Update in Internal Medicine
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UT Southwestern Medical Center

Role of Cardiac Computed Tomographic Angiography (CCTA)

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Disclosures

- No relevant disclosures

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CLINICAL PRACTICE GUIDELINE: FULL TEXT

2021 AHA/ACC/ASE/CHEST/SAEM/ SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain

A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

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*Writing committee members are required to recuse themselves from voting on sections to which their specific relationships with industry may apply; see Appendix 1 for detailed information.
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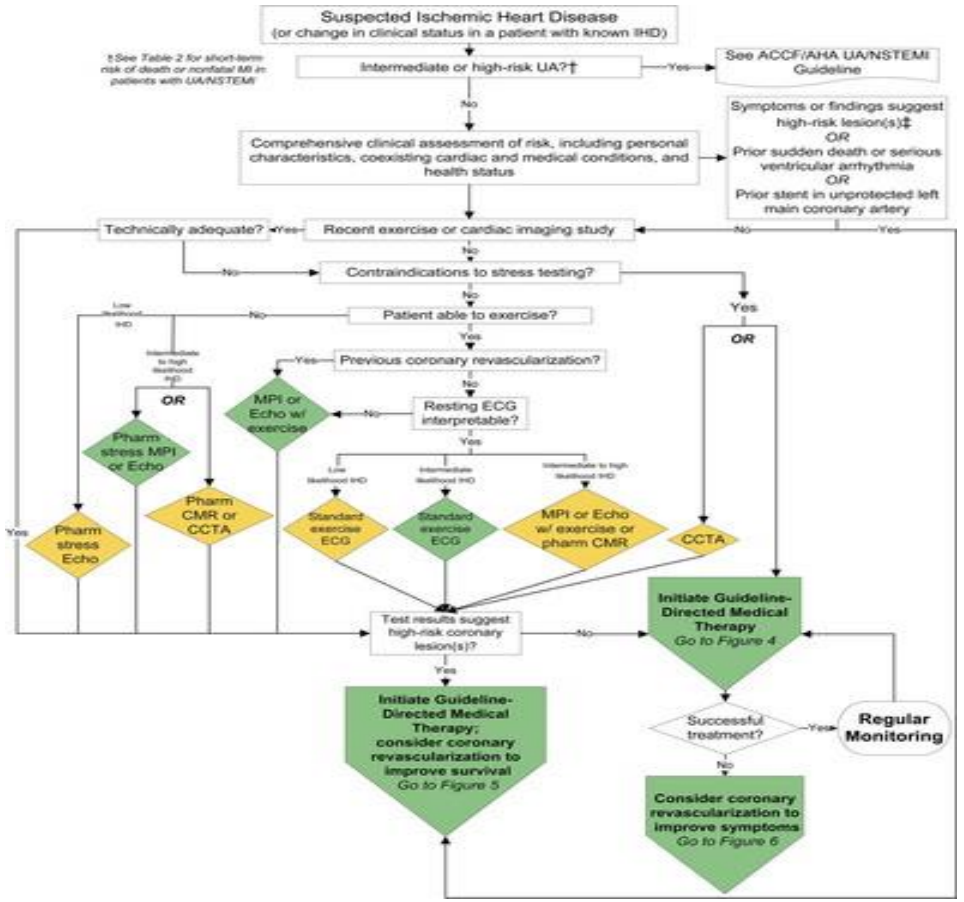
‡‡American Society of Echocardiography Representative.
§§Task Force on Performance Measures, Liaison.

Gulati, M. et al. JACC 2021

2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the Diagnosis and Management of Patients With Stable Ischemic Heart Disease

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American College of Physicians, American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons



Stephan D. Fihn et al. *JACC* 2012.

- Ischemia testing preferred
- Exercise stress testing preferred if
  - Interpretable ECG
  - Can exercise
  - No prior revascularization
  - Non-High pretest risk
- Pretest Risk: Diamond-Forrester
- Stress Echo and Stress SPECT preferred imaging tests

2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the Diagnosis and Management of Patients With Stable Ischemic Heart Disease

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American College of Physicians, American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons

- Class 2A recommendation:

-If unable to exercise

-Continued symptoms with prior normal test

-Inconclusive exercise or pharmacologic stress test

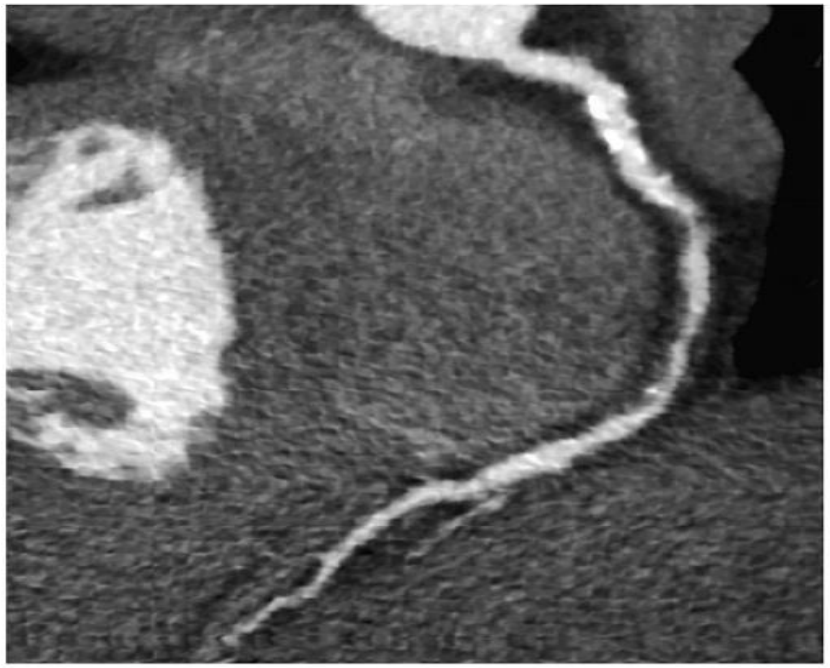
-Unable to undergo stress with MPI or Echo

- Class 2B recommendation:

If able to exercise or indeterminate results from non-invasive testing

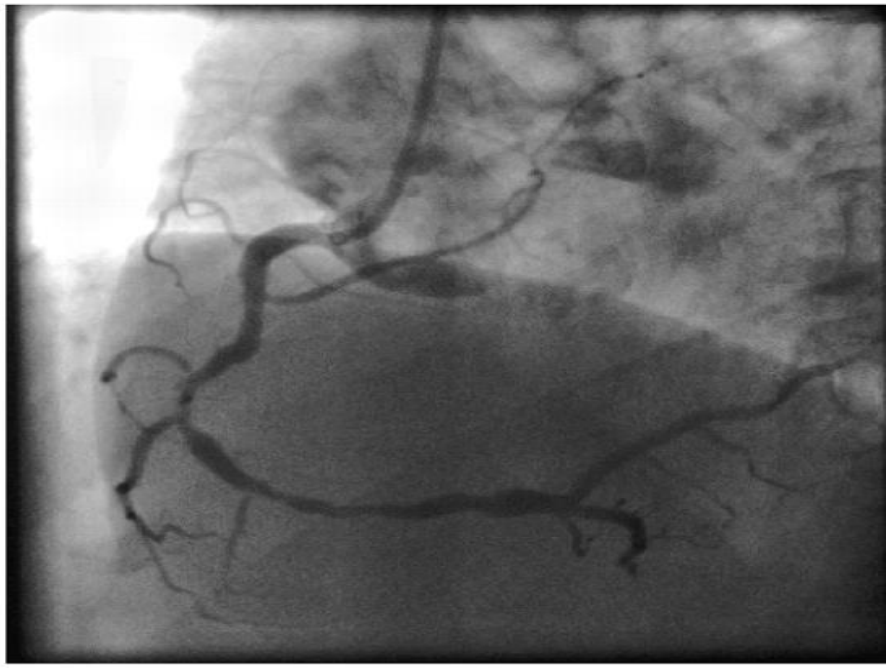
Stephan D. Fihn et al. *JACC* 2012

Coronary CT angiography



- Spatial resolution 0.2-0.4 mm
- Temporal resolution 83-200 ms
- IV contrast
- Direct intervention not possible

Invasive angiography

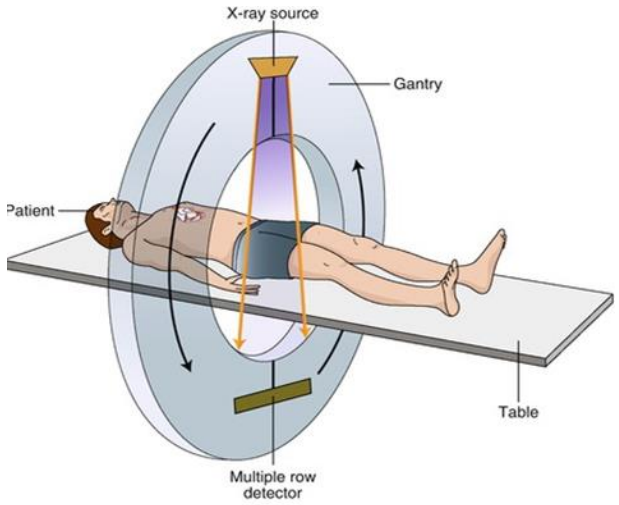


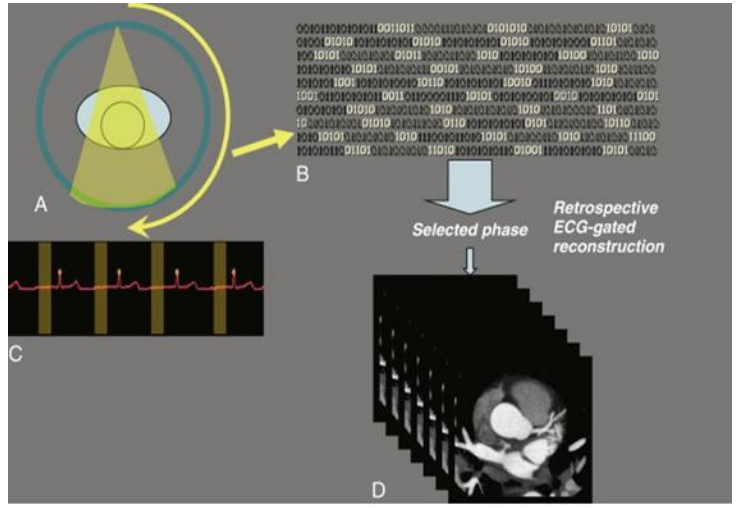
- Spatial resolution 0.2 mm
- Temporal resolution 8 ms
- Intracoronary contrast
- Direct intervention possible

Schuijf JD., *et al Heart* 2011.

How?


