Article

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The Value of Color Doppler Ultrasound and Mammography Combined with Tumor Marker Examination in the Diagnosis of Breast Cancer

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Background: Color Doppler ultrasound, mammography and serum tumor marker examination are commonly used tests for diagnosing breast cancer, while the value of individual test is limited. This study explored the clinical significance of these tests in combination, including color Doppler ultrasound, mammography, serum tumor markers, Carbohydrate antigen 153 (CA153), Carcinoembryonic antigen (CEA), and Carbohydrate antigen 125 (CA125) for the diagnosis of breast cancer.

Methods: A retrospective analysis of 80 patients diagnosed with breast cancer and 50 patients with benign breast lesions was performed. These study participants underwent color Doppler ultrasound and mammography, and their serum levels of tumor markers CA153, CEA, and CA125 were assessed using electrochemiluminescence immunoassay.

Results: Color Doppler ultrasound revealed irregular morphology, unclear boundaries, burr sign, posterior echo attenuation, tiny calcifications, aspect ratio $\geq$1, and proportions of blood flow grades II to III in the breast cancer group. The maximum blood flow velocity (Vmax), Resistance index (RI), and Pulse index (PI) of blood flow were significantly higher in the breast cancer group compared to those in the benign control group ($p < 0.01$). Mammography revealed that irregular morphology, unclear boundaries, lobulation signs, and spiculated changes in the tumor, and the proportions of tiny calcifications, granular calcifications, or cast-shaped calcifications were significantly greater in the breast cancer group compared to the benign control group ($p < 0.01$). Furthermore, serum CA153, CEA, and CA125 levels were significantly elevated in the breast cancer group compared to the benign control group ($p < 0.01$). Moreover, the levels of high clinical stage, poor differentiation, distant metastasis, and the levels of Estrogen Receptor (ER)/Progesterone Receptor (PR) negative and human epidermal growth factor receptor 2 (HER2) positive group were significantly greater compared to the benign control group ($p < 0.01$). Additionally, the sensitivity, accuracy and each individual examination of color Doppler ultrasound and mammography in combination with serum CA153, CEA, and CA125 in diagnosing breast cancer were significantly improved ($p < 0.01$), which were 95.00% and 92.31%, respectively.

Conclusion: The combination of ultrasound, mammography, and serum tumor markers CA153, CEA, and CA125 shows promise as a diagnostic approach for breast cancer. While individual tests have limited clinical significance, their combined use can substantially improve diagnostic sensitivity and accuracy, thereby reducing the likelihood of misdiagnosis.

Keywords: breast cancer; color Doppler ultrasound; mammography; serum CA153, CEA, CA125; joint examination

Introduction

Breast cancer is the most common malignant tumor affecting women. Global cancer research data showed that the morbidity and mortality of breast cancer rank first and second, respectively, among female patients with malignant tumors [1]. The recent trends of breast cancer indicate a steady rise in its incidence, with an increasingly younger age of onset, posing severe threats to the physical and mental health of women [2]. Early-stage breast cancer typically shows no distinctive symptoms, resulting in the diagnosis of patients in the middle or advanced stages, ultimately leading to an unfavorable prognosis. Therefore, precise diagnosis and early clinical intervention are pivotal for improving the survival rates and overall quality of life for breast cancer patients.

Imaging is a commonly used screening approach for breast cancer, particularly ultrasound. Ultrasound examinations are simple, convenient, and inexpensive while avoiding radiation damage, making them the preferred method for breast cancer screening. Ultrasound enables high-resolution imaging of soft tissues and remains unaffected by glandular density. However, the efficacy of ultrasound in detecting microcalcifications is relatively limited due to variations in the operator's experience. Mammography X-ray can accurately display the situation of breast calcification, but the operation of mammography X-ray is relatively complex, and involves radiation damage, which has poor diagnostic ability for dense glands and has certain limitations [3,4].

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Serum tumor markers play a crucial role in the occurrence and progression of malignant tumors, among which Carbohydrate antigen 153 (CA153), Carcinoembryonic antigen (CEA), and Carbohydrate antigen 125 (CA125) are closely related to the development of breast cancer [5]. This study uses data from previous clinical cases and aims to retrospectively analyze the diagnostic value of color Doppler ultrasound and mammography X-ray combined with serum examinations of CA153, CEA, and CA125, thereby providing a reference for the future diagnosis of breast cancer.

