THE CARDIOVASCULAR CENTER OF FLORIDA

2025 Cardiovascular Center Of Florida Annual Symposium

Multimodality Imaging

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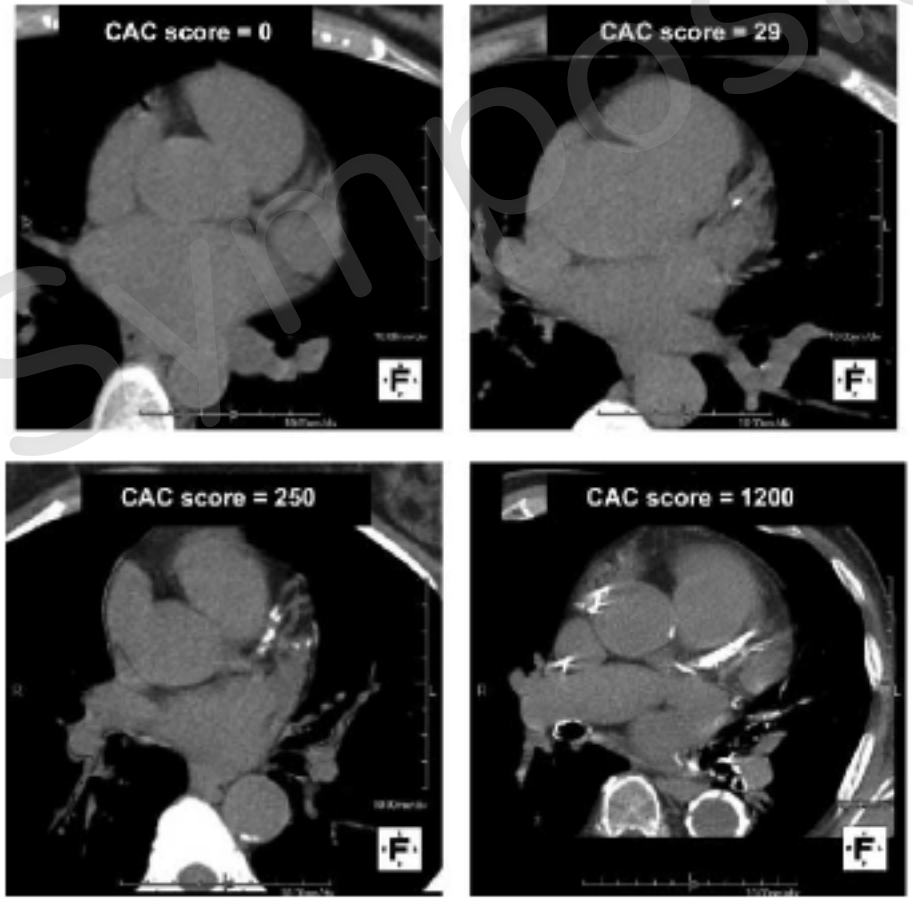
Multimodality Imaging

- Echocardiography – 3D and Strain imaging
- Nuclear Cardiology
- Cardiac CT
- Cardiac MRI
- Vascular imaging (Doppler, CTA)

Introduction

- CT calcium score
- Nuclear cardiology – SPECT and PET
- Cardiac CT

Calcium score



Introduction

- Cardiovascular disease (CVD) is a leading cause of death worldwide and in US
- Reducing coronary heart disease mortality and morbidity necessitates a highly sensitive risk assessment tool, followed by risk stratification and treatment strategies
- CAC is widely available, exhaustively studied, and a highly specific marker of subclinical atherosclerosis
- Vital arbitrator of atherosclerotic cardiovascular disease (ASCVD) and accounts for both stroke and coronary heart disease

Calcium scoring -Clinical practice guidelines

- CAC scoring is vital to up- or down-classify intermediate risk individuals
- ACC/AHA- intermediate risk adults (7.5%-20% 10-year ASCVD risk) and adults at borderline risk (5%-7.5% 10-year ASCVD risk)

CENTRAL ILLUSTRATION Summary of Major Global CAC Guidelines

Major Worldwide Coronary Artery Calcium Guidelines

- CAC as an arbitrator of statin use on intermediate risk.

- CAC as a tool for adjudicating statin allocation.
- For CAC scoring among all asymptomatic patients with suggested ECG changes for ischemia.

- CAC as an arbitrator of statin use on intermediate risk.

- CAC as a prognostic tool in intermediate- to high-risk individuals.
- Local studies suggested.

- CAC scoring to up-classify or down-classify their risk (T1DM <35 yrs old, T2DM <50 yrs old), with diabetes mellitus duration <10 years and without other risk factors.

- CAC as a risk assessing tool, risk reclassification and therapy determinator.
- Indicated in low risk with strong family history or other concern features.
- High risk reluctant to accept treatment, CAC is indicated.

- CAC as an arbitrator for aspirin allocation.

Common Indications

- Age: >40 y
+
- Risk: Intermediate
+
- Symptoms: Asymptomatic population

Common Treatment Threshold

- CAC = 0: downgrade risk, withhold statin
- CAC >100: Initiate / consider statin

Nonagreement Points

- CAC score for aspirin use
- CAC score for antihypertensive drugs

Specialty Guidelines

NATIONAL LIPID ASSOCIATION

- CAC = 0: No statin, repeat 3-7 years.
- CAC >100: High intensity statin + ASA 81 mg.

SCCT SOCIETY OF CARDIOVASCULAR COMPUTED TOMOGRAPHY

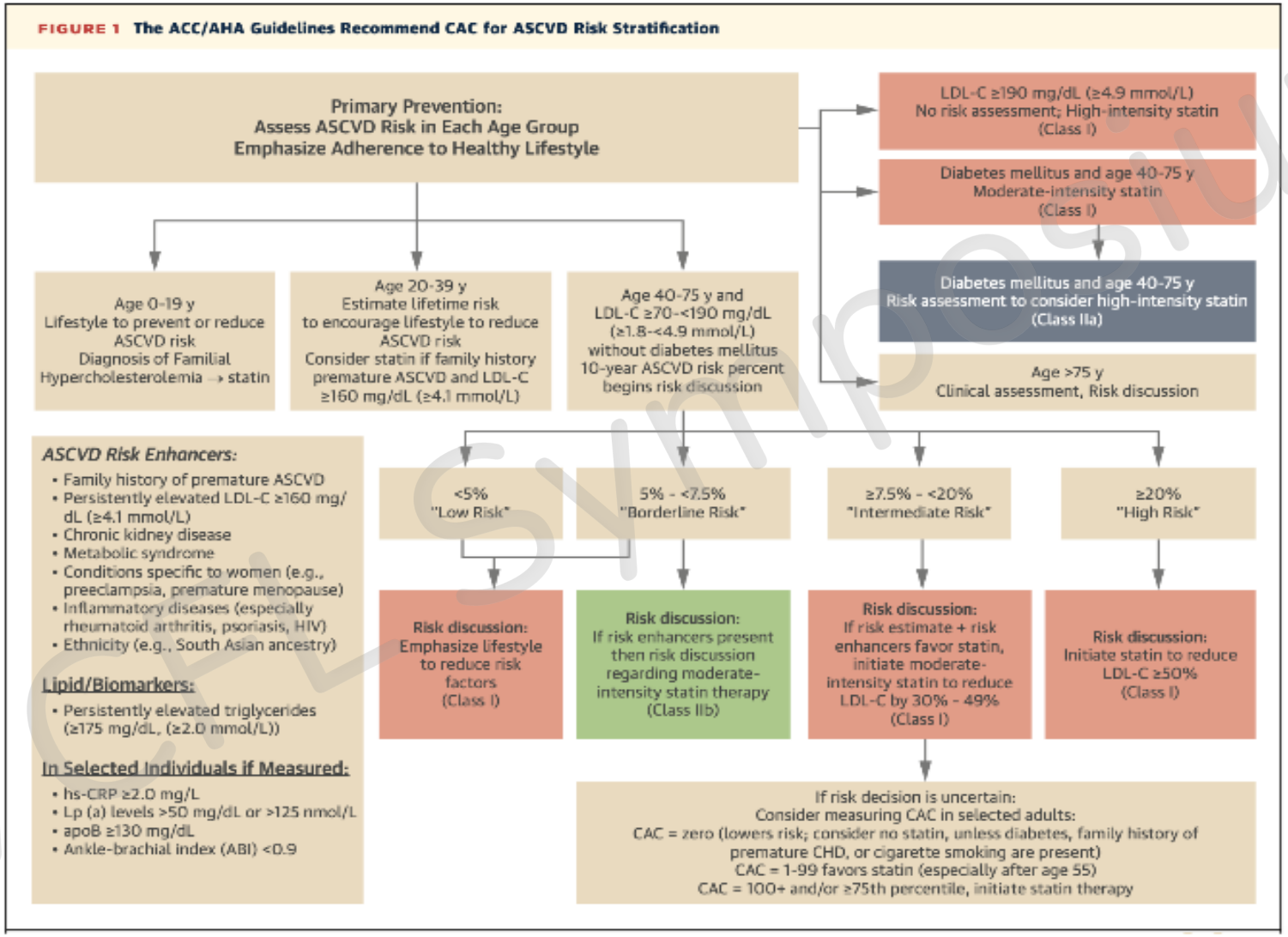
- CAC = 0: No statin.
- CAC >100: High intensity statin + ASA 81 mg.