SIEMENS

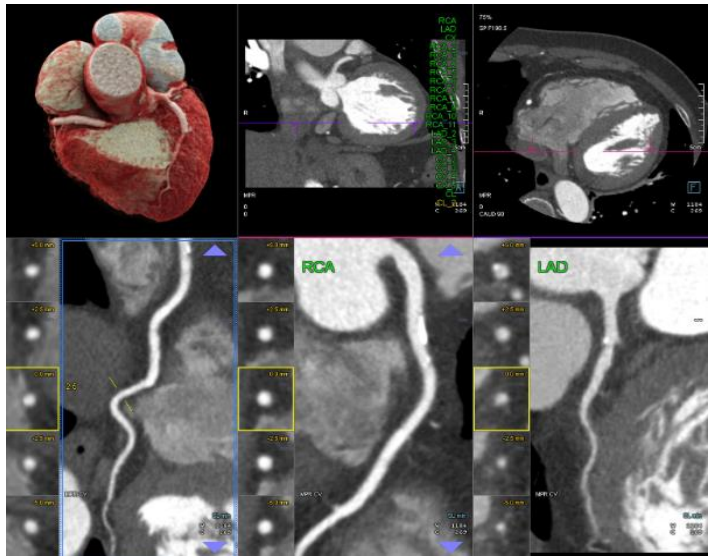

X-ray source
Gantry
Patient
Table
Multiple row detector

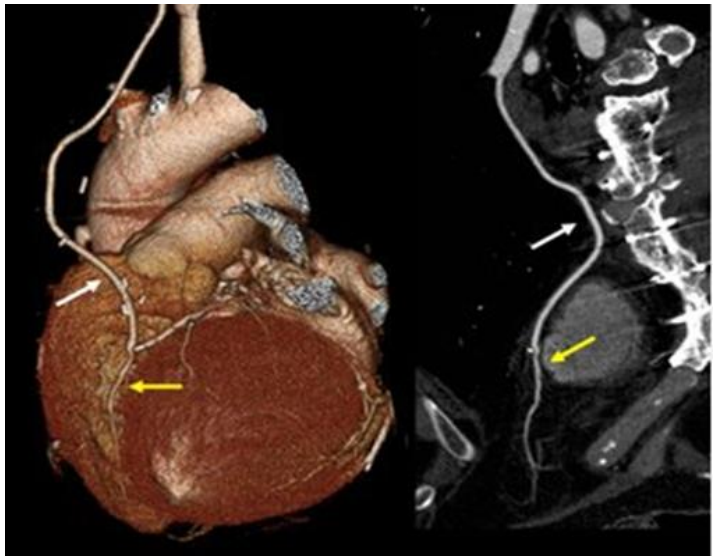

A
B
C
D
Selected phase
Retrospective ECG-gated reconstruction

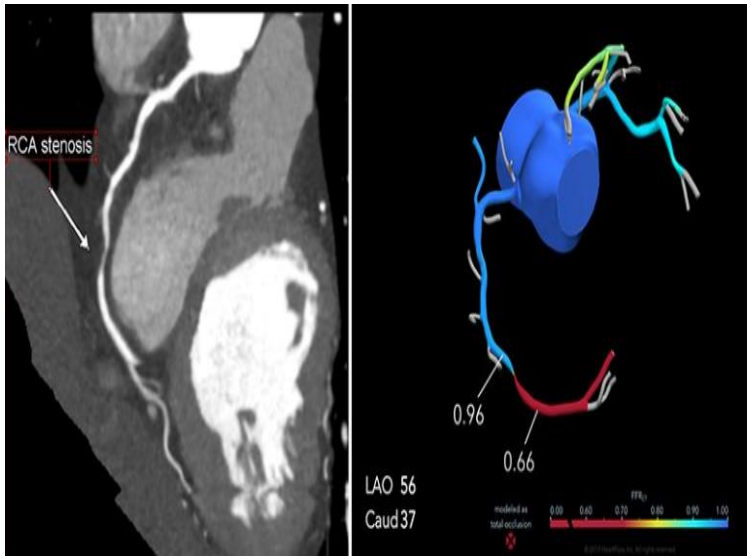
Gating

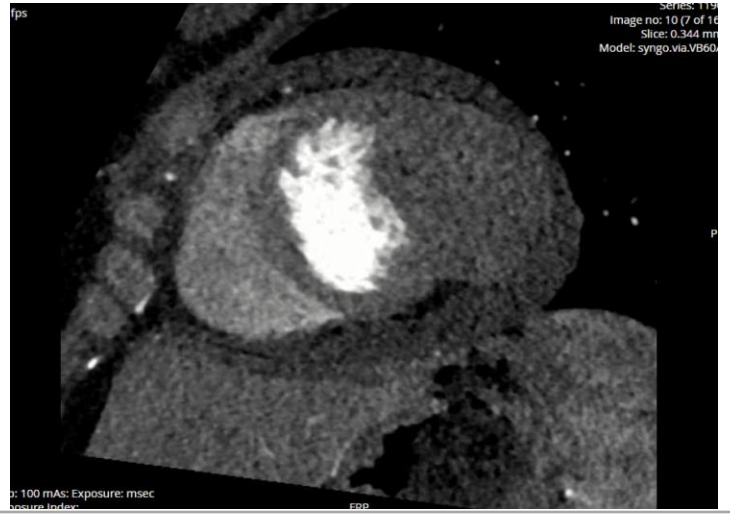

Retrospective
Retrospective with tube modulation
Prospective

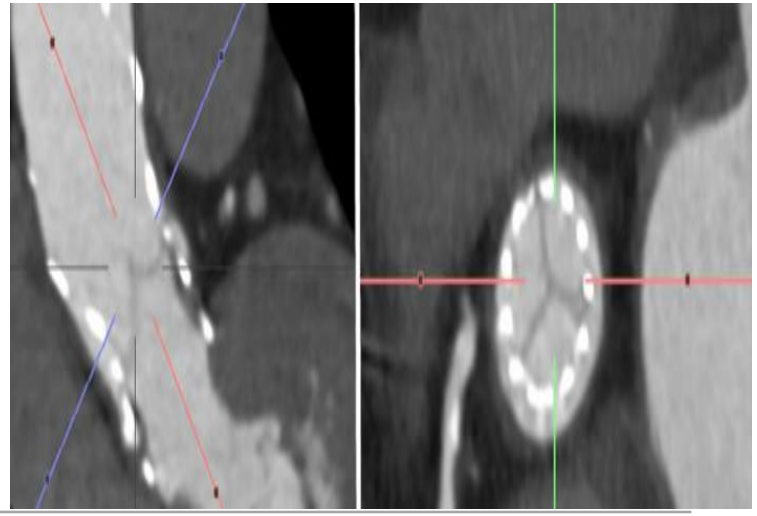
Value of CCTA



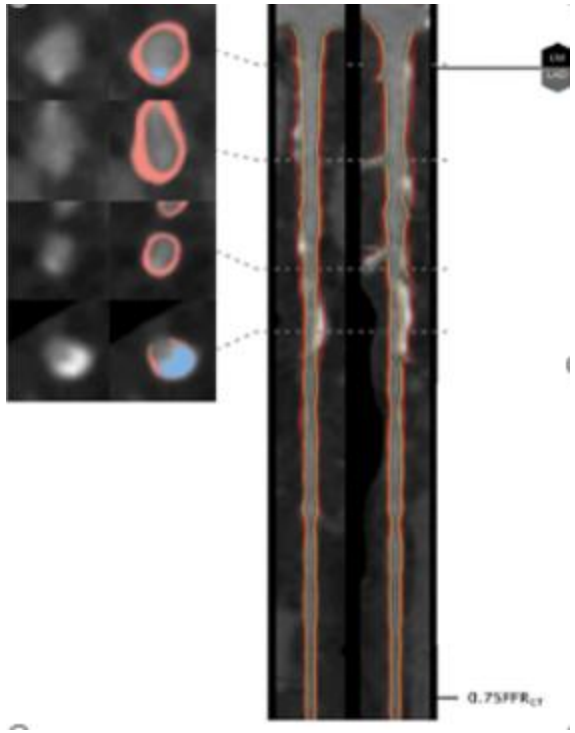








Quantitative Coronary Plaque Analysis

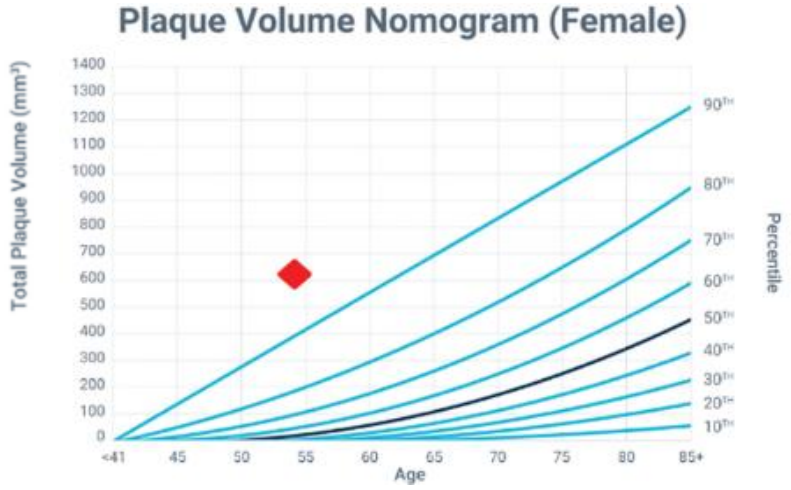


CORONARY SYSTEM (including branches)	TOTAL PLAQUE mm^3	CALCIFIED PLAQUE	NON-CALCIFIED PLAQUE	LOW ATTENUATION PLAQUE
Left Main	31	1	30	0
Left Anterior Descending	603	147	456	14
Total	634	148	486	14

Quantitative plaque is provided on vessels > 1.8 mm diameter.

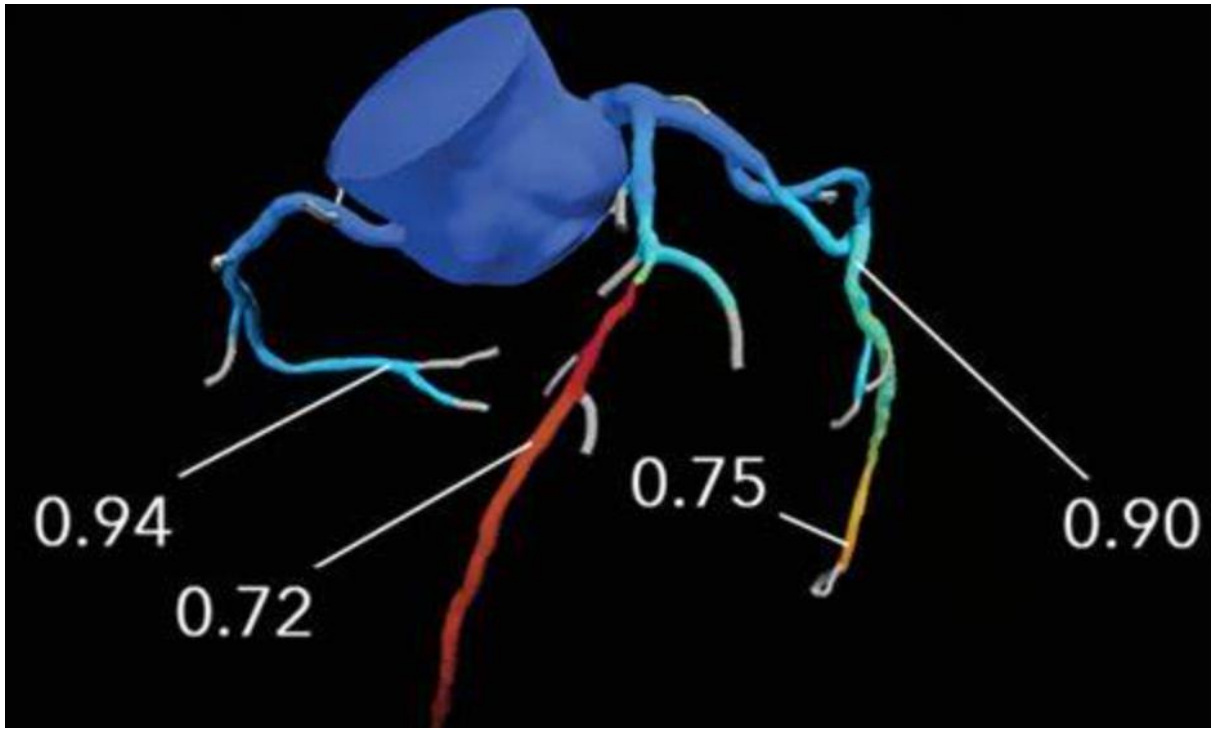
PLAQUE CHARACTERISTICS: calcified plaque; non-calcified plaque; low attenuation plaque

VESSEL BOUNDARY: lumen boundary; outer wall boundary



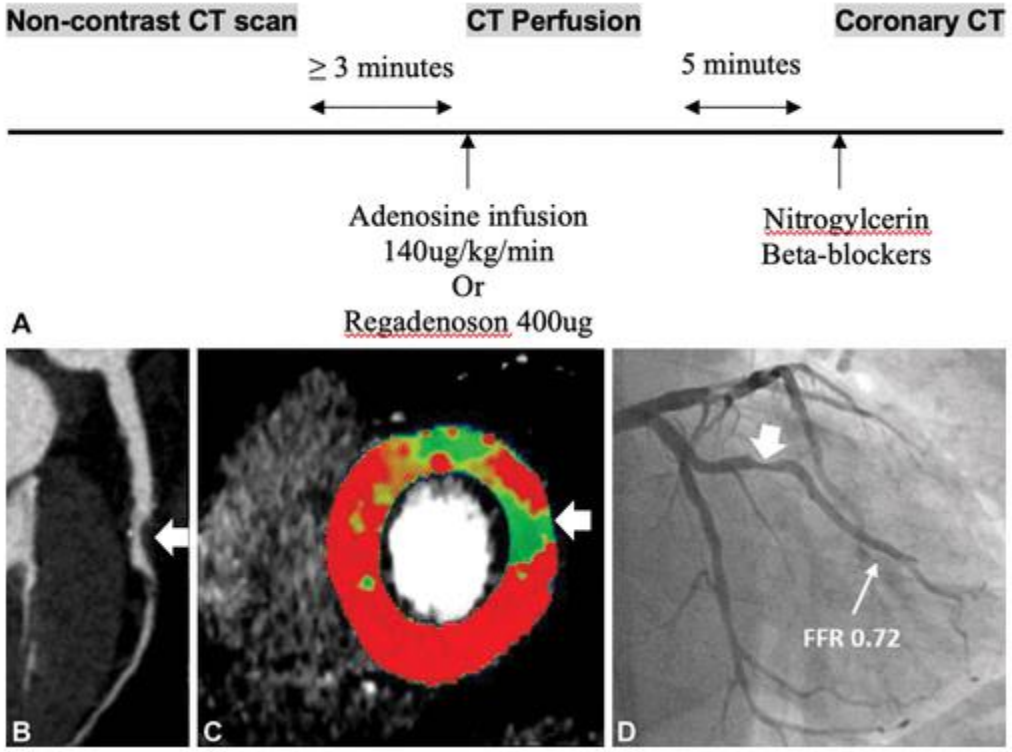
- Cardiac CT quantitative coronary plaque analysis (Plaque volume and subtype) allowing precision-based management

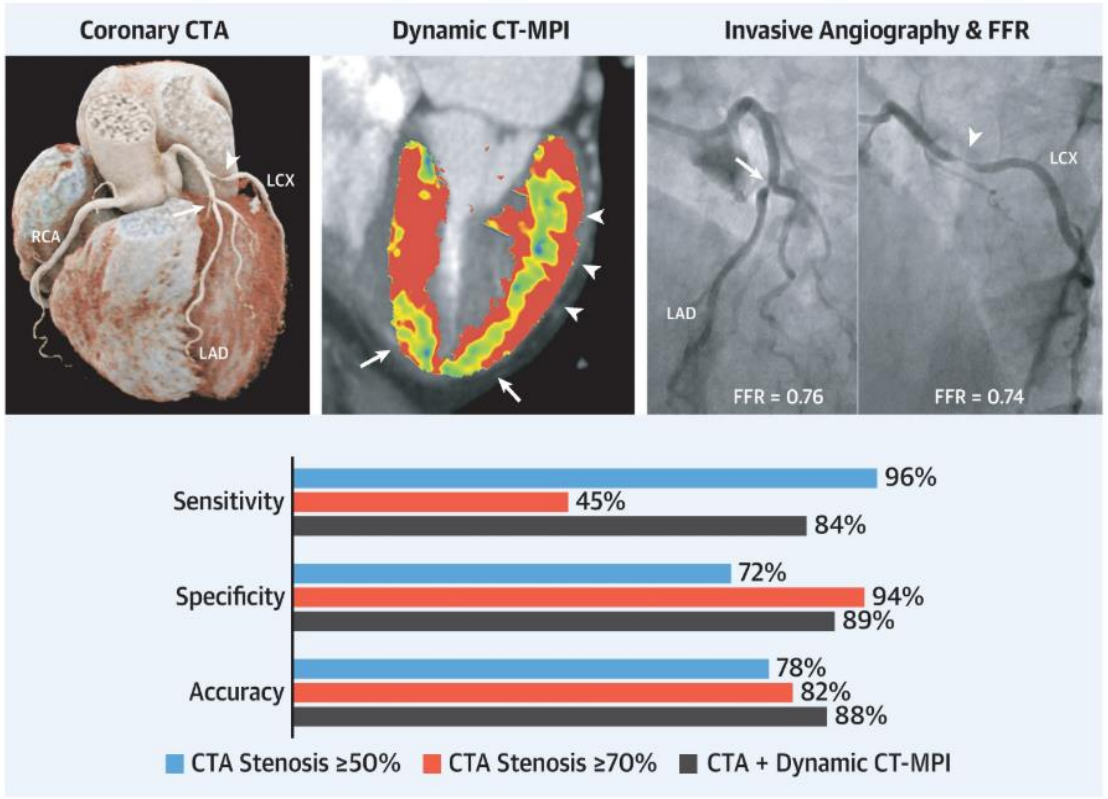
CT Fractional Flow Reserve



- CT fractional flow reserve and perfusion (improving revascularization planning)

