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STATE-OF-THE-ART REVIEW

Health Literacy, Individual and Community Engagement, and Cardiovascular Risks and Disparities

JACC: CardioOncology State-of-the-Art Review

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ABSTRACT

Cardiovascular and cancer outcomes intersect within the realm of cardio-oncology survivorship care, marked by disparities across ethnic, racial, social, and geographical landscapes. Although the clinical community is increasingly aware of this complex issue, effective solutions are trailing. To attain substantial public health impact, examinations of cancer types and cardiovascular risk mitigation require complementary approaches that elicit the patient's perspective, scale it to a population level, and focus on actionable population health interventions. Adopting such a multidisciplinary approach will deepen our understanding of patient awareness, motivation, health literacy, and community resources for addressing the unique challenges of cardio-oncology. Geospatial analysis aids in identifying key communities in need within both granular and broader contexts. In this review, we delineate a pathway that navigates barriers from individual to community levels. Data gleaned from these perspectives are critical in informing interventions that empower individuals within diverse communities and improve cardio-oncology survivorship. (J Am Coll Cardiol CardioOnc 2024;6:363–380)

A growing global population is either at risk of or managing cardiovascular disease (CVD) and cancer concurrently.[1,2] Remarkable advances in cancer detection and treatment have expanded the population of cancer survivors, which is projected to reach over 26 million by 2040.[3] However, CVD has emerged as the leading cause of mortality among cancer survivors,[4-11] with a 2- to 6-fold increased prevalence compared with the general population.[4,12] These trends have brought greater attention to the critical intersection of cancer survivorship and CVD, subsequently drawing attention to the amplified inequities in oncological and cardiovascular care.[13,14]

CVD influences clinical decisions and overall outcomes across various prevalent cancers, including breast, prostate, colorectal, and endometrial cancers. Despite sharing common risk factors such as tobacco use, hypertension, and physical inactivity, which promote chronic inflammation and oxidative stress, these diseases coincide in an aging population. Lifesaving cancer treatments, coupled with indirect

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ABBREVIATIONS AND ACRONYMS

ASCVD = atherosclerotic cardiovascular disease

BCPR = bystander cardiopulmonary resuscitation

CVD = cardiovascular disease

SDOH = social determinants of health

SEER = Surveillance, Epidemiology, and End Results

TNBC = triple negative breast cancer

post-treatment lifestyle changes like deconditioning, and the molecular influence of cancers themselves, contribute to adverse effects on cardiovascular structure and function.[15-17] In the short term, cardiovascular complications may lead to treatment delays, early termination of cancer treatment, or even exclusion from cancer trials. Over the long term, cancer survivors face a higher risk of developing heart disease compared with cancer recurrence.[18] This risk is even more pronounced among patients diagnosed with cancers with improved long-term survival rates, such as breast or prostate cancer.

Poor cardiovascular and oncological outcomes care are closely associated with adverse social determinants of health (SDOH), which the World Health Organization estimates influence up to 80% of health outcomes. These disparities disproportionately affect specific groups such as women and people of color.[19,20] Health literacy can mitigate the adverse impacts of other social determinants.[21] Addressing patient-centered factors is therefore crucial for achieving health equity, while ongoing exploration of the biology of cancer and CVD continues. Moreover, integrating SDOH in a geospatial analysis expands this perspective to include communities in need. Although disparities in cardio-oncological care have been recognized,[13,14,22-24] studies addressing behavioral and social factors remain limited.

In this review, we assess current evidence and identify knowledge gaps regarding cardiovascular disparities among patients diagnosed with prevalent cancers, particularly breast and prostate cancer. These target populations are focal points for interventions that could yield the highest impact. Additionally, we examine the evidence supporting patient-centered health literacy, interdisciplinary collaboration, and community interventions, alongside biological factors, as potential drivers for improving health equity in cardio-oncology.

HIGHLIGHTS

- Social determinants disproportionately impact cardiovascular outcomes in cancer survivors from marginalized communities.
- Health literacy and community engagement are important avenues for influencing health outcomes positively.
- Preventative interventions could be scaled across communities through geospatial analysis.
- A multidisciplinary strategy prioritizing patient-centered factors within a geospatial context has the potential to improve outcomes.

CARDIOVASCULAR RISK IN HIGHER PREVALENCE CANCERS IN THE U.S.

Although overall cancer incidence has declined, certain cancer cases are increasing. For instance, in the United States, in 2023, breast cancer accounted for 31% of diagnoses among women, and prostate cancer was the most common in men at 29%.[25] These 2 cancers also yield the largest racial disparities in mortality.[25,26] Moreover, this trend intersects with the cardiovascular risk. A SEER (Surveillance, Epidemiology, and End Results) program study involving more than 3 million cancer patients across 28 cancers revealed that breast and prostate cancers had the highest absolute counts of CVD mortality,[4] reflecting their higher prevalence, shared risk factors, and excellent long-term cancer survival.

BREAST CANCER. The substantially elevated risk of CVD among breast cancer survivors raises considerable concern.[27] Globally, CVD is a leading cause of death in women.[28] Women diagnosed with breast cancer face an increased susceptibility to heart failure, stroke, arrhythmia, cardiac arrest, and venous thromboembolism, often resulting in elevated mortality rates from cardiovascular events.[29] These adverse effects can occur acutely or emerge years after the completion of treatment. Within as few as 7 years postdiagnosis, mortality from CVD surpasses that attributed to breast cancer itself.[30-32]

