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Original Article

Two-dimensional speckle tracking imaging and tissue Doppler imaging can predict subclinical left ventricular systolic and diastolic dysfunctions after chemotherapy for breast cancer

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Abstract: Objective: This research primarily analyzes the clinical application of two-dimensional speckle tracking imaging (2D-STI), real-time 3-dimensional echocardiography (RT-3DE), and tissue Doppler imaging (TDI) in evaluating left ventricular dysfunction associated with breast cancer (BC) chemotherapy-related cardiotoxicity. Methods: First, we selected 106 BC patients who received treatment in The Affiliated Hospital of Chengde Medical University as the research group, all of whom underwent anthracycline-based chemotherapy; another 100 healthy subjects were chosen as the control group. Conventional ultrasound was employed to detect the mitral annular plane systolic excursion (MAPSE), mitral valve orifice early diastolic blood flow velocity (E), and left atrial volume index (LAVI) in the study subjects. 2D-STI was utilized to measure the global longitudinal strain (GLS) of the left ventricle, RT-3DE to measure left ventricular ejection fraction (LVEF), and TDI to measure the ratio of E to the average early diastolic mitral annulus velocity (E/e'), as well as systolic and early diastolic tissue velocities at the lateral wall of the mitral annulus and the ventricular septum (lateral s', septal s', lateral e', and septal e'). Left ventricular dysfunction was analyzed in both groups, and potential influencing factors were discussed. Results: The data revealed markedly lower GLS, MAPSE, E, lateral e', and septal e' in the research group compared to the control group. GLS<15.02% and LVEF<53% were defined as left ventricular systolic dysfunction. In comparison with the control group, the GLS and LVEF abnormality rates were evidently higher in the research group. No left ventricular diastolic dysfunction was observed in patients in both groups. Additionally, the dose of anthracyclines was a potential influencing factor for left ventricular dysfunction. Conclusions: 2D-STI and TDI have certain predictive implications for the occurrence of subclinical left ventricular systolic and diastolic dysfunctions after BC chemotherapy. Furthermore, high-dose anthracyclines might lead to left ventricular dysfunction.

Keywords: Two-dimensional speckle tracking imaging, tumor chemotherapy, cardiotoxicity, ventricular function, clinical research

Introduction

Breast cancer (BC) is a common tumor that wields a substantial influence on women's health, featuring four subtypes and a high degree of heterogeneity [1]. According to relevant epidemiological data, the number of new BC cases soared to as high as 2.3 million in 2020, and the number of deaths from BC was estimated at 700,000; furthermore, the risk of BC onset escalates with age [2, 3]. Surgery, chemotherapy, radiotherapy, and molecularly targeted endocrine therapy are all treatment options for BC patients. Early and effective interventions can raise the 5-year survival rate of BC patients to approximately 80.0% [4, 5]. Currently, anthracyclines constitute the main choice for first-line chemotherapy regimens for BC, including adriamycin, pirarubicin, daunorubicin, idarubicin, and other broad-spectrum anticancer drugs; although their therapeutic effect is definite, they may give rise to adverse

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reactions such as arrhythmia, heart failure, myocardial injury, alopecia, and anemia [6, 7]. Moreover, ventricular dysfunction related to cardiac insufficiency constitutes the principal cause of chemotherapy-related deaths in postmenopausal BC patients. Prompt detection and interventions of early cardiac insufficiency contribute significantly to prolonging patients' survival, which has considerable implications for improving their clinical outcomes [8].