Dynamic Perfusion Computed Tomography

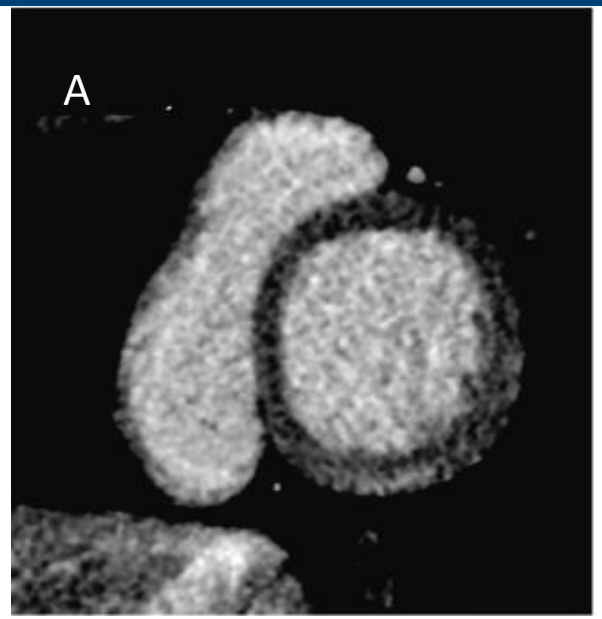


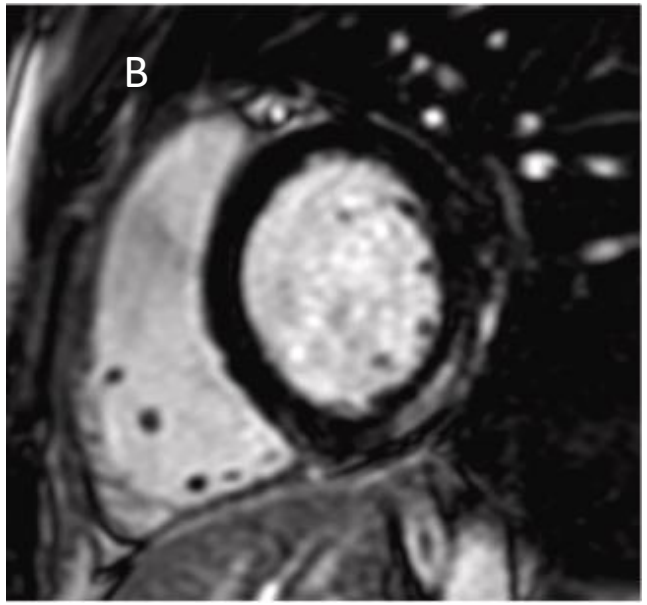


Nous, F.M.A. et al. J Am Coll Cardiol Img. 2022;15(1):75-87.

Nous, F.M.A. et al. J Am Coll Img. 2022

CT for myocardial fibrosis/scar

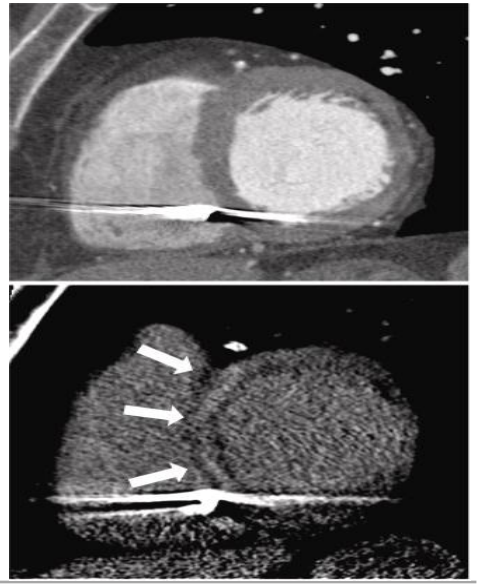




- Patient with myocarditis

A. Subepicardial infero-lateral midwall LCE by CT

B. LGE on CMR in the same location



Tore, D. et al. Heliyon 2024

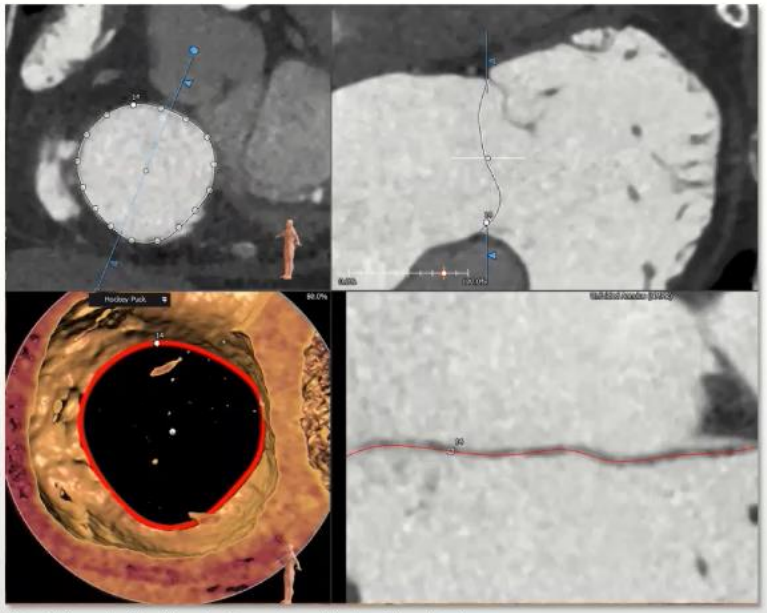
Structural CT Heart Evaluation

Annular Segmentation

CT methodology essentials

Utilizing CT analysis software, the tricuspid annulus is defined by:

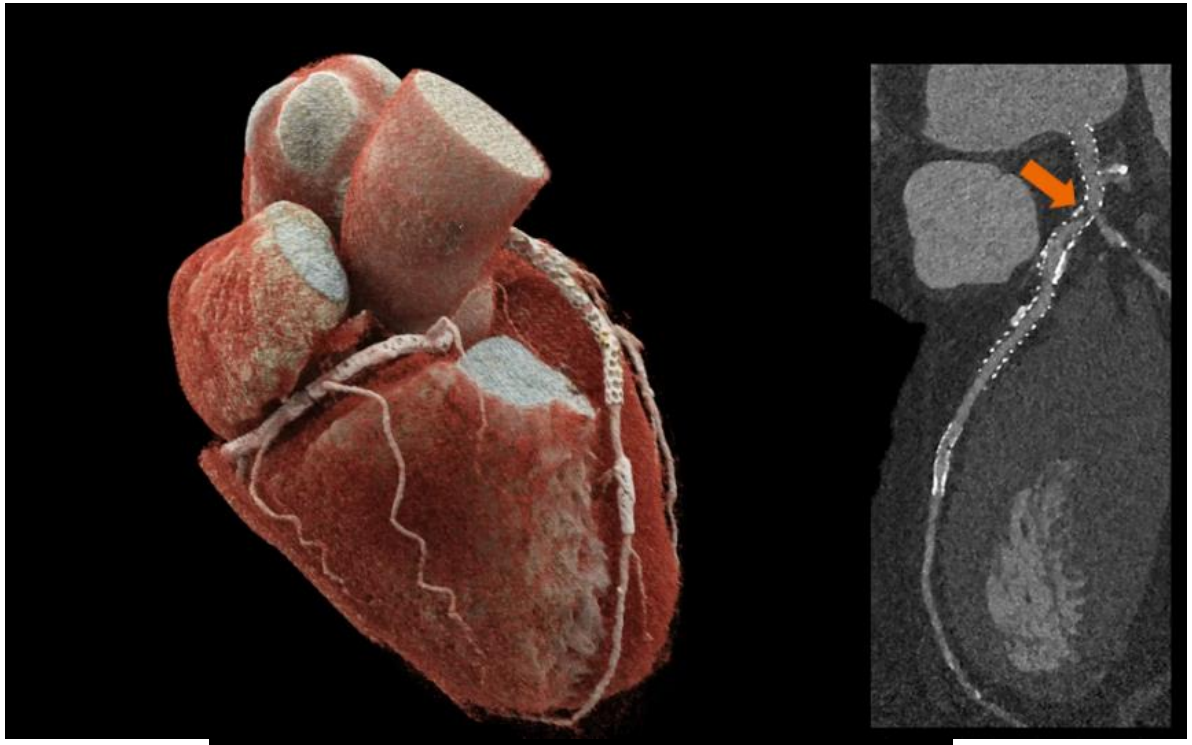
- **16 reference points** placed at the level of leaflet insertion around the annulus in both diastole and systole.*
  - Care is taken to assess "shelf-like" annular anatomy to define the annulus.
- Points are optimized along all peaks/valleys of annulus (along any saddle shape preservation)
- Above results in the true annular perimeter measurement in a 3D space.
  - Annulus measurements are in mm.



*The systolic and diastolic phases referred to in are based on the smallest and largest size of the right ventricles and *not timed based on the opening and closing of the aortic valve.*
Note: Reflects Edwards screening methodologies from TRISCEND & TRISCEND II trial protocols.

- Structural CT Heart evaluation (sizing/ risk assessment for catheter-based valve implantation)

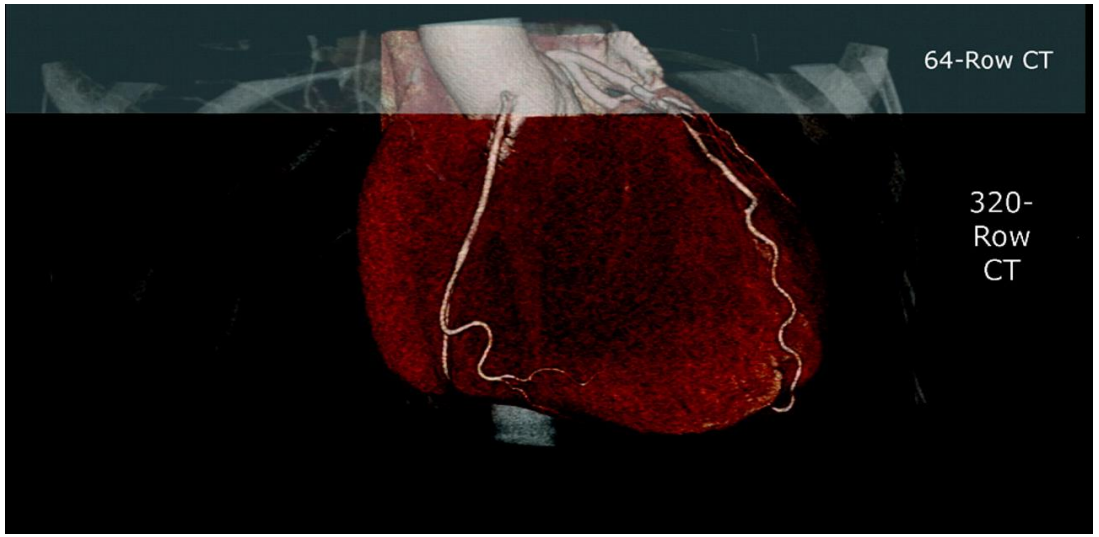
Photon-counting CT Scanner

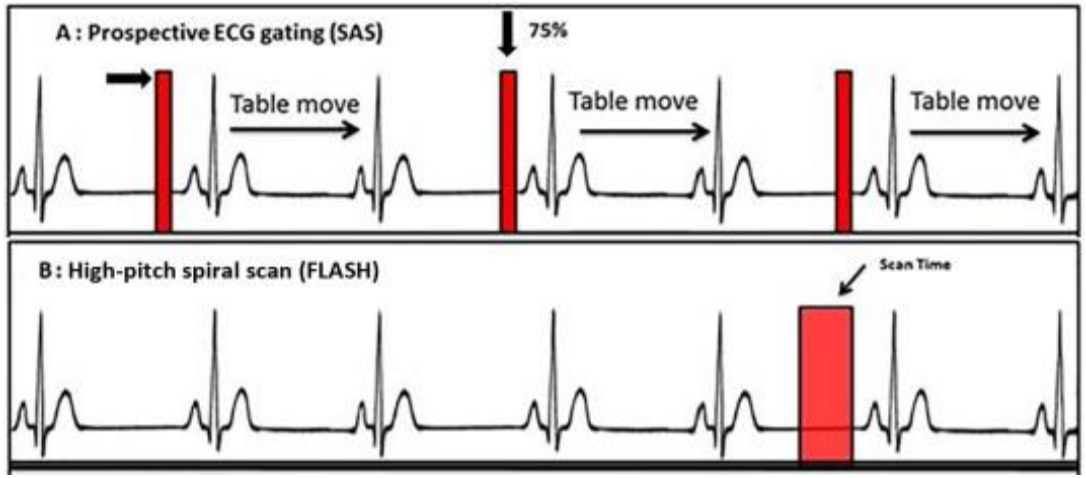


Courtesy of Semmelweis University, Budapest, Hungary

- High resolution (0.2 mm)
- Improved luminal stenosis quantification
- Stent evaluation

