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Authors
Alvarez-Cardona, Jose A
Ray, Jordan
Carver, Joseph
et al.

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JACC COUNCIL PERSPECTIVES

Cardio-Oncology Education and Training

JACC Council Perspectives

Jose A. Alvarez-Cardona, MD,[a,*] Jordan Ray, MD,[b,*] Joseph Carver, MD,[c] Vlad Zaha, MD, PhD,[d] Richard Cheng, MD,[e] Eric Yang, MD,[f] Joshua D. Mitchell, MD,[a] Keith Stockerl-Goldstein, MD,[g] Lavanya Kondapalli, MD,[h] Susan Dent, MD,[i] Anita Arnold, DO,[j] Sherry Ann Brown, MD,[k] Monica Leja, MD,[l] Ana Barac, MD, PhD,[m] Daniel J. Lenihan, MD,[a] Joerg Herrmann, MD,[n] for the Cardio-Oncology Leadership Council

ABSTRACT

The innovative development of cancer therapies has led to an unprecedented improvement in survival outcomes and a wide array of treatment-related toxicities, including those that are cardiovascular in nature. Aging of the population further adds to the number of patients being treated for cancer, especially those with comorbidities. Such pre-existing and developing cardiovascular diseases pose some of the greatest risks of morbidity and mortality in patients with cancer. Addressing the complex cardiovascular needs of these patients has become increasingly important, resulting in an imperative for an intersecting discipline: cardio-oncology. Over the past decade, there has been a remarkable rise of cardio-oncology clinics and service lines. This development, however, has occurred in a vacuum of standard practice and training guidelines, although these are being actively pursued. In this council perspective document, the authors delineate the scope of practice in cardio-oncology and the proposed training requirements, as well as the necessary core competencies. This document also serves as a roadmap toward confirming cardio-oncology as a subspecialty in medicine. (J Am Coll Cardiol 2020;76:2267–81) © 2020 Published by Elsevier on behalf of the American College of Cardiology Foundation.

The treatment of cancer has evolved dramatically over the past 2 to 3 decades such that the previous treatment triad of cytotoxic chemotherapy, radiation therapy, and surgery has been expanded to now include a plethora of targeted and immune-based therapies (1). Owing to the success of these therapies, the outcomes of patients with cancer have continued to improve to the point that there are now more cancer survivors than ever before, with projections to exceed 20 million in the United States alone in the near future (2). In particular, aging of the population (and other common risk factors) will contribute to the increase and clustering of cancer and cardiovascular (CV) disease

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From the [a]Cardio-Oncology Center of Excellence, Washington University in St. Louis, St. Louis, Missouri; [b]Department of Cardiovascular Medicine, Mayo Clinic, Jacksonville, Florida; [c]Division of Cardiology, University of Pennsylvania, Philadelphia, Pennsylvania; [d]Division of Cardiology, Department of Internal Medicine, University of Texas Southwestern, Dallas, Texas; [e]Division of Cardiology, University of Washington, Seattle, Washington; [f]Division of Cardiology, Department of Medicine, University of California, Los Angeles, Los Angeles, California; [g]Division of Oncology, Washington University in St. Louis, St. Louis, Missouri; [h]Division of Cardiology University of Colorado School of Medicine, Aurora, Colorado; [i]Duke Cancer Institute, Department of Medicine, Duke University, Durham, North Carolina; [j]Lee Physician Group Cardiology, Fort Myers, Texas; [k]Medical College of Wisconsin/Froedtert Hospital, Milwaukee, Wisconsin; [l]Department of Internal Medicine, Division of Cardiology, University of Michigan, Ann Arbor, Michigan; [m]MedStar Heart and Vascular Institute, Georgetown University, Washington, DC; and the [n]Department of Cardiovascular Disease, Mayo Clinic, Rochester, Minnesota. *Drs. Alvarez-Cardona and Ray are co-first authors.

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ABBREVIATIONS AND ACRONYMS

ACC = American College of Cardiology

CO = cardio-oncology

CT = computed tomography

CV = cardiovascular

CVD = cardiovascular disease

(CVD) (3). The interplay between these 2 disease entities has gained increasing attention (4) and led to the proposition of a new subspecialty: cardio-oncology (CO) (5,6).

Over the past 15 years, there has been an exponential growth in the number of CO services, not only in the United States, but also worldwide (7-10), which has occurred without much guidance endorsed by professional societies (11). In the void of evidence-based standards, practice patterns likely vary across offices, clinics, and institutions. Moreover, there have been no universal qualifications for physicians to be regarded as a "cardio-oncology specialist" or "cardio-oncologist" (12). Despite this, there is an expectation that any physician providing CO care would possess the experience and knowledge to do so in a manner analogous to other subspecialties (13). Delineating the scope of the practice of CO and its knowledge base and core competencies, as well as defining the unique and complex training requirements in CO, are the objectives of this proposal (**Central Illustration**). This document may further serve as a roadmap toward CO as a focused new discipline (subspecialty) in medicine.

DEFINITION OF THE SCOPE OF PRACTICE OF CO

CO addresses the CV needs of patients throughout the entire cancer journey: before (risk assessment), during (detection of CV toxicity), and after (survivorship) cancer treatment. It thus covers a broad spectrum of disease processes. Patients from various disciplines with various malignancies at various stages may be referred for a plethora of CV complications (9). Consequently, one might consider CO as an integration of the breadth and depth of knowledge in oncology, as well as cardiology (**Figure 1**). CO providers not only need to be well-rounded cardiologists, but they also must have a sound understanding of solid and hematologic malignancies, including an appreciation of the natural history, treatment options, and overall cancer prognosis. In general, the leading reasons for referral to the CO clinic are pretherapy evaluation for patients with high baseline risk and complications of cancer therapy, especially cardiomyopathy or heart failure, vascular disease, and arrhythmias (14,15). The guiding principle of the CO approach is to enable patients to complete the best possible cancer therapy with the lowest possible CV impact (16). This principle is applied across the entire continuum of cancer care (**Table 1**).

