Imaging Modalities And Cardiovascular Screening For Cardiomyopathy And Non-Cardiomyopathy Events In Cancer Patients

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Summary Recommendations Coronary Artery Disease screening in Newly Diagnosed Cancer or Survivorship

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Practice guidelines

Cardiac computed tomographic imaging in cardio-oncology: An expert consensus document of the Society of Cardiovascular Computed Tomography (SCCT). Endorsed by the International Cardio-Oncology Society (ICOS)

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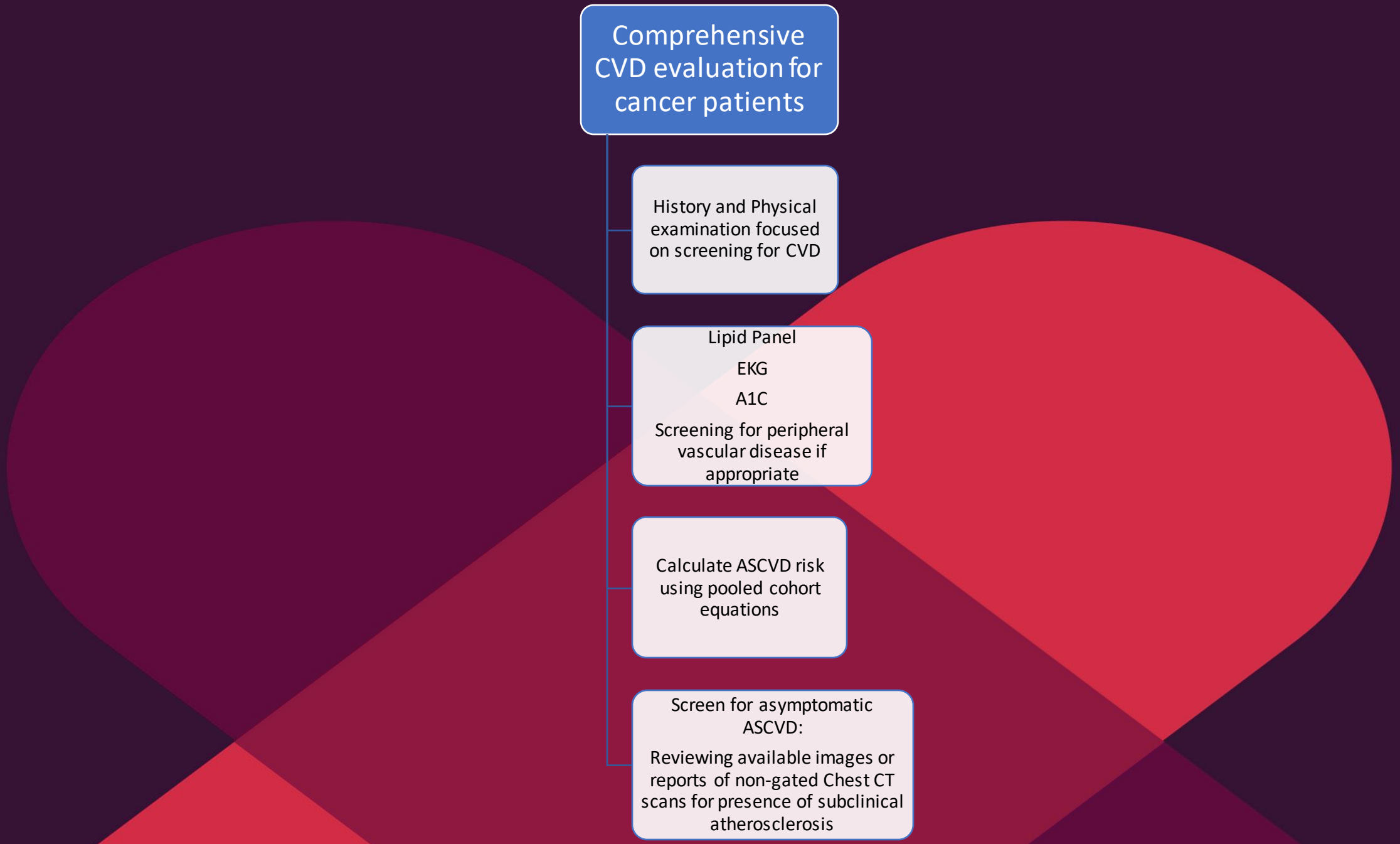
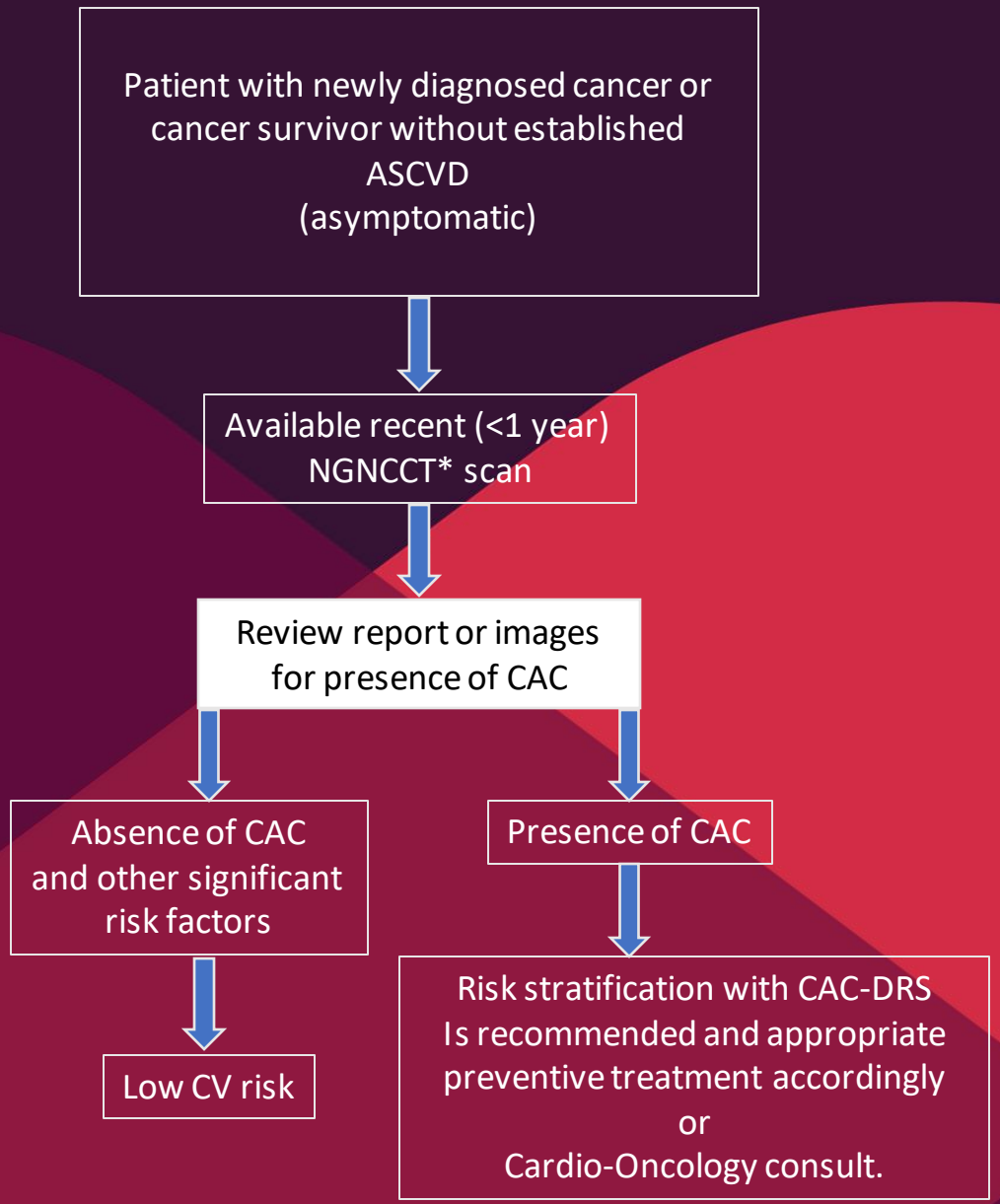
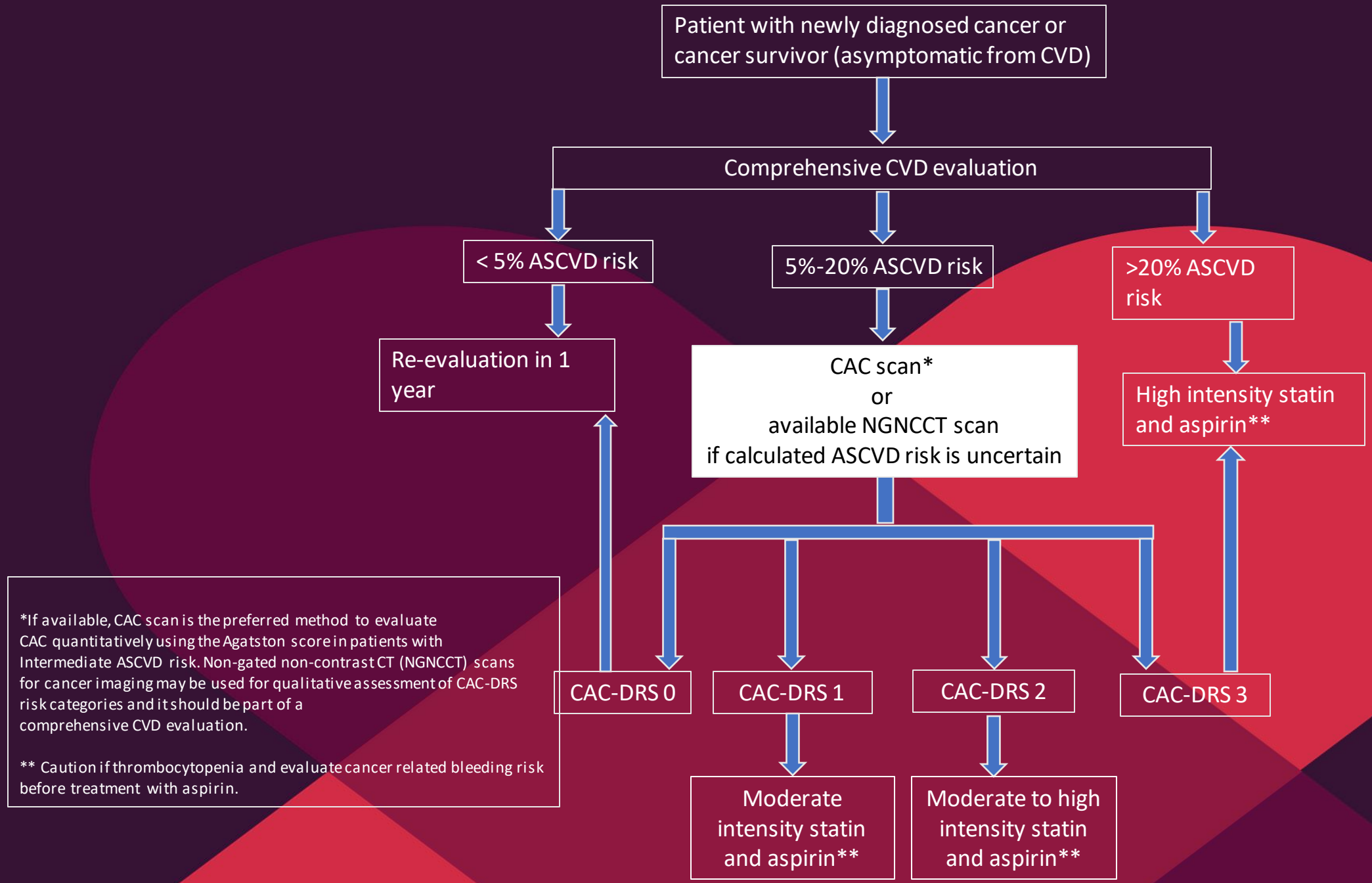
Comprehensive Cardiovascular evaluation (CVD) evaluation for cancer patients and survivors



Imaging for ischemia



*Non-gated non-contrast CT(NGNCCT) scans for cancer imaging may be used for qualitative assessment of CAC-DRS risk categories and it should be part of a comprehensive CVD evaluation.


