Η αξονική τομογραφία ως διαγνωστικό εργαλείο ΣΝ και ως εργαλείο διαστρωμάτωσης καρδιομεταβολικού κινδύνου

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Appropriate Use Criteria for CCTA

1. Detection of CAD in Symptomatic Patients Without Known Heart Disease

Non-acute chest pain: Intermediate PTP for CAD

low/interm PTP for CAD w/ ECG non-interpretable or unable to exercise

Acute chest pain: Normal ECG and cardiac biomarkers

ECG uninterpretable

2. Detection of CAD/Risk Assessment in Asymptomatic Patients (no known CAD)

CCS (not CCTA!) low/interm PTP for CAD

3. Detection of CAD in Other Clinical Scenarios

Reduced left ventricular ejection fraction (low/interm PTP)

Coronary evaluation before noncoronary cardiac surgery (interm PTP)

Prior normal ECG exercise test but continued symptoms

ECG exercise testing intermediate Duke risk score

Prior stress imaging procedure equivocal

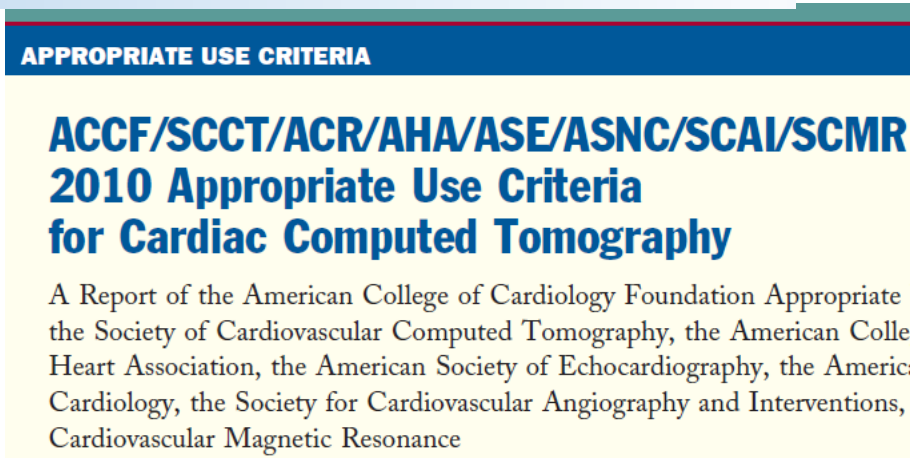
Prior CCS <400

New or worsening symptoms and normal previous imaging test

4. Prior revascularization

Evaluation of graft patency after CABG in symptomatic patients

Asymptomatic but prior LM PCI and/or stent diameter>=3 mm


APPROPRIATE USE CRITERIA

ACCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography

A Report of the American College of Cardiology Foundation Appropriate
the Society of Cardiovascular Computed Tomography, the American Colle
Heart Association, the American Society of Echocardiography, the Americ
Cardiology, the Society for Cardiovascular Angiography and Interventions,
Cardiovascular Magnetic Resonance

5. Adult Congenital Heart Disease

6. Evaluation of Ventricular Morphology and Systolic Function

7. Evaluation of Intra- and Extracardiac Structures

Cardiac valves

Valvular dysfunction

aortic stenosis severity

prosthetic heart valves

8. Pericardial anatomy

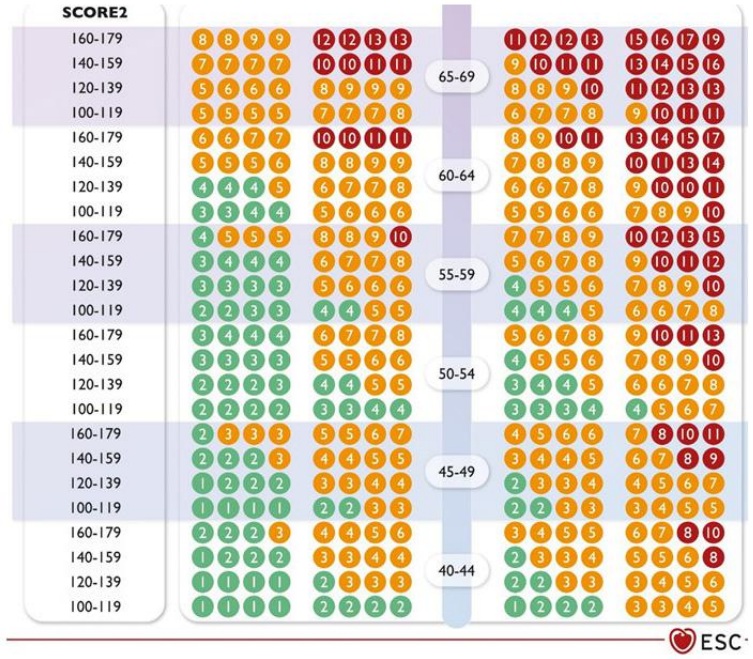
9. PV anatomy

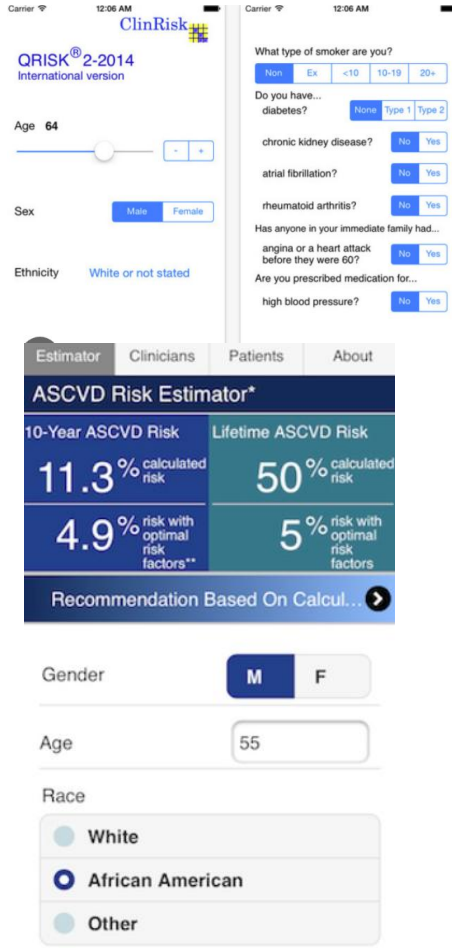
10. AF ablation

11. Noninvasive coronary vein mapping

Coronary calcium score: risk modifier

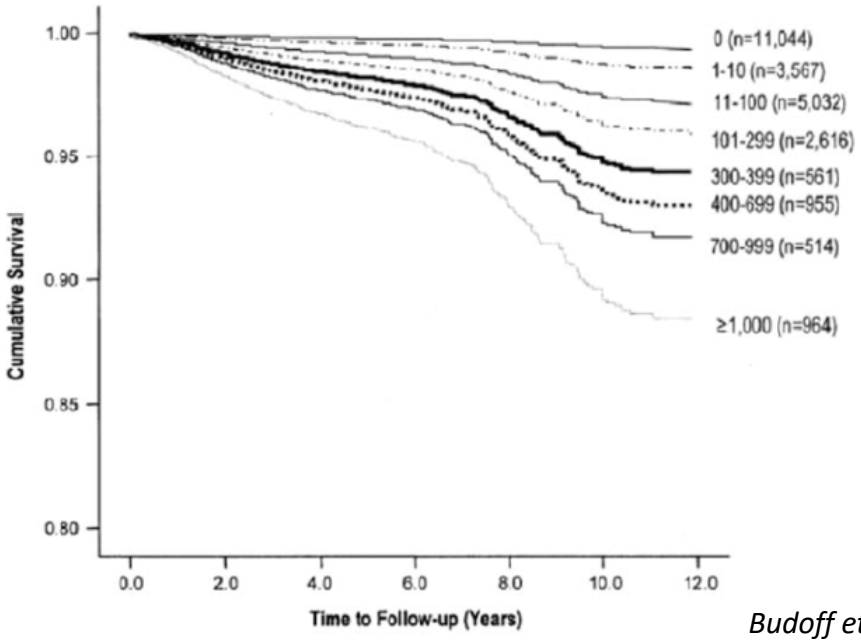
Clinical risk scores





- SCORE2
- QRISK
- ASCVD risk

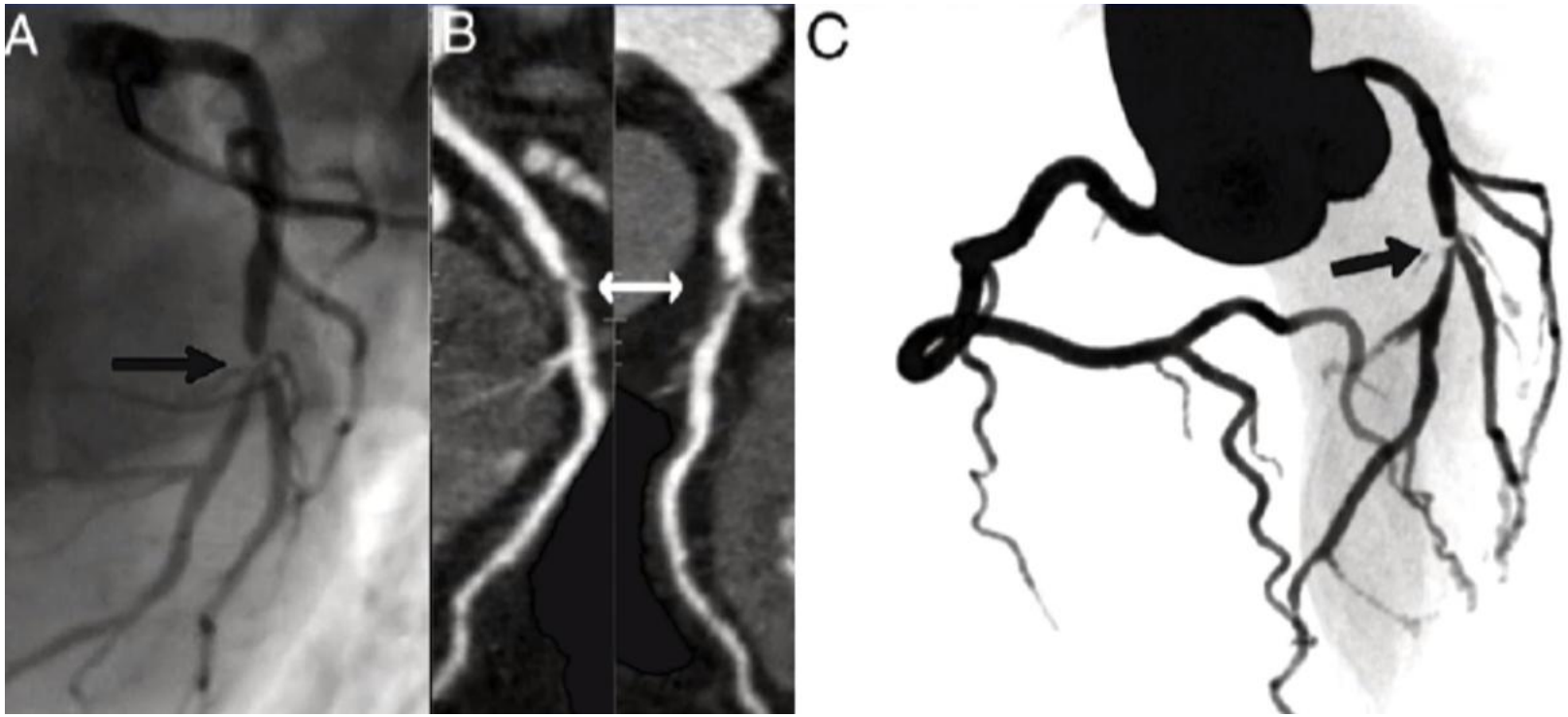
Coronary Calcium Score



Budoff et al.

- Risk modifier
- Surrogate of coronary plaque burden
- Prognostic value – risk reclassification
- Guide initiation of treament

Coronary calcium score: power of zero



Asymptomatic individuals: CCS=0 -> NPV for CAD >99%

Symptomatic individuals: CCS=0 -> NPV for CAD ~68%

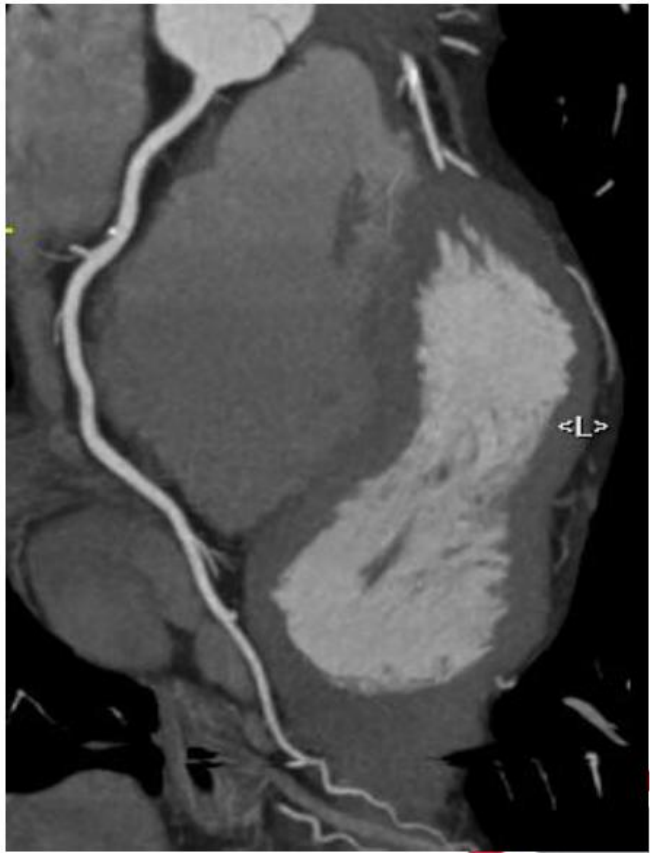
Gottlieb et al. JACC 2010

Appropriate use of CCS in asymptomatic individuals only! (Intermediate risk individuals)

If symptomatic / chest pain -> functional imaging or CCTA/ICA

(no value of CCS once CCTA is done)

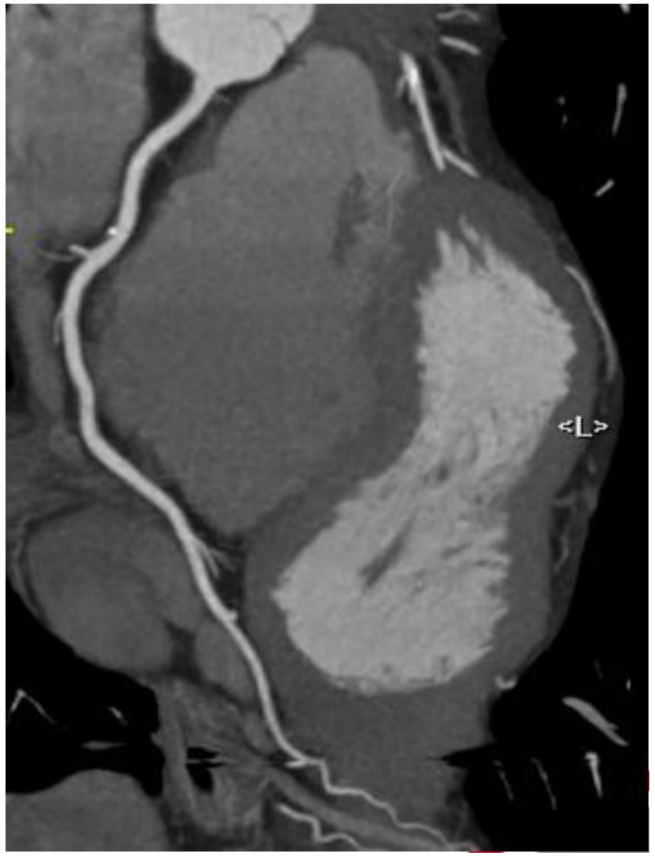
CCTA for diagnosis of obstructive CAD

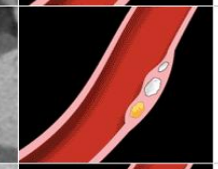
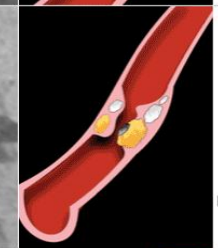
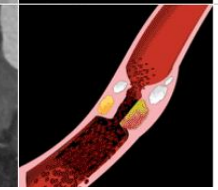


Test	Sensitivity	Specificity
Exercise ECG treadmill[1]	68%	77%
Exercise Echo treadmill[2]	86%	81%
Dobutamine Echo[2]	~85%	~85%
Exercise nuclear treadmill[3]	87%	73%
Pharmacologic nuclear[3]	89%	75%
Coronary CTA[4]	**95%**	**83%**

1. ACC/AHA 2002 Guideline Update for Exercise Testing
2. ACC/AHA/ASE 2003 Guideline Update for the Application of Echocardiography
3. ACC/AHA/ASNC Guidelines for the Clinical Use of Cardiac Radionuclide Imaging
4. ACCURACY study

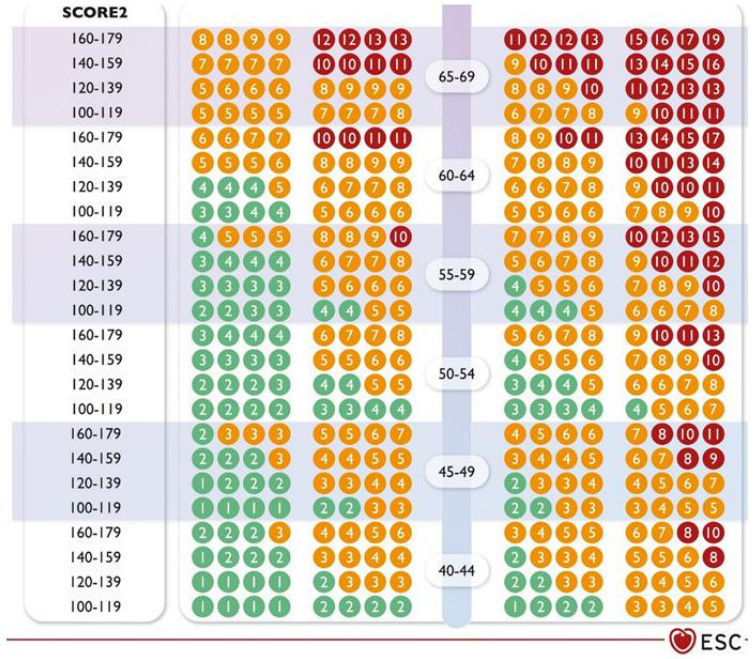
CCTA for diagnosis of obstructive CAD

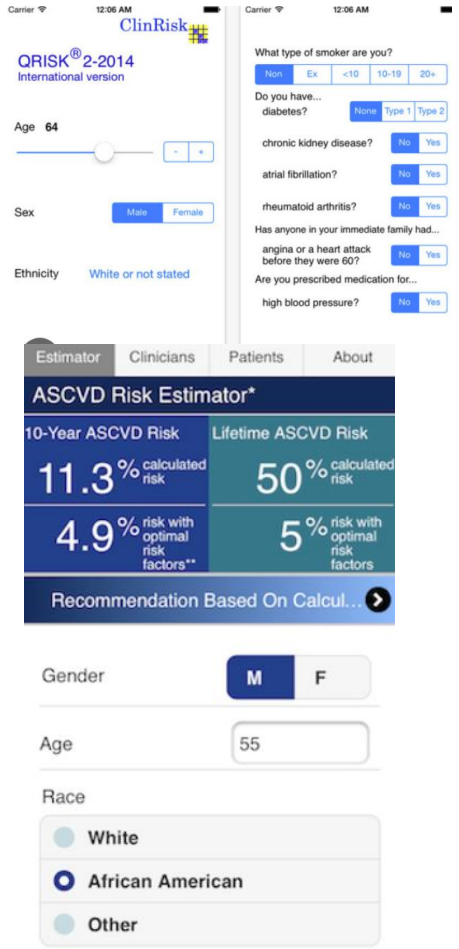


Cad-Rads	Stenosis	CT imaging	Illustration	Additional Tests
Cad-Rads **0**	0% No stenosis			None
Cad-Rads **1**	1-24% Minimal stenosis			None
Cad-Rads **2**	25-49% Mild stenosis			None
Cad-Rads **3**	50-70% Moderate stenosis			Consider functional assessment
Cad-Rads **4**	A: 70-99% stenosis in 1 or 2 vessels B: >50% stenosis in the left main or >70% stenosis in 3-vessels			A: Consider functional assessment or ICA B: ICA is recommended
Cad-Rads **5**	100% total occlusion			ICA and/or viability assessment