HIGHLIGHTS

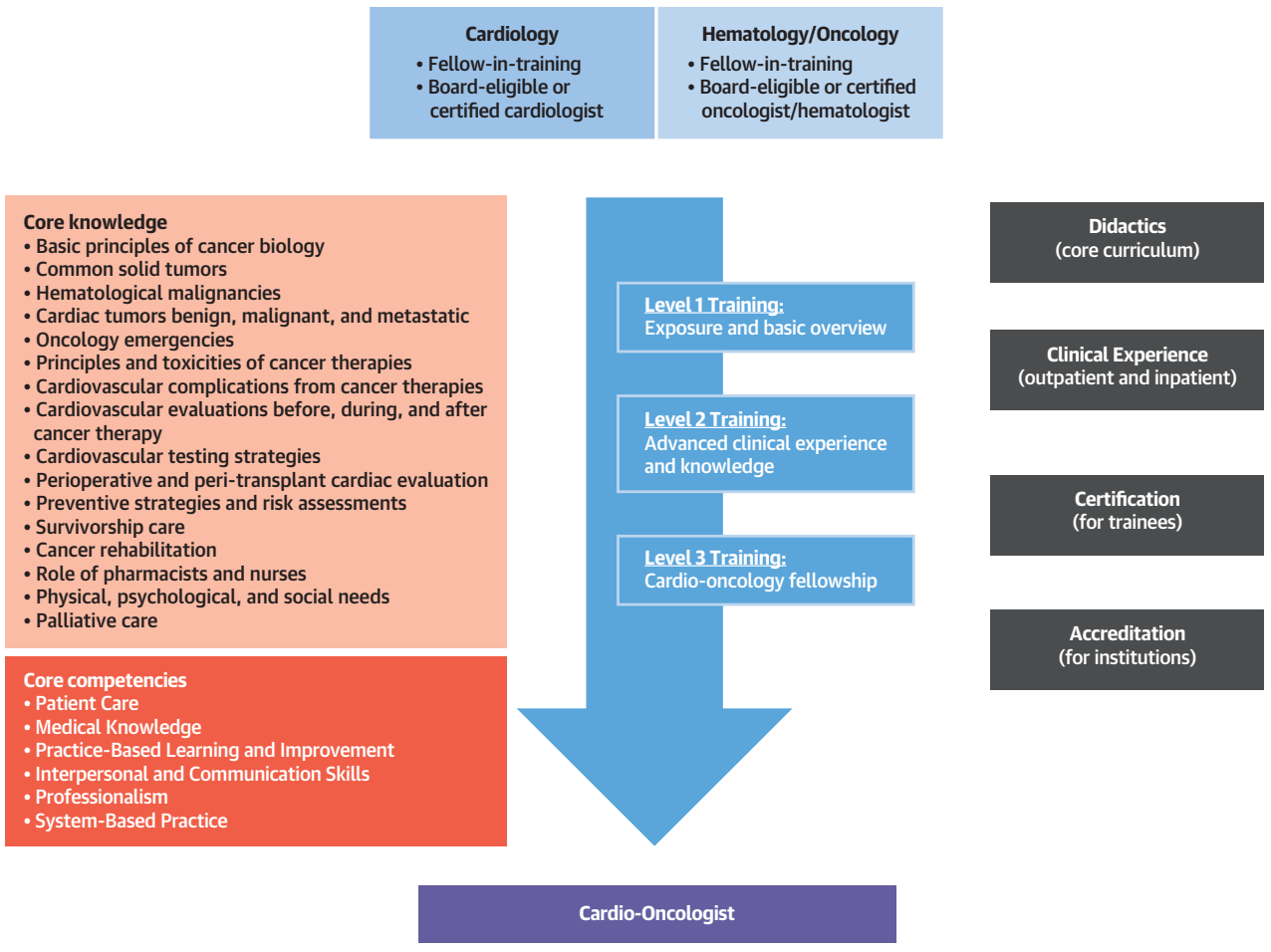
- Cardiovascular comorbidities and toxicities are increasingly important aspects of cancer therapies and outcomes.
- Enabling optimal cancer therapy at the lowest cardiovascular risk is a key goal of cardio-oncology.
- Cardio-oncology, like other subspecialties, requires expert knowledge, specific skills, and dedicated training.

KEY TOPICS AND CORE KNOWLEDGE ELEMENTS IN CO

The background of the CO provider may differ and needs to be accounted for in training and practice (**Figure 2**). For the cardiologist, becoming a cardio-oncologist requires collaboration with other disciplines in order to gain a proper perspective of oncology and malignant hematology. Education is needed in the general principles of oncology/hematology, including cancer biology, all forms of cancer therapy (chemotherapy, targeted therapy, hormone therapy, immunotherapy, radiation therapy, and surgery), bone marrow transplantation, and cancer survivorship with all its attendant CV considerations (17). Alternatively, those with an oncology/hematology background aspiring to become an expert in this field need to gain a perspective of CVD, imaging characteristics in all forms of CVD, and the general management of a broad range of CV conditions (**Figure 2**). Even though both a cardiology-focused and an oncology-focused training pathway can lead to subspecialty training in CO, the clinical practice patterns will likely diverge. Whereas a cardiology-pathway cardio-oncologist will focus on first-hand prevention of CV events and management of active CV problems in these patients, the oncology-pathway cardio-oncologist will lean toward (early) recognition of these issues and integration of best practices in cancer treatments and their planning, with an emphasis on prevention, rather than direct treatment, of CV complications, and comanagement with a cardiologist.

Irrespective of the training background, all providers must maintain core knowledge in the CV toxicities of cancer therapies, in CV risk evaluation before, during, and after cancer treatment, and in the unique management aspects of CVD in patients diagnosed with cancer. **Table 2** outlines the scope of knowledge for cardio-oncologists. In the following

CENTRAL ILLUSTRATION **Central Elements of Cardio-Oncology Training**



Alvarez-Cardona, J.A. et al. J Am Coll Cardiol. 2020;76(19):2267–81.

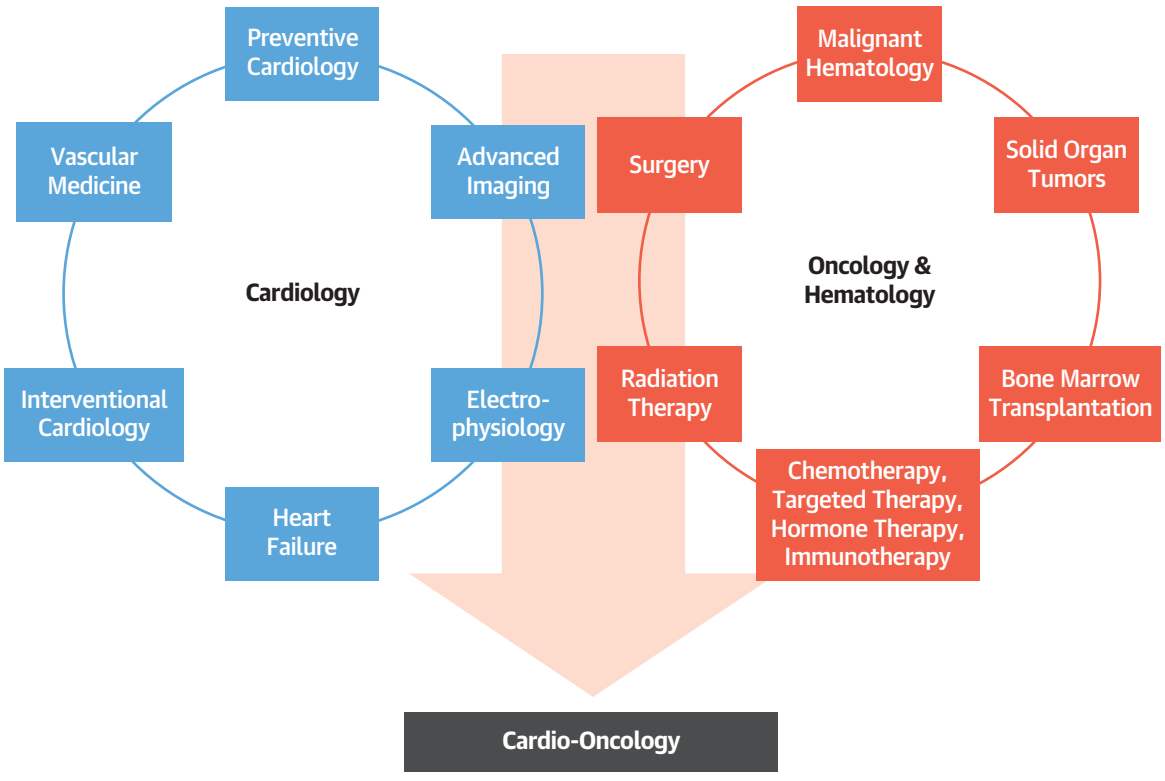
Cardiology and hematology/oncology trainees or specialists can aspire to different levels of cardio-oncology training and acquire core knowledge elements and core competencies as outlined in an environment that provides the appropriate learning environment.