Shorter scan durations + Lower Radiation dose exposure

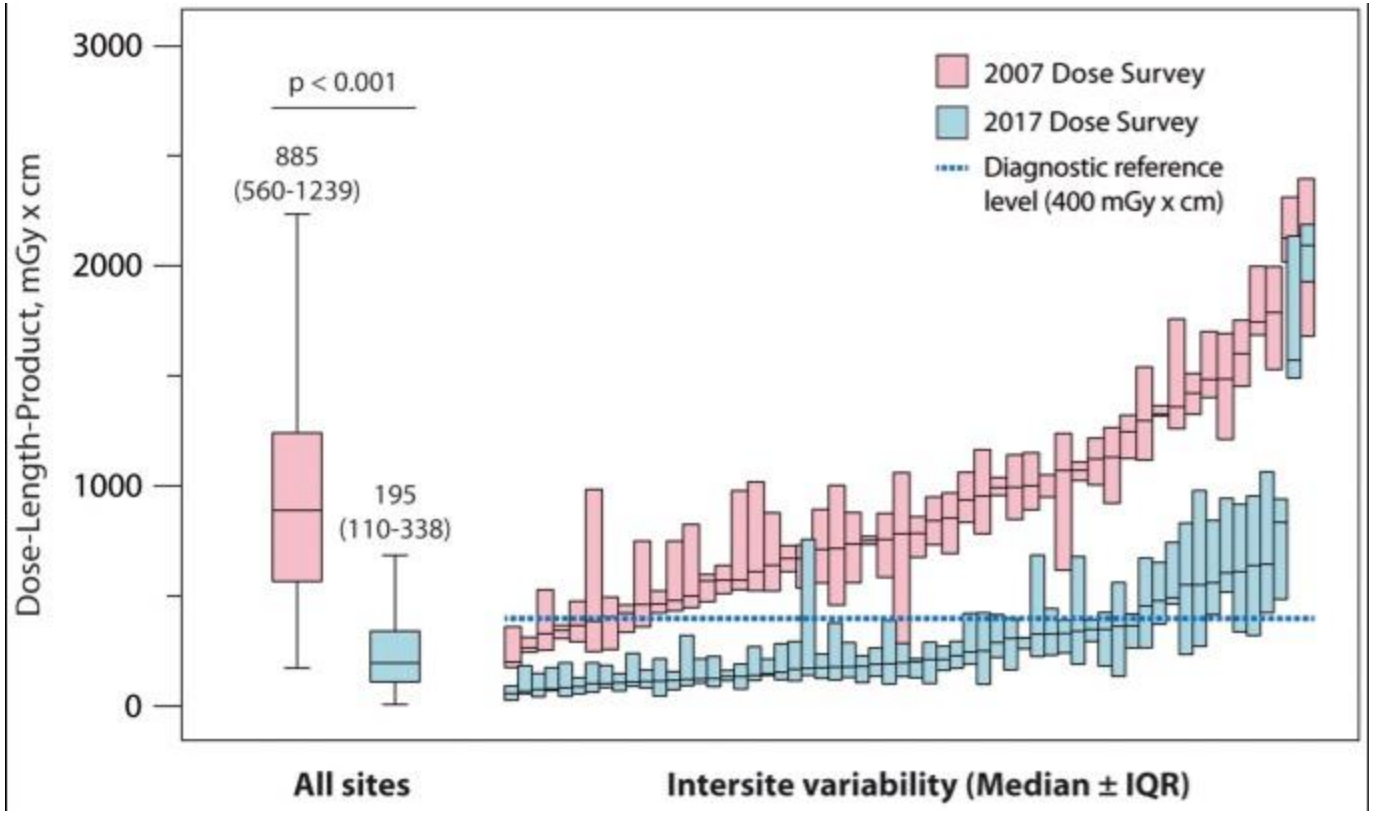




- Fast acquisition
- Low radiation exposure < 1 mSv

Dewey et al. Circulation 2009.

PROTECTION VI Study



- Reduction in radiation exposure in CCTA imaging .
- 78% reduction in DLP without an increase in non – diagnostic coronary CTAs.

Stocker T., et al. Eur Heart J. 2018

Contemporary Evidence

- Stenosis > 50% on cath
- FFR ≤ 0.80

The performance of non-invasive tests to rule-in and rule-out significant coronary artery stenosis in patients with stable angina: a meta-analysis focused on post-test disease probability

Juhani Knuuti[1]*, Haitham Ballo[1†], Luis Eduardo Juarez-Orozco[1†], Antti Saraste[1], Philippe Kolh[2], Anne Wilhelmina Saskia Rutjes[3], Peter Jüni[4], Stephan Windecker[5], Jeroen J. Bax[6], and William Wijns[7]

Table I The performance of different tests for anatomically and functionally significant coronary artery disease

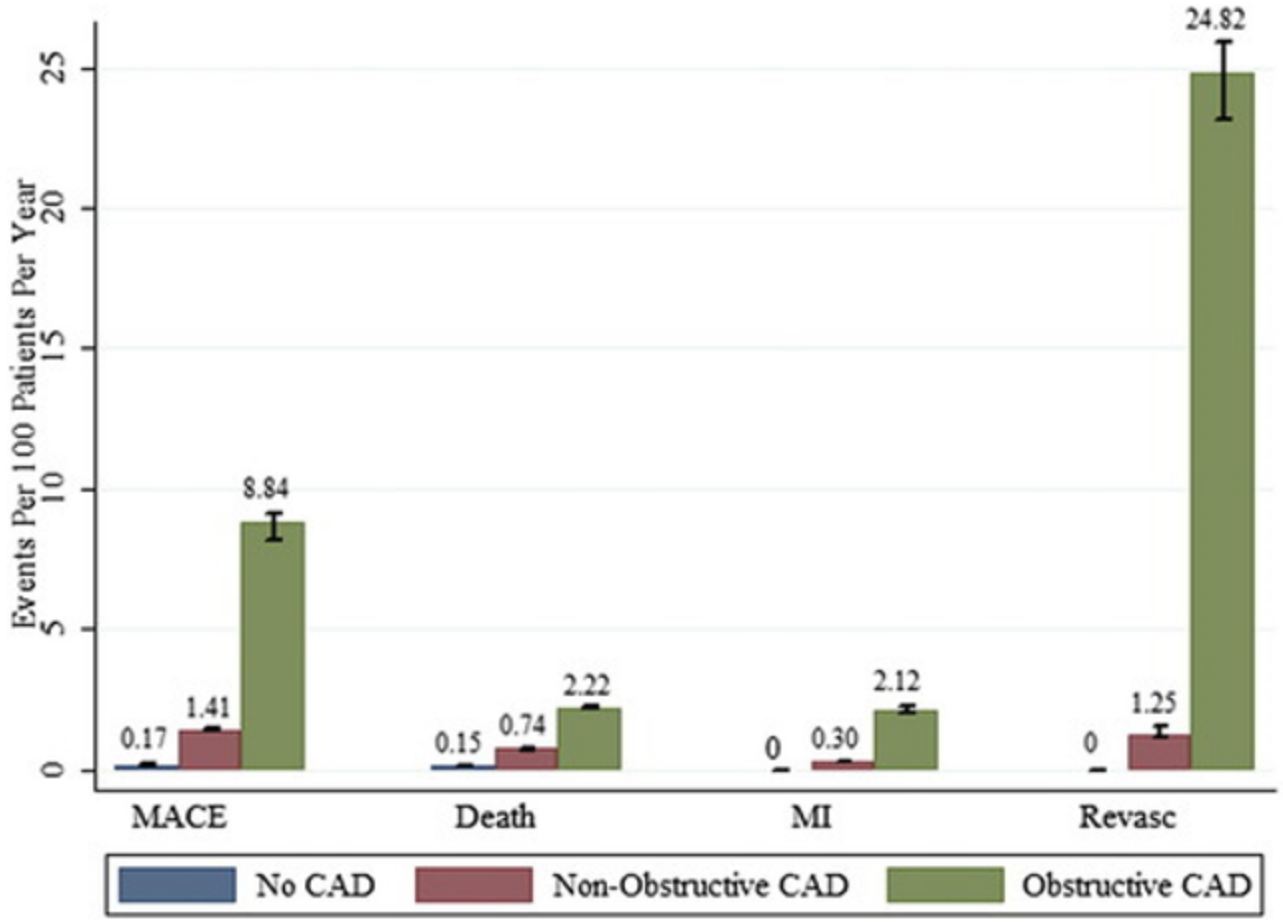
Anatomically significant CAD					Functionally significant CAD				
Test	Sensitivity (%), (95% CI)	Specificity (%), (95% CI)	+LR (95% CI)	−LR (95% CI)	Test	Sensitivity (%), (95% CI)	Specificity (%), (95% CI)	+LR (95% CI)	−LR (95% CI)
					ICA	68 (60–75)	73 (55–86)	2.49 (1.47–4.21)	0.44 (0.36–0.54)
Stress ECG	58 (46–69)	62 (54–69)	1.53 (1.21–1.94)	0.68 (0.49–0.93)					
Stress echo	85 (80–89)	82 (72–89)	4.67 (2.95–7.41)	0.18 (0.13–0.25)					
CCTA	97 (93–99)	78 (67–86)	4.44 (2.64–7.45)	0.04 (0.01–0.09)	CCTA	93 (89–96)	53 (37–68)	1.97 (1.28–3.03)	0.13 (0.06–0.25)
SPECT	87 (83–90)	70 (63–76)	2.88 (2.33–3.56)	0.19 (0.15–0.24)	SPECT	73 (62–82)	83 (71–90)	4.21 (2.62–6.76)	0.33 (0.24–0.46)
PET	90 (78–96)	85 (78–90)	5.87 (3.40–10.15)	0.12 (0.05–0.29)	PET	89 (82–93)	85 (81–88)	6.04 (4.29–8.51)	0.13 (0.08–0.22)
Stress CMR	90 (83–94)	80 (69–88)	4.54 (2.37–8.72)	0.13 (0.07–0.24)	Stress CMR	89 (85–92)	87 (83–91)	7.10 (5.07–9.95)	0.13 (0.09–0.18)

Note: ICA itself was used as a reference standard for the anatomically significant CAD estimates but was included as a technique when FFR was used as the reference. Not every test had enough data using FFR as reference.
CCTA, coronary computed tomography angiography; CI, confidence interval; CMR, stress cardiac magnetic resonance; ECG, electrocardiogram; ICA, invasive coronary angiography; LR, likelihood ratio; PET, positron emission tomography; SPECT, single-photon emission computed tomography (exercise stress SPECT with or without dipyridamole or adenosine); Stress echo, exercise stress echocardiography.

Knutti et al. *European Heart Journal 2018*

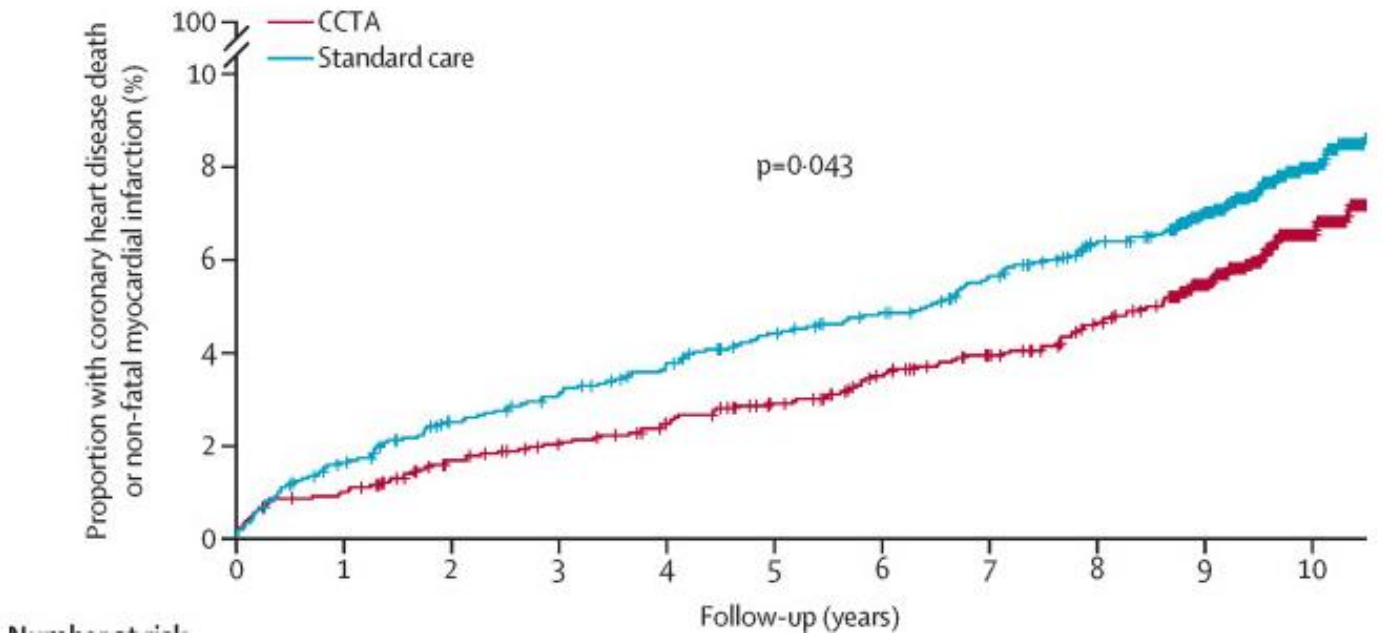
Prognostic value of a normal CCTA

- CCTA: 0.16%
- SPECT: 1.1%



Edward H et al. *JACC* 2010

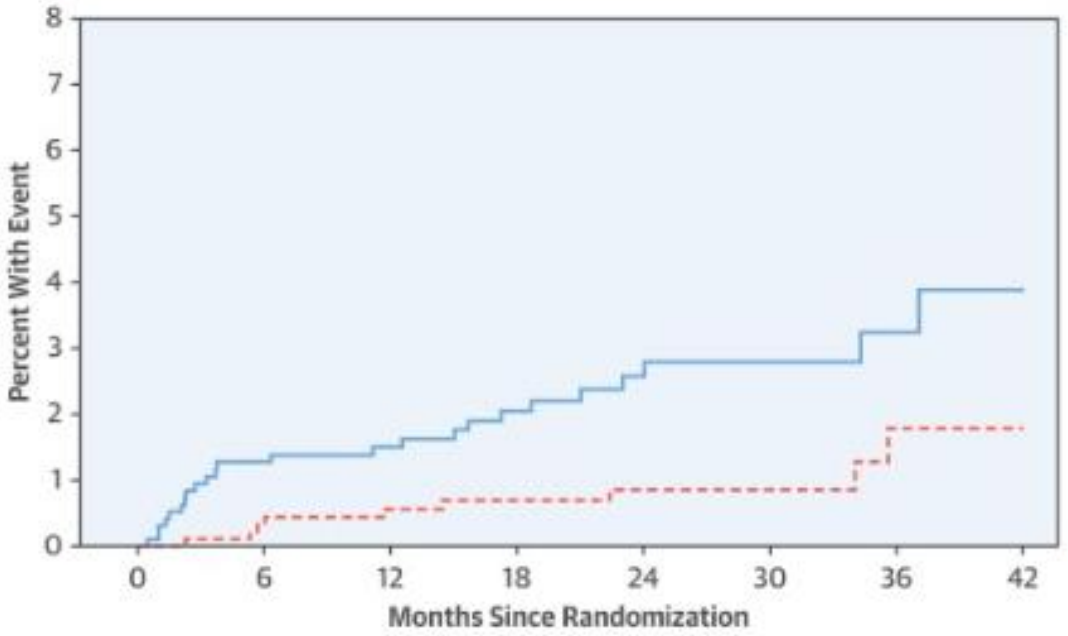
CCTA ➡ Improved Outcomes



- **SCOT HEART:** ~40 % reduction in MI/CHD death over 10 years
- Preventive therapies CCTA vs standard of care (56% vs. 49%)

Williams, M., et al. Lancet 2025.