The intersection between CVD and breast cancer is attributed to shared risk factors, the cardiotoxic effects of cancer therapy, and disparities in prevention and treatment strategies. Common cardiovascular risk factors such as tobacco use, Western diet, obesity, and a sedentary lifestyle overlap in both conditions. Breast cancer treatment often involves anthracyclines (eg, doxorubicin), human epidermal growth factor receptor 2 (HER2)-targeted drugs (eg, trastuzumab), alkylating agents, cyclophosphamides, cyclin-dependent kinase 4/6 inhibitors, aromatase inhibitors, and radiation therapy, all strongly associated with cardiotoxicity.[33-36] Research indicates that cancer therapy-induced heart failure has been associated with a substantially increased risk of mortality (HR: 2.64; 95% CI: 1.53-4.55; $P = 0.001$) and composite events such as death, left ventricular assist

device implantation, and heart transplantation (HR: 1.79; 95% CI: 1.10-2.91; $P = 0.019$) compared with control subjects, despite a baseline favorable clinical profile characterized by younger age, higher left ventricular ejection fraction, and fewer cardiovascular risk factors.[37] Furthermore, radiotherapy, particularly directed at the left chest wall, carries an elevated risk of myocardial infarction, heart failure, and valvular dysfunction, independent of adjuvant chemotherapy.[38-40]

Socioeconomic and racial factors substantially influence the risk of breast cancer, staging, survival, and the risk of CVD. Notably, breast cancer stands as the primary cause of cancer-related mortality among Black and Hispanic women,[41,42] who also experience elevated mortality rates due to heart disease.[19,43] Women affected by adverse SDOH, particularly historically marginalized populations of Black and Hispanic descent, confront a confluence of challenges, including the higher incidence of cardiovascular risk factors, disruptions and barriers to timely screening and treatment, and an increased likelihood of advanced cancer diagnoses.

Historically, Black women have borne the greatest burden of traditional cardiovascular risk factors and chronic comorbidities.[44,45] Moreover, their lower prevalence of breastfeeding, a protective lifestyle behavior against breast cancer,[46,47] and earlier diagnoses of advanced cancer underscore the complex factors influencing treatment decisions and subsequent survival outcomes. In addition, Black women diagnosed with hormone receptor-positive/HER2-negative, lymph-node positive breast cancer tend to exhibit inferior outcomes compared with their Asian, Hispanic, and White counterparts.[48] The compounded impact of diminished health literacy further impedes their engagement in shared decision-making with their health care team. Therefore, addressing health literacy has the potential to improve outcomes in this segment of population.

Biological factors also contribute to disparities in breast cancer outcomes, particularly evident in triple-negative breast cancer (TNBC), acknowledged as the most aggressive subtype. Black women experience a higher incidence of TNBC, increased severity at diagnosis, and elevated mortality compared to others with TNBC.[49,50] Beyond socioeconomic and lifestyle considerations, the heightened prevalence of genetic mutations within the Black population may contribute to this disparity. Treatment for TNBC often involves therapies with known cardiotoxic effects, such as anthracyclines and more recent immune checkpoint inhibitors.[51,52] Additionally, Black women may display differential responses to endocrine therapy and manifest increased treatment resistance. The existing gaps in understanding TNBC pose an elevated risk for this population in terms of developing cancer-related cardiotoxicity, emphasizing a call for further investigation.

PROSTATE CANCER. Prostate cancer is recognized as the most common non-cutaneous malignancy among men worldwide.[3] Despite its generally favorable prognosis, men diagnosed with prostate cancer face a 4.5-fold increased risk of non-cancer-related mortality compared with mortality directly attributable to cancer itself. CVD emerges as the leading cause of death in prostate cancer survivors,[7,53] with a 36% higher mortality rate from CVD compared with the general population. Beyond mortality, two-thirds of men diagnosed with prostate cancer are at an increased risk of CVD.[54] This heightened susceptibility is due to the elevated rates of early detection, as most men are diagnosed with localized or regional disease, resulting in 100% and 99.5% 5-year survival rates, respectively. This heightened survival is largely attributed to the effectiveness of androgen deprivation therapy. However, despite its demonstrated efficacy in inducing cancer remission, androgen deprivation therapy leads to unfavorable changes in lipid profiles, insulin resistance, and obesity.[55,56] It is associated with increased risks of coronary artery disease, myocardial infarction, heart failure, thromboembolism, and cardiac-related death.[55-60] Such cardiometabolic effects raise further concerns, particularly in disparate populations.

Prostate cancer predominantly affects older men who possess modifiable risk factors such as a sedentary lifestyle, obesity, diabetes, and tobacco use, which often overlap with CVD.[61] In a comprehensive study of 90,494 men treated within the U.S. Veterans Health Administration and diagnosed with prostate cancer between January 1, 2010, and December 31, 2017, it was observed that the modification of risk factors was less than optimal[62] among patients without a history of atherosclerotic cardiovascular disease (ASCVD) who were receiving androgen deprivation therapy.

Black men experience more than double the mortality rate from prostate cancer compared with White men[63] and are also at an increased risk of CVD mortality at every time point on the continuum. A recent review found Black patients, older patients, and those with non-private insurance were less likely to undergo baseline diagnostic magnetic resonance imaging as part of their staging and treatment plans.[64] Another population-based cohort study found that geographic differences, socioeconomic status, and racialized residential segregation mediated most of

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the disparity in prostate magnetic resonance imaging usage between Black men and White men.[65]

Currently, there is a lack of clarity regarding disparities in health literacy at the intersection of cardiometabolic health and prostate cancer care.

OTHER PREVALENT CANCERS. In the United States, research on disparities in common cancers with elevated cardiovascular risk, including lung,[66-68] colorectal,[69-72] bladder,[73,74] endometrial,[75,76] and hematologic malignancies,[77-81] is still underway. Understanding the shared risk factors between these cancers and CVDs, combined with recent treatment advancements, underscores the need to address social disparities in this space.

PATIENT AND CLINICIAN AWARENESS OF THE OVERLAP BETWEEN CARDIOLOGY AND ONCOLOGY

Although numerous strategies such as establishing precise clinical guidelines and improving trial recruitment have been recognized for advancing cardio-oncology, the potential role of the key person—the patient—is often overlooked. Both CVD and cancer are chronic conditions that necessitate active engagement and attention from patients. Bridging the gap between evidence-based practices and their actual impact on health often depends on partnering with patients at the individual level and empowering them to take an active role in managing their health. Shared decision-making, which entails collaborative discussions between health care providers and patients to make informed decisions, is essential.[82] This process involves exchanging information, discussing treatment options, and thoroughly exploring patients' values. However, challenges such as insufficient health literacy and limited interdisciplinary knowledge exchange hinder effective communication and treatment adherence.