sections, 3 areas will be highlighted that represent key elements of the CO practice.

CVD ASPECTS OF MALIGNANCIES

Commonly viewed as isolated entities, tumors and malignant disease processes can have a systemic component that affects the CV system. On the basis of the subject matter of CO, those seeking advanced training should have knowledge of these disease entities so that they are a resource to other providers in the care team for these patients. This is in light of the fact that all malignancies have broad CV effects, ranging from destabilizing previously controlled CVD to producing new CV risks or direct cancer involvement of the CV system (tumor spread). This includes (oncological) emergencies such as superior vena cava syndrome, cardiac tamponade, and fulminant myocarditis. Cardio-oncologists will be required to advise on the proper coordination of care for these patients, including selection of testing and treatment modalities. Further, CVD may influence the development and progression of malignancies, an aspect that has emerged in recent years and has become known as “reverse cardio-oncology.” Recognition of shared risk factors in CVD and cancer represents an opportunity for advancing research and understanding the interplay of these conditions (18,19).

FIGURE 1 **Cardio-Oncology as the Integration of Cardiology and Oncology/Hematology**



The specialty of cardio-oncology can be considered as the blend of both cardiology and oncology/hematology, with the large diversity in disease entities and subspecialty aspects, as illustrated.

CV TOXICITIES OF CANCER THERAPIES

The vast majority of CO practice focuses on the prevention and management of CV complications of cancer therapy (15): 1) treatment-based (what drugs, surgery, or radiation therapy are/were used?); 2) symptom/complication-based (what is/was the clinical manifestation i.e., dyspnea, chest pain, rhythm disturbance, etc.?); and 3) patient characteristic-based (what are/were the patient-specific CV risks or established disease?). Details of CV toxicity related to specific therapeutics have been widely published, and all classes of drugs seem to have some CV toxicity associated with their administration (20). Similarly, virtually every CV symptom or major adverse CV event has been the focus of some review. The major CV, oncological, and hematologic conditions to be familiar with are listed in **Table 2**. Cardiac-specific toxicities include myocardial diseases (cardiomyopathy, heart failure with preserved or reduced ejection fraction, asymptomatic left ventricular systolic dysfunction), hypertension, endothelial and vascular dysfunction, accelerated atherosclerosis, thrombosis and bleeding, pulmonary hypertension, pericardial disease, and QT prolongation and conduction disease/arrhythmias, as well as radiation-induced CV disease (myocardial, pericardial, valvular, arrhythmias and conduction, autonomic dysfunction) (21–26). A detailed listing of these studies is beyond the scope and purpose of this document.

CV EVALUATION OF CANCER PATIENTS

An integral part of providing optimal CV care to the patient being treated for cancer is the ability to select and perform CV testing. Accordingly, cardio-oncologists need to be familiar with and have a basic knowledge of all cardiac imaging and stress testing modalities, vascular studies, electrocardiography tools, and laboratory parameters. Over the past 2 decades, there has been a paradigm shift in the approach to the evaluation of CV toxicity in the oncology patient. Multimodality imaging is now an

TABLE 1 Common Reasons for CO Referral Across the Continuum of Cancer Care

Before cancer therapy	
High baseline cardiovascular risk (by history of risk factors or disease)	• Established CV disease, especially history of HF and MI • Diabetes mellitus • Hypertension • Hyperlipidemia • Pre-existing chronic inflammatory condition(s) • History of tobacco use • Prior anthracycline therapy • Prior radiation therapy with exposure of heart or vasculature • Prior cardiovascular toxicity related to cancer therapy
High cancer therapy-related risk	• HER2-targeted therapy, especially in patients with other CV risk factors or anthracycline exposure • Anthracyclines, especially with expected cumulative lifetime dose ≥250 mg/m^2 • Radiation with exposure to heart or vascular structures, especially in patients with a history of MI • Tyrosine kinase inhibitors that are anti-angiogenic in activity or are known to have important vascular effects (e.g., targeting VEGFR, BCR-ABL, EGFR, and PDGFR), especially in patients with high CV risk • Ibrutinib (BTK inhibitor), especially in patients with other risk factors for atrial fibrillation • Proteasome inhibitors, especially in combination with other therapies • Immune checkpoint inhibitors ICI, CAR T-cell therapy, and other forms of immunotherapy, especially with pre-existing immune conditions • ADT, especially in patients with high baseline CV risk • Hematopoietic stem cell transplantation
During cancer therapy	
Pre-existing compensated or decompensated CVD	• Cardiomyopathy/heart failure • Coronary artery disease, especially a history of MI • Arrhythmias/conduction disturbances including QT prolongation • Pulmonary hypertension
New CVD as a complication of cancer therapy	• Cardiomyopathy, acute HF with preserved or reduced ejection fraction • Myocarditis • Hypertensive crisis • Endothelial and vascular dysfunction (accelerated atherosclerosis) • Pericardial disease • Arrhythmias/conduction disturbances including QT prolongation • Pulmonary hypertension • Thrombosis and bleeding
After cancer therapy	
Pre-existing CVD	• Cardiomyopathy and HF • Atherosclerotic cardiovascular disease • Thromboembolic disease
Complications of cancer therapy	• Any CV complications from cancer treatment (see preceding text) • Prior history of ADT • Prior history of immunotherapy with ICI or CAR T-cell therapy • History of pericardial disease (e.g., pericarditis, pericardial effusion) or pericardiocentesis • Radiation-induced CV disease: myocardial, pericardial, coronary, valvular, arrhythmias, autonomic dysfunction
High long-term CV risk of cancer therapy	• History of high-dose anthracycline therapy (e.g., doxorubicin ≥250 mg/m^2) • Radiation to the heart, neck, vascular structures (≥30 Gy) • Lower-dose anthracycline plus trastuzumab • Young or old age at time of diagnosis/treatment