Two-dimensional speckle tracking imaging (2D-STI), as a non-Doppler technique, can provide biomechanical parameters representing left ventricular myocardial deformation (strain), like global longitudinal strain (GLS) [9, 10]. In comparison with conventional echocardiography, its application in patients with preserved ejection fraction can realize early identification of subclinical myocardial dysfunction more sensitively, in addition to benefiting the evaluation of chemotherapy-induced myocardial deterioration and cardiotoxicity [11]. Real-time three-dimensional echocardiography (RT-3DE) can provide real-time dynamic 3D images of the heart without depending on specific geometric assumptions. It exhibits higher accuracy and repeatability compared to conventional echocardiography and is also applicable for the assessment of anthracycline-related left ventricular dysfunction in children [12, 13]. Tissue Doppler imaging (TDI) can effectuate rapid assessment of myocardial function with less impact from volume load and ventricular filling pressure, demonstrating a prominent ability in the assessment of left ventricular diastolic function [14]. TDI also has great potential in the evaluation of anthracycline-related cardiotoxicity in childhood cancer survivors through assessing the subtle signs of their myocardial injury, which is conducive to initiating early preventive intervention for patients at risks [15].

The clinical application of 2D-STI, RT-3DE, and TDI in the prediction of left ventricular dysfunction from chemotherapy-related cardiotoxicity in BC is still limited. The majority of existing studies have primarily centered on the prediction in this regard using a solitary technique, rather than undertaking a comprehensive horizontal comparison of the predictive capabilities among multiple techniques [16-18]. This very aspect constitutes the innovative essence of our present study. Our research aims to discern the pros and cons of several imaging techniques so as to supplement the evidence for predicting anthracycline-related ventricular dysfunction in BC patients.

Clinical data

Patients' selection

After gaining approval from the Ethics Committee of The Affiliated Hospital of Chengde Medical University, a total of 106 BC patients admitted to the same hospital were selected as the research group, all of whom received anthracycline-based chemotherapy schemes; an additional 100 healthy individuals were enrolled as the control group. All clinical data employed in this retrospective study were retrieved from the medical record system of the hospital.

Inclusion criteria: Patients were eligible for enrollment if they were confirmed with BC prior to the onset of the study by histopathology [19]; they did not receive any treatment previously; their 2D-STI, RT-3DE, and TDI ultrasound images were clear and usable, and met the requirements of acquisition and analysis; their routine blood test results, liver and kidney functions, and electrocardiogram results were normal before medication; they underwent anthracycline chemotherapy only; they survived asymptomatically for 1-17 years; they had no significant abnormalities in the conventional echocardiogram before the first chemotherapy (no obvious segmental wall motion abnormalities); they had no other diseases that might affect their cardiac functions; their clinical data were complete.

Exclusion criteria: Patients were excluded from the study if they were pregnant or lactating; they had hypertension and cardiovascular diseases such as coronary heart disease, myocardial infarction, persistent atrial fibrillation, severe arrhythmia, and cardiomyopathy that were uncontrollable by medication; they had metabolic diseases like hyperthyroidism and diabetes; they needed concurrent radiotherapy during chemotherapy; they were complicated with other malignant tumors; they had multiple distant metastases and an inability to complete the entire chemotherapy cycle; they showed contraindications to the study drugs or allergic constitution; they had coagulation disorders. The flowchart of the selection process is shown in **Figure 1**.

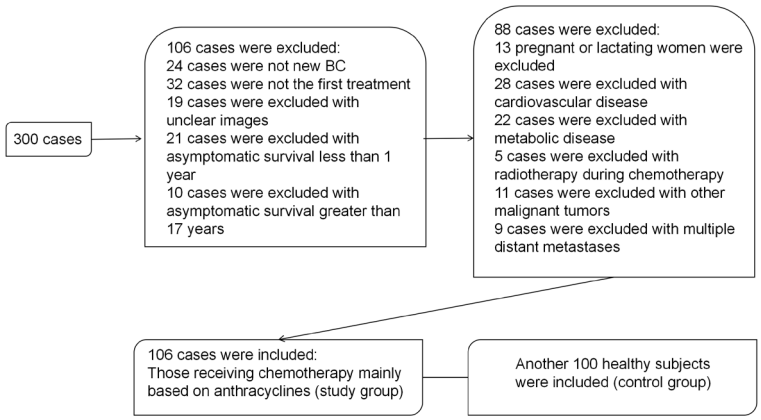

Figure 1. The flowchart of patients' selection. BC, breast cancer.

