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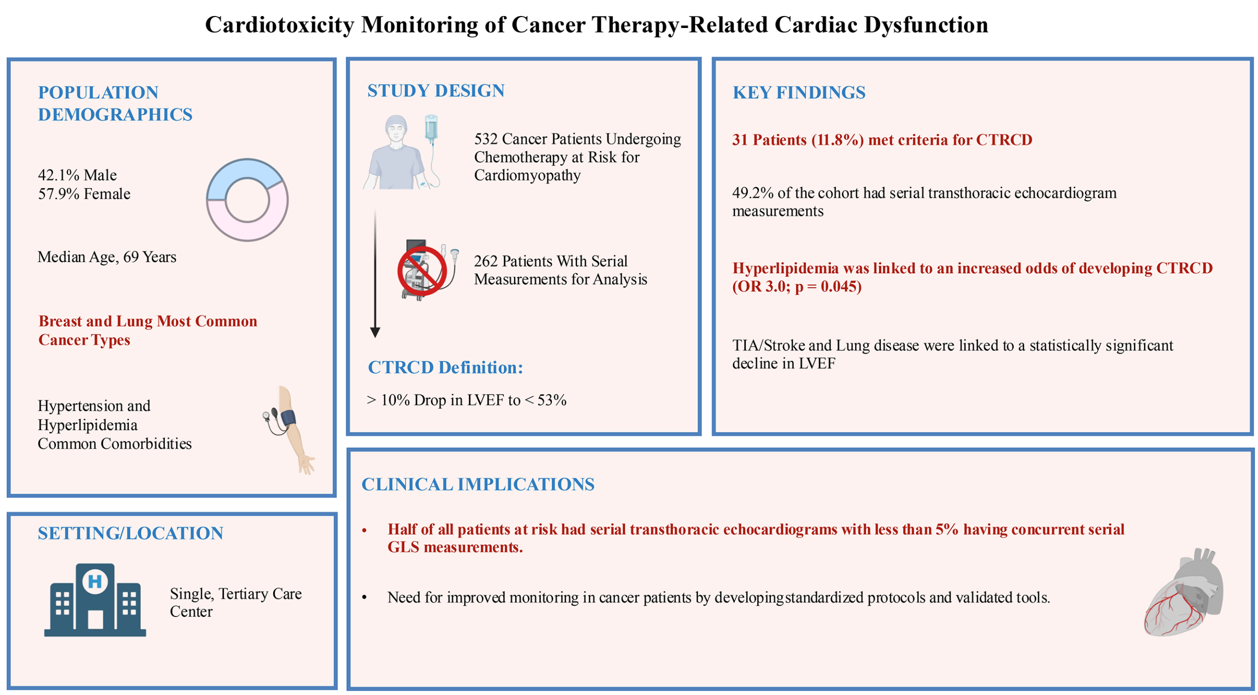
Cardiotoxicity monitoring and cancer therapy-related cardiac dysfunction in a heterogeneous cancer population

A retrospective study

Madeline Stevenson, BS[a], Sihyeong Park, BS[a], Taylor Hartshorne, BS[b], Zachary Mendoza, BS[c], Vinh Nguyen, MD[d], Lucas Wong, MD[d], Christopher D. Chiles, MD[d], R. Jay Widmer, MD, PhD[a,d,*]

Graphical abstract



[a] Department of Internal Medicine, Texas A&M College of Medicine, Bryan, Texas, USA, [b] Department of Internal Medicine, Baylor College of Medicine, Temple, Texas, USA, [c] Department of Internal Medicine, Texas A&M University School of Engineering Medicine, Houston, Texas, USA, [d] The Heart Group, Baylor Scott and White Medical Center - Mckinney, McKinney, Texas, USA.

* Correspondence: R. Jay Widmer, MD, PhD, The Heart Group, Baylor Scott and White Medical Center – McKinney, 5236 West University Drive, McKinney, TX 75071, USA (e-mail: robert.widmer@bswhealth.org).

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Abstract

Background: Chemotherapy-related cardiotoxicity can lead to significant heart damage, at times manifesting as cancer therapy-related cardiac dysfunction (CTRCD) or a decline in left ventricular ejection fraction (LVEF) by over 10% to below 53%. Current guidelines recommend cardiovascular risk assessments for cancer patients, yet standardized risk stratification is lacking. This study aimed to evaluate chemotherapeutic effects on LVEF in relation to risk factors for CTRCD, along with quality of surveillance and cardiotoxicity monitoring.

Methods: This study is a retrospective chart review at a single center to assess the incidence of CTRCD in patients referred for transthoracic echocardiography due to cardiotoxicity risk. Statistical analysis of 532 patients included Wilcoxon signed-rank tests for overall LVEF changes, multivariable linear regression for comorbidity and medication effects in relation to LVEF, and multivariable logistic regression for associations between comorbidities and CTRCD incidence.