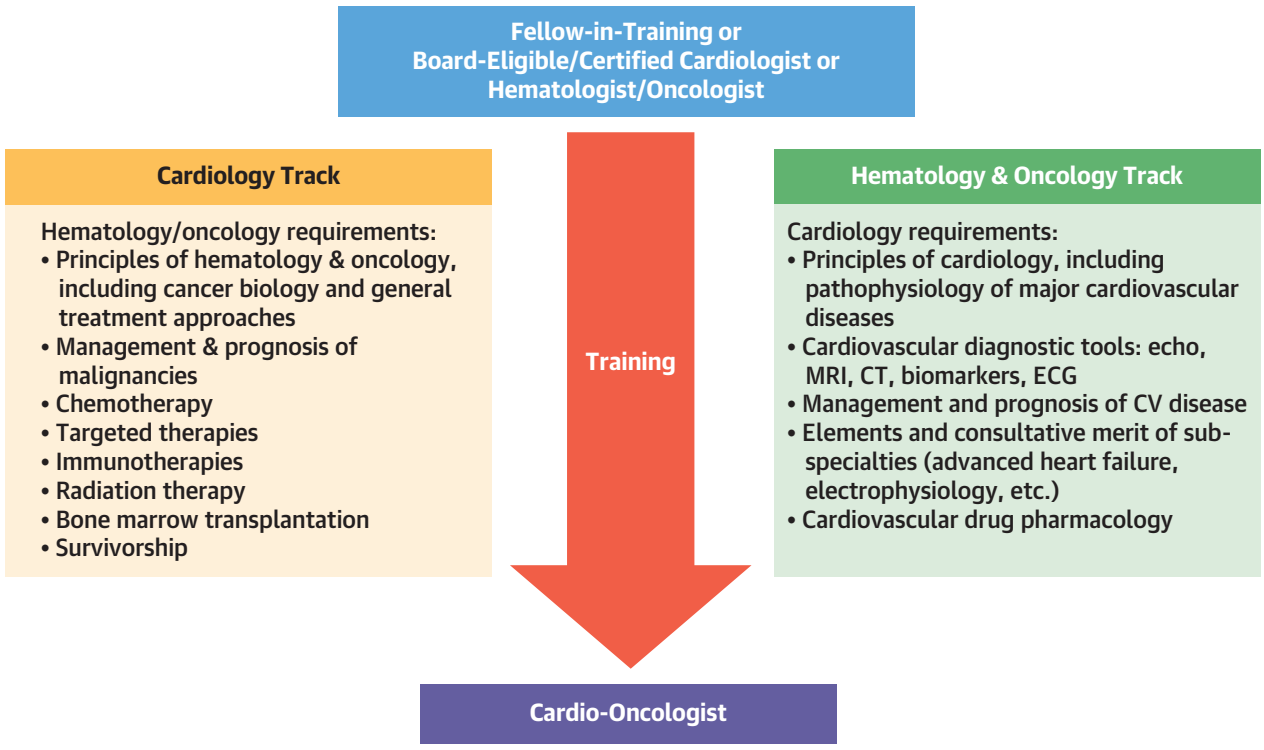
ADT = androgen deprivation therapy; BCR-ABL = breakpoint cluster region-Abelson murine leukemia; BTK = Bruton's tyrosine kinase; CAR = chimeric antigen receptor; CO = cardio-oncology; CV = cardiovascular; CVD = cardiovascular disease; EGFR = endothelial growth factor receptor; HF = heart failure; ICI = immune checkpoint inhibitor; MI = myocardial infarction; PDGFR = platelet-derived growth factor receptor; VEGFR = vascular endothelial growth factor receptor.

essential component and includes 2-dimensional and 3-dimensional echocardiography with strain imaging, cardiac magnetic resonance imaging with quantification of mechanical deformation, cardiac computed tomography (CT), and cardiac positron emission tomography (27-30). Hence, it is indispensable to collaborate with advanced CV imaging specialists in the care of these patients.

PROPOSED TRAINING IN CO

The aspects outlined in the preceding text are beyond what currently exists in the standard curriculum in cardiology or hematology/oncology fellowships, and thus there is a clear mandate for a more organized framework that properly conveys this content (31,32). An initial introduction into this topic must be present in general fellowship programs, both for cardiology and hematology/oncology. The integration of other specialties into cardiology fellowship training has been similarly proposed for other cardiology areas such as internal medicine and endocrinology for preventive medicine (33). Accordingly, as outlined in the general cardiology and subspecialty disciplines, we propose a level I to III training structure as summarized in **Table 3** (34).

FIGURE 2 Road to Cardio-Oncology Based on Prior Training Track



Both cardiology and hematology/oncology fellows are eligible for training in cardio-oncology. Their training needs, however, differ, emphasizing the learning of the knowledge of their counterpart discipline. CT = computed tomography; CV = cardiovascular; ECG = electrocardiography; MRI = magnetic resonance imaging.

LEVELS OF TRAINING

LEVEL I TRAINING. This level of training allows the trainee to obtain sufficient knowledge to understand the basic evaluation and management of the CO patient. The content can be delivered in a basic introductory "rotation" with a minimum of 2 to 4 weeks' exposure depending on the volume of the program. This rotation may be offered to internal medicine residents, as well as fellows, in cardiology and hematology/oncology. Upon completion, the trainee should have the skill set to recognize the complexity of the CO patient, understand the basic evidence-based approaches to management, and to understand when referral to a cardio-oncologist is needed. Trainees who have completed level I training should not be considered able to practice as independent consultants in CO.

LEVEL II TRAINING. This training level refers to the additional training in 1 or more areas that enables the cardiology or hematology/oncology specialist to provide more focused expert care for patients with specific CO conditions and to have an understanding regarding appropriate use of specific cardiac diagnostic testing, biomarkers, and interventional procedures in patients with cancer. This level of training is recognized in other subspecialties that have an available instrument or benchmark, such as a qualifying examination, to measure specific knowledge, skills, or competence. Level II training is appropriate for trainees who are seeking to join an existing CO practice or provide CO consultations to existing small practices without the resources of a large academic institution. This level of training is not sufficient to permit trainees to start their own CO programs.

On the basis of content delivery and educational experiences in this area, trainees seeking level II training should be exposed to 3 to 6 months of dedicated CO training. This includes a minimum of 20 unique half-day outpatient clinic sessions and participation in a minimum of 50 unique inpatient consultations (please see additional information

under Level III Training). It is anticipated that during a standard 3-year cardiology or hematology/oncology fellowship training program, sufficient time will be available to receive level II training in CO. This can be accomplished through elective rotations with a cumulative minimum of 3 months of didactic and clinical experience. It is recommended that trainees participate in a minimum of 2 to 4 days in oncology clinics during the training period (12 weeks), but more exposure is encouraged based on the institution and the trainee's basic understanding of oncology.

Trainees are encouraged, but not required, to contribute, start, and/or complete a research project in the area of CO. Level II trainees should obtain a fundamental understanding of the concepts outlined in the medical knowledge section of the core competencies in **Table 4**. Trainees should also have exposure to clinics in other complimentary areas. The goal is to obtain a basic understanding of the presentation, management, treatment duration, and outcome of a variety of malignancies, especially those likely to receive known cardiotoxic therapies. Those trainees joining the program from an oncology/hematology track should focus on the basic understanding of the presentation, management, treatment duration, and outcome of a variety of CV conditions, particularly those seen in patients being treated for cancer.