Materials and Methods

Clinical Materials

This study included data from 80 newly diagnosed breast cancer patients (the breast cancer group) admitted to Jinan City People's Hospital, China, between January 2020 and June 2023. The study participants were females, with an average age of 49.23 $\pm$ 7.05 years. The baseline characteristics, including age and body mass index, are given in Table 1. Based on AJCC clinical guidelines [6], the patients were grouped as follows: 15 patients diagnosed with stage I disease, 21 patients with stage II disease, 30 patients with stage III disease, and 14 patients with stage IV disease. Moreover, based on the degree of differentiation [7], there were 23 patients with well-differentiated tumors, 31 patients with moderately differentiated tumors, and 26 patients with poorly differentiated tumors. The inclusion criteria for study participants were as follows: (1) the patients with complete data required for the clinical analysis, and (2) those who underwent histopathological diagnosis for breast cancer. However, the patients who presented with severe liver or kidney dysfunction and those with tumors in other organs were excluded from this study. Moreover, additional 50 patients with benign breast diseases admitted during the same period were designated as the benign control group. The study participants in this group were all females, with an average age of 48.98 $\pm$ 6.97 years. There was no significant difference in general information, such as sex and age, between the two groups ($p > 0.05$, Table 1), making them comparable.

This retrospective study was approved by the Medical Ethics Committee of Jinan City People's Hospital, China (Approval number: 20230789), ensuring the subject's privacy and confidentiality of identity information and waiving the requirement for patient's informed consent. Furthermore, the study adhered to the Declaration of Helsinki.

Imaging Examinations

Imaging

The diagnostic criteria were based on the classification criteria of the Breast Imaging-Reporting and Data System (BI-RADS) of the American College of Radiology [8].

Table 1. Comparison of the baseline characteristics between the two study groups.

Groups	Cases	Age ($\bar{x} \pm s$)	Body mass index ($\bar{x} \pm s$)
Benign control	50	48.98 $\pm$ 6.97	22.18 $\pm$ 3.57
Breast cancer	80	49.23 $\pm$ 7.05	22.15 $\pm$ 3.62
t	-	0.198	0.046
p	-	0.844	0.903

Color Doppler Ultrasound Examination

We used a PHILIPS Ultrasound diagnostic instrument (EPIQ 7C EXP, Philips Ultrasound Inc., Bothell, WA, USA) and a GE Ultrasound diagnostic instrument (LOGIQ E9, GE Medical Systems Ultrasound and Primary Carc Diagnostics, LLC, Innovation Drive, Wauwatosa, WI, USA), with the probe frequency as 5–12 MHz. For the examination, the patient assumed a supine position, with hands behind the head to fully expose the bilateral breasts and the supraclavicular fossa and bilateral axillary areas. The probe scanned each quadrant of the breast, and the supraclavicular fossa and bilateral axillary regions. First, the location, shape, size, boundary, internal echoes, presence of posterior echo attenuation, calcification, relationship with the surrounding tissues, and presence of axillary and supraclavicular lymph node metastasis were observed by specialists, and then the blood flow signals inside and around the lesions were observed. Similarly, parameters such as morphology and distribution were assessed, and hemodynamic parameters, including maximum blood flow velocity (Vmax), Resistance index (RI), and Pulse index (PI) were measured.

Mammography Target X-Ray Examination

An Italy Gitto digital mammography X-ray system was used for imaging. The patients underwent routine imaging from inside and outside mediolateral oblique (MLO) and craniocaudal (CC) views. For minimal lesions, magnification photography or small compression photography was performed by specialists primarily to evaluate morphology, boundary, calcification, density, and indirect signs of the tumor.

