Advanced Cardiac Imaging – Cardiac CT

ד"ר אריה שלו

שירות דימות הלב

מרכז רפואי אוניברסיטאי סורוקה

Cardiac CT

Coronary Calcium score (CCS)

Cardiac CT Angiography (CCTA)

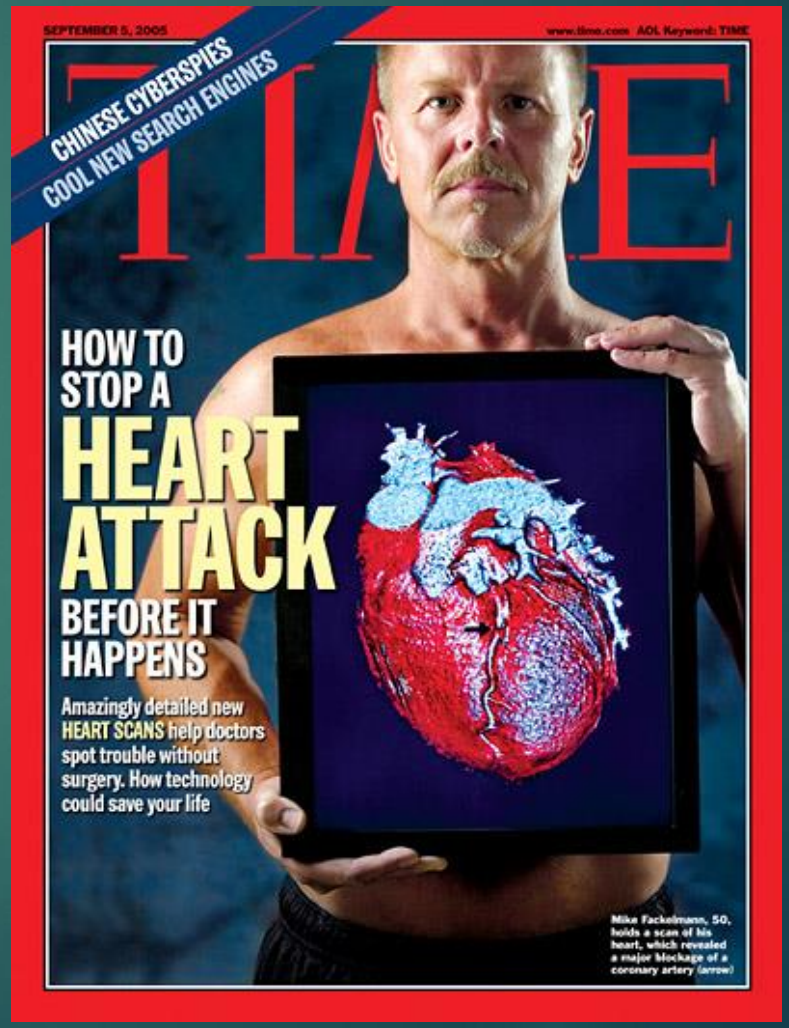
עובדות בסיסיות

- מחלות קרדיווסקולריות מהוות גורם מוביל לתמותה ברחבי העולם
- מחלת לב כלילית גורמת לכמחצית ממקרי התמותה
- בכמחצית מהארועים הלבביים ההסתמנות הראשונה מתבטאת באוטם שריר הלב או מוות פתאומי

מטרות דימות הלב

- אבחנה בשלב מוקדם
- האטת תהליך המחלה הטרשתית
- מניעה של Hard end-points

אוטם שריר הלב, ארוע מוחי, מוות



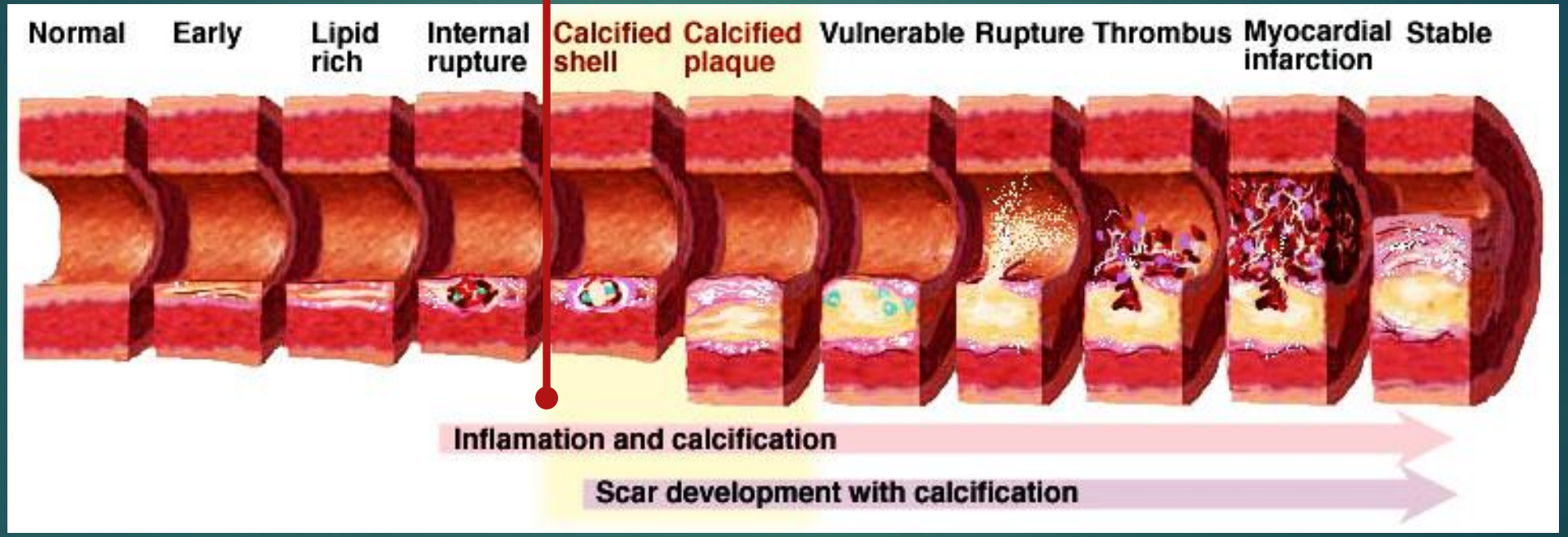
למה דימות?

- FRAMINGHAM RISK SCORE - הגורם המנבא החזק ביותר הוא גיל...
- הערכת סיכון בלתי ישירה
- שיטות הסווג למיניהן מוגבלות – כשליש מהאנשים שיסווגו כבעלי סיכון נמוך לפיהן, יעברו ארוע קרדיווסקולרי משמעותי
- המטרה - איתור טרשת תת-קלינית ע"י אמצעים מדוייקים יותר

PATIENT-TAILORED MEDICINE

Coronary Disease Progression

Calcified Plaque Detected by non-contrast CT



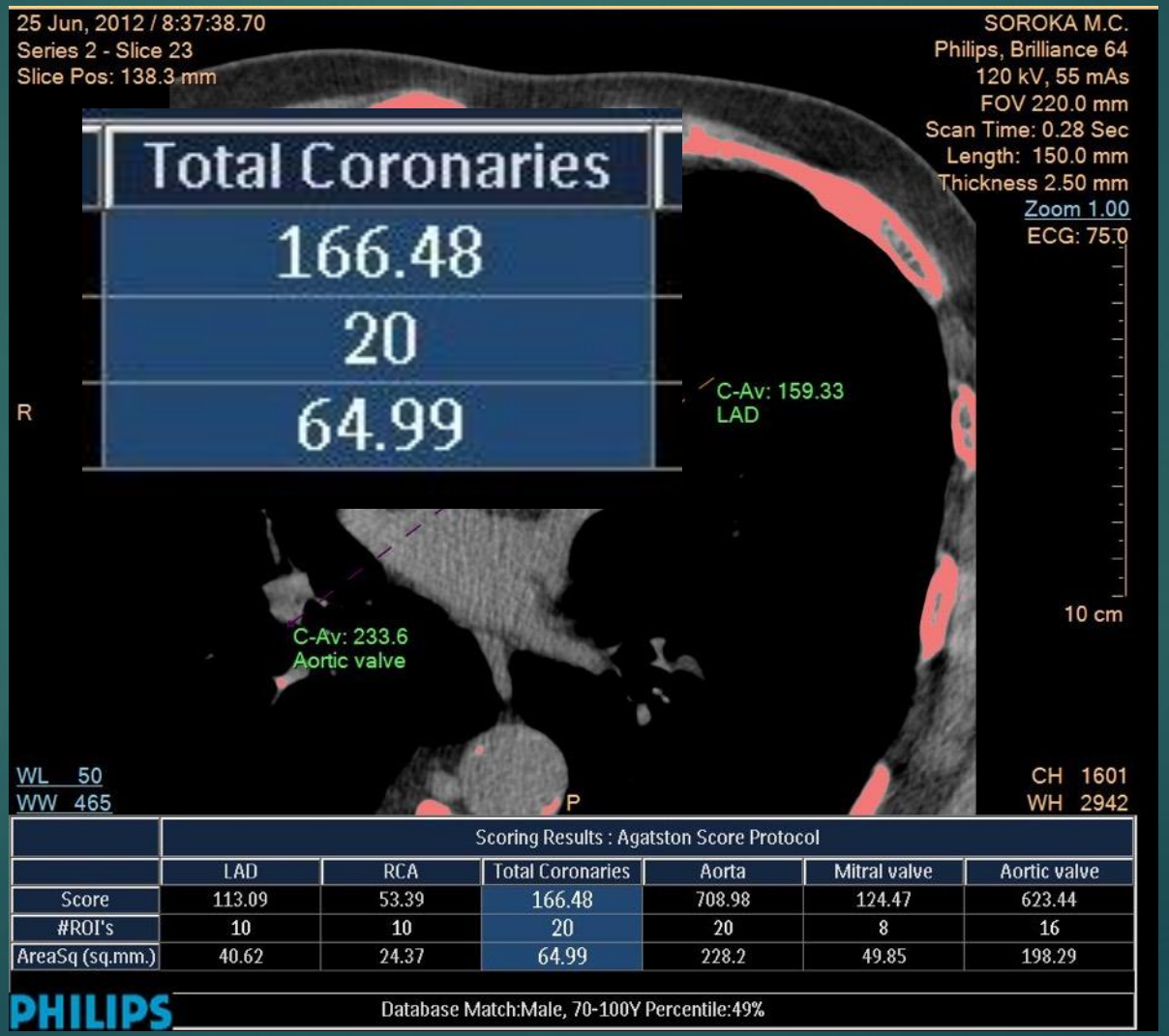
>60% stenosis (+) stress/imaging

Coronary Artery Calcium Scoring (CACS)

