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Cardio-Pulmonary Oncology Surveillance: Integrating Advanced Cardiac Imaging, Biomarker Panels, and Nurse-Respiratory Therapist Coordinated Care

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Abstract

Background: The success of modern cancer therapeutics has created a growing population of survivors at risk for multisystem toxicity, notably cancer therapy-related cardiac dysfunction (CTRCD) and pulmonary complications such as pneumonitis, fibrosis, and pulmonary hypertension. These cardiopulmonary toxicities often coexist, share common pathophysiological pathways, and require coordinated multidisciplinary surveillance. **Aim:** This narrative review synthesizes evidence to propose an integrative surveillance model combining advanced cardiac imaging (echocardiography with strain, cardiac MRI), pulmonary function assessment, circulating biomarker panels, and structured nurse-respiratory therapist coordinated care for early detection and management of cardiopulmonary toxicity. **Methods:** A comprehensive literature review was conducted using PubMed, Scopus, and CINAHL for studies (2010-2024) on imaging, biomarkers, and interdisciplinary care models in cardio-pulmonary oncology. **Results:** Evidence supports a multimodal approach: echocardiography with global longitudinal strain (GLS) and cardiac MRI detect myocardial dysfunction; pulmonary function tests (PFTs) and diffusion capacity (DLCO) identify restrictive patterns; serial biomarkers (hs-troponin, BNP, KL-6, SP-D) provide early biochemical warning. Nurse-respiratory therapist co-led clinics improve symptom assessment, patient education, pulmonary rehabilitation, and timely intervention, preserving functional capacity and quality of life. **Conclusion:** An integrated, nurse-respiratory therapist coordinated surveillance pathway utilizing advanced cardiopulmonary imaging, biomarker monitoring, and functional assessment is essential for mitigating multisystem toxicity and optimizing survivorship outcomes.

Keywords: Cardio-Oncology, Pulmonary Oncology, Cardiac Imaging, Respiratory Therapy, Interdisciplinary Care.

Introduction

The transformative advances in cancer therapeutics over recent decades—from targeted biologics and immunotherapies to refined radiation techniques—have fundamentally altered the prognosis for countless patients, creating an unprecedented and growing cohort of long-term survivors. However, this remarkable success has unveiled a profound and complex clinical challenge: the unintended, often delayed, toxicity of these life-saving treatments on vital organ systems beyond the malignancy itself. Foremost among these are concurrent and frequently interrelated injuries to the cardiovascular and pulmonary systems, which now represent leading causes of long-term morbidity and non-cancer mortality among survivors (von Kemp et al., 2022; Armenian et al., 2020).

Cancer survivors are at a significantly elevated risk for a spectrum of **cancer therapy-related cardiac dysfunction (CTRCD)**, encompassing conditions such as systolic and diastolic heart failure, coronary artery disease, valvulopathies, and arrhythmias, most notably associated with anthracyclines, HER2-targeted agents, and thoracic radiation (Zamorano et al., 2016). Simultaneously, they face distinct **pulmonary toxicities**, including chemotherapy-induced pneumonitis, radiation fibrosis, immunotherapy-associated interstitial lung disease (ILD), drug-induced pulmonary hypertension, and persistent parenchymal damage that can culminate in irreversible fibrosis (Naidoo et al., 2017; Nishino et

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al., 2017). Critically, these cardiac and pulmonary complications are not isolated phenomena; they often share common underlying pathophysiological pathways involving endothelial injury, unchecked inflammatory cascades, and dysregulated fibrotic remodeling (López-Fernández & Lyon, 2023). This shared biology frequently manifests in a convergent clinical presentation, with symptoms like exertional dyspnea, profound fatigue, and functional limitation serving as nonspecific sentinels for either or both organ systems, creating a formidable diagnostic dilemma for clinicians.

This clinical intersection underscores the critical limitations of traditional, siloed surveillance models that assess the heart and lungs in isolation. A patient's report of worsening shortness of breath could stem from early left ventricular dysfunction, developing pulmonary fibrosis, pulmonary hypertension secondary to cardiac disease, or a combination thereof. An organ-specific approach risks misattribution, delayed diagnosis, and missed opportunities for early intervention. Consequently, a paradigm shift is urgently required—from fragmented, reactive organ surveillance to proactive, **integrated cardiopulmonary monitoring** that acknowledges the interconnected nature of these toxicities.