Treatment methods

Patients in the research group received anthracycline-based chemotherapy schemes: 90 mg/m^2 of Epirubicin (E) and 600 mg/m^2 of Cyclophosphamide (C) (total dose less than 1000 mg) were intravenously injected on the first day, with 21 days as a cycle and a total of 4 cycles, sequenced or not sequenced with Docetaxel (T) and Trastuzumab (H).

Data extraction

In this research, clinical data were retrieved from the hospital's medical record system. The main data extracted are detailed as below:

(1) Acquisition of parameters from conventional echocardiography. The Philips EPIQ 7C ultrasonic diagnostic instrument and S5-1 probe were used, with the frequency set as 1-5 MHz. The subject was instructed to lie on the left side and breathe calmly to be connected to the synchronous electrocardiogram. The mitral annular plane systolic excursion (MAPSE) was measured using the M mode in the apical four-chamber view of transthoracic echocardiogram, and the mitral valve orifice early diastolic blood flow velocity (E) was measured in the apical four-chamber view; the left atrial volume index (LAVI) was measured using the biplane Simpson's method.

(2) Acquisition and analysis of 2D-STI images. Images of three consecutive cardiac cycles were collected in the apical four-chamber, apical two-chamber, and apical left ventricular long-axis views, which were subsequently imported into the QLAB8.1 offline analysis software. Under the CMQ mode, sampling points were placed on the left ventricular lateral wall of the mitral annulus, interventricular septum, and left ventricular apex when the endocardium and epicardium were the clearest. The software automatically traced the endocardium and epicardium curves and adjusted the curve range to make the width of the region of interest consistent with the thickness of the ventricular wall, so that the longitudinal peak systolic strains of 18 segments of the left ventricle could be obtained. The absolute value of the average value was defined as GLS. The 2D-STI image examples of the subjects are presented in **Figure 2**.

(3) Acquisition and analysis of RT-3DE images. The X3-1 matrix-array probe with a frequency of 1-3 Mhz was used. Then, the "Full Volume" imaging mode was activated, and the full-volume 3-dimensional images of the left ventricle for four consecutive cardiac cycles were collected in the apical four-chamber view, which were then imported into the QLAB8.1 offline analysis software with its 3DQ-Advanced mode being turned on. The software automatically generated three orthogonal sections. The position of the sections was adjusted, and the left ventricular endocardial curves were semi-automatically delineated at end-diastole and end-systole, respectively. The software could automatically obtain the time-volume curve and calculate the left ventricular ejection fraction (LVEF).

(4) TDI parameters. In the TDI imaging mode, the mitral annular lateral systolic peak velocity (lateral s') and early diastolic velocity (lateral e'), as well as the peak systolic velocity (septal s') and early diastolic velocity (septal e') of the ventricular septum of the mitral annulus were measured in the apical four-chamber view, and the ratio of E to the average early diastolic velocity of the mitral annulus (E/e') was calculated.

(5) Left ventricular systolic and diastolic dysfunctions. Because there are different kinds of

