ORIGINAL ARTICLE

Role of 3D Echocardiography Strain Analysis in Detecting Cardiotoxicity in Breast Cancer Patients Receiving Chemotherapy

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Abstract

Background: ***Cardiotoxicity represents a significant challenge for breast cancer patients undergoing anthracycline-based chemotherapy. Improving patient outcomes requires early detection of subclinical cardiac impairment. Three-dimensional speckle-tracking echocardiography (3D-STE) may provide better sensitivity and specificity in the early detection of cardiotoxic effects when compared to traditional two-dimensional global longitudinal strain (2D GLS).***

Methods: ***In this prospective study, 120 female breast cancer patients undergoing anthracycline-based chemotherapy were evaluated with comprehensive clinical, laboratory, and echocardiographic assessments, including both 2D and 3D strain analysis, at baseline, after 2 and 4 chemotherapy cycles, and at 3- and 6-month post-treatment. Cardiotoxicity was defined by international criteria based on changes in GLS and LVEF.***

Results: ***Cardiotoxicity incidence increased over time, reaching 31% at six months, and was significantly higher in patients receiving trastuzumab. At six months, the cardiotoxicity group had significantly impaired diastolic function and lower 2D LVEF. 2D GLS exhibited a significant decline starting from the fourth chemotherapy cycle (AUC=0.76). In contrast, both 3D GLS and 3D GAS demonstrated earlier and more marked decreases, achieving high diagnostic accuracy as early as after two treatment cycles. (3D GLS AUC=0.843; 3D GAS AUC=0.873).***

Conclusions: ***Three-dimensional speckle-tracking echocardiography (3D-STE) is a non-invasive, reproducible modality that demonstrates superior sensitivity and specificity to 2D-GLS for the early detection of cardiotoxicity in breast cancer patients receiving anthracycline chemotherapy.***

Keywords: Breast cancer; Anthracycline; 3D-STE; (CTRCD); Subclinical cardiac dysfunction

1. Introduction

Breast cancer remains the most frequently diagnosed malignancy among women worldwide, with an estimated 2.3 million new cases annually, accounting for 11.7% of all cancer diagnoses.[1] Treatment-related complications and mortality continue to be major clinical challenges, even in the face of significant advancements in therapeutic interventions that have increased the number of cancer survivors and improved survival rates .[2]

Cardiovascular diseases (CVDs) are now a major cause of premature morbidity and mortality among breast cancer survivors, even though chemotherapy is essential for increasing survival rates. Both the direct cardiotoxic effects of cancer treatments and the aggravation of pre-existing cardiovascular risk factors are responsible for this result .[3,4]

early detection and intervention for Cancer therapy related cardiac dysfunction (CTRCD) are critical to minimizing long-term cardiac complications, enhancing patient survival, and preserving quality of life. Traditional imaging modalities, such as 2D echocardiography, often fall short in accurately identifying subclinical myocardial dysfunction.[5,6]

Accepted 20 August 2025.
Available online 30 September 2025

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https://doi.org/10.21608/aimj.2025.399225.2602

The current definition for the assessment of (CTRCD) highlights reductions in left ventricular ejection fraction (LVEF) and changes in 2D global longitudinal strain (GLS) as primary diagnostic criteria.[7] In this context, three-dimensional speckle tracking echocardiography (3D-STE) has emerged as a promising imaging technique for the quantification of left ventricular volumes, EF, and multidirectional strain. This method is noted for its enhanced reproducibility and sensitivity, providing a comprehensive assessment of LV mechanics in a time-efficient manner compared to traditional 2D approaches .[8]

This study aimed to evaluate the role of 3D speckle-tracking echocardiography in the early detection of left ventricular dysfunction among breast cancer patients undergoing anthracycline-based chemotherapy. By addressing this knowledge gap, the objective was to improve the timely identification of cardiotoxicity, thus enhancing risk stratification and long-term cardiovascular outcomes in this vulnerable population.

2. Patients and methods

This prospective observational study aimed to assess the effectiveness of Three-Dimensional Speckle-Tracking Echocardiography (3DSTE) in detecting subclinical left ventricular dysfunction among breast cancer patients receiving anthracycline-based chemotherapy. Patient recruitment occurred at the Cardiology Department of Al-Azhar University Hospitals from March 2023 to February 2025.