Risk stratification & treatment decisions for CAD

Clinical risk scores





- SCORE2
- QRISK
- ASCVD risk

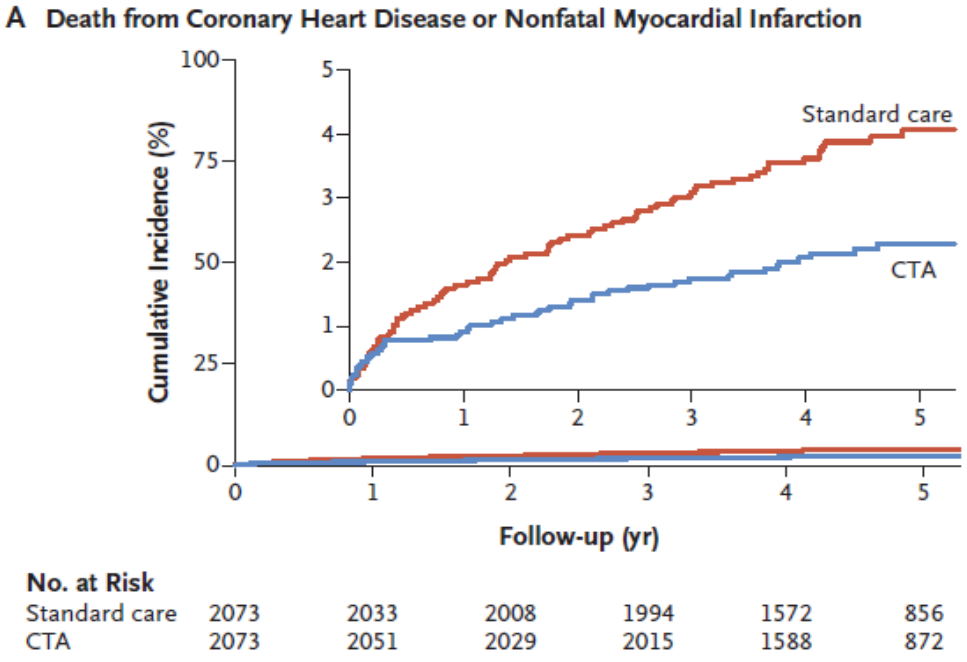
High-risk anatomy

- LM disease ≥50% stenosis
- 3VD with ≥70 stenosis, or
- 2VD with ≥70% stenosis, including prox LAD or
- 1VD of prox LAD with ≥70% stenosis and FFR-CT ≤0.8

CCTA as first line modality for assessment of obstructive CAD

The Scottish COmputed Tomography of the HEART (SCOT-HEART) Trial

CHD death or non-fatal myocardial infarction
HR 0.59 (95%CI 0.41–0.84), p=0.004

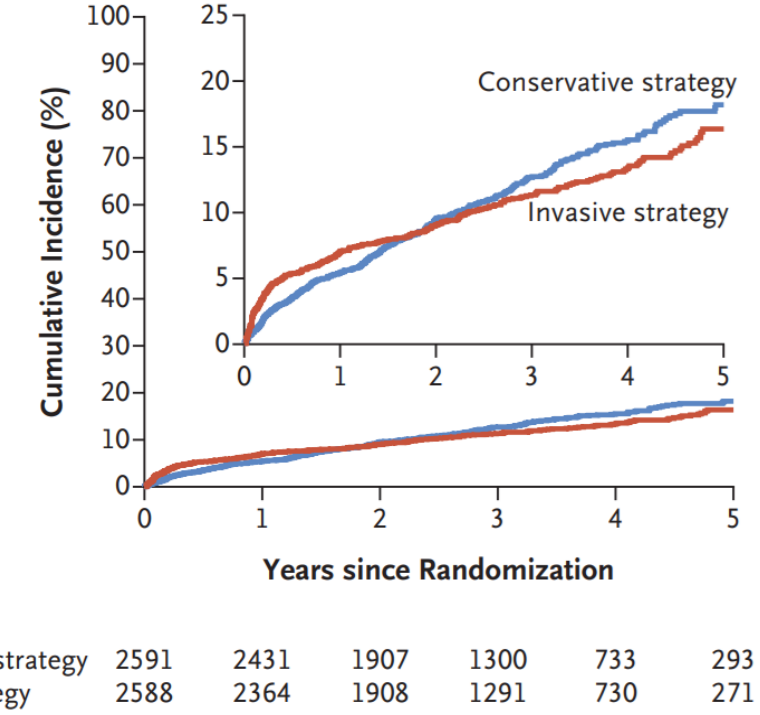


Newby et al. NEJM 2018

ISCHEMIA

The NEW ENGLAND JOURNAL of MEDICINE

All-cause death or non-fatal myocardial infarction



Maron et al. NEJM 2020

1st line imaging modality in low/moderate PTP for obstructive CAD

Non-invasive anatomical imaging tests in the initial diagnostic management of individuals with suspected obstructive coronary artery disease—coronary computed tomography angiography, if available and supported by local expertise—*Section 3*		
In individuals with suspected CCS and low or moderate (>5%–50%) pre-test likelihood of obstructive CAD, CCTA is recommended to diagnose obstructive CAD and to estimate the risk of MACE.	I	A
Non-invasive tests in the initial diagnostic management of individuals with suspected chronic coronary syndrome—stress echocardiography, if available and supported by local expertise—*Section 3*		
In individuals with suspected CCS and moderate or high (>15%–85%) pre-test likelihood of obstructive CAD, stress echocardiography is recommended to diagnose myocardial ischaemia and to estimate the risk of MACE.	I	B
During stress echocardiography, when two or more contiguous myocardial segments are not visualized, it is recommended to use commercially available intravenous ultrasound contrast agents (microbubbles) to improve diagnostic accuracy.	I	B
During stress echocardiography, myocardial perfusion using commercially available intravenous ultrasound contrast agents (microbubbles) is recommended to improve diagnostic accuracy and to refine risk stratification beyond wall motion.	I	B
During stress echocardiography, Doppler left anterior descending coronary artery flow reserve may be considered to improve risk stratification beyond wall motion and to assess microvascular function.	IIb	B

Selection of individual diagnostic tests in individuals with suspected chronic coronary syndrome—*Section 3*		
To rule out obstructive CAD in individuals with low or moderate (>5%–50%) pre-test likelihood, CCTA is recommended as the preferred diagnostic modality.	I	B
CCTA is recommended in individuals with low or moderate (>5%–50%) pre-test likelihood of obstructive CAD if functional imaging for myocardial ischaemia is not diagnostic.	I	B

1 Symptom score (0–3 points)

Chest pain characteristics		Symptom score
Type and location	Constricting discomfort located retrosternally or in neck, jaw, shoulder or arm (1 point)	Main symptom either: Chest pain (0–3 points) or Dyspnoea (2 points)
Aggravated by	Physical or emotional stress (1 point)	
Relieved by	Rest or nitrates within 5 min (1 point)	
Dyspnoea characteristics		
Shortness of breath and/or trouble catching breath aggravated by physical exertion (2 points)		

2 Number of risk factors for CAD (0–5):
Family history, smoking, dyslipidaemia, hypertension and diabetes

3 Estimate the Risk Factor-weighted Clinical Likelihood (RF-CL) of obstructive CAD

Number of risk factors	Symptom score: 0–1 point				2 points				3 points			
	Women		Men		Women		Men		Women		Men	
	0–1	2–3	4–5	0–1	2–3	4–5	0–1	2–3	4–5	0–1	2–3	4–5	0–1	2–3	4–5	0–1	2–3	4–5
Age 30–39	0	1	2	1	2	5	0	1	3	2	4	8	2	5	10	9	14	22
Age 40–49	1	1	3	2	4	8	1	2	5	3	6	12	4	7	12	14	20	27
Age 50–59	1	2	5	4	7	12	2	3	7	6	11	17	6	10	15	21	27	33
Age 60–69	2	4	7	8	12	17	3	6	11	12	17	25	10	14	19	32	35	39
Age 70–80	4	7	11	15	19	24	6	10	16	22	27	34	16	19	23	44	44	45

Clinical likelihood: Very low · Low · Moderate

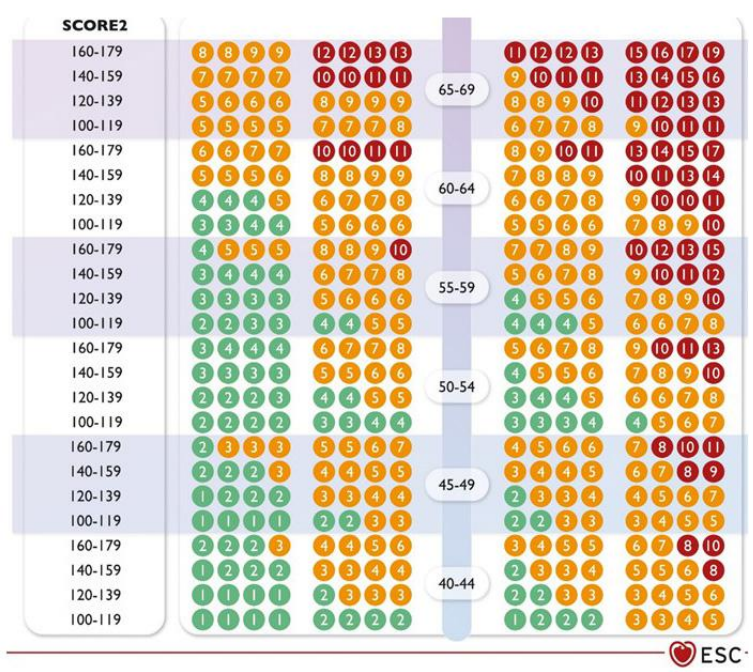
ESC

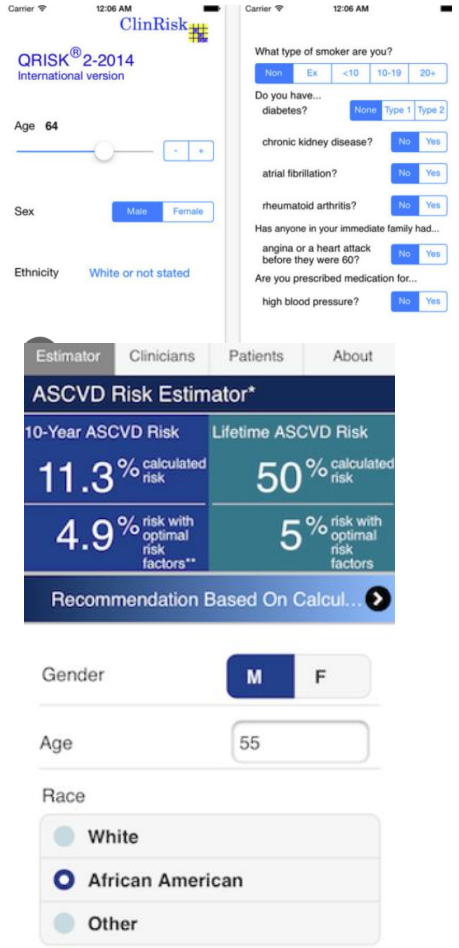
ESC Guidelines 2024 CCS

CCTA for risk stratification

Risk stratification & treatment decisions for CAD

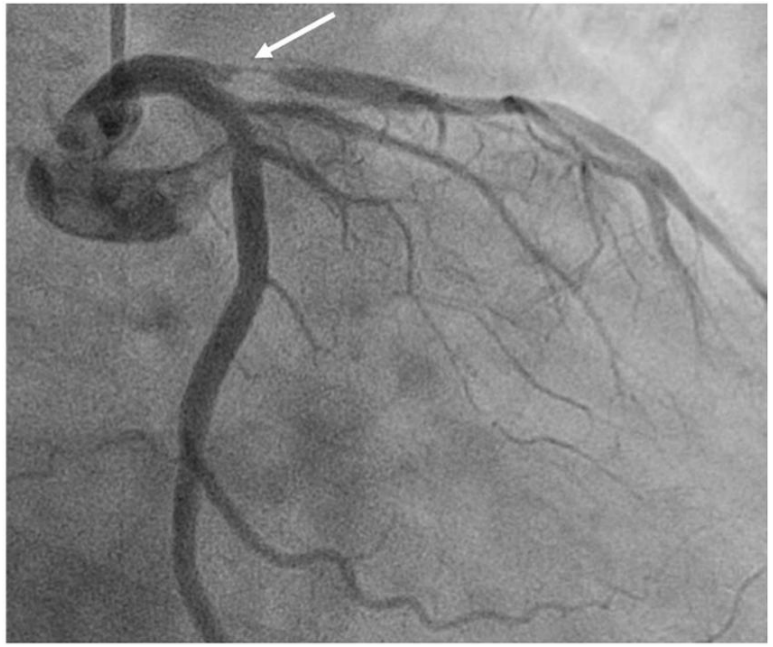
Clinical risk scores





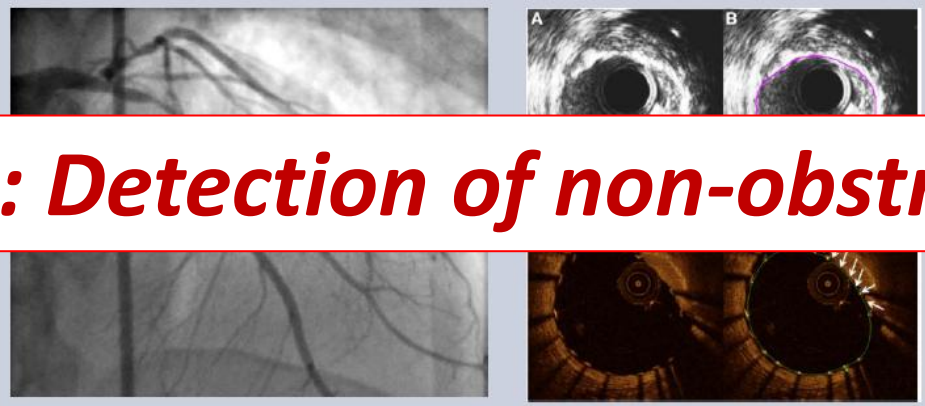
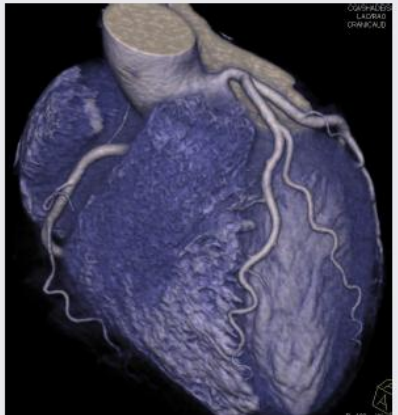
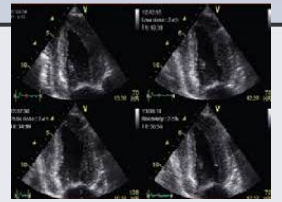
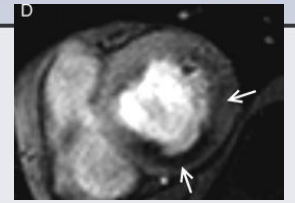
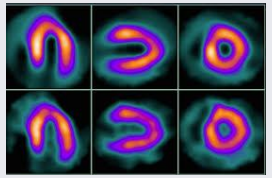
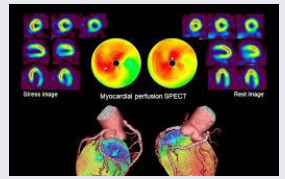
- SCORE2
- QRISK
- ASCVD risk

Symptoms / Luminal stenosis



- >50% of heart attacks occur in people with minor coronary artery stenoses (*Fishbein et al. Circulation. 1996;94:2662-2666)*
- Many patients at risk missed by current tests that rely on detecting luminal stenosis
- First presentation is often MI or death

CCTA for diagnosis of obstructive CAD

	ANATOMY ***Identify obstructive CAD***	***FUNCTION*** ***Identify lesion-specific ischemia that may benefit from PCI***
		
Non-invasive		   

CCTA BONUS: Detection of non-obstructive coronary plaques!

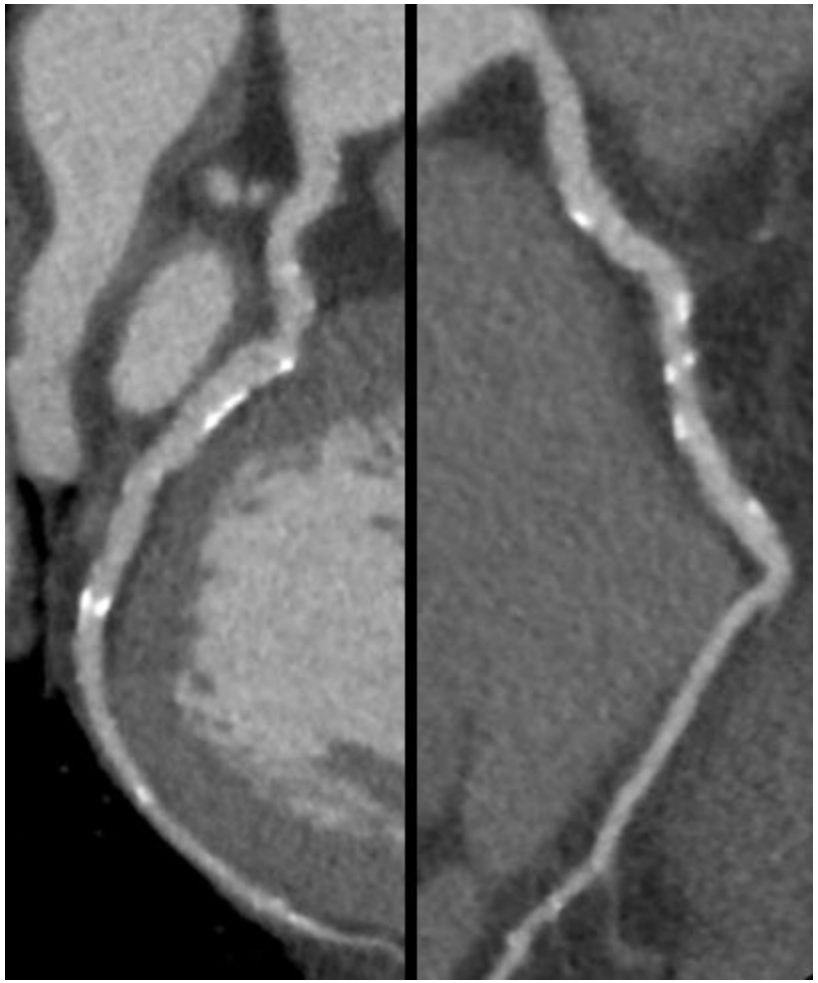
No plaque on CCTA = clinical reassurance

- Atypical symptoms
- No major risk factors
- Low-intermediate PTP
- >85% of patients referred for a CCTA