- סריקת CT ללא הזרקת חומר ניגודי
- חשיפה נמוכה לקרינה
- עלות נמוכה
- **סקירה של נבדקים אסימפטומטיים - Risk stratification**
- **ה- CACS מהווה סמן ל- Total plaque burden**

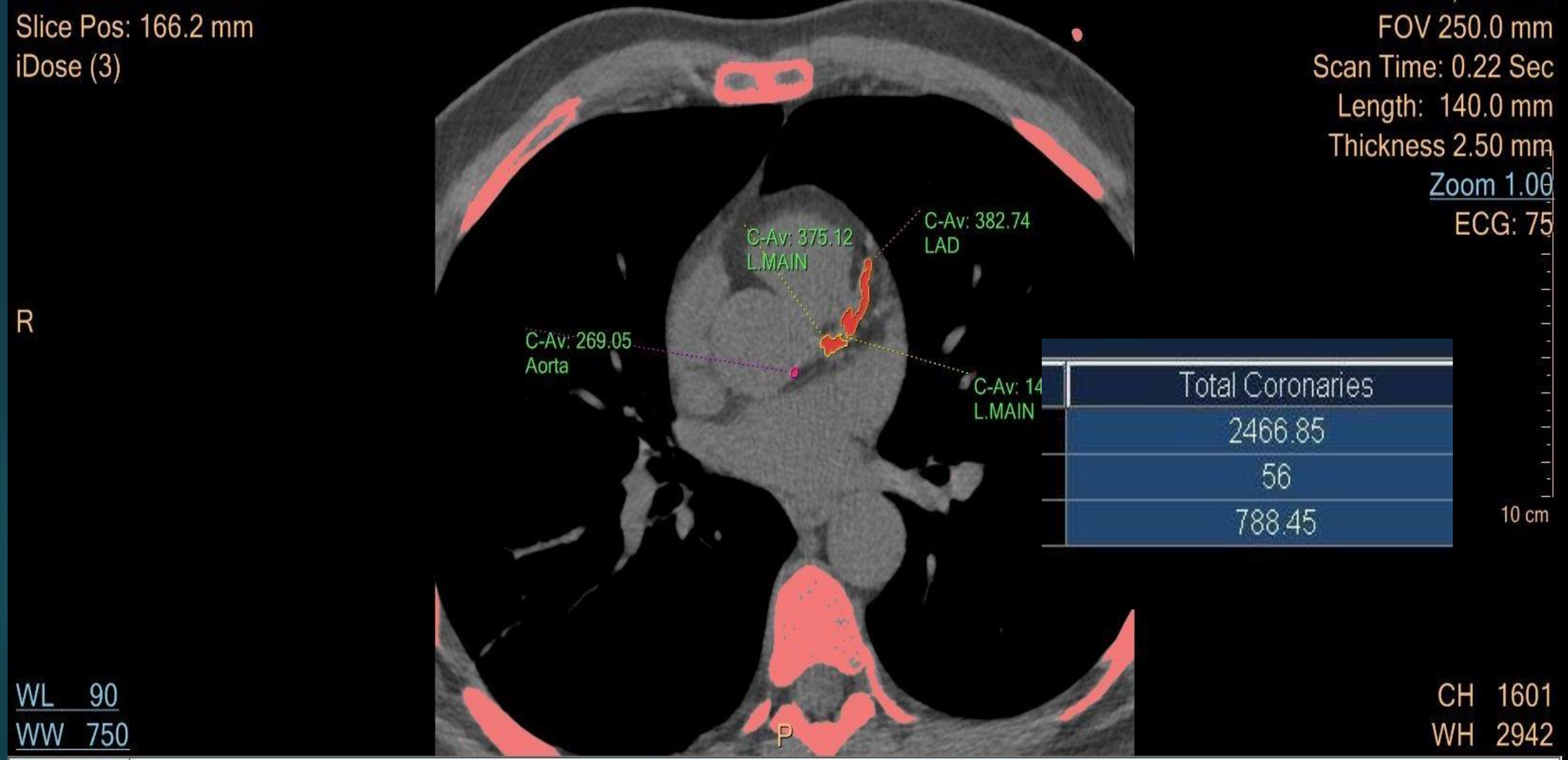
Agatston Score

Integration of plaque density and plaque area



	Scoring Results : Agatston Score Protocol					
	LAD	RCA	Total Coronaries	Aorta	Mitral valve	Aortic valve
Score	113.09	53.39	166.48	708.98	124.47	623.44
#ROI's	10	10	20	20	8	16
AreaSq (sq.mm.)	40.62	24.37	64.99	228.2	49.85	198.29

PHILIPS Database Match:Male, 70-100Y Percentile:49%



	Scoring Results : Agatston Score Protocol					
	L.MAIN	LAD	LCX	RCA	Total Coronaries	Aorta
Score	112.06	701.35	310.94	1342.5	2466.85	768.7
#ROI's	3	15	13	25	56	26
AreaSq (sq.mm.)	34.81	216.25	102.04	435.35	788.45	246.29

CACS Categories

סקאלה לינארית מורכבת מ- 4 דרגות:

- 0 – תקין
- 1-99 – נמוך
- 100-399 – בינוני
- 400< – חמור

- ה- CACS מדווח לפי אחוזון המותאם לגיל ולמין הנבדק

Age (45-84): 64

Gender: male

Race/Ethnicity: white

Observed Agatston Calcium Score (optional): 61

Calculate

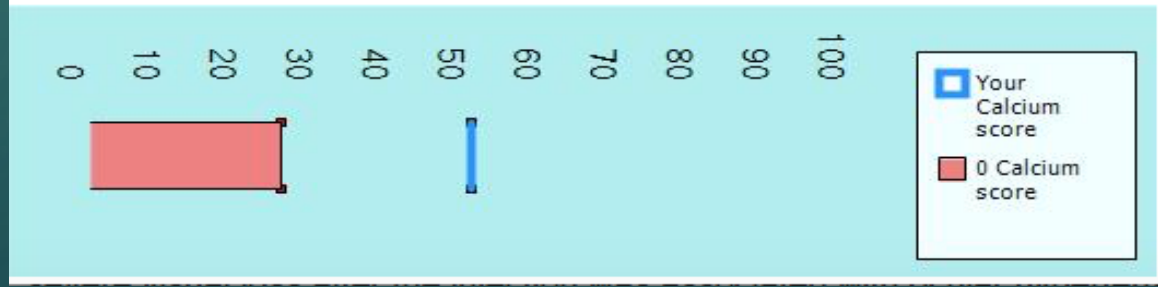
The estimated probability of a non-zero calcium score for a white male of age 64 is 75 %.

Percentiles and Calcium Scores for: white male of age 64

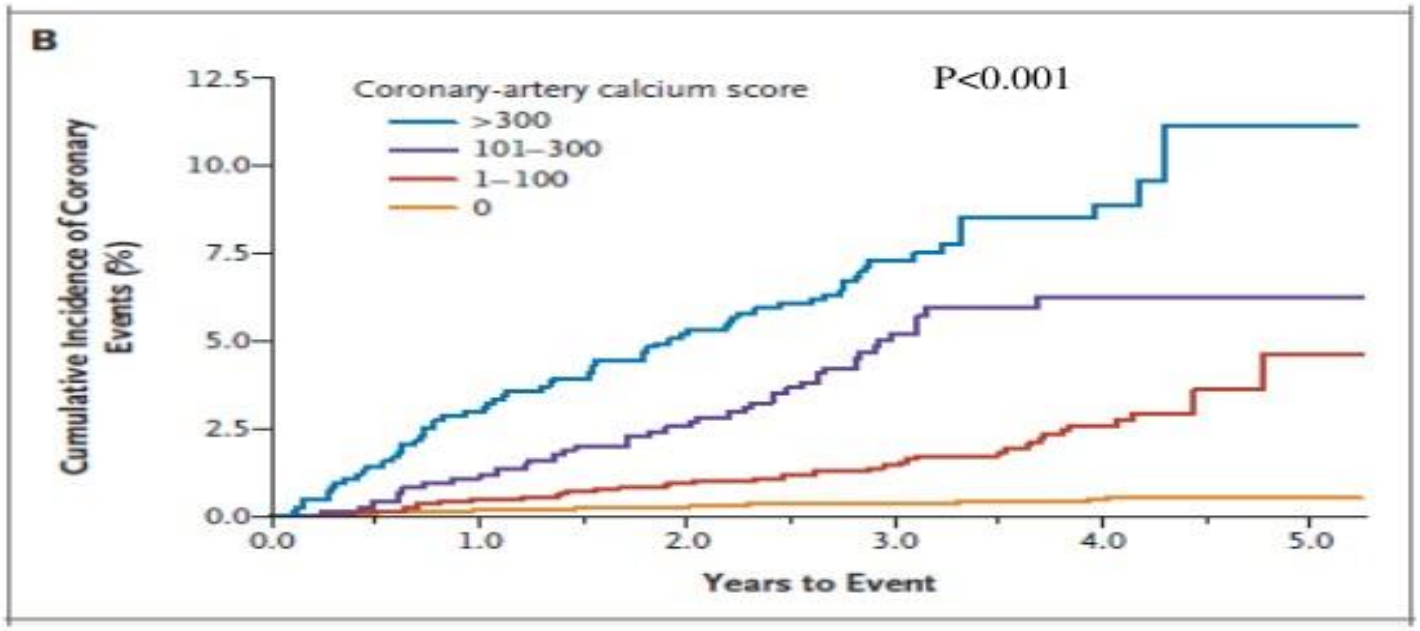
25th	50th	75th	90th
2	61	269	717

The observed calcium score of 61 is at percentile 50 for subjects of the same age, gender, and race/ethnicity who are free of clinical cardiovascular disease and treated diabetes.