Results: Among those assessed, the median LVEF decreased from 60% to 58%, with 11.8% meeting CTRCD criteria postchemotherapy. Lung disease and previous transient ischemic attacks were associated with more significant LVEF declines of 2.5% and 3.5%, respectively. Hyperlipidemia was associated with an increased risk of developing CTRCD. Of 262 patients with pre- and postchemotherapy echocardiograms, only 13 (5.0%) had left ventricular global longitudinal strain measurements on both pre- and postechocardiograms.

Conclusions: This study examines CTRCD incidence in a heterogeneous cancer population and explores associations between comorbidities, LVEF decline, and CTRCD development. It highlights gaps in echocardiographic monitoring for chemotherapy patients at risk of cardiomyopathy. Future efforts should focus on improving clinical gaps and advancing risk stratification research.

Abbreviations: COPD = chronic obstructive pulmonary disease, CTRCD = cancer therapy-related cardiac dysfunction, ESC = European Society of Cardiology, IQR = interquartile range, LVEF = left ventricular ejection fraction, LVGLS = left ventricular global longitudinal strain, OR = odds ratio, TIA = transient ischemic attack, TTE = transthoracic echocardiography.

Keywords: cancer, cardiac biomarkers, cardiac dysfunction, cardiac monitoring, cardiotoxicity, chemotherapy, echocardiography, left ventricular ejection fraction

1. Introduction

Cardiotoxicity is a well-known side effect of antineoplastic therapy, which encompasses chemotherapy, radiation, and immunotherapy.[1] It is defined as functional and/or structural damage to the heart, including cardiac valves, myocardium, pericardium, and coronary arteries, regardless of the presence of symptoms.[1,2] A specific subset of cardiotoxicity can furthermore be classified as cancer therapy-related cardiac dysfunction (CTRCD), which focuses on myocardial damage.[3] According to the American Society of Echocardiography and the European Association of Cardiovascular Imaging, CTRCD is defined as a greater than 10% decrease in left ventricular ejection fraction (LVEF) to a value less than 53%, the lower limit of normal.[3] However, this has yet to be standardized. Echocardiography plays an essential role in monitoring cardiotoxicity, especially CTRCD, and ensuring patient safety during treatment.[4] It allows for the recognition of cardiac dysfunction through several means, such as measuring changes in LVEF and left ventricular global longitudinal strain (LVGLS) and identifying structural damage. The detection of cardiac damage during antineoplastic therapy enables clinicians to add cardioprotective therapy and/or modify the patient's therapeutic regimen.[5]

As indicated by the 2022 European Society of Cardiology (ESC) cardio-oncology guidelines, a comprehensive cardiovascular risk assessment is recommended for cancer patients at the time of diagnosis and before the start of antineoplastic therapy to mitigate treatment-induced cardiotoxicity.[5] In addition, follow-up and monitoring may be needed based on various factors that affect patient susceptibility to cardiotoxicity. This is especially true for patients receiving antineoplastic therapeutics with a well-established cardiotoxic side effect profile, including anthracyclines, cyclophosphamides, and human epidermal growth factor receptor 2-targeted therapies.[5,6] A comprehensive assessment considers the patient's history of cardiovascular disease, relevant comorbidities, and prior cancer treatments.[5,7]

Various risk factors for chemotherapy-induced cardiotoxicity have been identified, such as age, cardiovascular-related comorbidities, and certain antineoplastic therapeutics.[5,8] However, there is limited consensus on cardiovascular risk stratification for cancer patients.[8] While various guidelines exist from organizations like the ESC, the European Society for Medical Oncology, and the American Society of Clinical Oncology, there is no universally accepted monitoring protocol. In these guidelines, there are differences in the recommendations of imaging modalities, biomarkers, frequency of monitoring, and thresholds.[1,5,9] Variations in the quantitative effects of identified risk factors on the heart likely contribute to this lack of standardized stratification. Therefore, while cardiac monitoring for cardiotoxicity through imaging or blood biomarkers is well established, it is challenging for healthcare providers to consistently implement these strategies and use preventative measures to their fullest capacity without definitive protocols.[5,10,11] This study aims to conduct a retrospective single-center cohort analysis to examine the incidence of CTRCD and its associated risk factors' effect on LVEF and the development of CTRCD in patients undergoing chemotherapy at risk for cardiomyopathy in a real-world tertiary setting. Furthermore, it will focus on the quality of surveillance and monitoring of patients with risk factors for chemotherapy-related cardiac dysfunction to shed light on areas for improvement.

2. Methods

This retrospective chart review aimed to describe the incidence of CTRCD, as defined by the earlier parameters, in patients treated at a single center from 2013 to 2023. This study was approved and conducted following the institutional review board (IRB) guidelines (IRB#019-180). Patient data were de-identified to protect confidentiality, and written consent was waived secondary to the study's retrospective nature.