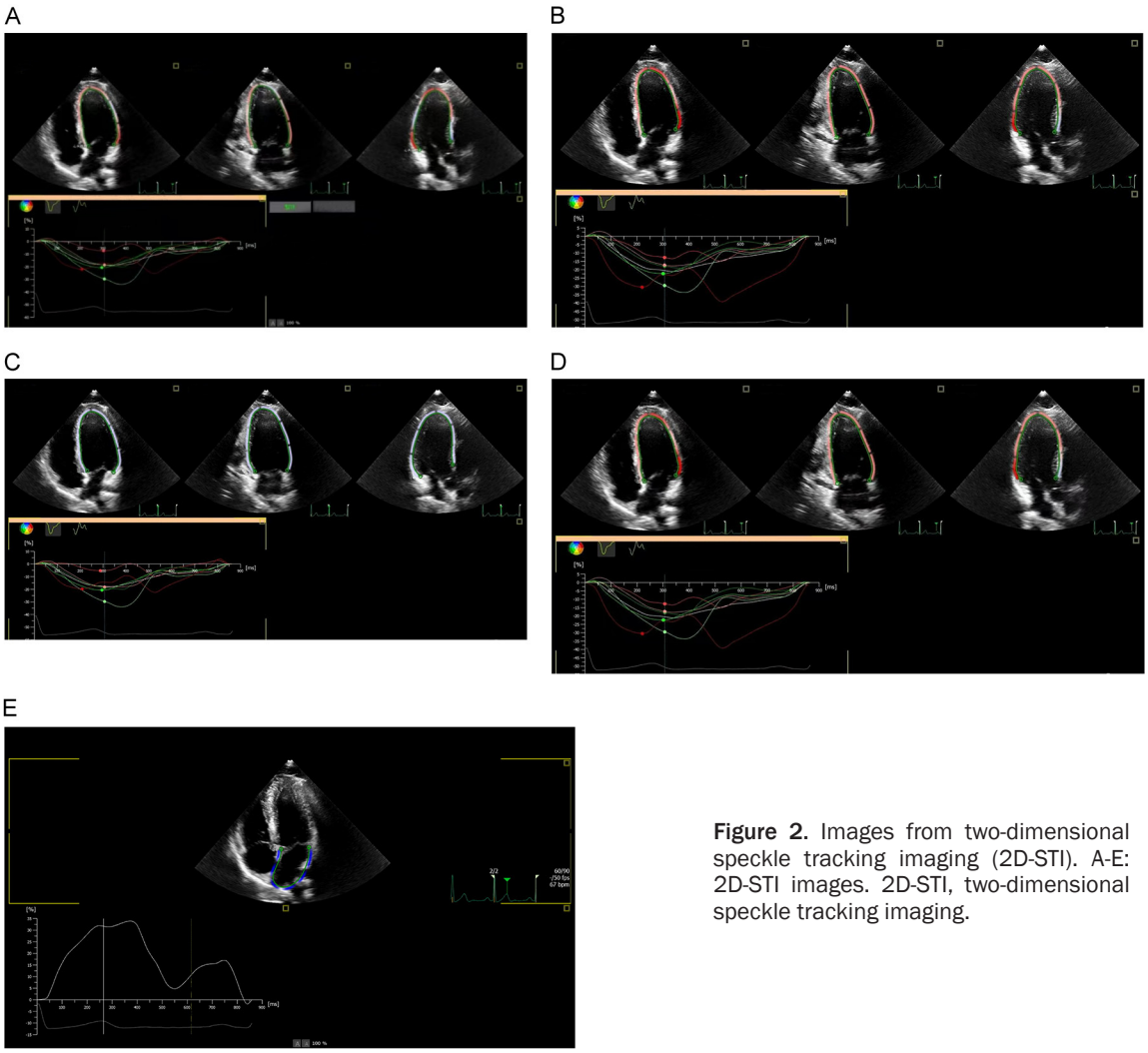

Figure 2. Images from two-dimensional speckle tracking imaging (2D-STI). A-E: 2D-STI images. 2D-STI, two-dimensional speckle tracking imaging.

software and instruments for analyzing GLS values, there is no internationally unified normal range for defining left ventricular systolic and diastolic dysfunctions at present. Therefore, a GLS value less than $\bar{x}$-1.96 s of individuals in the control group (where $\bar{x}$ is the mean value and s is the standard deviation) is defined as left ventricular systolic dysfunction. According to the updated consensus of the "Guidelines for Echocardiographic Evaluation of Left Ventricular Diastolic Function" issued by the American Society of Echocardiography and the European Association of Cardiovascular Imaging in 2016 [20], left ventricular diastolic dysfunction was determined when three or more of the following indicators exceeded critical values: lateral' <10 cm/s or septal e'<7 cm/s, maximum tricuspid regurgitation velocity >2.8 m/s, maximum left atrial volume index (LAVI) >34 mL/m^2, and E/e'>14.