A total of 150 female breast cancer patients, aged 18 years or older and free of cardiac symptoms or signs, were enrolled. All participants were scheduled to receive anthracycline-based chemotherapy, with or without trastuzumab.

All patients began treatment with an anthracycline (Adriamycin or Epirubicin) plus cyclophosphamide every 21 days for four cycles, followed by 4–6 cycles of taxane-based chemotherapy (either paclitaxel or docetaxel). For those with HER2-positive breast cancer, trastuzumab was added after the anthracycline regimen and continued alongside taxane therapy for up to one year or according to standard recommendation .[9]

Study approval came from Al-Azhar University Hospitals' Ethical Committee in Cairo, Egypt. Patients gave written consent.

Patients who did not meet the inclusion criteria were those with the following: Patient refusal to participate, Poor echocardiographic windows, Significant valvular, congenital, or myocardial heart disease, Diagnosed coronary artery disease, and Presence of arrhythmia.

At baseline, all patients underwent a comprehensive evaluation, including a detailed medical history that covered cardiovascular risk factors, symptoms, previous medications, cancer type, prognosis, and specific treatment regimens. Each patient received a thorough clinical examination with assessment of vital signs and screening for primary cardiac disease or heart failure. Baseline laboratory investigations included complete blood count, serum electrolytes, renal and liver function tests, HbA1c, and lipid profile.

A resting 12-lead ECG was performed at baseline and at follow-up visits to monitor heart rate, rhythm, chamber enlargement, and QT interval, with QTc calculated using the Fridericia correction .[10]

Echocardiographic assessments were conducted at predefined intervals—baseline, after 2 and 4 cycles of anthracycline therapy, and at 3- and 6-month post-chemotherapy—using a Vivid E95 system. This included both two-dimensional (2D) and three-dimensional (3D) echocardiography: 2D studies measured standard cardiac dimensions, left ventricular systolic function via Simpson's method, mitral inflow velocities, and tissue Doppler parameters in accordance with American Society of Echocardiography guidelines.[11,12] 2D Speckle Tracking Echocardiography (STE) was used to assess longitudinal strain based on the 17-segment LV model. Asymptomatic cancer therapy–related cardiac dysfunction (CTRCD) is classified as severe with a new LVEF <40%, moderate with a new LVEF of 40–49% accompanied by either a ≥10% absolute reduction, or a <10% reduction plus a >15% relative GLS decline, and mild when LVEF remains ≥50% but is associated with either a >15% relative GLS decline.[13,14]

Three-dimensional echocardiography provided volumetric measurements, including end-diastolic and end-systolic volumes, sphericity index, stroke volume, cardiac output, and ejection fraction[15], while 3D Speckle Tracking Echocardiography (3DSTE) calculated global area strain, GLS, global circumferential strain, and global radial strain by averaging values from 17 LV segments, excluding segments with inadequate tracking.[16] The 3DSTE protocol ensured optimal ECG setup, sufficient frame rates, and high-quality image acquisition, with manual adjustments for border accuracy and exclusion of poorly tracked segments. Patients were followed for major adverse cardiac events (MACE) and cancer therapy-related cardiovascular toxicity (CTR-CVT) through scheduled office visits and repeated ECG and laboratory assessments at all key treatment milestones and follow-up points.

Statistical analysis:

Statistical analysis was performed using SPSS v26, with quantitative variables compared via

Student's t-tests (means and standard deviations) and qualitative variables assessed using Chi-square or Fisher's exact tests (percentages and frequencies). Statistical significance was determined by a two-tailed P-value below 0. 05 Diagnostic performance was evaluated using sensitivity, specificity, PPV, NPV, and ROC curve analysis, with AUC values indicating test accuracy and statistical significance set at p<0.05.0.[17]

3. Results

This prospective observational study included 120 female breast cancer patients undergoing anthracycline-based chemotherapy after exclusion of 30 patients due to various reasons: 4 deaths unrelated to the tumor, 7 patients lost to follow-up, 9 cases with inadequate imaging quality during follow-up, and 10 patients who developed significant comorbidities such as renal failure (4), uncontrolled diabetes (2), and pneumonia (4) that could interfere with accurate cardiac function assessment as depicted in figure 1 . The baseline characteristics of the study population are summarized in Table 1, At follow-up, poor segment tracking occurred in 12% of patients for 2D GLS and was further increased for 3D STE and 3D volumetric imaging, with technical adaptations limited by factors such as left mastectomy, and breast prosthesis.

