single factor analysis of the indicators of multi-mode ultrasound

To determine the indicators of multi-mode ultrasound, single factor analysis was performed. As shown in Table 2, the indicators associated with the benign and malignant features of breast lesions were hyperechoic halo, tumor edge, enhanced range, enhanced mode, enhanced order, the scores of elastography, and, blood supply type in three-dimensional ultrasound ($P < 0.05$). The indicators of microcalcifications, vascular distribution in two-dimensional ultrasound, and enhanced strength were not associated with the benign and malignant features of breast lesions ($P > 0.05$). This result indicates that indicators related with tumor boundary and tumor microcircu-

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Table 3. Multiple factor analysis of the indicators of multi-mode ultrasound

Indicators	B value	S.E.	Wals	df	Sig.	OR	95% C.I. of OR	
							Lower limit	Upper limit
Tumor edge			15.644	2	0.0001			
Tumor edge (1)	3.014	1.086	7.699	1	0.006	20.36	2.423	171.095
Tumor edge (2)	4.471	1.138	15.433	1	0.0001	87.44	9.396	813.685
Enhanced mode			10.461	2	0.005			
Enhanced mode (1)	3.753	1.162	10.442	1	0.001	42.665	4.379	415.698
Enhanced mode (2)	2.105	1.1	3.666	1	0.049	8.211	0.952	70.851
Enhanced order	4.337	1.354	10.255	1	0.001	76.48	5.38	1087.243
Score of elastography			9.858	2	0.007			
Score of elastography (1)	2.525	0.92	7.524	1	0.006	12.489	2.056	75.859
Constant	0.636	0.156	16.662	1	0.001	1.889		

Note: B Value, partial regression coefficient; S.E., partial regression coefficient standard errors; OR: odds ratio. Likelihood ratio test, $\chi^2 = 161.876$, $P < 0.0001$, $R^2 = 0.813$. The number "1" in the bracket represents the first dummy variable of the corresponding risk factor and the number "2" in the bracket represents the second dummy variable of the corresponding risk factor.

lation are associated with the benign and malignant features of breast lesions.

Establishment of Logistic regression model

To exclude the influence of confounding factors in single factor analysis, Logistic analysis was performed. The benign and malignant features of breast lesions were used as the dependent variables (0 = No, 1 = Yes). The factors of single factor analysis were used as independent variables. Dummy variables were set up. As shown in **Table 3**, there were 4 kinds of risk factors entered the regression model. Totally 6 risk factors (including dummy variables) entered the regression model. These 6 risk factors included tumor edge feature (2), enhanced order, enhanced mode (1), tumor edge feature (1), scores of elastography (1), and enhanced mode (2). The number "1" in the bracket represents the first dummy variable of the corresponding risk factor and the number "2" in the bracket represents the second dummy variable of the corresponding risk factor. Thus, the risk factors for level 4 BI-RADS malignant breast lesions were as follows (by order of contribution): unclear tumor edge, centripetal enhancement, rapid rise rapid drop enhanced mode, un-intact tumor edge, score 4 of elastography, and, rapid rise slow drop enhanced mode. **Figure 1** showed the representative ultrasound images of a patient with invasive ductal carcinoma and **Figure 2** showed the representative ultrasound images of a patient with fibroadenoma. These images showed that malignant

lesions and benign lesions often had similar internal characteristics and blood supply, such as microcalcifications, blood vessel distribution in two-dimensional and three-dimensional color Doppler, and enhanced strength. However, indicators related with tumor boundary and tumor microcirculation, such as the edge of the lesion, score of elastography, enhanced order, and enhanced mode, were different between malignant lesions and benign lesions. These different factors were consistent with those entered the Logistic regression model.

The Logistic regression prediction model was established as follows: $\text{Logit}(P) = 0.636 + 4.471X1 + 4.337X2 + 3.753X3 + 3.014X4 + 2.525X5 + 2.105X6$. The variable X1 represented unclear tumor edge. X2 represented centripetal enhancement. X3 represented rapid rise rapid drop enhanced mode. X4 represented un-intact tumor edge. X5 represented score 4 of elastography, and X6 represented rapid rise slow drop enhanced mode. Under the premise that other independent variables remain the same, the OR value of this regression model can be explained as follows. The risk for breast cancer in lesions with unclear tumor edge was 87.44 folds higher than that with clear tumor edge. The risk for breast cancer in lesions with centripetal enhancement was 76.48 folds higher than that with overall enhancement or centrifugal enhancement. The risk for breast cancer in lesions with rapid rise rapid drop enhanced mode was 42.655 folds higher than that with slow rise slow drop enhanced mode. The risk for breast cancer in lesions with un-