- No plaque
- Clinical reassurance

Personal archive

No significant luminal stenosis but extensive disease



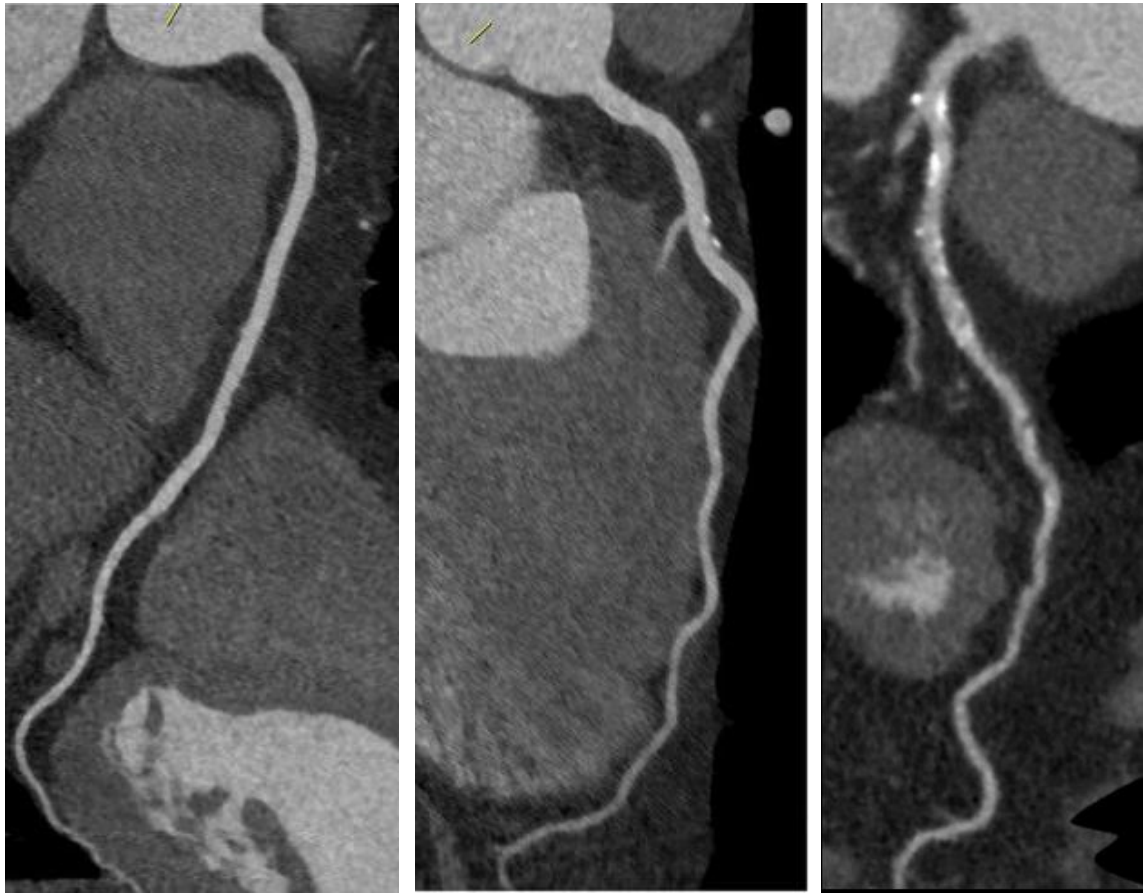
- No significant luminal stenosis
- No obstructive CAD (>50%)
- Moderate-high atheroma burden
- At risk for events
- Better control of RF
- Guiding treatment

Personal archive

Revisiting the definition of CAD in the era of CCTA

CAD

No | Non-obstructive | Obstructive

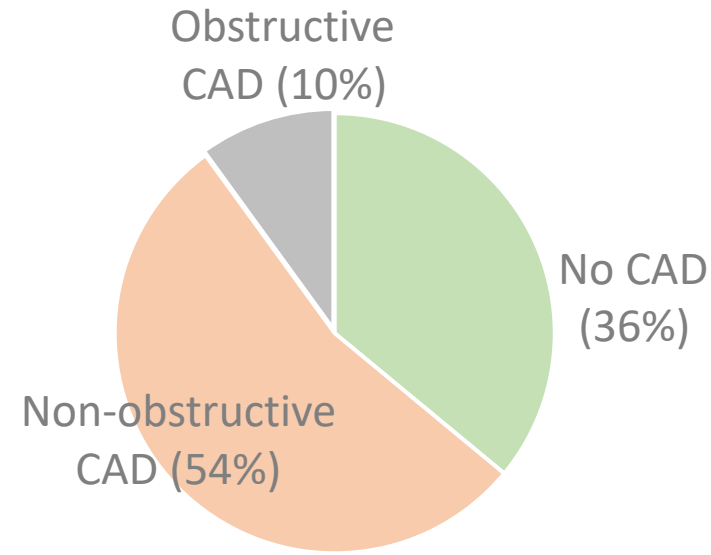


CCTA as the preferred 1st modality to screen for suspected CAD (Class IB)

*in the absence of relative contraindications that may compromise diagnostic quality
(arrhythmia, obesity etc.)

Copenhagen General Population Study, Denmark

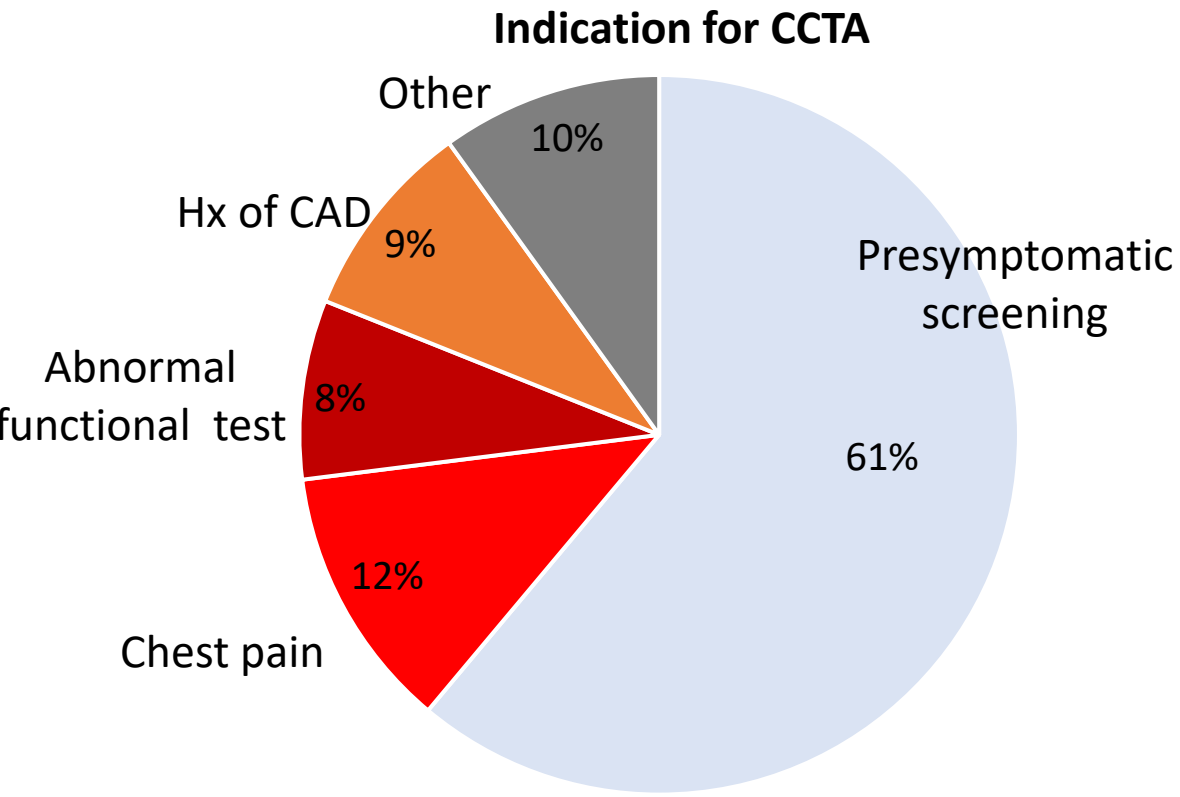
9533 asymptomatic persons >40y w/o known IHD



Fuchs et al. Ann Intern Med. doi.org/10.7326/M22-3027

Contemporary use of CCTA in Greece

COronary **CO**mputed Tomography **A**ngiography – **G**reek **R**egistry (**COCOA-GR**)

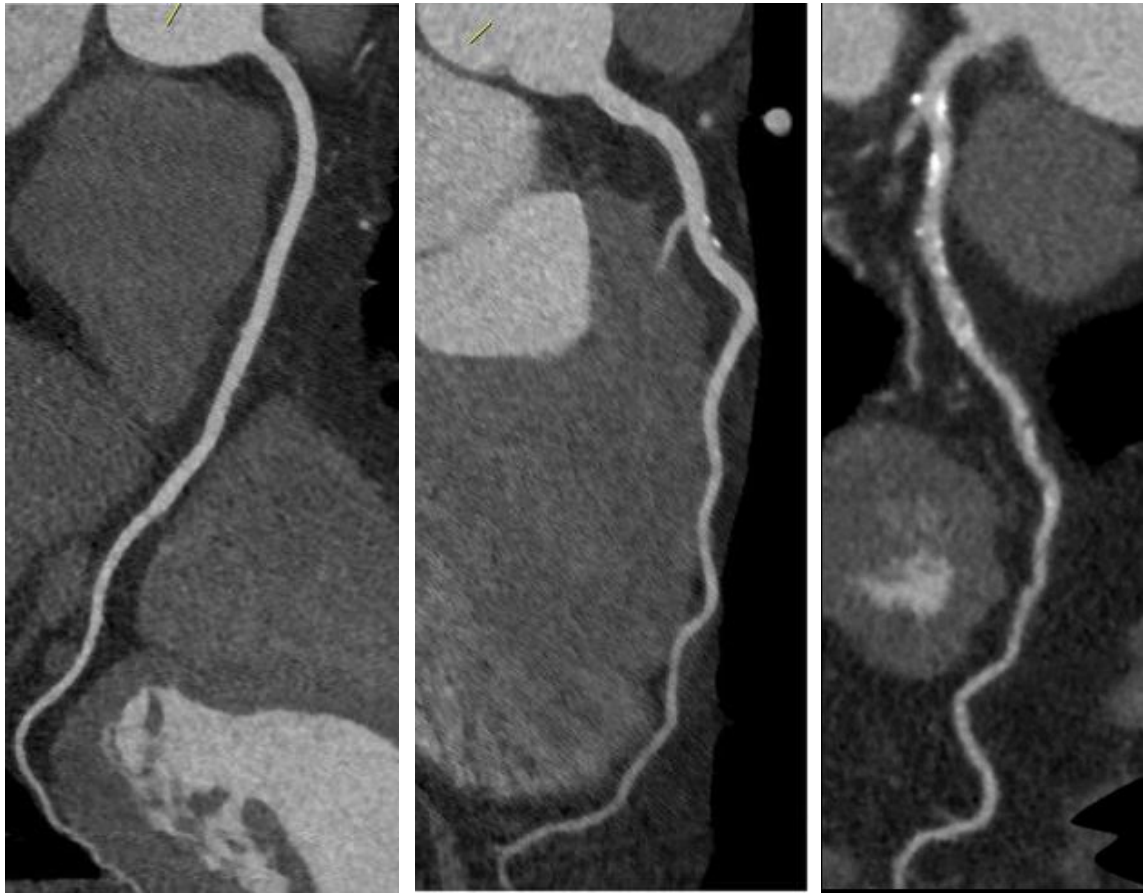


Antonopoulos AS et al. HSC Congress 2024

Revisiting the definition of CAD in the era of CCTA

CAD

No | Non-obstructive | Obstructive



Obstructive-extensive CAD	**~12x RR**
Obstructive-non-extensive CAD	**~8x RR**
Nonobstructive-extensive CAD	**~3x RR**
Non-obstructive-non-extensive	ref

- **Plaque burden**, not stenosis per se, is the main predictor of risk for CVD events and death

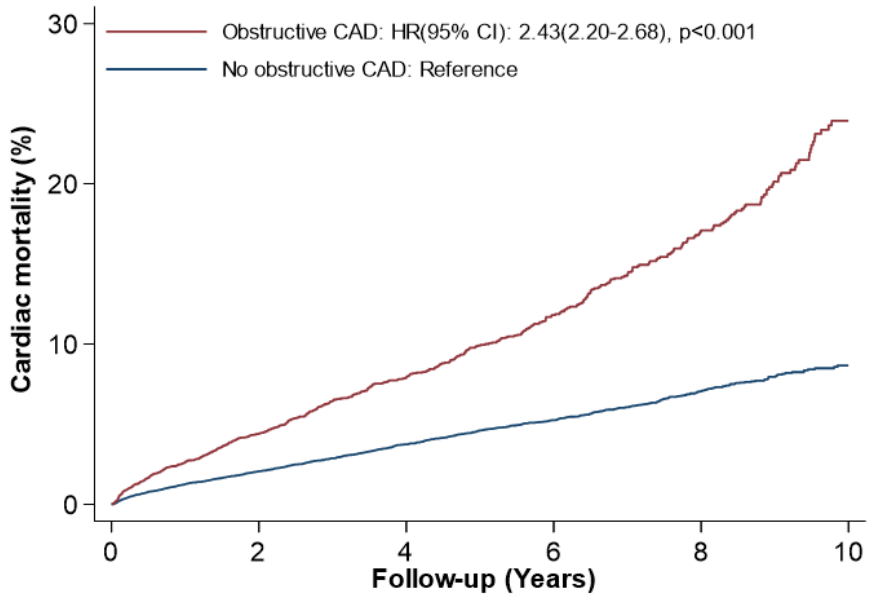
Fuchs et al. Ann Intern Med. doi.org/10.7326/M22-3027
Mortensen et al. J Am Coll Cardiol 2020;76:2803–13

ORFAN study: No-obstructive CAD on CCTA

Inflammatory risk and cardiovascular events in patients without obstructive coronary artery disease: the ORFAN multicentre, longitudinal cohort study

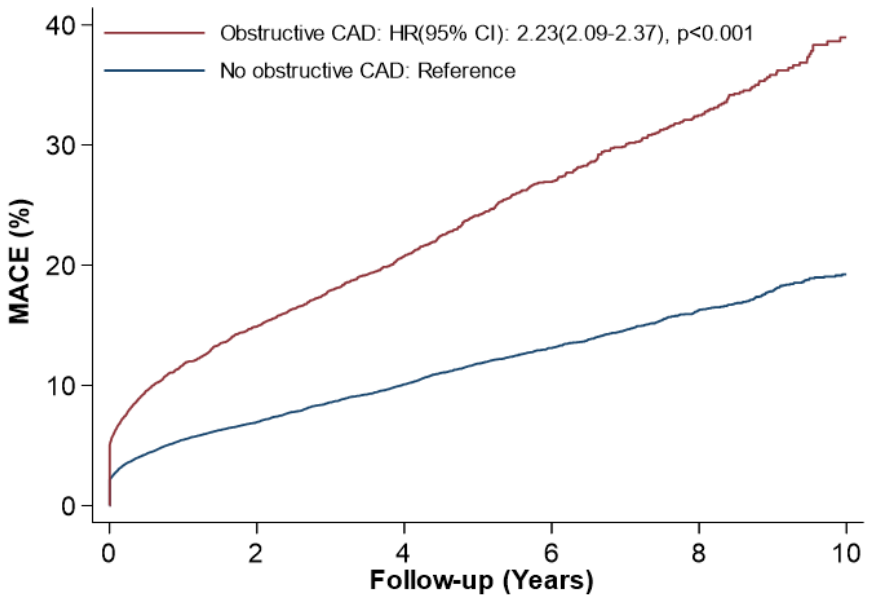
Kenneth Chan, Elizabeth Wahome*, Apostolos Tsiachristas, Alexios S Antonopoulos, Parijat Patel, Maria Lyasheva, Lucy Kingham, Henry West, Evangelos K Oikonomou, Lucrezia Volpe, Michail C Mavrogiannis, Edward Nicol, Tarun K Mittal, Thomas Halborg, Rafail A Kotronias, David Adlam, Bhavik Modi, Jonathan Rodrigues, Nicholas Screaton, Attila Kardos, John P Greenwood, Nikant Sabharwal, Giovanni Luigi De Maria, Shahzad Munir, Elisa McAlindon, Yogesh Sohan, Pete Tomlins, Muhammad Siddique, Andrew Kelion, Cheerag Shirodaria, Francesca Pugliese, Steffen E Petersen, Ron Blankstein, Milind Desai, Bernard J Gersh, Stephan Achenbach, Peter Libby, Stefan Neubauer, Keith M Channon, John Deanfield, Charalambos Antoniades, on behalf of the ORFAN Consortium*

ORFAN study ~40,000 patients undergoing CCTA in the UK



Number at risk

No obstructive CAD:	32,897	19,981	11,586	6,695	3,565	966
Obstructive CAD:	7,214	4,431	2,542	1,545	855	242



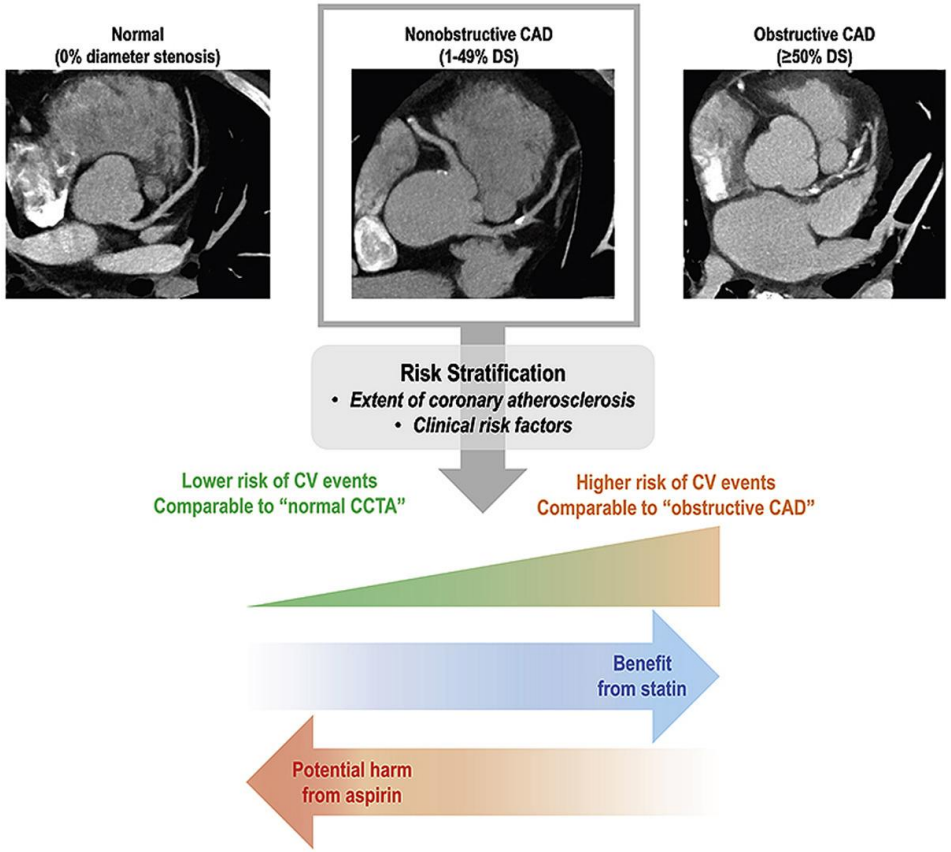
Number at risk

No obstructive CAD:	32,897	18,948	10,817	6,206	3,275	852
Obstructive CAD:	7,214	3,931	2,155	1,260	680	181