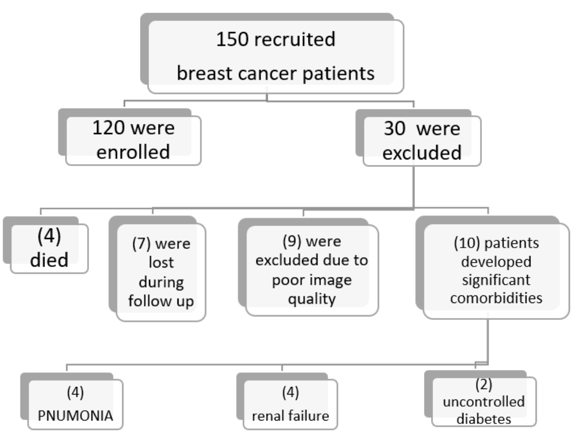

Figure 1. population description recruited in the study.

Table 1. Demographic data and risk factors of the patients studied.

			N=120
AGE (YEARS)	Mean ± SD (52.4 ± 12.4) Range (23 – 67)		
BMI	Mean ± SD (28.1 ± 3.7) Range (21- 37)		
RISK FACTORS		Diabetes mellitus	39 (32.5%)
		Hypertension	49 (40.83%)
COMORBIDITIES 27 (22.5%)		Hypothyroidism	3 (2.5%)
		Asthma	3 (2.5%)
		Post HCV	4 (3.3%)
		Anemia	11 (9.16%)
		Dyslipidemia	6 (5%)

This study found no significant cardiotoxicity (based on slandered definition of cardiotoxicity) at baseline or after 2 chemotherapy cycles; however, cardiotoxicity developed progressively in the cohort, affecting 5.8% of patients by the 4th cycle, 24.2% at 3 months post anthracycline and increasing to 31% by the 6-month follow-up as shown in figure 1 (Most patients were diagnosed according to the GLS criterion).

Patients were classified into two groups based on the presence or absence of cardiotoxicity: Group I included 83 patients without evidence of cardiotoxicity, while Group II comprised 37 patients who developed cardiotoxicity.

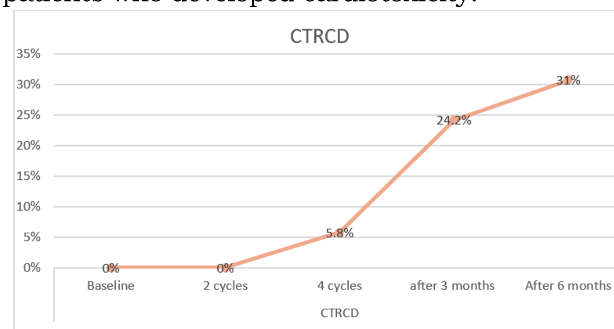

Figure 2. cardiotoxicity occurrence across different phases of treatment.

Regarding treatment regimen, Cardiotoxicity was significantly more frequent in patients receiving trastuzumab (35.9% vs. 12%, p<0.001). No significant differences in demographic factors or comorbidities were observed between the two groups, although. Heart rate and early QTc intervals showed no significant differences, but QTc was significantly increased in the cardiotoxicity group at 6 months.

The echocardiographic parameters were monitored at baseline, after the second and fourth cycles of chemotherapy, and at three- and six-month post-treatment. Table 2 provides a detailed comparison of these parameters between the two groups over time. Conventional 2D echocardiographic volumes showed no significant differences; however, diastolic function parameters (E/A, E/e' ratios, and LA diameter) and 2D ejection fraction were significantly impaired in the cardiotoxicity group at 6 months. A significant reduction in 2D global longitudinal strain (GLS) was observed beginning at the fourth chemotherapy cycle in patients who developed cardiotoxicity. ROC analysis showed good diagnostic utility at this stage, with an area under the curve (AUC=0.76, cutoff > -18.7).