Serum Tumor Marker Examination

The patients in the two groups provided 4 mL fasting venous blood from the cubital vein at 7:00 pm. After self-coagulation at room temperature (25 °C), the upper serum sample was centrifuged at 2264 g (3500 r/min). However, hemolyzed samples were excluded from the study cohort. The levels of CA153, CEA, and CA125 were assessed utilizing electrochemiluminescence immunoassay following the double-antibody sandwich principle. The assay was conducted employing an German Roche Cobas e 602 instrument (Roche, Basel, Switzerland). The diagnostic reagents were obtained from Roche Diagnostics (Roche, Basel, Switzerland), with item No: CA153:07027001190,

Table 2. Comparison of color Doppler ultrasound signs between the two groups (n).

Ultrasound signs		Breast cancer (n = 80)	Benign control (n = 50)	χ^2	p
Tumor morphology	Irregular	58	13	26.841[a]	<0.01
	Rules	22	37		
Boundary	Unclear	60	14	10.39[a]	<0.01
	Clear	20	36		
Spur sign	Yes	56	10	30.777[a]	<0.01
	None	24	40		
Rear echo	Attenuation	60	15	25.527[a]	<0.01
	Enhanced/unchanged	20	35		
Micro calcifications	Yes	57	16	19.252[a]	<0.01
	None	23	34		
Aspect ratio	≥1	53	13	19.944[a]	<0.01
	<1	27	37		
Blood flow	Grades 0–I	18	43	49.816[a]	<0.01
	Grades II–III	62	7		

Note: Compared with the control group, [a]$p < 0.01$.

Table 3. Comparison of color Doppler ultrasound blood flow parameters between the two groups.

	n	Maximum blood flow velocity (Vmax, cm/s)	Resistance index (RI)	Pulse index (PI)
Breast cancer group	80	24.36 ± 5.83[b]	0.83 ± 0.06[b]	1.66 ± 0.25[b]
Benign control group	50	13.79 ± 2.62	0.51 ± 0.05	1.02 ± 0.22
t		12.068	31.481	14.862
p		<0.01	<0.01	<0.01

Note: Compared with the control group, [b]$p < 0.01$.

CEA:07027079190, CA125:07026986190. The reference values were consulted from the manual as follows: CA153 ≤25.00 U/mL, CEA ≤5.00 ng/mL, and CA125 ≤35.00 U/mL.

Interpretation of Data

Utilizing pathological diagnosis as the gold standard, the consistency between the ultrasound, mammography, and pathological diagnosis within the breast cancer group was regarded as true positive, and the inconsistency (misdiagnosis, missed diagnosis, uncertainty) was determined as false-negative. Similarly, the consistency between the diagnosis and pathological diagnosis within the benign breast lesion group was regarded as true negative, and the inconsistency (misdiagnosis and uncertainty) was determined as false-positive. Serum tumor marker levels were considered to be positive if they were higher than the reference values and negative if they were equal to or lower than the reference values. In combination with a joint examination, one or more positive items were considered positive for a diagnosis of breast cancer, and all negative items were considered negative for a diagnosis of breast cancer.

Statistical Analysis

The data were statistically analyzed utilizing SPSS 23.00 software (IBM Corp., Chicago, IL, USA), The measured data conform to a normal distribution and are expressed as mean ± standard deviations. An independent sample t-test was performed to compare the two groups. Moreover, the count data were expressed as rate (%), and the χ^2 test was performed. The diagnostic significance of single and combined examinations of breast cancer was statistically assessed by the four-cell contingency table method. Differences were considered statistically significant at a p-value < 0.05.

Results

Comparison of Color Doppler Ultrasound Signs between the Two Groups

The color Doppler ultrasound images from breast cancer patients are shown in Fig. 1. Color Doppler ultrasound revealed irregular morphology, unclear boundaries, spur signs, posterior echo attenuation, tiny calcifications, an aspect ratio ≥1, and a proportion of blood flow grades II to III in the breast cancer group (Table 2). The blood flow parameters Vmax, RI, and PI were significantly higher in the breast cancer group compared to the benign control group ($p < 0.01$, Table 3). The color Doppler ultrasound images of breast cancer patients are shown in Fig. 1.

