CT Coronary Angiography

Indications, guidelines, patient preparation

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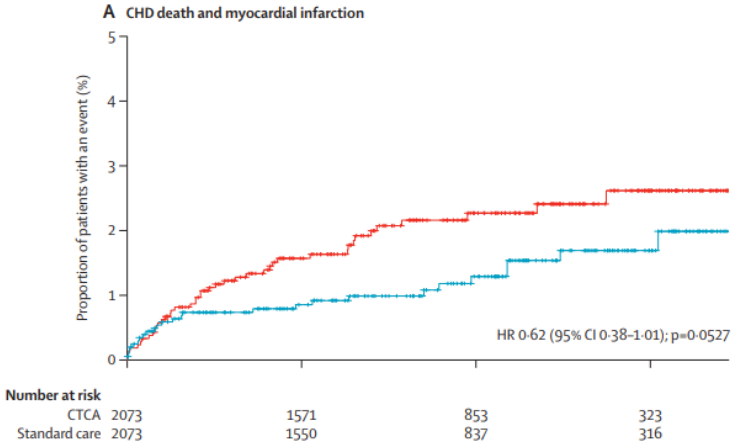
It all began…

SCOT-HEART study

- Suspected angina, standard care + CTCA vs standard care (mostly EET)
- CTCA
  - Reduced need for further test
  - Increased use of invasive angiography
  - Changed treatment regimes
- 38% reduction in CHD death and MI



PROMISE trial

- Stable symptomatic pts CCTA vs functional stress testing
- CTA associated with
  - More IA in 90 days
  - Fewer IA showing no obstructive CAD
- Reduced rates of MI
- No difference in overall mortality

Coronary CT Angiography and 5-Year Risk of Myocardial Infarction

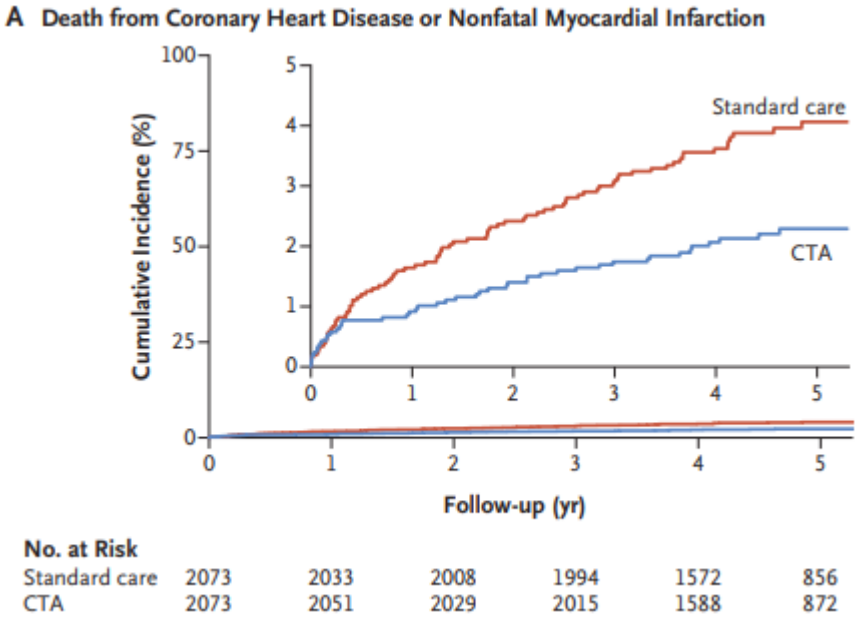
- Similar rates of IA
- More preventive therapies in CTCA group

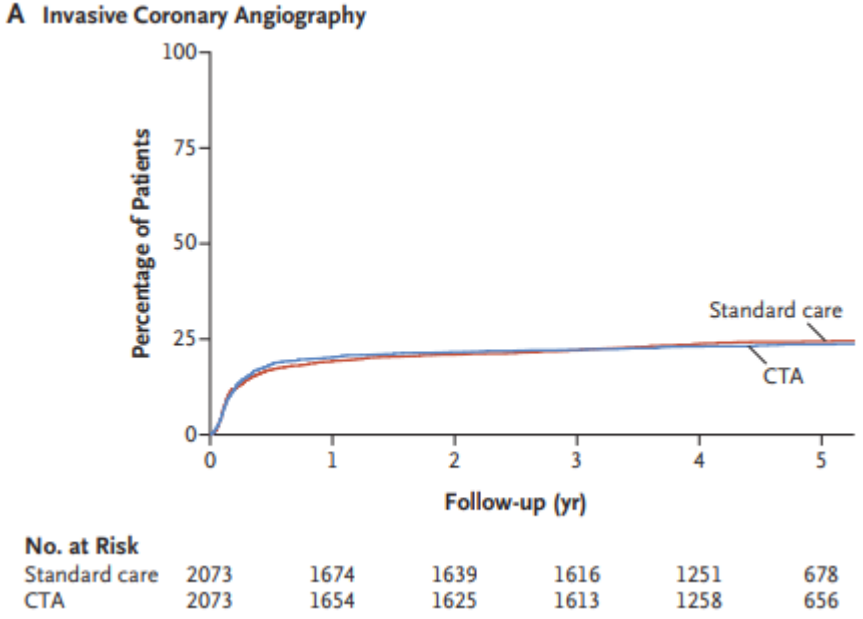
The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Coronary CT Angiography and 5-Year Risk of Myocardial Infarction

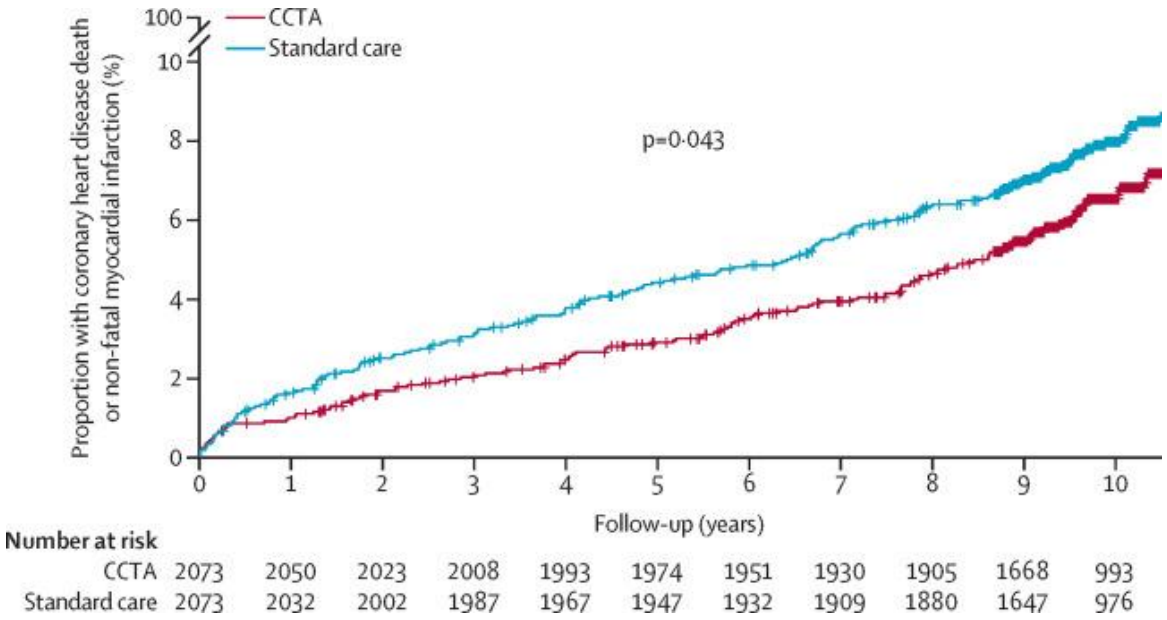
The SCOT-HEART Investigators*

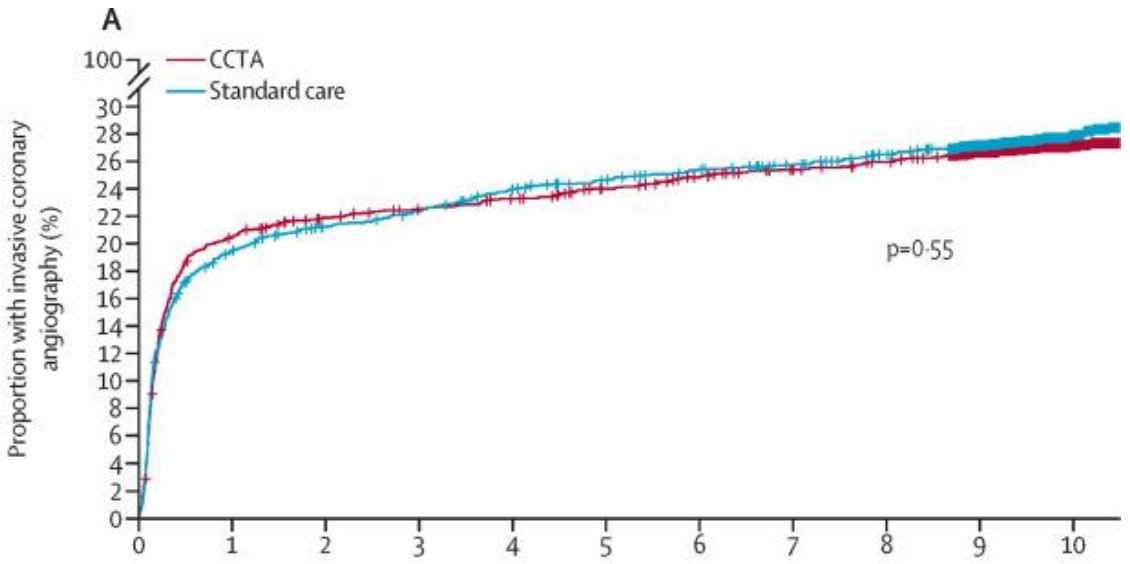




N Engl J Med. 2018 Sep 6;379(10):924-933

10-year outcomes from the SCOT-HEART trial





The Lancet, Volume 405, Issue 10475P329-337January 25, 2025

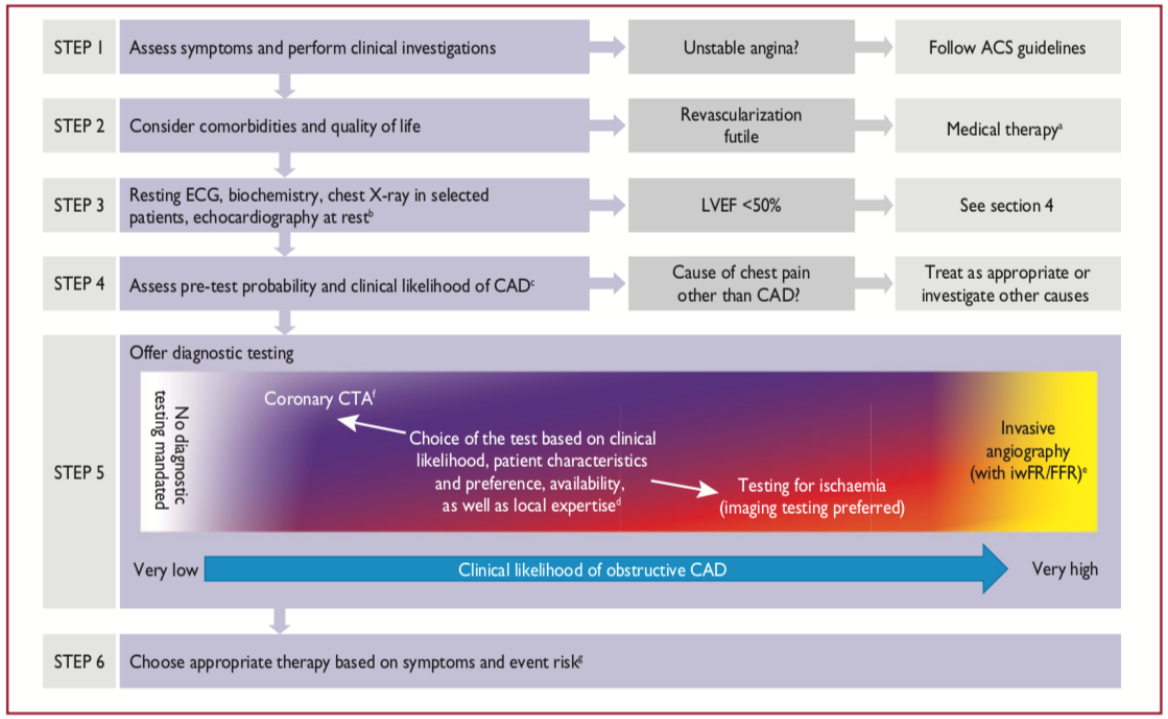
ESC guidelines 2019

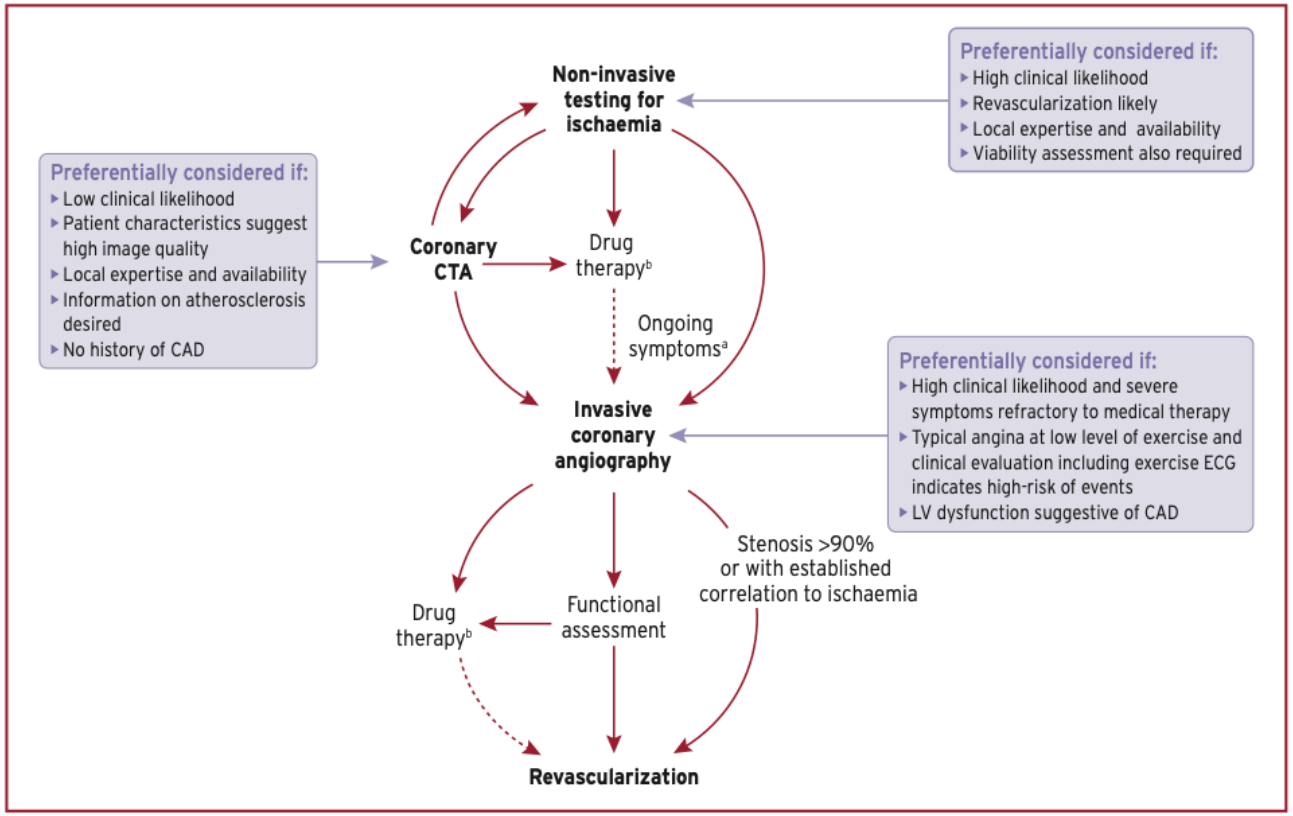
ESC European Society of Cardiology
European Heart Journal (2019) 00, 1–71
doi:10.1093/eurheartj/ehz425
ESC GUIDELINES