Study subjects were initially identified based on referral to our center for transthoracic echocardiography (TTE) with the indication "at risk for cardiomyopathy/cardiotoxicity." This search yielded 2,146 potential subjects. From this group, patients were included in the study if they had a documented cancer diagnosis identified by International Classification of Diseases, Tenth Revision codes, and had received chemotherapy. Patients who did not meet these criteria were excluded, as their cardiomyopathy/cardiotoxicity risk was determined to be unrelated to cancer treatment. Patients without a completed echocardiogram were also excluded due to a lack of TTE data, which is a critical component of the study. Based on these criteria, 532 patients were included in the study.

The EPIC electronic medical record system was used to extract patient data, including baseline demographics, comorbidities, medications, laboratory values, and serial echocardiograms. The data were initially captured in Microsoft Excel and subsequently transferred to REDCap for management and analysis.

The primary objective of this study was to determine the frequency of serial TTE screenings and the corresponding documentation of LVEF and global longitudinal strain measurements to assess the overall incidence of CTRCD within the cohort. Secondary objectives included evaluating changes in LVEF from pre- to postchemotherapy, analyzing the relationship between baseline comorbidities and medications with changes in LVEF, and examining associations between comorbidities and the development of CTRCD.

Descriptive statistics were used to summarize patient demographics and clinical characteristics. LVEF measurements from clinical TTEs were reported using Simpson's 2D biplane method and independently confirmed by 2 independent clinicians. The overall change in LVEF between pre- and postchemotherapy conditions was evaluated by calculating the median and interquartile range (IQR). Normality for LVEF data was tested using both the Shapiro–Wilk and Anderson–Darling tests, which indicated that the data did not follow a normal distribution ($p < 0.05$ for both tests). Therefore, we did not assume normality in the data and opted for nonparametric tests. To account for the nonnormal distribution of the data, the Wilcoxon signed-rank test was used to compare LVEF values pre- and postchemotherapy.

To investigate changes in LVEF, a multivariable linear regression analysis was conducted to assess the association between previously identified comorbidities and medications and the rate of LVEF decline. Age and gender were included as covariates in the model to control for potential confounding factors. Linear regression was chosen because the outcome variable, LVEF, is continuous. The regression output included the change in LVEF from pre- to postchemotherapy, along with the corresponding 95% confidence intervals (CIs) and p values.

Additionally, a multivariable logistic regression model was employed to evaluate the relationship between comorbidities and the development of CTRCD, while adjusting for age and gender. Logistic regression was preferred for this analysis because the outcome variable, CTRCD, is binary. For all logistic regression analyses, odds ratios (ORs) with 95% CI and p values were reported.

LVGLS was evaluated by calculating the average decrease in available data points pre- and postchemotherapy in the group overall while also assessing the average decrease in LVGLS between paired values within each individual patient.

Statistical analysis was conducted only for comorbidities and medications present in 30 or more patients. Significance was defined as a p value of <0.05 for all tests.

3. Results

Table 1 presents the demographic and clinical characteristics of the 532-patient cohort. The median age was 69 years (IQR = 61–78), with a greater proportion of females (57.9%) compared with males (42.1%). Commonly observed comorbidities included hypertension, hyperlipidemia, diabetes, and known coronary artery disease. Cancer types were grouped into 14 categories, with breast and lung cancers being the most prevalent.

With regards to echocardiographic assessment(s), 495 patients (93.1%) underwent pre- and/or postchemotherapy TTE, while 37 patients (6.9%) did not receive any echocardiography. Of the patients with echocardiographic assessments, 262 (49.25%) had both pre- and postchemotherapy echocardiographic assessments. There were 166 patients (31.2%) who did not receive a prechemotherapy echocardiogram and 141 patients (26.5%) who did not receive a postchemotherapy echocardiogram (Fig. 1A). For patients with both pre- and postchemotherapy echocardiograms, no statistically significant difference was observed in median LVEF values (Wilcoxon signed-rank test, $p = 0.19$) (Fig. 1B). However, a slight reduction in the median was observed from 60.0% prechemotherapy to 58% postchemotherapy.

Of the 262 patients who had both pre- and postchemotherapy LVEF measurements, 31 patients (11.8%) met the criteria for CTRCD. An additional 34 patients (13.0%) with an initial LVEF above 53% experienced a

Table 1

Demographic of the retrospective study population.