PROMISE : Diabetes Sub-study

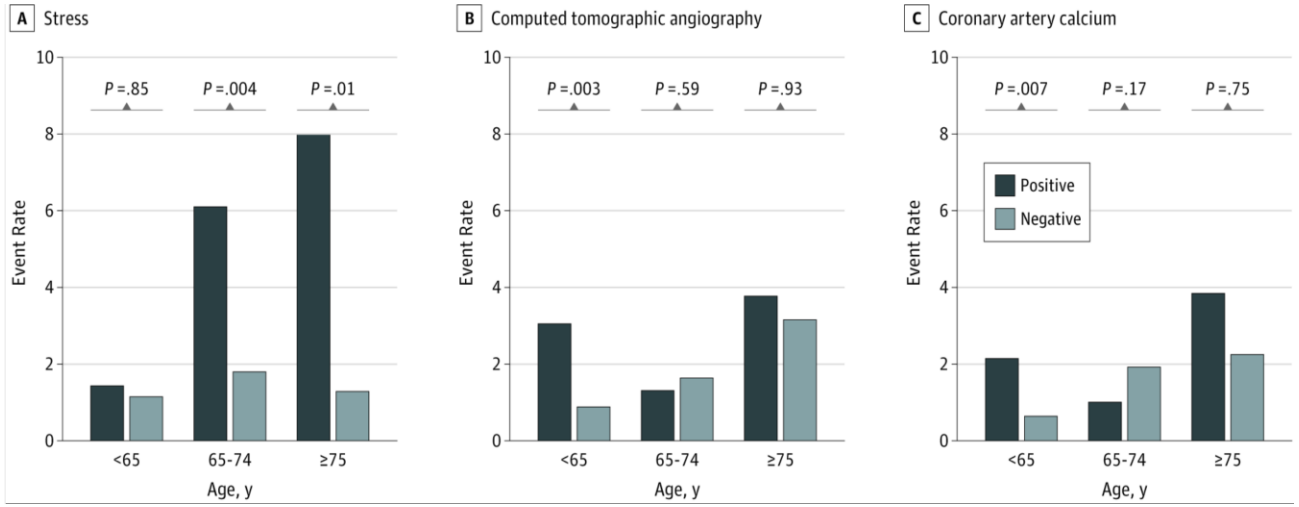


- **Stress testing** VS **Coronary CTA** in patients with diabetes and suspected CAD
- > 50 % reduction in CV death / MI with initial strategy of CTA

Sharma, A. et al. JACC 2019.

PROMISE Trial: Age Substudy

Age-Related Differences in the Noninvasive Evaluation for Possible Coronary Artery Disease
Insights From the Prospective Multicenter Imaging Study for Evaluation of Chest Pain (PROMISE) Trial



- <65 : Functional testing was not associated with outcomes; CTA (&CAC >100) strongly associated with outcomes (HR, 3.04; 95% CI, 1.46-6.34)
- ≥ 65: + functional testing was predictive of future risk of adverse events (HR, 3.18; 95% CI, 1.44-7.01

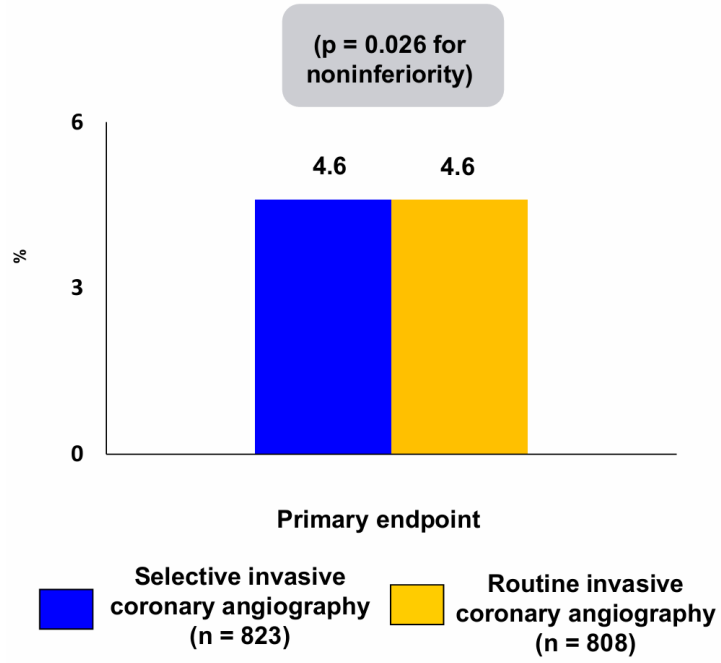
Lowenstern, A. et al. JAMA Cardiology 2019.

CCTA as gate keeper

CONSERVE

AMERICAN COLLEGE of CARDIOLOGY

Trial Description: Patients with suspected obstructive CAD were randomized to selective invasive coronary angiography after initial CT angiography vs. routine invasive coronary angiography.



RESULTS

- Primary efficacy endpoint, death, MI, unstable angina, cardiac hospitalization, or stroke, occurred in 4.6% of the selective angiography group vs. 4.6% of the routine angiography group (p = 0.026 for noninferiority)
- Major bleeding: None in the selective angiography group vs. 0.3% of the routine angiography group
- Transfusion: None in the selective angiography group vs. 0.1% of the routine angiography group

CONCLUSIONS

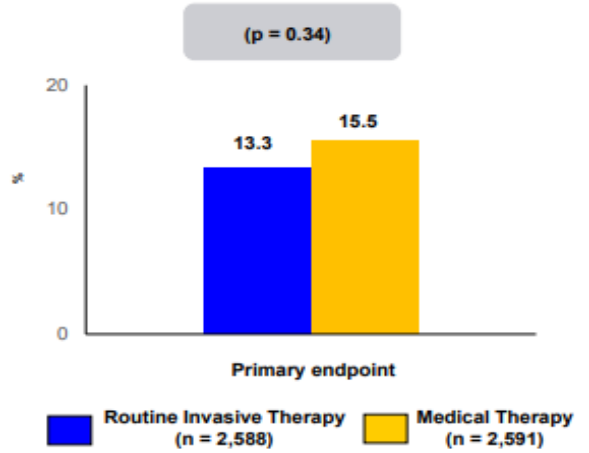
- Among patients with suspected stable ischemic heart disease, selective referral for invasive coronary angiography was noninferior to routine referral for invasive coronary angiography

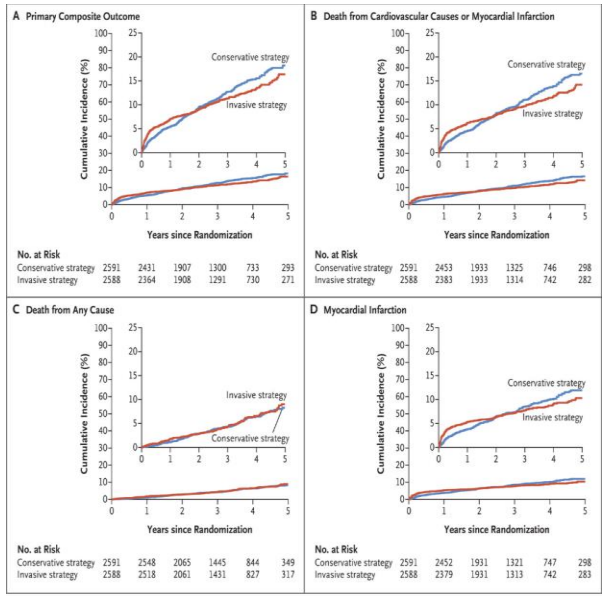
Chang HJ, et al. JACC Cardiovasc Imaging 2019;12:1303-12

Chang HJ, et al. JACC Cardiovasc Imaging 2019.

ISCHEMIA TRIAL

- Initial invasive VS Conservative strategy for stable CAD
- N= 5179 (mean age 64 years; 20% prior MI)
- Moderate or severe ischemia on functional testing (50% Nuclear)
- Coronary CTA (76%) to exclude LM CAD
- Results : No difference over 3.3 years in MACE outcome (13.3% VS 15.5%) P = 0.34

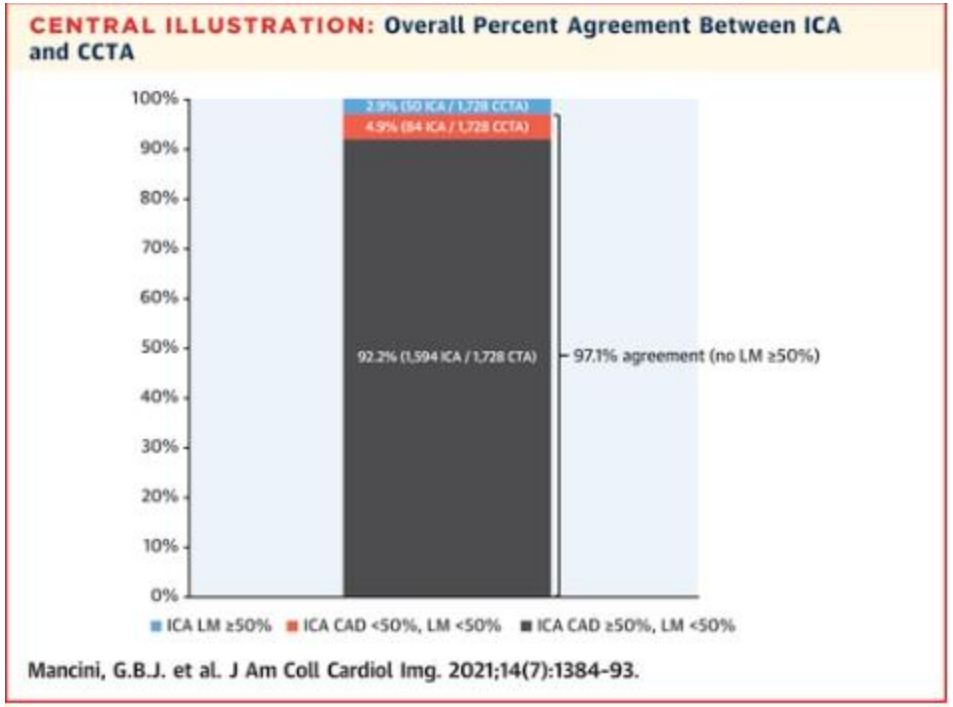




Maron DJ, et al. NEJM 2020.