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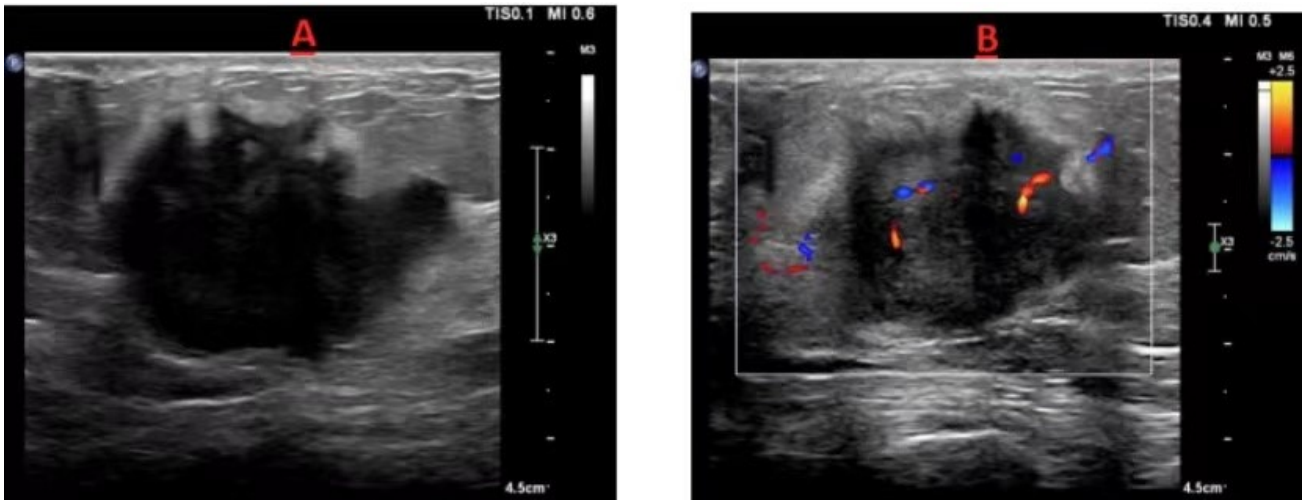

Fig. 1. Ultrasonographic evaluation of breast. (A) A 2-dimensional ultrasound image showing a solitary mass in the right breast with a size of approximately 3.7 × 3.6 × 2.7 cm, an irregular shape, a "crab-like" change, fuzzy edges, and burrs. The internal echoes were uneven, and hypoecho and spot-like strong echoes were observed. (B) Color Doppler flow imaging (CDFI) showed abundant blood flow signal within the tumor, with a Resistance index (RI) of 0.8. The diagnostic outcomes of color Doppler ultrasound indicated Breast Imaging-Reporting and Data System (BI-RADS) level 5.