Chart 1: Percentiles

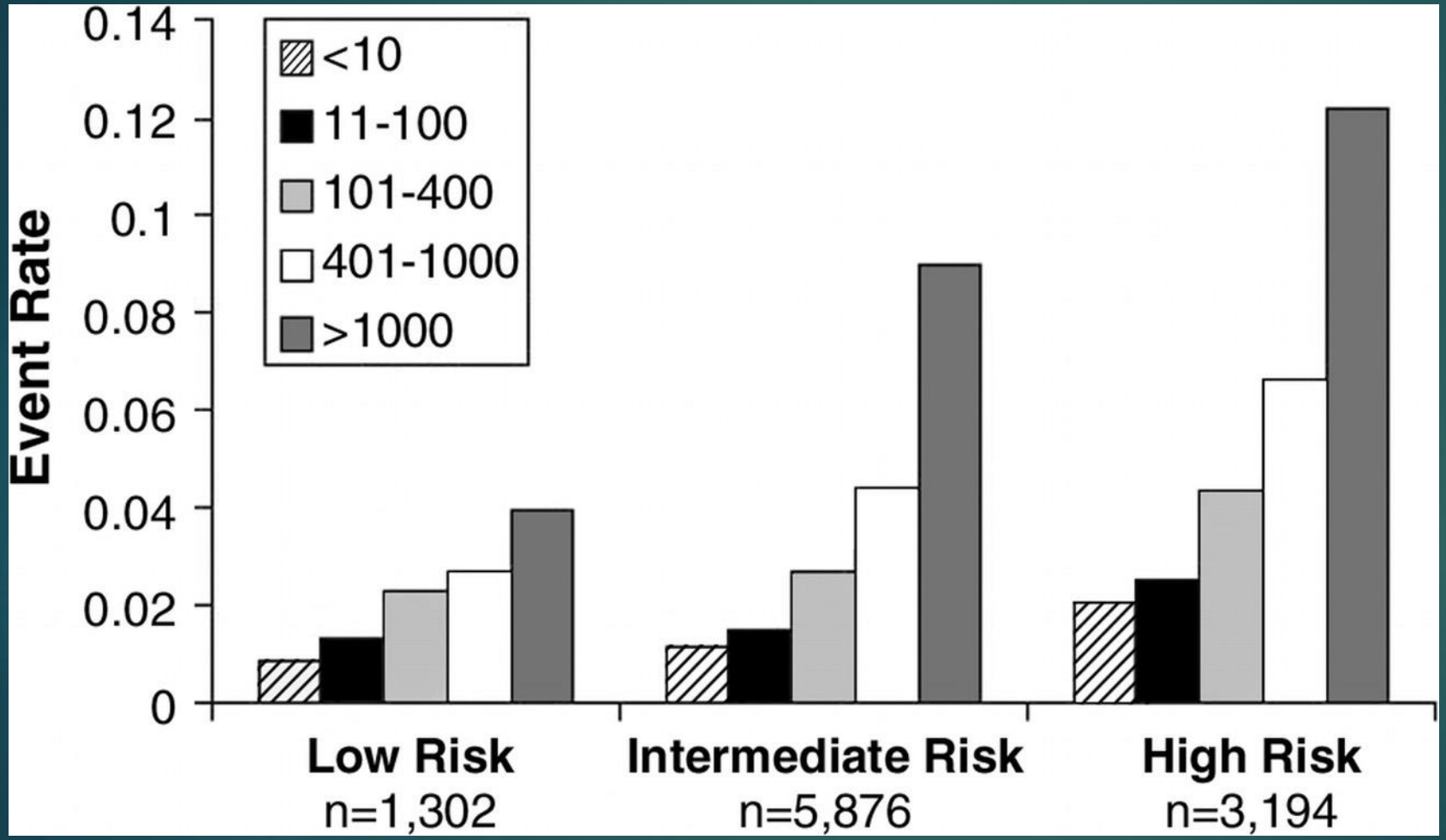


Calcium Score & Any Coronary Events:
MESA Study NEJM 2008;358:1336-45



סיכון מוגבר לאירוע כלילי – כאשר CACS>300 או >75%

CAC Score – Risk Reclassification



5-Year Mortality Rates in Framingham Risk Subsets by Coronary Calcium Score

Shaw et al. ***Radiology*** 2003; 228:826-833

Comparison of Novel Risk Markers for Improvement in Cardiovascular Risk Assessment in Intermediate-Risk Individuals

Context Risk markers including coronary artery calcium, carotid intima–media thickness, ankle-brachial index, brachial flow–mediated dilation, high-sensitivity C-reactive protein (CRP), and family history of coronary heart disease (CHD) have been reported to improve on the Framingham Risk Score (FRS) for prediction of CHD, but there are no direct comparisons of these markers for risk prediction in a single cohort.

Objective We compared improvement in prediction of incident CHD/cardiovascular disease (CVD) of these 6 risk markers within intermediate-risk participants (FRS >5%-<20%) in the Multi-Ethnic Study of Atherosclerosis (MESA).

Conclusions Coronary artery calcium, ankle-brachial index, high-sensitivity CRP, and family history were independent predictors of incident CHD/CVD in intermediate-risk individuals. Coronary artery calcium provided superior discrimination and risk reclassification compared with other risk markers.

JAMA. 2012;308(8):788-795

TABLE 2 Summary of 4 Major Guidelines and Expert Consensus Documents on Use of Coronary Artery Calcium for Risk Assessment in Asymptomatic Patients

Guideline/Statement	Summary of CT Recommendations
2013 ACC/AHA risk assessment guideline	If, after quantitative risk assessment using traditional risk factors, a risk-based treatment decision is uncertain, CAC score may be considered to inform treatment decision making. Class IIb, Level of Evidence: B (7).
2016 European guidelines on CVD prevention	CAC scoring may be considered as a risk modifier in CV risk assessment. Class IIb, Level of Evidence: B ( ).
2017 expert consensus from the Society of Cardiovascular Computed Tomography	It is appropriate to perform CAC testing in the context of shared decision making for asymptomatic individuals without clinical ASCVD who are 40–75 years of age in the 5%–20% ten-year ASCVD risk group and selectively in the <5% ASCVD risk group, such as those with a family history of premature CAD (91).
2018 U.S. Preventive Services Task Force draft guideline on nontraditional risk factors	In asymptomatic adults, the current evidence is insufficient to assess the balance of benefits and harms of adding CAC score to traditional risk assessment for CVD prevention. Class I (123).

Current Guidelines – Asymptomatic patients – USA vs. Europe

MESA The Multi-Ethnic Study of Atherosclerosis

MESA 10-Year CHD Risk with Coronary Artery Calcification

Back to CAC Tools

1. Gender	Male ●	Female ○				
2. Age (45-85 years)	64	Years				
3. Coronary Artery Calcification	175	Agatston				
4. Race/Ethnicity	**Choose One**					
Caucasian	●					
Chinese	○					
African American	○					
Hispanic	○					
5. Diabetes	Yes ○	No ●				
6. Currently Smoke	Yes ○	No ●				
7. Family History of Heart Attack (History in parents, siblings, or children)	Yes ○	No ●				
8. Total Cholesterol	189	mg/dL	or	4.9	mmol/L	
9. HDL Cholesterol	56	mg/dL	or	1.4	mmol/L	
10. Systolic Blood Pressure	115	mmHg	or	15.3	kPa	
11. Lipid Lowering Medication	Yes ○	No ●				
12. Hypertension Medication	Yes ○	No ●				

Calculate 10-year CHD risk

The estimated 10-year risk of a CHD event for a person with this risk factor profile including coronary calcium is 7.6%. The estimated 10-year risk of a CHD event for a person with this risk factor profile if we did not factor in their coronary calcium score would be 4.7%.

Coronary Artery Calcium Score

- בדיקה המיועדת לנבדקים אסימפטומטיים כבדיקת סקר לשם Risk stratification
- מוסיפה ערך פרוגנוסטי מעל ומעבר להערכת גורמי סיכון קונבנציונלית
- משפרת את הדיוק באיתור נבדקים בסיכון גבוה
- מדידה כמותית של ה- CACS נותנת הערכה טובה אודות כמות הטרשת בעורקי הלב
- כאשר CACS גבוה (>400) ניתן לשקול הערכת אסכמיה (ESC Guidelines 2013)

עם זאת...

- ערך פרוגנוסטי מופחת בנבדקים סימפטומטיים - אינה מאתרת טרשת לא מסויידת
- אין הערכה של חומרת הצרויות כליליות