CTA rarely misses severe CAD

CT Angiography Followed by Invasive Angiography in Patients With Moderate or Severe Ischemia-Insights From the ISCHEMIA Trial



- LM: 97.1% Concordance
- CCTA before randomization in ISCHEMIA demonstrated high concordance with subsequent ICA for identification of patients with angiographically significant disease without LM disease
- >1 of 5 patients (21.1%) with moderate-severe ischemia with no obstructive CAD

Mancini, G.B.J. el al. J Am Coll Cardiol Img. 2021

Guidelines

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*Writing committee members are required to recuse themselves from voting on sections to which their specific relationships with industry may apply; see Appendix 1 for detailed information.
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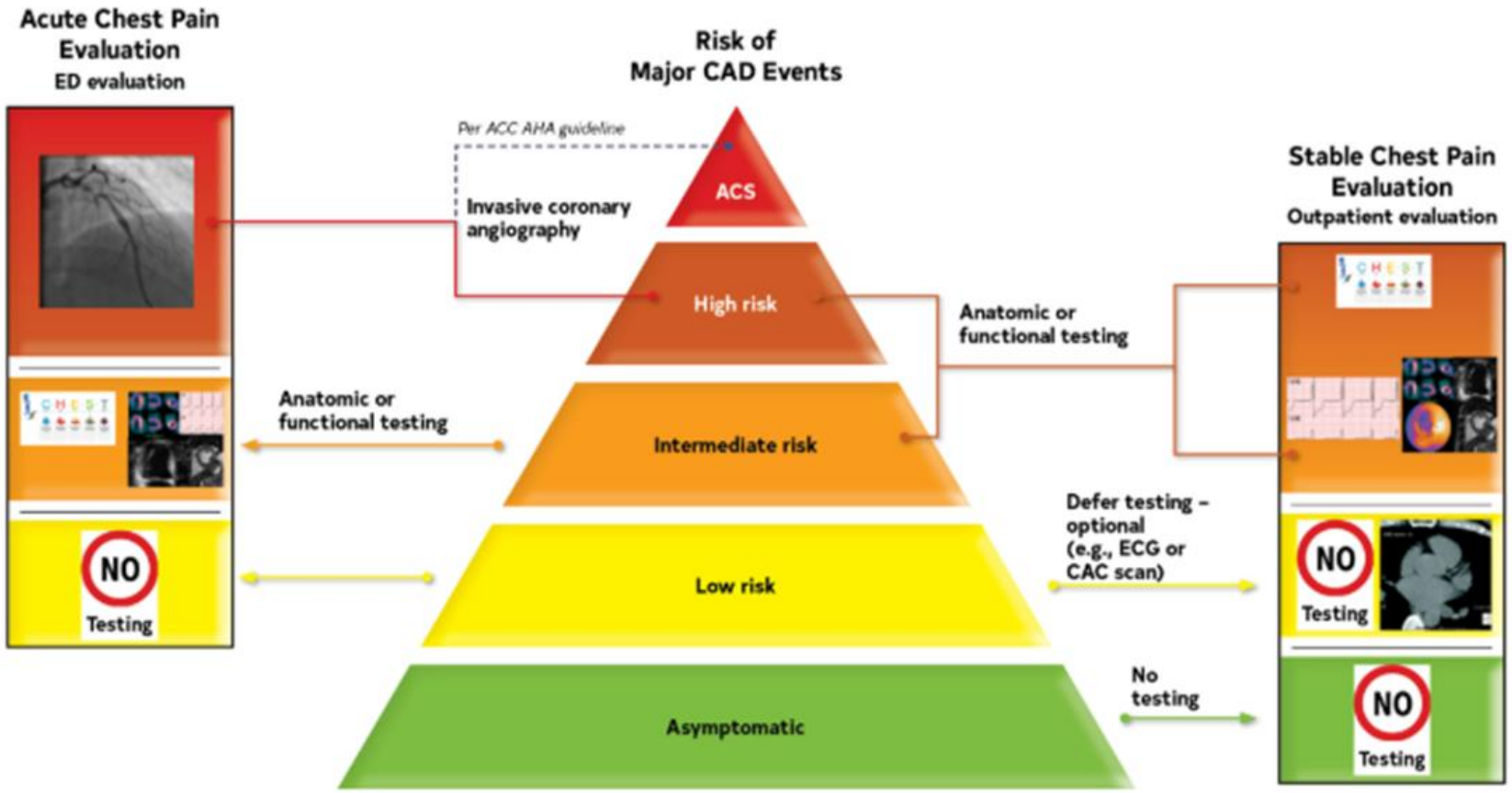
‡ACC/AHA Joint Committee on Clinical Practice Guidelines Liaison.
§Society of Cardiovascular Computed Tomography Representative.
‖Lay Patient Representative.
¶Society for Academic Emergency Medicine Representative.
#Former ACC/AHA Joint Committee member; current member during the writing effort.
**Society for Cardiovascular Magnetic Resonance Representative.
††American College of Chest Physicians Representative.
‡‡American Society of Echocardiography Representative.
§§Task Force on Performance Measures, Liaison.

Chest Pain and Cardiac Testing



Gulati, M. et al. JACC 2021

Pre-Test Probability: Include CAC burden if known

Age, y	Chest Pain		Dyspnea	
	Men	Women	Men	Women
30–39	≤4	≤5	0	3
40–49	≤22	≤10	12	3
50–59	≤32	≤13	20	9
60–69	≤44	≤16	27	14
70+	≤52	≤27	32	12

Intermediate to high = > 15% PTP

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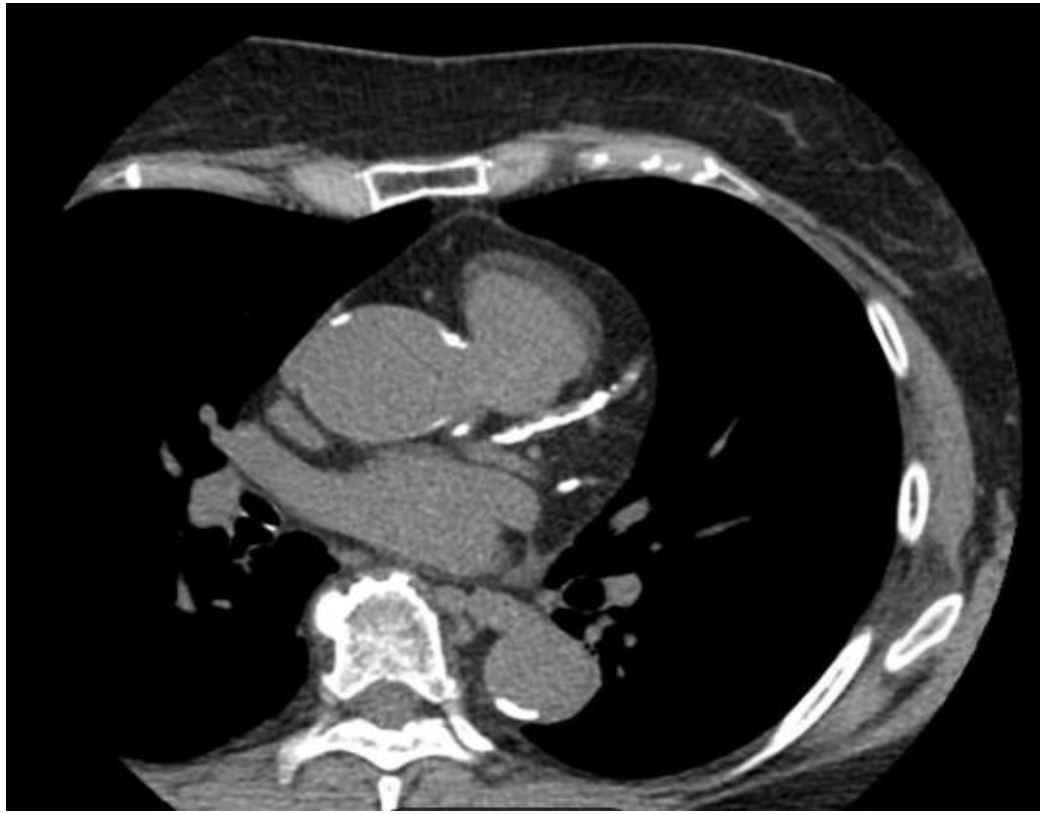
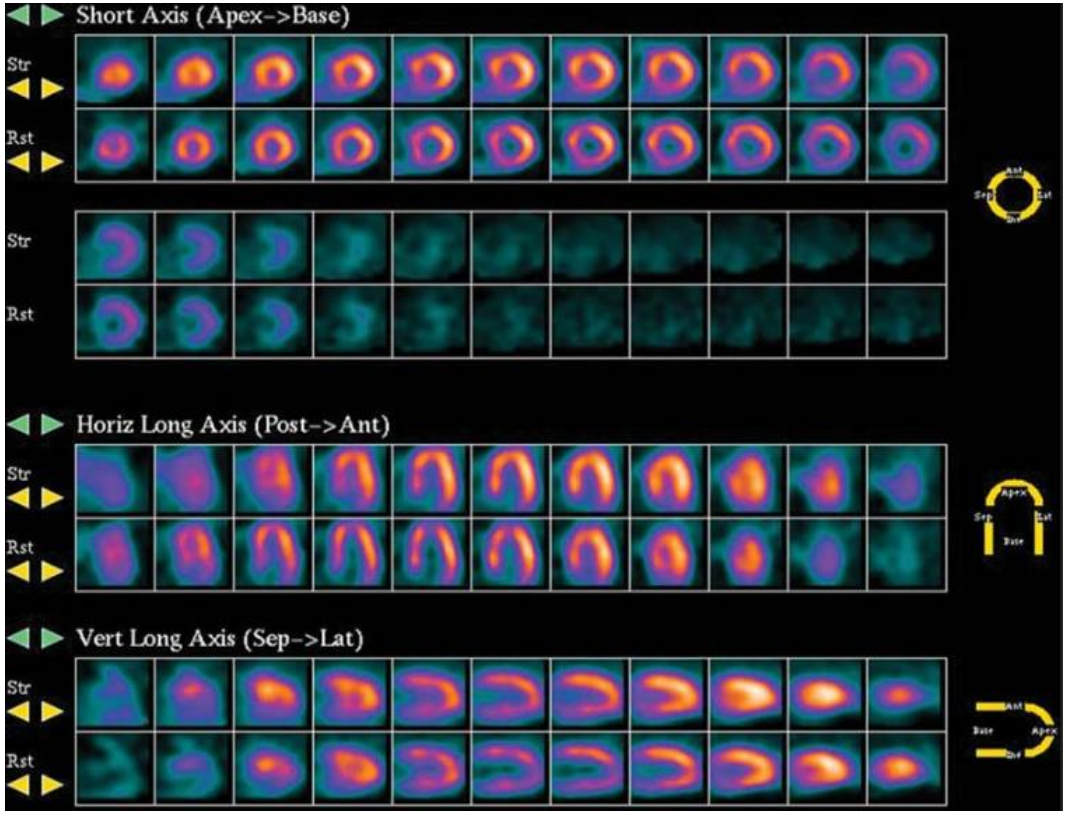
Prior Imaging Results to Refine Management



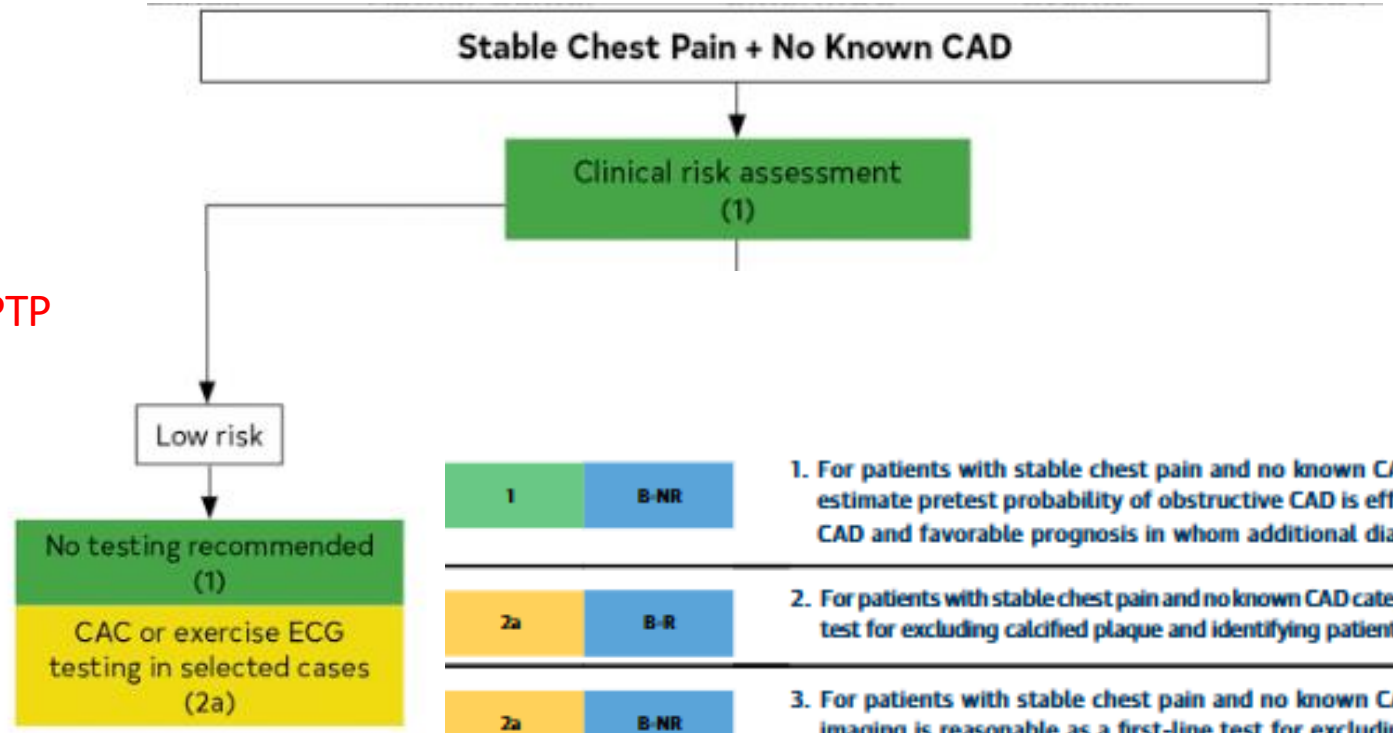


Functional testing preferred

Anatomical testing preferred

Stable Chest Pain

< 15% PTP



1	B-NR	1. For patients with stable chest pain and no known CAD presenting to the outpatient clinic, a model to estimate pretest probability of obstructive CAD is effective to identify patients at low risk for obstructive CAD and favorable prognosis in whom additional diagnostic testing can be deferred (1-5).
2a	B-R	2. For patients with stable chest pain and no known CAD categorized as low risk, CAC testing is reasonable as a first-line test for excluding calcified plaque and identifying patients with a low likelihood of obstructive CAD (6-9).
2a	B-NR	3. For patients with stable chest pain and no known CAD categorized as low risk, exercise testing without imaging is reasonable as a first-line test for excluding myocardial ischemia and determining functional capacity in patients with an interpretable ECG (10).