Patient with newly diagnosed cancer or cancer survivor (asymptomatic from CVD)
Comprehensive CVD evaluation
< 5% ASCVD risk
5%-20% ASCVD risk
>20% ASCVD risk
Re-evaluation in 1 year
CAC scan*
or
available NGNCCT scan
if calculated ASCVD risk is uncertain
High intensity statin and aspirin**
CAC-DRS 0
CAC-DRS 1
CAC-DRS 2
CAC-DRS 3
Moderate intensity statin and aspirin**
Moderate to high intensity statin and aspirin**
*If available, CAC scan is the preferred method to evaluate CAC quantitatively using the Agatston score in patients with Intermediate ASCVD risk. Non-gated non-contrast CT (NGNCCT) scans for cancer imaging may be used for qualitative assessment of CAC-DRS risk categories and it should be part of a comprehensive CVD evaluation.
** Caution if thrombocytopenia and evaluate cancer related bleeding risk before treatment with aspirin.

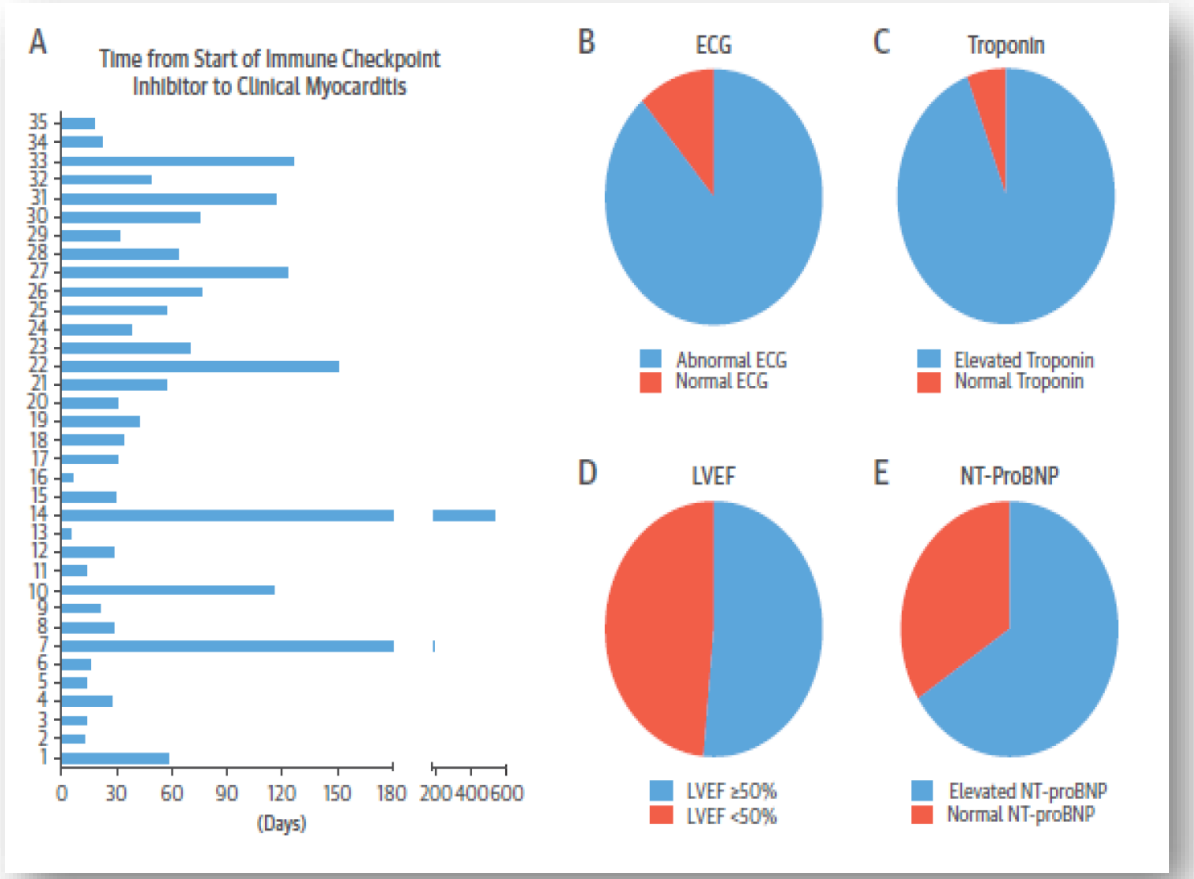
a. Agatston Score			
Categories	CAC score	Cardiovascular Risk	Possible Treatment Recommendation
CAC-DRS 0	0	Very low	Statin not recommended*
CAC-DRS 1	1-99	Mildly increased	Moderate intensity statin
CAC-DRS 2	100-299	Moderately increased	Moderate to high intensity statin + aspirin 81 mg#
CAC-DRS 3	≥300	Moderately- Severely increased	High intensity statin + aspirin 81 mg#
a. Visual Score			
Categories	CAC Score	Cardiovascular Risk	Treatment Recommendation
CAC-DRS 0	0	Very low	Statin not recommended*
CAC-DRS 1	1	Mildly increased	Moderate intensity statin
CAC-DRS 2	2	Moderately increased	Moderate to high intensity statin + aspirin 81 mg#
CAC-DRS 3	3	Moderately- Severely increased	High intensity statin + aspirin 81 mg#

Oncologic Therapy Type	Examples	Common Cardiovascular Side Effects	Possible Roles of Cardiovascular CT
Anthracyclines[184-187]	Doxorubicin Daunorubicin Idarubicin Mitoxantrone	Cardiomyopathy (toxicity increases in a cumulative, dose-dependent fashion) Myopericarditis Arrhythmia Pericardial effusion	• CCTA to rule out obstructive CAD as the etiology of decreased left ventricular systolic function/cardiomyopathy • CCTA to rule out obstructive CAD in patients with troponin elevation, when an alternative diagnosis for myocardial injury other than coronary thrombosis is more likely • CAC assessment on non-cardiac CT scans for baseline risk assessment
Alkylating Agents[188]	Cyclophosphamide	Hemorrhagic myopericarditis	• Cardiac CT to evaluate pericardial effusion (HU measurements for characterization of the effusion if clinically relevant) • CCTA to rule out obstructive CAD in patients with troponin elevation, when an alternative diagnosis for myocardial injury other than coronary thrombosis is more likely (e.g. myopericarditis) • CAC assessment on non-cardiac CT scans for baseline risk assessment
Fluoropyrimidines[189,190-195]	5-fluorouracil Capecitabine	Anginal chest pain (incidence up to 18%) Coronary vasospasm Myocardial infarction	• CCTA to rule out obstructive CAD in patients presenting with symptoms of chest pain suspected to be coronary vasospasm to exclude other concomitant processes that could account for an acute coronary event. • Coronary CTA to evaluate coronary atherosclerosis prior to therapy • CAC assessment on non-cardiac CT scans for baseline risk assessment
HER2/neu Receptor Inhibitors[196-198]	Trastuzumab Pertuzumab	Cardiomyopathy	• Same as anthracyclines
Taxanes[190, 195, 199, 200]	Paclitaxel Docetaxel	Myocardial ischemia Coronary vasospasm Cardiomyopathy Arrhythmias	• CCTA to rule out obstructive CAD as the etiology of decreased left ventricular systolic function/cardiomyopathy • CCTA to rule out obstructive CAD in patients with troponin elevation, when an alternative diagnosis for myocardial injury other than coronary thrombosis is more likely • Coronary artery calcium assessment on non-cardiac CT scans for baseline risk assessment
Vascular Endothelial Growth Factor (VEGF) Inhibitors[201-205]	Bevacizumab Sunitinib Sorafenib Pozapanib	Arterial hypertension Acute thromboembolic events, including ACS	• CCTA to rule out ACS • CCTA to rule out obstructive CAD in patients with troponin elevation, when an alternative diagnosis for myocardial injury other than coronary thrombosis is more likely
Immune Checkpoint Inhibitors[206-216]	Pembrolizumab Nivolumab Ipilimumab Atezolizumab	Myocarditis Increased risk of coronary atherosclerosis	• CCTA to rule out obstructive CAD when myocarditis is suspected (e.g. elevated troponin) • CCTA to evaluate coronary atherosclerosis prior to therapy • CAC assessment on non-cardiac CT scans
CAR-T Therapy[217]		Cytokine release syndrome Elevated troponin Cardiomyopathy Arrhythmias	• CCTA to rule out obstructive CAD with elevated troponin • CCTA to rule out obstructive CAD as the etiology of decreased left ventricular systolic function/cardiomyopathy • CCTA to rule out obstructive CAD in patients with troponin elevation, when an alternative diagnosis for myocardial injury other than coronary thrombosis is more likely
Hematopoietic Stem Cell Transplantation[218, 219]	Autologous Allogenic	Population with an increased prevalence of CV risk factors	• Coronary artery calcium assessment on non-cardiac CT scans or CAC scan for baseline risk assessment • CCTA to rule out obstructive CAD in patients with symptoms suggestive of obstructive CAD

The Non-Ischemic Complications

Check Point Inhibitors

- Conditions CPI used for:
  - Reports of fulminant myocarditis with rapid deterioration, need to anticipate and have a system in place for biopsy and potential VAD support in advanced cases