Table 2. Conventional 2D and strain parameters of both groups across different phases of chemotherapy

PARAMETER	TIME POINT	GROUP I (NO CARDIOTOXICITY)	GROUP II (CARDIOTOXICITY)	P-VALUE
LA DIAMETER (MM)	Baseline	32.9 ± 3.9	34.1 ± 2.9	0.06
	6 months post	33.7 ± 4.2	35.0± 3.2	0.011
E/A RATIO MEAN ±SD	Baseline	1.14 ± 0.09	1.12 ± 0.11	0.159
	6 months post	1.07 ± 0.08	0.99 ± 0.14	0.001

E/E' RATIO MEAN ±SD	Baseline	6.83 ± 0.53	7.08 ± 0.93	0.071
	6 months post	8.89± 0.43	9.86 ± 1.05	0.016
LVEDV MEAN ±SD	Baseline	104.3 ± 15.7	105.9 ± 14.8	0.610
	6 months post	111.02 ± 14.2	112.6 ± 14.2	0.838
LVESV MEAN ±SD	Baseline	39.4 ± 6.42	40.6 ± 6.7	0.353
	6 months post	45.8 ± 7.3	48.5 ± 7.2	0.07
2D EF MEAN ±SD	Baseline	62.7 ± 4.1	61.6 ± 4.4	0.201
	6 months post	58.1 ± 3.6	56.5 ± 3.6	0.014
2D GLS MEAN ±SD	Baseline	-21.5 ± 1.1	-21.3 ± 1.5	0.436
	At 2 cycles	-20.0 ± 1.4	-19.6 ± 1.3	0.179
	At 4 cycles	-20.3 ± 4.7	-18.7 ± 1.3	0.031
	3 months Post	-19.6 ± 1.4	-17.7 ± 1.2	< 0.001
	6 months post	-19.1 ± 1.4	-16.5 ± 1.5	< 0.001

Three-dimensional echocardiography revealed significant alterations in cardiac parameters among patients with cardiotoxicity, including progressive increases in left ventricular end-systolic volume (LVESV) and reductions in ejection fraction after four chemotherapy cycles and during follow-up (Table 3). However, 3D strain parameters showed earlier and progressive reductions in the cardiotoxicity group, with global longitudinal strain (GLS) and global area strain (GAS) demonstrating higher diagnostic accuracy as early as two cycles following anthracycline treatment. Early reductions in 3D GLS and GAS were significantly associated with subsequent declines in left ventricular ejection fraction (LVEF) at follow up underscoring their prognostic utility.

Table 3. Conventional 2D and strain parameters of both groups across different phases of chemotherapy

PARAMETER	TIME POINT	GROUP I (NO CARDIOTOXICITY)	GROUP II (CARDIOTOXICITY)	P-VALUE
3D LVEDV MEAN ±SD	Baseline	105.3 ± 15.1	109.8 ± 13.8	0.125
	At 2 cycles	108.1 ± 14.6	109.7 ± 14.1	0.595
	At 4 cycles	108.6 ± 13.9	112.5 ± 13.8	0.156
	3 months post	111.3 ± 14.1	114.4 ± 13.8	0.265
	6 months post	113.8 ± 14.03	116.1 ± 14.2	0.432
3D LVESV MEAN ±SD	Baseline	41.6 ± 7.6	42.2 ± 7.6	0.108
	At 2 cycles	42.4 ± 7.4	43.9 ± 7.5	0.099
	At 4 cycles	45.6 ± 7.9	49.1 ± 7.7	0.016
	3 months post	48.8 ± 7.1	53.2 ± 7.3	0.008
	6 months post	49.5 ± 8.6	56.7 ± 8.1	0.001
3D EF MEAN ±SD	Baseline	60.6 ± 3.4	59.5 ± 3.5	0.095
	At 2 cycles	59.4 ± 3.8	58.5 ± 3.4	0.214
	At 4 cycles	58.7 ± 3.7	56.3 ± 3.3	0.023
	3 months post	56.9 ± 2.8	54.8 ± 3	< 0.001
	6 months post	56 ± 3.1	53.2 ± 3.4	< 0.001
3D GLS MEAN ±SD	Baseline	-20.02 ± 1.9	-19.6 ± 1.8	0.261
	At 2 cycles	-18.7 ± 1.8	-17.2 ± 2.1	< 0.001
	At 4 cycles	-18 ± 1.9	-16 ± 2.4	< 0.001
	3 months post	-17.3 ± 1.9	-14.9 ± 2.5	< 0.001
	6 months post	-16.6 ± 2.1	-13.9 ± 2.7	< 0.001
3D GCS MEAN ±SD	Baseline	-21.6 ± 4.7	-21.2 ± 2.7	0.642
	At 2 cycles	-20.2 ± 4.8	-18.9 ± 2.8	0.069
	At 4 cycles	-18.7 ± 4.2	-15.5 ± 1.7	0.023
	3 months post	-18 ± 4.1	-14.9 ± 5.3	0.003
	6 months post	-16.4 ± 3.9	-14.3 ± 1.49	0.001
3D GAS MEAN ±SD	Baseline	-29.3 ± 9.5	-27.5 ± 10.1	0.332
	At 2 cycles	-28.9 ± 6.5	-24.9 ± 9.6	0.009
	At 4 cycles	-27.1 ± 8.9	-23.1 ± 8.9	0.027
	3 months post	-24.9 ± 8.3	-20.3 ± 11.3	0.014
	6 months post	-25 ± 8.2	-18.9 ± 8.5	< 0.001
3D GRS MEAN ±SD	Baseline	46.9 ± 4.2	46.1 ± 2.9	0.166
	At 2 cycles	44.9 ± 4.6	43.4 ± 3.3	0.071
	At 4 cycles	43.6 ± 3.1	41.9 ± 3.4	< 0.001
	3 months post	42.8 ± 3.3	39.5 ± 3.4	< 0.001
	6 months post	41.4 ± 3.3	35.9 ± 4.1	< 0.001