2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes

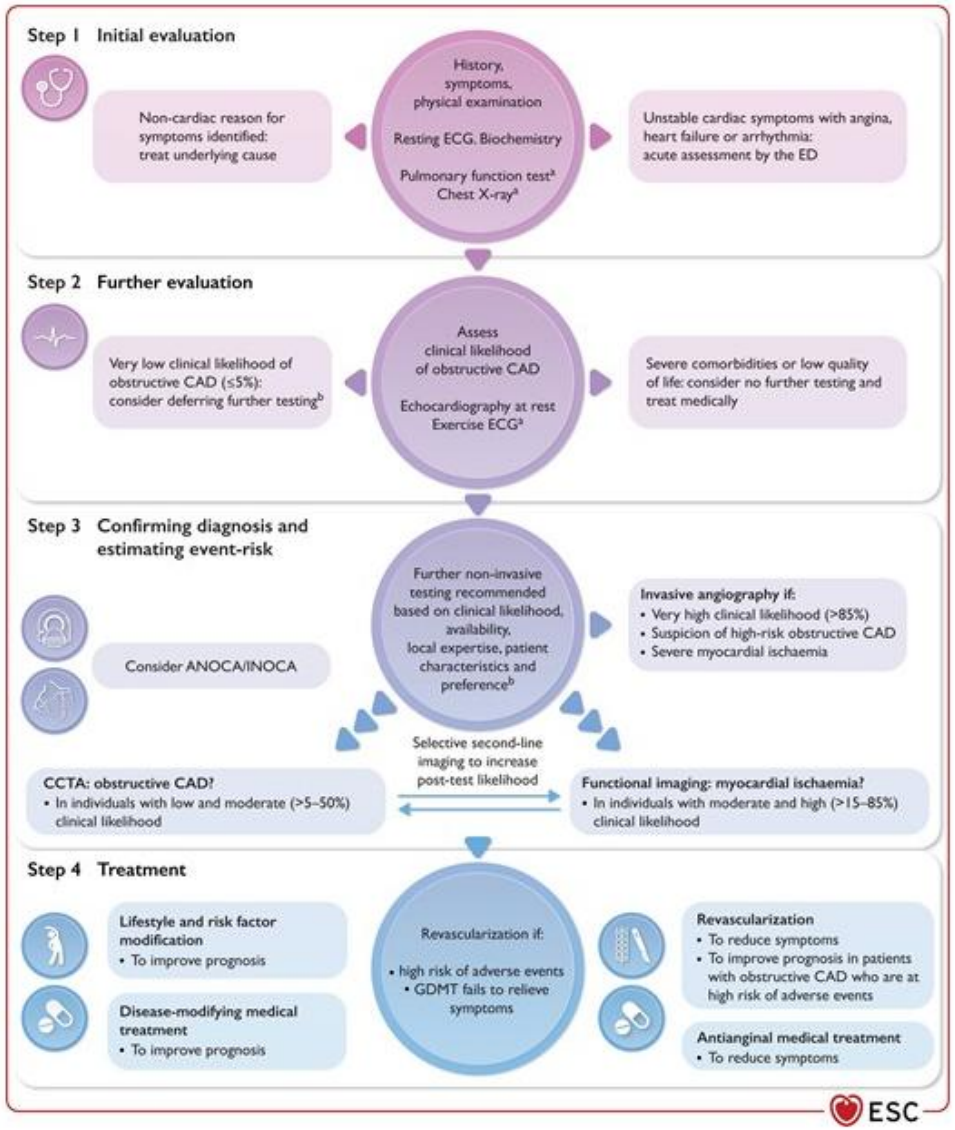
The Task Force for the diagnosis and management of chronic coronary syndromes of the European Society of Cardiology (ESC)

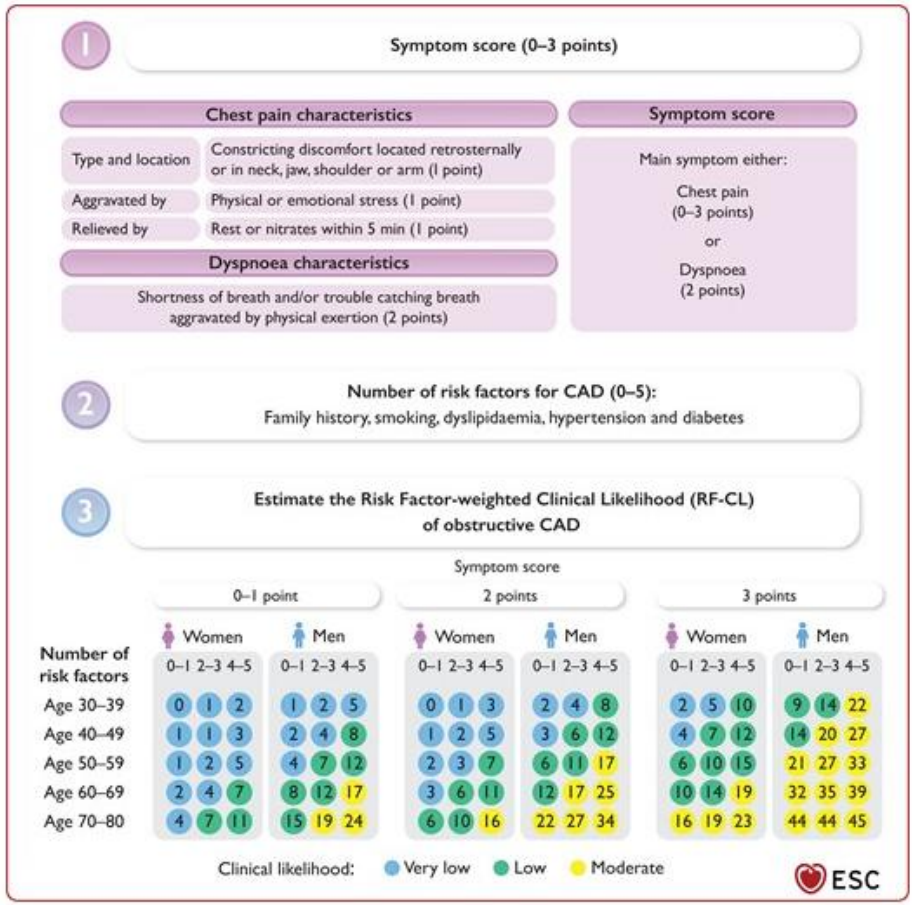
Authors/Task Force Members: Juhani Knuuti* (Finland) (Chairperson), William Wijns* (Ireland) (Chairperson), Antti Saraste (Finland), Davide Capodanno (Italy), Emanuele Barbato (Italy), Christian Funck-Brentano (France), Eva Prescott (Denmark), Robert F. Storey (United Kingdom), Christi Deaton (United Kingdom), Thomas Cuisset (France), Stefan Agewall (Norway), Kenneth Dickstein (Norway), Thor Edvardsen (Norway), Javier Escaned (Spain), Bernard J. Gersh (United States of America), Pavel Svitil (Czech Republic), Martine Gilard (France), David Hasdai (Israel), Robert Hatala (Slovak Republic), Felix Mahfoud (Germany), Josep Masip (Spain), Claudio Muneretto (Italy), Marco Valgimigli (Switzerland), Stephan Achenbach (Germany), Jeroen J. Bax (Netherlands)





ESC guidelines 2024





Low pre-test likelihood for obstructive CAD

Recommendations	Class[a]	Level[b]
It is recommended to estimate the pre-test likelihood of obstructive epicardial CAD using the Risk Factor-weighted Clinical Likelihood model.[139,140,142,143,161,162]	I	B
It is recommended to use additional clinical data (e.g. examination of peripheral arteries, resting ECG, resting echocardiography, presence of vascular calcifications on previously performed imaging tests) to adjust the estimate yielded by the Risk Factor-weighted Clinical Likelihood model.[163]	I	C
In individuals with a *very low* (≤5%) pre-test likelihood of obstructive CAD, deferral of further diagnostic tests should be considered.[139,164]	IIa	B
In individuals with a *low* (>5%–15%) pre-test likelihood of obstructive CAD, CACS should be considered to reclassify subjects and to identify more individuals with very low (≤5%) CACS-weighted clinical likelihood.[139,143,165]	IIa	B
In individuals with an initially low (>5%–15%) likelihood of obstructive CAD, exercise ECG and detection of atherosclerotic disease in non-coronary arteries may be considered to adjust the pre-test likelihood estimate.[144,166]	IIb	C

Recommendations	Class[a]	Level[b]
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.[33,34,145,212,214–221]	I	A
CCTA is recommended in individuals with low or moderate (>5%–50%) pre-test likelihood of obstructive CAD to refine diagnosis if another non-invasive test is non-diagnostic.[222]	I	B
CCTA is not recommended in patients with severe renal failure (eGFR <30 mL/min/1.73 m^2), decompensated heart failure, extensive coronary calcification, fast irregular heart rate, severe obesity, inability to cooperate with breath-hold commands, or any other conditions that can make obtaining good imaging quality unlikely.	III	C

Coronary artery disease

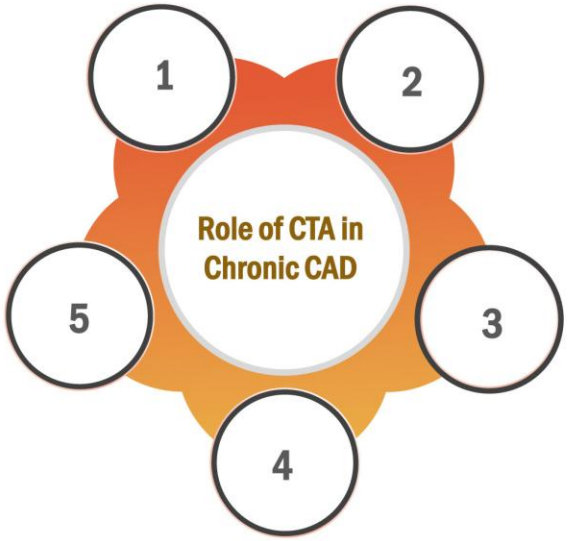
Guidelines

SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography

Jagat Narula [a, 1], Y. Chandrashekhar [b, 1], Amir Ahmadi [a], Suhny Abbara [c], Daniel S. Berman [d], Ron Blankstein [e], Jonathon Leipsic [f], David Newby [g], Edward D. Nicol [h], Koen Nieman [i], Leslee Shaw [j], Todd C. Villines [k], Michelle Williams [g], Harvey S. Hecht [a, *, l]

First line test for evaluating patients with:
- No known CAD and Stable Typical or Atypical Chest Pain, or Anginal Equivalent

Reasonable test for evaluating patients with:
- Known CAD and Stable Typical or Atypical Chest Pain, or Angina Equivalent



First line test for evaluating patients with:
- Coronary Anomalies
- Prior CABG, particularly if graft patency or location of LIMA is the primary objective

Reasonable test for evaluating patients with:
- A non-conclusive functional test; to obtain more precision regarding diagnosis and prognosis

Reasonable test for evaluating patients with:
- Coronary Stents > 3.0 mm
- Proximal, Non Bifurcation thin strut Stents < 3.0 mm
- Prior to Non Cardiac Surgery in younger patients with low-intermediate probability of CAD
- Evaluating Coronary Anatomy in patients with suspected Dissection of the Aorta

Clinical value

- Negative predictive value
- Assessing atherosclerosis

Diagnostic Accuracy of 64-Slice Computed Tomography Coronary Angiography

A Prospective, Multicenter, Multivendor Study

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Koen Nieman, MD, PhD,*† Jacob M. van Werkhoven, MD,‖# Gabija Pundziute, MD,‖#
Annick C. Weustink, MD,*† Alexander M. de Vos, MD,§‖ Francesca Pugliese, MD,*†
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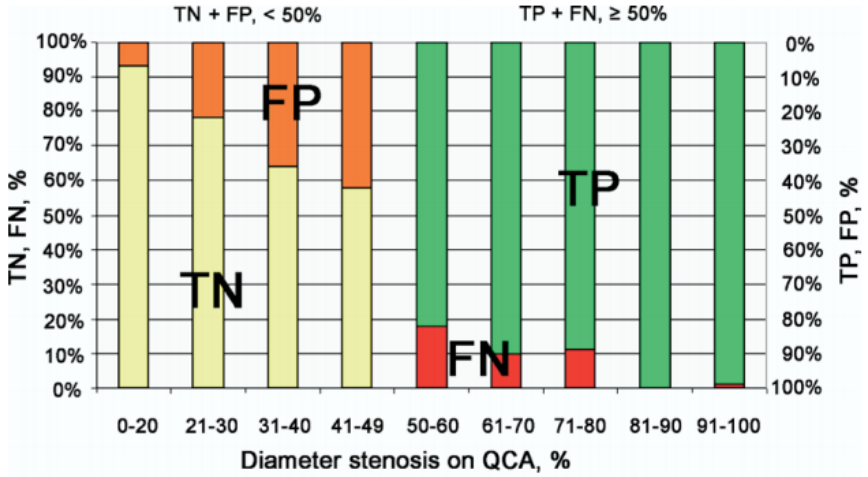
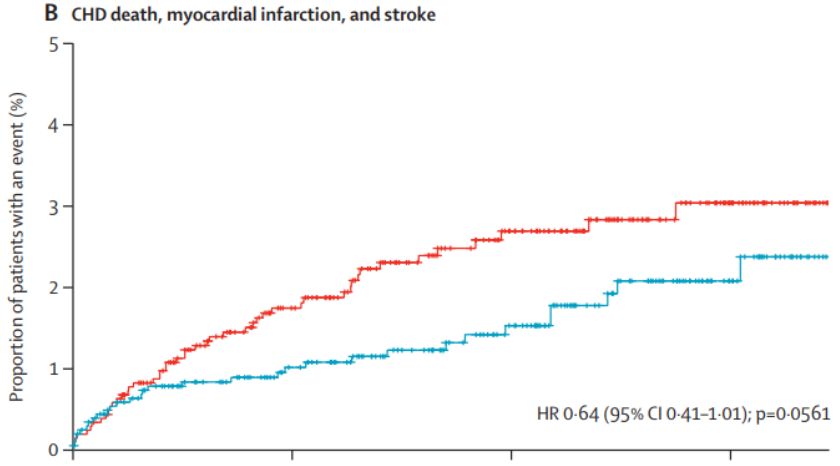
Mathias Prokop, MD, PhD,‖ Pieter A. Doevendans, MD, PhD,§ Myriam G. M. Hunink, MD, PhD,††
Gabriel P. Krestin, MD, PhD,† Pim J. de Feyter, MD, PhD*†

CT coronary angiography in patients with suspected angina due to coronary heart disease (SCOT-HEART): an open-label, parallel-group, multicentre trial