Outcome measures

In the present study, the primary outcome measures were GLS, LVEF, lateral s', lateral e', septal s', septal e', and E/e'. The secondary measures consisted of MAPSE, E, and LAVI. All of these indices were measured after the fourth cycle of chemotherapy. We extracted the aforementioned data to validate the predictive potential of 2D-STI, RT-3DE, and TDI for the occurrence of left ventricular dysfunction in BC chemotherapy-related cardiotoxicity and to analyze potential influencing factors of left ventricular dysfunction. Our objective in this study was to ascertain the predictive potential of 2D-STI, RT-3DE, and TDI in relation to left ventricular systolic or diastolic dysfunctions in BC chemotherapy-related cardiotoxicity and to unearth the potential influencing factors of left ventricular dysfunction.

Table 1. Analysis of general data between the two groups

Indicators	Research group (n=106)	Control group (n=100)	χ^2/t	P
Age (years old)	51.77±6.77	51.04±6.51	0.788	0.432
Body mass index (kg/m^2)	23.57±2.28	23.47±1.94	0.338	0.736
Body surface area (m^2)	1.51±0.15	1.50±0.13	0.510	0.611
Diastolic blood pressure (mmHg)	75.42±5.92	74.62±4.72	1.068	0.287
Systolic blood pressure (mmHg)	119.03±10.01	115.48±56.46	0.637	0.525
Dose of anthracyclines (mg/m^2)	296.18±67.29	-	-	-
Hypertension			-	-
No	90 (84.91)	-		
Yes	16 (15.09)	-		
Diabetes			-	-
No	94 (88.68)	-		
Yes	12 (11.32)	-		
Hyperlipidaemia			-	-
No	91 (85.85)	-		
Yes	15 (14.15)	-		

Table 2. Comparison of indicators for assessing left ventricular systolic function between the two groups

Indicators	Research group (n=106)	Control group (n=100)	t	P
GLS (%)	15.46±1.60	17.27±1.04	9.565	<0.001
LVEF (%)	62.31±7.22	63.40±6.05	1.171	0.243
MAPSE (cm)	1.49±0.19	1.7±0.14	8.989	<0.001
Lateral s' (cm/s)	9.74±1.96	9.38±1.81	1.367	0.173
Septal s' (cm/s)	7.49±1.4	7.64±0.99	0.883	0.378

Note: GLS, global longitudinal strain; LVEF, left ventricular ejection fraction; MAPSE, mitral annular plane systolic excursion; lateral s', peak systolic velocity of the mitral annular lateral wall; septal s', septal peak systolic velocity.

Statistical analysis

Statistical analysis was performed using SPSS 24.0 software. Measurement data were expressed as ($\bar{x} \pm s$); independent sample t-tests were used for comparisons between groups, and paired t-tests were used for comparisons within groups before and after treatment. Count data were expressed as n (%) and χ^2 tests were used to test the count data of the two groups. Factors resulting in left ventricular dysfunction in patients were analyzed using univariate analysis and binary logistic regression analysis. Statistical significance was reported at the P<0.05 level.

Results

Analysis of general data

No statistically significant differences were observed in subjects' age, body mass index (BMI), body surface area, diastolic/systolic blood pressure (DBP/SBP), and other general data between the research group and the control group (P>0.05). See **Table 1**.

Assessment of left ventricular systolic function

Left ventricular systolic function was evaluated by detecting GLS, LVEF, MAPSE, lateral s', and septal s'. The evaluation results showed lower GLS and MAPSE in the research group compared to the control group (P<0.001), but no statistically significant differences were observed in LVEF, lateral s', and septal s' between the two groups (P>0.05). See **Table 2**.