U.S. Preventive Services Task Force

- Evidence is insufficient for CAC addition to traditional CV risk assessment, in asymptomatic adults for ASCVD prevention.

Golub IS, et al. J Am Coll Cardiol Img. 2023;16(1):98-117.

FIGURE 1 **The ACC/AHA Guidelines Recommend CAC for ASCVD Risk Stratification**



Risk enhancers

- Family history of premature ASCVD
- Persistently elevated LDL-C ≥160 mg/dL or triglycerides ≥175 mg/dL
- Chronic kidney disease
- Metabolic syndrome
- Conditions specific to women (preeclampsia, premature menopause)
- Inflammatory diseases (rheumatoid arthritis, psoriasis)
- HIV
- High-risk race or ethnicity (South Asian origin)
- Elevated high-sensitivity C-reactive protein or lipoprotein(a)

Subgroups

CKD

- Significantly more pronounced, disseminated, and fast-progressing calcification of the vascular system (high risk)
- Coronary artery calcification develops early after the onset of CKD and is closely associated with mineral and bone disorders
- Associated risk factors + Inflammation
- Many guidelines and societies consider CKD to be very high risk level and agree that initiating statin therapy is warranted
- ESRD – limited data / conflicting data

Diabetes Mellitus

- Risk for CV events comparable to those for patients with an actual ASCVD history (CAD equivalent)
- Presence of any CAC in individuals with DM equates with a higher risk of all-cause mortality
- ACC/AHA guidelines - should not down-classify risk in diabetic patients who have a CAC of zero due to the potential presence of noncalcified plaques

Female gender

- Women have 2 times increased risk of CV death as compared with men with the same CAC burden
- FRS frequently underestimates women's risk, even in the presence of CAC >100 or CAC >75th percentile
- CAC screening is equally accurate in allocating risk in women and men
- Recommendations for gender-based CAC stratification are limited

Younger age group

- ACC/AHA recommends that ASCVD risk factors be evaluated every 4 to 6 years and that CAC scoring be performed if there are risk factors (hyperglycemia, hyperlipidemia, hypertension, or smoking)

- CCS guidelines are similar for this age group. Consider CAC scoring in individuals with a strong family history of premature CVD events, smoking history, diabetes, hypertension, or genetic dyslipidemias

Older age group

ACC/AHA guidelines state that for adults 76 to 80 years of age with an LDL-C level of 70 to 189 mg/dL, CAC of 0 warrants the deferral of statin therapy

Calcium score – Statin

- CAC 0 – no tx (history of cigarette smoking, diabetes, poorly controlled hypertension, genetic dyslipidemias such as familial hypercholesterolemia or elevated lipoprotein(a), or strong family history of premature ASCVD events)
- CAC 0-99- Statin (personalized tx)
- CAC 100 or > -- statin

Calcium score – ASA

- ACC/AHA Primary Prevention Guidelines recommend low-dose aspirin only among adults 40 to 70 years of age, who have increased ASCVD risk but no heightened bleeding risk

- For subgroups with CAC ≥100 (especially those with CAC >400), aspirin yields a net benefit regardless of risk factors

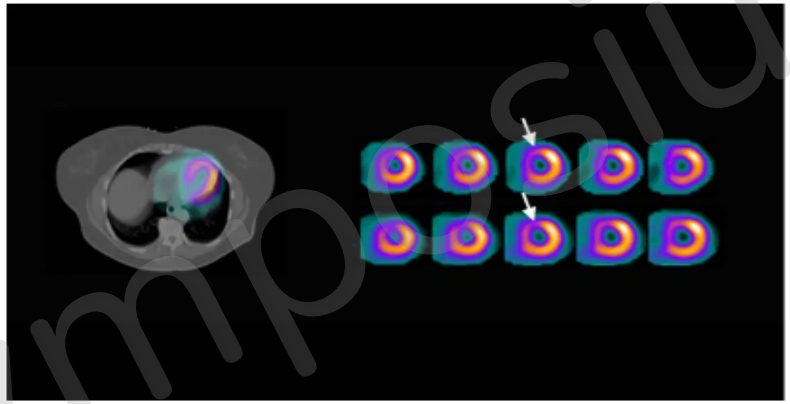
Score	Risk	Treatment Recommendation
0	very low	statin not recommended[a]
1-99	mildly Increased	moderate intensity statin if <75th%; moderate to high intensity if >75th%
100-299	moderately increased	moderate to high intensity statin + ASA 81 mg
>300	moderate to severely increased	high intensity statin + ASA 81 mg

Ilana S. Golub et al. *J Am Coll Cardiol Img* 2022; 16:98-117.

JACC Cardiovascular Imaging

CAC – rescanning

- CAC = 0, the ACC/AHA recommend that CAC screening may be repeated in 5 to 10 years
- CAC = 0 NLA advocates the following repeat scanning intervals
  - low-risk patients (<5% 10-year risk) warrant 5 to 7 years
  - intermediate-risk (5%-19.9% 10-year risk)- 3 to 5 years
  - high-risk or diabetes patients - 3 years
- SCCT advocates repeat screening every 5 years when CAC = 0 and every 3 to 5 years when CAC >0