Variable	Characteristics	Frequency (*N* = 532)	Percent (%)
Age (median = 69)	≤40	14	2.6
	41–50	31	5.8
	51–60	83	15.6
	61–70	156	29.3
	71–80	146	27.4
	>80	102	19.2
Sex	Male	224	42.1
	Female	308	57.9
Race	Caucasian	399	75
	African American	72	13.5
	Hispanic	35	6.6
	Other	21	3.9
Comorbidities	Hypertension	358	67.3
	Hyperlipidemia	292	54.9
	Diabetes	136	25.6
	Prior myocardial infarction	70	13.2
	Known coronary artery disease	116	21.8
	History of heart failure	67	12.6
	Atrial fibrillation/flutter	65	12.2
	Lung disease	145	27.3
	Prior transient ischemic attack/stroke	49	9.2
	Peripheral arterial disease	58	10.9
	Prior venous thromboembolism	36	6.8
Medications	Aspirin	183	34.4
	Beta-blocker	177	33.3
	Angiotensin-converting enzyme inhibitor	148	27.8
	Angiotensin receptor blocker	72	13.5
	Diuretic—Lasix	67	12.6
	Calcium channel blocker	81	15.2
	Mineralocorticoid receptor antagonist	22	4.1
	Angiotensin receptor-neprilysin inhibitor	2	0.4
	Nitrate	21	3.9
	Hydralazine	5	0.9
Cancer type	Breast	161	30.3
	Lung	105	19.7
	Colon	27	5.1
	Pancreatic	25	4.7
	Gastrointestinal	25	4.7
	Lymphoma	19	3.6
	Bladder	18	3.4
	Rectal	14	2.6
	Ovarian	14	2.6
	Squamous cell carcinoma	13	2.4
	Esophageal	12	2.3
	Prostate	10	1.9
	Endometrial	10	1.9
	Other	62	11.7

drop to below 53% postchemotherapy, while 39 patients (14.9%) had a LVEF reduction of 10% or greater irrespective of their starting or ending LVEF. Furthermore, there was a subgroup of 28 patients (10.7%) whose LVEF was below 53% both pre- and postchemotherapy. Among the 31 patients with CTRCD, 8 patients had breast cancer (25.8%) and 10 had lung cancer (32.3%). The remaining 13 patients had various types of cancer, including lymphoma, colon, and pancreatic cancers (Fig. 2). To assess the association between comorbidities and the development of CTRCD, a multivariable logistic regression analysis was performed, adjusting for potential confounders such as age and gender. The analysis identified hyperlipidemia as a statistically significant predictor of CTRCD (OR = 3.01, 95% CI: 1.02–8.88, $p = 0.045$), indicating that patients with hyperlipidemia had approximately 3 times higher odds of developing CTRCD compared with those without (Table 2).

Results from multivariable linear regression analysis, adjusting for age and gender, revealed no statistically significant associations between medication use and changes in LVEF following chemotherapy. However, 2 comorbidities—lung disease and prior transient ischemic attack (TIA)/stroke—were significantly associated