Assessment of left ventricular diastolic function

The performance of left ventricular diastolic function was evaluated by E, E/e', LAVI, lateral e', and Septal e'. Notably reduced E, lateral e', and Septal e' were observed in the research

Table 3. Comparison of indicators for assessing left ventricular diastolic function between the two groups

Indicators	Research group (n=106)	Control group (n=100)	t	P
E (cm/s)	71.75±11.54	81.54±16.66	4.926	<0.001
E/e'	8.0±1.86	8.13±2.09	0.472	0.637
LAVI (mL/m^2)	16.36±4.68	16.68±3.16	0.572	0.568
Lateral e' (cm/s)	9.71±2.61	12.04±2.24	6.857	<0.001
Septal e' (cm/s)	7.97±1.44	9.24±2.04	5.185	<0.001

Note: E, mitral valve orifice early diastolic blood flow velocity; E/e', the ratio of E to the average early diastolic velocity of the mitral annulus; LAVI, left atrial volume index; lateral e', early diastolic velocity of the mitral annular lateral wall; septal e', early diastolic velocity of the ventricular septum of the mitral annulus.

Table 4. Inter-group comparison of left ventricular dysfunction

Indicators	Research group (n=106)	Control group (n=100)	χ^2	P
GLS abnormalities	37 (34.91)	0 (0.00)	42.548	<0.001
LVEF abnormalities	10 (9.43)	0 (0.00)	9.915	0.002

Note: GLS, global longitudinal strain; LVEF, left ventricular ejection fraction.

group versus the control group (P<0.001), while the E/e' and LAVI showed no statistically significant difference between the two groups (P> 0.05). See **Table 3**.

Inter-group comparison of left ventricular dysfunction

Left ventricular systolic dysfunction was defined as LVEF<53% or GLS<15.02% (control group $\bar{x}$-1.96 s). There were 37 patients with GLS abnormalities and 10 patients with LVEF abnormalities in the research group, with higher abnormal rates of GLS and LVEF than the control group (P<0.05). However, no left ventricular diastolic dysfunction was observed in either group. See **Table 4**.

Univariate analysis of risk factors in association with left ventricular dysfunction in BC patients

The results of univariate analysis revealed that the dose of anthracyclines was significantly associated with abnormal GLS in BC patients (P=0.018). Meanwhile, the presence of hypertension (P=0.001), diabetes mellitus (P=0.003), and hyperlipidemia (P=0.014) all have significant correlations with the abnormality of LVEF in BC patients. See **Tables 5**, **6**.

Multivariate analysis of risk factors in association with left ventricular dysfunction in BC patients

Risk factors identified from the univariate analysis with significant differences, such as the dose of anthracyclines, the presence of hypertension, diabetes, and hyperlipidemia, were employed as independent variables, and the occurrence of left ventricular dysfunction (yes vs. no) as the dependent variable for the multivariate logistic regression analysis. The dose of anthracyclines was shown to be an independent risk factor for the occurrence of left ventricular dysfunction in BC patients (P=0.026). See **Table 7**.

Discussion

Chemotherapy-related cardiac dysfunction, as an anthracycline-induced cardiotoxicity, has some latent symptoms in the early stage, which can cause a continuous and progressive decline in LVEF [21, 22]. For BC patients, early detection of subclinical cardiotoxicity will be conducive to protecting their cardiac function and reducing the risk of cardiac dysfunction and heart failure [23]. This study is dedicated to the analysis in this aspect, and a detailed report is hereby formed.