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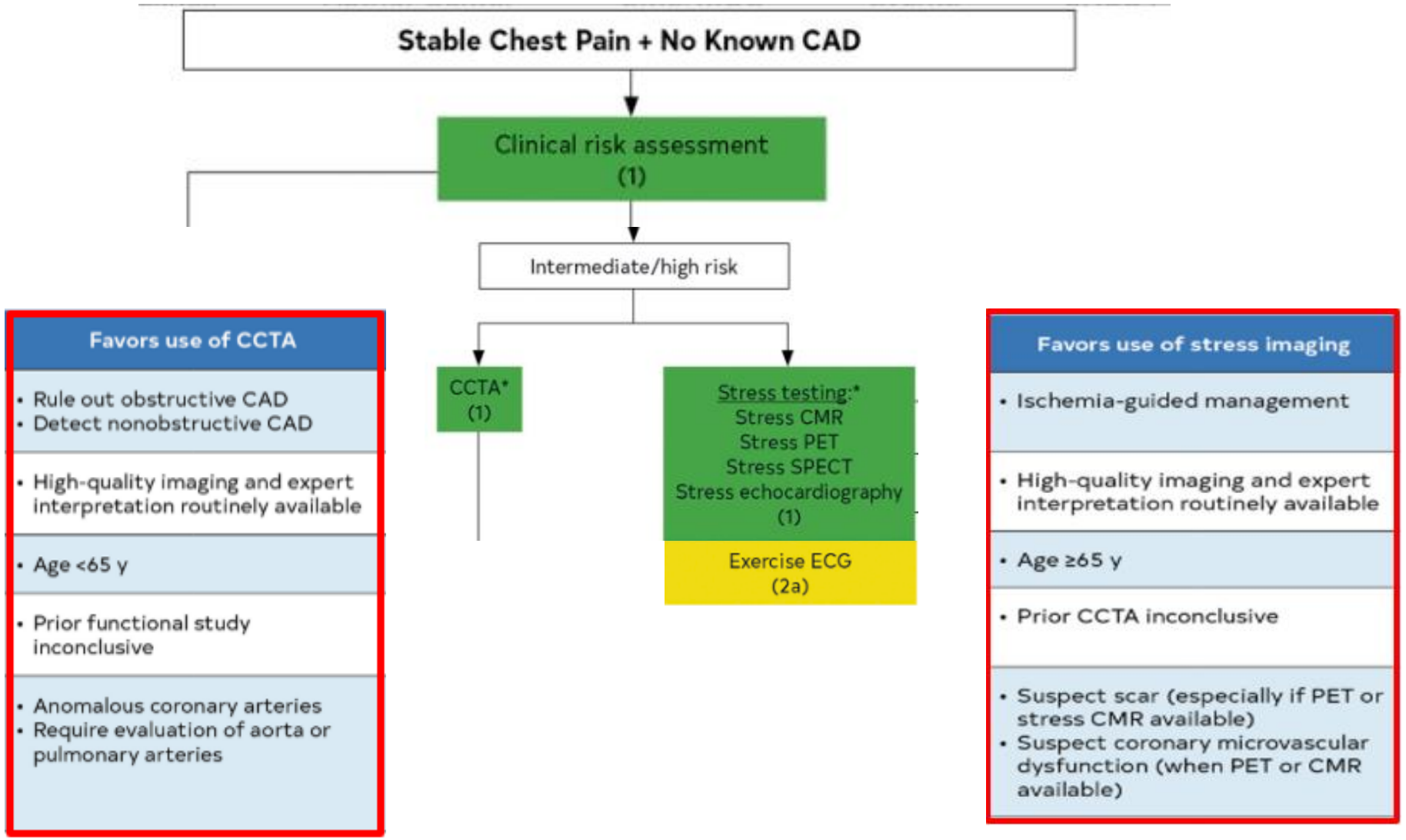
Stable Chest Pain



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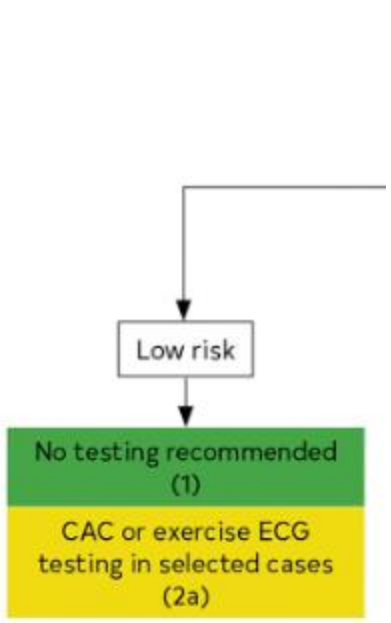
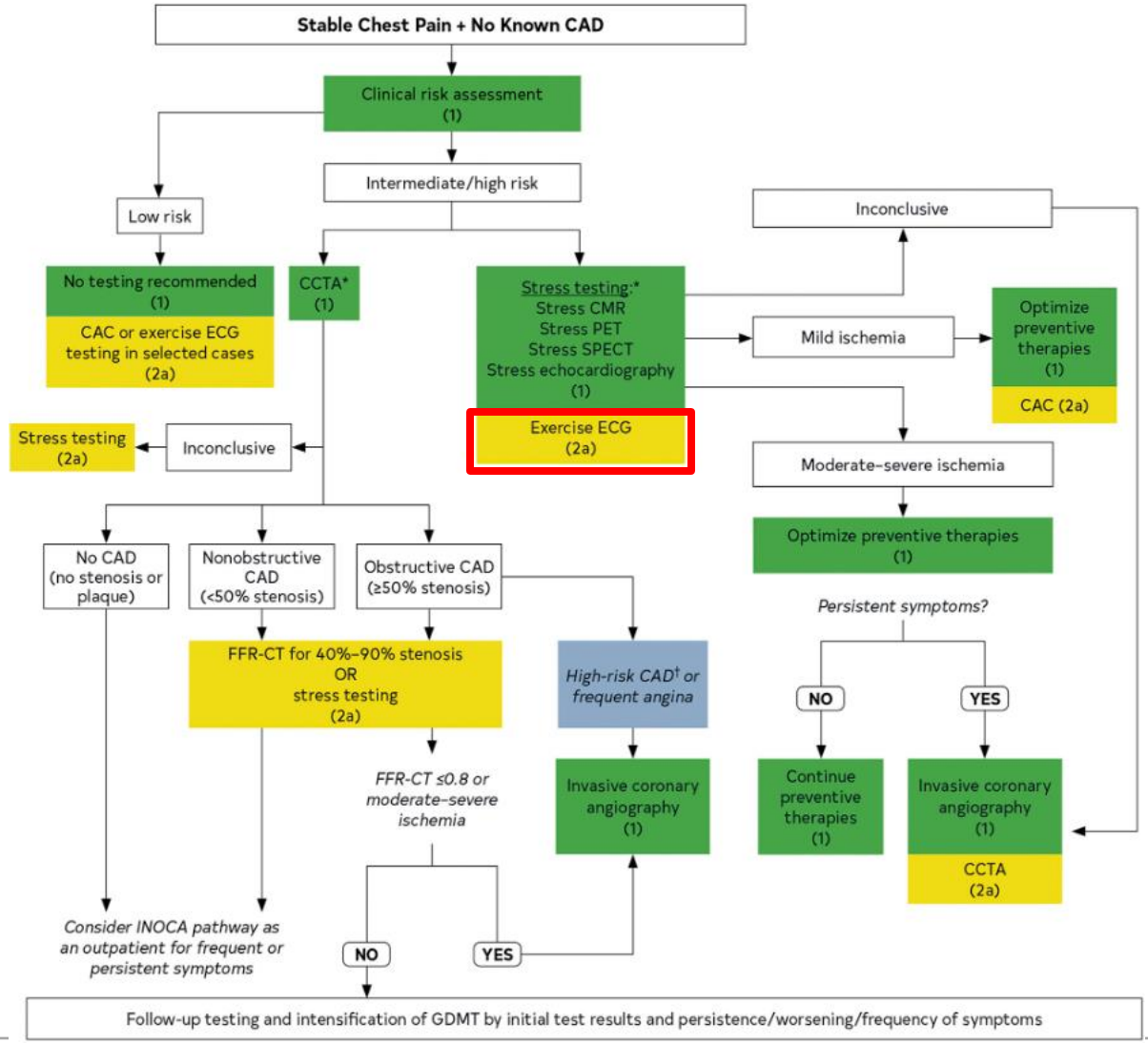
Stable Chest Pain





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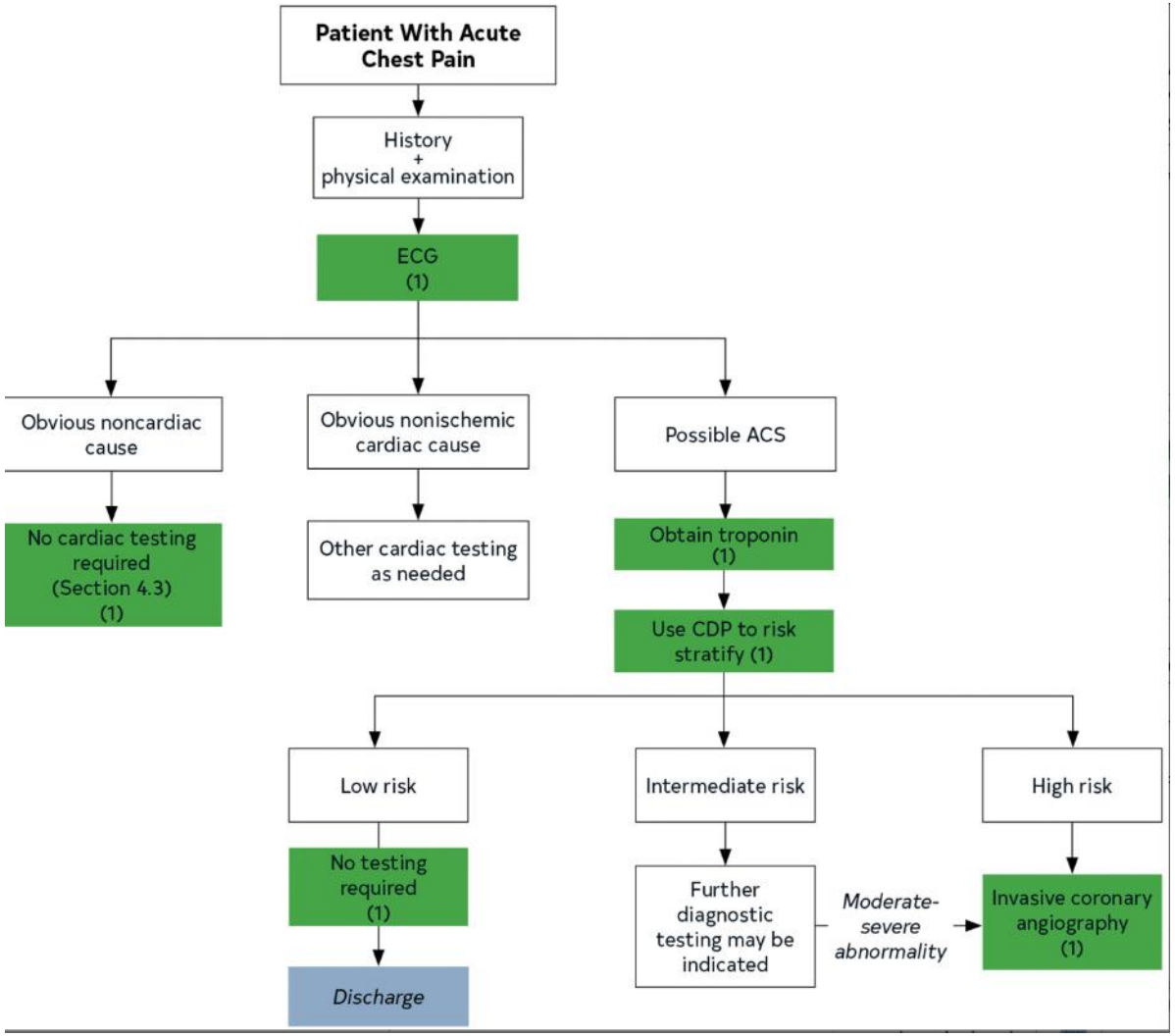
Acute Chest Pain Pathway



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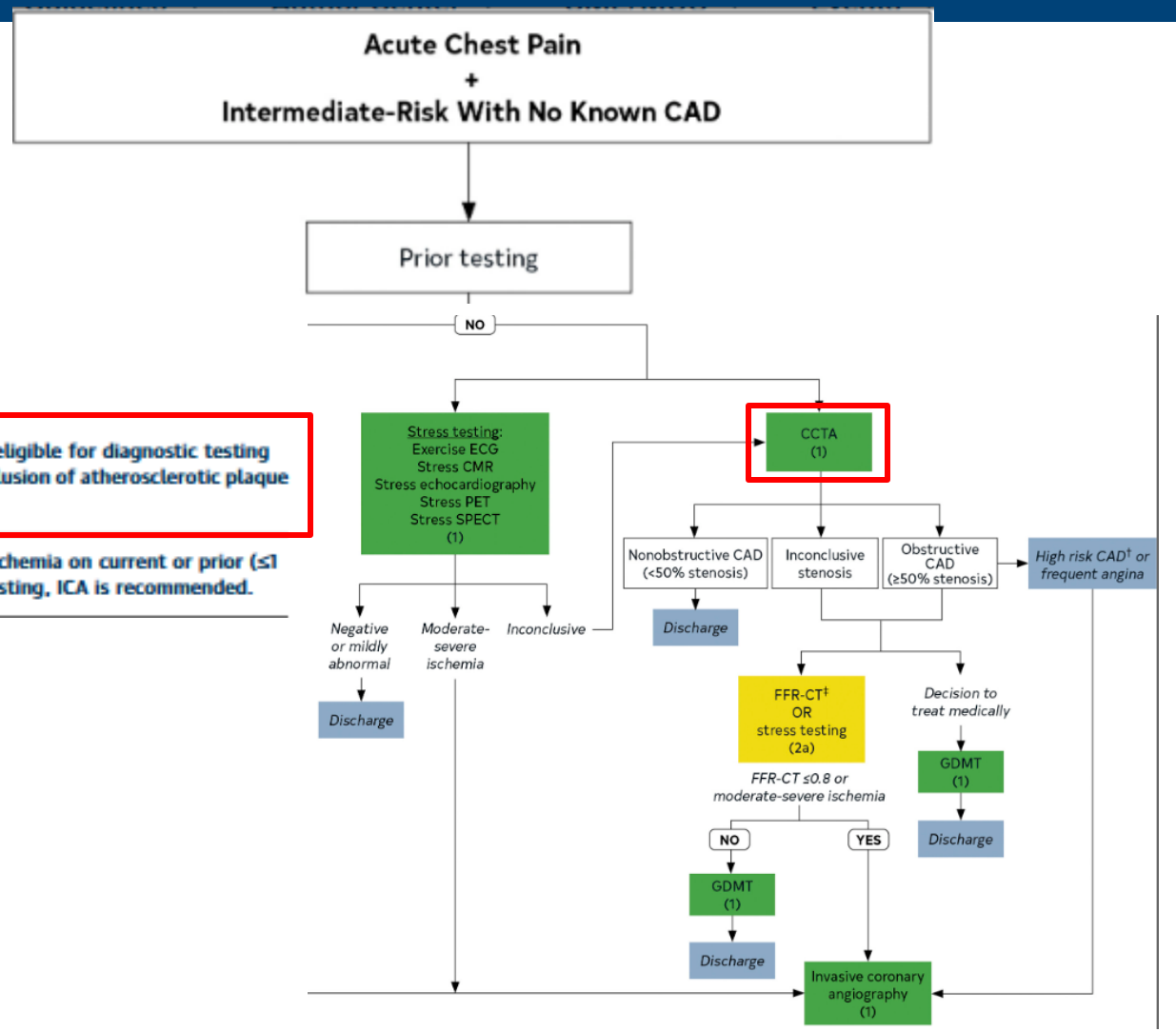
Acute chest pain without prior testing

☆ Intermediate risk

1	A	1. For intermediate-risk patients with acute chest pain and no known CAD eligible for diagnostic testing after a negative or inconclusive evaluation for ACS, CCTA is useful for exclusion of atherosclerotic plaque and obstructive CAD (1-11).
1	C-EO	2. For intermediate-risk patients with acute chest pain, moderate-severe ischemia on current or prior (≤1 year) stress testing, and no known CAD established by prior anatomic testing, ICA is recommended.