NEJM 2012;366:2517-2519
Curr Cardiol Rep 2017;19:21
JACC 2018;71:1755-64

Cardiotoxicity beyond cardiac dysfunction

Agent	Incidence	Manifestations	Oncological Use
thracyclines			
Doxorubicin	3%-26%	Myopericarditis, cardiac arrhythmia, ECG abnormalities	Acute myeloid leukemia, acute myelogenous leukemia, chroni lymphocytic leukemia, Hodgkin and non-Hodgkin lymphoma, Kaposi sarcoma, mycosis fungoides, thyroid cancer, breast cancer, Ewing sarcoma, transitional cell bladder cancer, multiple myeloma, gastric cancer, prostat cancer, lung cancer, nephroblastoma
Epirubicin	0.9%-3.3%	Cardiac arrhythmia, ECG abnormalities, arterial embolism	Breast, esophageal, and gastric cancer
Idarubicin	5%-18%	ECG abnormalities	Acute myeloid leukemia
Mitoxantrone	0.2%-30.0%	Cardiac arrhythmia, ECG abnormalities, myocardial ischemia	Acute nonlymphocytic leukemias, prostate cancer (multiple sclerosis)
kylating agents			
Cyclophosphamide (high dose)	7%-28%	Pericarditis/myocarditis, cardiac tamponade, arrhythmia	Bone marrow transplant, bladder cancer, lung cancer, sarcomas, anal cancer, myeloproliferative disorders, chronic myelogenous leukemias
Ifosfamide	17%	Arrhythmia, cardiac arrest, myocardial hemorrhage, myocardial infarction	Testicular cancer, cervical cancer, Hodgkin and non-Hodgki lymphoma, Ewing sarcoma, osteosarcoma, soft tissue sarcoma
Busulfan	Rare	Endomyocardial fibrosis, pericardial effusion and tamponade, ECG changes, chest pain, thrombosis, arrhythmia	Chronic myelogenous leukemia, hematopoietic stem cell conditioning regimen, polycythemia vera, essential thrombocythemia
Mitomycin	10%	–	Stomach or pancreas adenocarcinoma, anal carcinoma, bl
ntimetabolites			
Clofarabine	27%	Arrhythmias, hypotension/hypertension, pericarditis/pericardial effusion	Acute lymphocytic leukemia
5-Fluorouracil	2%-20%	Coronary vasospasm, myocardial ischemia and infarction, arrhythmias, ECG changes including ventricular ectopy, hypotension	Advanced colon cancer, anal cancer, gastrointestinal cancers, pancreatic cancer, hepatobiliary cancers, breast cancer, bladder cancer, head and neck cancers, and as a radiation sensitizer in several tumors
Capecitabine	2%-7%	Coronary vasospasm, myocardial ischemia and infarction, arrhythmias, ECG changes, thrombosis	Breast cancer, advanced colon cancer, anal cancer, gastrointestinal cancers, pancreatic cancer, hepatobiliary cancers
Cytarabine	Undefined	Pericarditis, chest pain (including angina)	Hodgkin and non-Hodgkin lymphoma, acute leukemia (myeloid and lymphocytic)
latinum agents			
Cisplatin	Rare	Arterial vasospasm, arrhythmia	Lung cancer, bladder cancer, sarcomas, testicular cancer, ovarian cancer, head and neck cancer, metastatic breast cancer, cancer of unknown origin, esophageal cancer
ntimicrotubule agents			
Vincristine	25%	Myocardial ischemia and infarction, arrhythmia	Acute lymphocytic leukemia, central nervous system tumors, Hodgkin and non-Hodgkin lymphoma, multiple myeloma, Ewing sarcoma, ovarian cancer, small cell lung cancer, thymoma
lonoclonal antibody-based tyrosine kinase inhibitors			
Bevacizumab	1.7%-3.0%	Arterial and venous thromboembolism	Renal cancer, colorectal cancer, lung cancer
Trastuzumab	2%-28%	Arrhythmia, vascular thrombosis	HER2+ breast cancer, HER2+ gastric cancer
Pertuzumab	3%-7%	–	HER2+ breast cancer
Alemtuzumab	Rare	Arrhythmia	Chronic lymphocytic leukemia, cutaneous T-cell lymphoma, bone marrow transplant

JACC 2018;72:202-27

Cardiotoxicity beyond cardiomyopathy

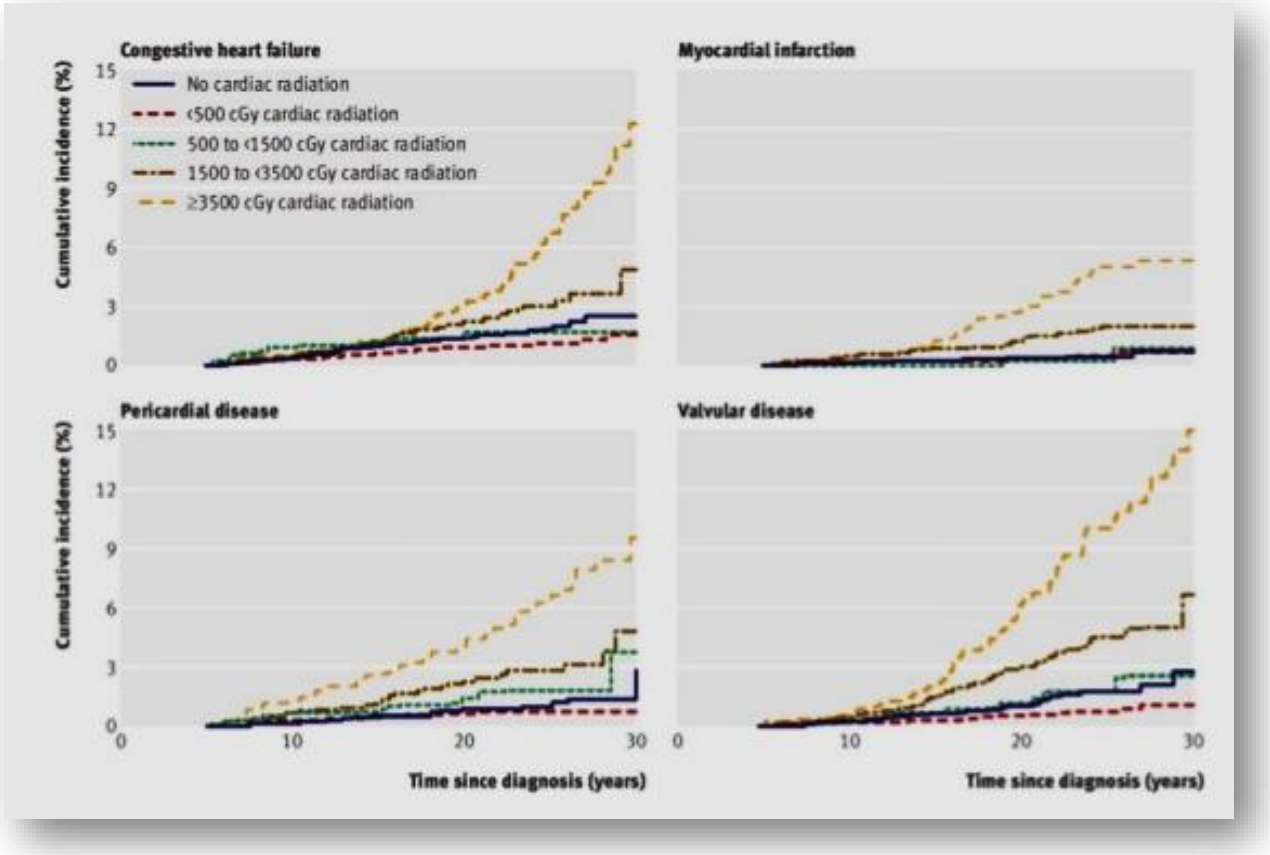
Chemotherapeutic Agent	Cardiotoxicity Incidence	Manifestations	Oncological Use
Small-molecule tyrosine kinase inhibitors			
Dasatinib	2%-4%	Pericardial effusion, hypertension, arrhythmia, ECG changes	Philadelphia chromosome-positive chronic myeloid leukemia and acute lymphoblastic leukemia
Imatinib mesylate	0.5%-1.7%	Pericardial effusion and tamponade, arrhythmia	Philadelphia chromosome-positive chronic myeloid leukemia and acute lymphoblastic leukemia, gastrointestinal stromal tumors, dermatofibrosarcoma protuberans, hypereosinophilic syndrome
Lapatinib	1.5%-2.2%	QTc interval prolongation, myocardial ischemia (Prinzmetal angina)	HER2+ breast cancer
Sunitinib	3%-15%	Arterial and venous thrombosis, aortic dissection, ECG changes	Renal cell cancer, pancreatic neuroendocrine tumors, gastrointestinal stromal tumors
Sorafenib	4%-28%	Thrombosis, coronary vasospasm, myocardial ischemia/infarction	Renal cell cancer, hepatocellular carcinoma, differentiated thyroid carcinoma
Pazopanib	7%-13%	Thrombosis, myocardial ischemia/infarction, bradycardia, ECG changes	Renal cell cancer, soft tissue sarcoma
Proteasome inhibitor			
Bortezomib	2%-5%	Ischemia, bradycardia	Multiple myeloma, mantle cell lymphoma
Immune checkpoint inhibitor			
Pembrolizumab	Unknown	Myocarditis	PD-L1+ tumors
Miscellaneous			
All-transretinoic acid	6%	Pericardial effusion	Acute myeloid leukemia (promyelocytic leukemia)
Pentostatin	3%-10%	Myocardial ischemia and infarction, arrhythmia	Hairy cell lymphoma, chronic lymphocytic leukemia, cutaneous T-cell lymphoma
Interferon alpha-2b	25%	Myocardial ischemia and infarction, ECG changes, sudden cardiac death	Metastatic melanoma, renal cell carcinoma
Aflibercept	1.0%-6.8%	Myocardial ischemia/infarction, stroke	Metastatic colorectal cancer

Drug	HTN	Ischemia	Arterial embolic	QT prolongation	CHF
Sorafenib	11.3%	3.8%	1.7%	40.5%	11%
Sunitinib	34.3%	-	-	-	5-10%
Dasatinib		-	-	<1%	2%
Imatinib	24.2%	-	-	18%	<2%
Axitinib	43%	<1%	-	<1%	21%
Regorafenib	38.3%	-	-	-	6%
Vatalanib	22.7%	-	-	-	22.6%
Nintedanib	15.4%	-	Rare	-	8.7%