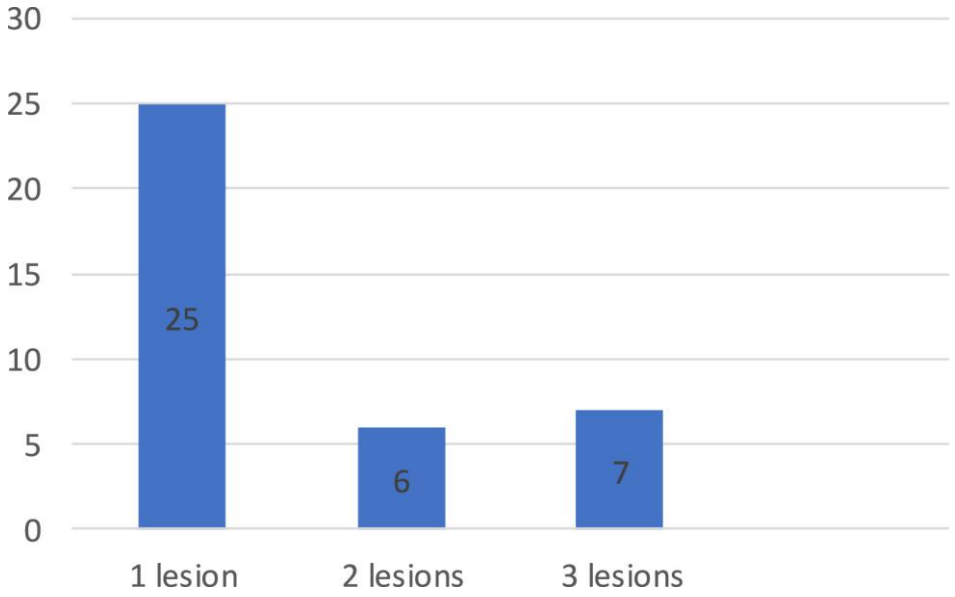
*The SCOT-HEART investigators**



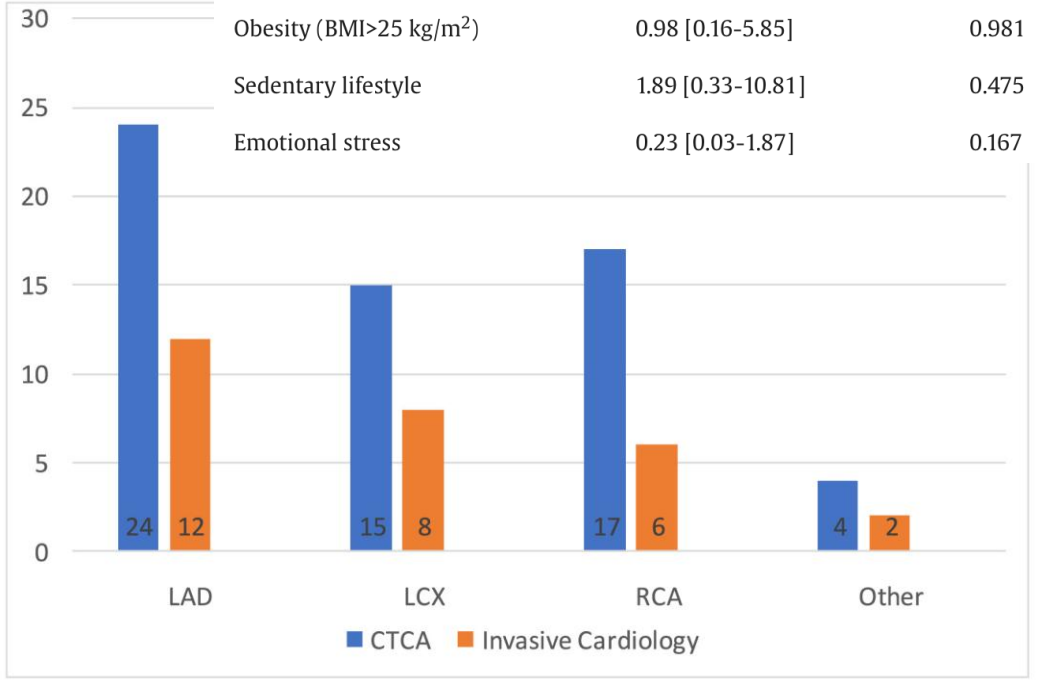


CTCA in asymptomatic patients

- N = 226
- Male, >50 years old
- 3 or more risk factors

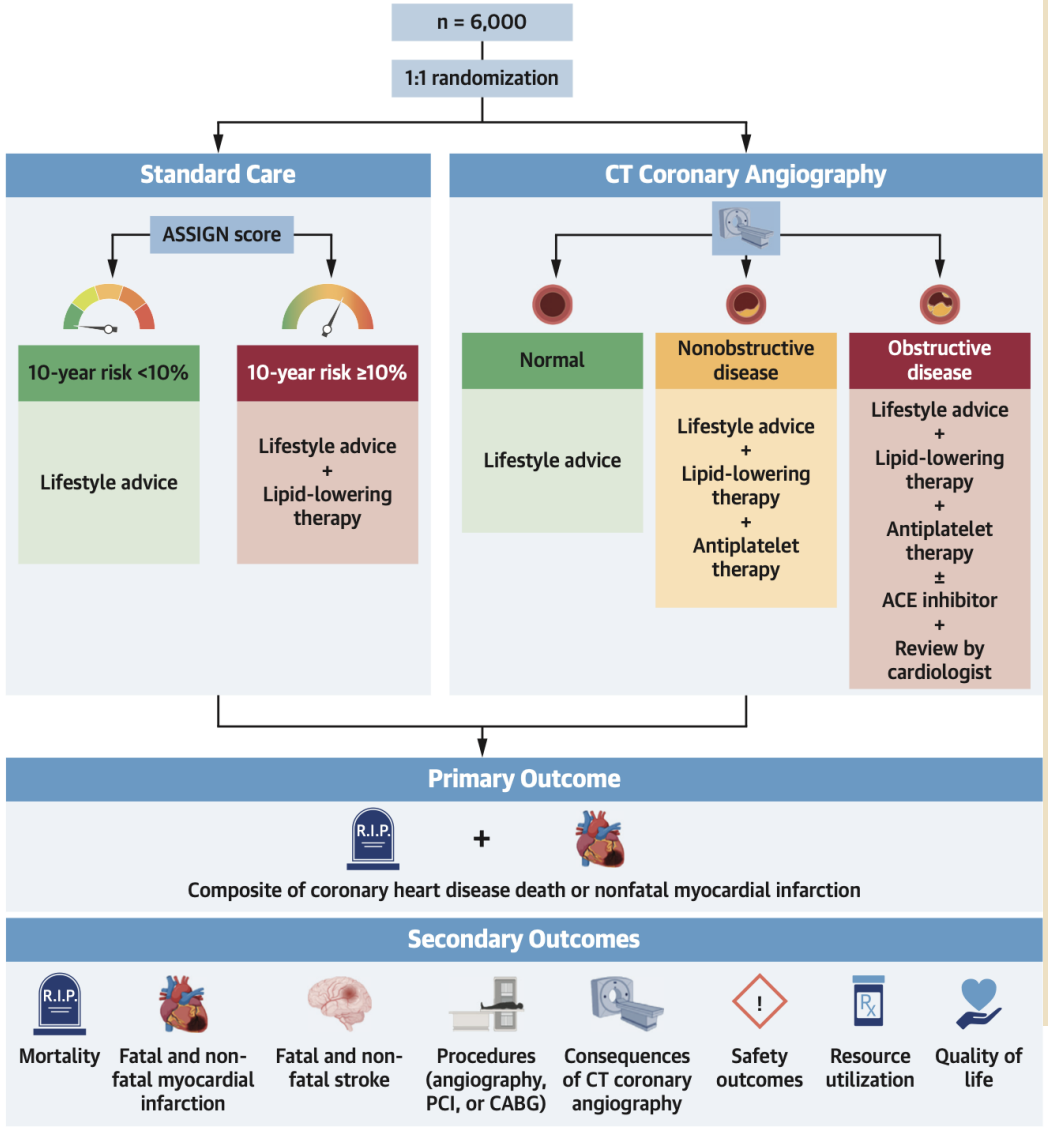


Variable	HR [95% CI]	Adjusted P-value
Positive family history*	19.71 [2.33-167.10]*	0.006*
Age (per year)	1.05 [0.92-1.19]	0.489
Active smoking	0.55 [0.05-5.63]	0.617
Hypercholesterolemia	4.80 [0.35-66.88]	0.243
Hyperlipidemia	0.60 [0.05-7.94]	0.695
Hypertension	3.06 [0.58-16.16]	0.187
Obesity (BMI>25 kg/m^2)	0.98 [0.16-5.85]	0.981
Sedentary lifestyle	1.89 [0.33-10.81]	0.475
Emotional stress	0.23 [0.03-1.87]	0.167

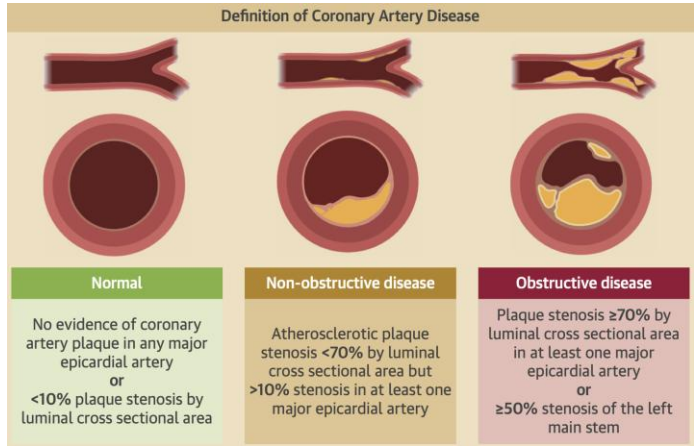


Hellenic J Cardiol. 2021 Mar-Apr;62(2):129-134

SCOT-HEART 2 Trial



Inclusion Criteria	Exclusion Criteria
≥40 and ≤70 years of age	Inability to give informed consent
Resident in Scotland	Inability or unwilling to undergo CT coronary angiography
At least one risk factor for coronary artery disease: 1. Hypertension 2. Hypercholesterolemia 3. Current or recent smoking habit 4. Diabetes mellitus 5. Family history of cardiovascular disease 6. Chronic kidney disease stage III (eGFR 30-59 mL/min) 7. Systemic inflammatory condition (rheumatoid arthritis, systemic lupus erythematosus) 8. Age ≥60 years	Pregnant or breastfeeding
	Known coronary artery disease or other major atherosclerotic cardiovascular disease
	Previous invasive or non-invasive coronary angiography within the last 5 years
	eGFR <30 mL/min/1.73 m^2
	Known familial hypercholesterolemia or other inherited lipid disorder requiring lipid lowering therapy
	Intolerance of all statins
	Lipid lowering therapy for >2 years

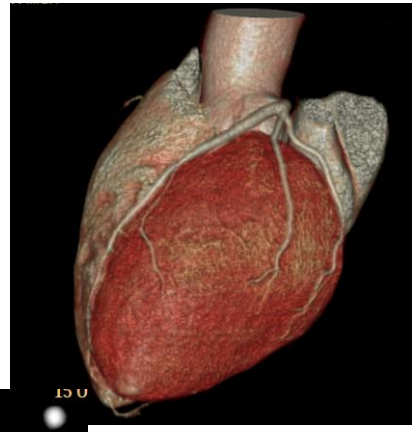


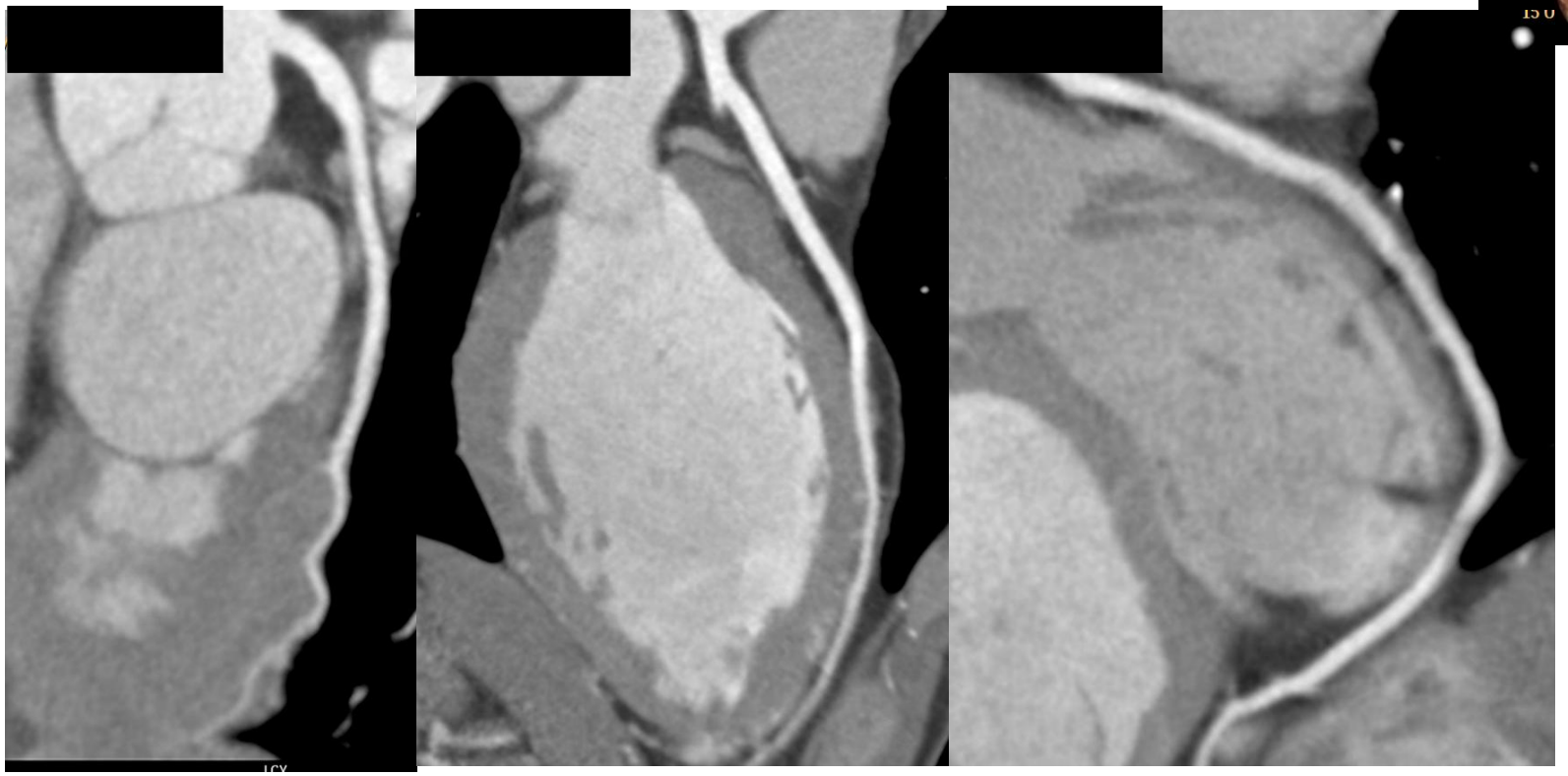
JACC Cardiovasc Imaging. 2024 Sep;17(9):1101-1112

Case 1

- 32-year-old male patient
- Strong family history for CAD, mild dyslipidaemia (LDL 130)
- Atypical chest pain for several months, tachycardias, anxious
- EET normal

Case 1

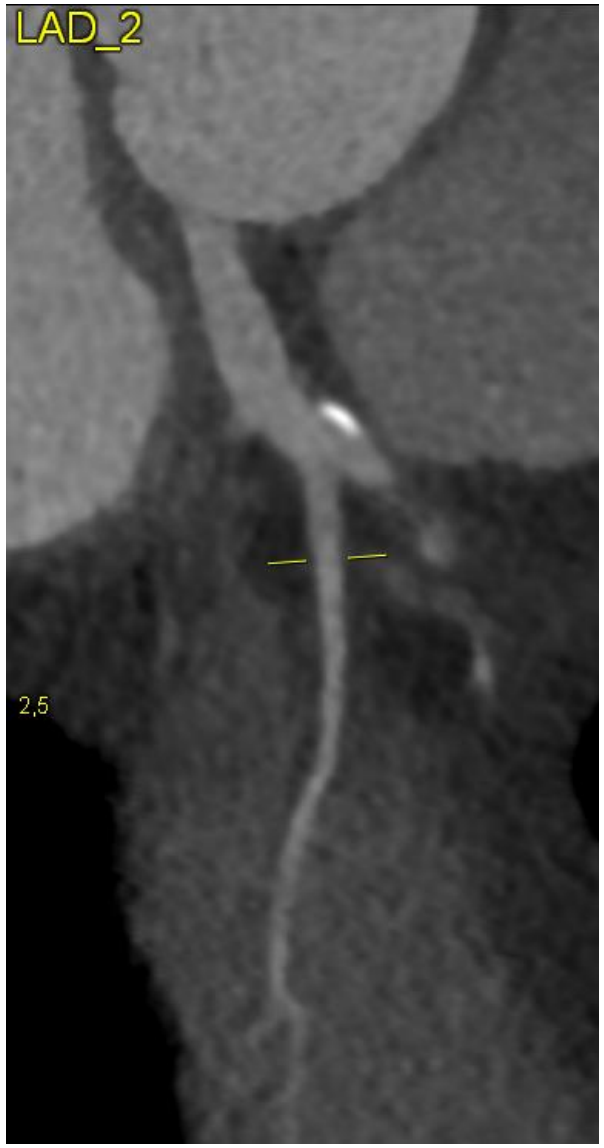




Case 2

- 39-year-old male patient
- Mild dyslipidaemia (LDL 125) non treated, BMI 27
- Family history of CAD
- Atypical chest pain
- Multiple EET normal