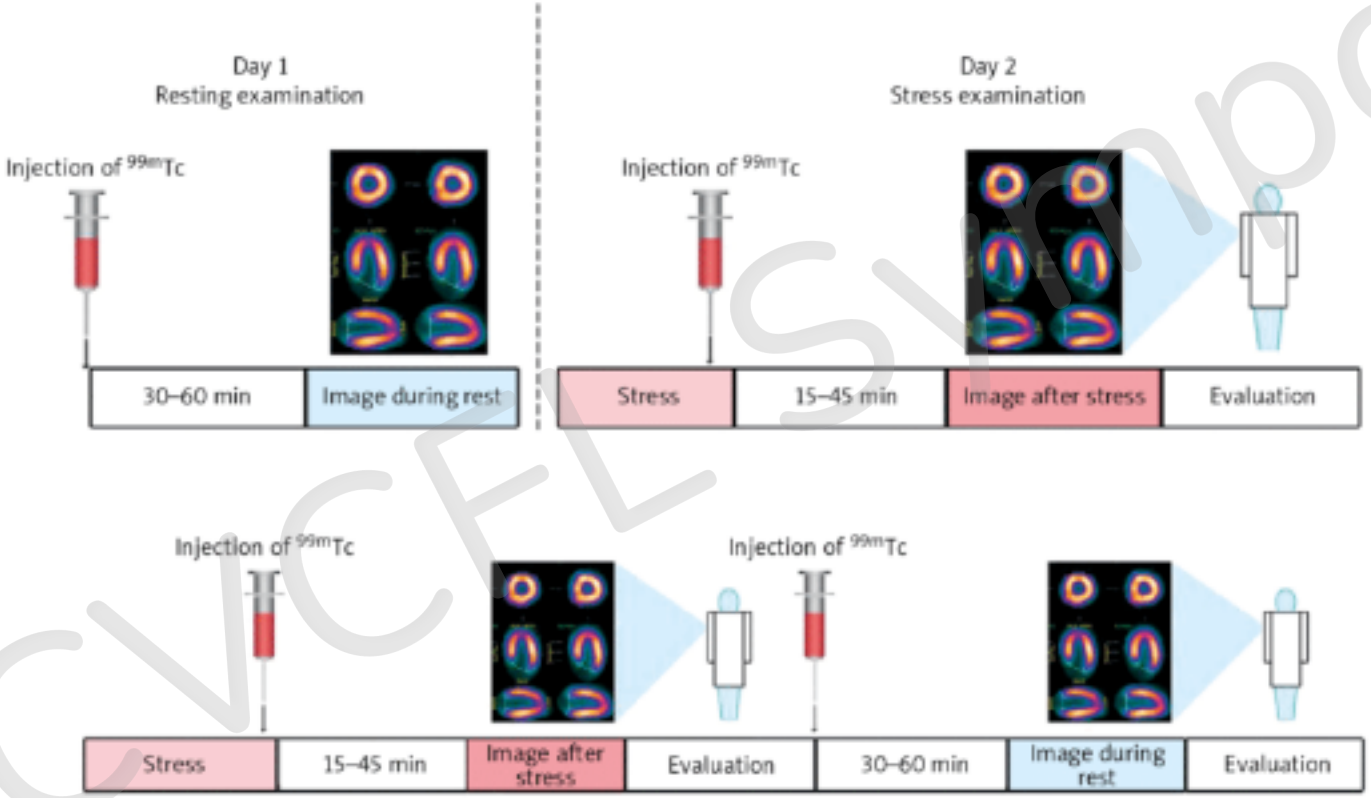


Myocardial Perfusion Imaging

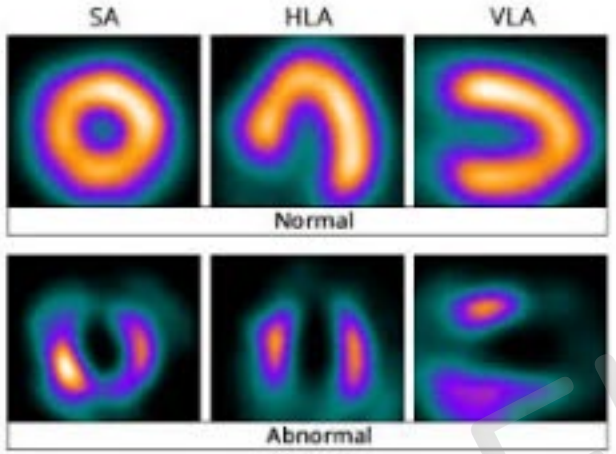
Myocardial perfusion imaging

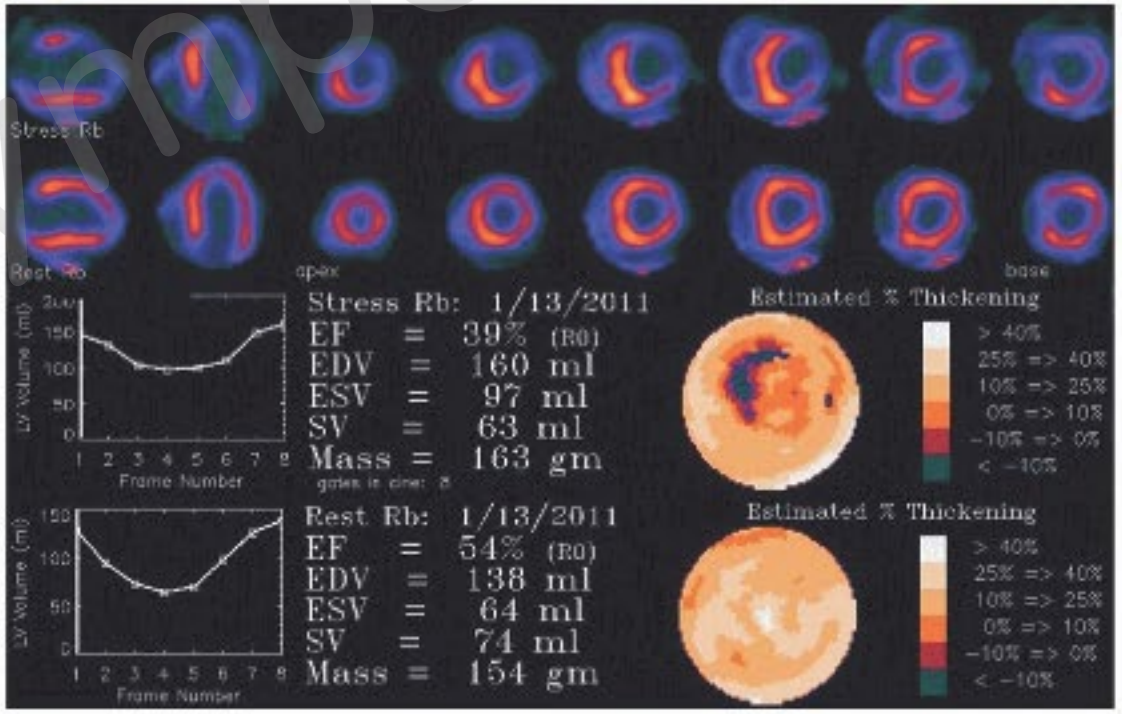
- SPECT (with or without CT)
- PET -CT

SPECT - protocol



SPECT –Perfusion and EF





Myocardial perfusion imaging - SPECT

- SPECT introduced in 1971
- Quantification of the burden of myocardial ischemia and scarring has played a critical role in the diagnosis, risk prediction, and management of CAD
- Risk stratification -myocardial scarring and ischemia, left ventricular volumes and ejection fraction, coronary artery calcification (CAC) burden with hybrid imaging

Myocardial perfusion imaging – risk stratification and referral for angiography

- Risk associated with normal study results is sufficiently low that referral to revascularization will not further improve patient outcomes
- Severely abnormal stress imaging results are at greater risk of adverse events and, thus, are potential candidates for intervention, and the magnitude of their risk is related to the extent and severity of the imaging abnormalities

Changing paradigm

- SPECT may be insufficient to adequately evaluate patients with stable chest pain syndrome in modern cardiovascular medicine
- Frequency of obstructive CAD as a key driver of symptoms and clinical outcomes is declining
- Temporal decline in the incidence of acute presentations of ST-segment elevation myocardial infarction
- Sharp increase in the rates of hospitalizations with a secondary myocardial infarction diagnosis and heart failure with preserved ejection fraction

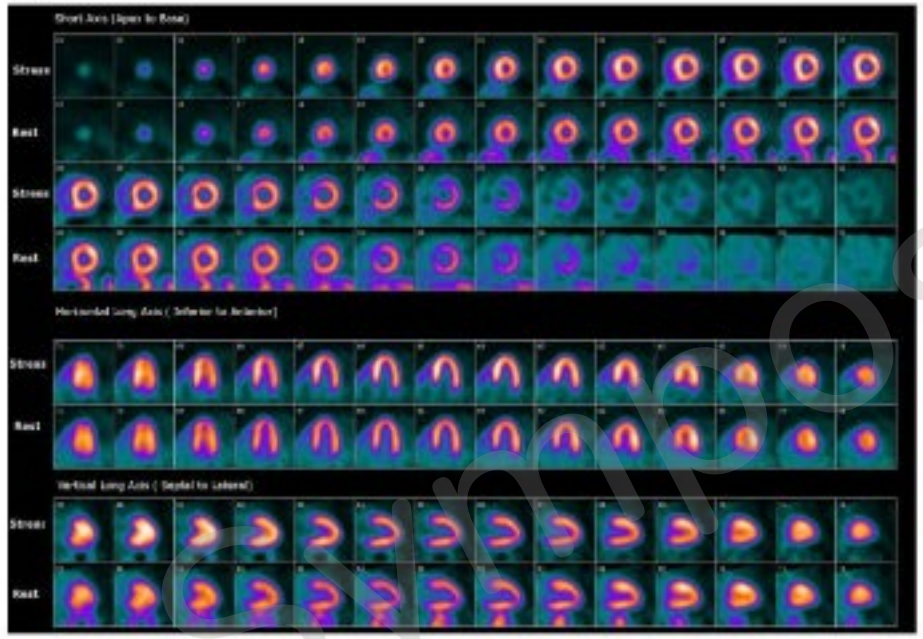
Changing paradigm

- Rising epidemic of cardiometabolic disease has been associated with an anatomic phenotype dominated by “diffuse atherosclerosis” and “microvascular remodeling”
- Cardiometabolic disorders represent a cluster of interrelated risk factors including hypertension, prediabetes and diabetes, obesity, and chronic kidney disease that are associated with an increased risk of adverse cardiovascular events
- Promote systemic proinflammatory state, endothelial dysfunction and coronary vasomotor abnormalities
- Subclinical myocardial injury (elevated troponin levels) and subsequent diffuse interstitial fibrosis, increased myocardial strain (elevated NT pro BNP), increased LV diastolic stiffness and systolic myocardial dysfunction