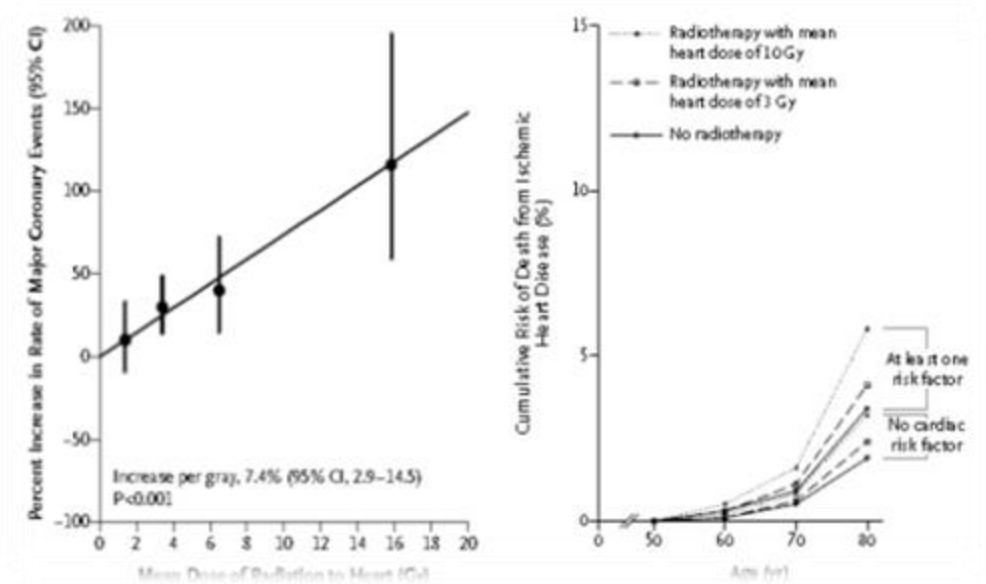
JACC 2018;72:202-27
Expert Opin Drug Safety 2015;14:253-267
Cardiovasc Toxicol 2012;12:191-207

Radiation Therapy

Radiation therapy

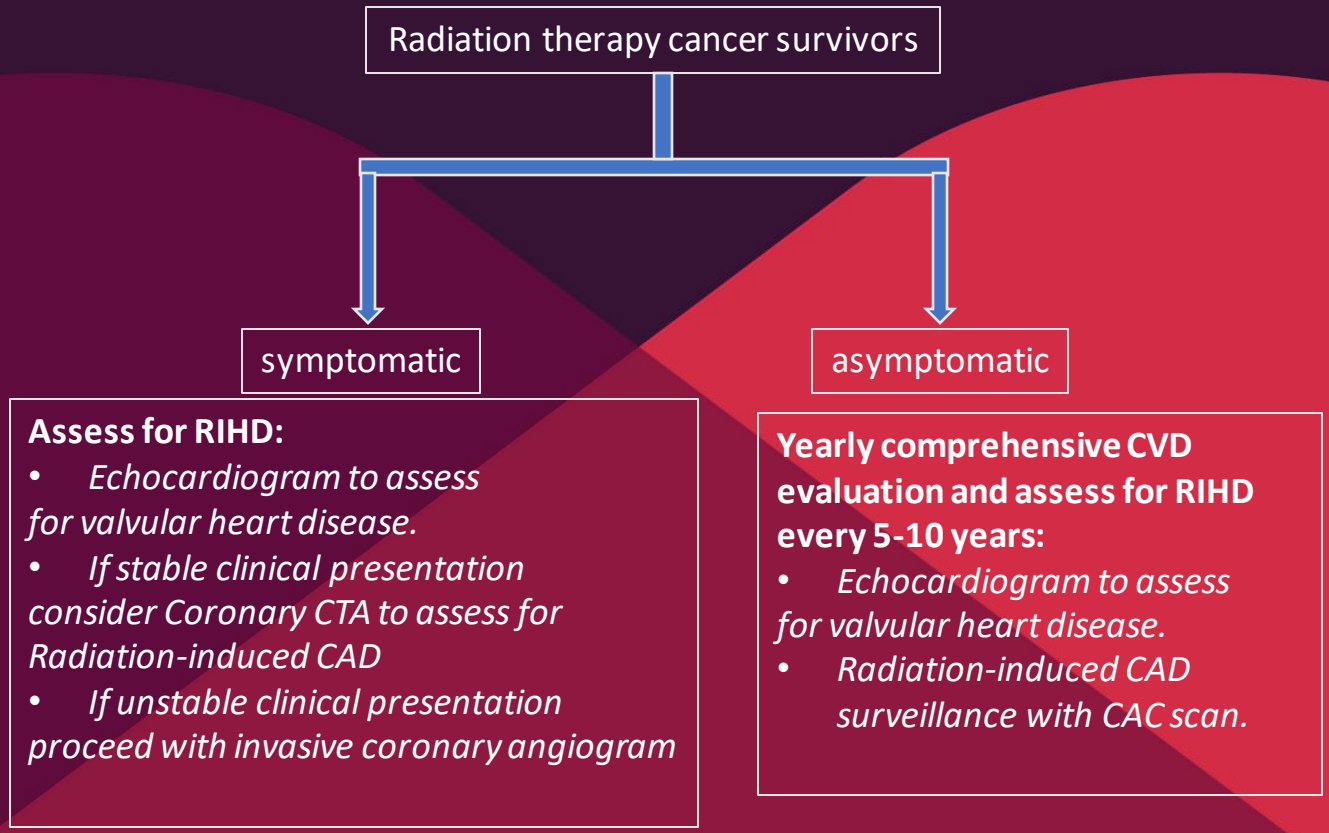


Childhood Cancer Experience



Breast Cancer Survivors

Mulrooney et al, BMJ 2009
Darby et al, NEJM 2013


Radiation therapy cancer survivors
symptomatic
asymptomatic
Assess for RIHD:
• Echocardiogram to assess for valvular heart disease.
• If stable clinical presentation consider Coronary CTA to assess for Radiation-induced CAD
• If unstable clinical presentation proceed with invasive coronary angiogram
Yearly comprehensive CVD evaluation and assess for RIHD every 5-10 years:
• Echocardiogram to assess for valvular heart disease.
• Radiation-induced CAD surveillance with CAC scan.

Nuclear Imaging In Cardio-Oncology

Equilibrium Radionuclide Ventriculography (ERNV)

- Can calculate systolic function
- Can evaluate for diastolic dysfunction
- Can assess RV function
- Most validated for screening and follow up for chemotherapeutic agents

Guidelines for Monitoring Doxorubicin (Adriamycin) Therapy with Serial Resting RNA

- LVEF > 50% at baseline:
  - Baseline MUGA within first 100 mg/m^2 in all patients
  - Next MUGA at 250 - 300 mg/m^2
  - Next MUGA at 450 mg/m^2 or 400 mg/m^2 if high risk: cyclophosphamide, heart disease, mediastinal radiation, abnormal ECG
  - Next MUGA prior to each dose > 450 mg/m^2
  - Discontinue therapy if LVEF decreases > 10% from baseline *AND* reaches ≤ 50%

Schwartz RG et al. American J. Med. 82: 1109-1118, 1987

Guidelines for Monitoring Doxorubicin (Adriamycin) Therapy with Serial Resting RNA

- *LVEF < 50%* at baseline:
  - Baseline MUGA within first 100 mg/m^2 in all patients
  - *Serial MUGA prior to each subsequent dose*
  - Discontinue therapy if LVEF *decreases > 10% from baseline*

  OR reaches LVEF < 30%

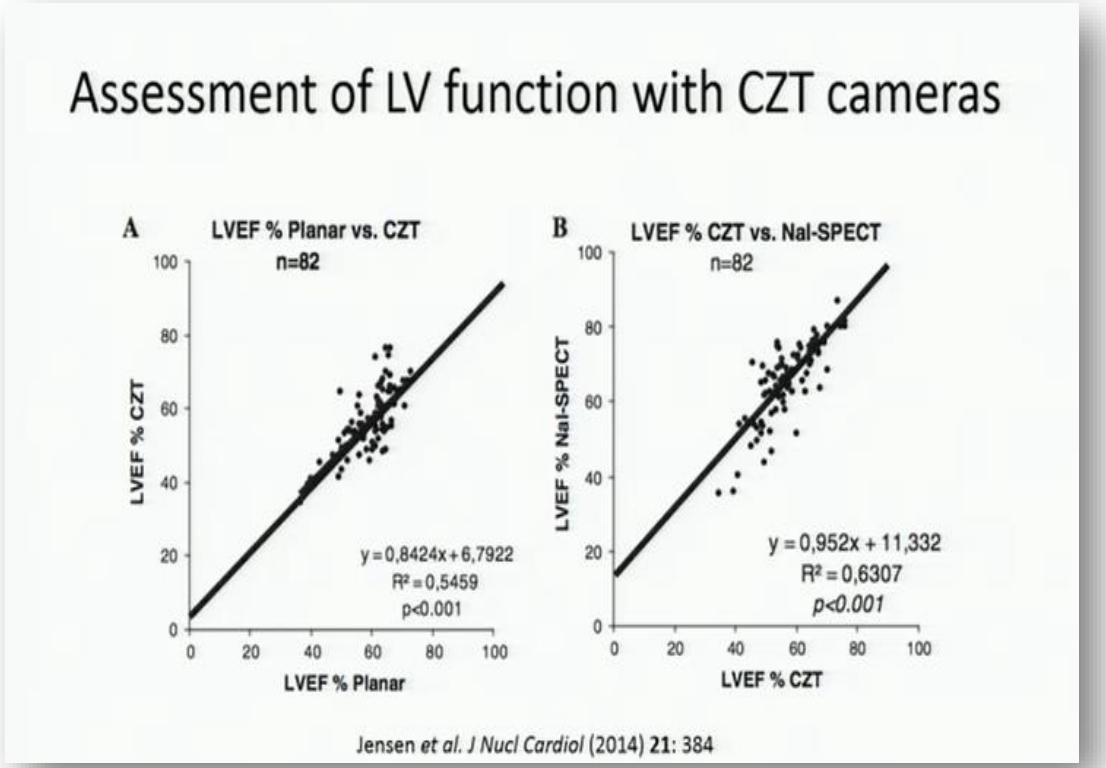
Schwartz RG et al. American J. Med. 82: 1109-1118, 1987