Receiver operating characteristic (ROC) curve analyses after two cycles identified 3D GLS (AUC=0.843, sensitivity=82.1%, specificity=68.4%) and 3D GAS (AUC=0.873, sensitivity=85.7%, specificity=71.7%) as the most sensitive early markers of myocardial injury. These findings highlight the incremental value of 3D speckle-tracking echocardiography in detecting subclinical cardiac dysfunction, providing a robust framework for early intervention in breast cancer patients undergoing anthracycline-based chemotherapy.

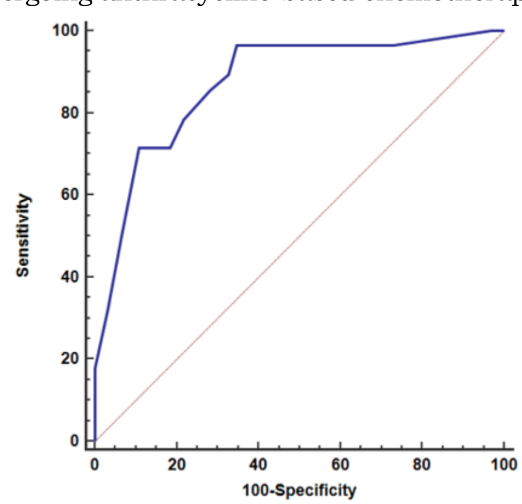

Figure 3. ROC curve for discrimination of cardiotoxicity as regard 3D GAS.

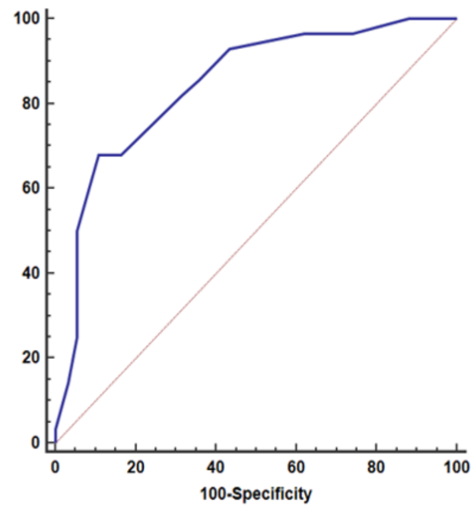

Figure 4. ROC curve for discrimination of cardiotoxicity as regard 3D GLS.