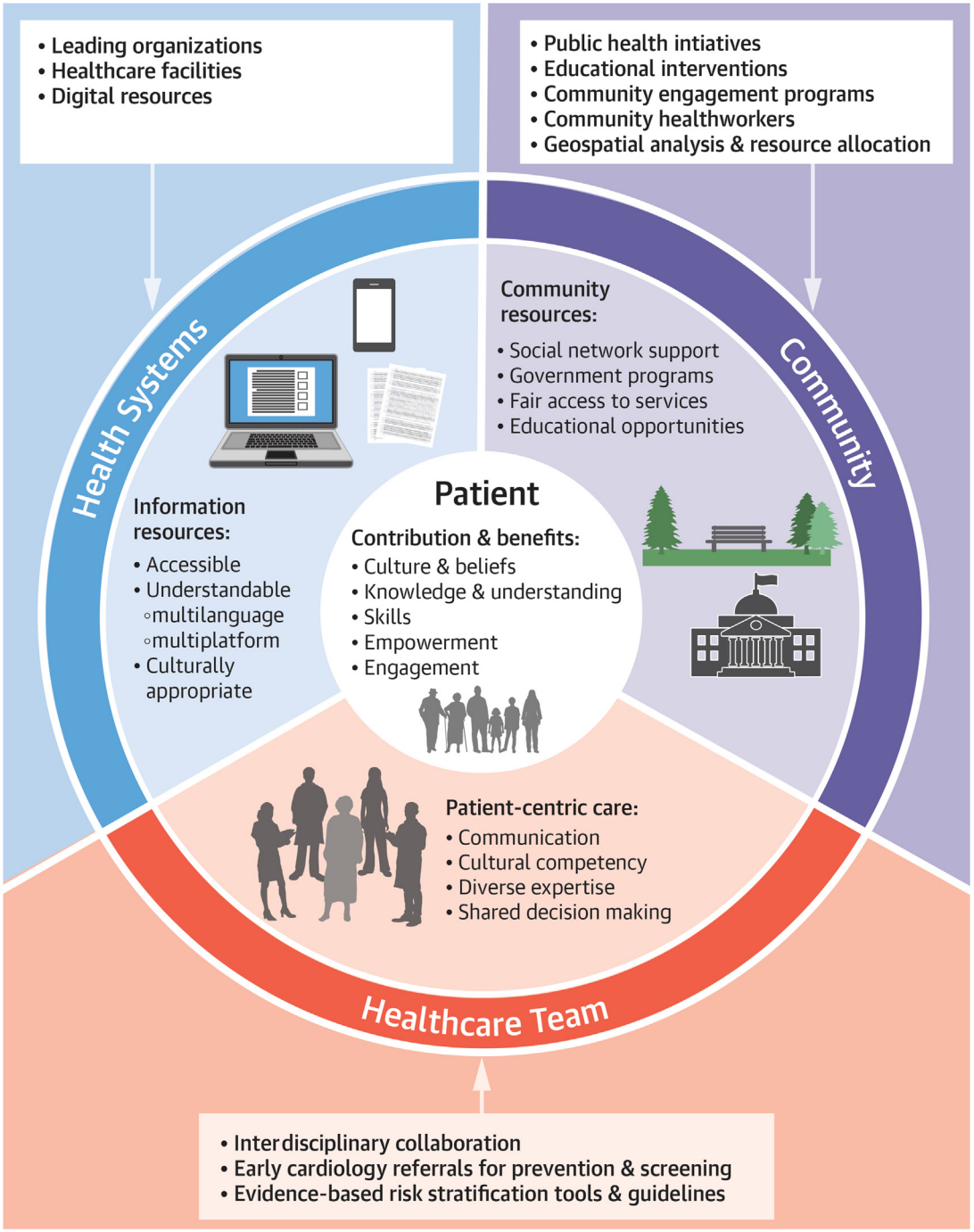
To bridge this gap in the current health care delivery model from a cardio-oncology perspective, it is necessary to integrate principles of health literacy, foster interdisciplinary collaboration, and address geographical disparities (**Central Illustration**). The first step would involve conducting large-scale risk assessments within the cardio-oncological domain. Empowering patients through subsequent targeted interventions to confidently engage in shared decision-making is a priority in cardio-oncological care, with the aim of enhancing survivorship outcomes.

THE ROLE OF HEALTH LITERACY. Health literacy, defined as the ability to find, understand, and use information and services to make informed health-related decisions,[83] is influenced by a multitude of individual, systemic, and societal factors. Patients with higher levels of health literacy are more likely to adhere to treatment plans, engage in preventive measures, and actively participate in their health care, leading to better overall health outcomes. Therefore, health literacy is closely tied to health equity, as it empowers individuals to understand and navigate complex health information, thereby facilitating informed decision-making.

According to the most recent available estimates, approximately 88% of adults living in the United States have inadequate health literacy to effectively navigate the health care system[84]. This inadequacy is particularly pronounced among specific demographic groups, including those with lower educational attainment, those from socioeconomically disadvantaged backgrounds, non-native English speakers, and elderly populations adapting to evolving health care practices.[85] Lower health literacy rates are also prevalent among racial and ethnic minority groups, immigrants, refugees, and individuals managing chronic health conditions. Studies have indicated that the prevalence of low health literacy increases with the number of chronic conditions, rising from 10.6% among those with no chronic conditions to 24.7% among those with 3 or more.[86] Additionally, in this electronic age, limited digital literacy has driven the formation of "the Digital Divide,"[87-90] particularly affecting underserved communities.