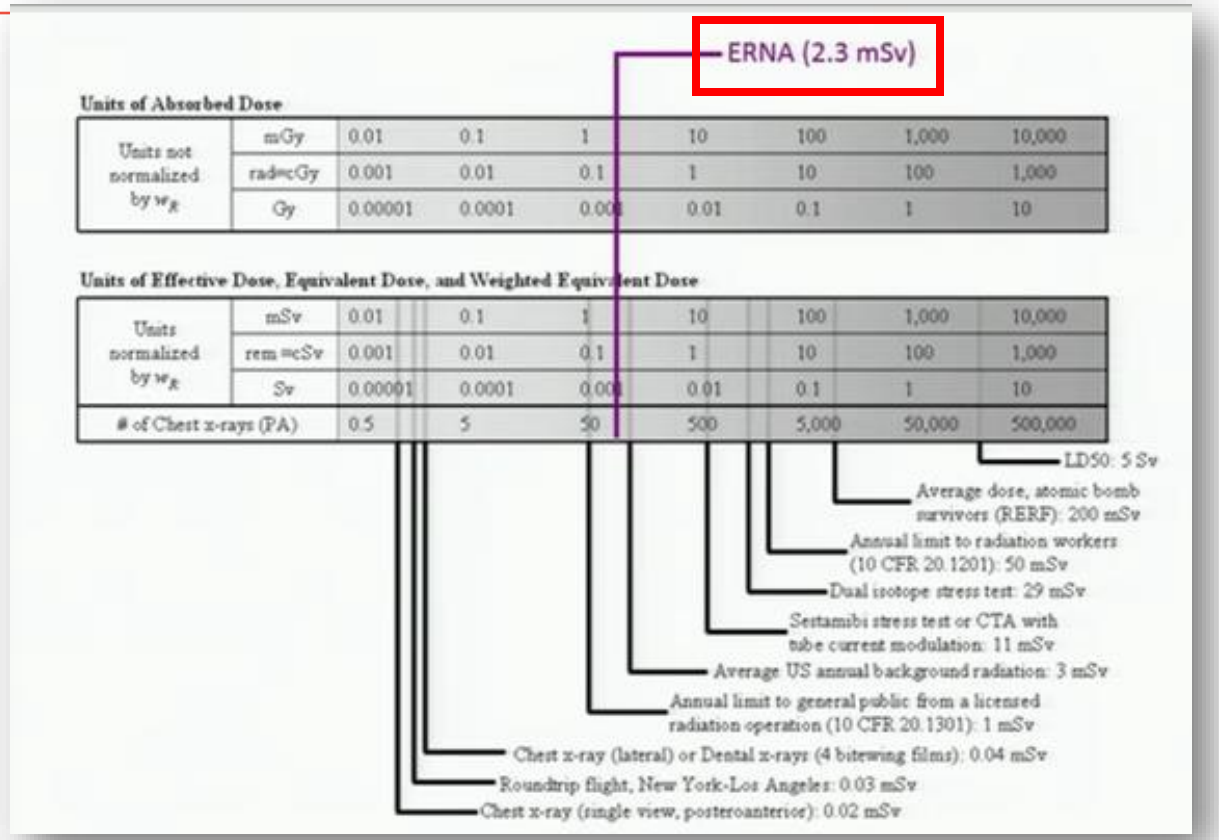
Reliability and accuracy of ERNA (MUGA)

- Diagnostic Accuracy of ERNV
  - Excellent correlation with LVG with calculated LVEF (r = 0.93)
  - Point-by-point LV volume curve
  - Excellent LVEF precision
  - Robust automated computer processing (90% correlation with manual analysis)
  - *repeat acquisitions (3.7% variability)*
  - *repeat processing (2% variability)*
  - *Excellent intra-observer agreement (1.4% variability)*
  - *Excellent inter-observer agreement (1.6% variability)*

1. Burrow RD, Circulation 1977; 56:1024-1028
2. Folland ED, J Nucl Med 1977; 18: 1159-1166
3. Ashburn WL, Prog Cardiovasc Dis 1978; 20:267-284
4. Shen AC, Am J Pathol 1972; 67:441-452
5. Christian PE, J Nucl Med 1985; 26:775-782
6. Wackers FJ, Am J Cardiol 979; 43:1159-1166

Can We Decrease Radiation Exposure?



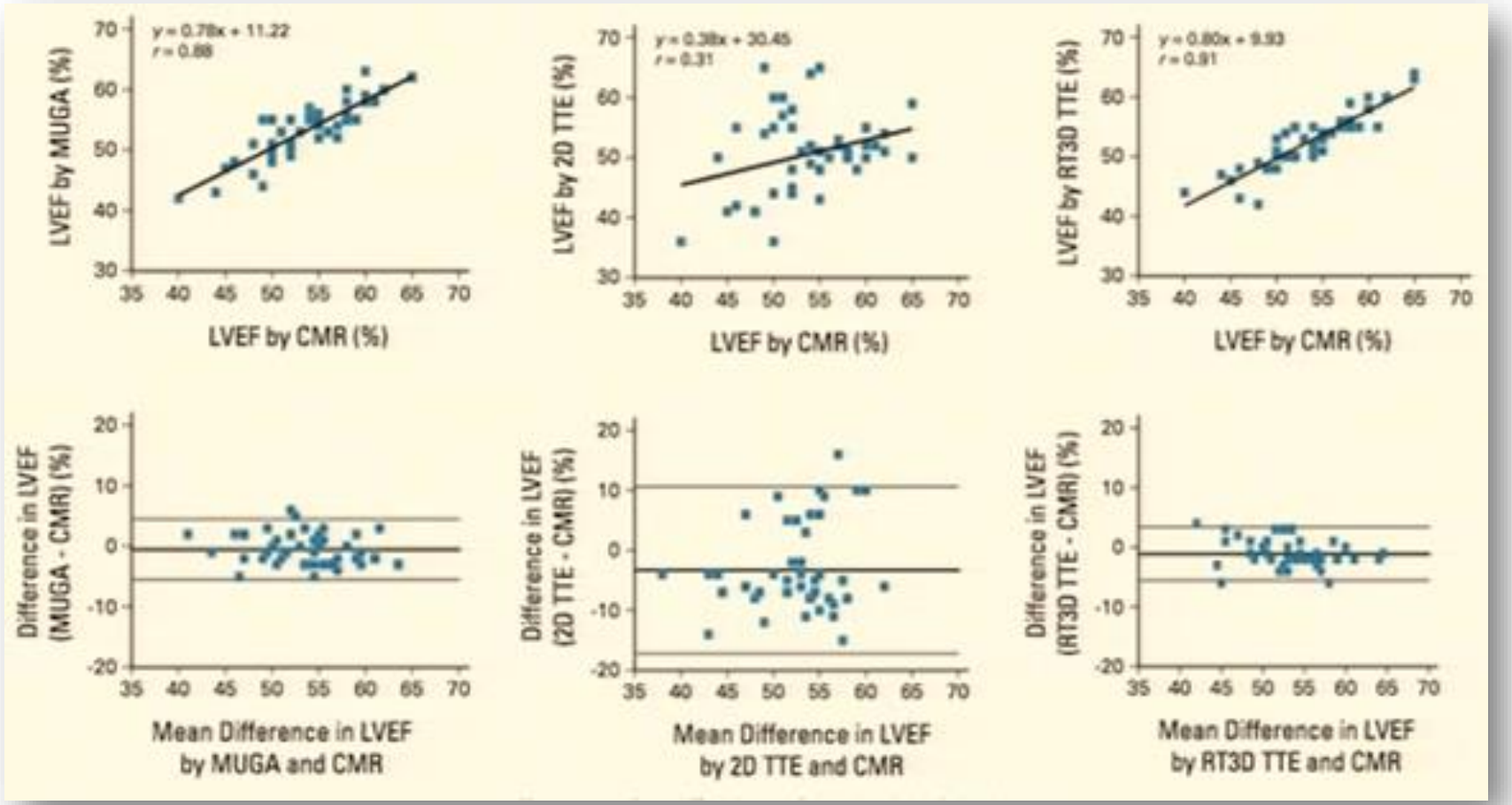


Einstein et al. Circ 116:1290,2007

ALTERNATIVES TO NUCLEAR IMAGING

Echocardiography with 3D EF and Global Longitudinal Strain

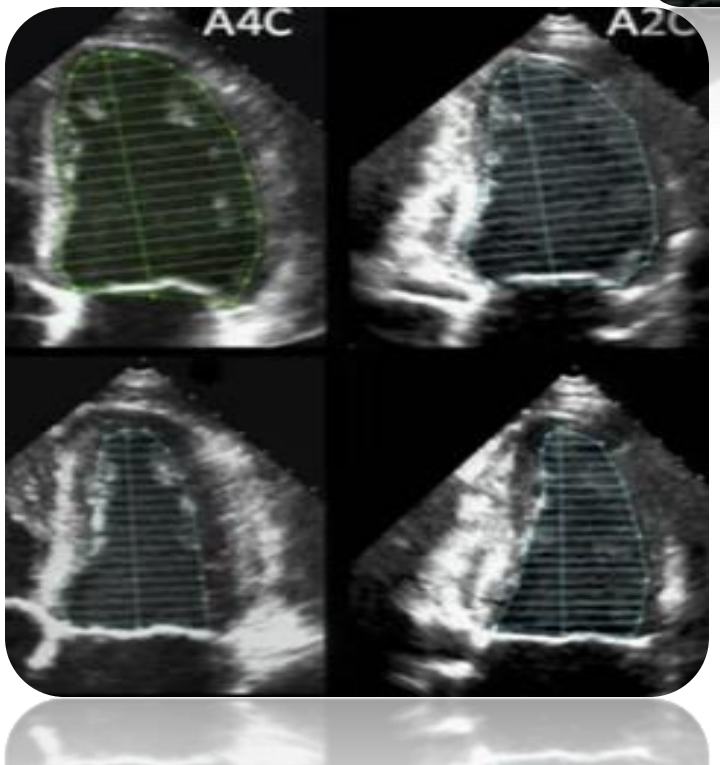
Multi-Imaging Modality Correlation



Walker et al. J Clin Oncol 28:3429,2010

Early Detection and Screening With Echocardiography

- LV Assessment 2D vs. 3D echocardiography:
- Modified Biplane Simpson's Technique:
  - Range 53% - 73% with wide variation
  - ***Inter- & Intra-observer variability of 8-9%***
- 3D EF: automated and reproducible with ***0.6% variability***



Thavendiranathan P, et al. Reproducibility of echocardiographic techniques for sequential assessment of left ventricular ejection fraction and volumes: Application to patients undergoing cancer chemotherapy. J Am Coll Cardiol. 2013;61:77–84