Changing paradigm

- Risk associated with a normal radionuclide MPI result has not necessarily been low (1%) in higher-risk cohorts
- Observed increased adverse event rate in higher-risk cohorts despite a visually normal radionuclide MPI result are likely multifactorial
- SPECT MPI, it is a somewhat insensitive test to uncover diffuse obstructive and nonobstructive CAD and coronary microvascular dysfunction (CMD) associated with myocardial ischemia and increased risk of adverse events

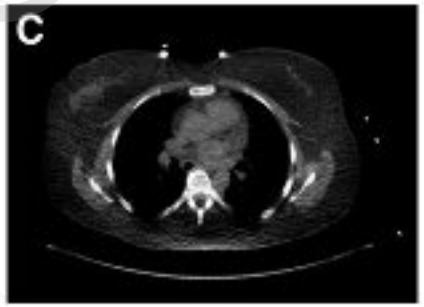
A



B

	Rest (mL/g/min)	Stress (mL/g/min)	Reserve Stress/Rest
LAD	1.20	4.13	3.44
LCx	1.12	3.40	3.06
RCA	1.13	4.12	3.60
Global	1.16	3.94	3.38

C

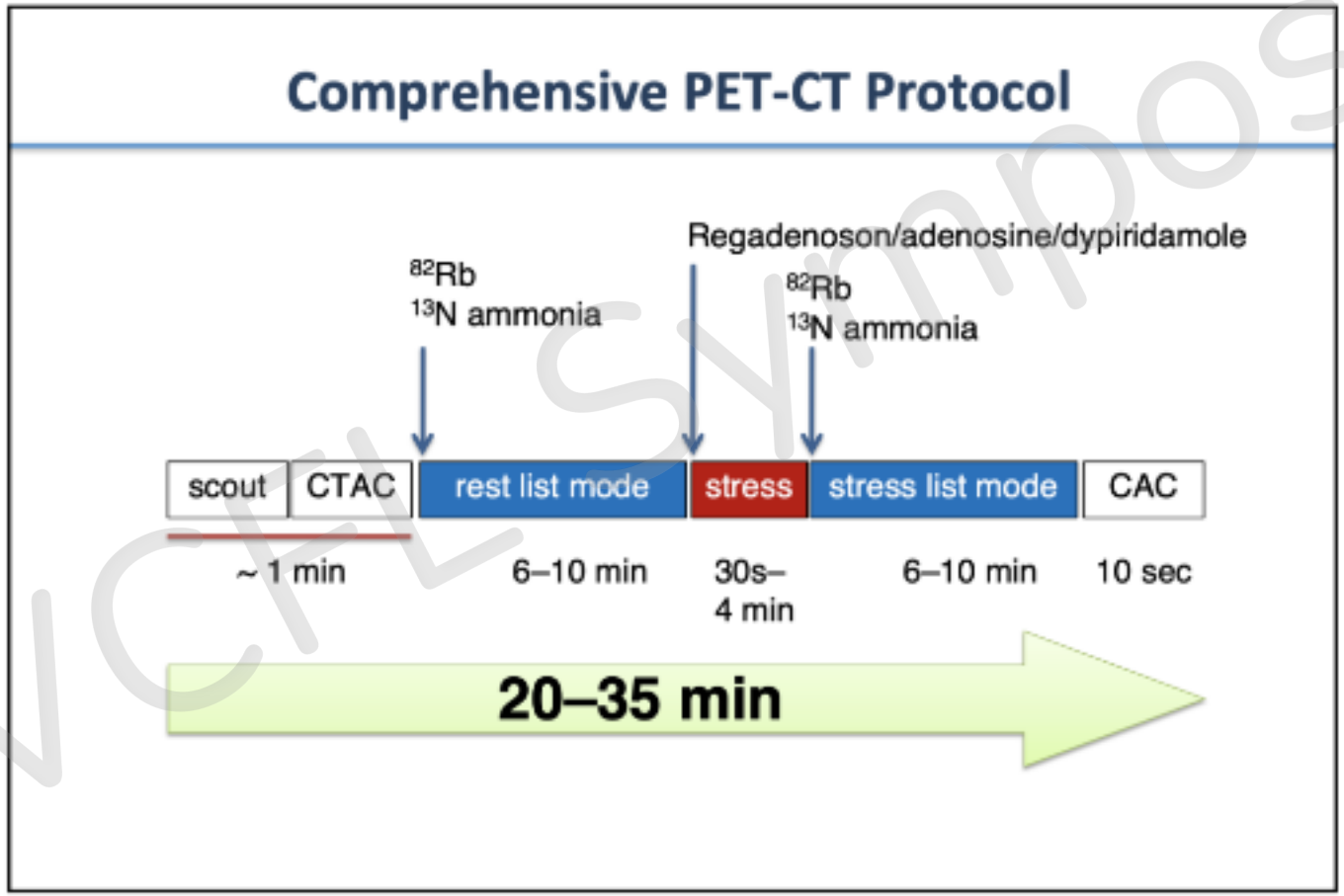


PET perfusion

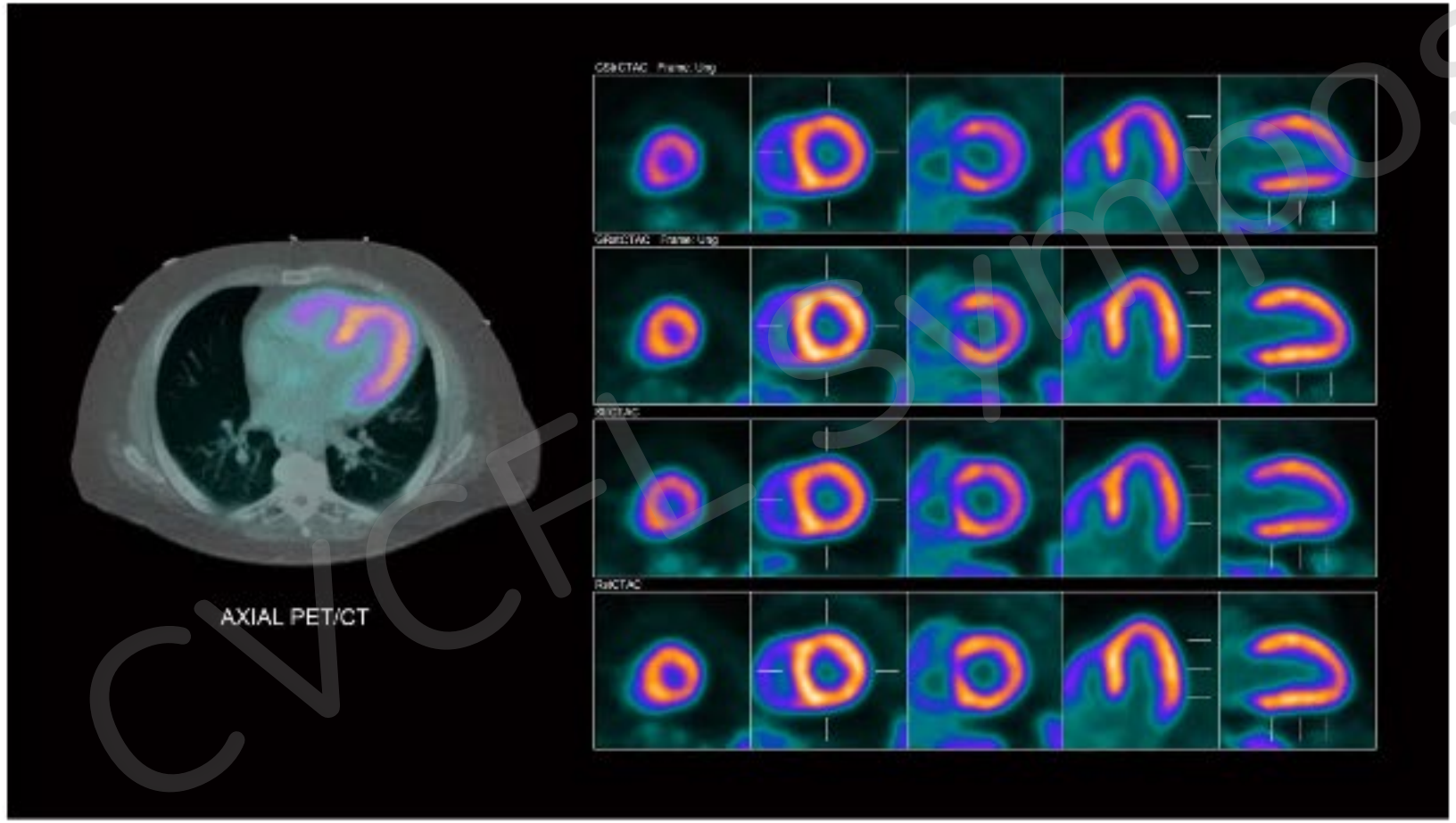
PET- Myocardial perfusion imaging

- Introduced in 1990's
- Alternative to SPECT