Chan et al. The Lancet 2024

Assessing coronary plaque burden on CCTA reports

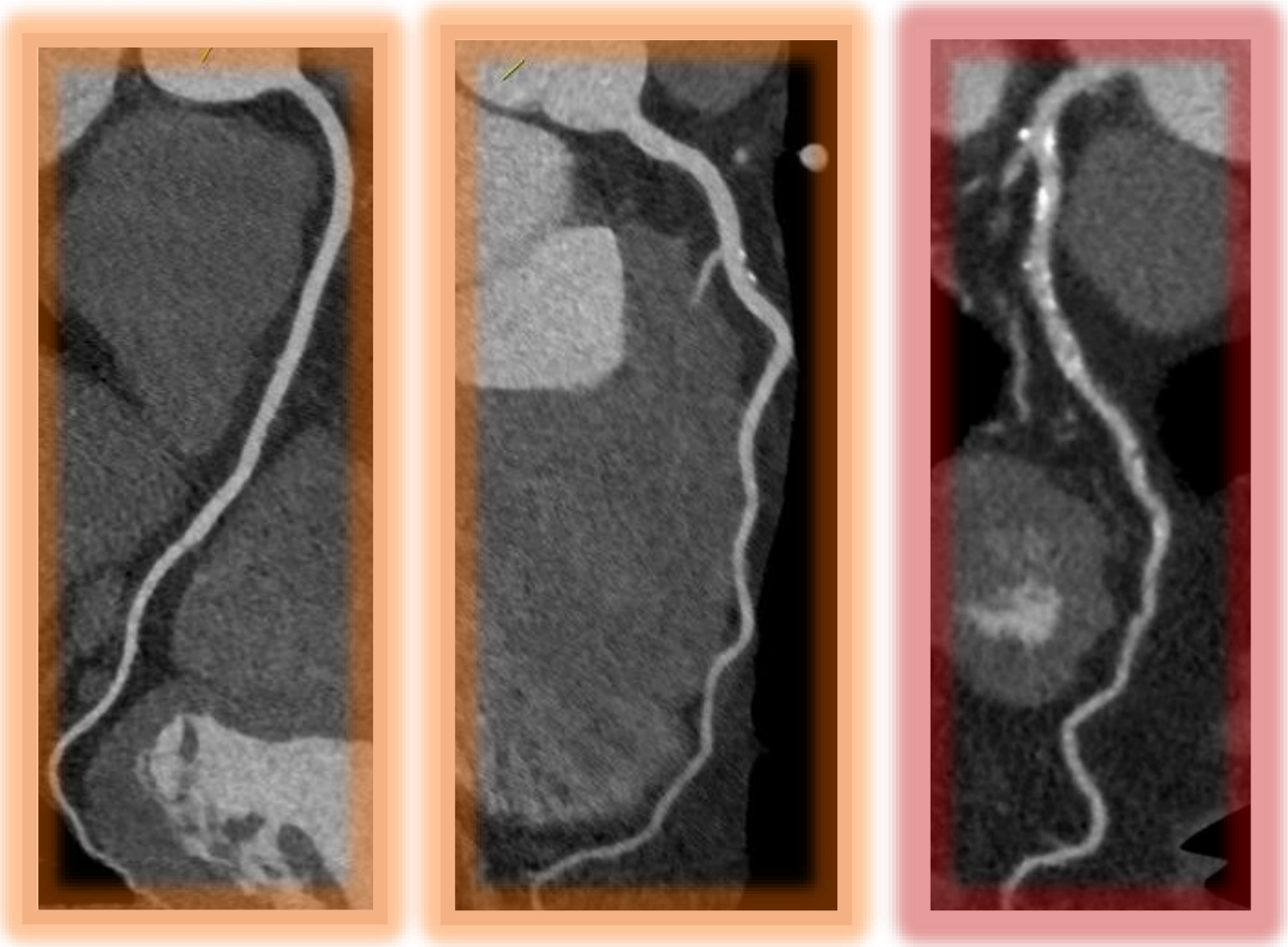
Coronary Plaque Burden				
	Amount of plaque	Calcium score	SIS*	Visual
P1	Mild	1-100	≤2	1-2 vessels with mild amount of plaque
P2	Moderate	101-300	3-4	1-2 vessels with moderate amount; 3 vessels with mild amount of plaque
P3	Severe	301-999	5-7	3 vessels with moderate amount; 1 vessel with severe amount of plaque
P4	Extensive	>1000	≥8	2-3 vessels with severe amount of plaque



Reducing risk by **facilitating evidenced therapy** or those with coronary artery disease independent of symptom characteristics.

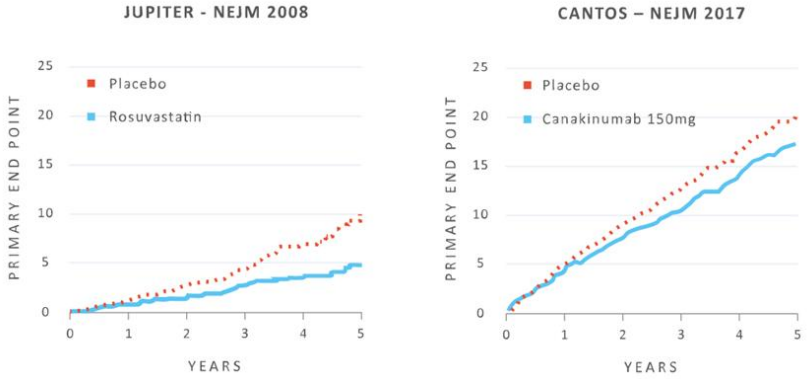
SCCT guidelines 2023

Remaining challenges: detecting vascular inflammation



- The vulnerable “healthy” individual who will develop atheroma
- The vulnerable “healthy” individual who has minor atheroma at risk for ACS
- The vulnerable patient with advanced disease, who despite OMT remains at risk for ACS (due to rupture of either significant or “minor” plaques)

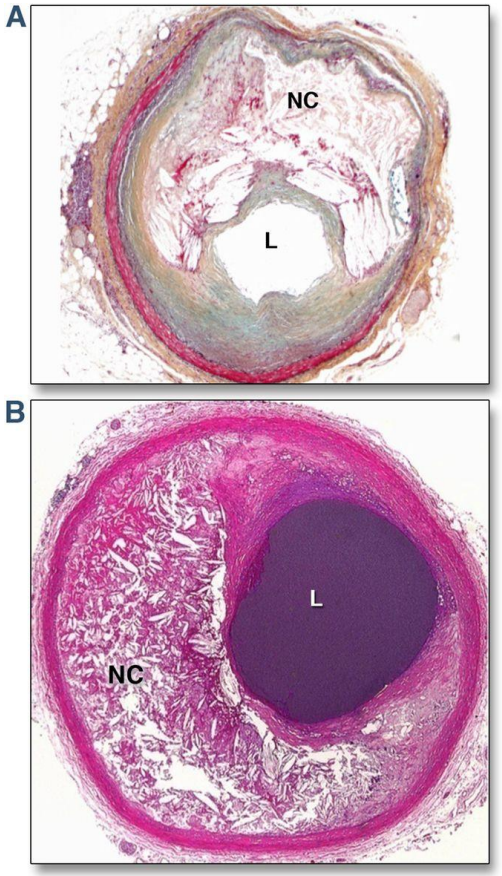
Treating vascular inflammation



CRP non-specific (>50% have high residual inflammation in 2ndary prevention based on CRP)

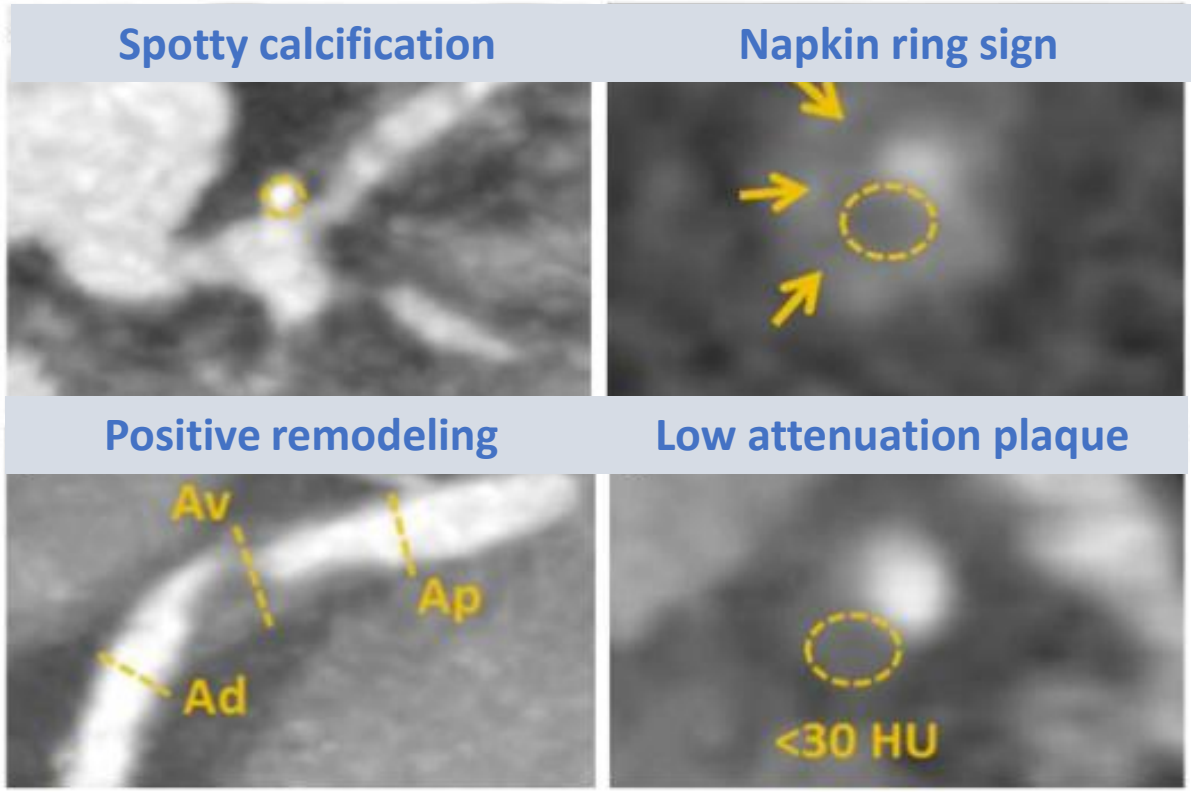
High risk plaque on CCTA

The *vulnerable* plaque



High-risk plaque (HRP) on CCTA

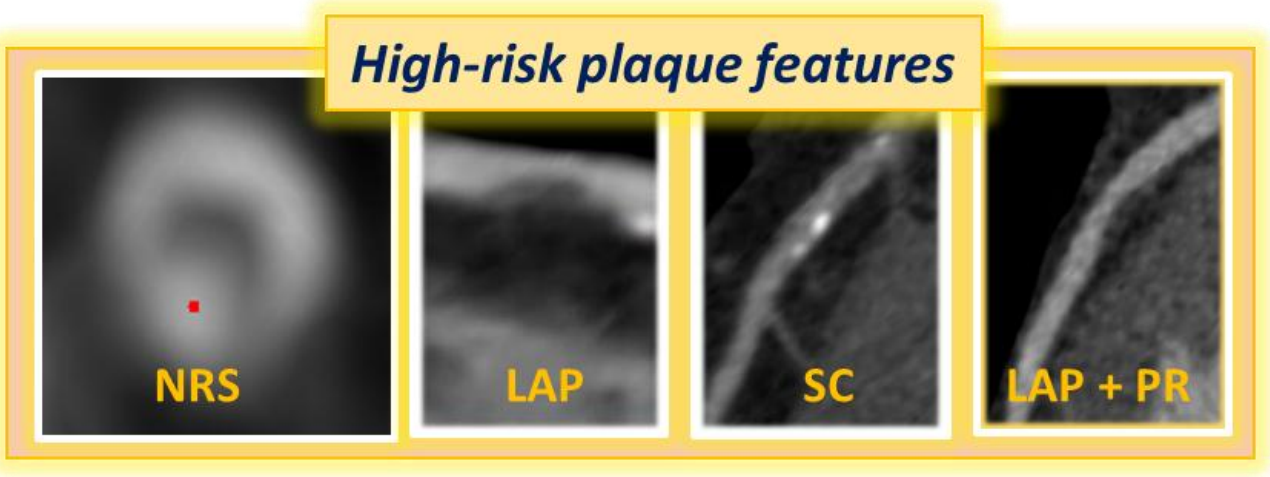
2 or more features



CAD-RADS 2.0–2022

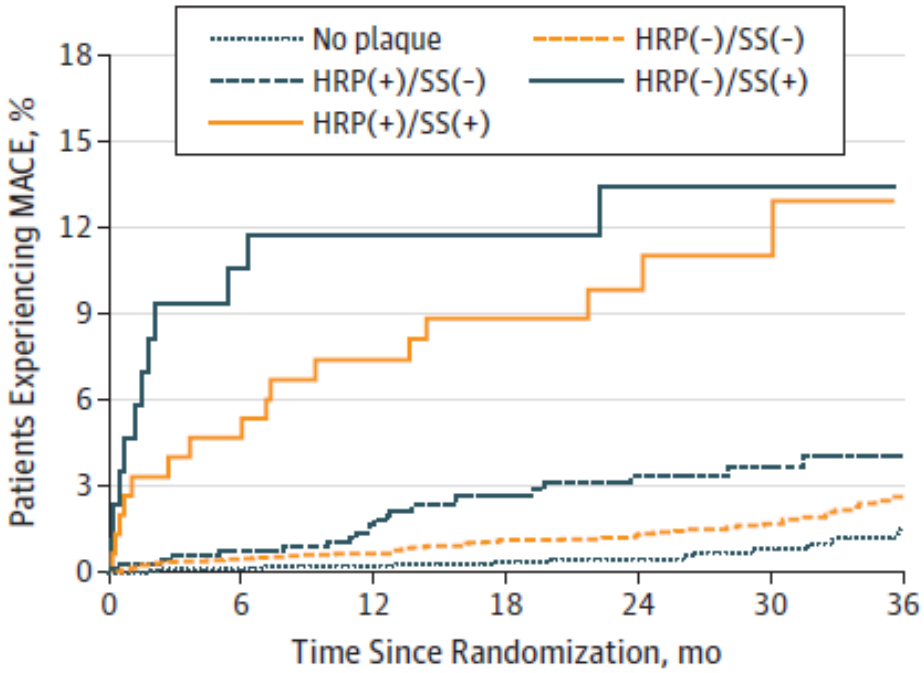
Coronary Artery Disease-Reporting and Data System

High-risk plaque on CCTA and risk stratification



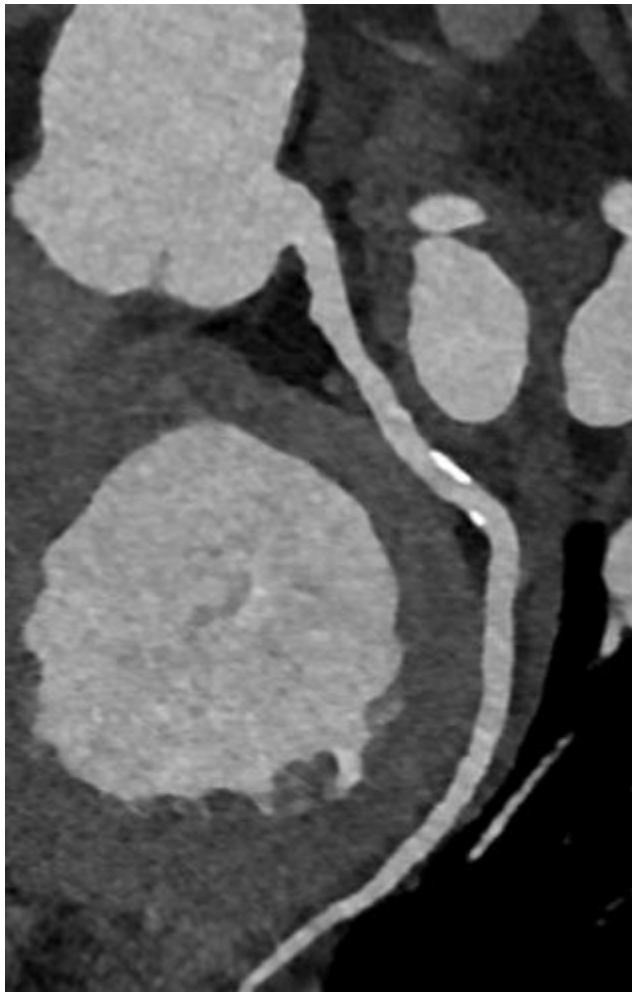
Frequent > 30%
Low positive predictive value

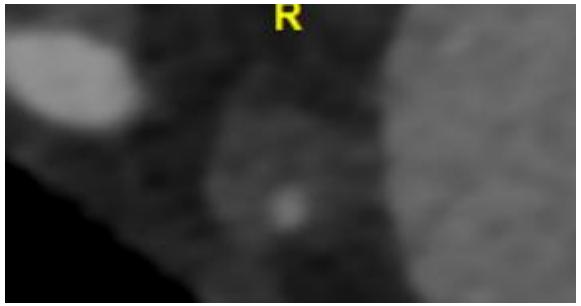
PROMISE study 4,415 pts
CCTA + plaque phenotyping



Ferencik et al JAMA Cardiology 2018

Unprecedented image CCTA quality with Photon Counting CT



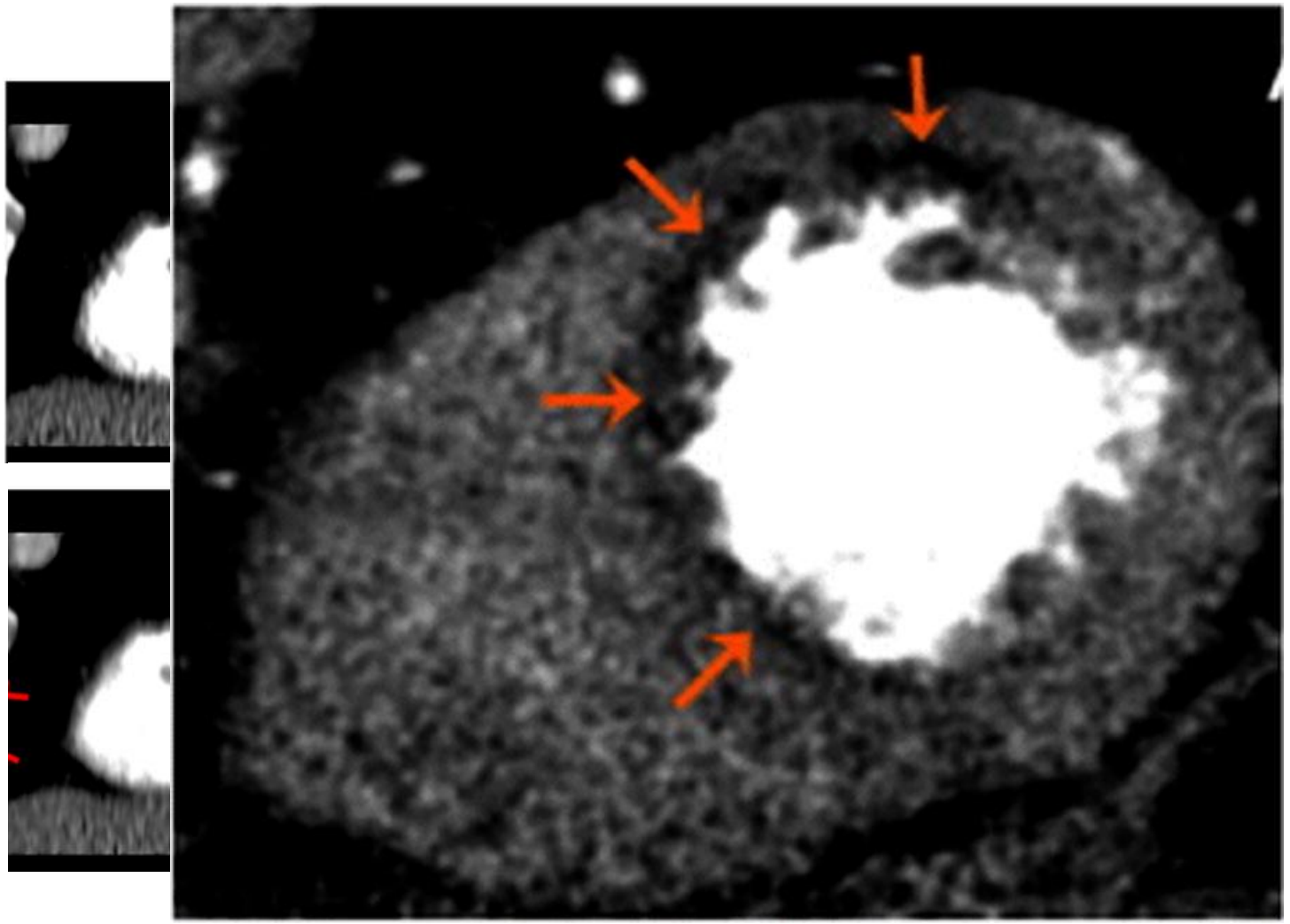


- **Ultra high-quality images**
- **No limitations from calcium / stents**
- **Capacity for tissue characterization**
- **<0.5 sec**

courtesy of Prof. Antoniades (University of Oxford)