Early Detection and Screening With Echocardiography

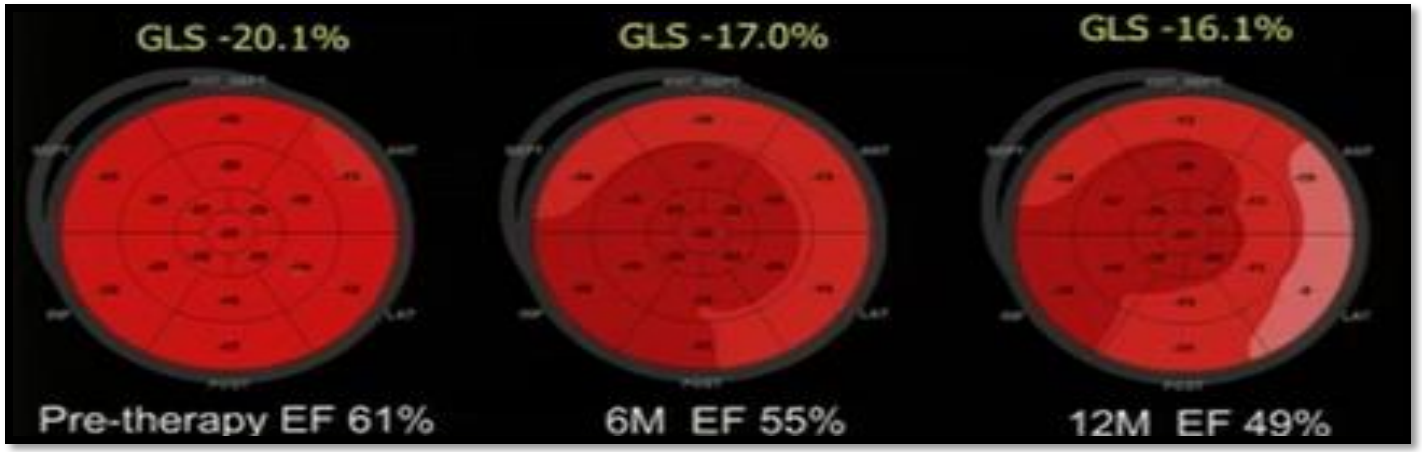


Table 3 Early Predictors of Cardiotoxicity

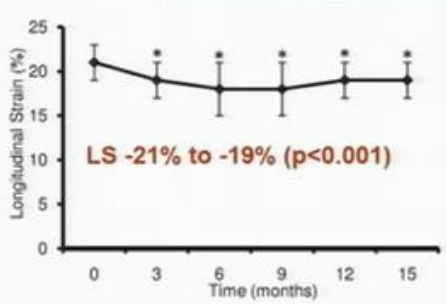
Studies/First Author (Ref. #)	Sensitivity	Specificity	PPV	NPV
Fallah-Rad et al. (44)*				
2% absolute (10.1% relative) decrease in LS	79%	82%	60%	92%
0.8% decrease in RS	86%	81%	60%	95%
Sawaya et al. (41)†				
10% decrease in GLS	78%	79%	50%	93%
Elevated hsTnI	67%	82%	50%	90%
10% decrease in GLS and elevated hsTnI	55%	97%	83%	89%
10% decrease in GLS or elevated hsTnI	89%	65%	40%	97%
Sawaya et al. (40)†				
GLS <19%	74%	73%	53%	87%
hsTnI >30 pg/ml	48%	73%	44%	77%
LS <19% and usTnI >30 pg/ml	35%	93%	67%	77%
LS <19% or usTnI >30 pg/ml	87%	53%	43%	91%

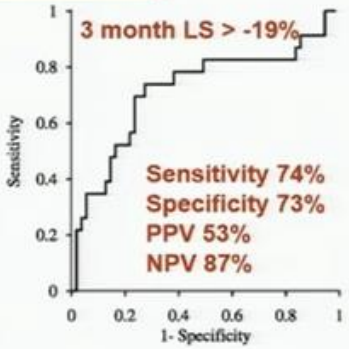
Thavendiranathan P, et al. JACC: 63:2751-68

Longitudinal Strain in Risk Assessment

Assessment of Echocardiography and Biomarkers for the Extended Prediction of Cardiotoxicity in Patients Treated With Anthracyclines, Taxanes, and Trastuzumab

Heloisa Sawaya, MD, PhD; Igal A. Sebag, MD; Juan Carlos Plana, MD; James L. Januzzi, MD; Bonnie Ky, MD, MSCE; Timothy C. Tan, MBBS, PhD; Victor Cohen, MD; Jose Banchs, MD; Joseph R. Carver, MD; Susan E. Wiegers, MD; Randolph P. Martin, MD; Michael H. Picard, MD; Robert E. Gerszten, MD; Elkan F. Halpern, PhD; Jonathan Passeri, MD; Irene Kuter, MD; Marielle Scherrer-Crosbie, MD, PhD





Cardiotoxicity defined as a reduction of EF ≥5% to <55% with HF or an asymptomatic reduction of EF ≥10% to <55%.

Sawaya, et al. Circ CV Imaging. 2012.

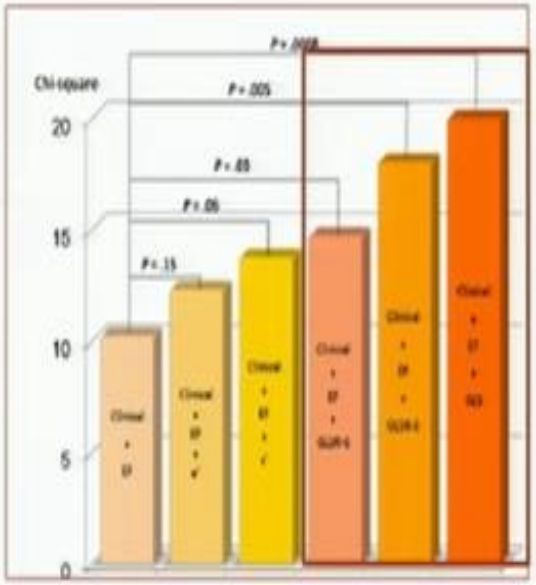
Independent and Incremental Value of Deformation Indices for Prediction of Trastuzumab-Induced Cardiotoxicity

Kazuaki Negishi, MD, PhD, Tomoko Negishi, MD, James L. Hare, MBBS, PhD, Brian A. Haluska, PhD, Juan Carlos Plana, MD, and Thomas H. Marwick, MBBS, PhD, MPH, *Cleveland, Ohio; Brisbane and Hobart, Australia*

- 81 breast cancer patients with at least 3 echocardiograms
- GLS and systolic and diastolic strain rate of incremental utility
  - 11% reduction in GLS had sensitivity 65%; specificity 94%

Table 3 Percent changes in echocardiographic parameters in 6 months within the groups

	No cardiotoxicity	Cardiotoxicity	P
GLS	0.2 ± 8.6	11.4 ± 9.8	<.001
GLSR-S	−0.2 ± 16.8	12.8 ± 19.4	.009
GLSR-E	5.1 ± 21.2	−11.9 ± 14.5	.002
s′	−5.0 ± 18.9	−17.0 ± 23.9	.04
e′	3.5 ± 37.1	−10.0 ± 28.7	.09
GCS	−1.0 ± 29.7	9.3 ± 27.4	.18
GRS	8.3 ± 46.5	−10.0 ± 39.3	.11



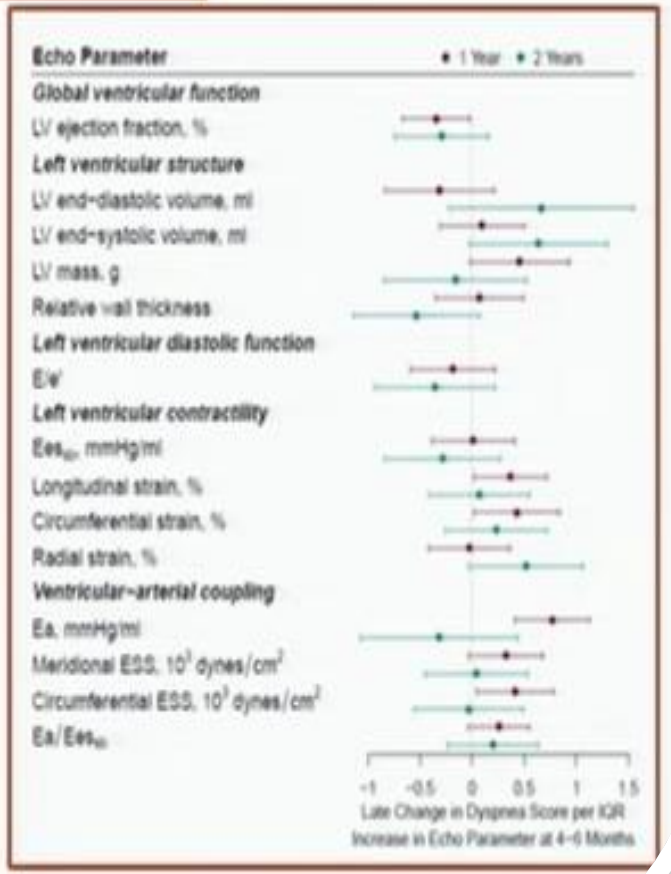
Negishi, et al. JASE. 2013.

ORIGINAL RESEARCH ARTICLE

Detailed Echocardiographic Phenotyping in Breast Cancer Patients

Associations With Ejection Fraction Decline, Recovery, and Heart Failure Symptoms Over 3 Years of Follow-Up

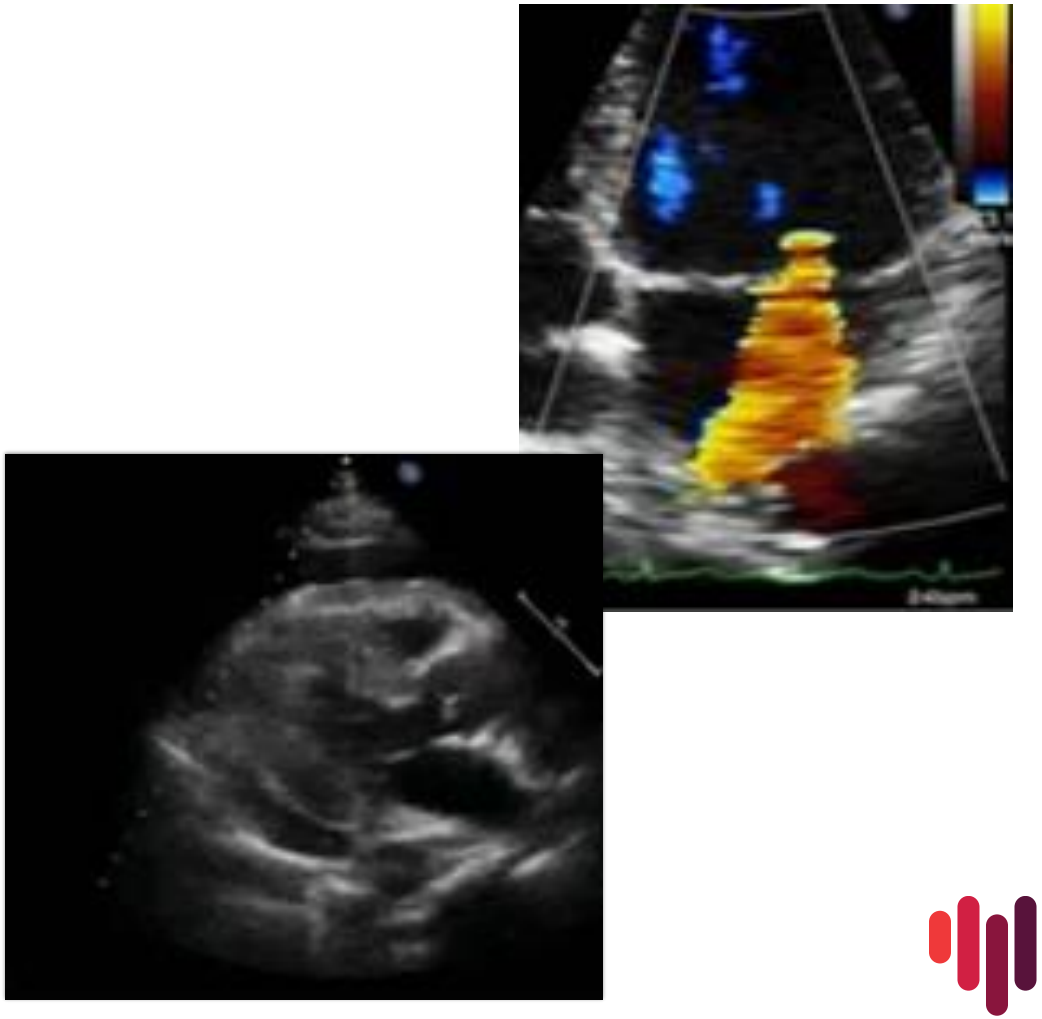
- 277 participants with breast cancer, treated with doxorubicin and/or trastuzumab
- Early changes in volumes, longitudinal & circumferential strain, arterial load (Ea), and Ea/Ees_{sb} are associated with subsequent LVEF declines and with cardiac symptoms