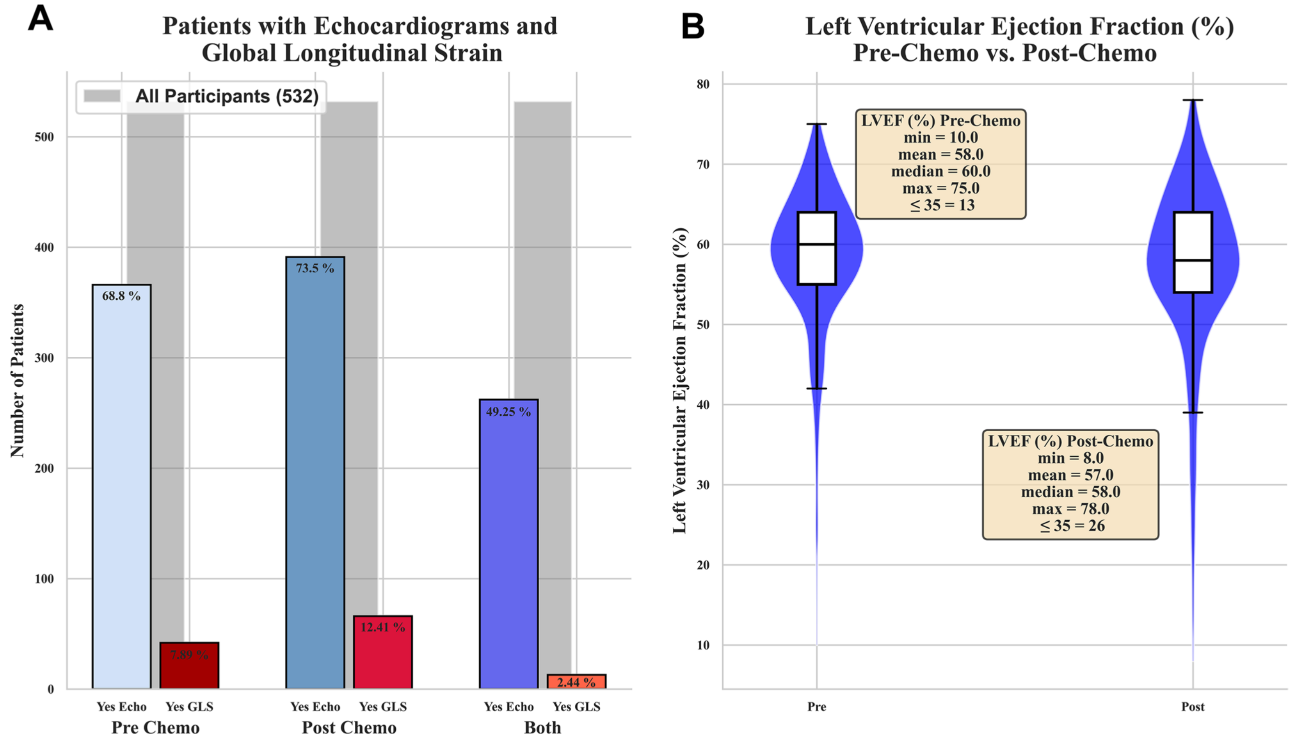

Figure 1. (A) Displays the percentage of patients with echocardiograms and LVGLS measurements prechemotherapy and/or postchemotherapy. (B) Compares the distribution of LVEF between prechemotherapy and postchemotherapy assessments. LVEF = left ventricular ejection fraction, LVGLS = left ventricular global longitudinal strain.

with a reduction in LVEF (Table 3). Specifically, the presence of lung disease was associated with an average LVEF decrease of 4.26 percentage points from pre- to postchemotherapy (95% CI: 0.14–8.38; $p = 0.042$). Similarly, patients with a history of TIA or stroke experienced an average LVEF decrease of 5.54 percentage points (95% CI: 1.16–9.93; $p = 0.013$). Additionally, hyperlipidemia demonstrated a borderline statistically significant association with LVEF decline, with an estimated change of 3.18 percentage points (95% CI: 0.01–6.35; $p = 0.050$), suggesting a potential but less robust link.

For patients with lung disease and both pre- and postchemotherapy LVEF measurements, chronic obstructive pulmonary disease (COPD) and asthma were the most common conditions. The patient's lung disease classification did not include any neoplastic lung diseases. In patients with pre-existing lung disease, the median LVEF of this group decreased by 2.5% (Fig. 3), with 13 patients (9.0%) meeting the criteria for CTRCD. For patients with prior TIA/stroke, the median LVEF decreased by 3.5% (Fig. 3), with 7 patients (14.3%) meeting the criteria for CTRCD.

Prechemotherapy LVGLS measurements were collected for 42 patients, with a median value of −17.1% (IQR = −19.6 to 17.1). Postchemotherapy LVGLS measurements were collected for 66 patients, with a median value of −17.7% (IQR = −19.5 to 11.7). There were 13 patients (2.4%) with both pre-and postchemotherapy LVGLS values out of 532 patients with both pre-and postchemotherapy echocardiograms performed; however, none met the criteria for subclinical cardiotoxicity (Fig. 1A).

4. Discussion

Chemotherapy can cause long-term damage to numerous body systems, with the cardiovascular system being a significant focus due to the well-known cardiotoxicity of many antineoplastic therapies.[5,6,12] In this single-center retrospective cohort study, a group of patients with heterogeneous cancer types were referred for TTE screening due to their risk of cardiotoxicity/cardiomyopathy. Of 532 patients, 262 (49.25%) underwent pre- and postchemotherapy TTE examinations. No statistically significant decrease in LVEF was observed among this subgroup. However, 11.8% of these patients met the criteria for CTRCD following chemotherapy. In a hypothesis-generating secondary analysis, lung disease and prior stroke/TIA emerged as potential risk factors for chemotherapy-induced cardiotoxicity. Additionally, of the patients with LVGLS measurements, only 13 (2.4%) had serial measurements, with no significant reductions found in this group.

Assessment of cardiotoxicity monitoring in cancer patients revealed a gap in validated monitoring techniques for identifying subclinical cardiotoxicity.[5] Only 68.8% of patients referred for TTE for being at risk of cardiotoxicity received baseline echocardiograms, and just 49.25% received a second measurement to monitor changes in