CACS אינה בדיקת הבחירה בנבדקים סימפטומטיים

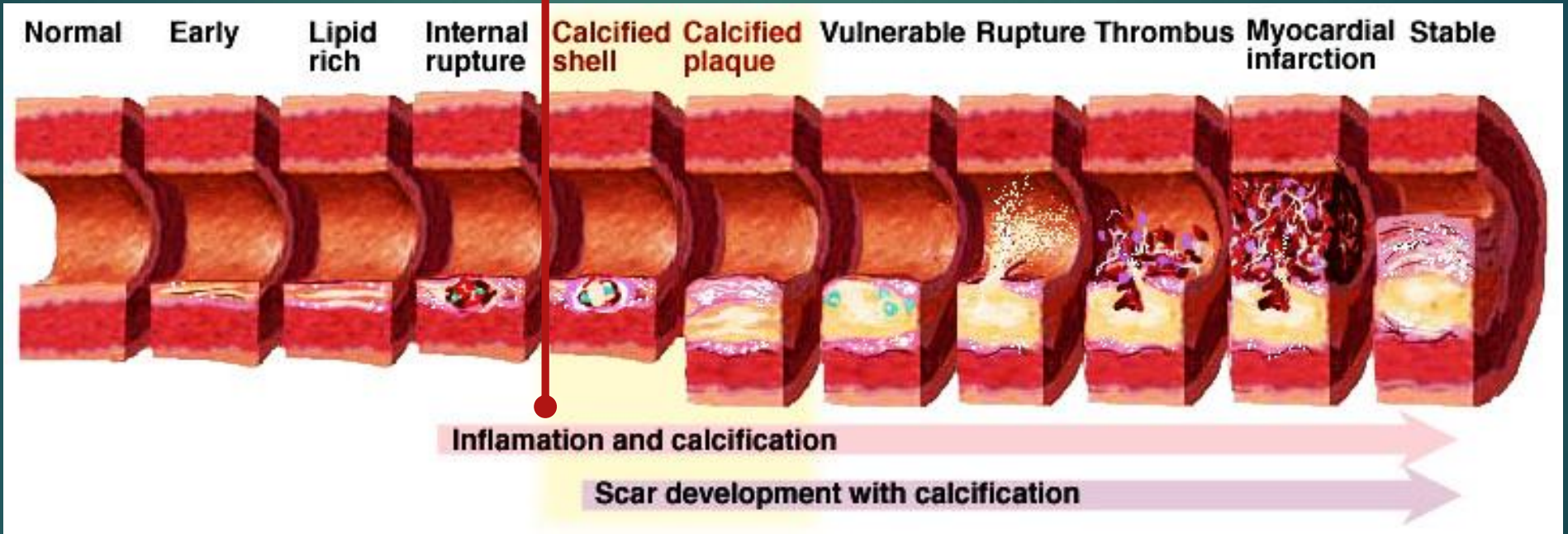
CENTRAL ILLUSTRATION: Proposed Decision-Making Approach to Selective Use of Coronary Artery Calcium Measurement for Risk Prediction

Using 10-year ASCVD risk estimate plus coronary artery calcium (CAC) score to guide statin therapy				
Patient's 10-year atherosclerotic cardiovascular disease (ASCVD) risk estimate:	<5%	5–7.5%	>7.5–20%	>20%
Consulting ASCVD risk estimate alone	Statin not recommended	Consider for statin	Recommend statin	Recommend statin
Consulting ASCVD risk estimate + CAC				
If CAC score =0	Statin not recommended	Statin not recommended	Statin not recommended	Recommend statin
If CAC score >0	Statin not recommended	Consider for statin	Recommend statin	Recommend statin
Does CAC score modify treatment plan?	✗ CAC not effective for this population	✓ CAC can reclassify risk up or down	✓ CAC can reclassify risk up or down	✗ CAC not effective for this population

Greenland, P. et al. J Am Coll Cardiol. 2018;72(4):434–47.

Coronary Disease Progression

Calcified Plaque Detected by non-contrast CT



Role of CCTA

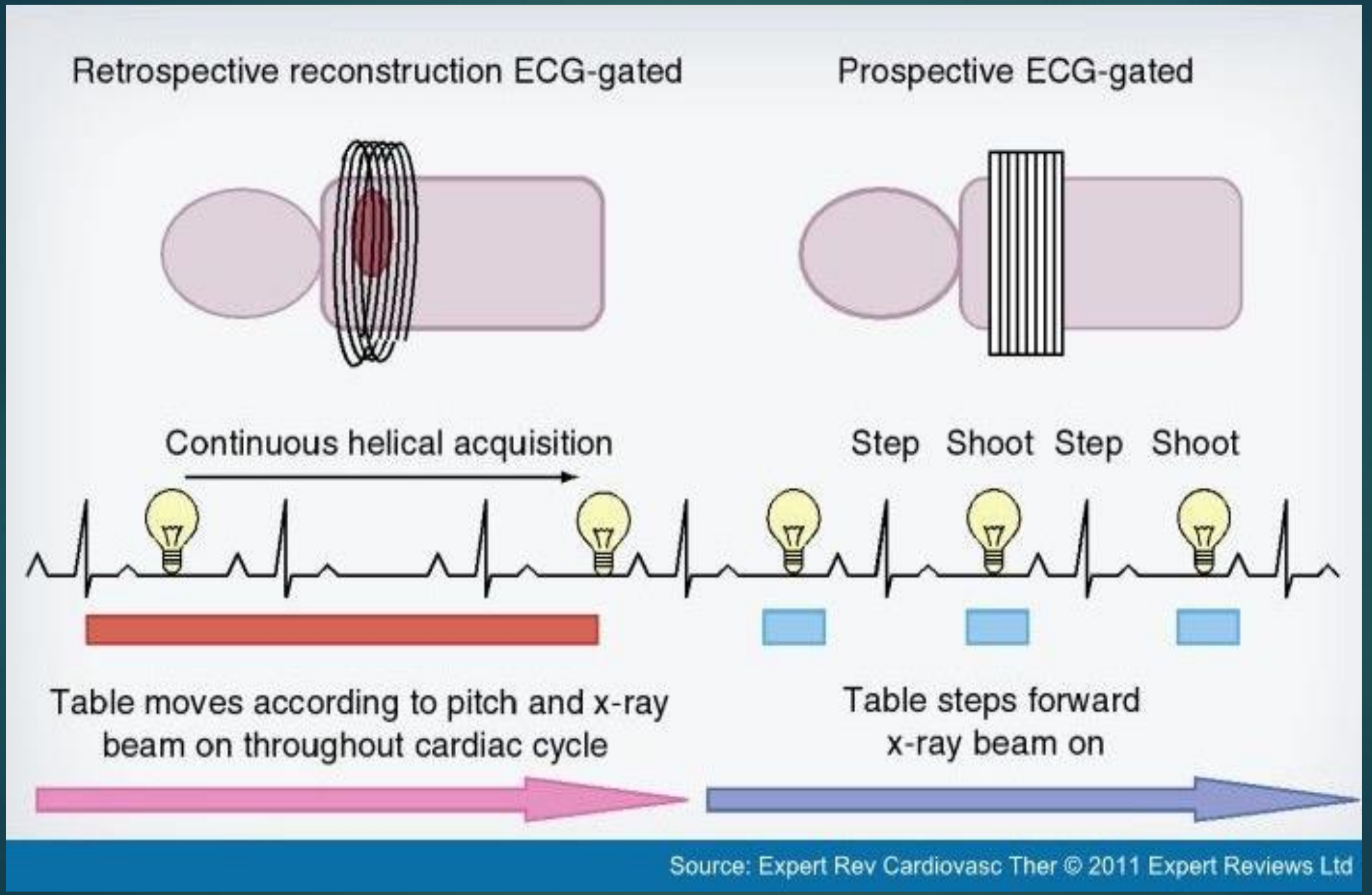
>50-70% stenosis
Ischemia assessment

Cardiac CT Angiography

- What is CCTA
- Diagnostic performance
- Indications
- Stable vs. Acute Chest Pain / ED patients
- Limitations
- Radiation
- Future perspectives

שיטות סריקה

Retrospective (spiral)
vs.
Prospective



Source: Expert Rev Cardiovasc Ther © 2011 Expert Reviews Ltd

Prospective vs. Retrospective Gating

Prospective Gating:

- הפחתת קרינה משמעותית (פי 2-3)
- אינה מתאימה לקצב לב גבוה מעל 70 לדקה או קצב לא סדיר
- אין אפשרות לשחזר פאזות נוספות של מחזור הלב

Retrospective Gating:

- ניתן לבצע גם בקצב לב גבוה יותר (שחזור פאזות נוספות)
- פעימות מוקדמות / קצב לא סדיר (יכולת לשחזר ולבטל פעימות מיותרות)
- בעת הערכה של תפקוד הלב / תנועת מסתמים / תהליכים תופסי מקום

חסרון – קרינה !!

Patient preparation

- Heart rate control - <65 bpm
- IV line (large gauge 14 / 16 G), antecubital
- Creatinine – GFR > 60ml/min
- Iodine allergy – steroid preparation
- Prior Iodine anaphylaxis – absolute CI
- Asthma - steroid preparation
- 5PDE Inhibitors – 48 hours avoidance

התוויות לביצוע Cardiac CT

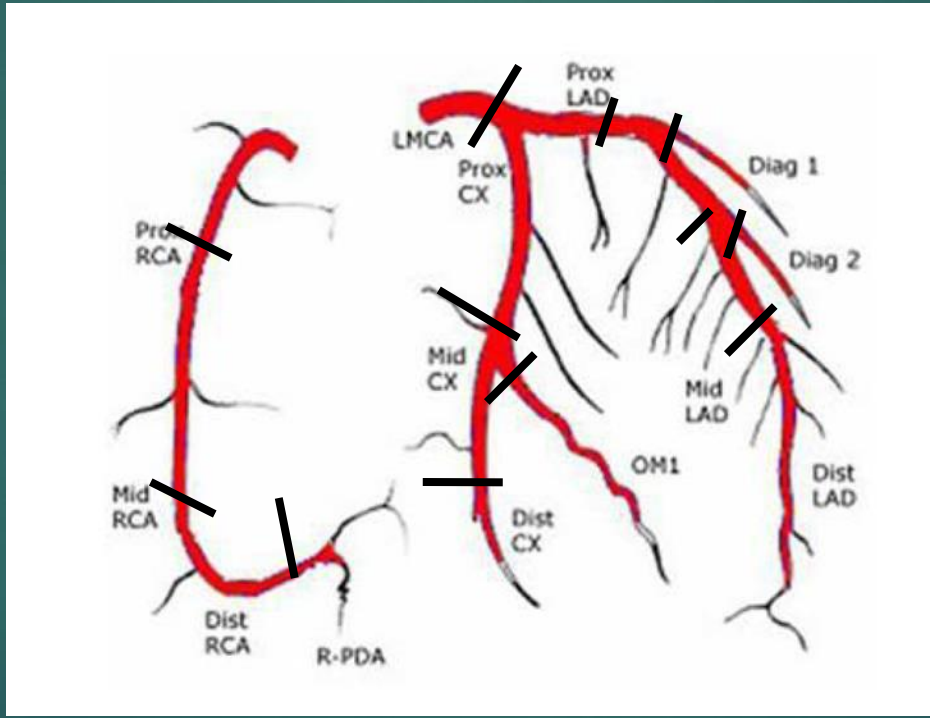
- הערכה של העורקים הכליליים
- אנטומיה של ורידי הריאה – לפני ביצוע אבלציה של פרפור פרוזדורים (PVI)
- לפני החלפה של מסתם אאורטלי בגישה מילעורית – TAVI - הערכת מבנה המסתם האאורטלי, האאורטה העולה וכלי דם פריפריים
- תהליכים תופסי מקום / מומי לב מולדים / הערכת פריקרד
- תפקוד גלובלי ואזורי של חדר שמאל, מקטע פליטה, נפח מדורי הלב