In both cardiology and oncology spaces, limited health literacy has been strongly associated with substantial patient morbidity, mortality, readmission rates, and health care costs.[91-96] The American Heart Association has recognized health literacy as a prominent invisible barrier to improving cardiovascular health.[97] The prevalence of low health literacy among cardiovascular patients averages at 32.8%, with a corresponding risk ratio of 1.90 for mortality and 1.35 for readmission, and has a strong association with education level, age, and sex.[91] A recent study[95] found that nearly 1 in every 6 cancer survivors reported low health literacy. The prevalence of low health literacy was higher among Black and Hispanic cancer survivors, those with lower educational attainment, lower household income, unemployment, and lack of insurance coverage. Among women from racial minority groups diagnosed with breast cancer, there is a decreased likelihood of accurately reporting or comprehending various tumor characteristics. This diminished capacity is associated with a

CENTRAL ILLUSTRATION **Patient-Centered Approaches to Improve Cardiovascular Disparities in Cancer Care**



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The health care team, health systems, information resources, and community resources—intersect with internal, patient-centered factors—culture and beliefs, health care literacy, understanding, motivation, and engagement. These internal factors are as important as external ones for long-term health outcomes, especially in cancer survivorship disparities.

lower quality of life attributed to inadequate health literacy levels, with heightened vulnerability due to socioeconomic disparities.

As health literacy continues to gain recognition, it has been proposed that it plays a partial mediating role in the association between various socioeconomic determinants and health outcomes.[21] Researchers posit that enhancing health literacy can mitigate the impact of specific underlying socioeconomic factors that contribute to health disparities.[98,99] For instance, 1 study demonstrated that for every 1-unit increase in health literacy among individuals born in the United States, the odds of health care delay decreased by 9%.[100] Another study suggests that health literacy may attenuate the heightened risk of cancer mortality in Black women.[101] Overall, these findings suggest that interventions aimed at improving health literacy may serve as a valuable strategy in addressing the broader issue of health inequalities stemming from socioeconomic disparities.

There is a notable lack of data evaluating health literacy within the cardio-oncology population. However, we identified 1 randomized control trial[102] in which health literacy was assessed using a 6-point system to compare a cardio-oncology rehabilitation program with usual community-based exercise training. This assessment instrument, called the Newest Vital Sign, is an efficient alternative to the S-TOFHLA (Short Test of Functional Health Literacy), which is the most widely used health literacy assessment tool in studies focusing on cardiovascular health. The trial revealed significant improvements in health literacy scores among those who underwent the rehabilitation program compared to those in the control group. Notably, the rehabilitation cohort also yielded greater improvements in exercise adherence, control of cardiovascular risk factors, and overall quality of life. Indeed, further studies within this population are needed to evaluate the effects of health literacy on cardio-oncology outcomes.

PATIENT KNOWLEDGE. In the context of widespread CVD and cancer, there is a lack of patient knowledge regarding these conditions and their associated symptoms. A survey conducted among a diverse breast cancer population highlighted a significant deficiency in understanding their cancer and the rationale behind treatment, despite participants expressing a perceived sense of being well-informed and acknowledging the importance of comprehending treatment rationale in decision-making processes.[103] Cancer survivors from Black and Hispanic backgrounds, as well as those with lower levels of health literacy, consistently demonstrated lower levels of knowledge about their respective cancers. Likewise, individuals with cardiac conditions encounter difficulties in identifying and addressing symptoms associated with heart disease.[104-106] This issue is particularly noteworthy in the case of women, as they often present with atypical symptoms,[107,108] potentially leading to more adverse health outcomes.

Moreover, awareness of cardio-oncology within the health care community lags behind,[109-112] indicating a knowledge gap that extends to cancer survivors who are even less informed about their heightened cardiovascular risk. The evaluation of patients' awareness concerning cardiac risks associated with cancer treatment remains an underexplored area. Patients undergoing cancer treatment often lack awareness of their susceptibility to CVD, despite having preexisting risk factors.[113] Concerns raised by patients include inadequate discussions on cardiotoxicity and risk modification strategies before treatment, the need for health education regarding heart failure risks associated with cancer treatment, and a perceived lack of collaboration between oncologists and cardiologists. In a study involving endometrial cancer survivors, the majority acknowledged their elevated cardiac risk and expressed the importance of discussing this risk with their oncologists.[114] Based on current knowledge, it is plausible to infer that cancer survivors from underserved communities may encounter more pronounced disparities in their awareness of their elevated cardiac risk. However, the extent of these disparities remains uncertain and is expected to vary among distinct sociodemographic groups. The first step is to delineate knowledge gaps within this population, enabling the formulation of targeted interventions to alleviate these disparities. This area of investigation would benefit from an interdisciplinary approach engaging clinicians, health care experts, and anthropologists.

COMMUNITY ENGAGEMENT. Public health and community-based interventions can bolster clinic-based efforts to promote cardiovascular health among oncology patients and their families, representing a crucial secondary site for health promotion.[115] Indeed, oncology patients facing heightened CVD risk are part of a growing global population living with multiple chronic conditions,[116] underscoring the importance of bolstering clinic-based efforts through coordinated education and engagement with community-based educational campaigns.

Addressing the inequitable distribution of health education resources,[117,118] which has become an international health care priority, is paramount in these efforts. Community-based strategies for education and engagement[119-124] offer several key advantages, particularly for populations vulnerable to cardio-oncological health disparities.[125]

Interventions aimed at enhancing patient knowledge have demonstrated positive impacts on quality of life and health outcomes. Educational goals revolve around empowering patients to actively engage in ongoing decision-making, heightening awareness, and enhancing functional performance. Thus, education emerges as a vital component in the holistic management of patients. Educational programs focusing on CVD have proven effective in promoting self-care, reducing risk, and minimizing readmissions.[126-130] Similarly, comparable improvements in self-management and quality of life have been observed among cancer survivors.[131-135] The rapid adoption of digital innovations in this context,[136-142] accelerated by the challenges of the COVID-19 pandemic, further underscores the potential for transformative advancements in patient education and support. Increasing patient knowledge addresses misconceptions and misunderstandings that would otherwise hinder adequate self-care.[143]

Recent efforts have focused on enhancing the dissemination of information regarding cardiovascular risks in cancer survivorship within the public domain. Initiatives such as the American College of Cardiology's 2019 forum[144] provide a platform for cancer survivors to share their experiences navigating their cancer treatment and heart disease risks. These initiatives have prompted the creation of online resources such as CardioSmart[145] by the American College of Cardiology and the American Society of Clinical Oncology[146] to deliver heart health knowledge to the public.