LEVEL III TRAINING. This level of training is currently proposed for cardiologists who would like to have the most advanced education and experience in this area in order to become "expert subspecialists." This translates to designation as a cardio-oncologist with the qualifications to start their own programs, qualify as director of a CO service line, and/or direct a research program.

Level III training cannot generally be obtained in the context of a standard 3-year CVD fellowship, but credit can be carried over from time spent during the first 3 years of fellowship. On the basis of volume and clinical availability, the recommended minimum duration for level III training is 6 months, and the average training time for most institutions will be 12 months. It is recommended that over time, completion of a 12-month program should become the reference standard for most institutions.

Similar to the common practice of the "continuity clinic," the concept of the half-day clinic was maintained in the current recommendations, and considering a full academic year with allotted time for absences (e.g., vacation), 40 weeks of half-day continuity clinics are expected to be attainable within 1 full year of CO training dedication. Higher volume centers with 2 half-day clinics or 1 full-day clinic opportunity are likely able to accommodate the fulfillment of this recommendation even within a 6-month time frame. Accordingly, trainees seeking level III training should be exposed to 6 to 12 months of dedicated CO training, including a minimum of 40 unique half-day outpatient clinic sessions and participation in a minimum of 100 unique inpatient consultations. Volumes for minimum expectations for level II and level III training in CO are correlated by a factor 2.

Level III trainees are expected to complete at least 1 research project in the area of CO, not including case report publications. Currently, there are several unaccredited programs for advanced training in CO at institutions with a comprehensive cancer center as listed in **Table 5**. Trainees who have completed a level III training program should have mastery in the diagnosis, evaluation, workup, management, and follow-up of the CO patient as outlined in the medical knowledge section of **Table 4**. There is, as of yet, no formal level III certification process for this level of certification in CO.

TRAINING COMPONENTS

DIDACTICS. Didactic instruction may take place in a variety of formats, including, but not limited to: lectures, conferences, tumor boards, journal clubs, grand rounds, clinical case presentations, and patient safety or quality improvement conferences. A recommended core lecture series should include, but is not be limited to: CV complications of specific cancers, cardiac tumors, anticipated or observed CV toxicities of cancer therapies, natural history and prognosis of common malignant diseases with and without treatment, and the comprehensive evaluation, treatment, and prognosis of CVD encountered in patients being treated for cancer. Beyond providing excellence in clinical care, a cardio-oncologist has the responsibility to educate other trainees and colleagues about important CO principles (35–37).

HANDS-ON EXPERIENCE, OUTPATIENT VISITS, AND INPATIENT CONSULTATION. Hands-on experience is vitally important for training in CO and is necessary to acquire the core competencies for level I to III training as detailed in the preceding text. This experience includes exposure to structured CO clinics and inpatient consultative services. In addition, CV trainees should have observational experiences in oncology clinics. The goal is to obtain a basic understanding of the presentation, management, treatment duration, and outcome (prognosis) of a variety of malignancies across a broad spectrum of clinical situations. During rotations, trainees should review case

TABLE 2 Specific Core Medical Knowledge Elements for Cardio-Oncology Training

1. Understanding of the basic principles of cancer biology, including tumor development, growth, and dissemination
2. Knowledge of the epidemiology, diagnosis, staging, management, and prognosis of common solid tumors
   i. Glioblastoma
   ii. Head and neck cancers
   iii. Thyroid cancer
   iv. Lung cancer
   v. Breast cancer
   vi. Esophageal and gastric cancer
   vii. Colorectal cancer
   viii. Pancreas cancer
   ix. Liver cancer
   x. Gallbladder cancer
   xi. Renal cancer
   xii. Bladder cancer
   xiii. Testicular cancer
   xiv. Prostate cancer
   xv. Ovarian cancer
   xvi. Endometrial cancer
   xvii. Cervical cancer
   xviii. Melanoma
   xix. Carcinoid
3. Knowledge of the epidemiology, diagnosis, staging, management, and prognosis of hematologic malignancies
   i. Leukemias
   ii. Lymphomas
   iii. Multiple myeloma
   iv. Amyloidosis
4. Understanding of cardiac tumors benign, malignant, and metastatic
   i. Knowledge of the types and differential diagnosis of cardiac masses
   ii. Utilization of multiple advanced cardiac imaging techniques in the diagnosis of cardiac tumors
   iii. Understanding and utilizing interventional techniques for tissue diagnosis (biopsy)
   iv. Understanding the clinical decision making for treatment of cardiac tumors, surgery and/or systemic therapy
5. Diagnosis and management of oncology emergencies (with cardiovascular disease aspects)
   i. Superior vena cava syndrome
   ii. Disseminated intravascular coagulation
   iii. Cardiac tamponade
   iv. Fulminant myocarditis
6. Knowledge of the principles and (general) toxicities of cancer therapies
   i. Classes, mode of action, and toxicities of systemic chemotherapies
   ii. Classes, mode of action, and toxicities of targeted therapies
   iii. Classes, mode of action, and toxicities of hormone therapies
   iv. Classes, mode of action, and toxicities of immunotherapies
   v. Types, physics, planning, and toxicities of radiation therapy
   vi. Types, conditioning, and toxicities of bone marrow transplantation
   vii. Types, general conduct, and complications of oncological surgery
7. Understanding of the cardiovascular complications from cancer therapies
   a. Diagnosis and management of chemotherapy-induced cardiomyopathy
      i. Molecular mechanisms underlying cardiotoxicity with conventional chemotherapies, including anthracyclines
      ii. Molecular mechanisms underlying cardiotoxicity with targeted therapies
      iii. The cellular and molecular mechanisms underlying immune check point receptor therapy cardiotoxicity
      iv. Workup and diagnosis and management of chemotherapy related heart failure
   b. Diagnosis and management of pericardial complications of malignancy
      i. Pericarditis
      ii. Pericardial effusion/tamponade
      iii. Pericardial metastases
   c. Diagnosis and management of vascular toxicity in cancer therapy
      i. Venous thromboembolic complications in the cancer patient
      ii. Arterial disease complications in the cancer patient including coronary artery, carotid artery, and peripheral arterial disease with acute and chronic presentations
      iii. Vasculitis
      iv. Thrombotic microangiopathy
      v. Systemic hypertension
      vi. Pulmonary hypertension
   d. Diagnosis and management of cardiac arrhythmias in cancer therapy
      i. Prolongation of the QT interval
      ii. Atrial tachyarrhythmias
      iii. Ventricular tachycardias
      iv. Bradycardias
      v. Cardiac device management
      vi. Autonomic dysfunction
   e. Diagnosis and management of radiation-induced heart disease
   f. Diagnosis and management of cardiovascular diseases in the bone marrow transplant patient