Functional assessment of plaques by CT

CT-perfusion imaging for ischaemia detection



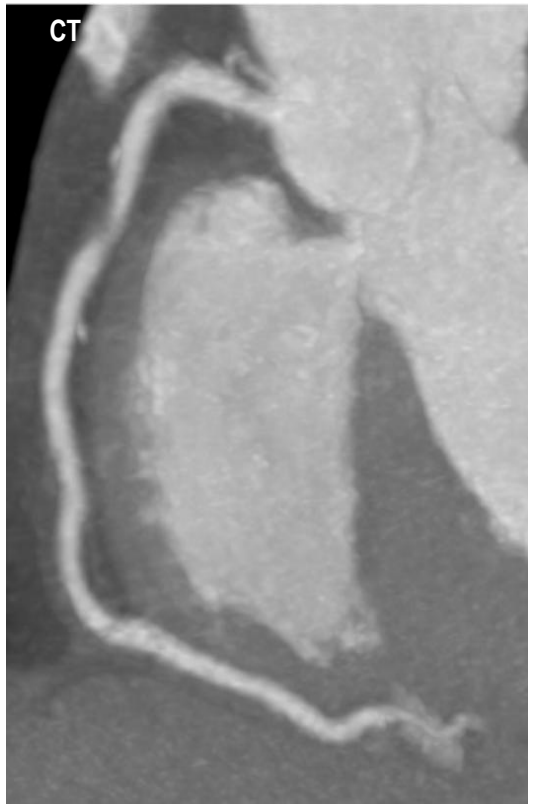
Strengths

- Good diagnostic accuracy for ischaemia

Limitations

- Repeated scanning
- High radiation dose
- Scan logistics
- Limited clinical adoption
- Consensus on scanning acquisition details

FFR-CT for functional assessment of stenoses on CCTA



[redacted]

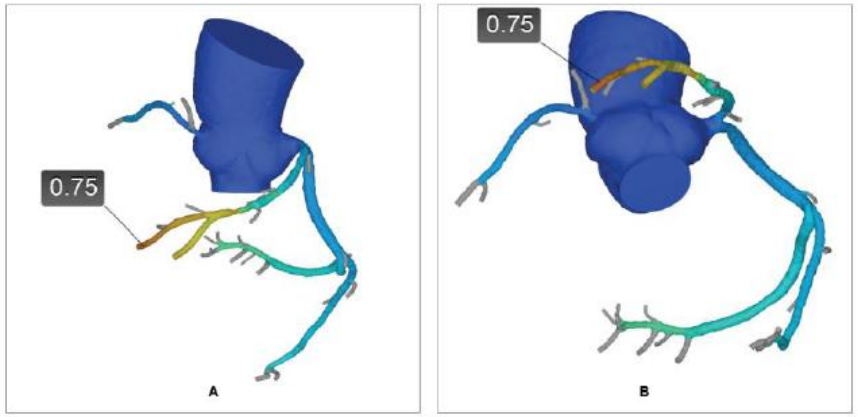
Patient ID 29-0070-G-C
Birth Date *Not provided*
CT Study Date 1/14/2014

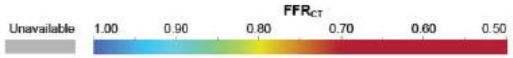
Summary

CORONARY ARTERY		FFR_{CT}
Left Main	LM	0.98
Left Anterior Descending System	LAD	0.75
Left Circumflex System	LCx	0.86
Right Coronary Artery System	RCA	0.94

FFR_{CT} 1.00 0.90 0.80 0.70 0.60 0.50

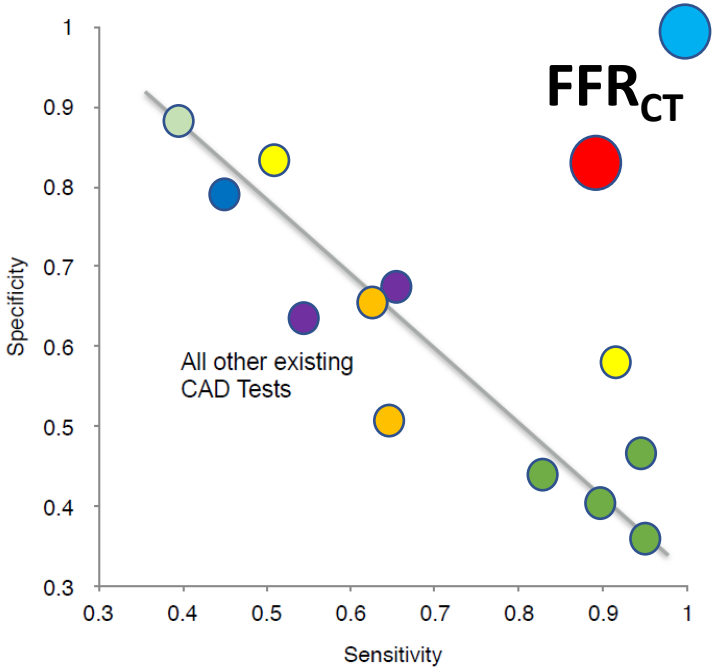
Measured Fractional Flow Reserve (FFR) values ≤ 0.80 suggest hemodynamic (functional) significance (1,2,3).





CCTA
CCTA+TAG
CMR
Stress echo
ICA - QCA
IVUS

FFR (Gold standard)



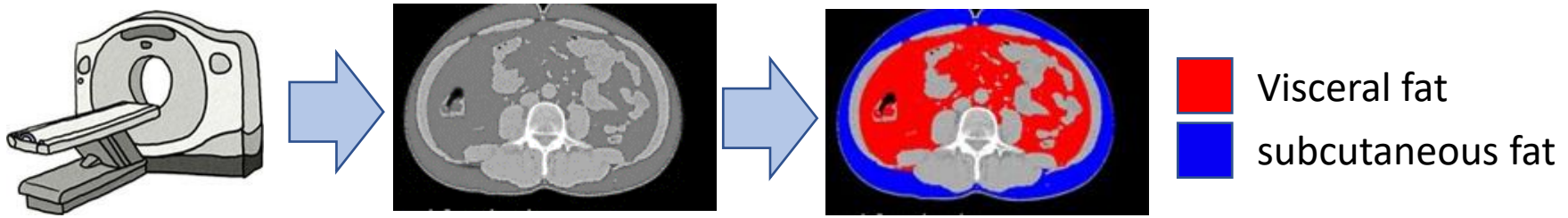
Danad et al. EHJ 2016

Assessing cardiometabolic risk by CT imaging

Visceral vs. abdominal fat and cardiovascular disease risk

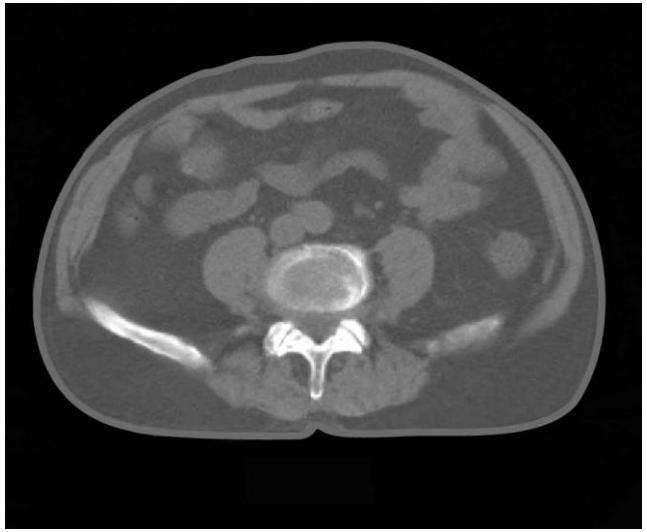
CT imaging of abdominal fat

Fat: -190 to -30 HU



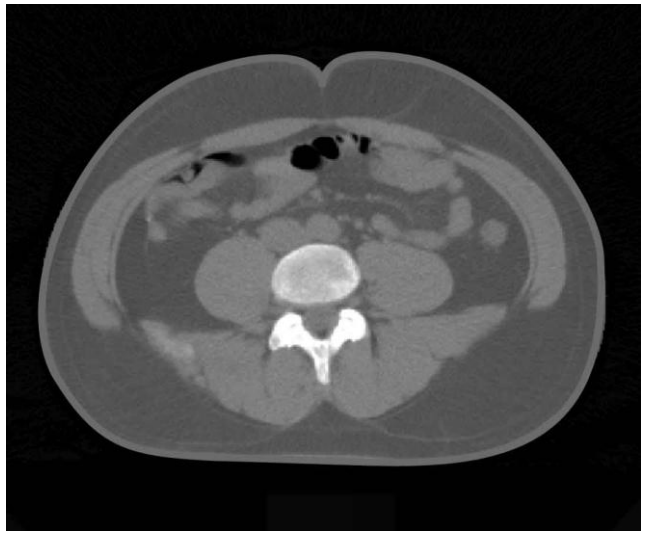
Same WC but different fat distribution

Case 1



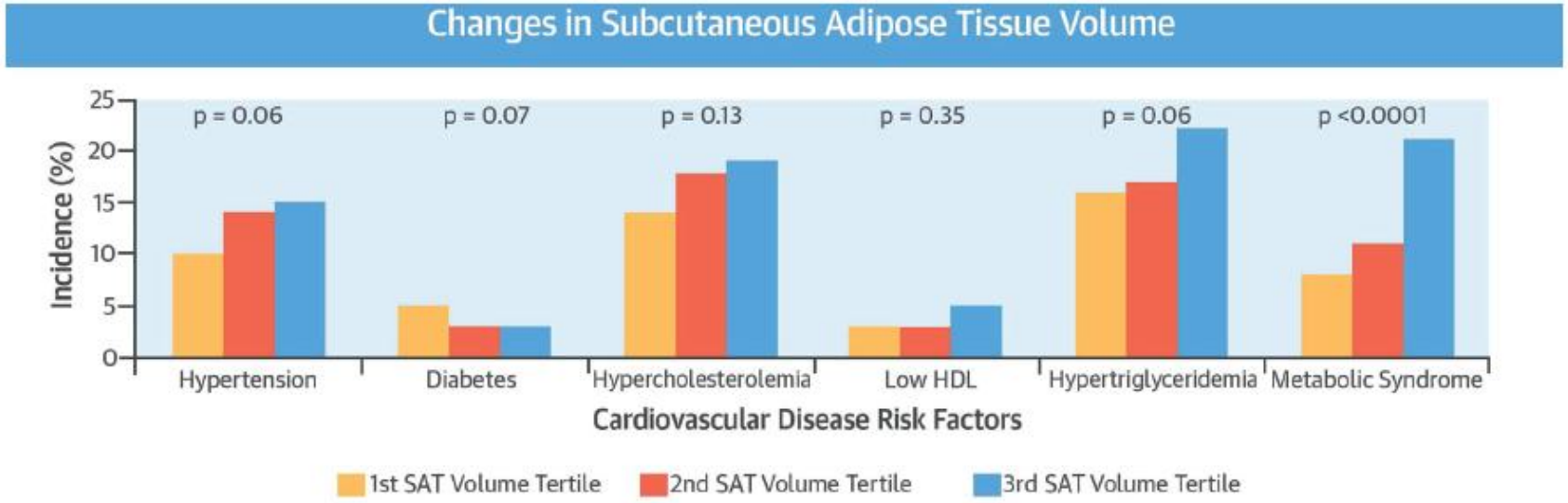
- **Waist Circumference: 91 cm**
- **Intra-abdominal Fat: 190 cm^2**
- **Subcutaneous Fat: 162 cm^2**

Case 2



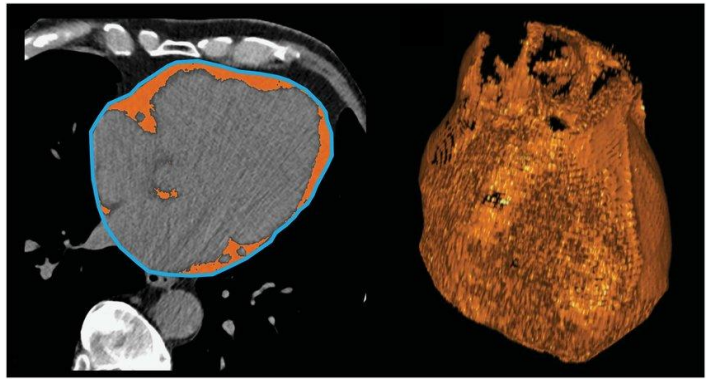
- **Waist Circumference: 93 cm**
- **Intra-abdominal Fat: 98 cm^2**
- **Subcutaneous Fat: 274 cm^2**

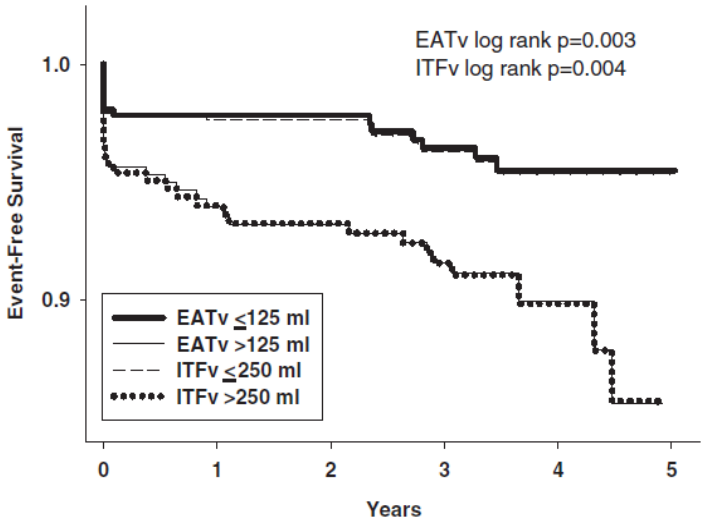
Visceral vs. abdominal fat and cardiovascular disease risk



Ectopic adiposity and cardiovascular disease risk

Epicardial adiposity

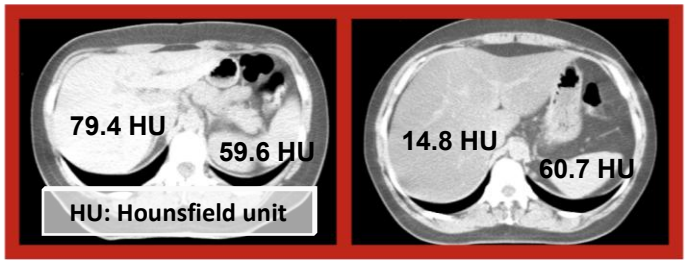




Forouzandeh Circ Cardiovasc Imaging. 2013;6:58-66.

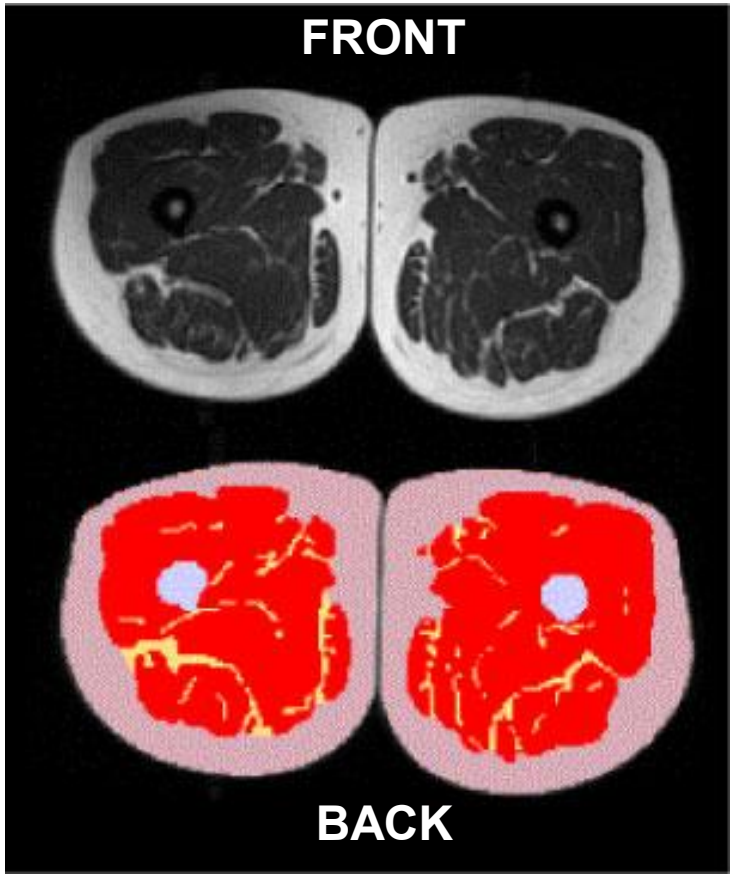
Fatty liver

Mean Liver Attenuation Value / Mean Spleen Attenuation Value → **CTL/CTS ("Fatty Liver" Index)**



Normal Liver	"Fatty Liver"
CTL/CTS = 1.33	CTL/CTS = 0.24

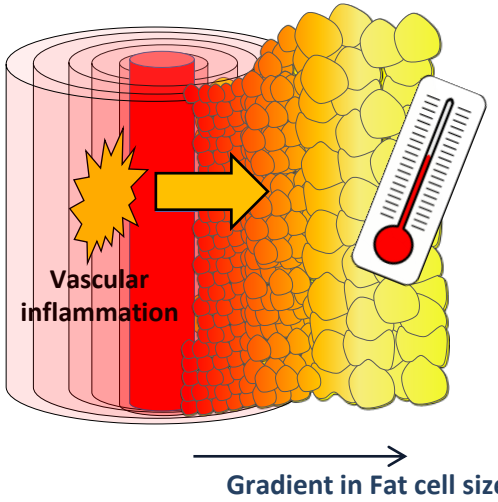
Intramuscular fat



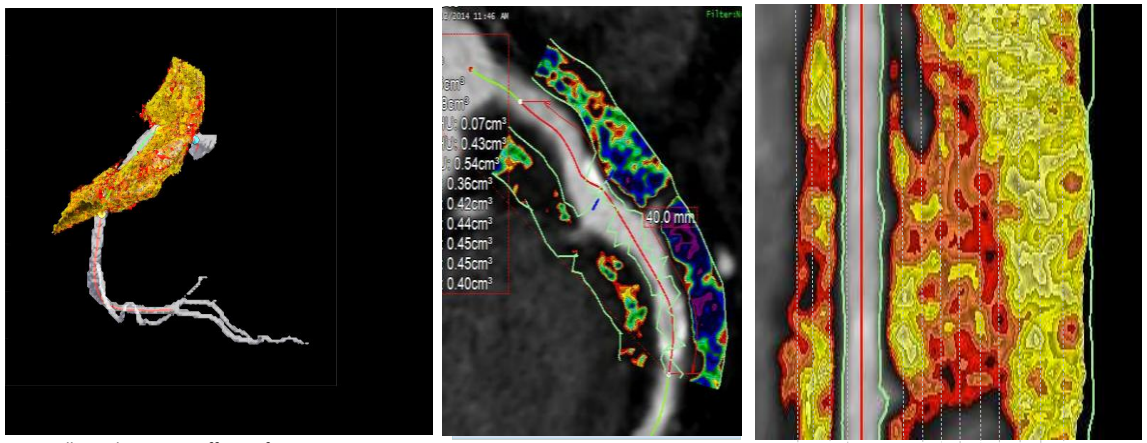
Han et al. Cardiovasc Diabetol (2017) 16:54