There is an urgent call to provide culturally appropriate care, education, prevention, and monitoring of heart disease and its risk factors among diverse cancer survivors, particularly among Black, Asian American and Native Hawaiian/Pacific Islander, and Latina women diagnosed at younger ages and more advanced stages.[13,14,147,148] Cultural norms, traditions, and beliefs significantly shape patients' attitudes toward health care, profoundly impacting their understanding of cardiovascular health risks associated with cancer treatment. Addressing cardio-oncology disparities through community-based health interventions involves implementing culturally sensitive programs that consider health literacy, language preferences, and cultural beliefs. Tailored educational campaigns should aim to improve understanding of cardiovascular risks related to cancer treatment within specific cultural communities, utilizing linguistically appropriate materials. Community health workers, well-versed in the cultural nuances of the target population, can play a pivotal role in bridging communication gaps and providing personalized health education. Ensuring accessibility to health care services, including screening and preventive measures, requires addressing structural barriers and integrating community-specific resources. Genetic counseling and testing programs should be culturally competent, acknowledging ethnic and genetic variations. Cultivating partnerships between health care providers and community organizations can enhance cultural competence in health care delivery. Ultimately, community-based interventions must be holistic, acknowledging and respecting cultural diversity to effectively reduce cardio-oncology disparities within diverse populations.

INTERDISCIPLINARY COLLABORATION. Effective collaboration between oncologists and cardiologists is crucial for delivering comprehensive care to cancer patients.[14,27,149] A study confirmed that enhanced training and attention by oncologists to discharge conversations with patients could improve patients' sense of control, coping and adaptation, self-esteem, and perceived quality of life.[150] However, the significance of this collaboration may not be fully recognized by the medical community and the general public. Increasing awareness about the necessity of interdisciplinary teamwork and encouraging the establishment of joint clinics or consultations can help close this knowledge gap. By doing so, patients can receive integrated care that addresses both their cancer treatment and cardiovascular well-being, ensuring a more holistic approach to their health care needs.

In recent years, efforts aimed at enhancing awareness of cardio-oncology among health care professionals and the public have included educational campaigns, patient advocacy organizations, and informational resources provided by cancer centers and health care institutions. These initiatives also emphasize the role of social determinants of health, ethnicity, and race in adverse outcomes. Notably, current cardio-oncology guidelines, including those from the American Society of Clinical Oncology,[151] the European Society for Medical Oncology,[152] and the European Society of

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Cardiology,[153] provide valuable recommendations for the prevention, monitoring, and management of cardiovascular complications in cancer patients, including "social class indicator" and ethnic group in androgen deprivation therapy.[153] These guidelines serve as important resources for health care providers involved in the care of cancer patients, offering evidence-based recommendations for addressing cardiovascular issues associated with cancer treatments. Furthermore, focused efforts such as the American College of Cardiology's "Advancing the Cardiovascular Care of the Oncology Patient"[154] conference, and social media campaigns like the Society of Behavioral Medicine's Twitter Chat moment #CardioOncology,[155] have provided the field with a greater platform for discussion.

Despite these efforts, a noteworthy proportion of clinicians remain unaware of these guidelines, leading to substantial disparities in knowledge and attitudes. A 2019 international survey of clinicians demonstrated profound differences in the definition, diagnosis, and approach to monitoring cardio-oncology patients.[111] Oncologists were less tolerant (20%) of cancer-related cardiac risk compared with cardiologists (38.7%), especially in the setting of advanced disease. However, cardiologists expressed stronger conviction about the clinical value of cardio-oncology clinics; 88.3% of cardiologists believed cardio-oncology clinics would significantly improve prognosis compared with 45.8% of oncologists. Further, cardiologists were more likely to monitor for cardiotoxicity in cancer patients and refer early to cardio-oncology (50%) compared with oncologists (6.5%). This difference in care is important, as some cardiotoxicities are reversible if treated early, such as anthracycline-induced cardiotoxicity, or possibly preventable, such as post-lung cancer resection atrial fibrillation. Although based on a limited sample size, a clear distinction in care between medical specialties is evident.

VALIDATED RISK STRATIFICATION TOOLS IN CARDIO-ONCOLOGY. The ASCVD risk calculator serves as a valid and comprehensive summary of major cardiovascular risk factors and has been regularly used in primary care settings for risk-stratified clinical practice interventions. This approach has led to widespread use in population-health settings to identify and target clinical interventions to patients across varying levels of CVD risk.[156-158]

ASCVD specifically estimates a 10-year risk for heart attack or stroke, providing guidance to patients and clinicians regarding expected risk reductions with specific interventions, such as improved hypertension control or initiation of statin medication. However, its applicability to predicting CVD in the cancer survivor population is largely unstudied. Furthermore, it is unclear how baseline CVD risks interact with risks resulting from cancer and cancer treatment.

In the past decade, risk stratification tools and prediction models have emerged for certain cancer populations, such as survivors of breast, prostate, and childhood cancer, as well as those who have undergone hematopoietic stem cell transplantation,[159] though further validation studies are needed. For example, the 2022 European Society of Cardio-Oncology guidelines provide guidance on risk stratification, detection, and management of cancer therapy-related cardiovascular toxicity.[153] These guidelines endorse the utilization of the HFA-ICOS risk score,[160] which was developed for 7 types of known cardiotoxic cancer therapies, including anthracyclines and androgen deprivation therapy. However, the guidelines are based on expert consensus, and studies validating the HFA-ICOS risk score are limited to breast cancer survivors and those with low to moderate cardiotoxicity risk. In addition to a thorough history and physical exam, further recommendations include trending serum cardiac biomarkers and imaging.[152,153,161] These risk prediction tools, as outlined in **Table 1**, are initial steps demonstrating the potential of personalized cardio-oncological risk stratification, and there is a need for their expansion to more diverse patient populations.