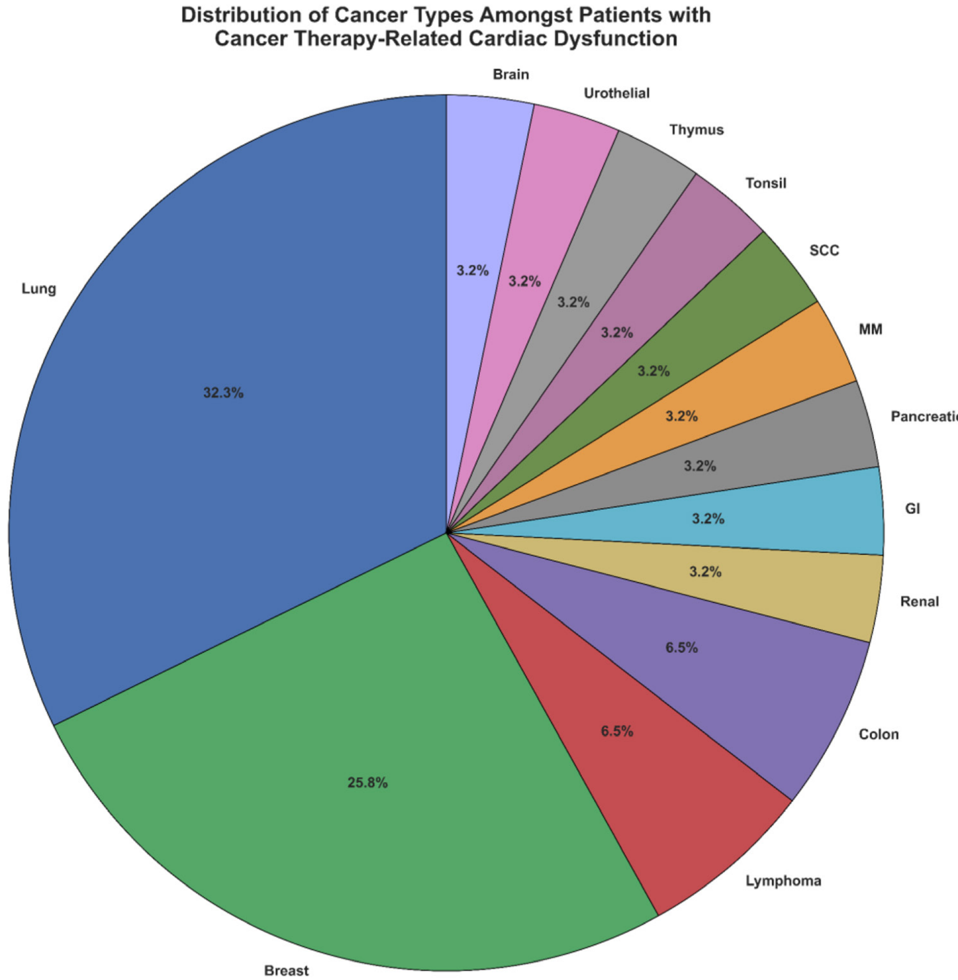

Figure 2. Distribution of cancer types among patients with CTRCD. CTRCD = cancer therapy-related cardiac dysfunction.

Table 2

CTRCD significance testing regarding comorbidities.

Comorbidity	a (Condition+/CTRCD+)	b (Condition+/CTRCD−)	OR	(95% CI)	*p* value
Hyperlipidemia	26	134	3.01	(1.02–8.88)	0.045
History of heart failure	10	38	1.83	(0.64–5.24)	0.263
Hypertension	27	163	1.57	(0.44–5.55)	0.487
Diabetes	7	59	0.58	(0.22–1.49)	0.256
Prior myocardial infarction	8	37	0.98	(0.29–3.33)	0.969
Known coronary artery disease	12	61	0.60	(0.17–2.11)	0.429
Atrial fibrillation/flutter	5	29	0.88	(0.27–2.87)	0.831
Lung disease	13	73	1.07	(0.46–2.53)	0.869
Prior transient ischemic attack/stroke	7	23	1.57	(0.56–4.38)	0.388
Peripheral arterial disease	8	31	1.65	(0.55–4.93)	0.367
Prior venous thromboembolism	3	22	1.00	(0.26–3.90)	1.000

Bolded comorbidity highlights statistical significance.CI = confidence interval, CTRCD = cancer therapy-related cardiac dysfunction, OR = odds ratio.

their heart function postchemotherapy (Fig. 1A). While these numbers seem low, protocols on serial measurements vary between chemotherapy types, making it difficult to comment on overall adherence to TTE surveillance guidelines.[5,13] A goal of the cardio-oncology field has been to detect subclinical cardiotoxicity before significant LVEF declines occur in the hope that therapeutic regimen adjustments or additional interventions can prevent the development of severe cardiotoxicity that may become irreversible even if a patient reaches remission.[2,3] One of these validated factors is a decrease in LVGLS > 15% from baseline. This decrease has been shown to signify subclinical cardiotoxicity and to be a strong predictor of CTRCD development.[4,14] According to the 2022 ESC cardio-oncology guidelines, LVGLS measurements should be performed in every cancer

Table 3

LVEF significance testing regarding comorbidities and medications.