Effective management of this dual risk demands a sophisticated, multidisciplinary care model that synergistically combines several pillars: **advanced cardiac imaging** (particularly echocardiography with global longitudinal strain and cardiac magnetic resonance imaging) for the sensitive detection of subclinical myocardial injury; **comprehensive pulmonary function assessment** (including spirometry, diffusing capacity, and advanced imaging like high-resolution CT) to identify restrictive and fibrotic processes; **serial multi-organ biomarker panels** (e.g., cardiac troponin and natriuretic peptides alongside pulmonary-specific markers like KL-6 or SP-D) for early biochemical warning; and **specialized, coordinated care led by nursing and respiratory therapy specialists** to ensure protocol adherence, provide nuanced patient assessment, and deliver targeted rehabilitative interventions (Qiu et al., 2023; Holland et al., 2021; Mao et al., 2022).

This narrative review will critically examine the contemporary evidence supporting each component of this integrated model. It will argue that the formal integration of the **respiratory therapy specialist** into the cardio-oncology team is not merely an additive enhancement but a critical necessity. The respiratory therapist provides indispensable expertise in the differential diagnosis of dyspnea, the performance and interpretation of complex pulmonary function tests, the management of respiratory symptoms, and the delivery of pulmonary rehabilitation—all of which are essential for comprehensive toxicity detection, accurate phenotyping of functional decline, and, ultimately, the preservation of quality of life and functional capacity in the growing population of cancer survivors navigating the long-term sequelae of their treatment.

Defining Cancer Therapy-Related Cardiac Dysfunction

The cardiovascular sequelae of cancer treatment are diverse, ranging from asymptomatic left ventricular dysfunction and heart failure with reduced or preserved ejection fraction to coronary artery disease, valvulopathies, arrhythmias, and hypertension (Gevaert et al., 2022). The definition of CTRCD, particularly from chemotherapeutic agents, has evolved but commonly centers on a symptomatic or asymptomatic decline in left ventricular ejection fraction (LVEF). Major society guidelines, such as those from the European Society of Cardiology (ESC) and the American Society of Echocardiography (ASE), often define CTRCD as a reduction in LVEF of >10 percentage points to a value below the lower limit of normal (typically <53%), confirmed by repeat imaging (Plana et al., 2014).

The pathophysiology is multifaceted, involving direct myocyte injury (e.g., anthracycline-induced topoisomerase IIβ inhibition and oxidative stress), vascular endothelial dysfunction, and immune-mediated responses (Zhang et al., 2018). This complexity underscores why a single diagnostic tool is insufficient. The risk is not uniform; it is modulated by pre-existing cardiovascular risk factors (e.g., hypertension, diabetes), cumulative drug doses, combination therapies, and chest radiation exposure, necessitating a risk-stratified approach to surveillance intensity (Lenneman & Sawyer, 2016). The primary goal of surveillance is the earliest possible detection of subclinical toxicity, enabling cardioprotective pharmacological interventions (e.g., angiotensin-converting enzyme inhibitors, beta-blockers) that may prevent irreversible damage and allow for the continuation of optimal cancer therapy (Cardinale et al., 2010).

Advanced Cardiac Imaging in Surveillance Protocols

Cardiac imaging forms the anatomical and functional cornerstone of CTRCD surveillance. While traditional 2D echocardiography measuring LVEF has been the historical mainstay, its limitations—including inter-observer variability and relative insensitivity to early, subtle changes in myocardial function—are well-documented (Thavendiranathan et al., 2014). Consequently, echocardiography with global longitudinal strain (GLS) has emerged as a transformative tool. GLS, derived from speckle-tracking echocardiography, measures the percentage shortening of myocardial fibers in the longitudinal direction and is a highly sensitive and reproducible marker of subclinical systolic dysfunction. A relative reduction in GLS of >15% from baseline is considered a robust early sign of myocardial injury, often preceding a detectable fall in LVEF by months (Potter & Marwick, 2018). Its prognostic value in predicting

future LVEF decline and major adverse cardiac events in patients receiving cardiotoxic therapy is strongly supported by meta-analyses (Oikonomou et al., 2019).