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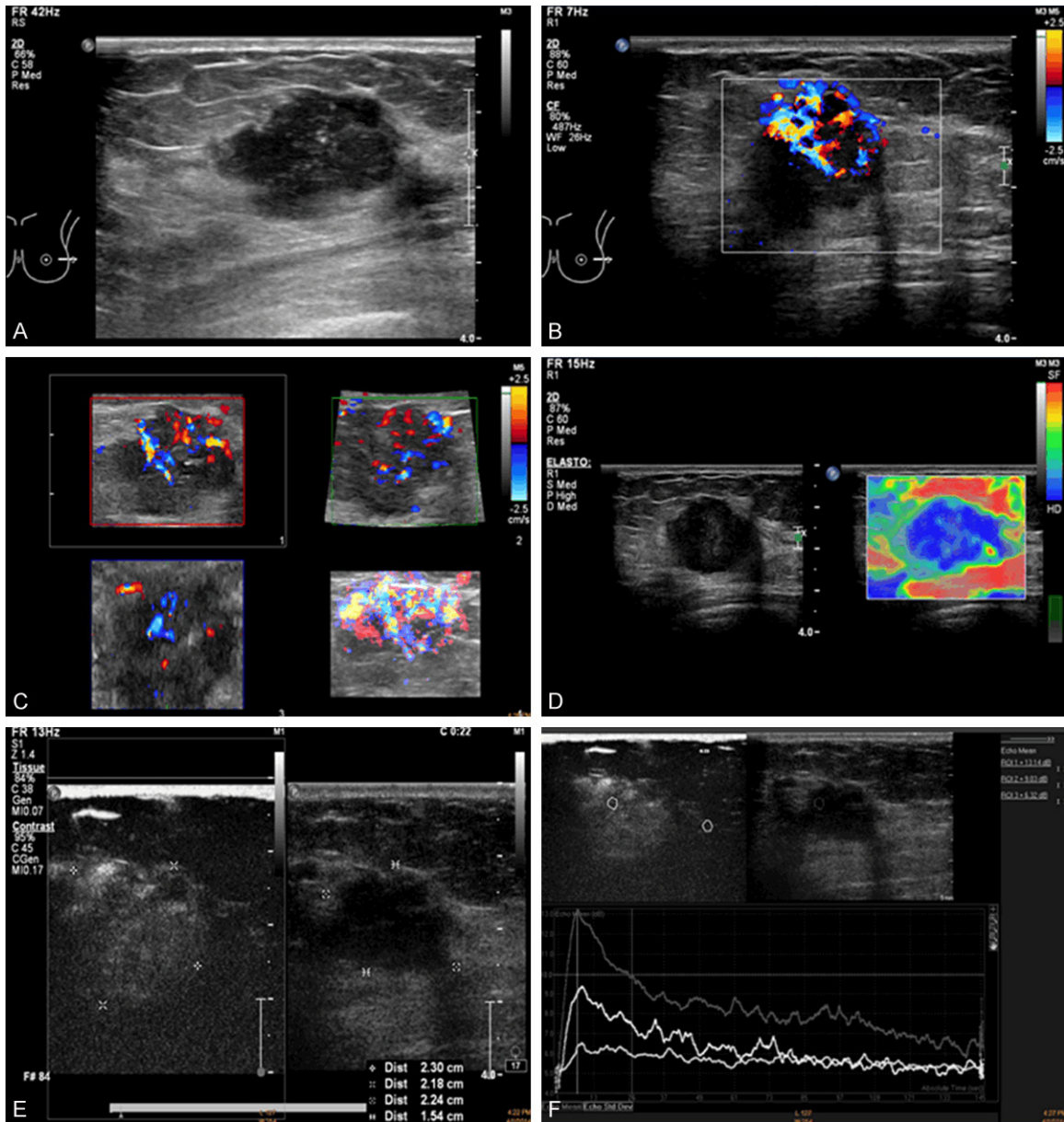