Variable	Characteristics	Frequency (*N* = 262)	LVEF change (%) (pre–post)	(95% CI)	*p* value
Comorbidities	Hypertension	189	0.38	(−3.08 to 3.88)	0.829
	Hyperlipidemia	160	3.18	(0.01 to 6.35)	0.050
	Diabetes	66	−1.13	(−4.44 to 2.19)	0.503
	Prior myocardial infarction	45	1.98	(−1.89 to 5.85)	0.315
	Known coronary artery disease	73	2.36	(−0.99 to 5.72)	0.166
	History of heart failure	48	−0.59	(−4.29 to 3.12)	0.756
	Atrial fibrillation/flutter	34	−0.94	(−5.24 to 3.36)	0.667
	Lung disease	86	4.26	(0.14 to 8.38)	0.042
	Prior transient ischemic attack/stroke	30	5.54	(1.16 to 9.93)	0.013
	Peripheral arterial disease	39	0.10	(−3.15 to 5.14)	0.636
Medications	Aspirin	98	−1.19	(−4.15 to 1.78)	0.433
	Beta-blocker	102	−0.72	(−3.70 to 2.26)	0.634
	Angiotensin-converting enzyme inhibitor	76	−1.87	(−5.00 to 1.26)	0.239
	Angiotensin receptor blocker	37	−0.10	(−4.87 to 3.07)	0.656
	Diuretic–Lasix	49	−1.10	(−4.79 to 2.58)	0.555
	Calcium channel blocker	43	0.92	(−2.84 to 4.68)	0.629

Bolded comorbidity highlights statistical significance.LVEF = left ventricular ejection fraction.

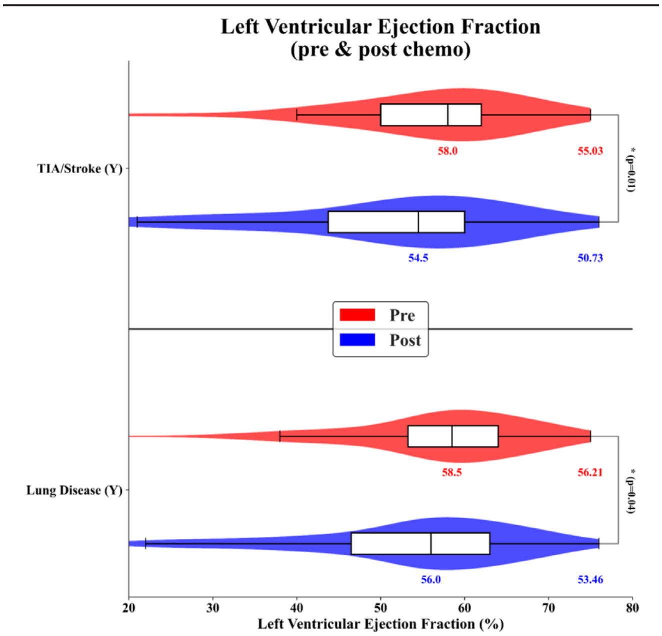

Figure 3. Prechemotherapy and postchemotherapy median (left) and mean (right) LVEF in relation to patients with lung disease or previous TIA/stroke as comorbid conditions. A multivariable linear regression was performed with the *p* value and significance displayed. LVEF = left ventricular ejection fraction, TIA = transient ischemic attack.

patient undergoing TTE.[5] In this study population, only 13 patients had serial LVGLS measurements out of 262 patients who had serial echocardiograms and were identified at risk of cardiotoxicity or cardiomyopathy while undergoing chemotherapy. While new research involving algorithmic analysis of electrocardiograms, blood biomarkers, and cardiac magnetic resonance imagings for subclinical cardiotoxicity identification has emerged, our findings indicate that the already established LVGLS early detection method has been underutilized, underscoring opportunities to identify subclinical disease and potentially limit CTRCD development.[2,11,15–18]

The incidence of CTRCD was observed in 31 patients, representing 11.8% of the cohort. This aligns with literature estimates suggesting that about 10% of patients develop CTRCD.[3] Among the cohort, breast and lung cancers were the most common types associated with CTRCD, likely due to the well-known cardiotoxic effects of treatments for these cancers.[5,6,12] More than 13 other cancer types were also represented in the group, indicating that severe cardiotoxicity is not limited to just a few types of cancer and calls attention to the fact that cardiovascular disease can arise as a side effect of neoplasm itself.[19] To further explore the risk of development of CTRCD's in this cohort, comorbidities were analyzed. Upon analysis of CTRCD, the multivariable logistic regression highlighted the significance of hyperlipidemia in the incidence rate of CTRCD. These findings emphasize the importance of considering hyperlipidemia as a factor in patients undergoing chemotherapy, which may provide a potential avenue for intervention to reduce the risk of CTRCD. Upon analysis of CTRCD, the multivariable logistic regression highlighted the significance of hyperlipidemia in the incidence rate of CTRCD. These findings emphasize the importance of medical management of hyperlipidemia in this at-risk population, as well as the need to maintain a high level of clinical suspicion for CTRCD in patients with hyperlipidemia who are undergoing chemotherapy.[5] In further analysis of LVEF, patients with pre-existing lung conditions, primarily COPD and asthma, or a history of TIA/stroke before cancer treatment demonstrated a statistically significant change in LVEF (Table 3). The observed reduction in median LVEF, combined with the statistically significant *p* values, indicates that lung disease may be a potential comorbid risk factor for chemotherapy-induced cardiotoxicity. Lung disease, such as COPD or asthma, may increase the risk of heart-related chemotherapy complications through various mechanisms, including inflammation, oxidative stress, and microvascular dysfunction, which may make the heart more vulnerable to the cardiotoxic effects of chemotherapy.[20,21] These hypothesis-generating results warrant further investigation to establish a more definitive correlation between these factors.