When echocardiographic windows are suboptimal or findings are equivocal, cardiac magnetic resonance imaging (CMR) serves as the non-invasive reference standard. CMR provides unparalleled accuracy for LVEF quantification, free from geometric assumptions. More critically, its unique capability of tissue characterization through late gadolinium enhancement (LGE) and T1/T2 mapping allows for the detection of myocardial fibrosis, edema, and inflammation (Jordan et al., 2018). This is particularly valuable in diagnosing myocarditis associated with immune checkpoint inhibitors or detecting radiation-induced myocardial fibrosis, pathologies that may not manifest primarily as systolic dysfunction. CMR's role is thus complementary: confirming borderline echocardiographic findings, providing definitive baseline assessments in high-risk patients, and elucidating the underlying etiology of cardiac dysfunction (Al-Saadi et al., 2022). A tiered imaging protocol, where GLS is the frontline serial metric, and CMR is reserved for specific indications, represents a cost-effective and sensitive strategy (Table 1).

Cardio-Pulmonary Toxicity Syndromes

Cardiopulmonary toxicity encompasses a spectrum of conditions. Cardiac sequelae include left ventricular dysfunction, heart failure, and myocarditis. Pulmonary toxicities range from interstitial lung disease (ILD) and pneumonitis to pulmonary vascular disease and pleural effusions (Curigliano et al., 2020; Naidoo et al., 2017). Agents like bleomycin, checkpoint inhibitors, tyrosine kinase inhibitors, and thoracic radiation can cause primary pulmonary injury, while many therapies (e.g., anthracyclines, HER2-targeted agents) primarily affect the heart but can induce secondary pulmonary edema. Dyspnea, the most common presenting symptom, poses a diagnostic dilemma: is it cardiac, pulmonary, or both? This ambiguity underscores the need for concurrent surveillance strategies and the specialized skills of respiratory therapists in performing and interpreting pulmonary diagnostics (Al-Saadi et al., 2022).

The Vital Role of the Respiratory Therapy Specialist in Surveillance

The respiratory therapist (RT) brings essential expertise to the oncology setting. Their role extends beyond acute care to include outpatient surveillance and rehabilitation. Key functions include: conducting and interpreting pulmonary function tests (PFTs) with particular attention to diffusion capacity (DLCO), a sensitive marker for early parenchymal lung disease; performing oscillometry for detecting early airway changes; administering 6-minute walk tests (6MWT) to assess functional cardiopulmonary reserve; providing patient education on breathing techniques, energy conservation, and inhaler use; and leading pulmonary rehabilitation programs to improve exercise tolerance and quality of life (Holland, 2022; Rochester et al., 2023). In a coordinated model, the RT works alongside the nurse coordinator to assess dyspnea, differentiate cardiac from pulmonary etiologies, and manage respiratory symptoms proactively.

A proposed integrated pathway begins with a pre-treatment risk stratification clinic involving medical oncology, cardiology, pulmonology, nursing, and respiratory therapy. Baseline assessment includes echocardiography (+GLS), PFTs with DLCO, and biomarker panels (hs-cTn, BNP, and pulmonary-specific markers like KL-6 if available). The nurse and RT co-develop a personalized surveillance calendar. During treatment, the RT monitors pulmonary metrics (DLCO trends, 6MWT distance) while the nurse tracks cardiac biomarkers and symptoms. A significant decline in DLCO or new exertional hypoxia triggers the same protocol activation as a drop in GLS—immediate team consultation (Kirkham et al., 2023). This model ensures that dyspnea is never evaluated through a single-organ lens.