Narayan, Finkelman…Ky. Circulati

Structural Heart Disease in Echocardiography

- Valvular pathology with stenosis or regurgitation (aortic and mitral) from remodeling or radiation
- Tumor expansion :
  - Metastatic tumors >Primary (Lung, renal Cell, Melanoma and Mesothelioma)
  - Pericarditis/Pericardial effusion : Mets vs. radiation
- Pulmonary hypertension with RV dysfunction
  - Dasatinib, carfilzomib
  - Malignancies



Chemotherapy related cardiac dysfunction (CTRCD): Definition

	Definition	Modality of Measurement	Chemotherapy Agents	Comments
Alexander et al.	***Mild: Decline in LVEF > 10%*** ***Moderate: Decline in LVEF > 15% to final LVEF < 45%*** ***Severe: congestive HF***	Multigated acquisition (MUGA) scan	Anthracycline	
Schwartz et al.	***Decline in LVEF > 10% to final LVEF < 50%***	MUGA scan	Anthracycline	
Cardiac Review and Evaluation Committee	***1. Cardiomyopathy characterized by a decrease in LVEF globally or more severe in the septum*** ***2. Sign and symptoms of HF*** ***3. Decline of EF ≥5% to final ejection fraction < 55% with symptoms of congestive HF*** ***4. Asymptomatic decline of LVEF ≥ 10% to final ejection fraction < 55%***	MUGA scan and echocardiogram	Trastuzumab +/- Anthracycline	
Common Terminology Criteria for Adverse Events, version 4.03 (HF, left ventricular dysfunction)		Not defined	N/A	Other definitions included such as troponin and clinical HF
American Society of Echocardiography and European Association of Cardiovascular Imaging	***≥10% decline in LVEF to final LVEF < 53%*** (suggests repeat imaging)	Echocardiography; two-dimensional (2D) and three-dimensional (3D) contrast, cardiac magnetic resonance imaging, MUGA scan	N/A	***First guideline to include global longitudinal strain > -15%***

Alexander J, Dainiak N, Berger HJ, et al. Serial assessment of doxorubicin cardiotoxicity with quantitative radionuclide angiocardiography. N Engl J Med 1979;300:278-83.
23. Schwartz RG, McKenzie WB, Alexander J, et al. Congestive heart failure and left ventricular dysfunction complicating doxorubicin therapy. Seven-year experience using serial radionuclide angiocardiography. Am J Med 1987;82:1109-18.
24. Seidman A, Hudis C, Pierri MK, et al. Cardiac dysfunction in the trastuzumab clinical trials experience. J Clin Oncol 2002;20:1215-21.
Common Terminology Criteria for Adverse Events (CTCAE) (U.S Department of Health and Human Services website). 2010. Available at: http://evs.nci.nih.gov/ftp1/CTCAE. Accessed February 2016.

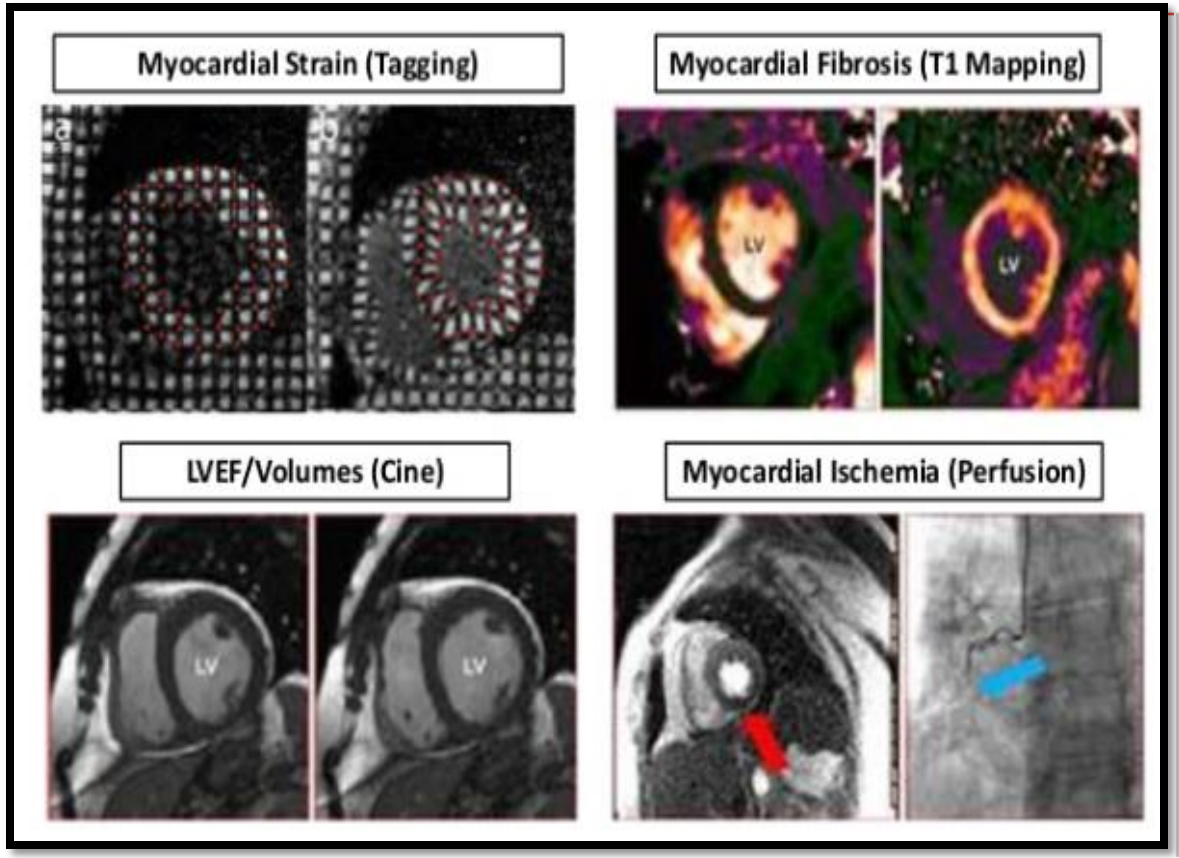
Routine Surveillance, How Often & For How Long?

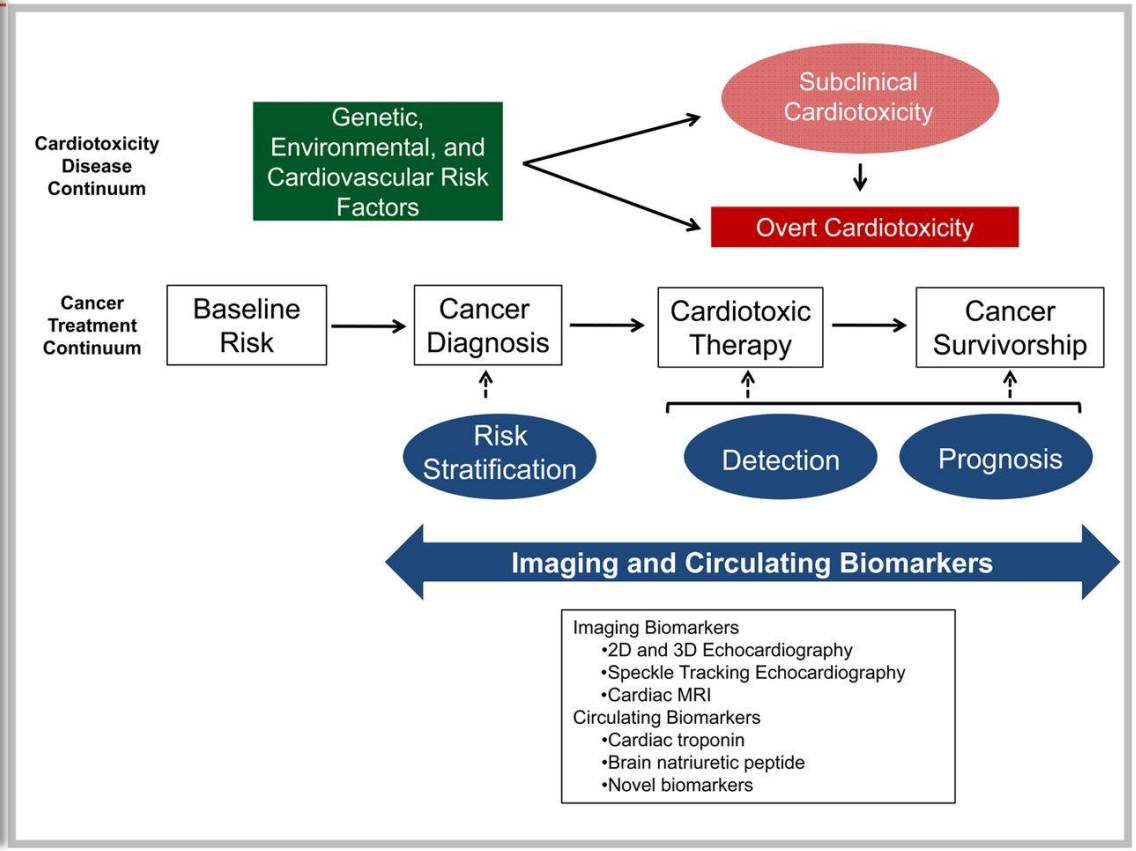
Guideline	Who?	How Often
ASE *Plana, et al. JASE. 2014.*	• Anthracyclines • Anti-HER2 therapies • VEGF Inhibitors • Proteasome inhibitors	• Repeat 2-3 weeks after abnormal study • 6 months after therapy completed • Annual assessment with imaging as per provider
ESC *Zamorano, et al. EHJ. 2016.*	• Cardiotoxic therapies (Broadly defined)†	• LVEF before and periodically during • Repeat 2-3 weeks after abnormal study
	• Survivors	• Periodic screening
ASCO *Armenian, et al. JCO. 2016.*	• Asymptomatic, high risk DURING treatment*	• Routine surveillance, frequency determined by provider
	• Those with signs/symptoms concerning for dysfunction	
ASCO *Armenian, et al. JCO. 2016.*	• Asymptomatic, high risk AFTER treatment	• 6 to 12 months after therapy completion
	• Those with signs/symptoms concerning for dysfunction	