Case 2

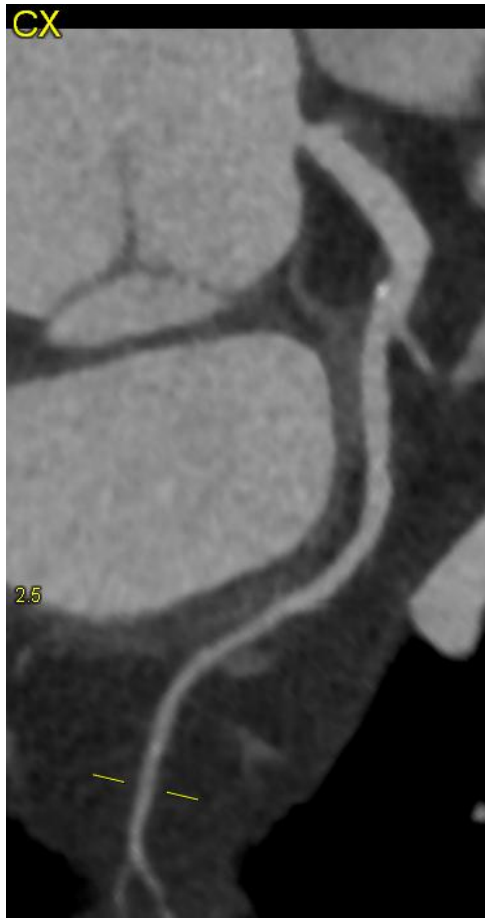


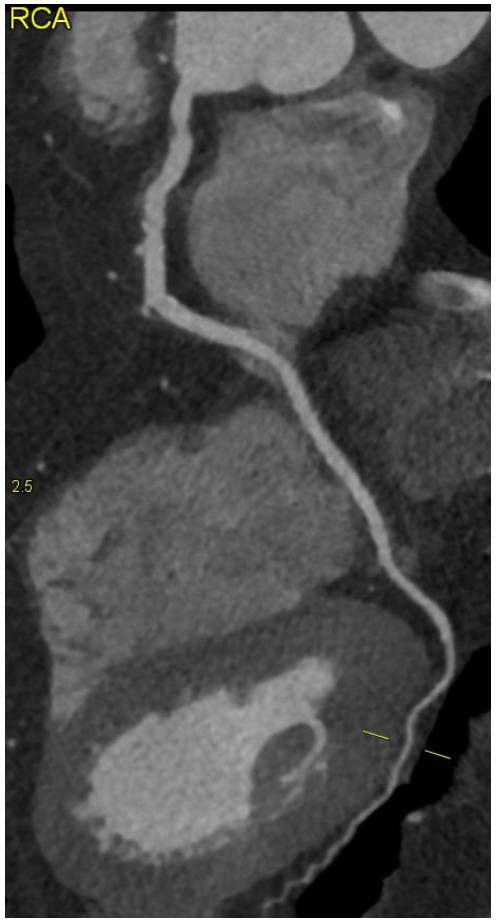
Rad 2.4 mS

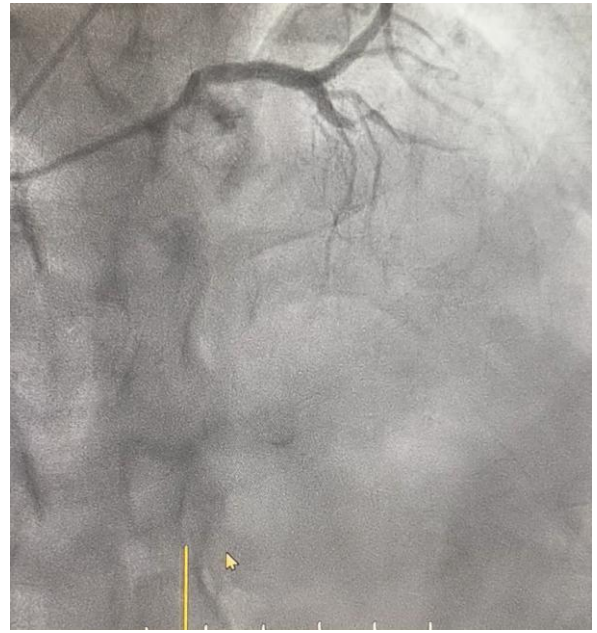
Case 3

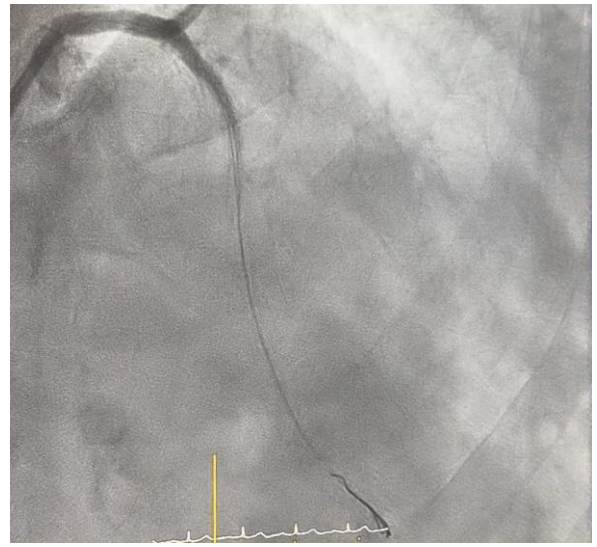
- 60-years-old male
- Hx of dyslipidaemia, smoking, increased BMI
- Atypical chest pain

Case 3

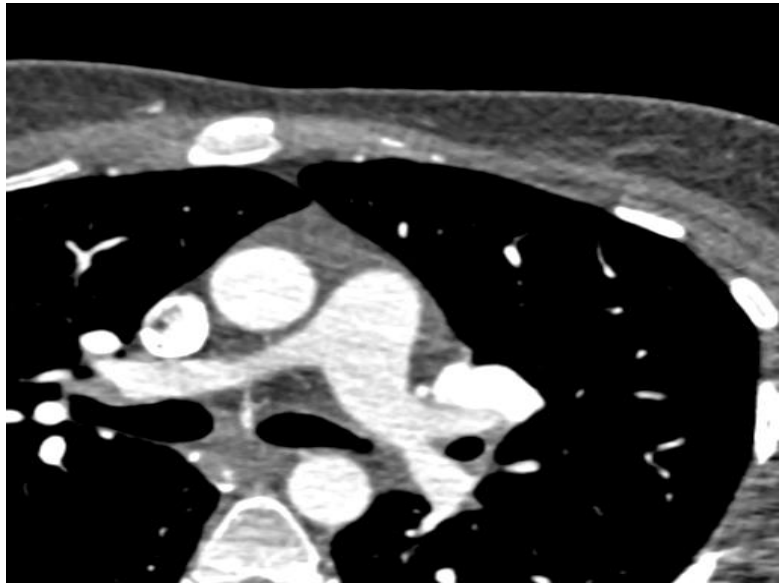


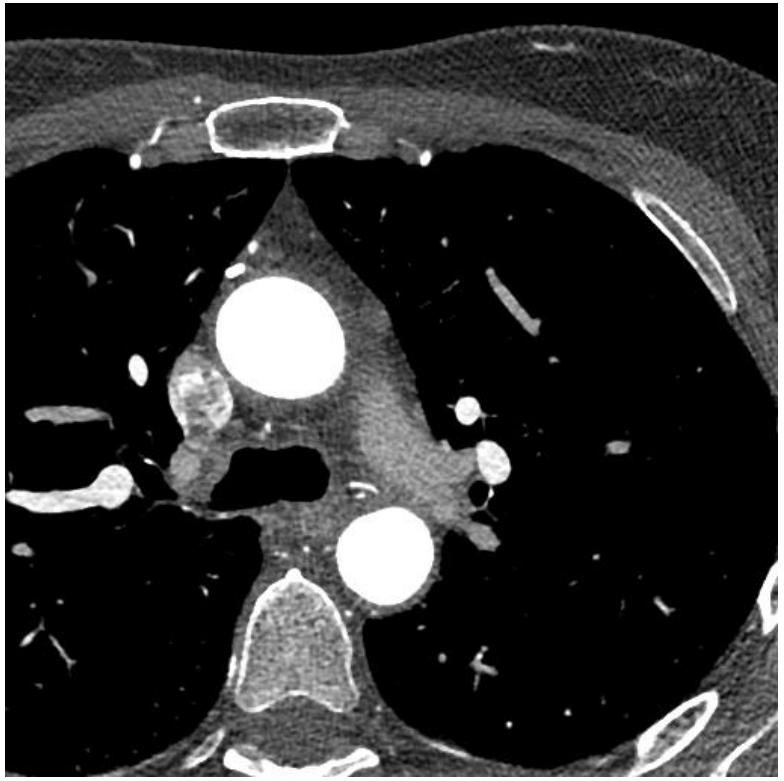


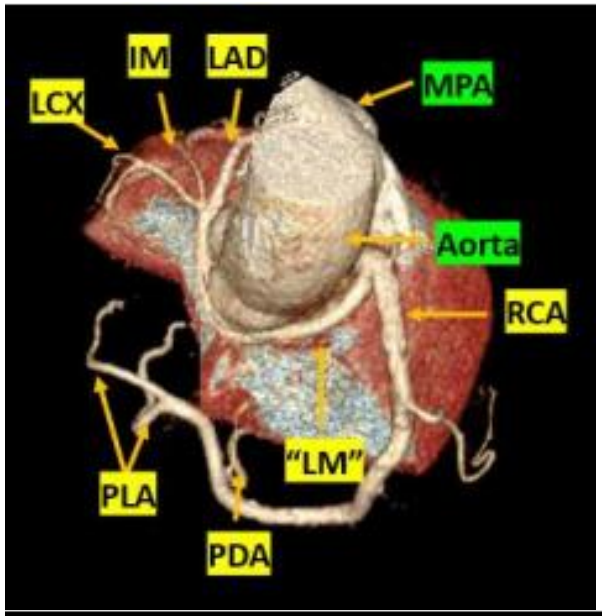




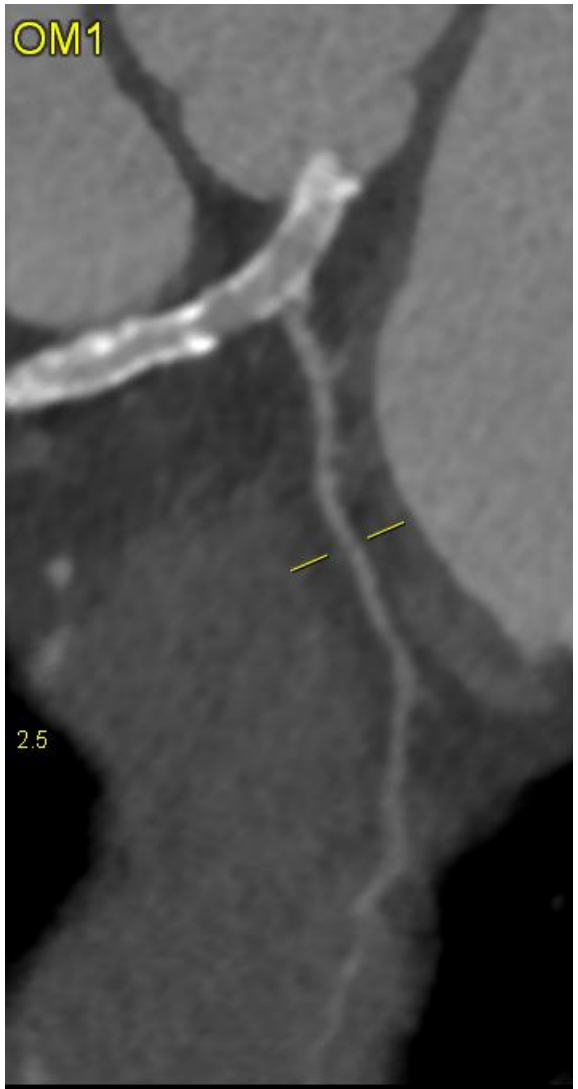
Congenital anomalies







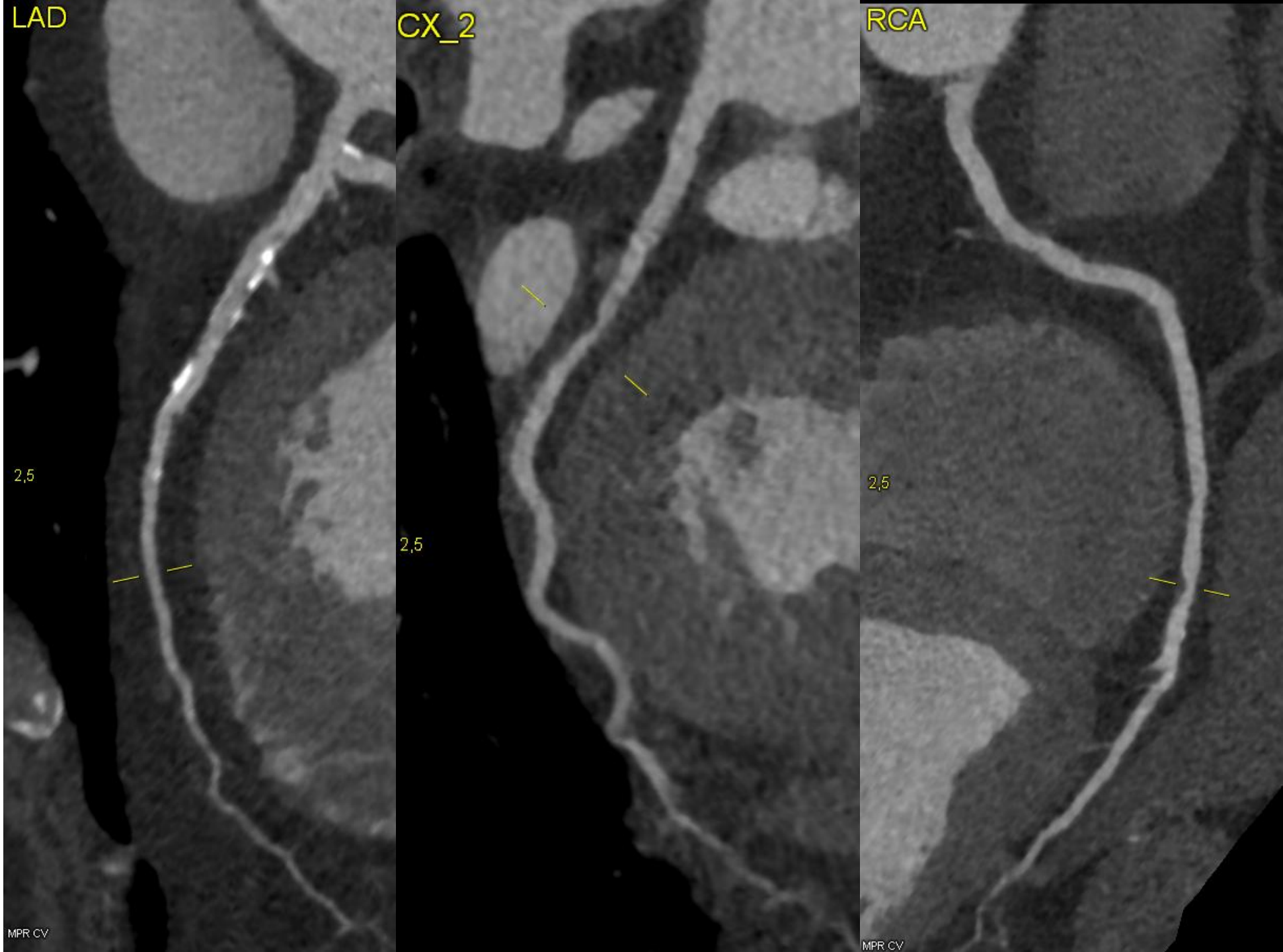
Case 4



Case 5

Case 6

- 68 years-old male
- Pre-diabetic
- Obese (BMI 33 kg/m2)
- Hypertension
- Dyslipidaemia
- Asymptomatic (?)