4. Discussion

Breast cancer remains the most frequently diagnosed malignancy in women worldwide, accounting for 11.7% of all cancer diagnoses .[1] Despite significant advancements in therapies that have improved survival rates and increased the population of cancer survivors, treatment-related complications and mortality continue to present major clinical challenges .[2] Among these, cardiovascular diseases (CVDs) have emerged as a leading cause of morbidity and mortality among breast cancer survivors, attributable to both the direct cardiotoxic effects of treatments and the acceleration of pre-existing cardiovascular risk factors .[3,4]

Early detection and intervention for cancer therapy-related cardiac dysfunction (CTRCD) are critical to minimizing long-term cardiac complications and improving patient survival and quality of life. However, traditional imaging modalities, such as 2D echocardiography, often fall short in identifying subclinical myocardial dysfunction .[5,6] Current recommendations for CTRCD cite reductions in left ventricular ejection fraction (LVEF) and changes in 2D global longitudinal strain (GLS) as diagnostic criteria .[7] In this context, three-dimensional speckle tracking echocardiography (3D-STE) has emerged as a promising imaging technique for the quantification of LV volumes and LVEF, noted for its enhanced reproducibility, sensitivity, and comprehensive assessment of LV mechanics compared to traditional 2D approaches .[8]

This study evaluated the role of 3D-STE in detecting early left ventricular (LV) dysfunction among breast cancer patients undergoing anthracycline-based chemotherapy. Among 120 patients, the incidence of cardiotoxicity was 5.8% after the fourth cycle of anthracycline-based chemotherapy, rising significantly to 31% by the 6-month follow-up. This trend is consistent with findings from Guo et al. and Poovorawan et al., who documented lower incidences during initial cycles (2–5% in the first two cycles) but a notable increase up to 30% during follow-up after chemotherapy termination .[18,19]

Patients were classified into two groups, as defined by Cardio-Oncology recommendations [20], into two groups: Group I (83 patients without cardiotoxicity) and Group II (37 patients with cardiotoxicity). The concomitant use of trastuzumab with anthracyclines poses an additional risk for acute and chronic cardiac events. Our study revealed a statistically significant increase in the incidence of cardiotoxicity among patients receiving trastuzumab after anthracycline therapy, aligning with findings from several studies. For instance, Zhang et al. conducted a meta-analysis highlighting the elevated risk of cardiotoxicity with combined anthracyclines and trastuzumab.[21] Also, Poovorawan et al. reported higher rates of heart failure and a decline in LV function in patients treated sequentially with these agents .[19] Additionally, it was shown by Guo et al. and Kaboré et al. that the risk of cardiac dysfunction is greatly increased by cumulative exposure to both agents .[18,22]

Regarding demographic data, although age and BMI were higher in the cardiotoxicity group, these differences were not statistically significant, consistent with Santoro et al., who found that age and comorbidities were not always predictors of cardiotoxicity when using traditional echocardiographic measures .[23] However, Guo et al. observed that older individuals are generally more vulnerable to complications arising from chemotherapy [18], and Kaboré et al. reported that increased BMI raises the risk of anthracycline- and trastuzumab-related cardiotoxicity.[22] The prevalence of comorbidities was higher in the cardiotoxicity group, but without statistical significance, differing from studies such as Azim et al. and Chen et al., which highlight diabetes and hypertension as significant contributors to cardiovascular toxicity risk in breast cancer patients receiving anthracyclines .[24,25]

Heart rate (HR) and corrected QT interval (QTc) did not differ significantly between groups during treatment, except for a notable increase in QTc at 6 months among patients with cardiotoxicity (436.5 ± 17.3 ms vs. 429.2 ± 16.4 ms, p = 0.03). This finding is corroborated by Zhang Y et al., who documented similar QTc prolongation trends in patients receiving anthracyclines, suggesting QTc as a sensitive indicator of cardiac complications even when HR remains stable .[26]

Focusing on left ventricular diastolic function, we assessed left atrial (LA) diameter, mitral E/A ratio, and E/e′ ratio. No significant differences were observed during treatment cycles; however, 6 months post-therapy, patients with cardiotoxicity showed a significant increase in LA diameter and E/e′ ratio ($p < 0.001$), and a decrease in E/A ratio ($p = 0.005$). These findings indicate diastolic dysfunction due to chemotherapy and are consistent with Upshaw et al., who documented persistent deterioration in diastolic function among patients treated with anthracyclines and trastuzumab .[27] Guan et al. highlighted the predictive role of diastolic parameters [28], and Guo et al. emphasized the clinical relevance of LA diameter in identifying patients at risk .[18] Chen et al. and Piveta et al. also underscored the sensitivity of E/e′ in detecting elevated LV pressures and early diastolic dysfunction .[25,29]