Coronary CTA

- הערכה של העורקים הכליליים - "צנתור וירטואלי"
- טרשת עורקים – קיום מחלה טרשתית, חומרת הצרויות, הרכב הטרשת
- הערכה לאחר השתלת סטנט / לאחר ניתוח מעקפים
- אנומליות במוצא או מהלך העורקים הכליליים

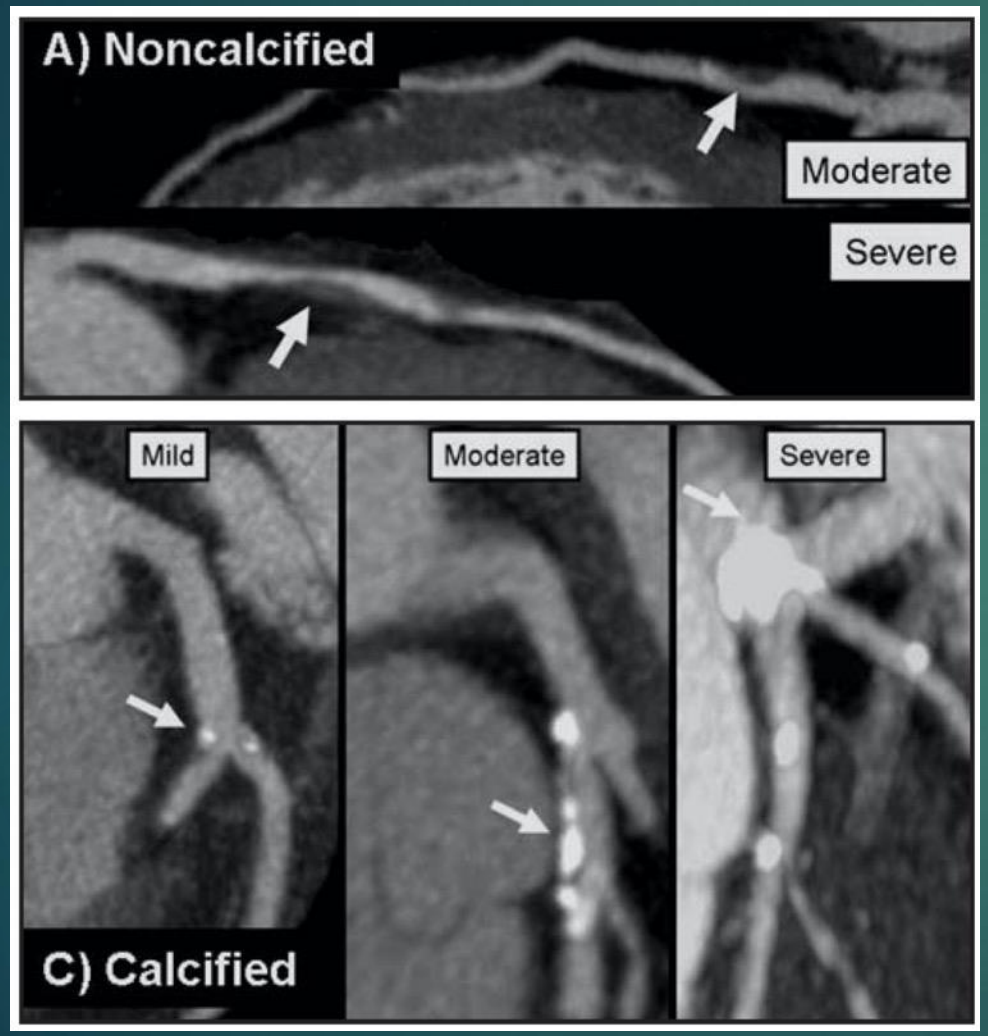
CCTA Interpretation and Report

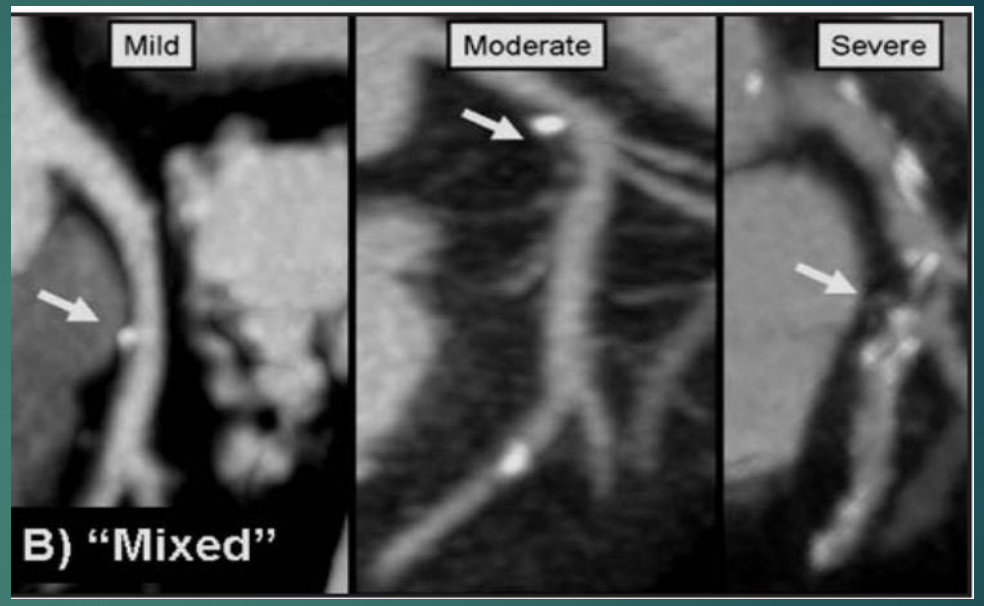
Coronary segmentation



AHA/ACC 17-segment model

Assessment of Stenosis

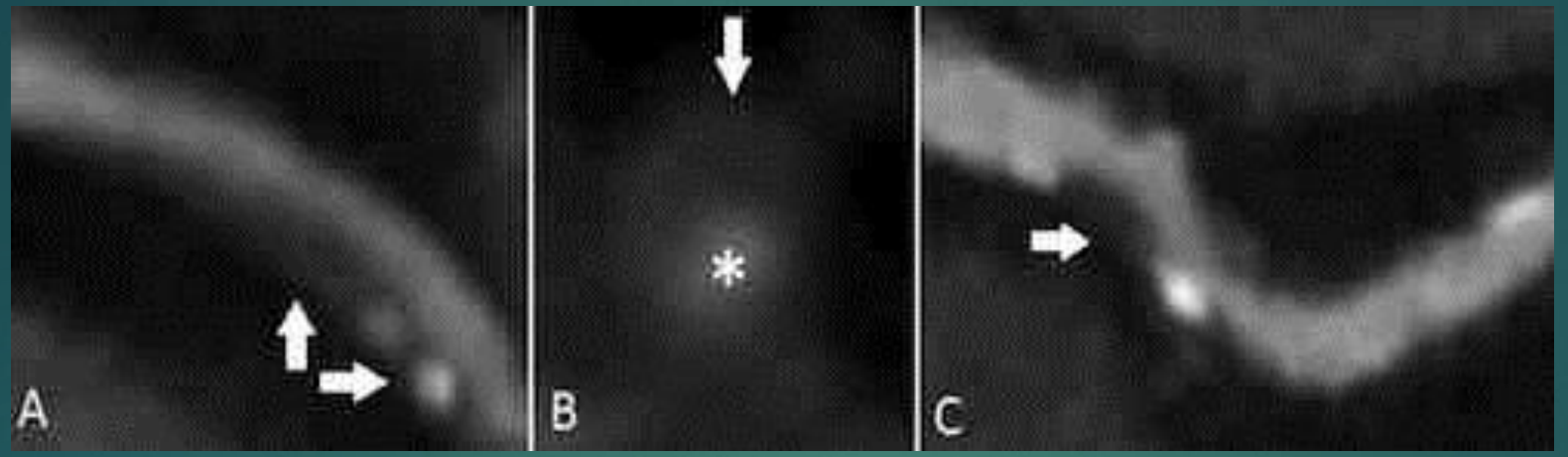




0 – normal
1-24% - mild
25-49 % - mild
50-69% - Moderate → Ischemia testing
70-99% – Severe
100% - Occlusion

Invasive Angiography

Adverse plaque features



Positive remodeling
Spotty calcification

Napkin ring sign

Low attenuation plaque

The patients demonstrating plaques with adverse features were at a higher risk of ACS developing over time when compared with patients having lesions without these characteristics.