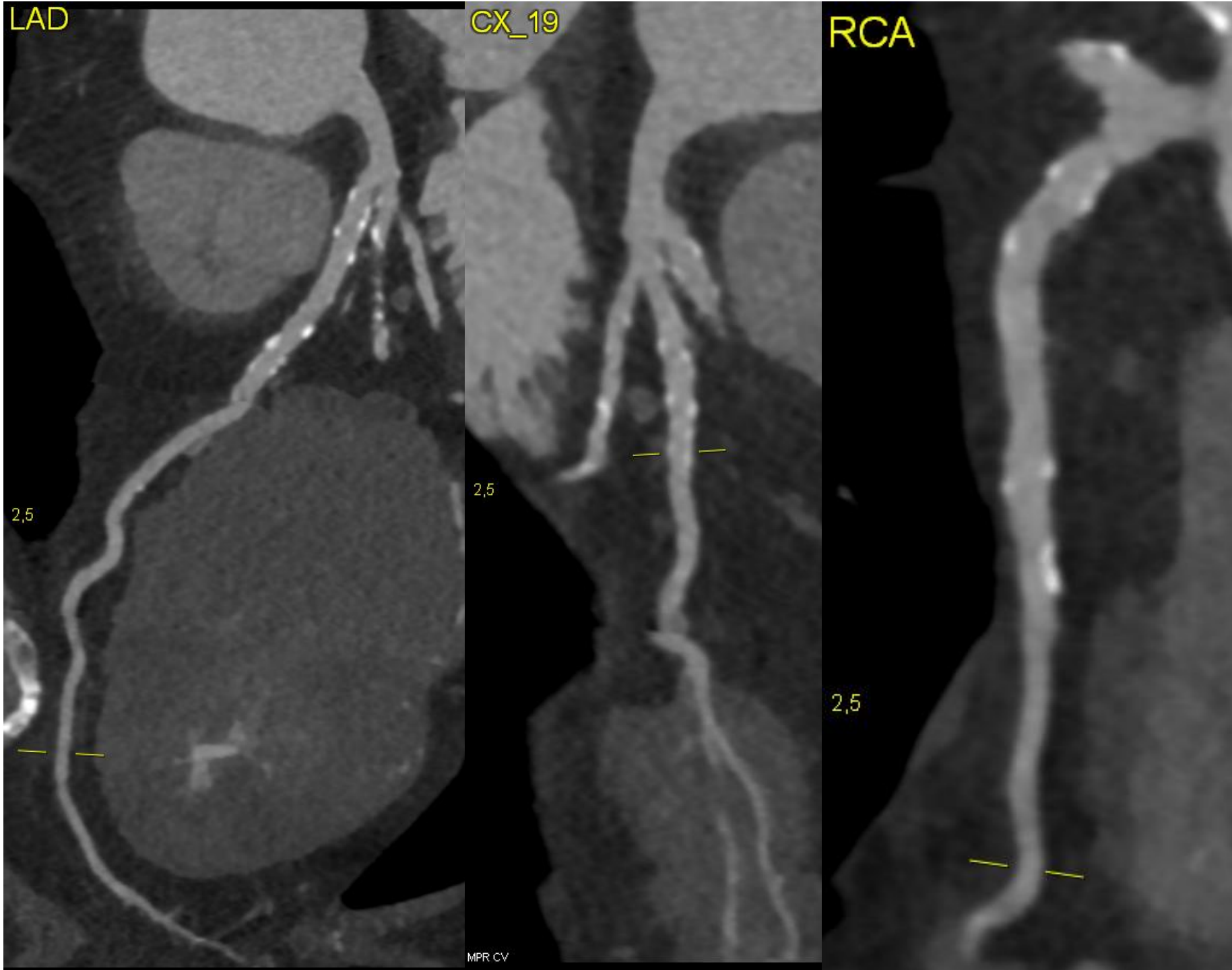
Case 7

- 60 years-old male
- Dyslipidaemia
- Chest pain on exertion

Case 8

- 78 years-old male
- Hypertension
- Atypical chest pain
- Calcification of coronary arteries in Chest CT

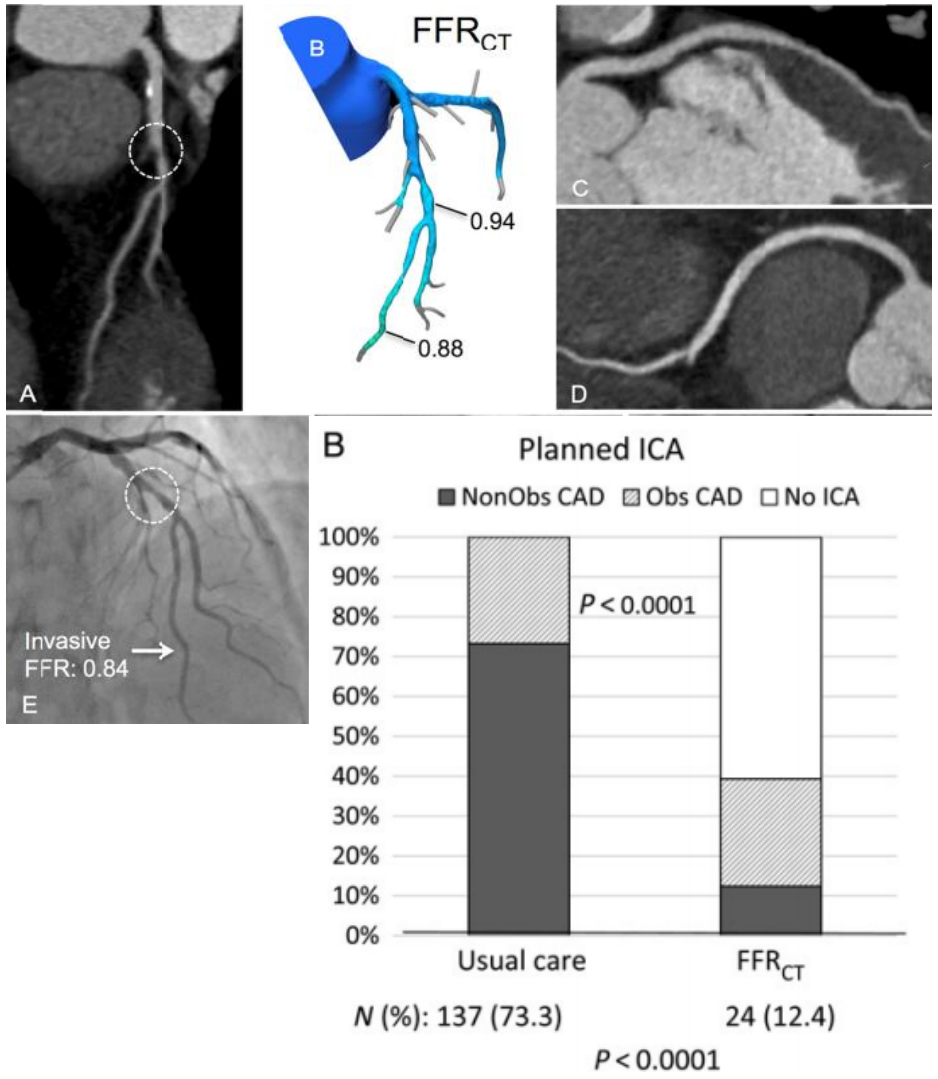
Agatston score: 1076



Beyond anatomy:
Functional assessment

FFR-CT

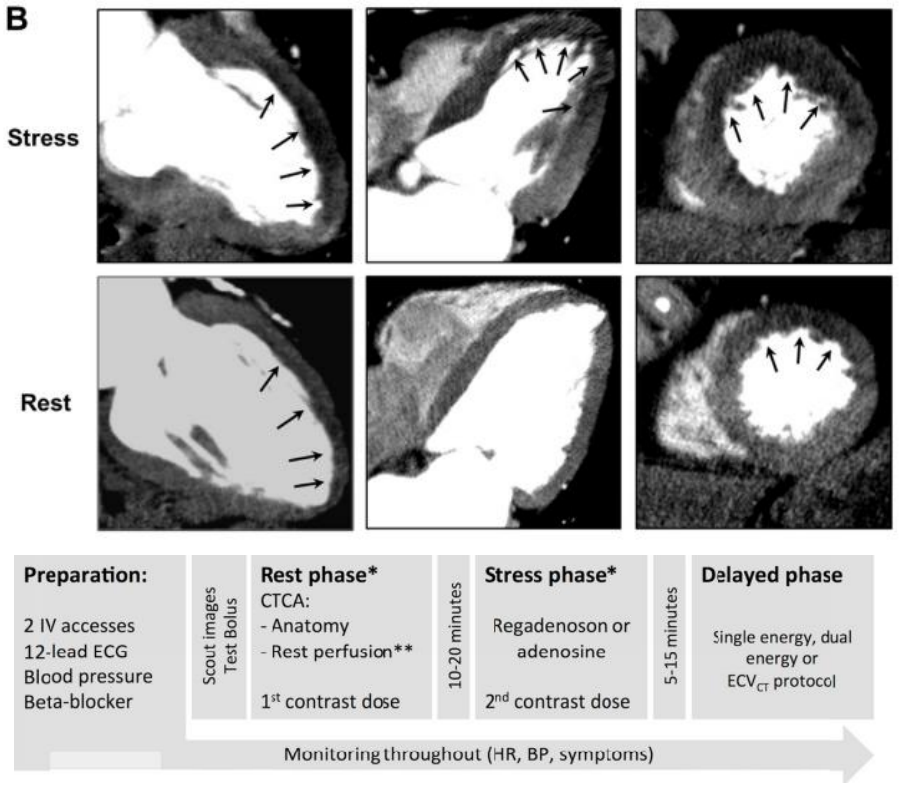
- Computational fluid dynamic models
- High image quality but no additional image acquisition needed
- Improved specificity
- **FFR-CT led to less invasive CA showing non-obstructive CAD** (12% from 73%)
- 13% of patients, excluding high BMI, Afib and previous revascularized, were non-analyzable
- Availability - cost



Treibel et al, 2017
Douglas et al, 2015

Stress perfusion

- Vasodilator test (hyperaemia)
- High temporal resolution needed (10-20% increase of HR)
- Lower tube voltage (poorer contrast resolution)
- Wide volume coverage (whole heart in 1 heart beat)
- Wide detector CT scanner (256- and 320-CT scanners) or dual source CT scanners
- Static or Dynamic – myocardial blood flow
- Compared to SPECT, 90% sensitivity and 84% specificity
- Higher radiation exposure (2-9 mSv and 5-15 mSv respectively)



Treibel et al, 2017
Cury et al, 2014

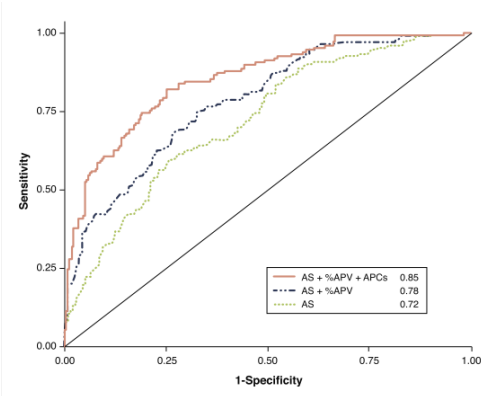
But…

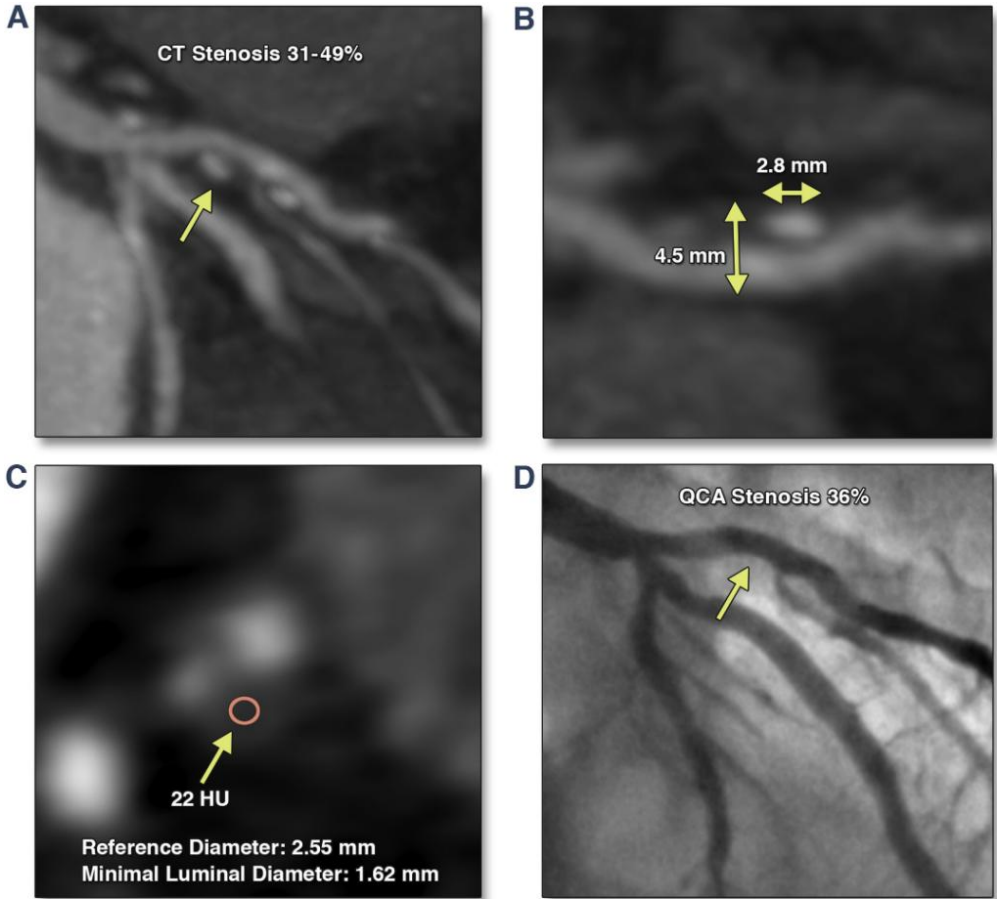
- Only half of >50% diameter stenosis are haemodynamically significant
- 17% of <50% diameter stenosis caused ischaemia

Rossi et al, 2014
Park et al, 2015
Sarno et al, 2009
Meijboom et al, 2008

Vulnerable plaque

- Spotty calcifications (<3 mm)
- Napkin ring sign
- Positive remodelling
- Low attenuation plaques (<30 HU)