- Quantification of the burden of myocardial ischemia and scarring
- Left ventricular volumes and ejection fraction, coronary artery calcification (CAC) burden with hybrid imaging
- Myocardial blood flow (rest, stress) and myocardial blood flow reserve

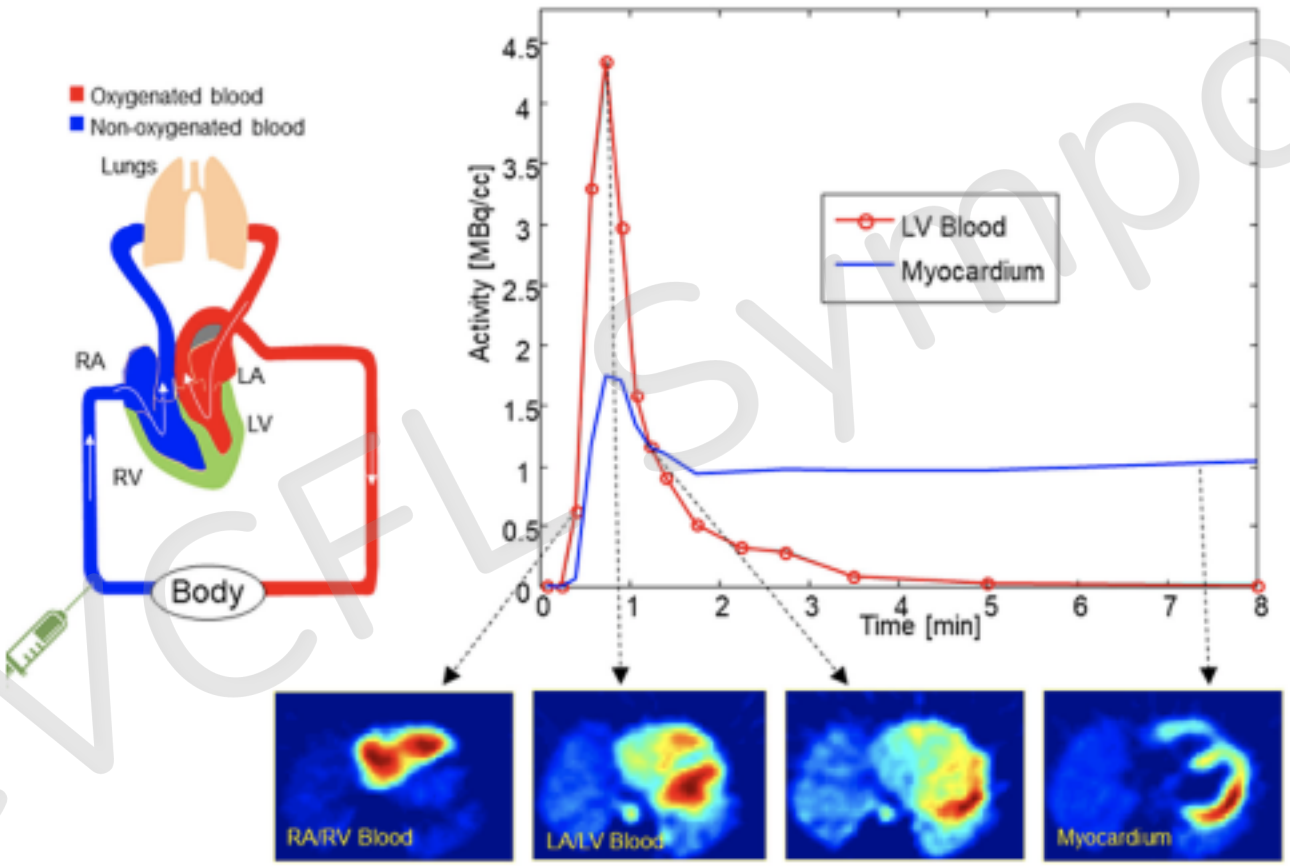
PET- Protocol



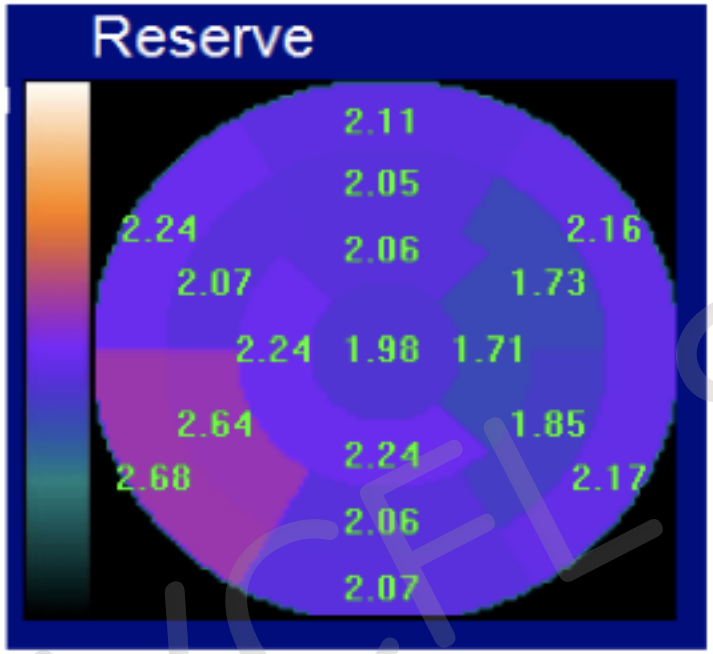
PET Perfusion and EF



PET time activity curves



PET- MBF and Reserve



	Rest (ml/gm/min)	Stress (ml/gm/min)	Reserve (Stress/Rest)
LAD	0.81	1.70	2.10
LCx	0.78	1.65	2.11
RCA	0.79	1.95	2.46
Global	0.80	1.72	2.15

Figure 5. Review segmental measurements of MBF, as sometimes the global and coronary territory scores can be normal, despite abnormal values in side-branch territories. Note reduced flows in the distal territory of the LCx coronary artery, despite the global LV and LCx MBFR 2x resting flows.