Motoyama et al. JACC 2009

CCTA - Diagnostic Performance

	Sensitivity	Specificity	PPV	NPV
ACCURACY[2]	95%	83%	64%	99%
CORE-64[3]	85%	90%	91%	83%
Meijboom *et al.*[4]	99%	64%	86%	97%

Key: ACCURACY = Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography; CORE-64 = Coronary Artery Evaluation Using 64-Row Multi-detector Computed Tomography Angiography; NPV = negative predictive value; PPV = positive predictive value

JACC: CARDIOVASCULAR IMAGING
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CT Angiography for the Prediction of Hemodynamic Significance in Intermediate and Severe Lesions

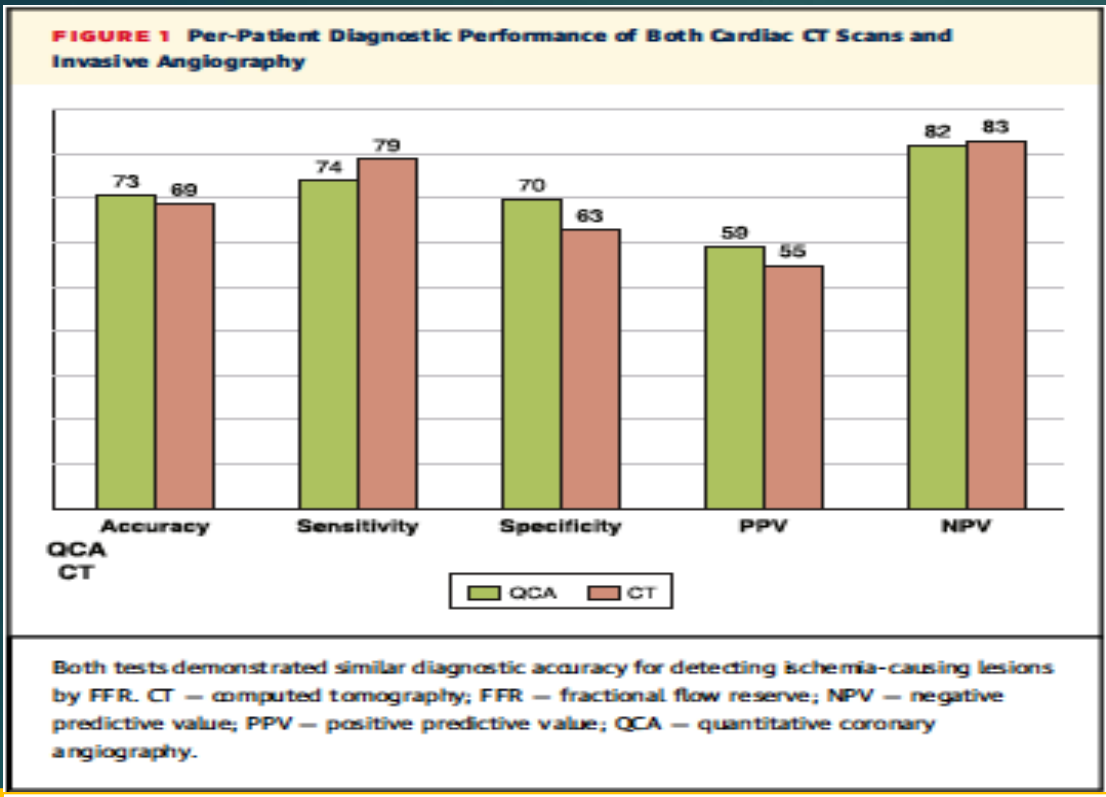
Head-to-Head Comparison With Quantitative Coronary Angiography Using Fractional Flow Reserve as the Reference Standard

Matthew J. Budoff, MD,[a] Ryo Nakazato, MD,[b] G.B. John Mancini, MD,[c] Heidi Gransar, PhD,[b] Jonathon Leipsic, MD,[c] Daniel S. Berman, MD,[b] James K. Min, MD[d]

- Patients underwent coronary CTA and invasive coronary angiography (ICA) with FFR in 407 lesions.
- Stenosis severity according to coronary CTA and QCA were graded as

0% -29%, 30% -49%, 50% -69%, and 70% -100%

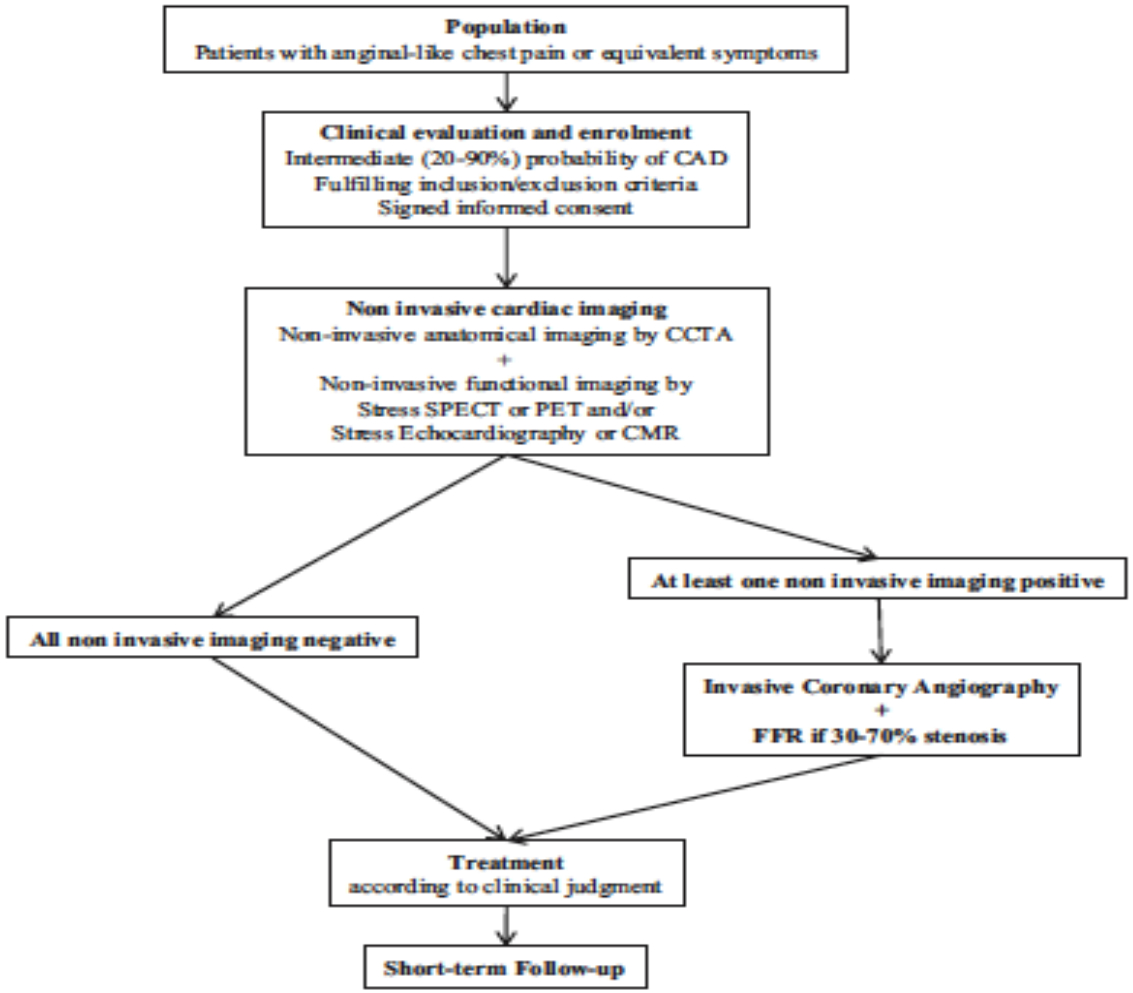
- Stenosis >50% was considered anatomically obstructive.
- Lesion-specific ischemia was defined according to FFR <0.8



QCA and coronary CTA had similar correlation and predictive accuracy for ischemia

- Conclusions:
- Coronary CTA, applied instead of ICA, provides similar diagnostic accuracy for detection and exclusion of lesion-specific ischemia.
- This has potential for coronary CTA largely replacing ICA for diagnosing obstructive coronary artery disease in low and intermediate risk patients

Detection of Significant Coronary Artery Disease by Noninvasive Anatomical and Functional Imaging



- **475 patients with stable CP, intermediate likelihood of CAD, underwent CCTA, stress MPI by SPECT or PET and ventricular wall motion imaging by stress echo or CMR.**
- **If at least 1 test was abnormal, the patients underwent ICA and FFR.**

Circ Cardiovasc Imaging. 2015;8

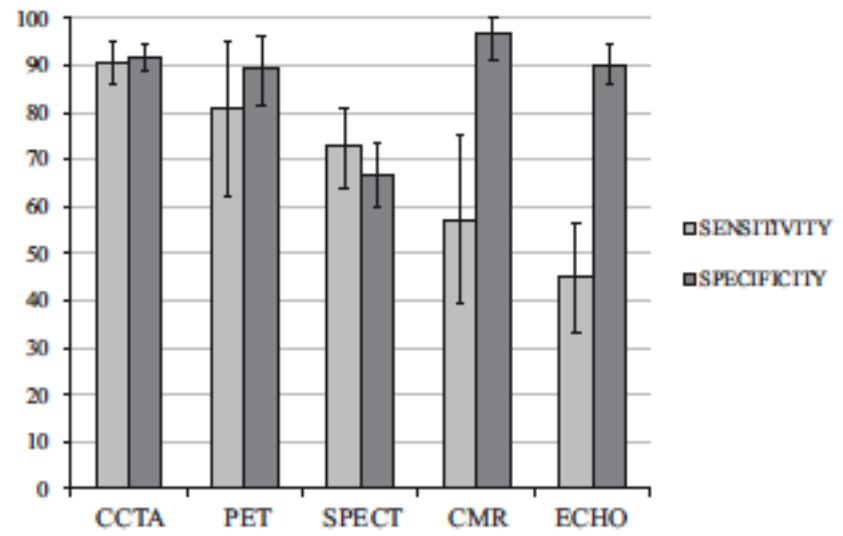


Figure 3. Sensitivity and specificity of noninvasive imaging techniques.
CCTA indicates coronary computed tomography angiography; CMR, cardiac magnetic resonance; ECHO, echocardiography; PET, positron emission tomography; and SPECT, single-photon computed emission tomography.

CCTA had the highest diagnostic accuracy for significant CAD

AUC-ROC:

CCTA - 0.91

MPI –0.74

Wall motion imaging - 0.70

<u>Conclusion</u>:

- **In a multicenter European population of patients with stable chest pain and low prevalence of CAD, <u>CCTA is more accurate</u> than noninvasive functional testing for detecting significant CAD defined invasively.**

Characteristics of tests commonly used to diagnose the presence of CAD

	Diagnosis of CAD	
	Sensitivity (%)	Specificity (%)
Exercise ECG[a]	45-50	85-90
Dobutamine stress MRI[b]	79-88	81-91
Vasodilator stress echocardiography	72-79	92-95
Vasodilator stress SPECT	90-91	75-84
Vasodilator stress MRI[b]	67-94	61-85
Coronary CTA[c]	95-99	64-83
Vasodilator stress PET	81-97	74-91

Optimal test to rule out CAD in patients with low-to-intermediate likelihood of disease

CAD = coronary artery disease; CTA = computed tomography angiography; ECG = electrocardiogram; MRI = magnetic resonance imaging; PET = positron emission tomography; SPECT = single photon emission computed tomography.
[a]Results without/with minimal referral bias; [b]Results obtained in populations with medium-to-high prevalence of disease without compensation for referral bias; [c]Results obtained in populations with low-to-medium prevalence of disease.
This slide corresponds to Table 12 in the full text.