Continued on the next page

TABLE 2 Continued

8. Understanding cardiovascular evaluations before, during, and after cancer therapy i. Echocardiography including strain imaging ii. Cardiac biomarkers iii. Exercise stress testing, oxygen consumption testing iv. Cardiac magnetic resonance imaging v. Cardiac computed tomography vi. Nuclear myocardial perfusion imaging vii. Cardiac positron emission tomography viii. Angiography and advanced intravascular imaging, hemodynamic and vasoreactivity testing ix. Noninvasive vascular imaging reactivity testing x. Hemodynamic catheterization xi. Electrocardiography, including 12-lead ECG and Holter
9. Knowledge of the rationale, utility, appropriate use, and interpretation of cardiovascular testing strategies
10. Understanding of the perioperative and peri-transplant cardiac evaluation in the surgical oncology and stem cell transplant patient
11. Understanding of preventive strategies and risk assessments in efforts to reduce the risk of cardiovascular disease as a consequence of malignancy or its treatment
12. Understanding of individualized treatment plans specific to the needs of the cardio-oncology patient that will best serve the patient's long-term medical goals (survivorship care)
13. Understanding of the principles of cardiac and cancer rehabilitation
14. Understanding of the potential roles of pharmacists and nurses in cardio-oncology care teams
15. Understanding of physical, psychological and social needs of adults with cardiovascular disease as a consequence of their malignancy or cancer treatment.
16. Basic knowledge of palliative care in cancer patients with cardiovascular diseases and toxicities

CO = cardio-oncology; ECG = electrocardiogram.

histories, investigate the mechanisms of cancer therapies including type and amounts of therapy, clarify physical findings, interpret electrocardiograms, as well as review advanced cardiac imaging studies performed.

Likewise, hematology/oncology trainees should attend general cardiology and cardiology subspecialty clinics and practices. The goal for these trainees is to obtain a basic understanding of the presentation and management of CVD in patients with cancer and especially CV toxicities of cancer therapies, including prevention, treatment duration, and outcome. Similar to the CV trainee, they will review case histories, physical examination findings, and test results that help define CV side effects and the best mode of treatment and prevention.

To obtain advanced training (level II or III), programs should provide adequate exposure to allow the trainee to obtain the knowledge and skills required to manage the broad spectrum and complexities of the CO patient. Programs should be able to provide access and exposure to CV complications of a variety of cancer treatments including different systemic agents, immune and radiation therapies, and stem cell transplantation. At a minimum, the program should provide a structured CO clinic at least 2 half days per week, with the addition of inpatient consultation (**Table 3**). The latter type of hospital-based practice includes mainly patients with active cancer who require expert consultations for the management of CVD and toxicities. Training programs should provide the framework that enables CO trainees to obtain proficiency and meet requirements in all areas either on campus or by external rotations.

Trainees should log their experience in: 1) clinical consultations by disease and complication; and 2) interpretation of echocardiograms (including acquisition and troubleshooting of strain and 3-dimensional imaging techniques). Trainees should understand the basics in acquisition and interpretation of advanced cardiac imaging in the form of cardiac CT, cardiac magnetic resonance imaging, and if possible, cardiac positron emission tomography.

For all trainees, attendance at tumor boards and oncology-led morbidity and mortality case conferences with CV cases is highly encouraged, not only to provide expert opinion and guidance on patient management, but also to learn how to navigate the close collaboration needed between hematology/oncology and cardiology in the field. There is a need for cross-disciplinary communication and education, and regular joint conferences and programs are a very efficient and effective way to reach this common goal.

The complexity of the care of patients with cancer is evident in the outpatient setting and even more so in the hospital setting (**Table 6**). The latter provides exposure to a wide array of CV complications that are potentially life-threatening and thus have a direct and tangible impact on overall outcomes (21,38,39). Intuitively, the requirement of CV and even intensive care expertise in this setting is very compelling (40). There should be specific exposure for discerning the presence of CV emergencies that include major CV events requiring nuanced management such as acute

TABLE 3 Essential Elements Required for Each Representative Level of Cardio-Oncology Training

Level	Elements
Level I training	
Exposure and basic overview: basic core curriculum	Context • General internal medicine residency, fellowship training program ("rotation") Goal • To gain basic exposure and understanding of cardio-oncology Eligibility • Residents and fellows in internal medicine, cardiology, and hematology & oncology Format • Inpatient and outpatient care, core didactic lectures, exposure to key review articles Duration • 2 to 4 weeks
Level II training	
Advanced clinical experience and knowledge	Context • General fellowship training program Goal • To broaden exposure and understanding in cardio-oncology • To contribute, start, and/or complete a research project Eligibility • Fellows in cardiology or hematology & oncology Format • Exposure to inpatient (≥50 unique consults) and outpatient clinics (≥20 half-day sessions) for evaluation and treatment • Exposure to clinic in other complimentary areas Duration • ≥3 months or equivalent exposure during fellowship training
Level III training	
Cardio-oncology fellowship	Context • Advanced training in cardiology or hematology & oncology fellowship program Goal • To grain proficiency and specialization in the core competencies of cardio-oncology • To complete a scholarly or research project leading to a publication Eligibility • Fellows in cardiology or hematology & oncology Format • Exposure to inpatient (≥100 unique consults) and outpatient clinics (≥40 half-day sessions) for evaluation and treatment • Enhanced exposure to clinics in other complimentary areas Duration • 6 to 12 months

coronary syndrome, pericardial tamponade, acute arrhythmias requiring treatment, and acute heart failure, as well as hypertensive emergency and other vascular events (41,42). In addition, hospitalized bone marrow transplant recipients are typically very vulnerable and require special considerations regarding the management of blood pressure, volume status, antiplatelet and anticoagulant medications, and in particular, drug-drug interactions that have an important impact on therapeutic choices. An understanding of the role and the goals of palliative care in the CO patients completes the spectrum.

FOCUS ON CO RESEARCH (CLINICAL, TRANSLATIONAL, AND/OR BASIC INVESTIGATION). For level III training, it is expected that at least 1 clinical project is completed during the training period leading to publication (43,44). It is crucial to balance clinical demands with research productivity, especially in such a novel discipline in which more detailed observations are always necessary to improve patient care (45,46). Programs should, therefore, incorporate protected time for research and academic pursuits.

Upon completion of training, a cardio-oncologist should be able to evaluate patients receiving experimental therapies and identify potential CV adverse events from these therapies. Furthermore, a cardio-oncologist will need to be aware of ongoing clinical trials for which patients may be eligible and serve as a referring provider and/or collaborator.