Park et al, 2015

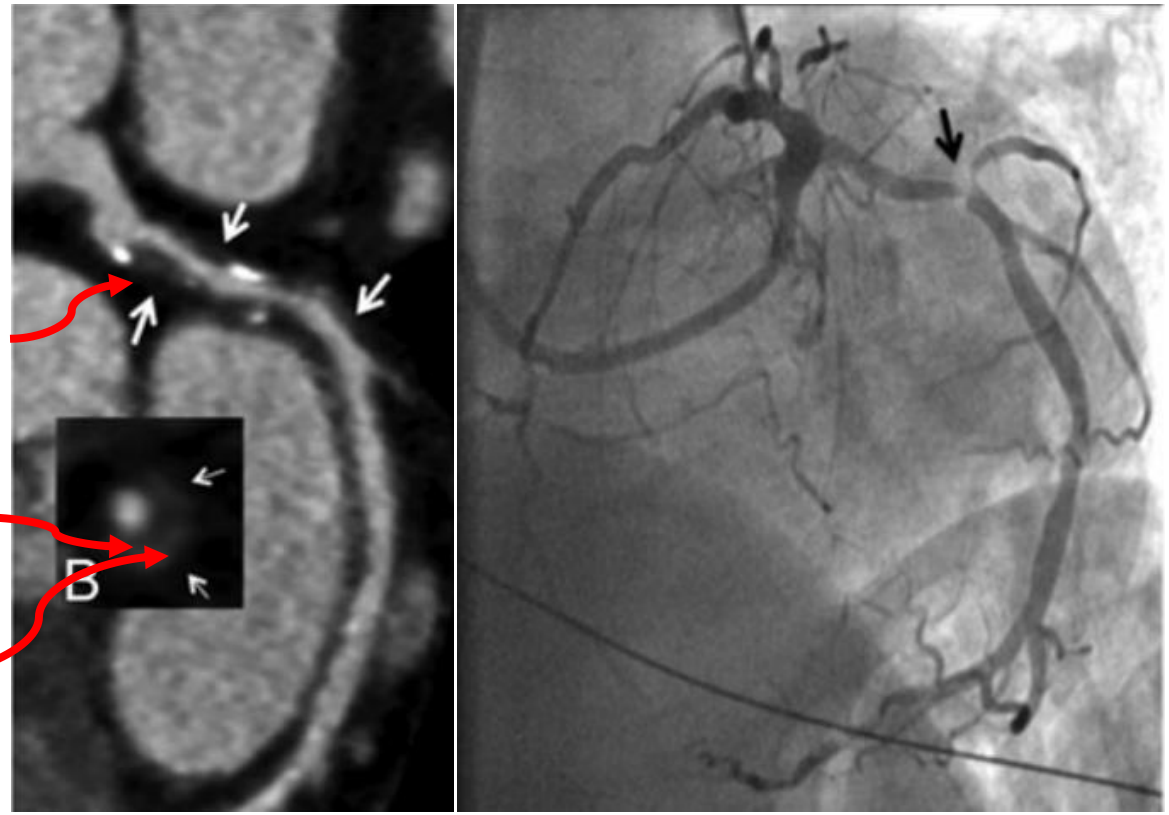
Vulnerable plaque

- Mixed plaques
- Moderate stenosis

Non-calcific component

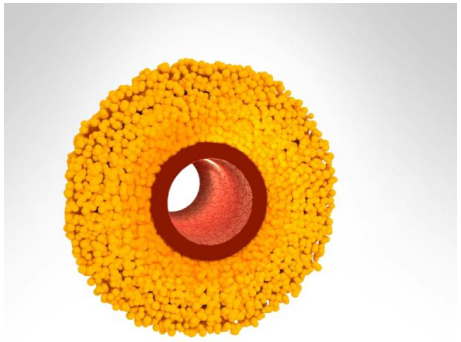
Low attenuation plaque

Napkin ring sign

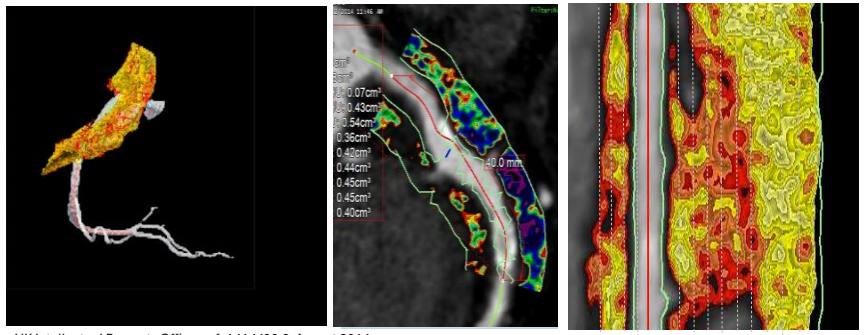


Feuchtner et al, 2016

Perivascular adipose tissue

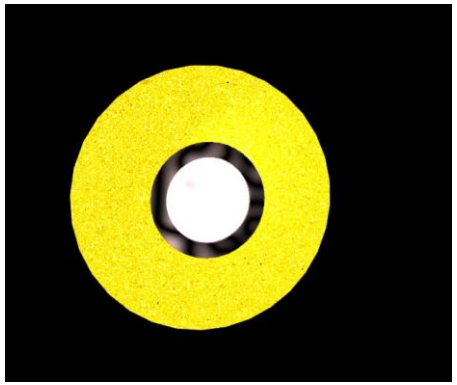


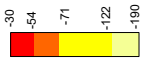
Perivascular Fat Attenuation Index (FAI_{PVAT})



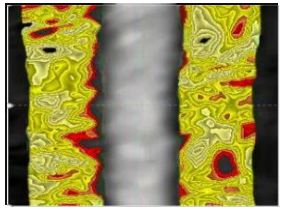
UK Intellectual Property Office, ref. 1414496.8, August 2014

CT angiography



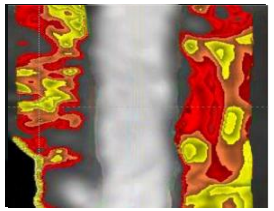


Low FAI

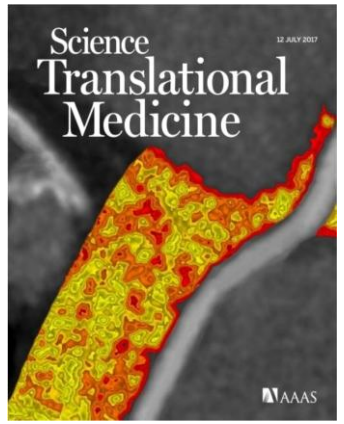


Healthy

High FAI

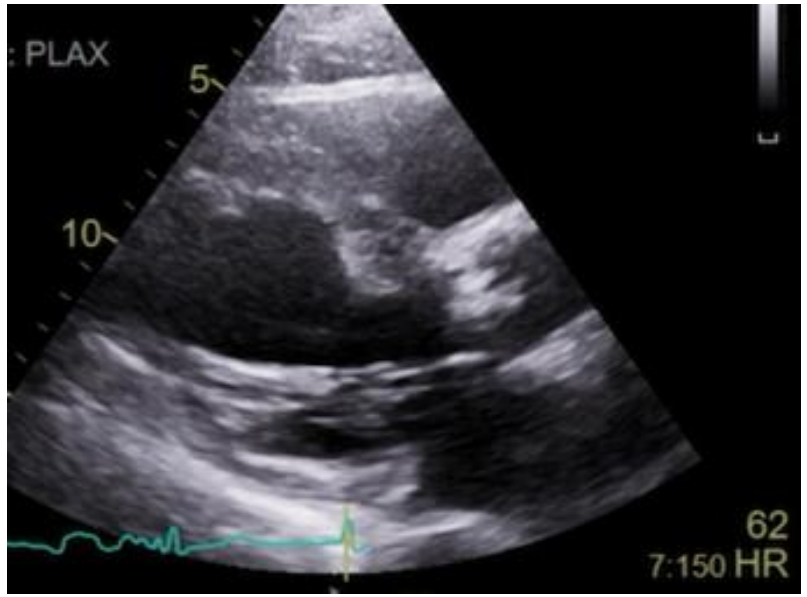


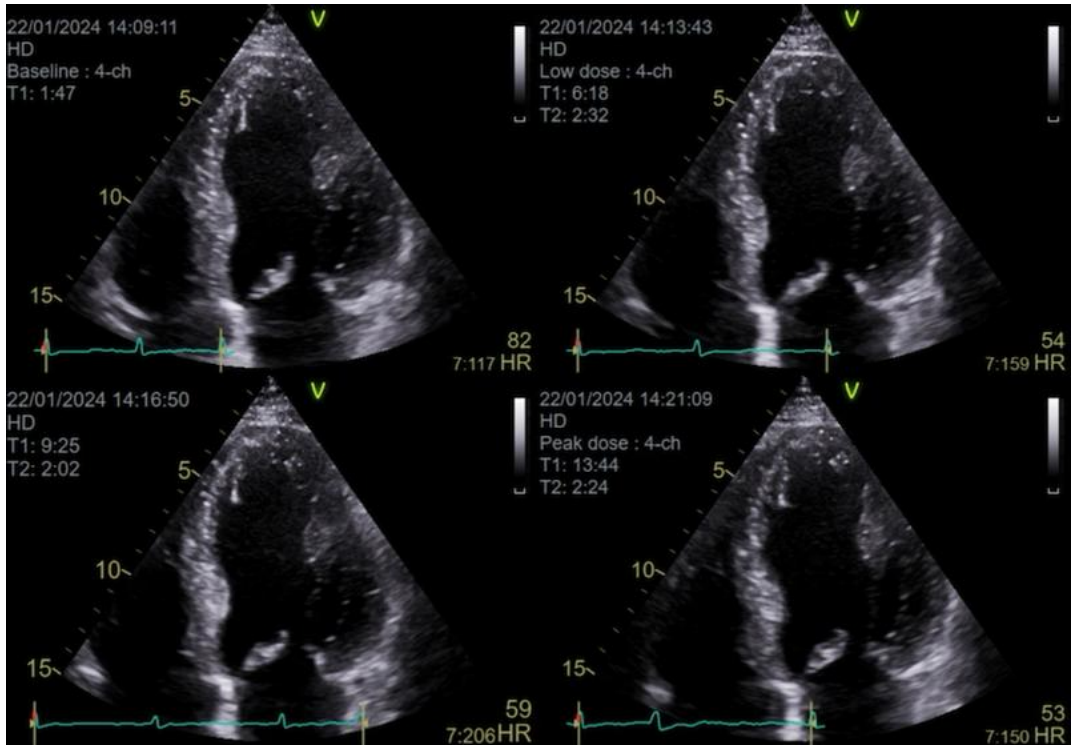
Healthy
(STEMI 3 years later)

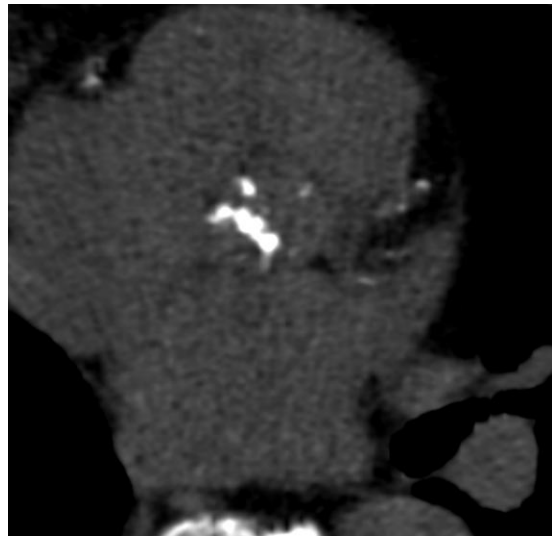


Antonopoulos A et al, 2017

Cardiac CT for aortic valve



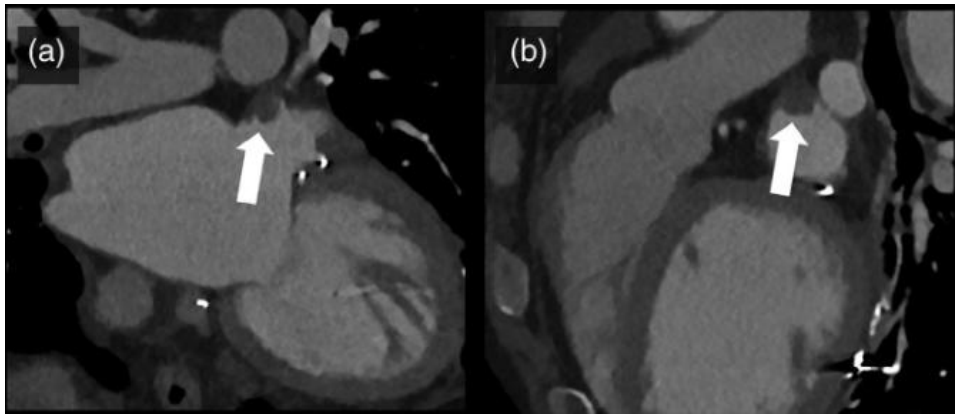




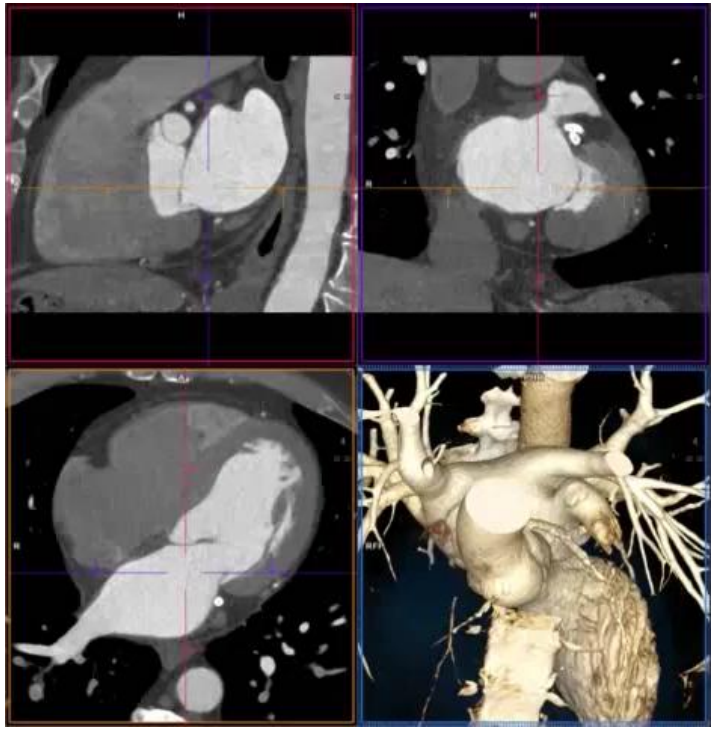
SVi	30 ml/m2
AV Vmax	2,7 m/s
LVOT Vmax	0,7 m/s
AVA	0,9 cm2
DVI	0,26

Score ασβεστίου: 2092

CTCA in structural disease



Peters A et al, *Catheter Cardiovasc Interv*. 2021;97:E719–E723

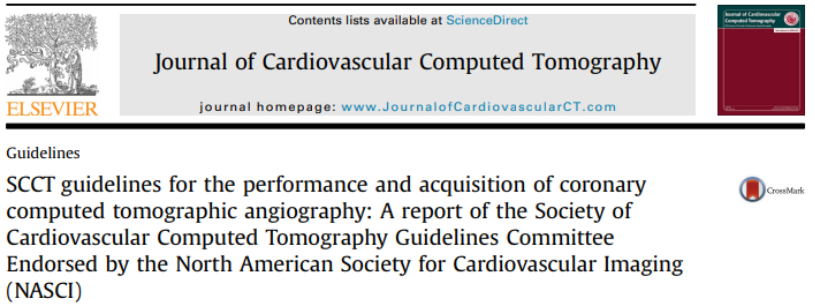


Korsholm et al, 2020

Key issues

- Patient selection
- Protocol selection
- Patient preparation

Patient selection


Contents lists available at ScienceDirect

Journal of Cardiovascular Computed Tomography

journal homepage: www.JournalofCardiovascularCT.com

Guidelines

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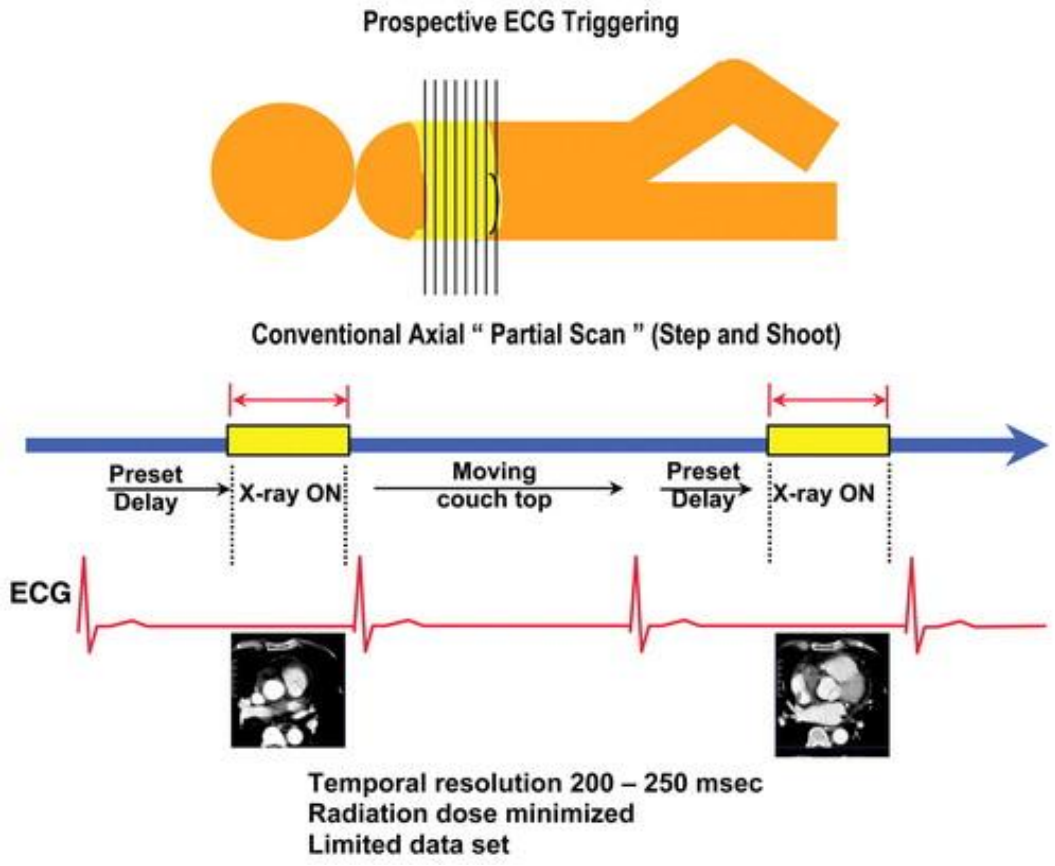
Relative Contraindications