Eur Heart J 2013;34:2949–3003. doi:10.1093/eurheartj/eht296

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APPROPRIATE USE CRITERIA

ACCF/AHA/ASE/ASNC/HFSA/HRS/S

JOURNAL OF CARDIOVASCULAR

Available online
Sci
journal homepage: ww

SCCT Guidelines

SCCT guidelines on the use
tomographic angiography fo

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)

מסמך עמדה

התוויות לביצוע טומוגרפיה ממוחשבת של הלב

מסמך עמדה משותף מטעם:
האיגוד הקרדיולוגי ואיגוד הרדיולוגים בישראל

אפריל 2010

ההסתדרות הרפואית בישראל
המועצה המדעית ● המנף לאבטחת איכות

Pretest probability of obstructive CAD

Table A. Pretest Probability of CAD by Age, Sex, and Symptoms

Age	Sex	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Nonanginal Chest Pain	Asymptomatic
<39	Men	Intermediate	Intermediate	Low	Very low
	Women	Intermediate	Very low	Very low	Very low
40–49	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Low	Very low	Very low
50–59	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Intermediate	Low	Very low
>60	Men	High	Intermediate	Intermediate	Low
	Women	High	Intermediate	Intermediate	Low

High: >90% pretest probability; intermediate: between 10% and 90% pretest probability; low: between 5% and 10% pretest probability; and very low: <5% pretest probability.

Modified from Gibbons et al. (9) to reflect all age ranges.

Table 5 Pre-test probabilities of obstructive coronary artery disease in 15 815 symptomatic patients according to age, sex, and the nature of symptoms in a pooled analysis[64] of contemporary data[7,8,62]

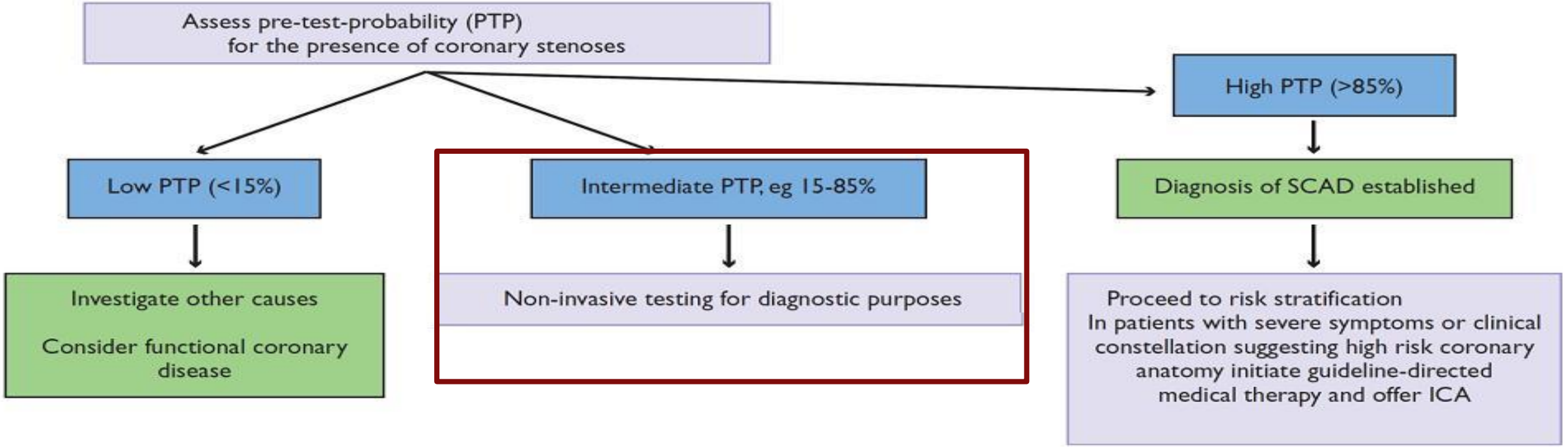
	Typical		Atypical		Non-anginal		Dyspnoea[a]	
Age	Men	Women	Men	Women	Men	Women	Men	Women
30–39	3%	5%	4%	3%	1%	1%	0%	3%
40–49	22%	10%	10%	6%	3%	2%	12%	3%
50–59	32%	13%	17%	6%	11%	3%	20%	9%
60–69	44%	16%	26%	11%	22%	6%	27%	14%
70+	52%	27%	34%	19%	24%	10%	32%	12%

©ESC 2019

Modifiers of the PTP estimate

- **Presence of risk factors for CVD:**
  - **Family history of CVD**
  - **Dyslipidemia**
  - **Diabetes**
  - **Hypertension**
  - **Smoking**
- **Q-wave, ST-segment, or T-wave changes on the ECG**
- **LV dysfunction suggestive of ischemia**
- **Coronary calcium obtained by computed tomography (CT)**
  - **Can be used to improve estimations of the PTP of obstructive CAD**

Initial diagnostic management of patients with suspected SCAD (2)

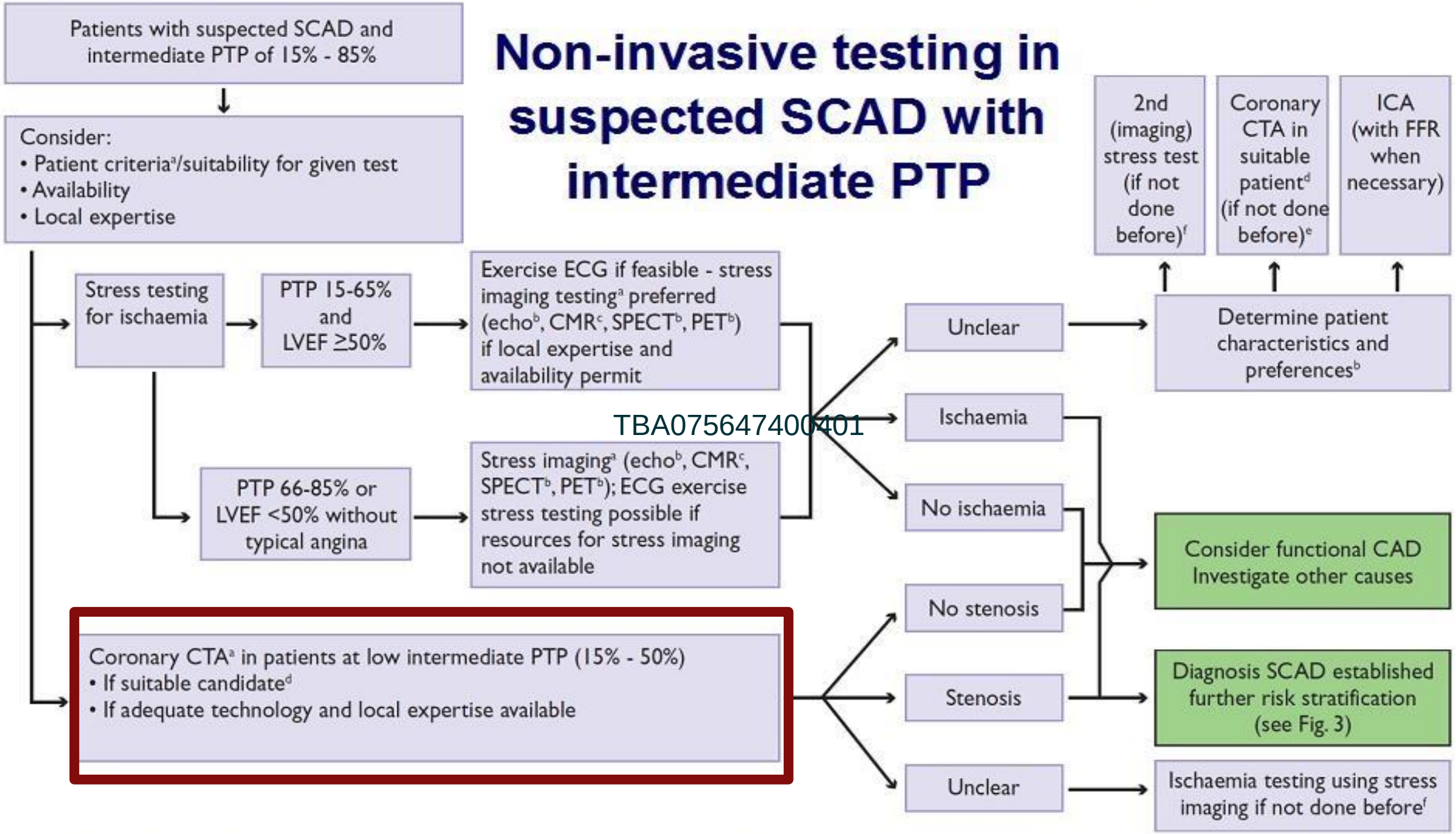


This slide corresponds to Figure 1 in the full text
ICA = invasive coronary angiography.