GEOGRAPHIC DISPARITIES AND GEOSPATIAL ANALYSIS AS A KEY APPROACH TO IMPROVING OUTCOMES. Geospatial analysis is an established method for understanding and leveraging local and global geographic patterns in health care. Through geospatial data, we can identify disparities in health outcomes based on geographic access to health care services, such as proximity to clinics, prevention, treatment, diagnosis, or various health-related factors observed across different geographic areas. However, many of these geospatial analyses are limited, primarily focusing on regional and socioeconomic analyses.

Distinct geospatial patterns have been observed in CVD[162-165] and cancer outcomes,[166-168] emphasizing socioeconomic factors such as racial composition or income level of the area across the spectrum of presentation and medical care. In an analysis of

TABLE 1 Risk Prediction Models in Cardio-Oncology

Risk Prediction Model	Intended Cancer Population	Predictors	Outcomes	Strengths	Limitations
HFA-ICOS[153]	Those treated with 1 of 7 classes of cardiotoxic cancer therapies	HF/CM, valvular heart disease, MI or previous revascularization, stable angina, baseline LVEF, baseline cardiac biomarkers, age, HTN, DM, CKD, prior cancer therapy, prior radiation to left chest or mediastinum, smoking history, obesity	Risk stratification into low, moderate, high, and very high risk	Comprehensive tool with 7 main classes of cardiotoxic cancer therapies Various patient and cancer therapy–related risk factors Provides guidelines for recommended surveillance	Expert consensus Validated studies are limited to low- to medium-risk breast cancer patients Short intervals between CTRCD screening tests Prior studies are nonrandomized and not prospective[a]
CHEMO-RADIAT[174]	Breast	HF, HTN, elderly, MI, PAD, BMI, CKD, abnormal lipid profile, DM, irradiation of the left breast, anthracycline dose, and transient ischemic attack/CVA	MACE: composite of HF, MI, TIA/CVA, cardiovascular deaths	Predictive model based on CV risk factors and breast cancer treatment–related risk factors (eg, dose) Validated in a real-world multicenter cohort	Small validation cohort[a] Only included symptomatic CV events Short-term follow-up Missing risk factors, such as tobacco use Composite risk factors, not individual
Yu et al[175]	Breast	Age, race, BMI, left ventricular ejection fraction, systolic blood pressure, coronary artery disease, DM, arrhythmia, anthracycline exposure	1-y probability of CTRCD, defined as an absolute decline of left ventricular ejection fraction of at least 10% to <53% or at least 16% from baseline (pretreatment)	Prediction probability of 1-y CTRCD with good discrimination Similar predicted and observed CTRCD probabilities, good calibration Validated discrimination and calibration	Needs prospective validation Needs a larger external data set Did not incorporate other imaging or circulating biomarkers LVEF assessments were performed at the discretion of the treating provider Did not use consensus CTRCD definition Only studies patients treated with trastuzumab[a]
Ezaz et al[176]	Breast	Age, chemotherapy type, coronary artery disease, AF/flutter, DM, HTN, renal failure	HF or cardiomyopathy defined as ICD-9-CM codes in at least 1 inpatient claim or 2 outpatient claims at least 30 days apart	Demonstrated proof-of-concept that a 7-factor clinical risk score can risk stratify HF/CM risk in older women with BC receiving trastuzumab	Cohort limited to SEER-Medicare[a] administrative/claims data, trastuzumab, no baseline HF/CM Missing risk factors, such as tobacco use Outcome limited to HF/CM Short-term follow-up
Fogarassy et al[177]	Breast	Age, DM, HTN, CAD, CVA, epirubicin cumulative dose, docetaxel cumulative dose, capecitabine, gemcitabine, bevacizumab, and cancer stage	HF defined by ICD codes on discharge from hospital or issuance from autopsy report	Did not report cancer stage	Needs prospective validation Endpoints based on ICD codes rather than clinical data
Goel et al[178]	Breast	Baseline LVEF and LVEF change	Death due to HF, acute MI, cardiac arrhythmia, ischemia, or MI; NYHA functional class III or IV; an asymptomatic decrease in LVEF of >15%; an asymptomatic decrease in LVEF >10% to an absolute value <50%	Therapy-related factors Prospective data Wide range of HF risk (2%-30%) Identifying low-risk patients could eliminate unnecessary surveillance SNPs and biomarkers not predictive of 3-month TRC	Designed to study 3-months post-trastuzumab Needs a larger study cohort to increase statistical power