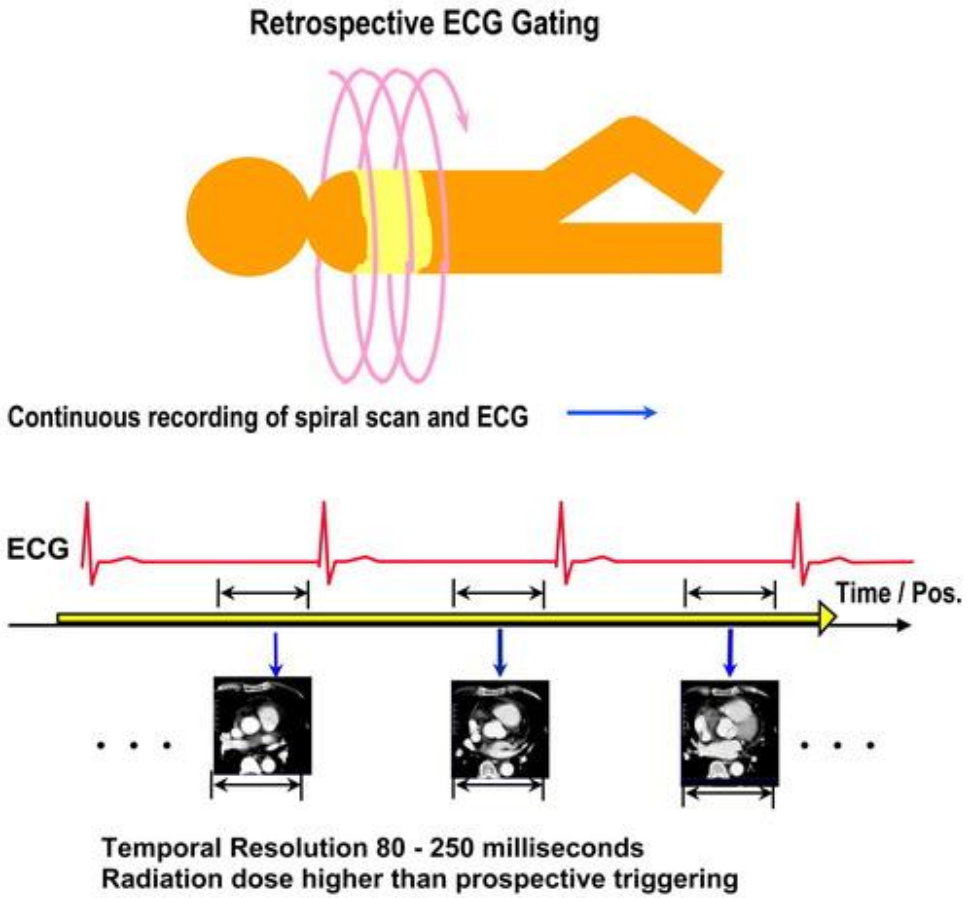
- Hx of anaphylactic contrast reaction
- Inability to cooperate – breath-hold
- Pregnancy
- Clinical instability
- Renal impairment

Decreased diagnostic accuracy

- Obesity
- Difficult to breath-hold
- Difficult to remain still or supine position
- High heart rate
- Arrhythmia
- Contradiction to NTG

ECG-Gating





Mahesh, M., & Cody, D. D. (2007). Physics of cardiac imaging with multiple-row detector CT. Radiographics, 27(5), 1495-1509.

Radiation considerations and protocol

- Average annual radiation exposure 3.6 mSv in USA, 2.2 mSv in UK
- Harmful effect of radiation is cumulative
- Long latency (10-30 years)
- Breast tissue particularly sensitive

Radiation considerations and protocol

- **CTCA: 2-10 mSv**
  - Wide detector and high-pitch helical dual source even <1 mSv
- **Prospective** vs retrospective acquisition – only during a short ECG phase but no flexibility to select other phases of cardiac cycle
- Flash – scan in 1 heartbeat
- **ALARA - As Low As Reasonably Achievable**

CHEST

Procedure	Approximate effective radiation dose	Comparable to natural background radiation for:
Computed Tomography (CT)–Chest	6.1 mSv	2 years
Computed Tomography (CT)–Lung Cancer Screening	1.5 mSv	6 months
Chest X-ray	0.1 mSv	10 days

ABDOMINAL REGION

Procedure	Approximate effective radiation dose	Comparable to natural background radiation for:
Computed Tomography (CT)–Abdomen and Pelvis	7.7 mSv	2.6 years
Computed Tomography (CT)–Abdomen and Pelvis, repeated with and without contrast material	15.4 mSv	5.1 years
Computed Tomography (CT)–Colonography	6 mSv	2 years
Intravenous Urography (IVU)	3 mSv	1 year
Barium Enema (Lower GI X-ray)	6 mSv	2 years
Upper GI Study with Barium	6 mSv	2 years

2017

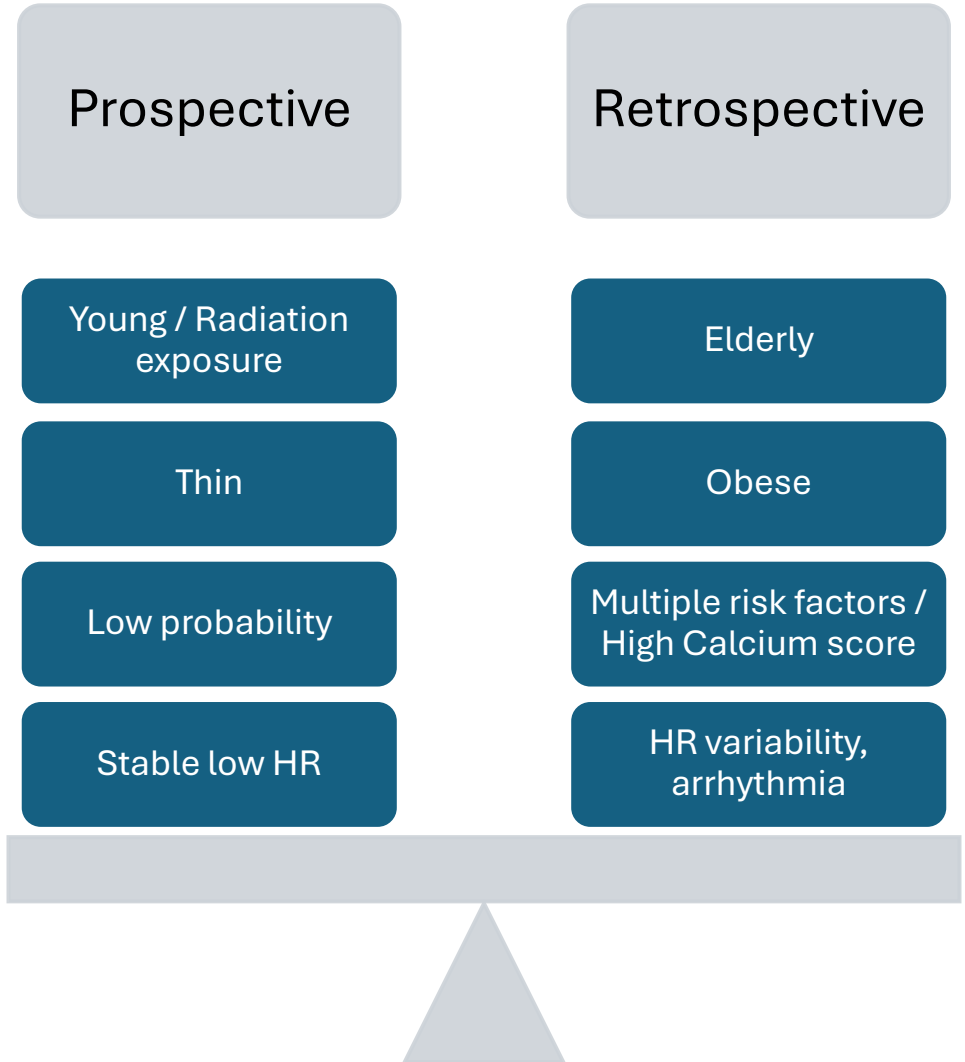
NHS

Barts Health

NHS Trust

Examination	Effective dose	Time equival.	CXR equival.
Ca Score	1.4	8 months	88
Prospective CTCA	8.4	4 years	525
Retrospective CTCA	42	19 years	2625

Protocol selection

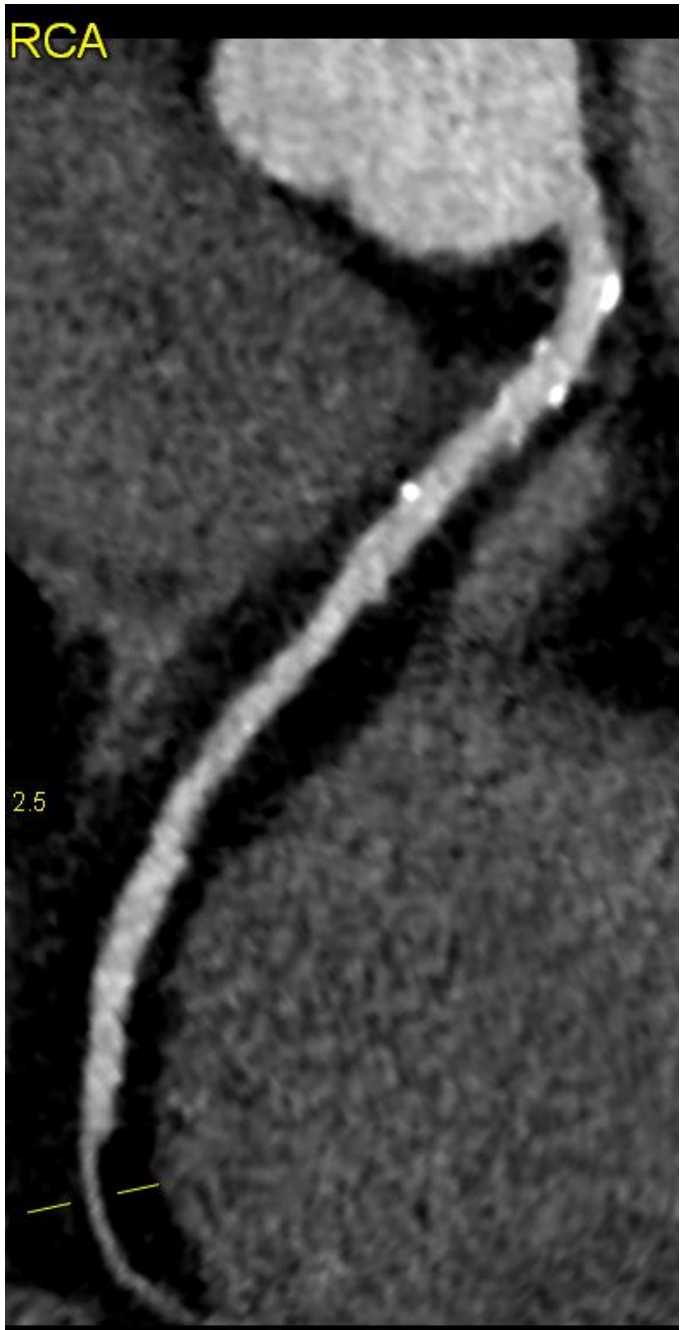


Not ideal patient

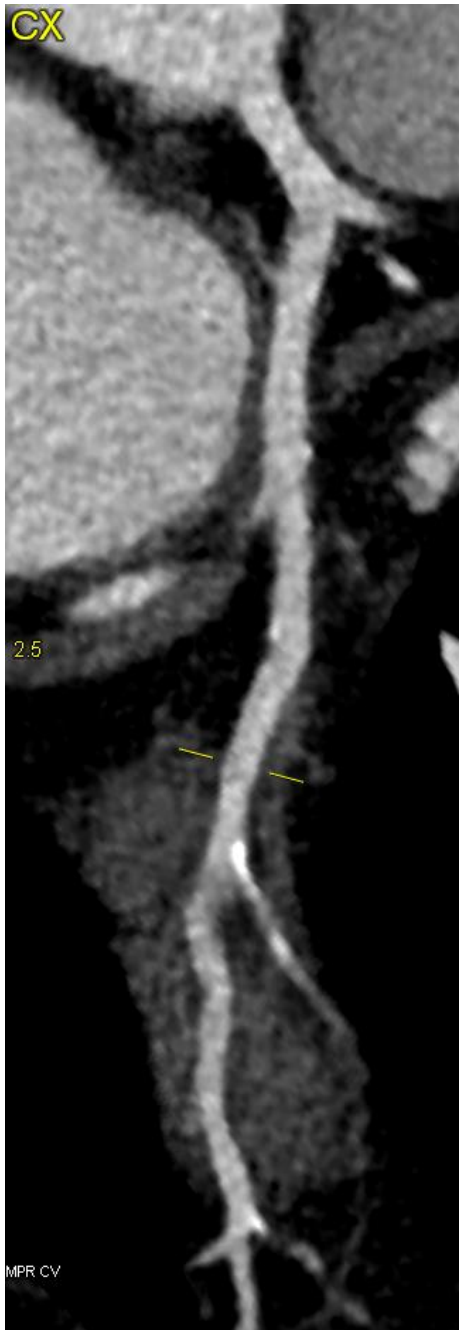
- 62 male
- Hx HTN, Dyslipidaemia
- Smoking
- Obesity (BMI 34 kg/m^2)
- Chest pain

Artery	Lesions	Volume / mm^3	Equiv. Mass / mg	Score
LM	2	3.4	1.03	2.8
LAD	7	267.3	63.05	368.1
CX	10	152.8	32.12	158.9
RCA	12	156.4	36.77	178.7
Ca	0	0.0	0.00	0.0
Total	**31**	**579.8**	**132.98**	**708.5**
U1	0	0.0	0.00	0.0
U2	0	0.0	0.00	0.0

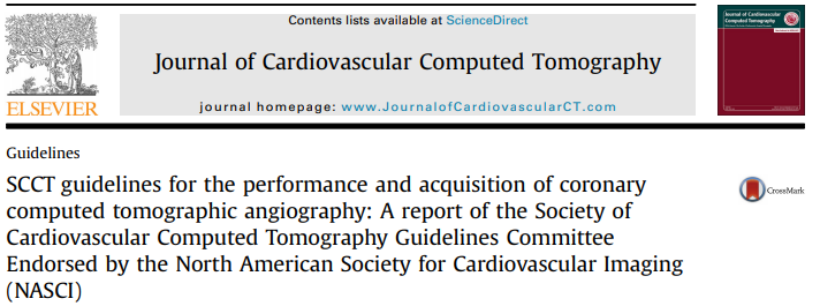

LAD
2.5
MPR CV


RCA
2.5


LAD
MPR CV


CX
2.5
MPR CV

Patient preparation
Before the test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- Adequate hydration, especially in GFR 30-60
- Avoid food, coffee, smoking
- Target HR <65/min
  - Oral beta-blockers (alternatively ivabradine)
  - Depends on resting HR
  - E.g. 25 mg metoprolol 2 days before and uptitration or 50 2 hours prior to exam
- In case of allergies
  - Corticosteroids
  - Antihistamine drugs