In the present study, the performance of left ventricular systolic function was analyzed at first. We found that GLS and MAPSE were markedly reduced in the research group compared to the control group, while LVEF, lateral s', and septal s' presented no significant difference. It was suggested that 2D-STI-measured GLS was indicative of the occurrence of anthracycline-related left ventricular systolic dysfunction in BC patients, and MAPSE measured by conventional ultrasound also showed prominent diag-

Table 5. Univariate analysis of risk factors of left ventricular dysfunction in breast cancer patients after anthracycline treatment

Indicators	Abnormal GLS group (n=37)	Normal GLS group (n=69)	χ^2	P
Age (years old)			0.134	0.714
<52 (n=49)	18 (48.65)	31 (44.93)		
≥52 (n=57)	19 (51.35)	38 (55.07)		
Body mass index (kg/m^2)			0.220	0.639
<24 (n=54)	20 (54.05)	34 (49.28)		
≥24 (n=52)	17 (45.95)	35 (50.72)		
Body surface area (m^2)			1.649	0.199
<1.5 (n=52)	15 (40.54)	37 (53.62)		
≥1.5 (n=54)	22 (59.46)	32 (46.38)		
Diastolic blood pressure (mmHg)			0.070	0.791
<75 (n=44)	16 (43.24)	28 (40.58)		
≥75 (n=62)	21 (56.76)	41 (59.42)		
Systolic blood pressure (mmHg)			2.863	0.091
<120 (n=52)	14 (37.84)	38 (55.07)		
≥120 (n=54)	23 (62.16)	31 (44.93)		
Dose of anthracyclines (mg/m^2)			5.599	0.018
<300 (n=51)	12 (32.43)	39 (56.52)		
≥300 (n=55)	25 (67.57)	30 (43.48)		
Hypertension			0.649	0.421
No (n=90)	30 (81.08)	60 (86.96)		
Yes (n=16)	7 (18.92)	9 (13.04)		
Diabetes			1.357	0.244
No (n=94)	31 (83.78)	63 (91.30)		
Yes (n=12)	6 (16.22)	6 (8.70)		
Hyperlipidaemia			0.019	0.890
No (n=91)	32 (86.49)	59 (85.51)		
Yes (n=15)	5 (13.51)	10 (14.49)		

Note: GLS, global longitudinal strain.

nostic value for predicting left ventricular systolic dysfunction associated with anthracycline. According to Liu W et al. [24], 2D-STI could be used to identify early subclinical myocardial dysfunction in patients with invasive ductal carcinoma in the breast receiving neoadjuvant chemotherapy, and GLS could reflect the early myocardial injury induced by anthracyclines, which is consistent to our findings. In the study of Chen Wet al. [25], GLS measured by 2D-STI exhibited excellent capability to monitor the occurrence of left ventricular dysfunction induced by anthracycline, corroborating our research findings again. MAPSE can be utilized to evaluate the left ventricular regional myocardial systolic function, and is associated with its ability to obtain relevant data regarding the local myocardial longitudinal displacement beneath the endocardium of the left ventricle [26]. In this study, the limited evaluation significance of lateral s' and septal s' might be attributed to the fact that they can merely reflect the local myocardial systolic function of the left ventricle [27]. Moreover, lateral s' and septal s' detected from TDI are dependent of a certain angle during the measurement process, which, to some extent, has restricted its clinical applications. According to the assessment results of left ventricular diastolic function, the research group had evidently lower levels of E, lateral e', and septal e' than the control group, while no significant inter-group difference was found in E/e' and LAVI, indicating that TDI-related parameters (E, lateral e', and septal e') were significant in predicting anthracycline-related left diastolic dysfunction in BC patients. This might be

Table 6. Univariate analysis of risk factors of left ventricular ejection fraction (LVEF) abnormalities in breast cancer patients after anthracycline treatment