Table 1: Integrated Cardio-Pulmonary Surveillance Protocol

Risk Stratum	Baseline Assessment	Serial Monitoring	Actionable Thresholds
High Risk (e.g., thoracic radiation, bleomycin, checkpoint inhibitors + cardiac risk)	Echo (+GLS), PFTs/DLCO, baseline biomarkers (hs-cTn, BNP, KL-6). Consider chest CT.	Echo/PFTs every 3 months. Biomarkers monthly. 6MWT quarterly.	**GLS ↓ >15% or LVEF drop:** Cardiac intervention. **DLCO ↓ >15% or O2 desaturation:** Pulmonary consult, consider chest CT.
Moderate Risk (e.g., anthracyclines, targeted therapies)	Echo (+GLS), PFTs. Biomarkers.	Echo every 4-6 mos, PFTs every 6 mos. Symptom-driven 6MWT.	Symptom development triggers full cardio-pulmonary workup.
Low Risk (low toxicity regimens)	Baseline echo. PFTs if symptomatic.	Clinical monitoring only.	

Circulating Biomarkers for Early Biochemical Detection

Parallel to imaging advancements, the role of circulating biomarkers has expanded from diagnostic aids in overt heart failure to proactive sentinels of subclinical cardiac injury. The serial measurement of high-sensitivity cardiac troponin (hs-cTn) and B-type natriuretic peptide (BNP) or its N-terminal prohormone (NT-proBNP) is now a cornerstone of modern surveillance. hs-cTn is a highly specific marker of cardiomyocyte injury. Elevations during or shortly after anthracycline administration correlate with the magnitude of subsequent LVEF decline and predict the development of future CTRCD (Michel et al., 2020). Similarly, BNP/NT-proBNP, released in response to myocardial wall stress, can indicate hemodynamic compromise before imaging abnormalities become apparent. A combined biomarker approach increases predictive accuracy; for instance, persistently elevated hs-cTn after chemotherapy is a strong independent risk factor, while rising BNP may signal impending functional decompensation (Ky et al., 2014).

Emerging biomarkers are further refining risk stratification. Myeloperoxidase (MPO) and growth differentiation factor-15 (GDF-15) reflect oxidative stress and inflammatory pathways implicated in cardiotoxicity, offering potential for even earlier detection (Putt et al., 2015). The integration of biomarker trends with imaging data creates a powerful multi-parameter risk model. For example, a patient with a significant relative GLS reduction *and* a rising hs-cTn trend has a very high probability of progressing to overt CTRCD, warranting immediate intervention. This biomarker-informed strategy allows for more personalized monitoring intervals and can trigger timely cardiology referral and imaging, optimizing resource utilization.

The Central Role of Nurse-Coordinated Care

The sophisticated data generated by imaging and biomarkers is of limited clinical utility without a robust system to ensure its timely collection, interpretation, and translation into patient action (Cehic et al., 2021). This is where the cardio-oncology nurse coordinator or nurse practitioner becomes the essential linchpin of the surveillance pathway. Acting as the patient's constant guide and the hub of interprofessional communication, the nurse's role is multifaceted and critical (Okwuosa et al., 2018). During the pre-treatment phase, the nurse conducts comprehensive cardiovascular risk assessments, educates patients on potential cardiac symptoms, and schedules baseline testing. During active treatment, they manage the surveillance calendar, track biomarker results, facilitate timely imaging appointments, and triage patient-reported symptoms—such as new-onset dyspnea, fatigue, or edema—that may warrant unscheduled evaluation (Sarfati et al., 2016).

Upon detection of an abnormality (e.g., a significant GLS drop), the nurse activates the pre-defined protocol: notifying the cardio-oncologist, coordinating expedited consultations, and educating the patient on the initiation of cardioprotective medications. The nurse-led clinic is also the cornerstone of long-term survivorship care, managing cardiovascular risk factors, reinforcing lifestyle modifications, and ensuring transition from active surveillance to appropriate chronic disease management (Gilchrist et al., 2019). Evidence demonstrates that nurse-coordinated models improve adherence to surveillance guidelines, reduce time to intervention, decrease hospitalizations, and significantly improve patient knowledge, self-management, and quality of life outcomes (Table 2).