SUMMARY OF INSTITUTIONAL AND FACULTY REQUIREMENTS

Successful training programs in CO need equal contributions from the institution as well as the faculty. The primary requirement is having accredited training programs in cardiology and hematology/oncology. Programs providing level III training must have a close relationship with an established high-volume, full-spectrum cancer program, for example, a National Cancer Institute-designated cancer program or equivalent with an adequate flow of patients. It is also critical that there are regularly scheduled, dedicated, and structured outpatient CO clinics and either a

TABLE 4 Core Competencies for Cardio-Oncology Training

Patient care	• The fellow is expected to gain greater expertise in CO • Patients are seen in consultation and the fellow may interact with other medical subspecialists, surgeons, and nonmedical specialists • The fellow will learn to help coordinate care between multiple services • Decision making on the balance between cardiac risk and cancer treatment for patients with active CV complications from cancer treatment • Skills tailor to advanced imaging specific to the cancer patient and active CO concern • Evaluation tool(s): chart-stimulated review, direct observation, and multisource evaluation
Medical knowledge	• The fellow will know the specifics of CO (as shown in Table 2) • The fellow will be expected to research the clinical trials that support the therapy of these patients • It is expected that the fellow will present the results of trials, which are germane to the care of their patients • Evaluation tool(s): chart-stimulated review, direct observation, case presentations, and in-training examination
Practice-based learning and improvement	• All trainees must understand the limitations of their knowledge and accept constructive feedback • The fellow must understand the variability of patient care styles of different attending physicians and reconcile this with existing data • Identify knowledge and performance gaps and engage in opportunities for improvement • Integrate decision support tools, guidelines, and consensus statements at the point-of-care • Evaluation tool(s): direct observation, multisource evaluation, self-assessment
Interpersonal and communication skills	• The fellow must demonstrate caring and respect for all patients and families • The fellow must conduct supportive and respectful discussions goals of care • The fellow will facilitate the learning of students and residents • The fellow will communicate with and educate patients and families despite their complex interplay of cancer and CV problems • The fellow will engage in shared decision making with patients and families, as well as oncology providers, when deciding on a treatment strategy for each individual patient • The fellow will develop skills to provide emotional support to patients and families with acute CV problems during cancer treatment • Evaluation tool(s): direct observation, multisource evaluation
Professionalism	• The fellow will demonstrate respect and compassion for all patients, families, and the health care team, including ancillary and support staff • The fellow will appreciate the diversity of ethical, religious, and socioeconomic factors that impact patients and their families and their response to health care professionals • The fellow will demonstrate high ethical standards including the recognition of potential conflicts of interest when making patient care decisions • Evaluation tool(s): direct observation, multisource evaluation, self-assessment
System-based practice	• The fellow must work well in a complex system of nurses, social workers, and other health care professionals • The fellow will try to facilitate the transition from inpatient to outpatient and will utilize appropriate resources to continue high quality care as an outpatient • The fellow will cultivate relationships with the oncology team to help improve patient care • The fellow will understand risk/benefit analysis and cost-effectiveness of diagnostic and treatment decisions • Evaluation tool(s): chart-stimulated review, direct observation, multisource evaluation, quality improvement projects

Abbreviations as in Table 1.

standing or an on-demand CO inpatient consultative service. Furthermore, for advanced training in CO, the program should be well equipped to evaluate the full spectrum of CV complications of cancer therapies and cardiac tumors. Institutions offering level III training are required to provide all aspects of an advanced cardiac imaging service. Identifying patients who may be eligible for advanced heart failure therapies, including heart transplantation and durable mechanical circulatory support, is of utmost importance. It has previously been demonstrated that patients with chemotherapy-induced cardiomyopathy have a survival after heart transplantation that is comparable to those who receive cardiac allografts for other cardiomyopathies (47,48). Thus, it is fundamental to understand the utility and limitations of these treatment options for cancer survivors.

Furthermore, it is critical to have at least 1 dedicated faculty member with experience and/or specific training in CO. This faculty member should have achieved the skills equivalent to level III training. Coupled with that expertise, this faculty physician should have adequate dedicated CO clinic time to provide clinical volume for training (49). In addition, there must be formal mentoring to provide didactic as well as clinical research exposure in CO. Didactic topics should include, but are not limited to, cancer therapy-related cardiac dysfunction and basic understanding of appropriate CV imaging strategies, as well as knowledge of CV risk assessment (risk stratification) and the short- and long-term consequences of cardiotoxic cancer therapy. Adjunctive faculty in cardiology with expertise in vascular medicine and atherosclerosis, heart

TABLE 5 List of Cardio-Oncology Fellowship Programs in the United States

Name of Program	Location	Contact Information	Program Description
Mayo Clinic	Rochester, Minnesota	Martha Grogan, MD E-mail: grogan.martha@mayo.edu Phone: (507) 284-3667; education coordinator Kris Baldwin	1-yr fellowship (board-eligible cardiology trainees/certified cardiologists) with focus on cardiac amyloidosis and cardio-oncology
Memorial Sloan Kettering Cancer Center	New York, New York	Sade Gibbons E-mail: gibbonss@mskcc.org Phone: (212) 639-5154	1- to 2-yr research and clinical fellowship in cardio-oncology for board-eligible/certified cardiologists
University of Alabama	Birmingham, Alabama	Carrie Lenneman, MD E-mail: clenneman@uabmc.edu Phone: (205) 975-7123	2-yr program with 1 yr dedicated to clinical cardio-oncology and additional year to complete a clinical research project on a T32 grant
University of Pennsylvania	Philadelphia, Pennsylvania	Joseph Carver, MD E-mail: jrc@mail.upenn.edu Phone: not available	Either a 3-month rotation for cardiology or oncology fellows, or a 1-yr intensive training position for board-eligible/certified cardiologists or oncologists
University of Texas MD Anderson Cancer Center	Houston, Texas	Lauren Sutton E-mail: lmsutton1@mdanderson.org Phone: (713) 792-1958	1-yr clinical and research fellowship
University of South Florida & Moffitt Cancer Center	Tampa, Florida	Twyla Sumpter Fellowship coordinator E-mail: tsumpter@health.usf.edu Phone: (813) 259-0600	1-yr clinical and research fellowship
Vanderbilt University	Nashville, Tennessee	Javid Moslehi, MD E-mail: javid.moslehi@vanderbilt.edu Phone: not available	1- or 2-yr clinical and research fellowship
Washington University School of Medicine	St. Louis, Missouri	Joshua Mitchell, MD E-mail: jdmitchell@wustl.edu Phone: (314) 273-2255	1-yr program designed to provide comprehensive exposure to all aspects of inpatient and outpatient cardio-oncology and cardiac amyloidosis

Programs are listed in alphabetical order and are current as of June 2020; the most up-to-date status is available on the American College of Cardiology website.

failure physiology and clinical management, arrhythmias, valvular disease, pericardial disease, and advanced cardiac imaging should be available to participate and supplement the integration of the management of these conditions in the setting of cancer therapies. Training programs should also engage faculty in oncology for additional didactics and clinical experiences. Last, but not least, the training environment should be such that alternatives to face-to-face consultations are reviewed including virtual electronic consultations (e-consultations), and non-face-to-face phone and video visits (telemedicine). These provide opportunities for health care delivery in the setting of numerous potential restraints, including (timely) appointment accessibility due to limited provider or facility availability, for example due to geographic distances including rural areas or other environmental factors such as outbreaks of viral pandemics.