Figure 1. Multi-mode ultrasound images of a breast cancer patient with invasive ductal carcinoma. A. Two-dimensional ultrasound image. The lesion boundary was not clear and was in lobulated shape. There were microcalcifications. No hyperechoic halo was observed. B. Two-dimensional color Doppler images. The blood vessels were rich and were distributed in chaos. C. Reconstructed three-dimensional color Doppler images. The spatial distribution of blood vessels was irregular. D. Image of elastography. The score of this image was 4. The un-deformed area covered the entire range of lesion revealed by two-dimensional ultrasound. E. Image of contrast-enhanced ultrasonography. The range of the lesion enhancement was bigger than that of the two-dimensional ultrasound. Centripetal enhancement was observed. F. Curve image of contrast-enhanced ultrasonography. The enhanced mode showed rapid rise slow drop. High enhancement was observed.

intact tumor edge was 20.36 folds higher than that with intact tumor edge. The risk for breast cancer in lesions with score 4 of elastography was 12.489 folds higher than that with score ≤ 3 of elastography. The risk for breast cancer in lesions with rapid rise slow drop enhanced

mode was 8.211 folds higher than that with slow rise slow drop enhanced mode. This model was statistically significant ($\chi^2 = 161.876$, $P < 0.0001$) as analyzed by likelihood ratio test. $R^2 = 0.813$, indicating the good fitting of this model. This Logistic regression prediction mo-

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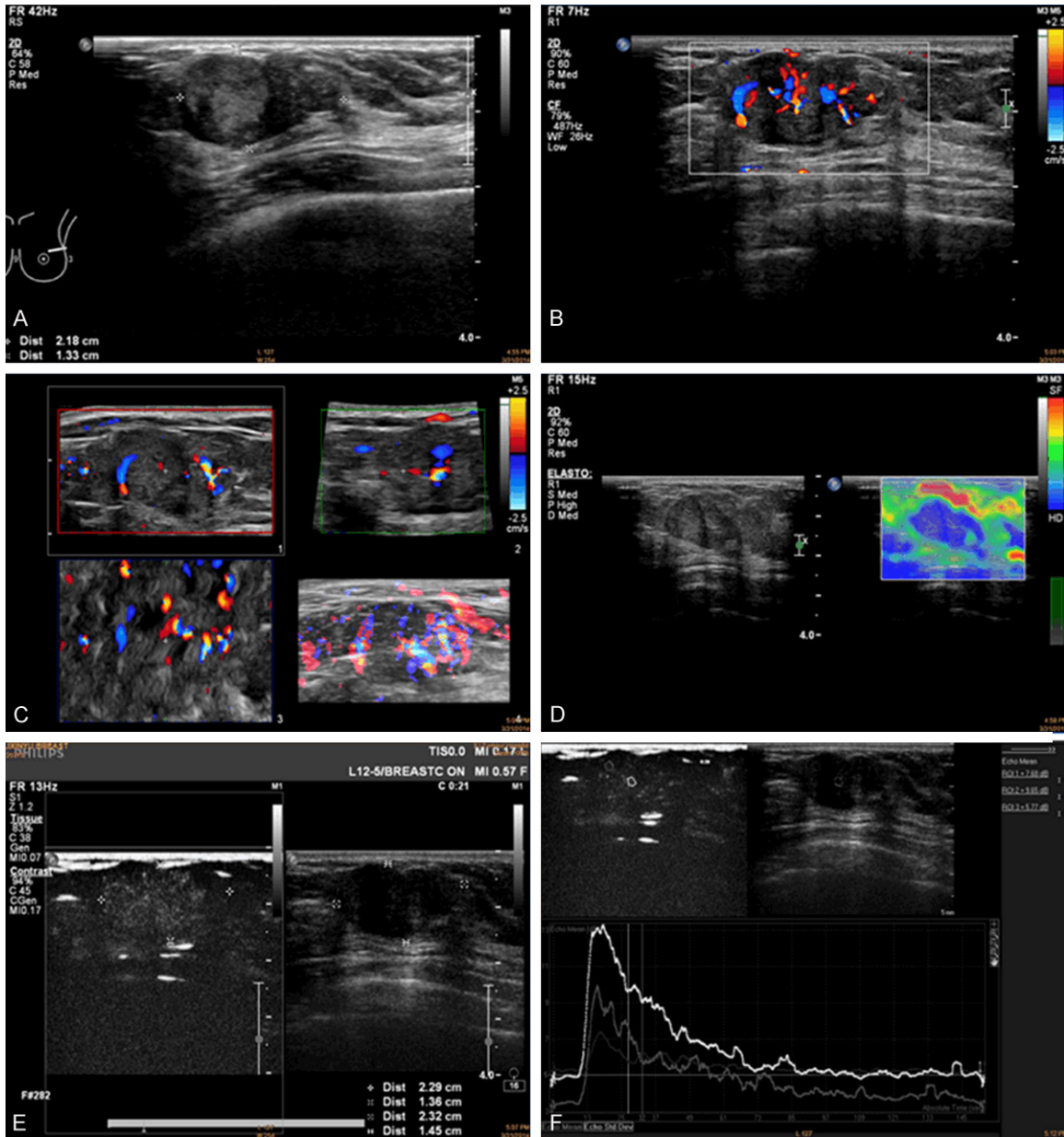