MBF reserve

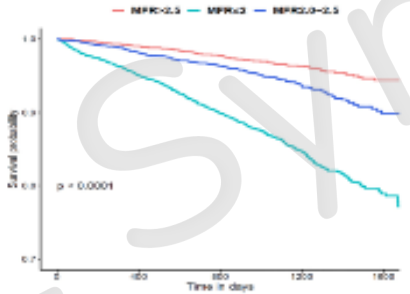
Is reduced **myocardial flow reserve** associated with **all-cause mortality** independently of **perfusion defects** on ^{82}Rb PET

N = 7169
Clinically referred with symptoms of chronic coronary syndromes

^{82}Rb PET myocardial perfusion imaging from multiple nuclear centers

Myocardial flow reserve (MFR) **≤2**

Survival probability



Risk of all-cause mortality

MFR≤2 vs ref.	HR	95% CI
Crude	3.22	(2.74-3.78)
Adjusted*	2.46	(2.09-2.90)
Multivariable adjusted†	1.62	(1.31-2.02)

*Sex, age, prior diagnosis of IHD, †comorbidities and ^{82}Rb PET variables including perfusion defects

- MFR is a predictor across the entire range of perfusion defects
- Consistency in results across clinically relevant sbgroups
- Prognostic value for both cardiac and noncardiac death

Risk stratification

MFR ≤2 is a strong predictor of all-cause mortality across the entire range of perfusion defects. MFR ≤2 was also significantly associated with cardiac and noncardiac death. The results were consistent in clinically relevant sub- groups after adjustments for comorbidities.

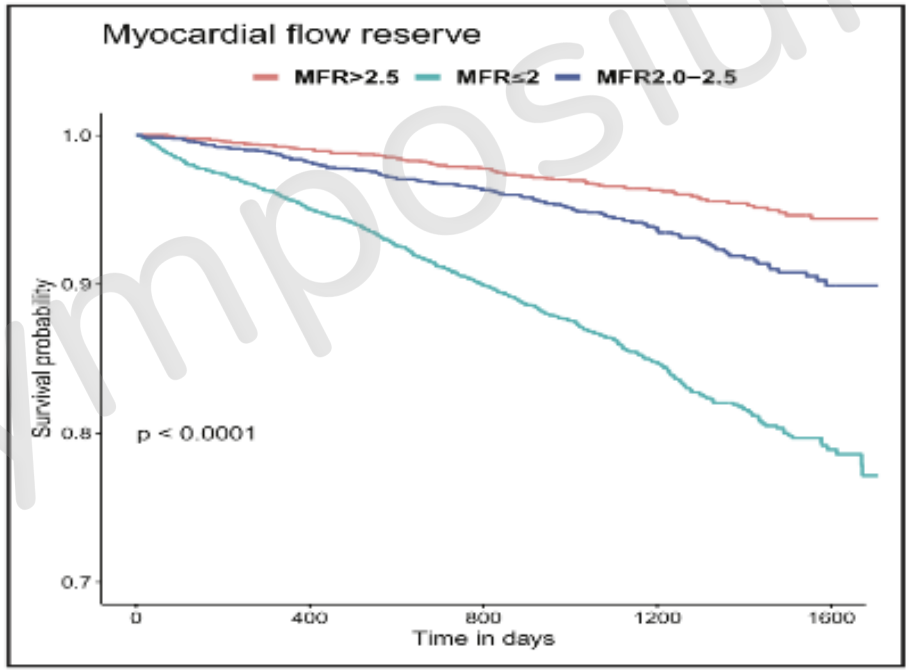


Figure 1. Myocardial flow reserve (MFR) ≤2 in light blue (n=2793), MFR 2.0–2.5 in dark blue (n=2390), and MFR >2.5 in red (n=2389).
The *P*-value was calculated by Log-rank test.

Circ Cardiovasc Imaging. 2023;16:e015184. DOI: 10.1161/CIRCIMAGING.122.015184

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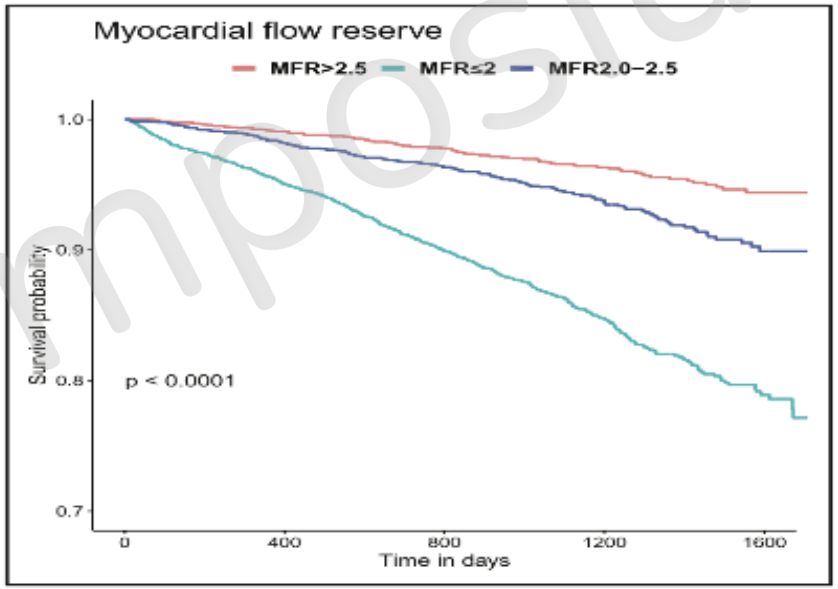

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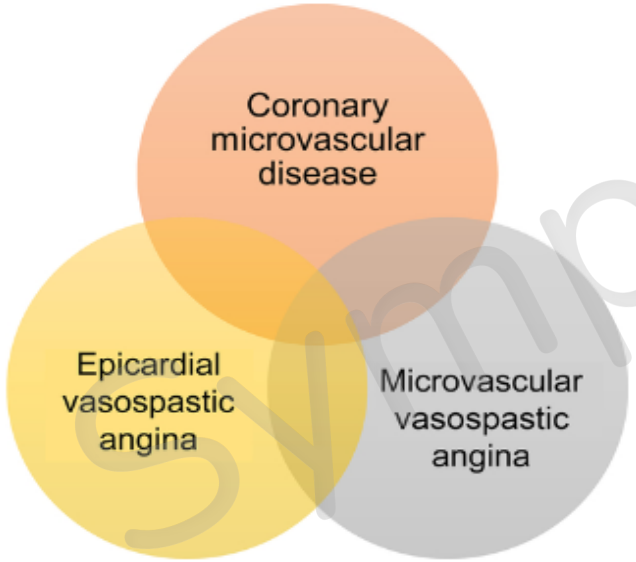


Doyeon Hwang et al. *JACC: Asia* 2023; 3:169-184.

JACC Asia
An Open Access Journal

PET vs. SPECT – Diagnosis

Curr Cardiovasc Imaging Rep (2014) 7:9266

In a meta-analysis of 44 studies published the sensitivity of exercise SPECT was found to be 87% with specificity of 64%

In contrast, both sensitivity and specificity of CAD detection with PET is at least 95% in populations with an intermediate pretest probability of CAD

Cost

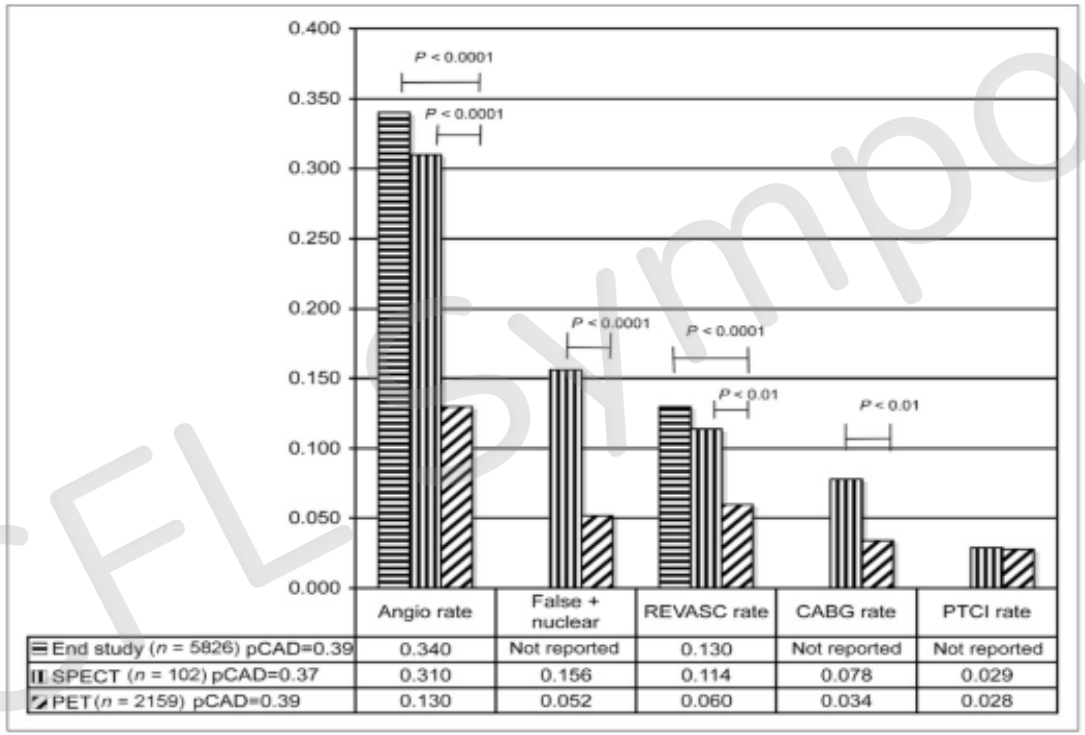
Estimated Global Charges for CAD Diagnostic Tests

Test	Global charge ($)
Exercise treadmill ECG	300
SPECT with exercise treadmill ECG	1,000
PET with pharmacologic stress	1,850
Coronary angiography	4,800
PTCI	10,000
CABG	40,000

ECG = electrocardiography.