EVALUATION OF COMPETENCY

Under the tutelage of the program director, the faculty should obtain a record and verify each trainee's experiences, assess performance, and document satisfactory achievement. A logbook that meets Accreditation Council for Graduate Medical Education reporting standards and summarizes pertinent clinical information (number of cases, diversity of referral sources, diagnoses, disease severity, outcomes, and disposition) for each encounter should be considered. The program director is responsible for confirming the experience and competence, and for reviewing the overall progress of individual trainees with the clinical competency committee to ensure achievement of selected training milestones and identify areas in which additional focused training may be required.

Program directors should evaluate the quality of care and follow-up, they should evaluate the judgment of the trainee and their ability to make appropriate decisions in the care of patients. Trainees receiving level II training should have a fundamental knowledge of the diagnosis, management, and follow-up of the CO patient, as well as when to refer to a level III-trained clinician and/or a more suitable facility. Trainees who have received level III training should be regarded by their program to have mastery in the diagnosis, management, and follow-up of the CO patient. In addition, trainees should have a fundamental knowledge in CO research. Trainees who have completed level III training are regarded as "safe to practice," that is, competent to provide advanced care independently. It is the duty of the program director to document milestones showing mastery in these areas.

TABLE 6 The Importance of Inpatient and Outpatient CO Training Experience

Outpatient training	
CV risk assessment and mitigation strategies before cancer therapy	Anticipation for high-risk cancer treatment • Perform a comprehensive baseline CV risk and disease assessment • Review medication- and patient-related risks for negative effects on cardiac function, the vascular system, arrhythmias including drug-drug interactions and QTc prolongation • Individualize preventive strategies as well as type and timing of follow-up based on expected CV risk profile and disease burden Optimization of pre-existing CVD • Assess for the presence, type and extent of CVDs as well as prior and current management of these • Determine repeat evaluation and optimization • Anticipate impact of pre-existing CVD on cancer therapy and vice versa
Evaluation and management of common CVDs in cancer patients on active therapy (pre-existing and newly arising)	Left ventricular dysfunction • Evaluate the contribution from cancer treatment and guide ongoing treatment in collaboration with the oncologist • Institute appropriate HF guideline-directed medical therapy CAD • Determine when and how to work up and treat CAD in this population PAD • Assess whether cancer treatment is contributing to PAD VTE and PE • Identify patients at risk of VTE and PE, and provide therapeutic recommendations to minimize such risk • Guide need for anticoagulation and medical management Arrhythmias • Assess whether current cancer treatment is contributing to arrhythmia burden • Guide need for anticoagulation and medical management • Recognize potential drug-drug interactions between anti-arrhythmic drugs and chemotherapy, targeted therapy and immunotherapy Cardiac masses • Contribute to the diagnostic work-up and the management of patients with cardiac masses
Survivorship	• Understand long-term CV and oncological risk in survivors of cancer • Provide aggressive CV risk factor reduction in this population • Plan appropriate cardiac follow-up/monitoring based on the specific risk of the patient
Inpatient training	
Evaluation and management of cardio-oncological emergencies	Cardiac tamponade • Appraise the risks/benefits of emergent pericardiocentesis in critically ill patients, including those with hematologic complications (e.g., thrombocytopenia) SVC syndrome • Provide recommendations for the management of symptomatic SVC syndrome including endovenous recanalization, surgery, and/or thrombolysis ACS • Select the best treatment option in patients presenting with ACS and malignancy Cardiac arrhythmias • Diagnose and manage hemodynamically significant arrhythmias • Recognize potential drug-drug interactions between anti-arrhythmic drugs and chemotherapy/targeted therapy/immunotherapy VTE and PE • Identify patients at risk of VTE and PE, and provide therapeutic recommendations to minimize such risk • Guide need for anticoagulation and medical management Acute heart failure • Recognize potential causes of acute heart failure in the oncology patient • Apply evidence-based strategies in the diagnosis and treatment of acute heart failure Myocarditis • Diagnose and manage myocarditis due to cancer therapy Cardiac masses • Diagnose and contribute to the management of patients with primary or metastatic cardiac masses
Evaluation and management of bone marrow transplant patients	• Provide cardiovascular risk stratification for candidates in which bone marrow transplantation is planned, including potential drug-drug interactions • Recognize and manage cardiovascular complications due to acute and chronic graft-versus-host disease
Evaluation and management of the oncology patient in the intensive care unit	• Provide expert recommendations on the cardiovascular care of the critically ill oncology patient • Demonstrate proficiency in the management of cardiogenic shock in the oncology patient considering a patient's cancer diagnosis, treatment, and prognosis

ACS = acute coronary syndrome; CAD = coronary artery disease; PAD = peripheral arterial disease; PE = pulmonary embolism; SVC = superior vena cava; VTE = venous thromboembolism; other abbreviations as in Table 1.

CERTIFICATION

Although critical evaluation of a trainee's competency by the program is essential, an independent form of certification and accreditation is equally important. A universal knowledge base is a key step toward standardization and is to be expected from any provider who provides designated CO care. As outlined in another recent American College of Cardiology (ACC) council perspective, the American Board of Internal Medicine has traditionally been the accrediting and certifying body but has its own

requirements and limitations that can hinder implementation (33). For an emerging discipline such as CO, similar to preventive cardiology, different modes of certification and accreditation need to be considered. For instance, the ACC and/or the International Cardio-Oncology Society could serve as a responsible body to facilitate a certification process and develop a competency exam. In fact, the International Cardio-Oncology Society has commenced such efforts and has completed a certification examination that tests competency in CO in a standardized manner. A score of 80% or higher is required to become certified.

CONCLUSIONS AND THE FUTURE

It has become increasingly clear that the involvement of a cardio-oncologist enables the cancer treatment team to provide the most effective cancer therapies while minimizing CV toxicity and improving the health of long-term survivors of cancer. As such, over the last 15 years, CO has begun establishing itself as an independent subspecialty of medicine and has already been recognized by most major cardiology and oncology societies as a distinct specialty area. Guideline and/or expert recommendations specific to CO have been published by the American Society of Clinical Oncology, European Society of Cardiology, European Society for Medical Oncology, Canadian Cardiovascular Society, and the National Comprehensive Cancer Network, among others. CO is increasingly represented at every national and international cardiology meeting, and there are currently 2 dedicated CO journals (the *Cardio-Oncology Journal*, and *JACC: CardioOncology*) with other journals incorporating CO sections. The ACC has established its own CO council as has the European Society of Cardiology with important contributions (7,50).

On a global scale, the number of dedicated training programs has been increasing, but this particular aspect has not yet received widespread attention, and there is currently no standardization. This document provides key recommendations to address critical gaps in education and to establish appropriate and consistent expectations for a CO-trained provider to meet the growing demand. This perspective is also a first crucial step toward an accreditation process in this area.

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ADDRESS FOR CORRESPONDENCE: Dr. Joerg Herrmann, Department of Cardiovascular Diseases, Mayo Clinic, 200 First Street SW, Rochester, Minnesota 55902. E-mail: herrmann.joerg@mayo.edu. Twitter: @mayocvonc.

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