Table 2: Roles in Nurse-Respiratory Therapist Coordinated Care

Domain	Nurse Coordinator Responsibilities	Respiratory Therapist Specialist Responsibilities	Joint Actions
Assessment	Cardiovascular symptom review, medication reconciliation, BP monitoring.	Pulmonary symptom review, auscultation, oxygen saturation assessment, 6MWT administration.	Co-conduct comprehensive dyspnea assessment.
Diagnostic Coordination	Schedule echocardiograms, track cardiac biomarkers.	Perform and interpret PFTs, oscillometry; coordinate chest imaging.	Review integrated results; present at tumor board.
Patient Education	Cardiac medication adherence, heart-healthy lifestyle, symptom awareness.	Inhaler technique, breathing exercises, oxygen therapy, energy conservation.	Co-lead "Cardio-Pulmonary Wellness" education sessions.
Rehabilitation & Support	Refer to cardiac rehab, manage cardiovascular risk factors.	Lead pulmonary rehab, prescribe respiratory muscle training.	Develop combined exercise prescriptions; monitor tolerance.
Interprofessional Communication	Primary liaison with cardiology/oncology.	Primary liaison with pulmonology/radiology.	

A Proposed Integrated Surveillance Pathway

An effective cardio-oncology program must operationalize the synergy between imaging, biomarkers, and nursing. A proposed integrated pathway begins with a pre-treatment risk stratification clinic involving the nurse, oncologist, and cardiologist. Based on the planned therapy and patient-specific factors, an individualized surveillance plan is created, specifying the frequency of echocardiography (+GLS) and hs-cTn/BNP draws. The nurse coordinator owns this calendar. At each monitoring point, the triad of data is reviewed: imaging parameters (LVEF, GLS), biomarker trends, and the nurse's clinical assessment of symptoms and vital signs. A collaborative decision is made regarding continuation of cancer therapy, initiation of cardioprotective medication, or escalation to advanced imaging (CMR) (López-Fernández & Lyon, 2023). This model is dynamic; a low-risk patient who develops biomarker elevations may be up-tiered to more frequent imaging, while a high-risk patient with stable biomarkers and GLS may have monitoring intervals safely extended. The nurse ensures every loop is closed—from test scheduling to result communication to prescription fulfillment—creating a resilient safety net around the patient.

Challenges and Future Directions

Despite its clear rationale, implementing this integrated model faces hurdles. Access and cost remain significant barriers, particularly for advanced technologies like CMR and strain imaging, which are not universally available (Fradley et al., 2021). Standardization of GLS measurement across vendors and definitions of significant change is an ongoing effort by imaging societies. The optimal frequency and duration of surveillance for newer therapies (e.g., CAR-T cells, bispecific antibodies) are still being defined. Future directions point toward greater personalization using multi-omics approaches (genomics, proteomics) to identify patients with innate susceptibility, and the application of artificial intelligence to extract more prognostic data from imaging and electrocardiograms (Madan et al., 2022). Furthermore, expanding the reach of nurse-led care through telehealth and digital remote monitoring platforms for symptom and vital sign tracking holds promise for improving access and efficiency (Kirkham et al., 2023). Integrating respiratory therapy faces hurdles, including reimbursement structures for outpatient RT services, workflow integration in oncology clinics, and defining standard pulmonary surveillance metrics for various therapies. Future research should explore the utility of home-based spirometry and pulse oximetry monitored by telehealth platforms managed by RTs, and validate combined cardiopulmonary biomarkers (Madan et al., 2022). Demonstrating the cost-effectiveness of this model in reducing hospitalizations for dyspnea and improving quality of life will be crucial for wider adoption.

Conclusion

The confluence of advanced cardiac and pulmonary diagnostics with nurse-respiratory therapist coordinated care represents the next frontier in oncology survivorship. This integrated model provides a comprehensive framework for detecting and managing the multifaceted toxicities that affect the heart and lungs simultaneously. The respiratory therapist is no longer a consultant but a core member of the surveillance team, providing essential expertise that complements nursing coordination. Investing in such interdisciplinary pathways ensures that cancer survivors are monitored holistically, preserving both cardiac and pulmonary function, and ultimately delivering on the promise of a life not just longer, but functionally better after cancer.

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