J Nucl Med 2007; 48:1069–1076

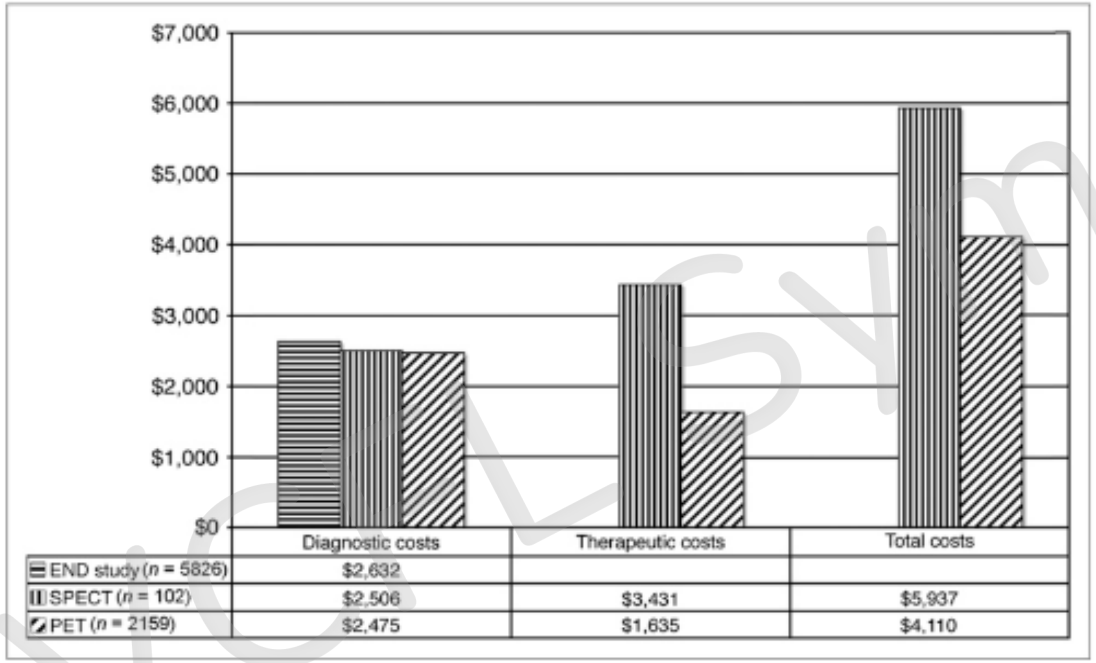
Cost



	Angio rate	False + nuclear	REVASC rate	CABG rate	PTCI rate
End study (n = 5826) pCAD=0.39	0.340	Not reported	0.130	Not reported	Not reported
SPECT (n = 102) pCAD=0.37	0.310	0.156	0.114	0.078	0.029
PET (n = 2159) pCAD=0.39	0.130	0.052	0.060	0.034	0.028

J Nucl Med 2007; 48:1069–1076

Cost



	Diagnostic costs	Therapeutic costs	Total costs
END study (n = 5826)	$2,632		
SPECT (n = 102)	$2,506	$3,431	$5,937
PET (n = 2159)	$2,475	$1,635	$4,110

FIGURE 3. CAD management costs in patients studied with SPECT vs. PET MPI.

Myocardial perfusion imaging

SPECT

- Resolution range 7-15 mm
- Longer acquisition time (10 min)
- More artifacts
- No MBF quantification
- More radiation (9-11 mSv/ 12-15 mSv)
- Exercise and Pharmacological

PET

- Resolution range 2-6 mm
- Shorter acquisition time (5 min)
- Less artifacts
- MBF quantification
- Less radiation (2-3 mSv)
- Pharmacological
- Cost effective

Appropriate Use Criteria

Symptomatic patients with intermediate pretest probability of CAD: interpretable ECG AND able to exercise			
5	Symptomatic patients with an intermediate pretest probability for CAD, who have an interpretable ECG and are able to undergo adequate exercise stress	Appropriate	7
Symptomatic patients with intermediate pretest probability of CAD: uninterpretable ECG OR unable to exercise			
6	Symptomatic patients with an intermediate pretest probability for CAD, who have an uninterpretable ECG	Appropriate	9
7	Symptomatic patients with an intermediate pretest probability for CAD, who are unable to undergo adequate exercise stress	Appropriate	9
Symptomatic patients with high pretest probability of CAD: interpretable ECG AND able to exercise			
8	Symptomatic patients with a high pretest probability for CAD, who have an interpretable ECG and are able to undergo adequate exercise stress	Appropriate	8
Symptomatic patients with high pretest probability of CAD: uninterpretable ECG OR unable to exercise			
9	Symptomatic patients with a high pretest probability for CAD, who have an uninterpretable ECG	Appropriate	9
10	Symptomatic patients with a high pretest probability for CAD, who are unable to undergo adequate exercise stress	Appropriate	9

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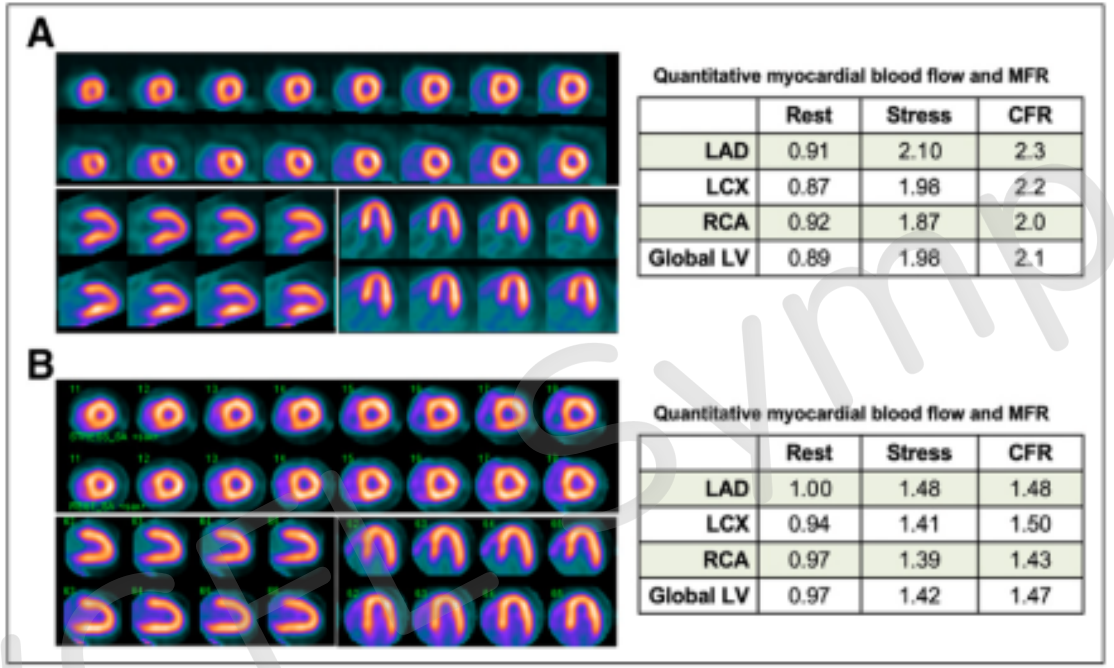
Coronary microvascular dysfunction