Indicators	Abnormal LVEF group (n=10)	Normal LVEF group (n=96)	χ^2	P
Age (years old)			0.843	0.359
<52 (n=49)	6 (60.00)	43 (44.79)		
≥52 (n=57)	4 (40.00)	53 (55.21)		
Body mass index (kg/m^2)			0.004	0.950
<24 (n=54)	5 (50.00)	49 (51.04)		
≥24 (n=52)	5 (50.00)	47 (48.96)		
Body surface area (m^2)			0.362	0.547
<1.5 (n=52)	4 (40.00)	48 (50.00)		
≥1.5 (n=54)	6 (60.00)	48 (50.00)		
Diastolic blood pressure (mmHg)			0.328	0.567
<75 (n=44)	5 (50.00)	39 (40.63)		
≥75 (n=62)	5 (50.00)	57 (59.38)		
Systolic blood pressure (mmHg)			1.605	0.205
<120 (n=52)	3 (30.00)	49 (51.04)		
≥120 (n=54)	7 (70.00)	47 (48.96)		
Dose of anthracyclines (mg/m^2)			3.496	0.062
<300 (n=51)	2 (20.00)	49 (51.04)		
≥300 (n=55)	8 (80.00)	47 (48.96)		
Hypertension			10.497	0.001
No (n=90)	5 (50.00)	85 (88.54)		
Yes (n=16)	5 (50.00)	11 (11.46)		
Diabetes			9.046	0.003
No (n=94)	6 (60.00)	88 (91.67)		
Yes (n=12)	4 (40.00)	8 (8.33)		
Hyperlipidaemia			6.073	0.014
No (n=91)	6 (60.00)	85 (88.54)		
Yes (n=15)	4 (40.00)	11 (11.46)		

Table 7. Multivariate analysis of risk factors of left ventricular dysfunction in breast cancer patients after anthracycline treatment

Factor	β	S.E.	Wald	P	OR	95% CI
Dose of anthracyclines	0.951	0.428	4.929	0.026	2.588	1.118-5.991
Hypertension	-0.564	0.605	0.869	0.351	0.569	0.174-1.862
Diabetes	-0.488	0.672	0.529	0.467	0.614	0.164-2.289
Hyperlipidemia	-0.845	0.647	1.702	0.192	0.430	0.121-1.528

due to the relatively minor interference of TDI detection by volume load and left ventricular filling pressure, while conventional ultrasound is prone to be influenced by factors such as volume load and heart rate [14]. E/e', as an assessment indicator of left ventricular diastolic function, can well reflect the left ventricular filling pressure and jointly reflect the further impairment of left ventricular diastolic function along with LAVI [28, 29]. Furthermore, a persistently elevated left ventricular filling pressure can be manifested as an increase in LAVI. The lack of a significant inter-group difference in LAVI might be associated with the absence of an increase in E/e' and of diastolic dysfunction in patients in this study. The analysis results of left ventricular systolic dysfunction revealed greatly elevated abnormality rates in GLS and

LVEF in the research group than in the control group, indicating that GLS determined by 2D-STI sensitively captured the occurrence of left ventricular systolic dysfunction in patients and was able to reflect reduced or disordered left ventricular systolic function related to anthracycline in BC patients. Our results also indicated that LVEF detected by RT-3DE was sensitive to predict anthracycline-related left ventricular systolic dysfunction in BC patients. Finally, both univariate and multivariate analyses verified that a high dose of anthracyclines constituted an independent risk factor for left ventricular dysfunction among BC patients. This suggested that the administration of high-dose anthracyclines would, to a certain degree, augment the risk of left ventricular dysfunction occurrence in BC patients.

In conclusion, BC patients presented with impaired subclinical left ventricular systolic and diastolic functions after receiving anthracycline treatment. However, GLS measured by 2D-STI can be used to assess the reduced or disordered left ventricular systolic function in such patients; LVEF quantified by RT-3DE can be utilized to identify left ventricular systolic dysfunction, and, to a certain extent, E, lateral e', and septal e' measured by TDI are powerful indicators for detecting impaired left ventricular diastolic function. Moreover, high-dose anthracyclines may elevate the risk of left ventricular dysfunction in BC patients.

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Disclosure of conflict of interest

None.

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