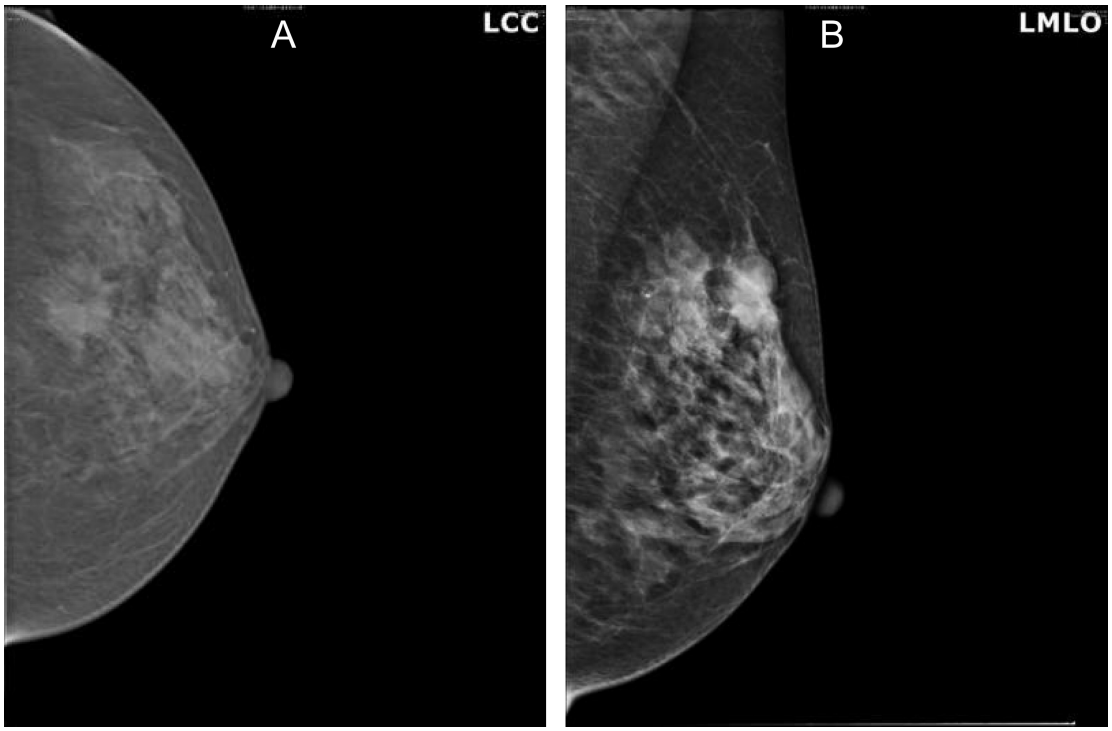

Fig. 2. Mammographic examination. (A) Craniocaudal (CC) views. (B) Mediolateral oblique (MLO) views. A mass was observed on the outer surface of the left breast, the size of the mass was approximately 3.0 × 2.5 cm, the edges were unclear, and the lobulation sign and elongated spur-like changes were observed. The diagnostic outcomes of mammography indicated Breast Imaging-Reporting and Data System (BI-RADS) level 5.

Comparison of the Mammography X-Ray Diffraction Results between the Two Groups

The mammography images from the breast cancer group showed irregular morphology, unclear boundaries, lobulation signs, and spiculated changes. Furthermore, the proportions of tiny calcifications, granular calcifications, and cast-shaped calcifications were significantly greater in the tumor group compared to the benign control group ($p < 0.01$, Table 4). The mammography X-ray images of breast cancer patients are shown in Fig. 2.

Table 4. Comparison of the mammography X-ray data between the two groups (n).

Mammographic radiographs		Breast cancer (n = 80)	Control (n = 50)	χ^2	p
Tumor morphology	Irregular	56	12	26.099[c]	<0.01
	Rules	24	38		
Boundary	Unclear	58	15	22.573[c]	<0.01
	Clear	22	35		
Lobulation sign	Yes	52	8	29.727[c]	<0.01
	None	28	42		
Spur sign	Yes	54	9	30.186[c]	<0.01
	None	26	41		
Micro calcifications	Yes	53	15	16.208[c]	<0.01
	None	27	35		
Granular point or cast-shaped calcification	Yes	49	10	21.122[c]	<0.01
	None	31	40		

Note: Compared with the control group, $^c p < 0.01$.

Table 5. Comparison of serum tumor marker levels between the two groups.

Groups	n	CA153 (U/mL)	CEA (ng/mL)	CA125 (U/mL)
Breast cancer group	80	68.25 ± 12.03^d	26.57 ± 5.26^d	97.26 ± 20.15^d
Benign control group	50	15.23 ± 4.27	3.34 ± 0.39	22.37 ± 5.08
t		29.972	31.129	25.732
p		<0.01	<0.01	<0.01

Note: Compared with the control group, $^d p < 0.01$. CA153, Carbohydrate antigen 153; CEA, Carcinoembryonic antigen; CA125, Carbohydrate antigen 125.

Comparison of Serum Tumor Marker Levels between the Two Groups

The serum levels of CA153, CEA, and CA125 were significantly elevated in the breast cancer group compared to the benign control group ($p < 0.01$, Table 5).

Analysis of Different Clinicopathological Factors in the Breast Cancer Group: Comparison of CA153, CEA, and CA125 Levels

Serum levels of CA153 and CEA in breast cancer patients with high clinical stage, low differentiation, distant metastasis, and negative Estrogen Receptor/Progestrone Receptor but positive epidermal growth factor receptor 2 were significantly higher compared to those in patients with low clinical stage, high differentiation, absence of distant metastasis, positive Estrogen Receptor (ER)/Progesterone Receptor (PR) but negative human epidermal growth factor receptor 2 (HER2) ($p < 0.01$, Table 6).