* High risk = high dose anthracyclines, high dose radiotherapy; multiple CV risk factors, older age, compromised CV function; sequential therapy (anthracyclines + radiation or trastuzumab)
† Cardiotoxic therapies = anthracyclines, alkylating agents, antimetabolites, antimicrotubules, monoclonal antibodies, TKIs, proteasome inhibitors, misc

Cardiac Magnetic Resonance Imaging

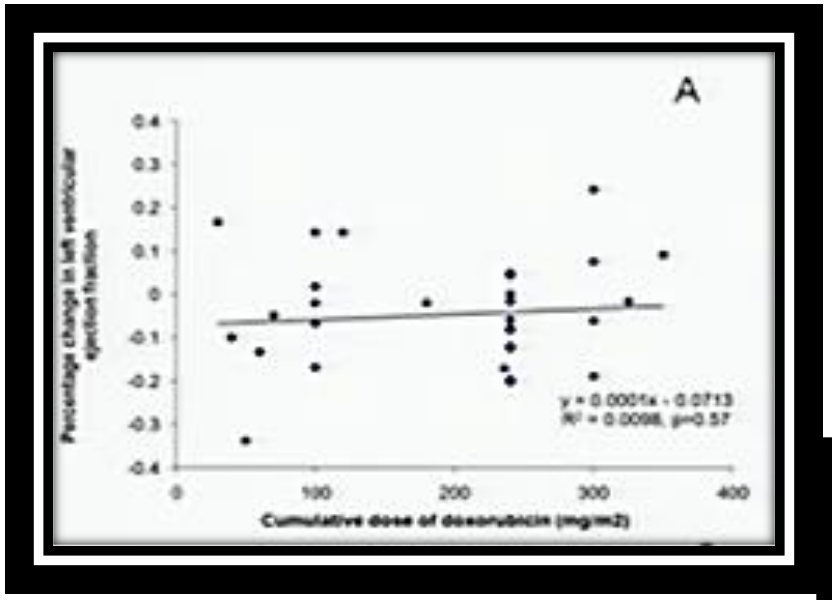
Chemotherapy and CMR

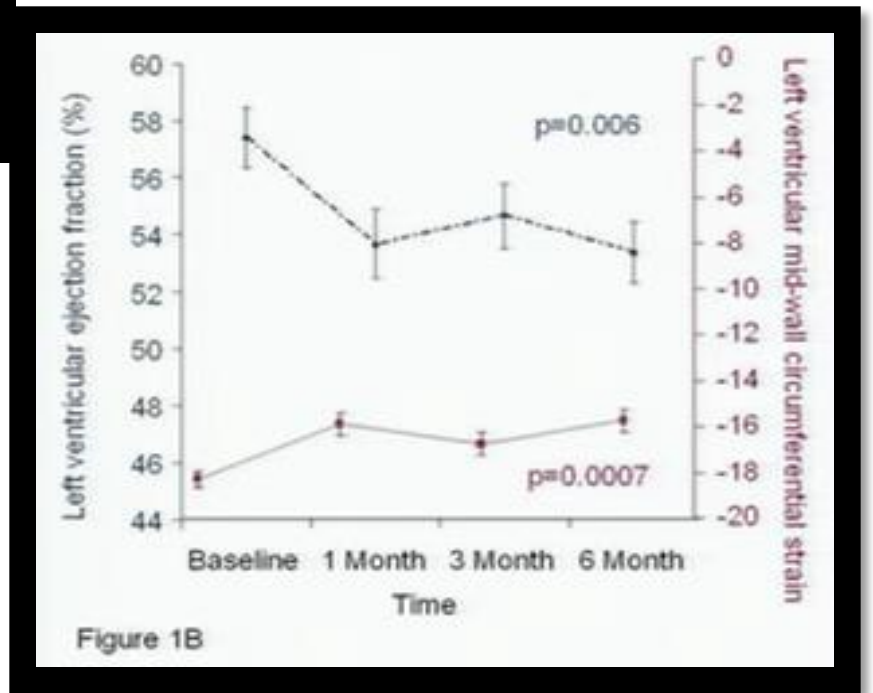




Hundley, et al J Cardiovasc MR 2013
Drafts, et al., JACC Imaging 2012

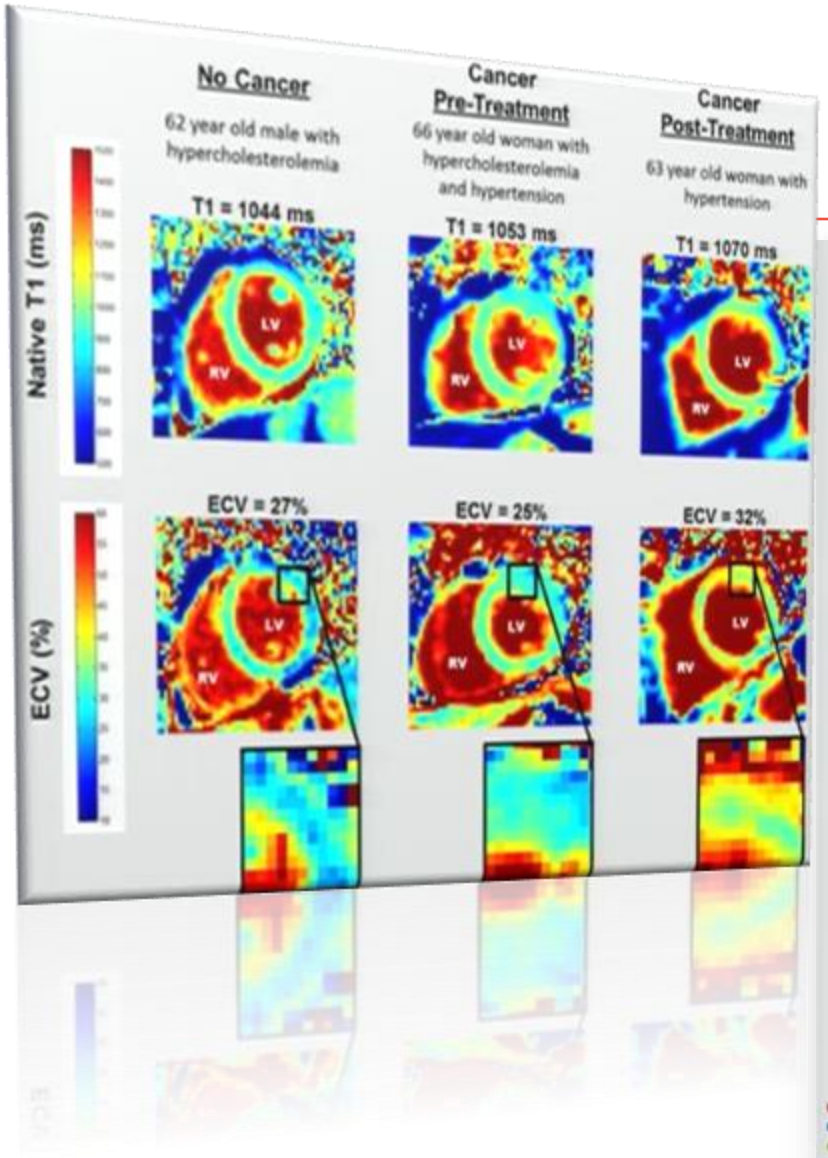
Anthracyclines Based Chemotherapy and Strain on CMR

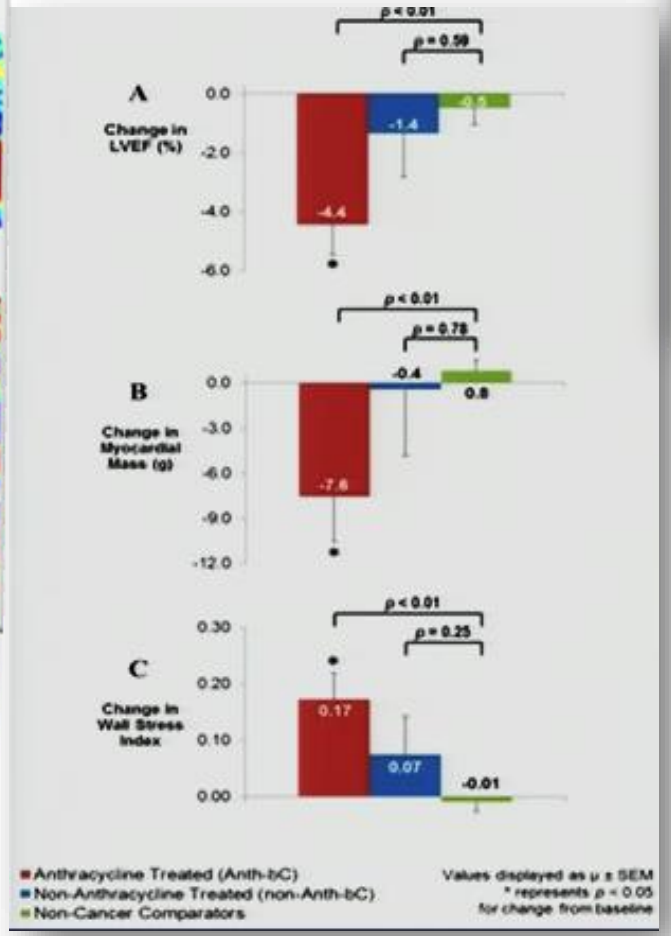


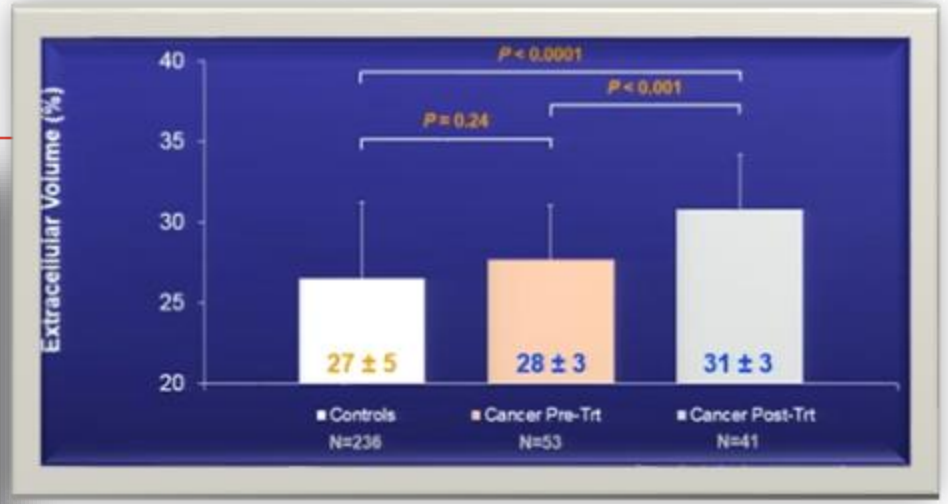


- Independent of:
  - Gender/Age or Race
  - Type of Cancer
  - Chemotherapy dose
  - Cardiovascular co-morbidities

Drafts, et al., JACC Imaging 2012







Jordan, et al., Circulation Imaging 2016

Questions