Continued on the next page

TABLE 1 Continued

Risk Prediction Model	Intended Cancer Population	Predictors	Outcomes	Strengths	Limitations
Mayo Clinic Cardiotoxicity Risk Score (CRS)[179]	Breast	Age, cardiomyopathy or HF, CAD or equivalent, HTN, DM, anthracycline, chest radiation, female	Cardiotoxicity risk stratification: very low, low, intermediate, high, very high	Includes various cardiotoxic therapies and patient-related risk factors Prospective data	Older study, may not apply to newer insights Missing clinically important risk factors such as tobacco use history, therapy dose
Upshaw et al[180]	Breast	Age, BMI, HTN, baseline LVEF	Composite of LVEF reduction from baseline of at least 10% to <50% and/or clinical diagnosis of HF through the first y of follow-up	Internally validated using bootstrapping to overcome overfitting Prospective data	Needs a larger study[a] Needs longer-term cardiac outcomes Based on limited number of risk factors No external validation Insufficient model performance assessment so unclear risk of bias
Abdel-Qadir et al[181]	Breast	Age, HTN, DM, ischemic heart disease, AF, HF, cerebrovascular disease, peripheral vascular disease, COPD, CKD	MACE: composite of hospitalizations for acute MI, unstable angina, TIA, CVA, PAD, HF, deaths from circulatory disease	5- and 10-y risk score Comparable to Framingham CVD risk score Appropriately classified patients across a broad range of risks	Limited to early breast cancer patients Reliance of administrative data Did not include important risk factors such as baseline LVEF, tobacco use Did not include outpatient CV diagnoses Needs prospective external validation
Armenian et al[182]	HCT recipients	Age, anthracycline dose, HTN, DM, smoking, chest radiation, dyslipidemia, obesity	HF or CVD (CAD, MI, symptomatic coronary artery stenosis requiring intervention) by 10 y from index date	Risk prediction model for adult-onset cancer survivors Identified high-risk and low-risk survivors External validation Data from medical records	Chronic GVHD not included Did not include family history of CVD May not take into account recent treatment changes
Childhood Cancer Survivor Study[183-185]	Childhood	Sex, age at diagnosis (5-y increments), history of alkylating agents, anthracyclines, platinum agents, vinca alkaloids, radiation to the head, neck, chest, abdomen; HTN, dyslipidemia, DM	HF, ischemic heart disease, CVA by age 50 y after recently completed cancer treatment (5 y from cancer diagnosis)	Three risk tiers depending on information (eg, dosing) Robust internal validation	Needs external validation[a] Missing risk factors, such as tobacco use and physical activity

[a]Low racial/ethnic diversity.

AF = atrial fibrillation; BC = breast cancer; BMI = body mass index; CAD = coronary artery disease; CKD = chronic kidney disease; CM = cardiomyopathy; COPD = chronic obstructive pulmonary disease; CTRCD = cancer therapy-related cardiac dysfunction; CV = cardiovascular; CVA = cerebrovascular accident; CVD = cardiovascular disease; DM = diabetes mellitus; GVHD = graft vs host disease; HCT = hematopoietic cell transplantation; HF = heart failure; HTN = hypertension; LVEF = left ventricular ejection fraction; MACE = major adverse cardiovascular events; MI = myocardial infarction; PAD = peripheral arterial disease; SNP = single nucleotide polymorphism; TIA = transient ischemic attack; TRC = trastuzumab-related cardiotoxicity.

bystander cardiopulmonary resuscitation (BCPR) for White and non-White patients,[169] Black patients had a lower BCPR rate compared with White patients. Also, it was noted that both low- and high-income Black neighborhoods had low BCPR rates, whereas only low-income White neighborhoods had low BCPR rates, leading to higher mortality.[170] These results demonstrate, not only racial disparities, but also neighborhood disparities in accessibility to health care.

In a study of women with stage I-III breast cancer,[164] geospatial disparities (by region/health service) explained a larger proportion of observed variation (24%-48%) than patient factors (1%-4%). Studies show that women living in urban areas tend to have a higher occurrence of breast cancer, whereas women in rural areas have a higher likelihood of being diagnosed with late-stage disease.[171] This translates into higher breast cancer rates in urban areas compared to rural areas, partly due to higher socioeconomic status and density of primary care providers, leading to increased detection rates.[172] Such findings highlight the disparities in access to diagnosis based on the level of urbanization.

The location or setting of care can also modulate the observed racial disparities in breast cancer care.

Among all U.S. counties, 2.6% were identified as hot spots exhibiting a high risk of breast cancer mortality, with 3.5% considered hot spots for non-Hispanic Black women, mostly located in the Southern region of the United States.[172] Moreover, non-Hispanic Black women living in hot spots had a 15% higher risk of breast cancer mortality than non-Hispanic Black women living in other regions, indicating regional disparities even within the same racial group. Identifying areas of high and low risk of cancer and understanding how community-level socioeconomic status impacts health are vital steps in comprehending geospatial factors associated with health literacy, medical knowledge, and personal engagement.

Examining health care accessibility reveals limited proximity to cardio-oncology clinics and providers, especially in underserved communities such as low-income and rural areas, or regions with a higher proportion of Black patients. A national cardio-oncology survey indicated that <10% of cardiovascular programs offer specialized training in cardio-oncology.[173] Despite the establishment of clinics since then, they are predominantly affiliated with large academic centers and located in urban areas (**Figure 1**). This restricted availability of cardio-oncology services in certain regions may lead to long travel distances and delayed or inadequate care for patients who would benefit from closer monitoring and earlier intervention. Disparities in cardiovascular and oncological care become more evident when analyzed in parallel. For instance, lower income regions exhibit fewer cardiac revascularizations, indicating a correlation between residing neighborhoods and personal health engagement.

Significant geospatial disparities exist in cardiovascular and cancer outcomes; however, the intersection of CVD and cancer in geospatial terms remains unexplored. Moreover, many studies highlighting geospatial differences overlook the role of community-level factors contributing to these disparities, which subsequently impact health literacy, medical insight, and individual engagement. Existing literature often focuses on urbanity or socioeconomic factors, neglecting the importance of proximity to health services, a significant factor in geospatial analysis. Hence, there is need for a specialized cardio-oncology geospatial model that integrates both cardiovascular and oncological treatments and comprehensively incorporates socioeconomic factors.

In the current era of electronic data access and artificial intelligence, dynamic geospatial analysis of cardio-oncological resources has the potential to drive health care policy and enact systemic changes. Census tract data and zip code analysis serves as vital tool for clinicians to identify socioeconomic determinants, health disparities, and health literacy levels within specific communities. Through the analysis of digital access and literacy levels in specific areas, clinicians can guide the development of educational programs aimed at enhancing digital health literacy. This information enables clinicians to tailor communication strategies, design culturally competent interventions, and target health education initiatives to address the unique needs of their patient population. Ongoing data analysis allows clinicians to measure the effectiveness of health literacy interventions over time, facilitating the refinement strategies. These insights contribute to more personalized and effective health care delivery, fostering improved health literacy and equitable access to resources.