Comparison of the Results from Color Doppler Ultrasound, Mammography, Tumor Marker Examination, and Pathological Diagnosis between the Two Groups

Analysis of the diagnostic significance of color Doppler ultrasound, molybdenum target X-ray, tumor marker single and their combined examinations for breast cancer was performed using the contingency table method, as shown in Table 7.

Comparison of the Diagnostic Value of Color Doppler Ultrasound, Mammography, and Tumor Markers Individually and in Combination with Breast Cancer Patients

The contingency table method was employed to evaluate the diagnostic significance of color Doppler ultrasound, mammography, and tumor markers alone and in combination (Table 8).

Discussion

Breast cancer is the most common malignant tumor worldwide and is one of the leading causes of cancer-related death in women. Relapse and metastasis are the predominant factors in the death of breast cancer patients. Therefore, a precise diagnosis of breast cancer is particularly important [9]. The pursuit of achieving an early and precise diagnosis of breast cancer while avoiding missed diagnoses has been a challenging and demanding focus within the medical community.

Color Doppler ultrasound, a commonly used screening method for breast cancer, offers advantages, including high resolution for soft tissue, convenience, cost-effectiveness, and absence of radiation damage, making it useful for breast cancer patients. The preferred examination method for tumors includes evaluating different aspects such as shape, edge, aspect ratio, echo, calcification, and more through two-dimensional ultrasound images [10].

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Table 6. Comparison of CA153, CEA, and CA125 levels in serum samples from patients with different clinicopathological factors in the breast cancer group.

Parameters	n	CA153 (U/mL)	*t*	*p*	CEA (ng/mL)	*t*	*p*	CA125 (U/mL)	*t*	*p*
Tumor size										
≤2 cm	38	67.34 ± 11.58^{e}	0.65	0.517	27.05 ± 5.32^{e}	0.784	0.436	97.15 ± 20.19^{e}	0.046	0.963
>2 cm	42	69.07 ± 12.15			26.14 ± 5.06			97.36 ± 20.22		
Age (years)										
≤50	35	67.98 ± 11.65^{e}	0.178	0.859	25.97 ± 5.11^{e}	0.872	0.385	98.59 ± 20.55^{e}	0.518	0.606
>50	45	68.46 ± 12.22			27.04 ± 5.68			96.23 ± 19.97		
Clinical stage										
I~II	36	55.15 ± 9.13	8.873	0.000	20.80 ± 4.63	7.894	0.000	80.74 ± 15.67	6.204	0.000
III~IV	44	81.02 ± 15.41^{f}			31.29 ± 6.78^{f}			110.78 ± 25.34^{f}		
Differentiation										
High	54	57.16 ± 8.13	13.04	0.000	14.70 ± 2.97	28.42	0.000	71.69 ± 12.35	18.01	0.000
Poorly	26	91.28 ± 15.32^{f}			51.23 ± 8.42^{f}			150.37 ± 26.87^{f}		
Distant metastasis										
None	66	59.13 ± 8.72	15.48	0.000	16.91 ± 3.26	36.62	0.000	81.20 ± 18.34	15.58	0.000
Yes	14	111.24 ± 20.13^{f}			72.13 ± 10.22^{f}			172.39 ± 26.34^{f}		
ER										
Negative	32	79.27 ± 13.25^{f}	8.483	0.000	35.47 ± 6.35^{f}	12.67	0.000	112.97 ± 25.44^{f}	5.736	0.000
Positive	48	57.05 ± 10.14			20.64 ± 4.13			86.79 ± 15.39		
PR										
Negative	30	75.32 ± 14.03^{f}	3.614	0.000	31.20 ± 5.98^{f}	5.088	0.000	105.23 ± 24.12^{f}	2.675	0.000
Positive	50	65.11 ± 11.03			23.79 ± 5.12			92.48 ± 18.27		
HER2										
Negative	58	63.14 ± 10.29	5.884	0.000	22.16 ± 4.32	13.02	0.000	87.41 ± 16.79	7.206	0.000
Positive	22	81.69 ± 17.36^{f}			38.21 ± 6.27^{f}			123.24 ± 26.45^{f}		

Note: Comparisons within the groups: $^{e}p > 0.05$; $^{f}p < 0.01$. ER, Estrogen Receptor; PR, Progestrone Receptor; HER2, human epidermal growth factor receptor 2.