Regarding 2D LV volume and EF, our findings indicated no significant differences during and shortly after treatment; however, a significant trend of decreasing EF was observed 6 months after therapy in patients who developed cardiotoxicity. This is consistent with Kaboré et al., Piveta et al., and Alam S. et al., who noted that early detection of changes in LV volume and 2D EF were crucial for predicting cardiotoxicity.[22,29,30]

Two-dimensional GLS did not differ significantly at baseline between groups, but as treatment progressed, consistent decreases in 2D GLS values and increased mean percentage changes were observed. Statistically significant decreases in 2D GLS were noted at the fourth cycle and became highly significant at 3- and 6-month post-anthracycline in the cardiotoxicity group. These results were in agreement with recent studies (Nagueh et al., López-Fernández et al., Galderisi et al.) that established GLS as a critical parameter for early detection of chemotherapy-induced cardiotoxicity .[31-33] ROC curve analysis confirmed the utility of 2D GLS at four cycles (cutoff > -18.7, AUC = 0.76), which is in line with Prat et al.[34] and recent international recommendations .[20]

For 3D LV volumes, no significant differences in LVEDV were observed at baseline, during, or after treatment, but LVESD showed a significant increase at four cycles, persisting and becoming highly significant by six months. While 3D EF did not differ significantly at baseline and after two cycles, a significant decrease was observed at four cycles in the cardiotoxicity group, becoming highly significant at three- and six-month post-therapy. These findings are consistent with Zhang et al.[21], Lorenzini et al.,[21,35] and Santoro et al., who highlighted the value of 3D EF in detecting LV dysfunction earlier than 2D EF, with close agreement to cardiac MRI .[23]

Furthermore, 3D EF measured three months after anthracycline therapy effectively discriminated cardiotoxicity at a cutoff of ≤ 54 (sensitivity 71.4%, specificity 67.3%), reinforcing the importance of 3D echocardiographic parameters for monitoring cardiotoxicity during and after chemotherapy .[20]

We also evaluated 3D strain parameters—GLS, GCS, GRS, and GAS for their efficacy in monitoring cardiotoxicity. Significant reductions in these parameters were observed in patients with cardiotoxicity. Notably, GAS and GLS exhibited the best performance for early detection, with significant differences emerging as early as the second cycle. 3D GCS and GRS demonstrated significant differences later, at the fourth cycle. The diagnostic performance of 3D strain parameters was notable, with a cutoff for 3D GLS at the second cycle of > -19% (sensitivity 82.1%, specificity 68.4%) and for 3D GAS of > -26% (sensitivity 85.7%, specificity 71.74%). Mihalcea et al. reported similar findings, further confirming the use of 3D strain for early cardiotoxicity detection .[36] Moreover, a recent systematic review highlights the effectiveness of 3D strain imaging in detecting cardiac dysfunction earlier than traditional measures .[37]

In conclusion, our findings underscore the progressive nature of cardiotoxicity in breast cancer patients treated with anthracycline-based chemotherapy. Advanced 3D speckle-tracking echocardiography provides sensitive and specific tools for early detection and monitoring of subclinical cardiac dysfunction, supporting its integration into routine clinical practice for at-risk patients. Future research should confirm these findings in larger, multicenter cohorts and explore the impact of early intervention strategies guided by advanced echocardiographic parameters on patient outcomes.

Limitations of the study: This study has several limitations. First, the accuracy of 3D speckle-tracking echocardiography is highly dependent on image quality, which was often compromised in patients with poor acoustic windows due to factors such as aging, obesity, prior radiotherapy, or breast surgeries like left mastectomy. Consequently, the feasibility of 3D imaging was reduced, particularly following anthracycline treatment. Second, the relatively short follow-up period limited the ability to assess long-term and late-onset cardiotoxic effects, underscoring the need for extended monitoring in future studies. Finally, the modest sample size may have constrained the statistical power and generalizability of the findings, highlighting the importance of larger, multicenter trials to confirm and expand upon these results.

4. Conclusion

Three-dimensional speckle-tracking echocardiography (3D-STE) is a non-invasive, reproducible modality that demonstrates superior sensitivity and specificity to 2D-GLS for the early detection of cardiotoxicity in breast cancer patients receiving anthracycline chemotherapy.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

Funding

No Funds : Yes

Conflicts of interest

There are no conflicts of interest.

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