Detecting vascular inflammation by perivascular fat imaging

Perivascular fat as a sensor of coronary inflammation

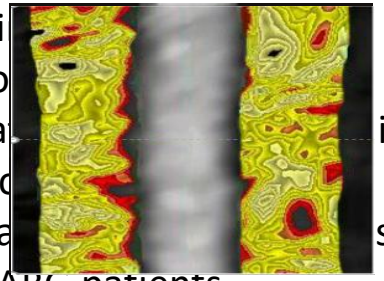
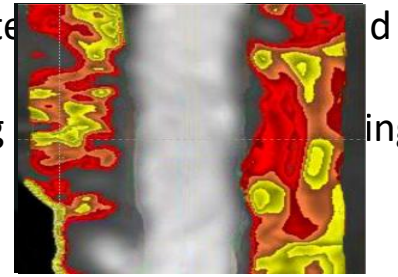


Perivascular Fat Attenuation Index (FAI$_{PVAT}$)

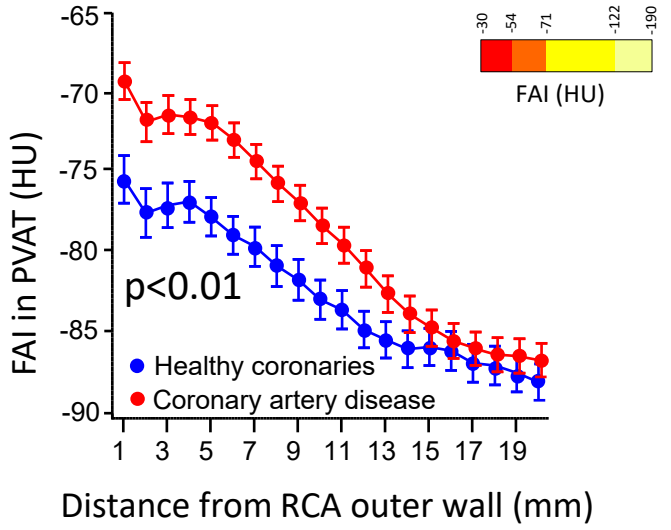


UK Intellectual Property Office, ref. 1414496.8, August 2014

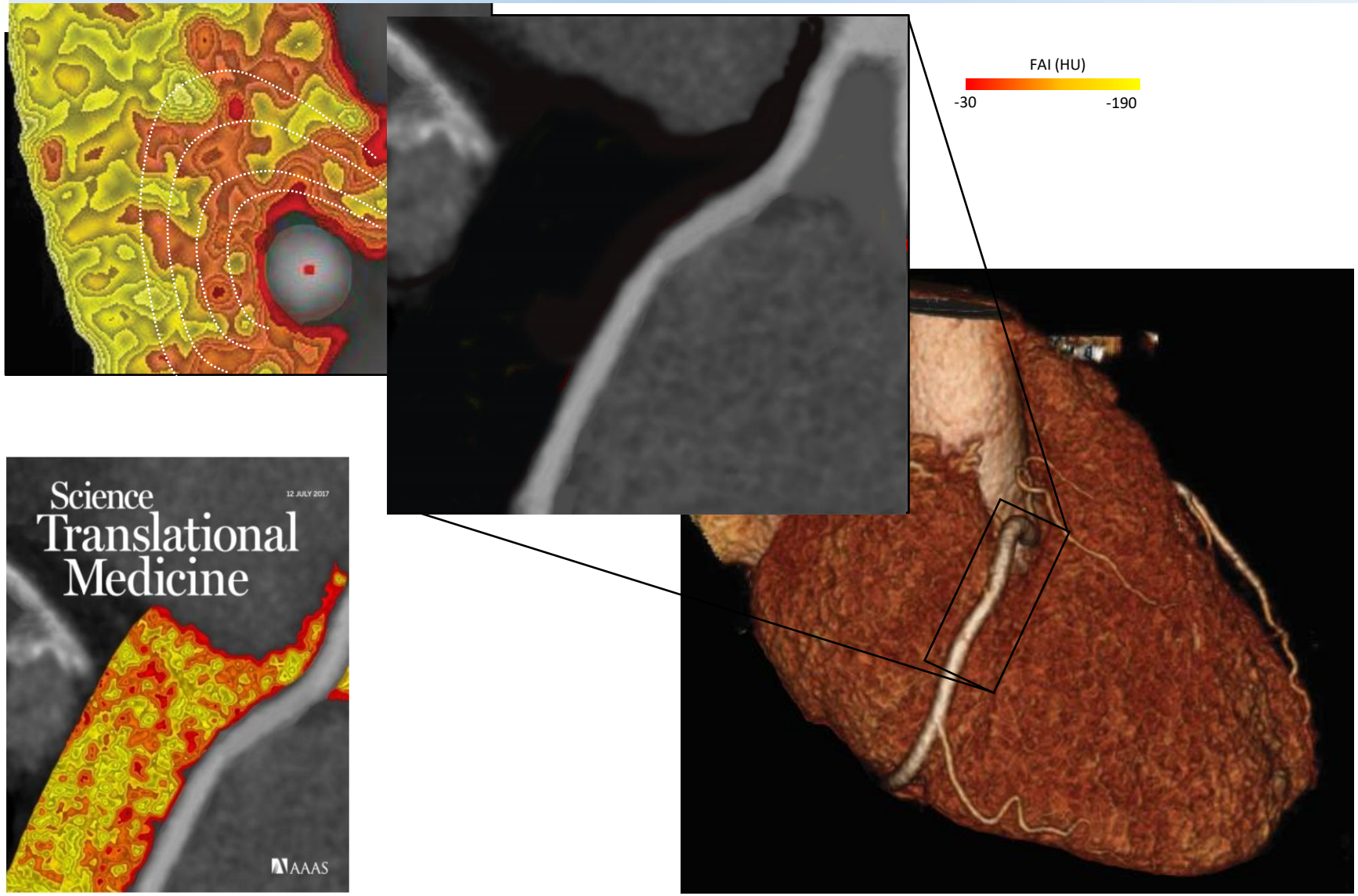
Low FAI **High FAI**

3D mappi  inte  d the
human co
Mathema ing ing with
Images fr
- ✓ 1400 a s
- ✓ 902 CABG patients
- ✓ 4273 CTAs (CAD, ACS, "healthy" coronaries)

Antonopoulos A, Sanna F et al. *Science Translational Medicine 2017*

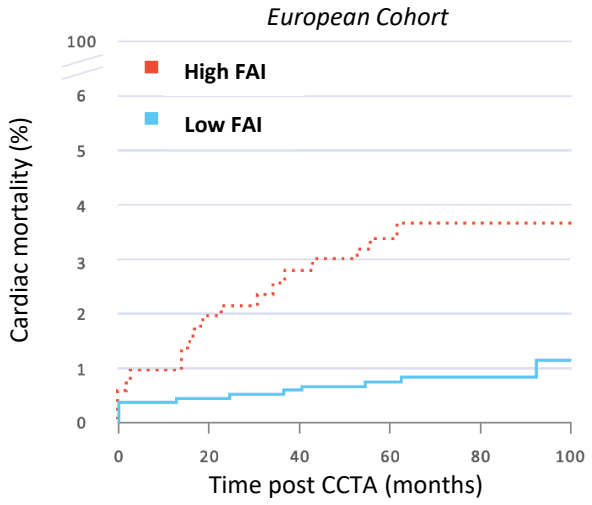


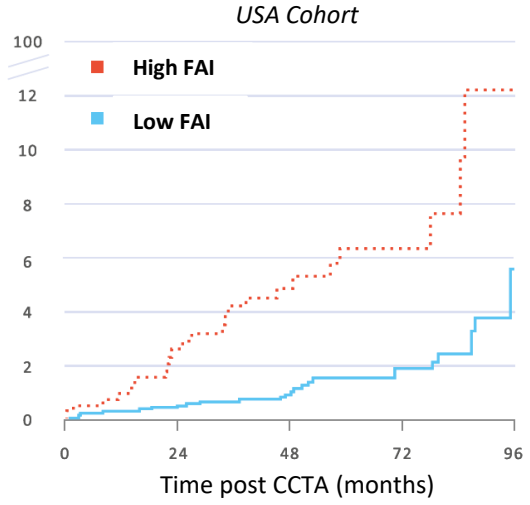
Perivascular fat as a sensor of coronary inflammation

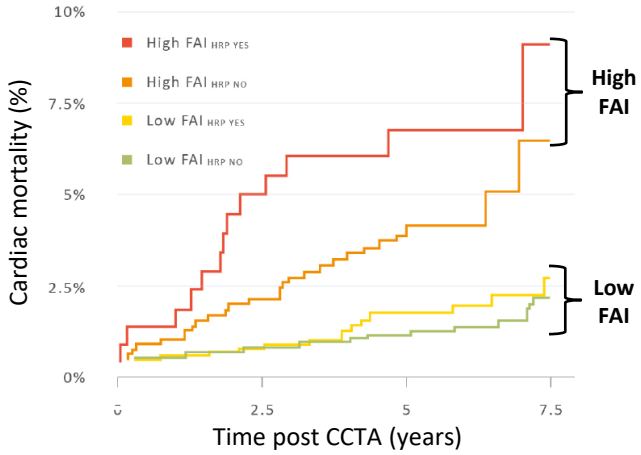


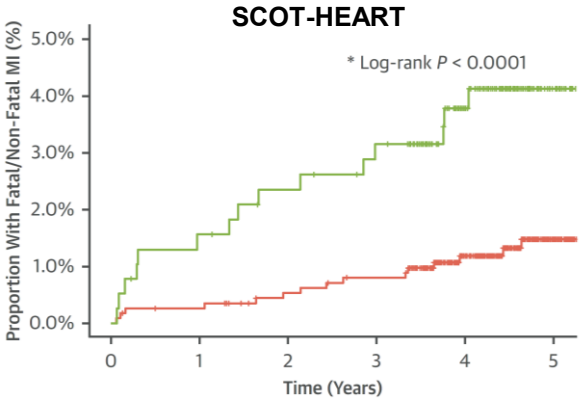
Antonopoulos A, Sanna F et al. *Science Translational Medicine 2017*

FAI Predicts Future Heart Attack Risk









CRISP-CT Study Design [1]

- 4000 participants from Europe and US
- Up to 10 years follow up

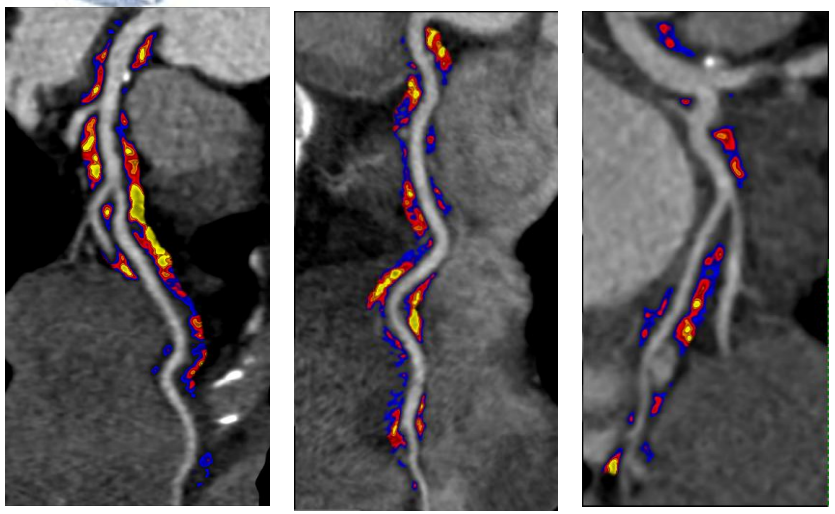
CRISP-CT Findings

- Abnormal FAI associated with a
  - **6-9x** higher risk for **fatal heart attacks**
  - **5x** higher risk for **non-fatal heart attacks**
- After adjusting for all conventional risk factors (e.g., smoking, age, diabetes, high cholesterol)
- FAI is more predictive of future heart attacks than high-risk plaque (HRP) features [2]
- Findings confirmed in SCOT-HEART using uncorrected perivascular attenuation (PCAT) [3]

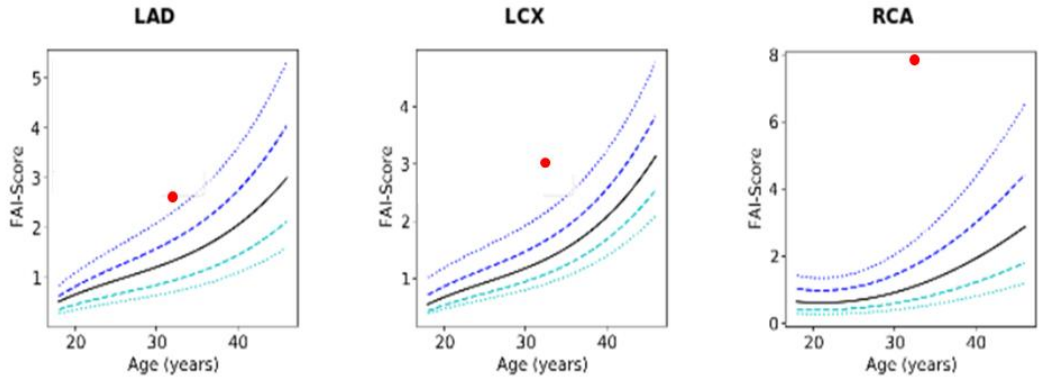
1. *Lancet* 2018; 392: 929–39
2. *J Am Coll Cardiol* 2020; 76 (6) 755–757
3. *J Am Coll Cardiol Img*. 2022, 15 (6) 1078–1088

Measuring FAI-Score Identifies High Risk Patients

CASE A

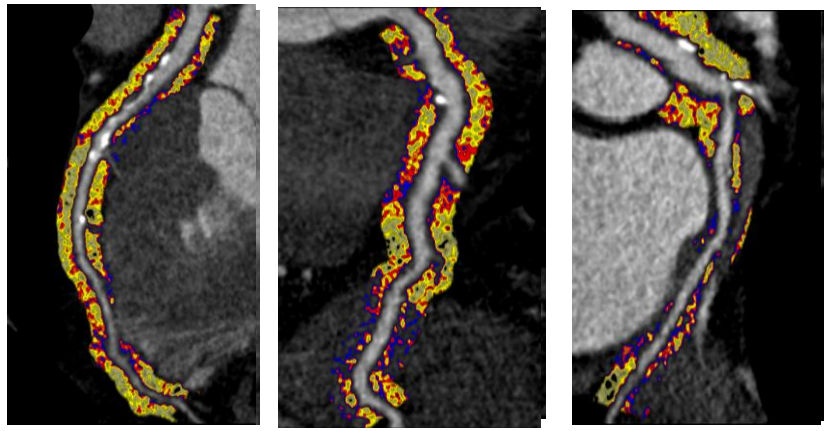


CaRi-Heart® Risk (8y risk for cardiac death: 31.2%

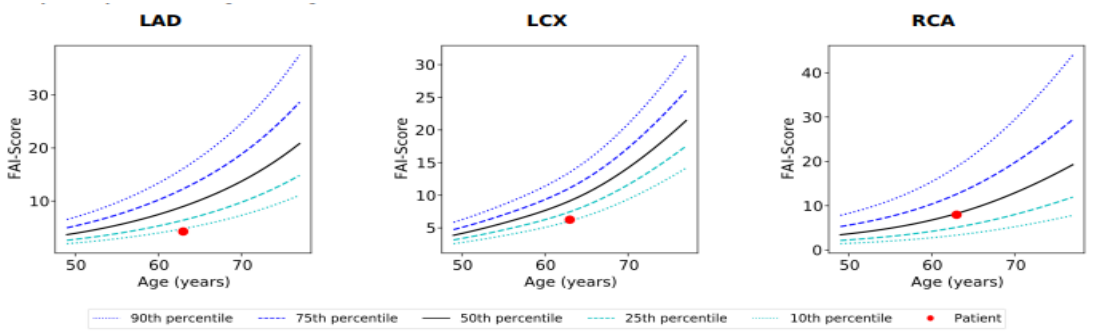


Vessel	FAI-Score	Percentile of Coronary Inflammation for Age and Gender
Left Anterior Descending Artery	2.7	93rd percentile
Left Circumflex Artery	3.0	99th percentile
Right Coronary Artery	7.7	99th percentile

CASE B



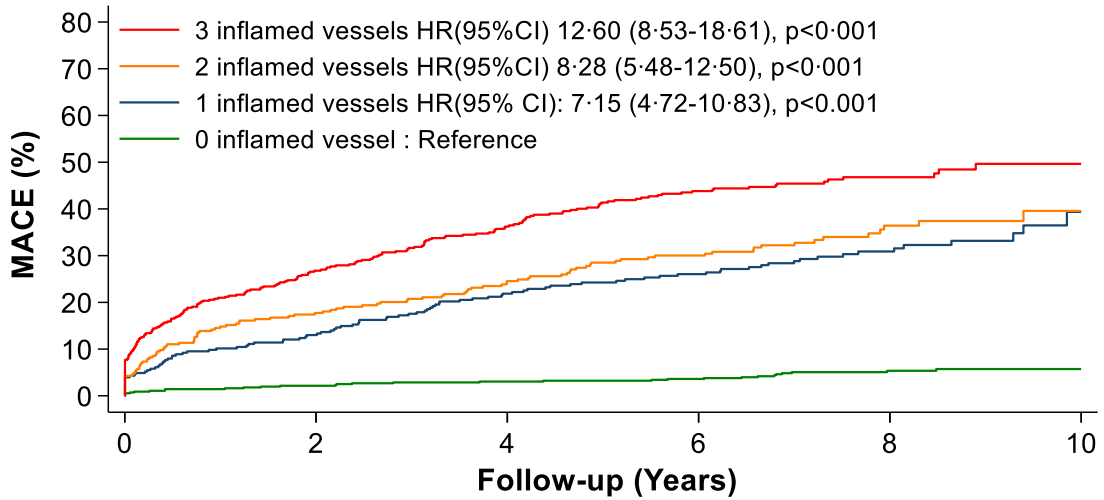
CaRi-Heart® Risk (8y risk for cardiac death: 9.8%



Vessel	FAI-Score	Percentile of Coronary Inflammation for Age and Gender
Left Anterior Descending Artery	4.2	6th percentile
Left Circumflex Artery	6.3	12th percentile
Right Coronary Artery	7.9	48th percentile

Vascular inflammation for cardiovascular risk prediction (ORFAN)

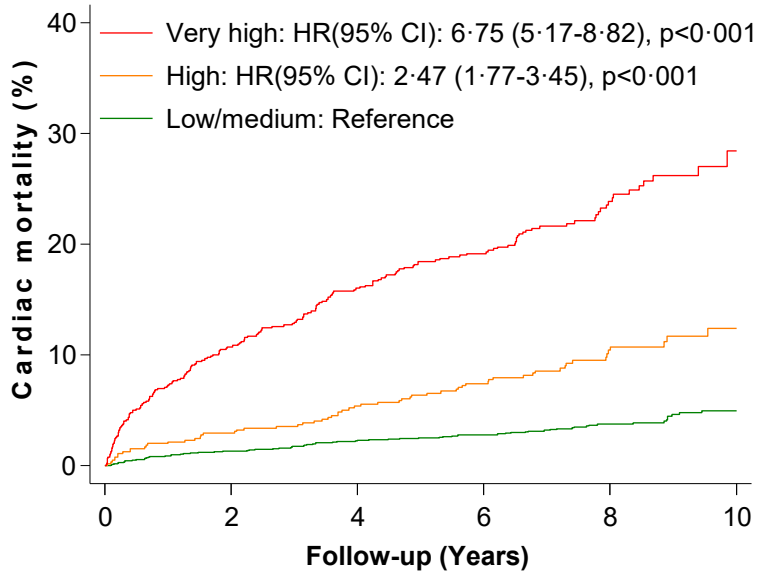
Number of inflamed vessels in predicting MACE



Number at risk

0 inflamed vessel	558	543	534	520	315	85
1 inflamed vessel	328	272	231	203	104	18
2 inflamed vessels	329	249	215	178	76	14
3 inflamed vessels	494	321	254	198	88	14