Table 7. Comparison of the results from color Doppler ultrasound, mammography, tumor marker examination, and pathological examination between the two groups (n).

Parameters	Test results	Pathological diagnosis	
		Malignant	Benign
Ultrasound	Positive	58	4
	Negative	22	46
Mammography target X-ray	Positive	55	5
	Negative	25	45
CA153	Positive	47	2
	Negative	33	48
CEA	Positive	40	1
	Negative	40	49
CA125	Positive	43	2
	Negative	37	48
Joint detection of five indicators	Positive	76	6
	Negative	14	44

Additionally, blood flow parameters such as Vmax, Resistance index (RI), and Pulse index (PI) offer clear hemodynamic information, enabling comprehensive analysis to distinguish between benign and malignant lesions [11,12]. Ultrasound demonstrates strong diagnostic capability for invasive ductal carcinoma, especially in dense breast lesions [13]. Our ultrasound findings in the breast cancer group revealed several features like irregular morphology, irregular boundaries, spiculated signs, posterior echo attenuation, presence of microcalcifications, aspect ratio ≥1, proportion of blood flow grades II to III, and blood flow parameters Vmax and RI. The PI was significantly elevated compared to that in the benign control group ($p < 0.01$). However, the ability of ultrasound to capture images of the entire breast simultaneously is limited, and the diagnostic results strongly rely on the quality of the equipment and the expertise of the diagnostic physician. Moreover, ultrasound exhibits a reduced detection rate for tiny calcifications. Additionally, ultrasound helps detect early-stage lesions, particularly those without apparent masses or with only local structural distortion. Breast cancer is difficult to detect, often leading to missed or misdiagnosis cases [14]. The findings of this study showed that the sensitivity of color Doppler ultrasound in the diagnosis of breast cancer was 72.50%, indicating the limited utility of a single examination approach.

Mammography examination offers several advantages, such as its capability to capture images of the entire breast, enhance global awareness, and alleviate the chance of tumor misdiagnosis. Therefore, it is a commonly em-

Table 8. Comparison of the diagnostic value of color Doppler ultrasound, mammography, and tumor markers individually and in combination [% (n)].

Detection indicators	Sensitivity	Specificity	Accuracy	Positive predictive value	Negative predictive value
Ultrasound	72.50 (58/80)	92.00 (46/50)	87.69 (114/130)	93.55 (58/62)	67.65 (46/68)
Mammography target X-ray	68.75 (55/80)	90.00 (45/50)	76.92 (100/130)	96.67 (55/60)	64.29 (45/70)
CA153	58.75 (47/80)	96.00 (48/50)	73.08 (95/130)	95.92 (47/49)	59.26 (48/81)
CEA	50.00 (40/80)	98.00 (49/50)	68.46 (89/130)	97.56 (40/41)	55.06 (49/89)
CA125	53.75 (43/80)	96.00 (48/50)	70.00 (91/130)	95.56 (43/45)	56.47 (48/85)
Joint detection of five indicators	95.00 (76/80)^{g}	88.00 (44/50)	92.31 (120/130)^{g}	92.68 (76/82)	75.86 (44/58)
χ^2	35.397	6.214	36.679	2.319	8.995
p	<0.01	>0.05	<0.01	>0.05	>0.05

Note: Compared with each individual examination, $^{g}p < 0.01$.

ployed screening method for early breast cancer [15]. In particular, mammography exhibits high sensitivity in diagnosing early-stage breast cancer, with calcification lesions serving as the malignant sign. It can achieve a high detection rate of characteristic calcification lesions, particularly in patients with intraductal carcinoma [16]. Our study showed that mammography revealed irregular morphology, unclear boundaries, lobulation signs, and spiciclelike changes. Moreover, the proportions of tiny calcifications, granular dots, and cast-shaped calcifications were higher in the breast cancer group than in the benign control group ($p < 0.01$). However, the resolution of tissue density of mammography is limited, and its diagnostic efficacy is slightly reduced in dense breast tissue due to the covering of the lesions by the glands [17]. Furthermore, mammography poses a risk of radiation damage, and lesions located within the deep part of the breast or near the chest wall may be difficult to visualize due to limitations in imaging. Additionally, early-stage breast cancer lacking calcification manifestations and masses near the chest wall can easily be missed [18]. The findings of mammography showed a sensitivity of 68.75% in diagnosing breast cancer, indicating that the outcomes of individual examinations remained unsatisfactory.