The primary findings and significance of this study are 2-fold. First, with respect to risk factors, we identified several patient characteristics that were significantly associated with a decline in LVEF or the development of CTRCD. Specifically, patients with pre-existing lung disease or a history of stroke/TIA demonstrated a higher likelihood of experiencing reduced LVEF. Additionally, hyperlipidemia was found to be significantly associated with increased risk of CTRCD.

In terms of clinical significance, which is our greater focus for the paper, we aim to highlight the considerable gap between cardiotoxicity screening guidelines and current clinical practices. While there are a variety of guidelines based on risk stratification with regards to patient-level characteristics, cancer type, and amount of chemotherapy received, cardiovascular risk assessment is still lacking for many cancer patients despite the knowledge that they are at high risk for cardiac dysfunction. Of the patients who do undergo echocardiogram, we found that important measurements are often not documented including LVGLS, which is a validated predictor for detecting subclinical cardiotoxicity before significant LVEF reduction, enabling alteration of treatment regimens to limit the administration of cardiotoxic agents or addition of cardioprotective medications.

The findings of this study are limited by the lack of explicit identification of the chemotherapeutic regimen for each patient, preventing a thorough analysis of the impact of strongly cardiotoxic treatments, such as anthracyclines, on the incidence of CTRCD.[12] Moreover, other anticancer therapies, such as radiation, can impact LVEF, global longitudinal strain, and the onset of CTRCD.[22] Without accounting for this confounding variable, its effects on the results cannot be adequately assessed. Although we did not analyze specific chemotherapy regimens, all patients in our study who were undergoing chemotherapy were referred for TTE because of their risk of developing cardiotoxicity/cardiomyopathy. Therefore, it is likely that this cohort mostly received cardiotoxic therapies or had a risk factor at their baseline cardiovascular exam that put them at risk for developing chemotherapy-related cardiotoxicity. Since many chemotherapeutic agents impose some level of cardiac stress in addition to neoplasm itself, assessing the risk and incidence of CTRCD in this diverse group still offers valuable insights despite the limitation of regimen variation.[1,12,19] Furthermore, the study was limited by challenges in collecting data on troponin I and brain natriuretic peptide levels, which are potential predictive markers for CTRCD.[2] The inconsistency in prechemotherapy screening practices means that troponin I and brain natriuretic peptide values were often collected incidentally rather than as part of a formal baseline cardiac assessment.[2,12] Postchemotherapy values were collected less often than prechemotherapy values and at a greater time interval variance, making it challenging to analyze these values in a meaningful way. Although the study intended to compare these biomarkers with comorbidity and CTRCD findings, this limitation highlights the need for more standardized pre- and postchemotherapy cardiac evaluations to better monitor the development of cardiac dysfunction over time. Finally, although our institution is a tertiary referral center with a diverse patient population and broad catchment area, our results may not be generalizable to other institutions due to inherent limitations in representativeness of a single-center study. This study highlights the clinical gap in the cardiotoxicity monitoring of cancer patients. This gap is not due to improper medical care but rather the challenges of forming definitive protocols that accommodate large variability in patient characteristics, cancer type, therapeutic intervention, and life expectancy. However, with ongoing advancements in antineoplastic therapies that significantly extend patient survival and improve remission rates, addressing and mitigating the associated cardiovascular side effects has become critically important. Further research is needed to provide more definitive and validated imaging, biomarkers, and comorbidities risk stratification to provide better care in real-world settings.

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Dr. Widmer, MD, PhD, mentored the team throughout the entire process and planning of this review.

Ethical statements

The data of this study was approved by the Institutional Review Board of Baylor Scott and White Research Institute (IRB#019-180, June 2019) and conforms to the norms established by the Declaration of Helsinki.

Conflicts of interest

The authors have no conflicts of interest to disclose.

Funding source

Not applicable.

Data availability statement

Per institutional review board protocol, the abstracted materials and associated datasets cannot be transferred from behind the security of BSW firewalls for a minimum of 6 years and no longer than 10 years, with only recognized study members having access to the data.

Author contributions

The initial dataset analysis was done by MS and SP. Secondary analyses were done by MS, SP, and TH. ZM and the rest of the authors proceeded to write the manuscript. All authors and the principal investigator read and approved the final manuscript.

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