Quantitative myocardial blood flow and MFR

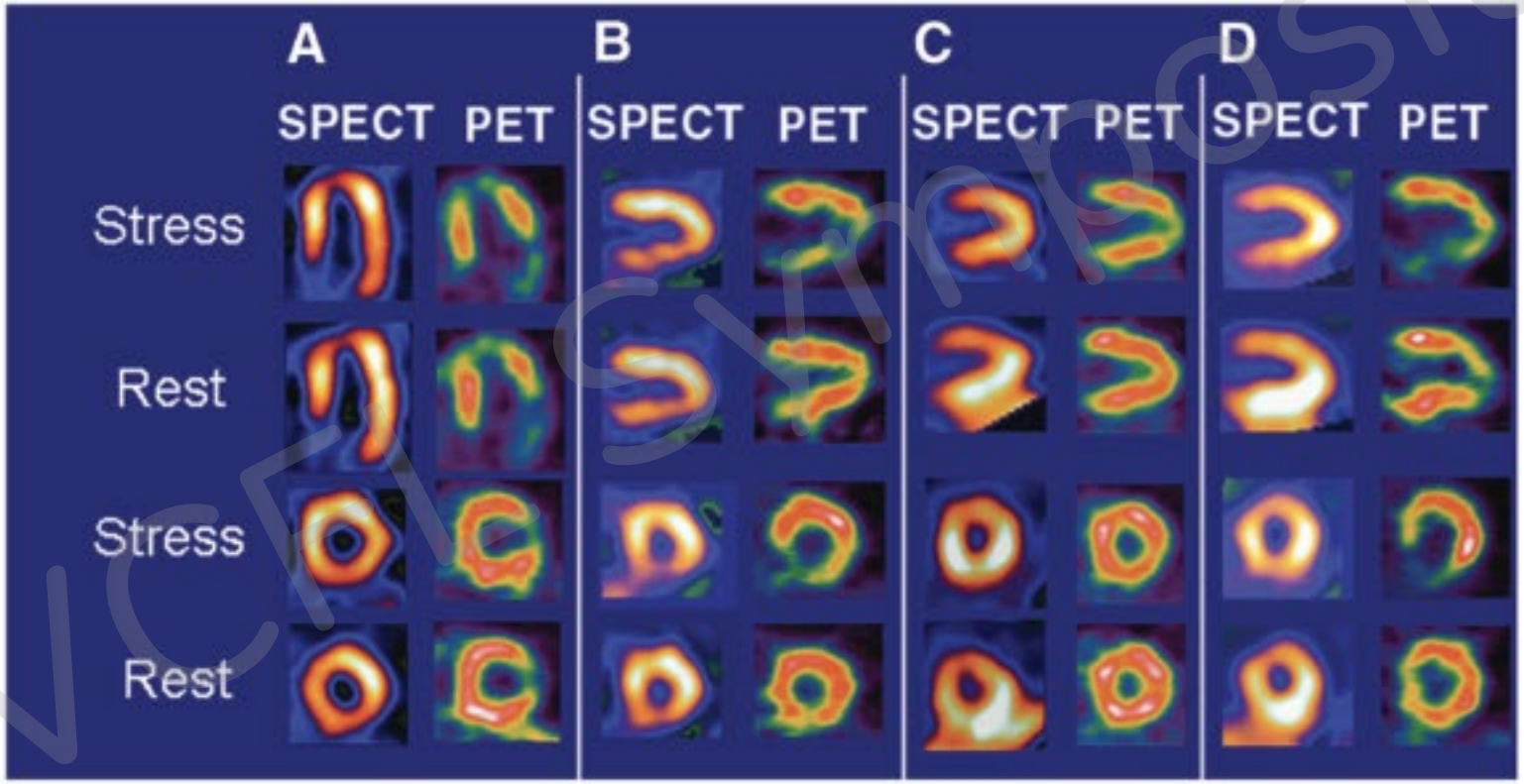
	Rest	Stress	CFR
LAD	0.91	2.10	2.3
LCX	0.87	1.98	2.2
RCA	0.92	1.87	2.0
Global LV	0.89	1.98	2.1

Quantitative myocardial blood flow and MFR

	Rest	Stress	CFR
LAD	1.00	1.48	1.48
LCX	0.94	1.41	1.50
RCA	0.97	1.39	1.43
Global LV	0.97	1.42	1.47

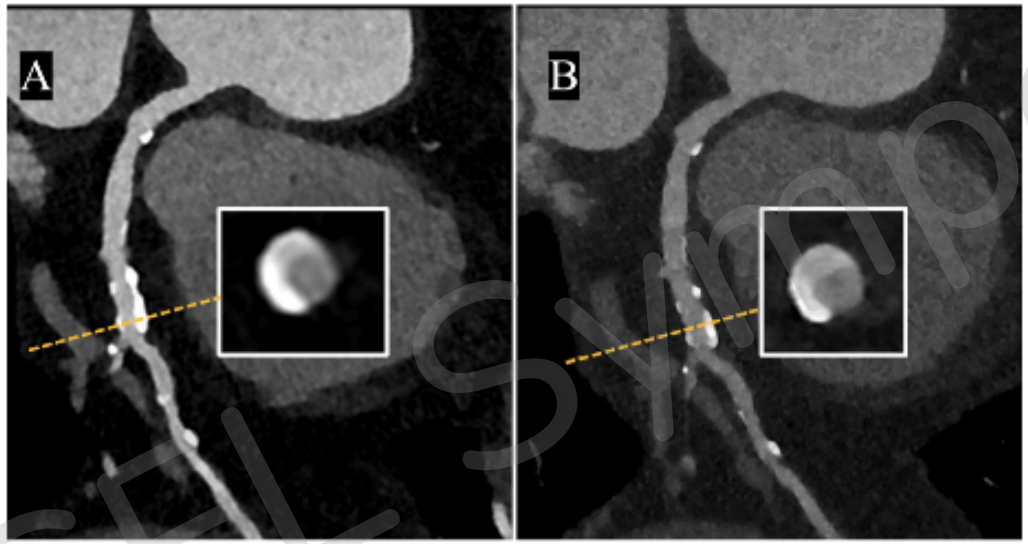
FIGURE 5. Examples of patients with and without CMD. (A) A 58-y-old man with hypertension and diabetes evaluated for atypical chest pain. (B) A 63-y-old man with hypertension, diabetes, and high cholesterol evaluated for dyspnea. In both cases, myocardial perfusion results are normal, suggesting no evidence of flow-limiting CAD. Patient A has normal stress MBF and MFR. However, patient B shows severely reduced stress MBF and MFR. Follow-up CT coronary angiography showed no evidence of obstructive CAD. Thus, abnormalities in coronary vasoreactivity in patient B are consistent with CMD. CFR = coronary flow reserve; LAD = left anterior descending coronary artery; LCX = left circumflex coronary artery; LV = left ventricular; RCA = right coronary artery.

SPECT vs. PET



Cardiac CT

Cardiac Photon Counting CT



Kabakus IM et al., Ultrahigh-resolution photon-counting detector coronary CT angiography: Practical insights and workflow integration from a high-volume center, Journal of Cardiovascular Computed Tomography, https://doi.org/10.1016/j.jcct.2025.10.013

Cardiac Photon Counting CT

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Disclosures- None

References

- *Circ Cardiovasc Imaging.* 2023;16:e015184.
- Journal of Nuclear Medicine Vol. 64 No. 11 (Suppl. 2) November 2023
- Journal of Nuclear Medicine • Vol. 55 • No. 2 • February 2014
- Journal of Nuclear Medicine March 2021, jnumed.121.261989
- J Am Coll Cardiol Img 2023;16:98–117
- Curr Cardiovasc Imaging Rep (2014) 7:9266
- Society of Nuclear Medicine and Molecular Imaging. DOI: 10.2967/jnumed.120.246280
- J Nucl Med 2007; 48:1069–1076
- JACC: ASIA, VOL. 3, NO. 2, 2023
- Practical insights and workflow integration from a high-volume center, Journal of Cardiovascular Computed Tomography