Tumor markers are substances produced during the occurrence and development of malignant tumors, and can be secreted into the peripheral blood. Serum tumor marker examination, serving as an *in vitro* noninvasive liquid biopsy diagnostic technique, is widely used to screen malignant tumors [19]. CA153, a member of the mucin family and a cell surface glycoprotein molecule, is an early marker used in the screening of breast cancer. When cells undergo malignant transformation, the activity of proteases and salivary enzymes on the cell membrane increases, disrupting the cytoskeleton, and releasing cell membrane components into the blood, consequently increasing the level of CA153. Therefore, CA153 is a common specific marker for breast cancer [20]. The serum CA153 level in patients with early-stage breast cancer is abnormally increased. Furthermore, it is related to the expression of tissue ER, PR, and HER2, the degree of differentiation, and the TNM stage [21].

CEA, an acidic glycoprotein possessing human embryonic antigen characteristics, can be found on the surface of cancer cells as a cell membrane structural protein and can be released into the peripheral fluid. It has been used in the early screening of various malignant tumors [22], serving as a non-specific tumor marker. CEA is commonly used in the diagnosis of malignant gastrointestinal tumors; nevertheless, it has also been found on the surface of breast epithelial cells, displaying high expression levels in breast cancer patients [23]. It has been reported that CEA possesses an excellent predictive capability for tumor metastasis [24]. CA125, a glycoprotein detected by an epithelial ovarian cancer antigen, shows high expression in nonmucinous ovarian tumors of epithelial origin. Recent advancements in clinical medical research have revealed the presence of CA125 in breast cancer cells, indicating its potential as a diagnostic marker for breast cancer [25]. Evidence revealed that CA125 plays a significant role in the development of breast cancer in patients and can provide a reference basis for clinical prognosis [26]. Specifically, CA125 levels also increase with the recurrence and metastasis of breast cancer patients.

Our study showed that the sensitivities of serum CA153, CEA, and CA125 for diagnosing breast cancer were 58.75%, 50.00% and 53.75%, respectively. It is evident that single-item testing alone may not sufficiently meet clinical needs. Furthermore, while color Doppler ultrasound, mammography, serum CA153, CEA, and CA125 can all serve as diagnostic methods for breast cancer, each method has limitations. Nevertheless, combining these approaches can complement and validate each other, significantly improving sensitivity and accuracy in the diagnosis of breast cancer to 95.00% and 92.31%, respectively. Consequently, this method reduces the occurrence of false and missed diagnoses, facilitating early diagnosis of breast cancer.

Despite the promising findings, it is crucial to acknowledge several inherent limitations in this study, including the relatively small number of study participants. In the future, it is required to expand the sample size and continue the research to improve its clinical significance.

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Conclusion

The integration of color Doppler ultrasound, molybdenum target X-ray, and serum examinations for CA153, CEA, and CA125 can significantly enhance the sensitivity and accuracy of breast cancer diagnosis. By analyzing the levels of these serum tumor markers, it is possible to predict the clinical stage of tumors, their degree of differentiation, and the presence of distant metastasis. Consequently, this informs the clinical treatment plan and aids in prognostic assessments.

Availability of Data and Materials

All experimental data included in this study can be obtained by contacting the first author if needed.

Author Contributions

ML and QLG designed the retrospective research. GHW performed the research and analyzed all the data gleaned. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This retrospective study was approved by the Medical Ethics Committee of Jinan City People's Hospital, China (Approval number: 20230789), ensuring the subject's privacy and confidentiality of identity information and waiving the requirement for patient's informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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