AI-Risk Classification

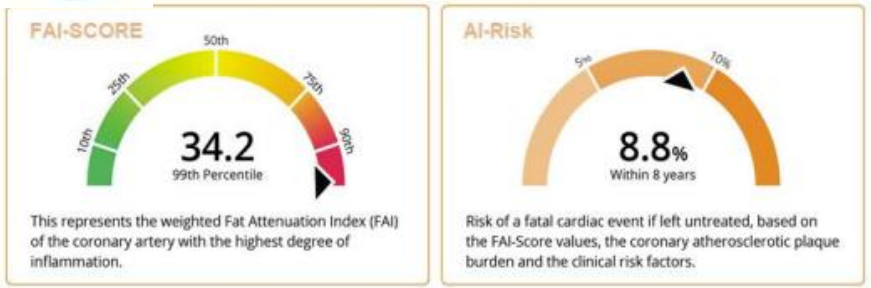


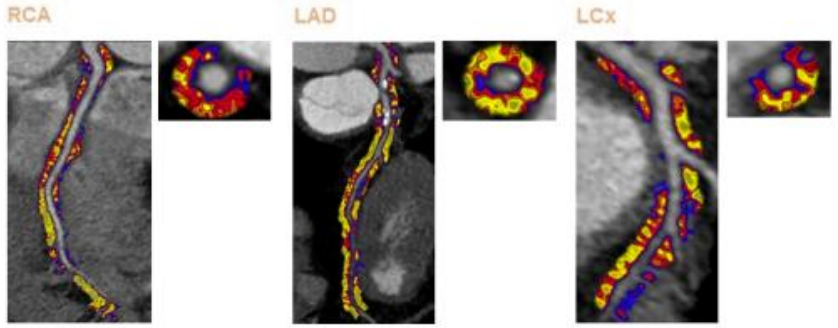
Number at risk

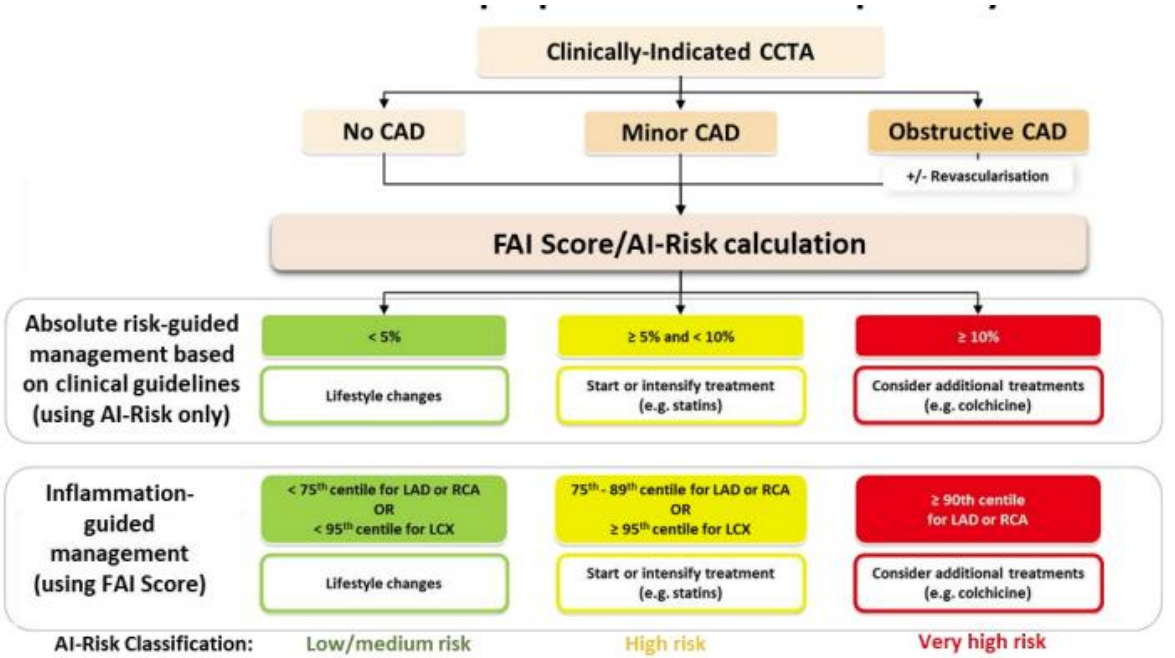
Low/medium:	1,804	1,747	1,693	1,633	956	269
High:	662	617	569	523	295	74
Very high:	913	736	639	544	240	47

Chan et al. The Lancet 2024

Imaging of coronary inflammation by pericoronary fat (AI-Risk)

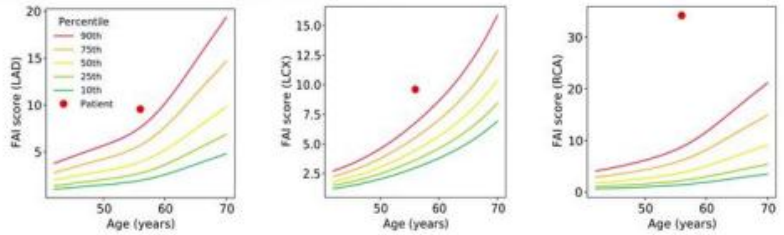






B

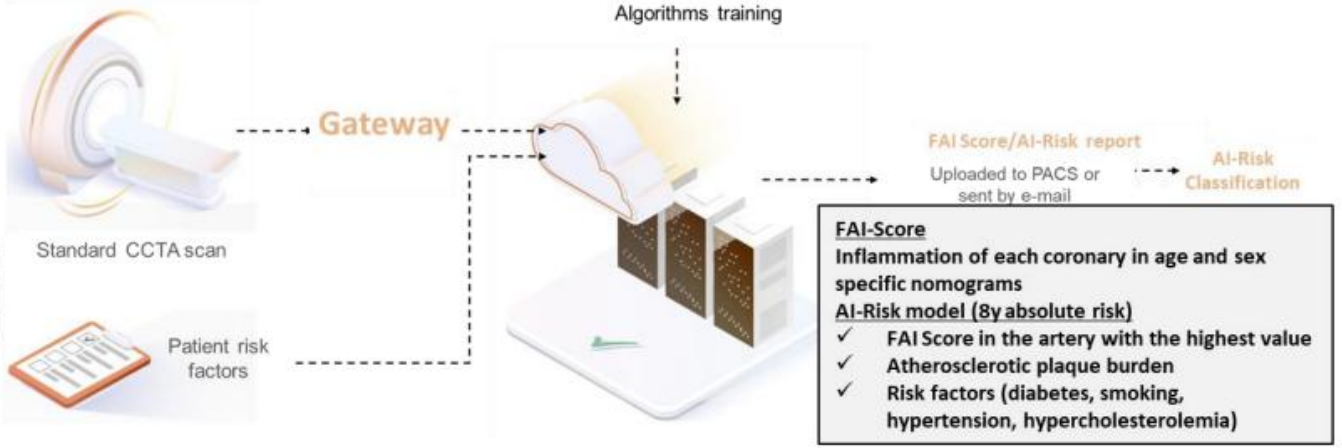
FAI-SCORE - RELATIVE RISK, ADJUSTED FOR AGE AND GENDER



Vessel	FAI-Score	Percentile of Coronary Inflammation for Age and Gender
Left Anterior Descending Artery	9.5	95th percentile
Left Circumflex Artery	9.6	99th percentile
Right Coronary Artery	34.2	99th percentile

D FAI Score / AI-Risk delivery

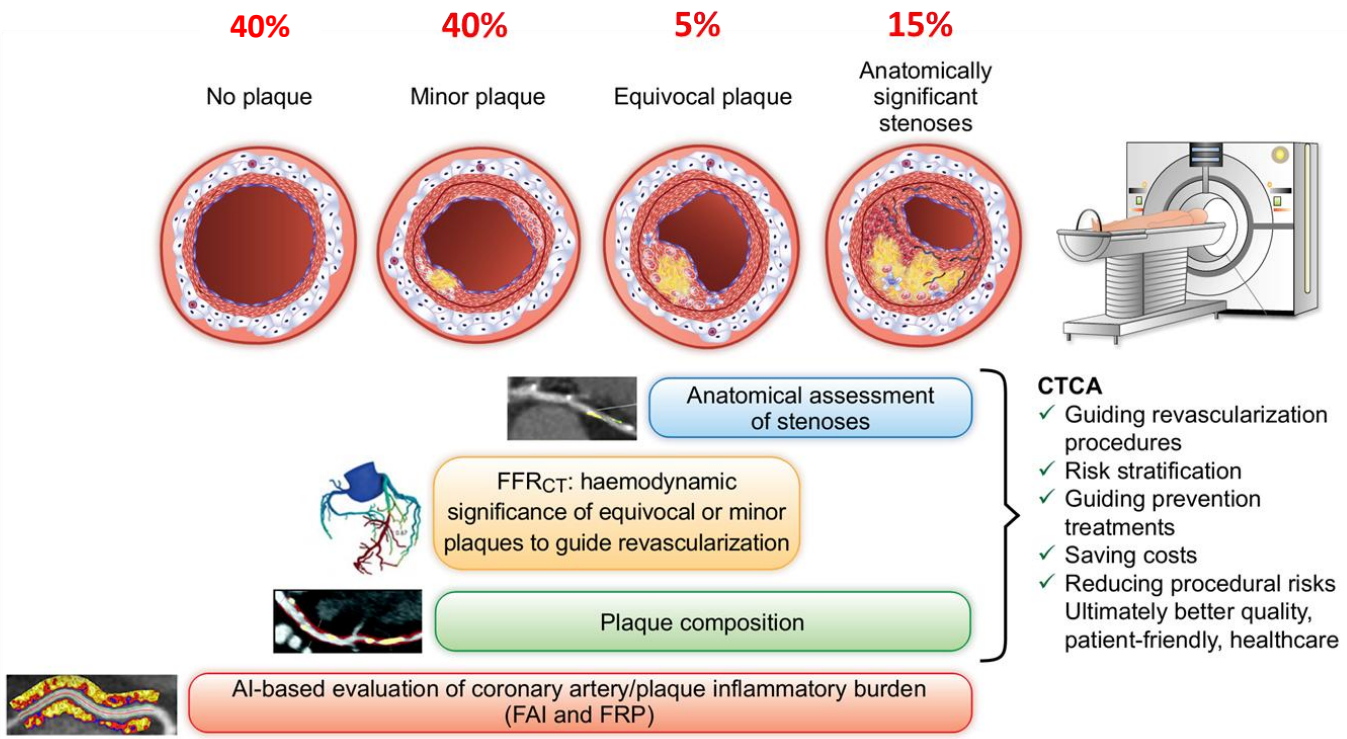
Large, international clinical datasets for Risk Prediction Algorithms training



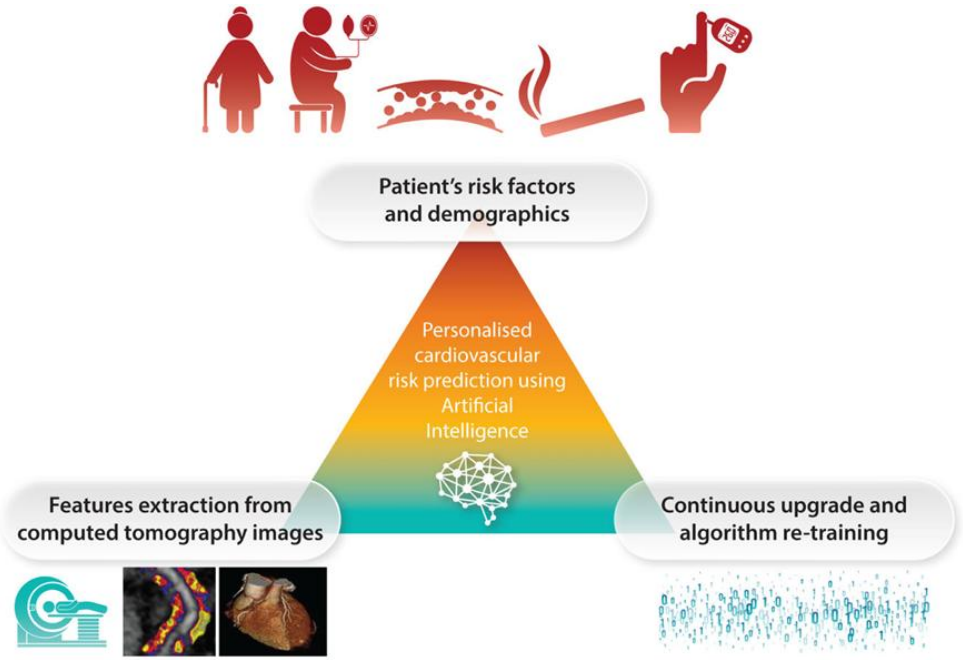
FAI-Score
Inflammation of each coronary in age and sex specific nomograms
AI-Risk model (8y absolute risk)
- ✓ **FAI Score in the artery with the highest value**
- ✓ **Atherosclerotic plaque burden**
- ✓ **Risk factors (diabetes, smoking, hypertension, hypercholesterolemia)**

CTCA: One-Stop-Shop for Coronary Diagnostics

Enhanced Diagnostics

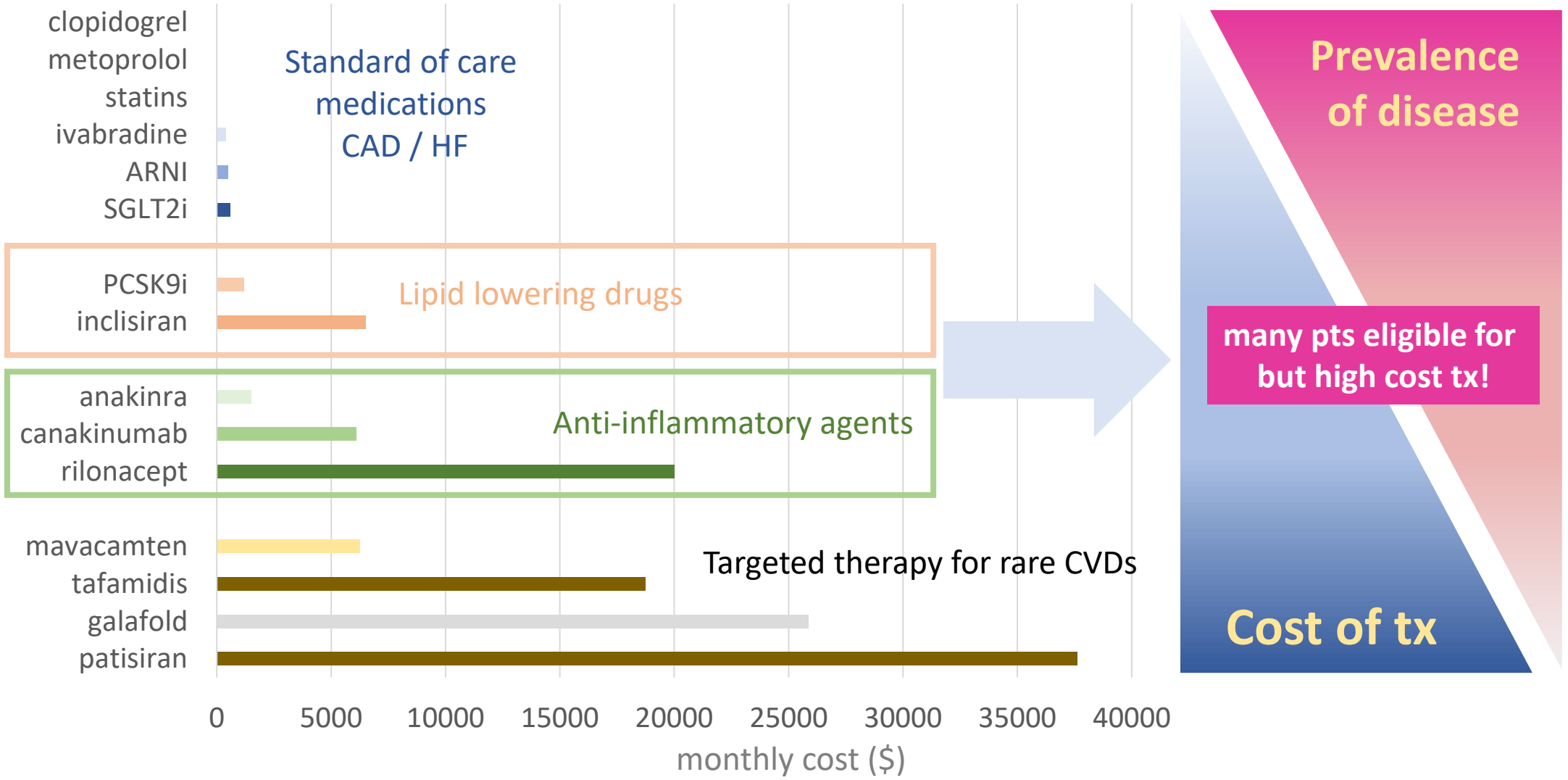


Improved Risk Stratification



Antonopoulos AS et al. Eur J Prev Cardiology 2021
Antoniades & West; Eur Heart J 2021

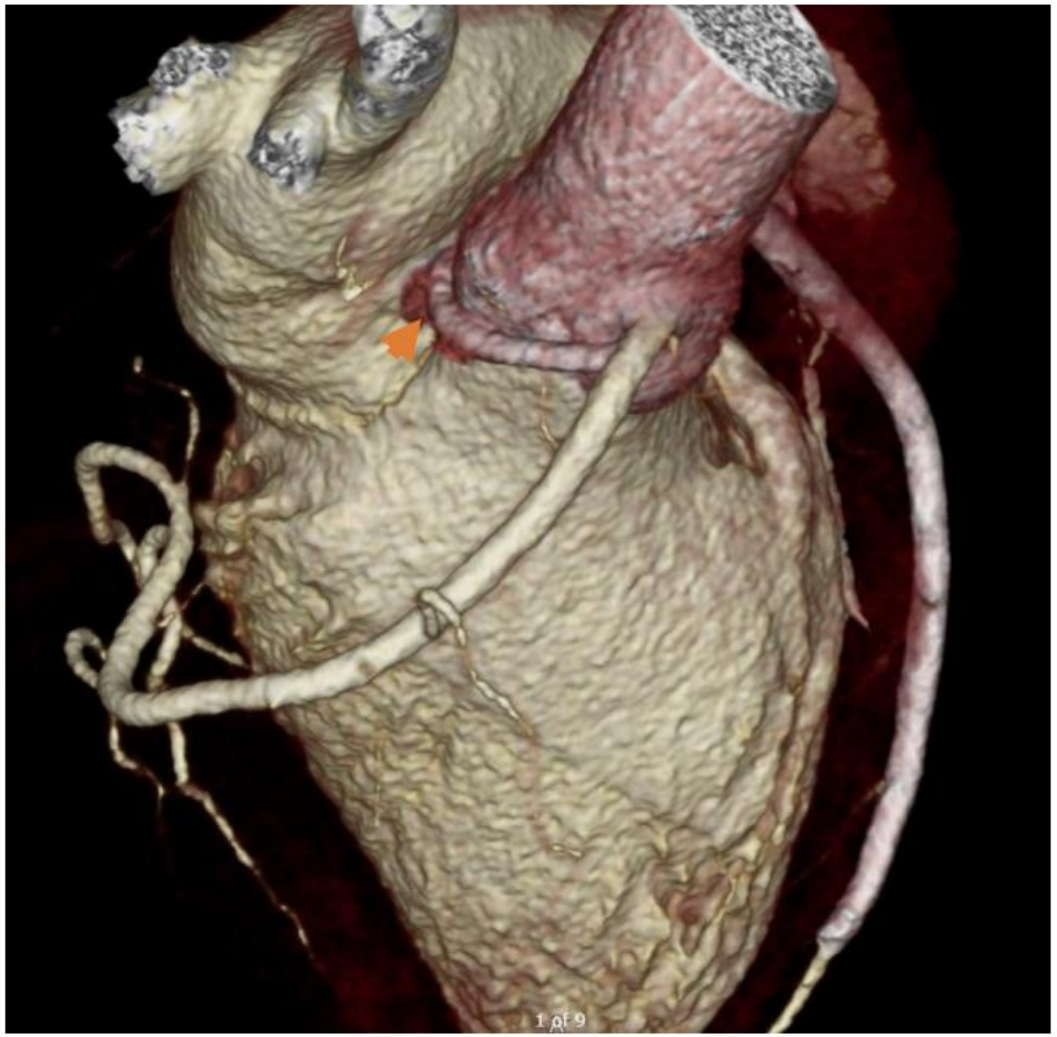
CCTA-guided treatment of coronary atherosclerosis