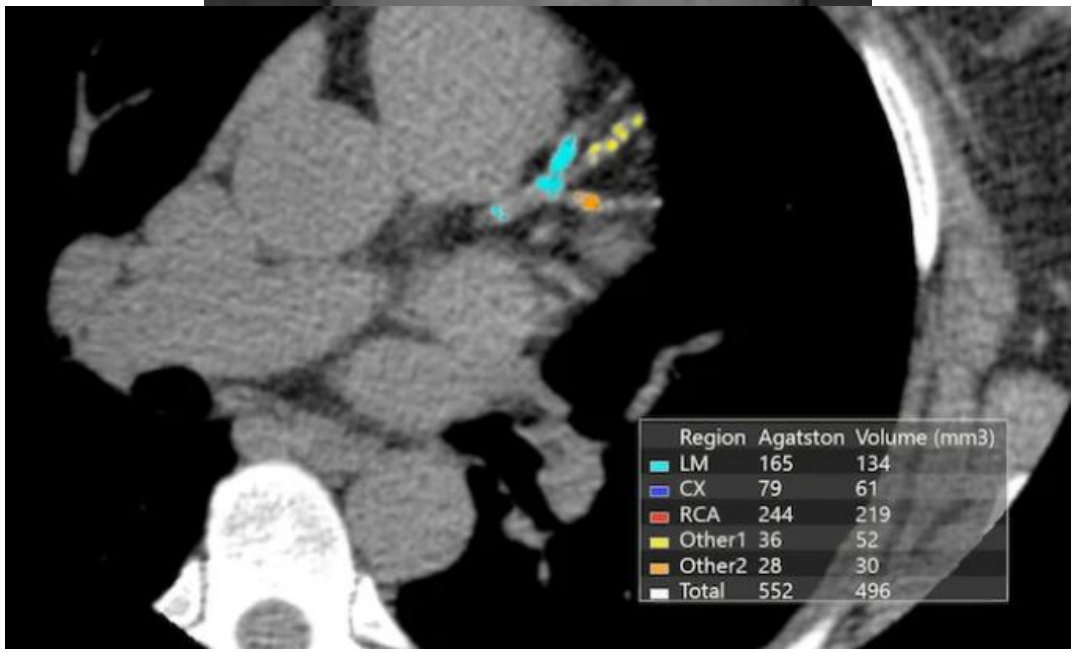
Patient preparation
On the day

- Clinical history (indication, contraindications, CVD risk factors, stents details, renal function, allergy history etc)
- Blood pressure and heart rate measurement
- Explanation of the precedure
- Venus cannula
- ECG leads
- Breathing simulation – checking timing and heart rate
- B-blocker iv (metoprolol 5-40 mg)
- Nitrates sl

Scanning

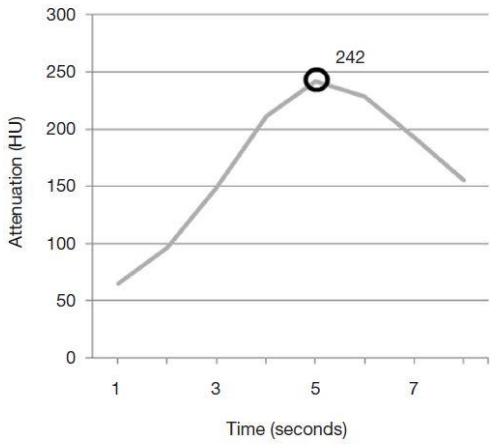
1. Topogram

2. Calcium Score

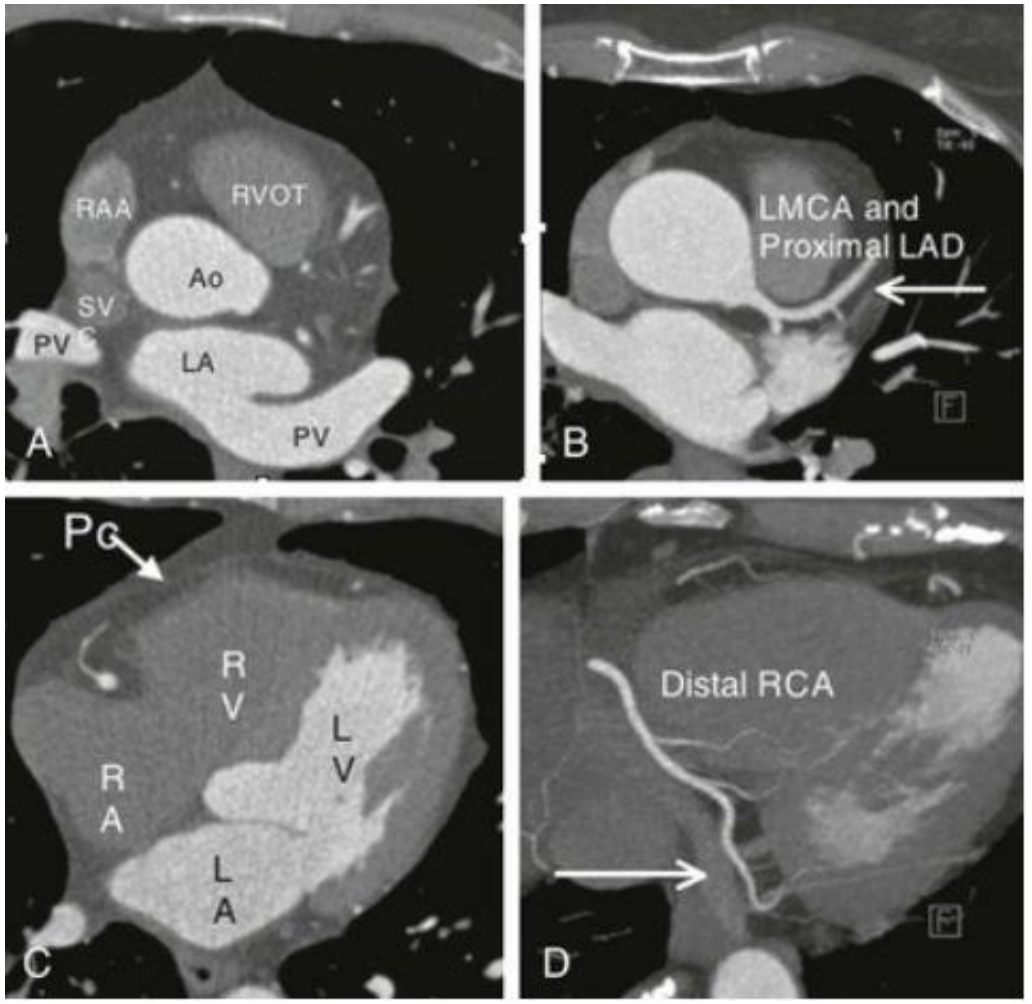


Scanning

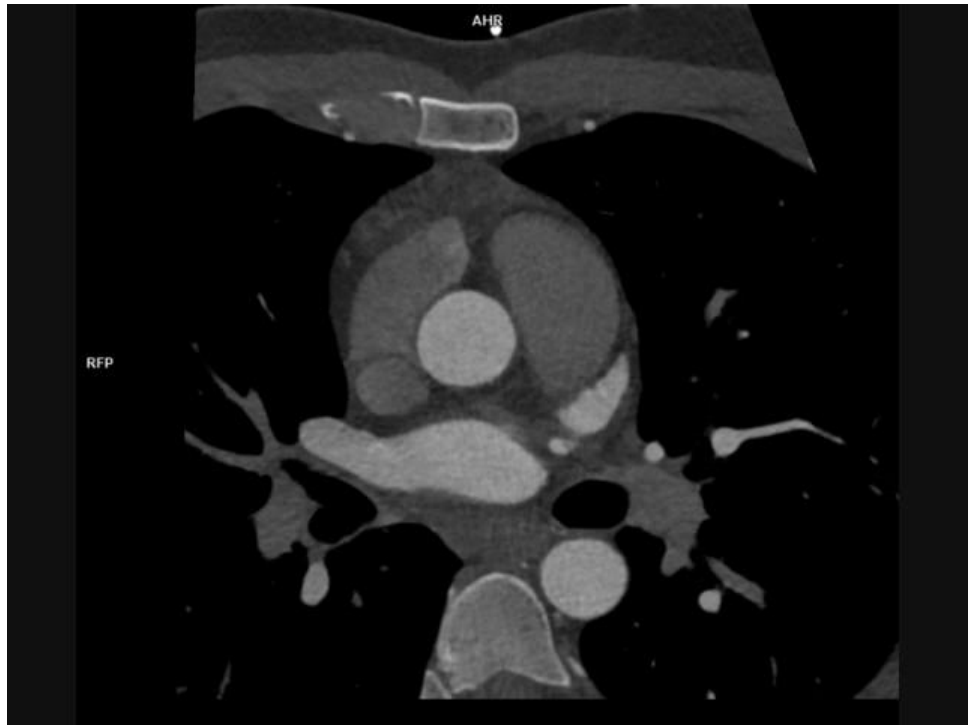
3. Test Bolus/ Bolus Tracking



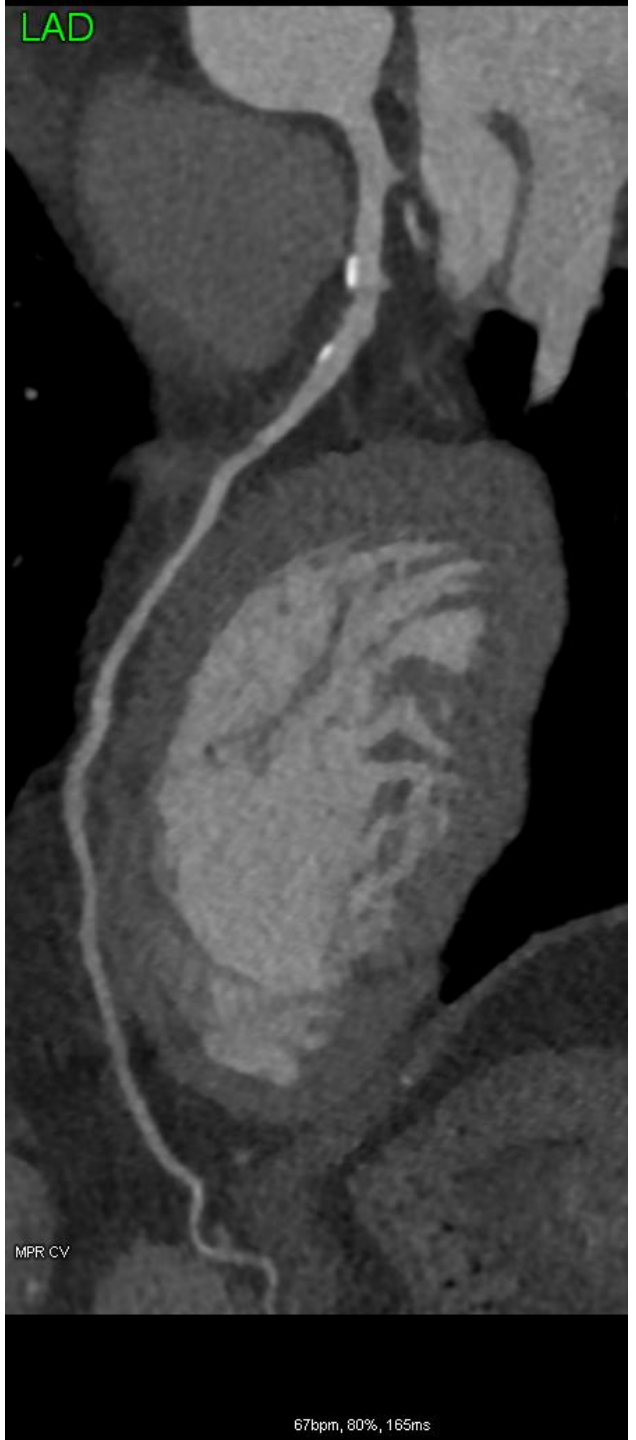
4. Cardiac computed tomography angiography (CTA)



35 years-old male
Hx of familiar hypercholesterolaemia under statin treatment since 25 yo
Atypical chest pain



Rad 2.4 mS



Report components

- Patient information & indication
- Procedure
- Image quality and limitations
- Results
  - Coronary artery findings
  - Non-coronary artery cardiac findings
  - Extracardiac findings
- Impression and recommendations

Procedure

- Type of study (Calcium score, coronary angiography)
- Equipment details
- Acquisition protocol (prospective/retrospective)
- Contrast administration (bolus tracking/test bolus)
- Other medications (beta blocker, NTG)
- Radiation dose
- Clinical parameters (Heart rate/Blood pressure/Arrhythmia)
- Complications

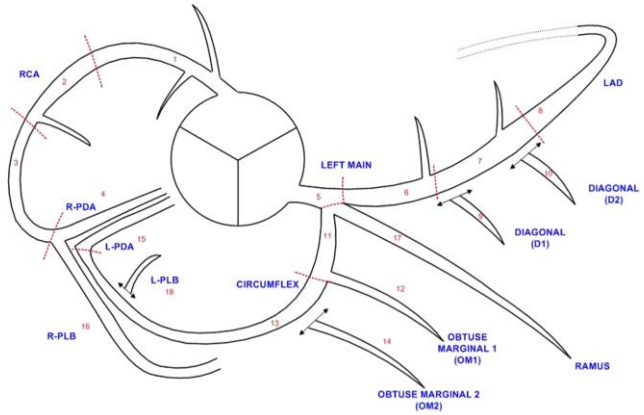
Study quality

- Diagnostic accuracy of study
- Quality
  - Excellent
  - Good
  - Average
  - Poor
- Inadequate contrast opacification?
- Noise or SNR (HU SD)

- Artefacts
  - Longitudinal misalignment
  - Phase inconsisteny
  - Motion blurring
  - Beam hardening
  - Calcium related partial volume artefact

Clearly state if sections are interpretable

Coronary artery findings



- Noncontrast interpretation
  - Agatston score (total/per artery) and percentile
- Anatomy
  - Dominance
  - Variance
  - Origin – course – lumen caliber – termination
- Disease
  - Plaque location and stenosis severity
  - Plaque morphology
  - Extent

CAD-RADS	Stenosis	Percentage
0	No	0
1	Minimal	<25%
2	Mild	25-49%
3	Moderate	50-69%
4A	Severe in 1 or 2 vessels	70-99%
4B	Severe in 3 vessels (or LM >50%)	70-99%
5	Occlusion	100%

Plaque morphology

- Calcified/non calcified
  - Calcified
  - Predominantly calcified
  - Noncalcified
  - Predominantly noncalcified
  - Mixed
- Length
- Eccentric
- Dissection
- Ulceration
- Positive remodeling
- Tortuous segment

Example of description

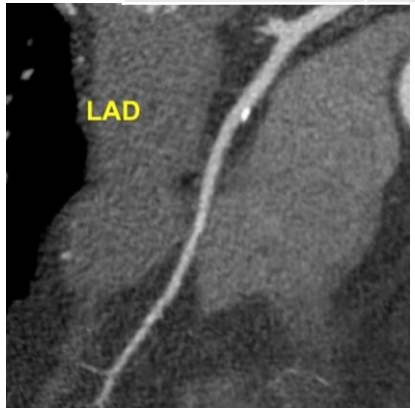
- “In the proximal segment of LAD there is a non-calcified plaque with positive remodeling causing moderate stenosis (50-69%)”
- “In the mid segment of RCA there is small eccentric calcified plaque causing mild stenosis (25-49%)”

CAD-RADS 2.0

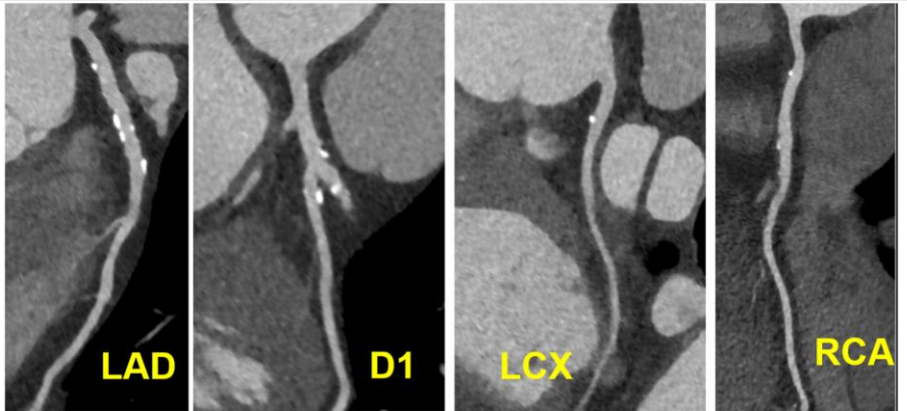
- Stenosis severity (0-5)
- Plaque burden (P1-mild, P2-moderate, P3-severe, P4-extensive)
- Modifiers
  - N – Non-diagnostic
  - HRP – High-risk plaque
  - I – Ischaemia (I+, I-. I+/-)
  - S – Stent
  - G – Graft
  - E – Exceptions

Plaque burden

Modifier	Burden	CAC	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 or 3 vessels with mild
P3	Severe	301-999	5-7	3 vessels with moderate amount or 1 vessel with severe
P4	Extensive	>1000	≧ 8	2-3 vessels with severe amount of plaque



P1



P3

Conclusion

- Great tool with limitations
- Anatomical information with great NPV
- Risk stratification (CAC score, atherosclerosis)
- Functional information
- Vulnerable plaque identification
- Cardiac risk prediction

Thank you for your attention