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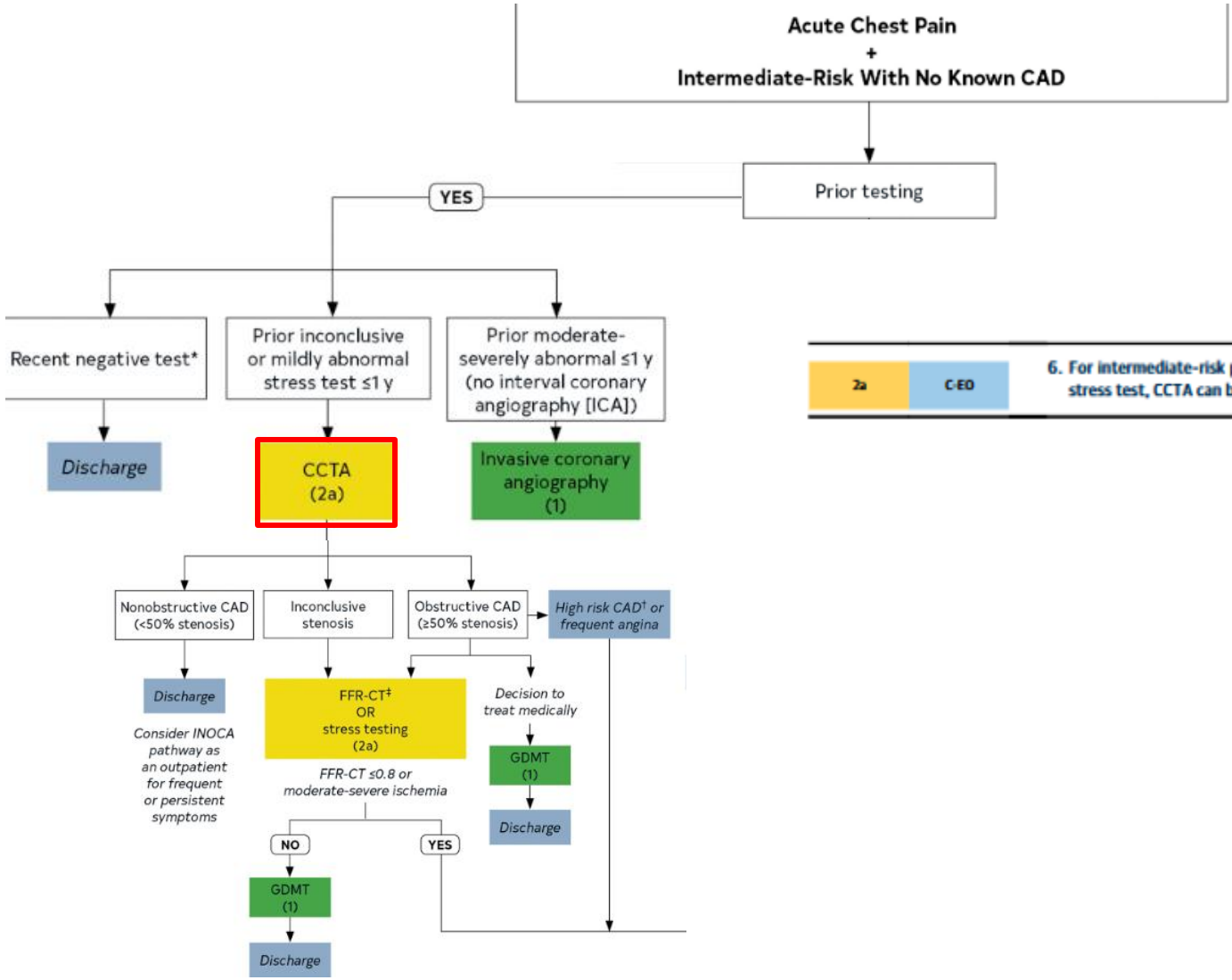
Acute chest pain with prior testing



2a	C-EO	6. For intermediate-risk patients with acute chest pain and no known CAD, as well as an inconclusive prior stress test, CCTA can be useful for excluding the presence of atherosclerotic plaque and obstructive CAD.

Gulati, M. et al. J Am Coll Cardiol 2021.

Unique Populations: Women

Prevalence and predictors of nonobstructive coronary artery disease identified with coronary angiography in contemporary clinical practice

Manesh R. Patel MD, MPH [a], David Dai MS [a,d], Adrian F. Hernandez MD [b], Pamela S. Douglas MD [b], John Messenger MD [b], Kirk N. Garratt MD [c], Thomas M. Maddox MD [b], Eric D. Peterson MD, MPH [b], Matthew T. Roe MD, MHS [a]

Can we better select people for invasive angiography and revascularization?

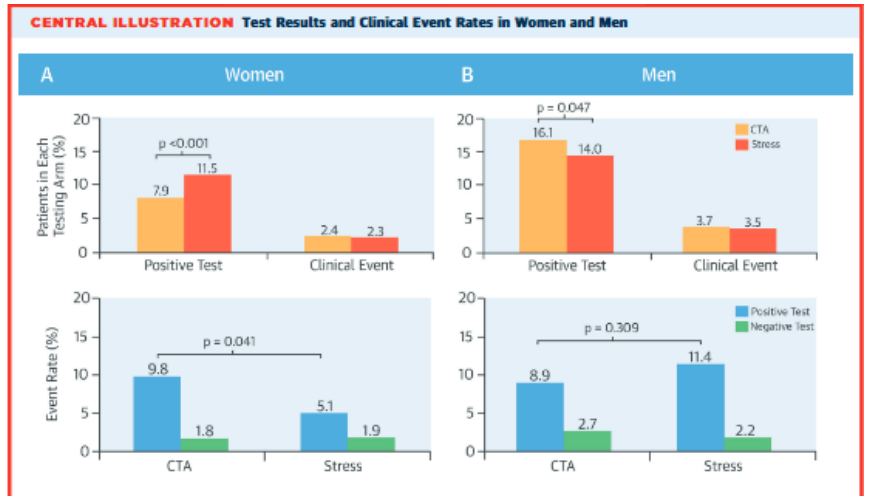
- NCDR cath PCI registry (2009-2011)
- N= 661,063
- 63% had non-invasive testing (78% nuclear MPI)
- Strongest predictor of findings of a normal cath on invasive angiography: Female sex: OR 2.48 (95% CI 2.43-2.53)

Patel MR, et al. Am H J 2014.

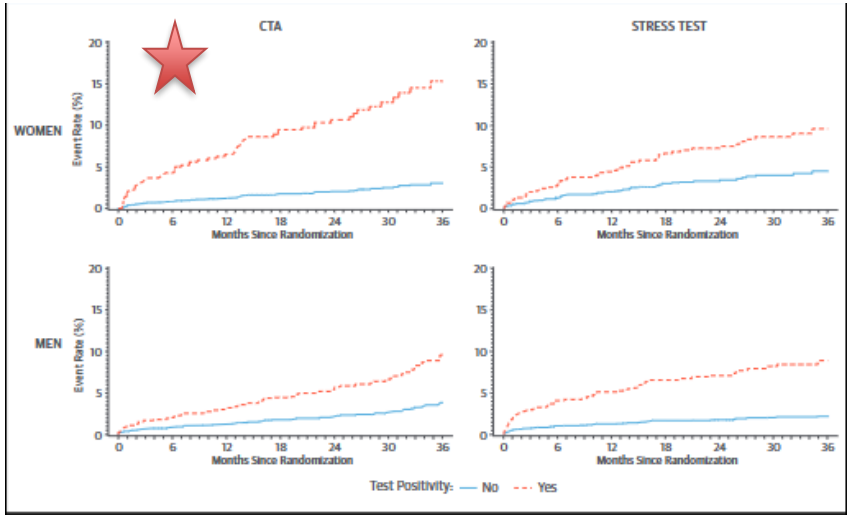
PROMISE TRIAL

Sex Differences in Functional and CT Angiography Testing in Patients With Suspected Coronary Artery Disease

Neha J. Pagidipati, MD, MPH,[a] Kshipra Hemal,[a] Adrian Coles, PhD,[a] Daniel B. Mark, MD, MPH,[a] Rowena J. Dolor, MD, MHS,[a,b] Patricia A. Pellikka, MD,[c] Udo Hoffmann, MD,[d] Sheldon E. Litwin, MD,[e] James Udelson, MD,[f] Melissa A. Daubert, MD,[a] Svati H. Shah, MD,[a,b] Beth Martinez, BS,[a] Kerry L. Lee, PhD,[a] Pamela S. Douglas, MD[a]



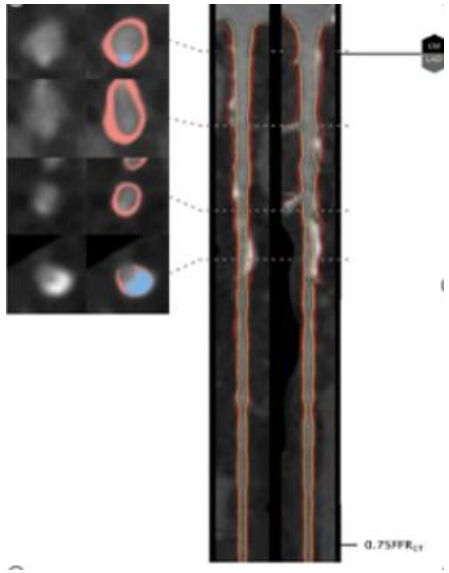
- In women, a positive CTA (>70% stenosis) was more strongly associated with subsequent clinical events than a positive stress test (HR 5.86 vs 2.27; p=0.028)



Pagidipati N.J. et al. J Am Coll Cardiol. 2016


FUTURE

AI – Based Quantitative Coronary Plaque Analysis



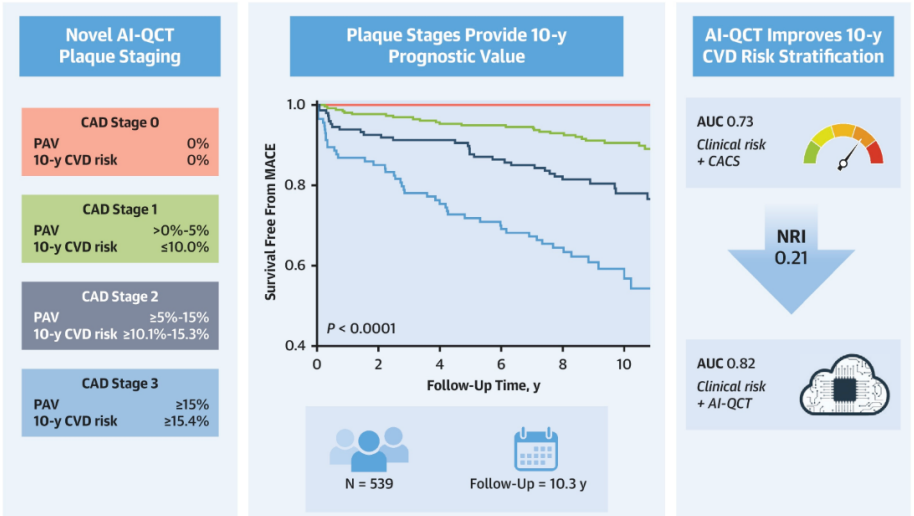
CORONARY SYSTEM (including branches)	TOTAL PLAQUE mm³	CALCIFIED PLAQUE	NON CALCIFIED PLAQUE	LOW ATTENUATION PLAQUE
Left Main	31	1	30	0
Left Anterior Descending	603	147	456	14
Total	634	148	486	14

Quantitative plaque is provided on vessels > 1.8 mm diameter.

PLAQUE CHARACTERISTICS: calcified plaque; non-calcified plaque; low attenuation plaque

VESSEL BOUNDARY: lumen boundary; outer wall boundary

CENTRAL ILLUSTRATION: AI-QCT Plaque Staging Improves Long-Term CVD Risk Stratification



Nurmohamed NS, et al. J Am Coll Cardiol Img. 2024;17(3):269-280.

- Cardiac CT quantitative coronary plaque analysis (Plaque volume and subtype) allowing precision-based management

Nurmohamed NS, et al. J Am Coll Img. 2024)

Update in Internal Medicine

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