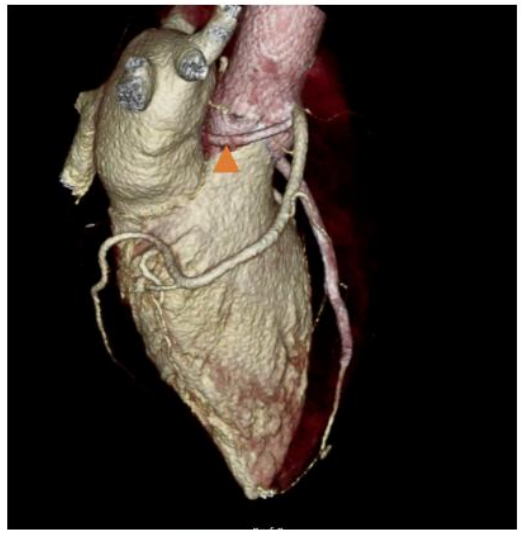


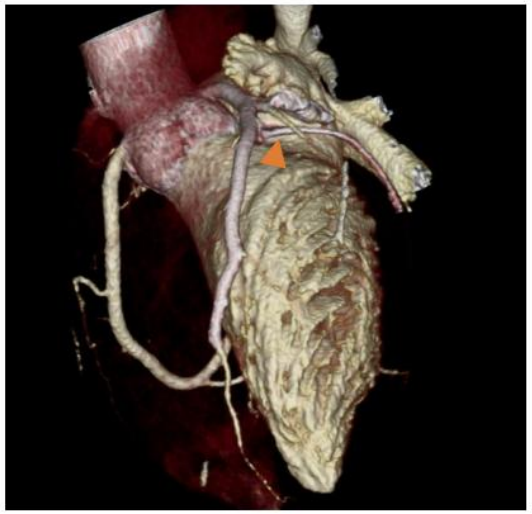
Αλέξιος Αντωνόπουλος
e-mail: antonopoulosal@yahoo.gr

Other uses of CCTA

Anomalous coronary arteries





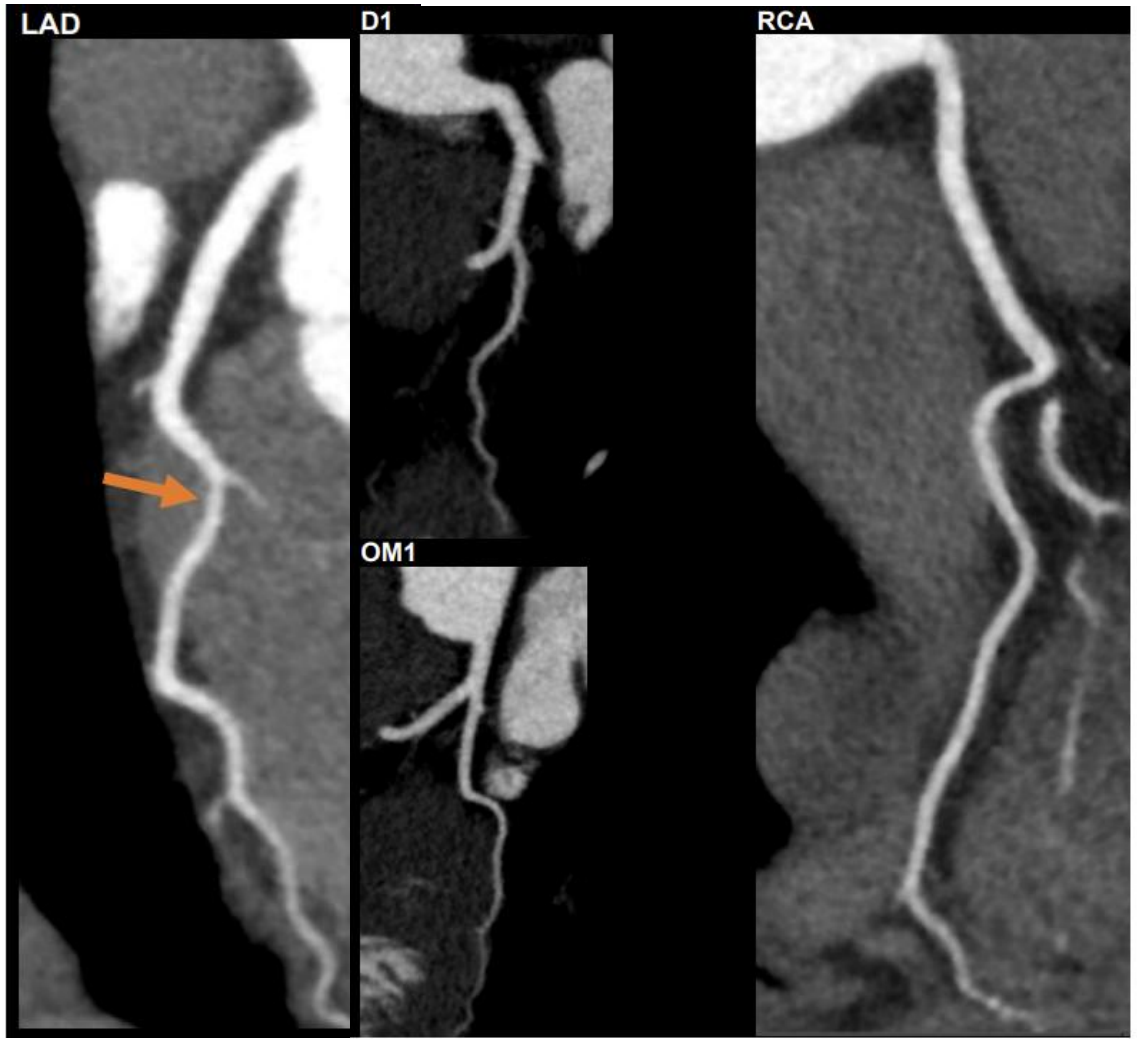


- 19M
- Footballer
- Deepening of inferior TWI on ETT
- Assessment for CAA

- 80keV
- 85DLP
- ~1mSV

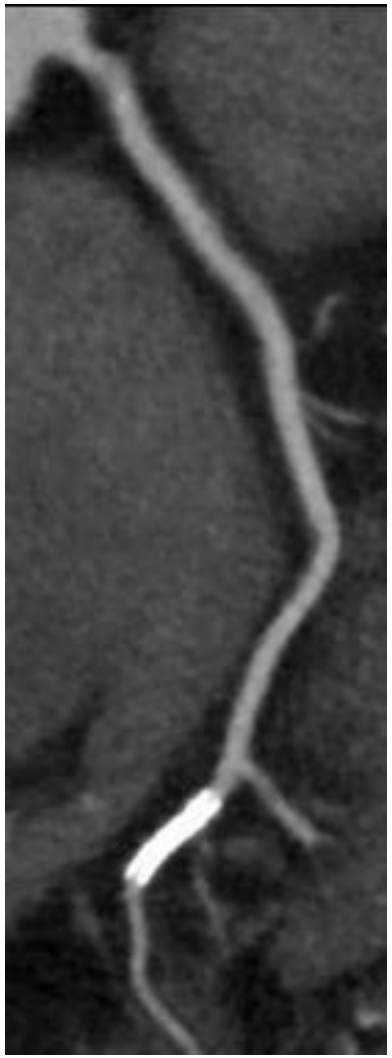
Personal archive

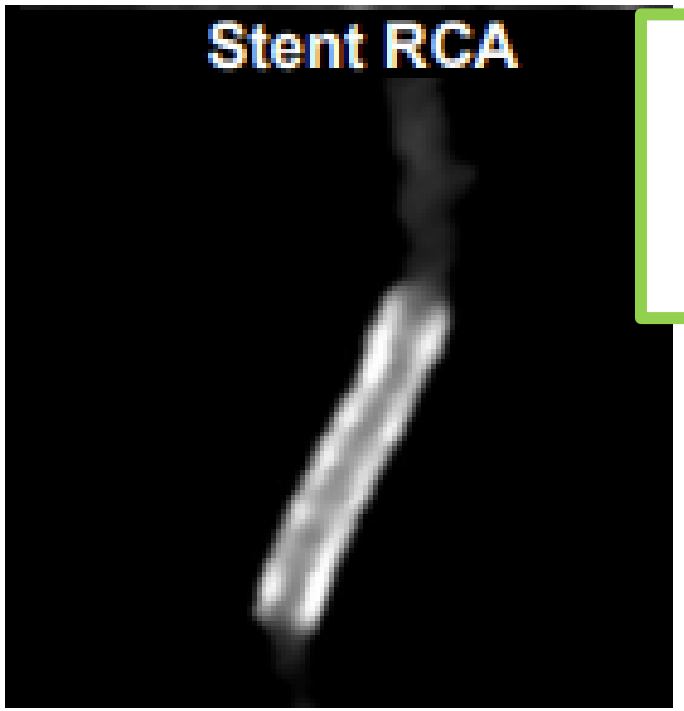
Myocardial bridges



Personal archive

Coronary stents



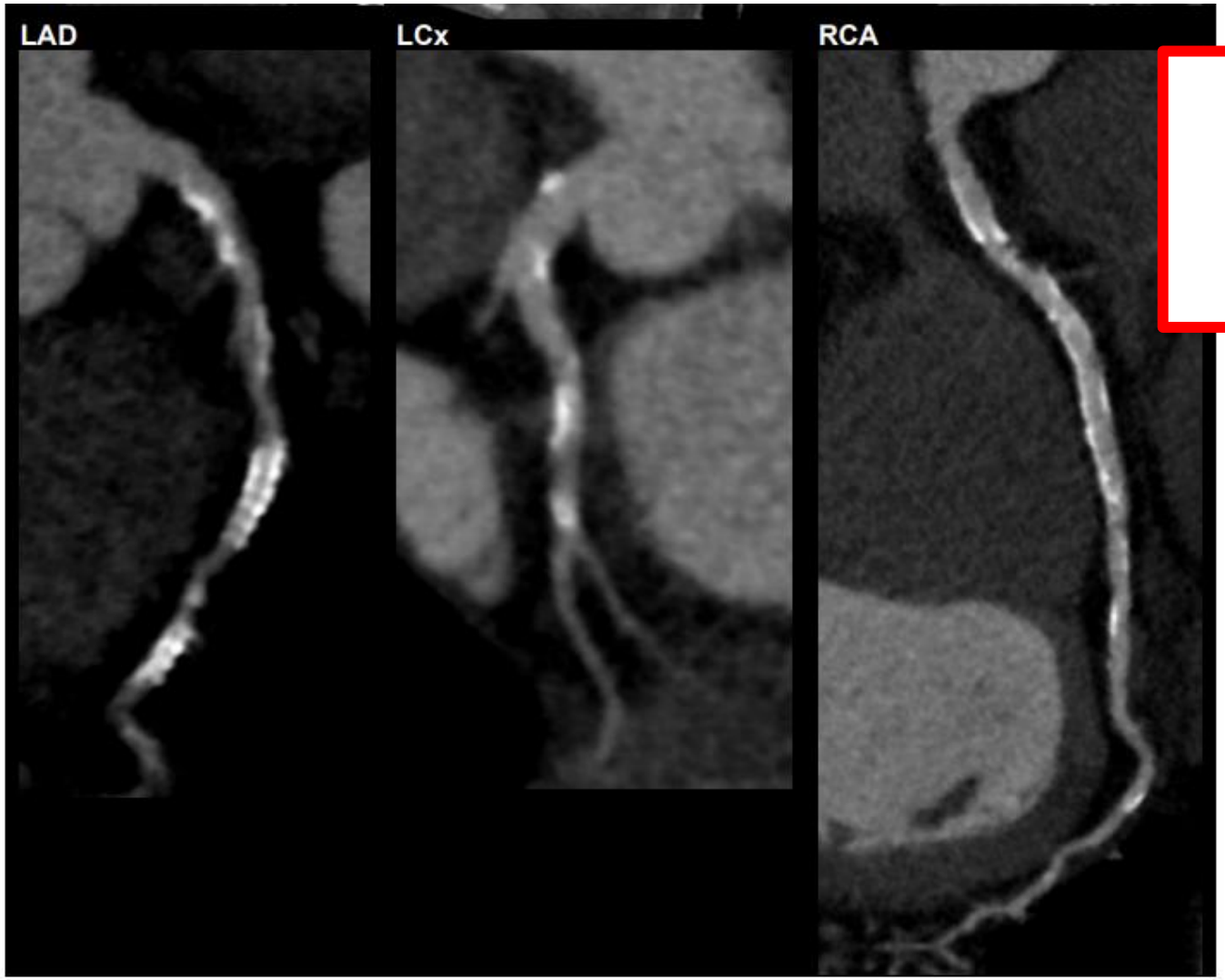


√

- Not the best modality
- OK if proximal, large stents (>3mm)
- Not good for distal, smaller stents

Personal archive

Coronary stents



X

Not the best modality
OK if proximal, large stents (>3mm)
Not good for distal, smaller stents

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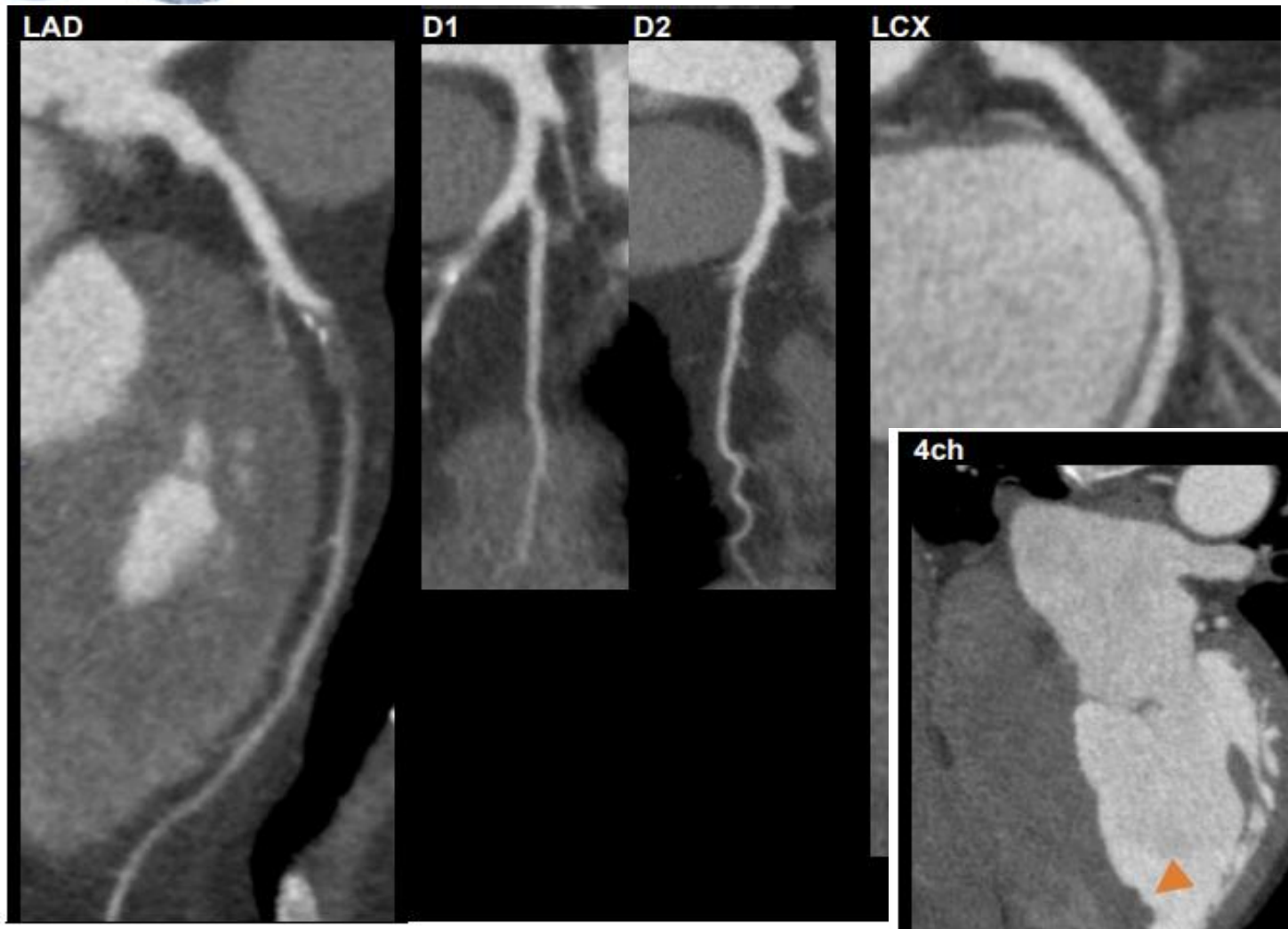
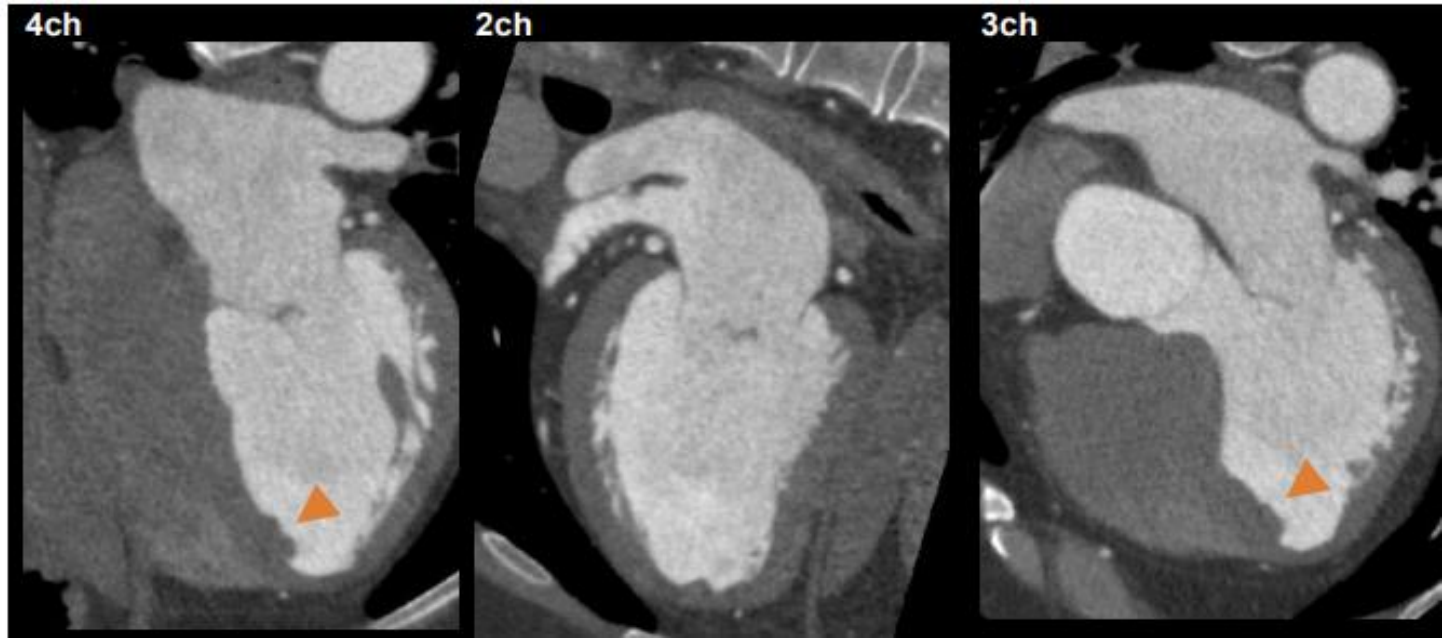
For intervention planning (prior to CABG or PCI)





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