Figure 2. Multi-mode ultrasound images of a breast cancer patient with fibroadenoma. A. Two-dimensional ultrasound image. The lesion was clear and intact. There were microcalcifications. No hyperechoic halo was observed. B. Two-dimensional color Doppler images. The blood vessels were rich and were distributed in chaos. C. Reconstructed three-dimensional color Doppler images. The lesion had embracing blood supply. D. Image of elastography. The score of this image was 3. The size of the un-deformed area was similar to that of the deformed area in the lesion. E. Image of contrast-enhanced ultrasonography. The range of the lesion enhancement was less than that of the two-dimensional ultrasound. Centrifugal enhancement was observed. F. Curve image of contrast-enhanced ultrasonography. The enhanced mode showed rapid rise rapid drop. High enhancement was observed.

del was used to predict the malignancy of 182 breast lesions. The value 0.5 was used as a cutoff point. Lesions with value > 0.5 were considered as malignant whereas lesions with value < 0.5 were considered as benign. Compared with the postoperative pathological diag-

nosis, the accuracy rate of the Logistic regression prediction model was 92.3%. These results indicate that the Logistic regression prediction model could distinguish benign and malignant breast lesions of level 4 BI-RADS breast lesions.

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Table 4. The diagnostic results of different methods

Diagnostic methods	Diagnostic results	Malignant (cases)	Benign (cases)	In total	Sensitivity (%)	Specificity (%)	The positive prediction value	The negative prediction value	The positive likelihood ratio	The negative likelihood ratio	Accuracy	Youden index	The area under the ROC curve
Routine ultrasound	Positive diagnosis	98	23	121	0.82	0.63	0.81	0.66	2.21	0.29	0.76	0.45	0.73
	Negative diagnosis	21	40	61									
Multi-mode ultrasound	Positive diagnosis	117	6	123	0.98	0.9	0.95	0.97	9.8	0.02	0.96	0.88	0.95
	Negative diagnosis	2	57	59									
Logistic regression model	Positive diagnosis	112	7	119	0.94	0.89	0.94	0.89	8.55	0.07	0.92	0.83	0.92
	Negative diagnosis	7	56	63									
Pathological examination		119	63	182									

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Table 5. Comparison of different diagnostic methods

Three-dimensional X ² test		+ (truly positive)			- (truly negative)		
		Multi-mode ultrasound			Multi-mode ultrasound		
		+ (positive)	- (negative)	In total	+ (positive)	- (negative)	In total
Routine ultrasound	+ (positive)	97	1	98	6	17	23
	- (negative)	20	1	21	0	40	40
Logistic regression model	+ (positive)	105	7	112	6	1	7
	- (negative)	2	5	7	3	53	56

Comparison of different diagnostic methods

The diagnostic results of routine ultrasound, multi-mode ultrasound, and Logistic regression model were compared. As shown in **Table 4**, the diagnostic sensitivity of routine ultrasound, multi-mode ultrasound, and Logistic regression model was 0.82, 0.98 and 0.94. The diagnostic specificity of routine ultrasound, multi-mode ultrasound, and Logistic regression model was 0.63, 0.9 and 0.89. The area under the ROC curve of multi-mode ultrasound and Logistic regression model were between 0.9 to 1, much higher than that of routine ultrasound. There was no significant difference in the diagnostic results between multi-mode ultrasound and Logistic regression model.