CONCLUSIONS AND FUTURE DIRECTIONS

After successful cancer treatment, many patients face an elevated risk of developing CVD, which can surpass the mortality risk posed by the original cancer itself. Providing optimal care for this growing demographic requires the successful integration of specialized care while considering cultural differences and acknowledging socioeconomic and health care disparities prevalent within this population. Effectively addressing disparities in cardio-oncology care requires a comprehensive approach (**Central Illustration**). We have identified three key domains where synergistic improvements may occur: 1) development of risk assessment tools attuned to the diverse factors impacting patient risk; 2) implementation of educational community-based and public health interventions; and 3) promotion of professional and clinic-based education initiatives.

Understanding individual preferences, motivations, and engagement forms the basis for developing targeted educational efforts and further strategies for health literacy in cancer survivors, as well as improving the crosstalk between cardiovascular and oncological specialists. Targeted education can empower patients and health care professionals with the necessary knowledge to make informed decisions aimed at improving cardiovascular health outcomes during and after cancer treatment.

Furthermore, for minority populations, geographical factors may exert a more pronounced influence on both cancer and CVD. Consequently, racial and socioeconomic disparities linked to the area where patients live may provide further insights into barriers to care. Exploring the association between cardiovascular and cancer treatment while accounting

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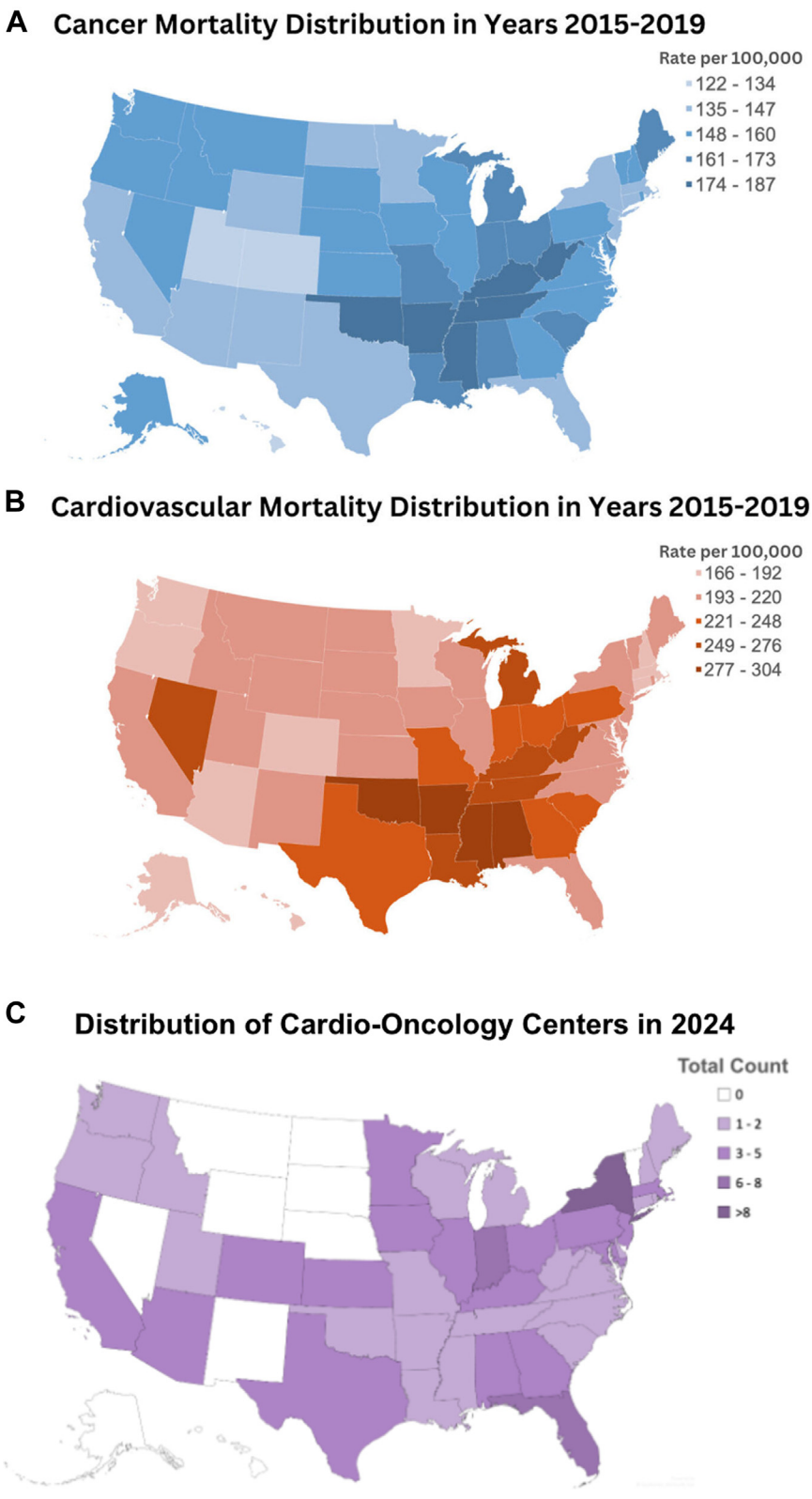
FIGURE 1 U.S. Distribution of Cancer Mortality, Cardiovascular Mortality, and Cardio-Oncology Centers



(A) U.S. state-level cancer mortality between 2015 and 2019.[128] (B) U.S. state-level cardiovascular mortality between 2015 and 2019.[129] (C) U.S. state-level distribution of Cardio-Oncology Programs based on the International Cardio-Oncology Society Global Directory of Cardio-Oncology Programs[186] and search on Google[187] of "cardio-oncology" and "state name" in February 2024.

for the impact of socioeconomic and geographic location factors remains an untapped opportunity at the geospatial level. Clusters of disparate populations often lack the voice and resources that ultimately influence local health outcomes. Hence, empowering patients through community engagement emerges as an important means to promote health equity and address these disparities effectively.

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