The diagnostic results of routine ultrasound, multi-mode ultrasound, and Logistic regression model were further compared with three dimensional X² test (**Table 5**). The sensitivity (odds X² = 15.42, P < 0.001) and specificity (odds X² = 15.01, P < 0.001) of multi-mode ultrasound was significantly higher than that of routine ultrasonography. However, no significant difference was found between multi-mode ultrasound and Logistic regression model in the diagnostic sensitivity (odds X² = 1.78, P > 0.05) and specificity (odds X² = 0.25, P > 0.05). These results indicate that the diagnostic value of the Logistic regression model is similar to that of multi-mode ultrasound.

Discussion

In this study, we found that tumor edge, enhanced range and score of elastography had relatively high sensitivity and specificity in diagnosing breast lesions. The cases included in this study were mostly invasive ductal carcinoma. Breast ductal carcinoma shows obvious heterogeneity in histological type and cell differentiation degree, resulting in burr-like tumor

edges [10]. The epithelial-mesenchymal transition of breast cancer can increase microvessel density of tumor edge and the hardness of tumor [11], which is also the reason that the area of enhanced range and the un-deformed area in elastography is greater than that of the two-dimensional ultrasound. The stromal reaction zone rarely appears in benign lesions [12].

Our results also showed that the sensitivity of enhanced range and elastography score was significantly higher than that of hyperechoic halo, suggesting that contrast-enhanced ultrasonography and elastography are better than two-dimensional ultrasonography in evaluating stromal regions of breast cancer. This may be related with the reason that the dense glandular lesions of breast decrease the contrast resolution of two-dimensional ultrasonography on areas with hyperechoic halo [13]. The tumor cell invasion range around tumor edge cannot be observed by two-dimensional ultrasonography. However, through contrast agent perfusion, contrast-enhanced ultrasonography can reveal the whole tumor and the microcirculation around the tumor, display the entire shape of the tumor, and reveal perforator vessels with irregular edges and small lesions, thus more objectively reflecting the actual size of the tumor and the invasion condition of the tumor [14-16]. The formation of hyperechoic halo is dependent on the organization of the invaded area [17]. When the tumor is located in the dense glands, the hyperechoic halo is often difficult to show. And, the hardness by elastography is better than the hyperechoic halo in evaluating the stromal reaction.

Through single factor analysis, we found that the factors related with the benign and malignant feature of breast lesions were hyperechoic halo, tumor edge, enhanced range, enhanced mode, enhanced order, score of elastography, and, vascular distribution in three-dimensional

ultrasound. However, in multiple factor analysis, the three variables of hyperechoic halo, enhanced range, and vascular distribution in three-dimensional ultrasound were excluded. This may be because that these variables affect the diagnosis through the factors of tumor edge, contrast mode, enhanced order, and score of elastography. A total of 6 variables entered the Logistic regression model, including dummy variables. The partial regression coefficients of these variables were positive, indicating that these variables are positively correlated with the malignancy degree of breast lesions. Thus, the risk factors for malignant breast lesion were unclear tumor edge, centripetal enhancement, rapid rise rapid drop enhanced mode, un-intact tumor edge, score 4 of elastography, and, rapid rise slow drop enhanced mode. The Logistic regression model included relatively more ultrasound contrast variables, thus reflecting the superiority of ultrasound contrast more.

The factor of unclear tumor edge was the first variable to enter the Logistic regression model and its odds ratio was 87.44. This means that when other independent variables are constant, the malignant risk of lesions with unclear edge is 87.44 times higher than that of lesions with regular sharp edges. This result was consistent with the diagnostic result of the method using the edge feature as a single indicator, indicating that tumor edge plays an important role in diagnosis of breast lesions. And, the malignant risk of lesions with centripetal enhancement was second to that of lesions with unclear tumor edge. In addition, our results showed that the tumor edge revealed by two-dimensional ultrasound, enhanced order and enhanced mode revealed by contrast ultrasound, and score of elastography had strong correlation with the benign and malignant features of breast lesions. These results suggest that the stromal reaction and microcirculation state of breast lesions are the strongest risk factors associated with the benign and malignant features of breast lesions.

In summary, multi-mode ultrasound and Logistic regression model are better in diagnosing level 4 BI-RADS breast lesions than routine ultrasound. Moreover, the Logistic regression model may diagnose breast lesions more objectively, practically and simply.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (No. 81260332).

Disclosure of conflict of interest

None.

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