Eur Heart J 2013;34:2949–3003. doi:10.1093/eurheartj/eht296

EUROPEAN SOCIETY OF CARDIOLOGY®

Non-invasive testing in suspected SCAD with intermediate PTP

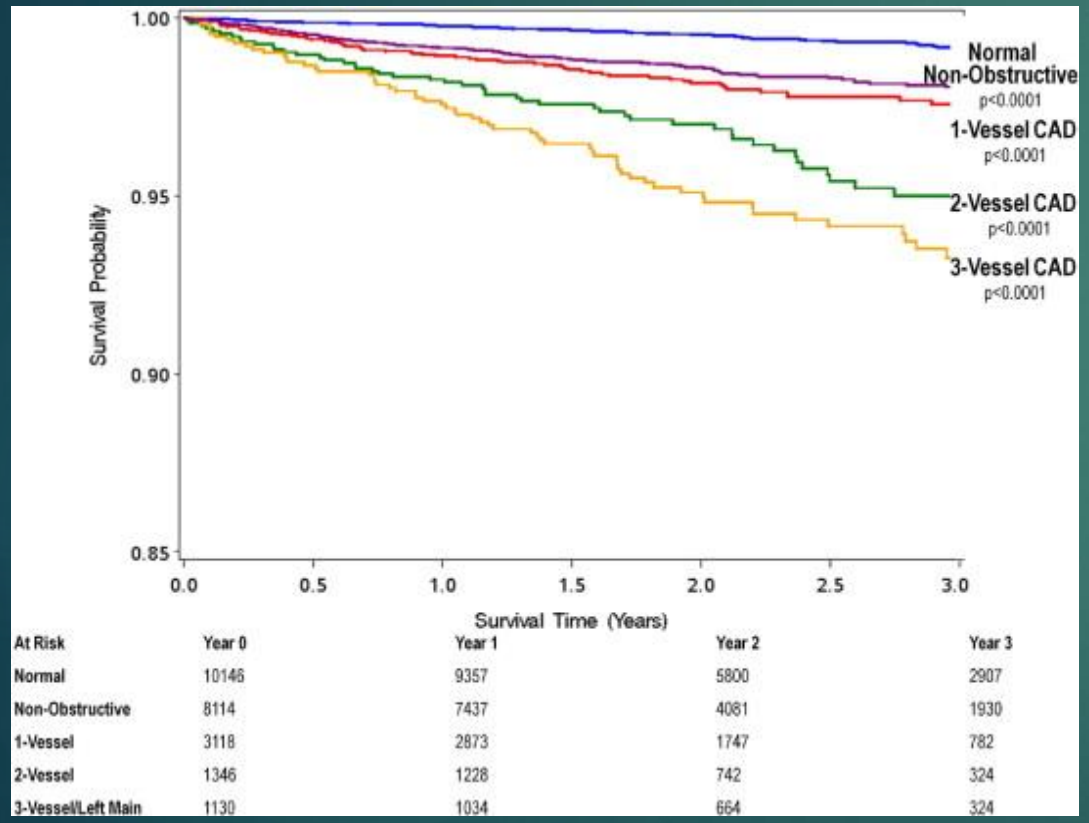


TBA07564740401

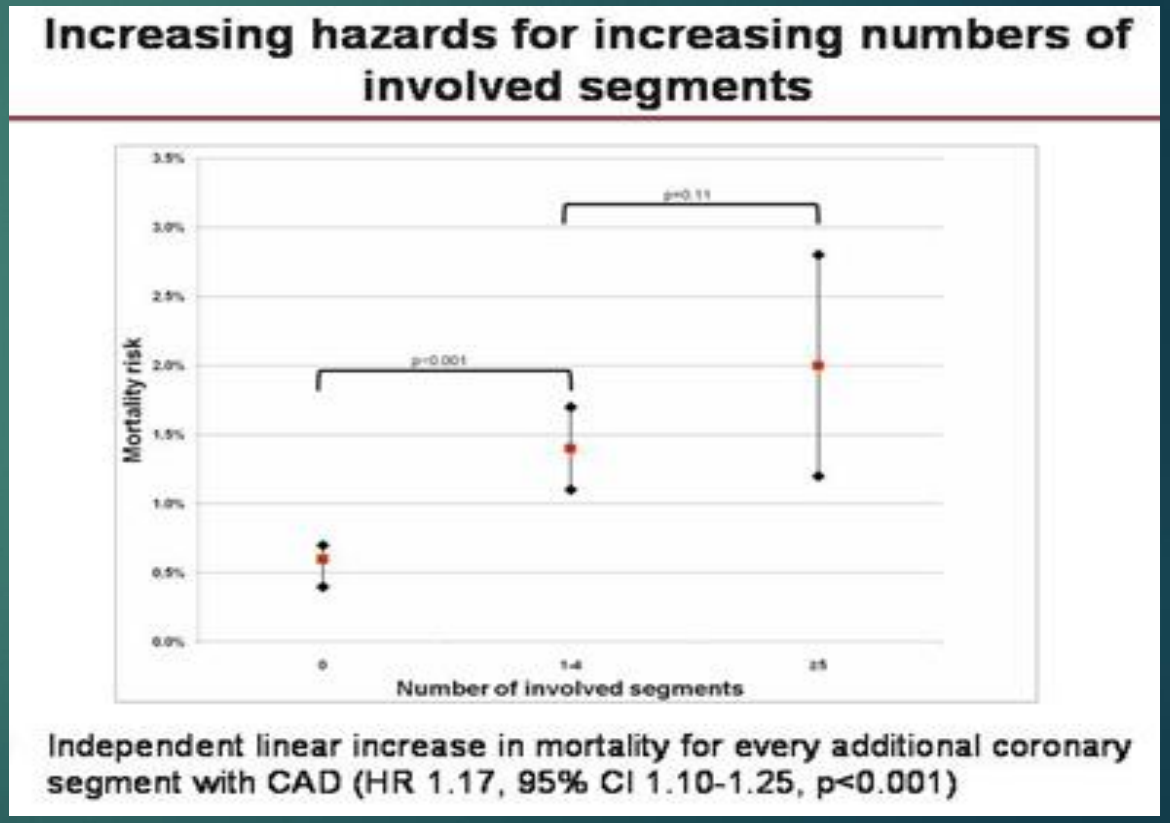
Table 1. Detection of CAD in Symptomatic Patients Without Known Heart Disease*

Indication		Appropriate Use Score (1–9)		
Nonacute Symptoms Possibly Representing an Ischemic Equivalent				
	Pretest Probability of CAD	**Low**	**Intermediate**	**High**
1.	• ECG interpretable AND • Able to exercise	U (5)	A (7)	I (3)
2.	• ECG uninterpretable OR • Unable to exercise	A (7)	A (8)	U (4)
Acute Symptoms With Suspicion of ACS (Urgent Presentation)				
3.	• Definite MI		I (1)	
4.	• Persistent ECG ST-segment elevation following exclusion of MI		U (6)	
5.	• Acute chest pain of uncertain cause (differential diagnosis includes pulmonary embolism, aortic dissection, and ACS ["triple rule out"])		U (6)	
	Pretest Probability of CAD	**Low**	**Intermediate**	**High**
6.	• Normal ECG and cardiac biomarkers	A (7)	A (7)	U (4)
7.	• ECG uninterpretable	A (7)	A (7)	U (4)
8.	• Nondiagnostic ECG OR • Equivocal cardiac biomarkers	A (7)	A (7)	U (4)

CONFIRM - prospective, multicenter registry (>30,000 patients)

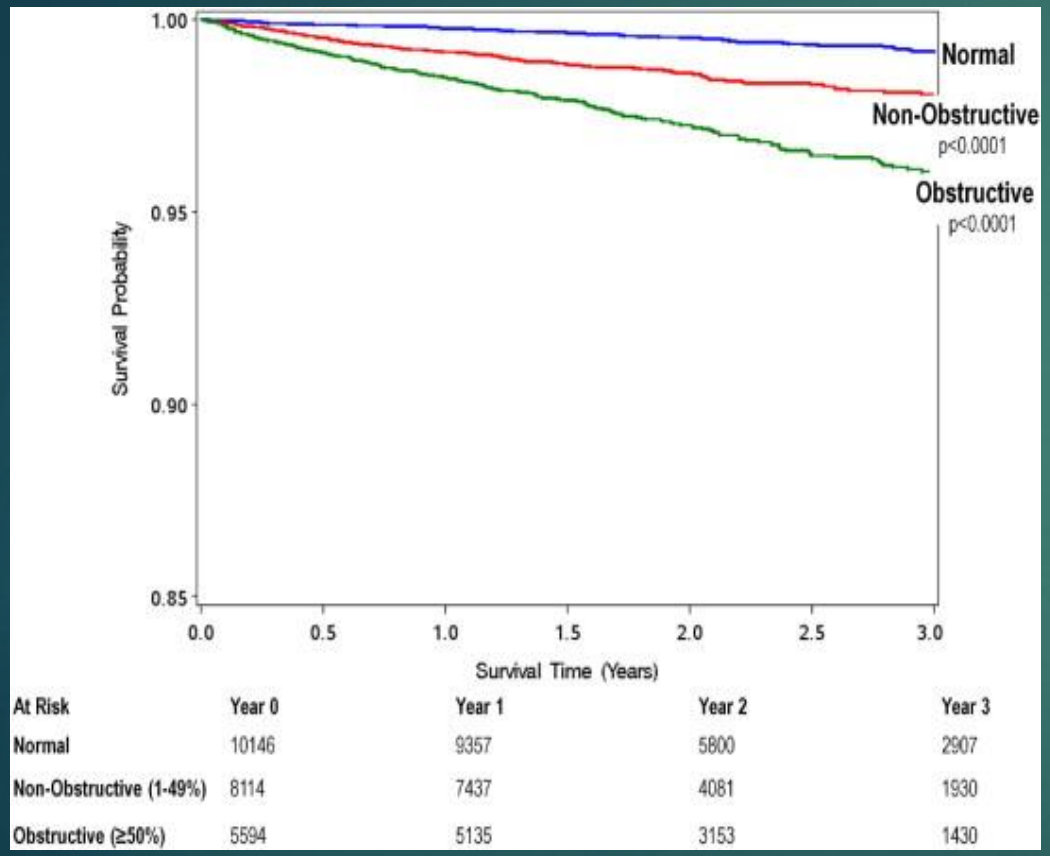


At Risk	Year 0	Year 1	Year 2	Year 3
Normal	10146	9357	5800	2907
Non-Obstructive	8114	7437	4081	1930
1-Vessel	3118	2873	1747	782
2-Vessel	1346	1228	742	324
3-Vessel/Left Main	1130	1034	664	324



James K. Min. J Am Coll Cardiol. 2011;58(8):849-860.

CONFIRM – Non-obstructive CAD



At Risk	Year 0	Year 1	Year 2	Year 3
Normal	10146	9357	5800	2907
Non-Obstructive (1-49%)	8114	7437	4081	1930
Obstructive (≥50%)	5594	5135	3153	1430

Non-obstructive CAD Hazards Ratio

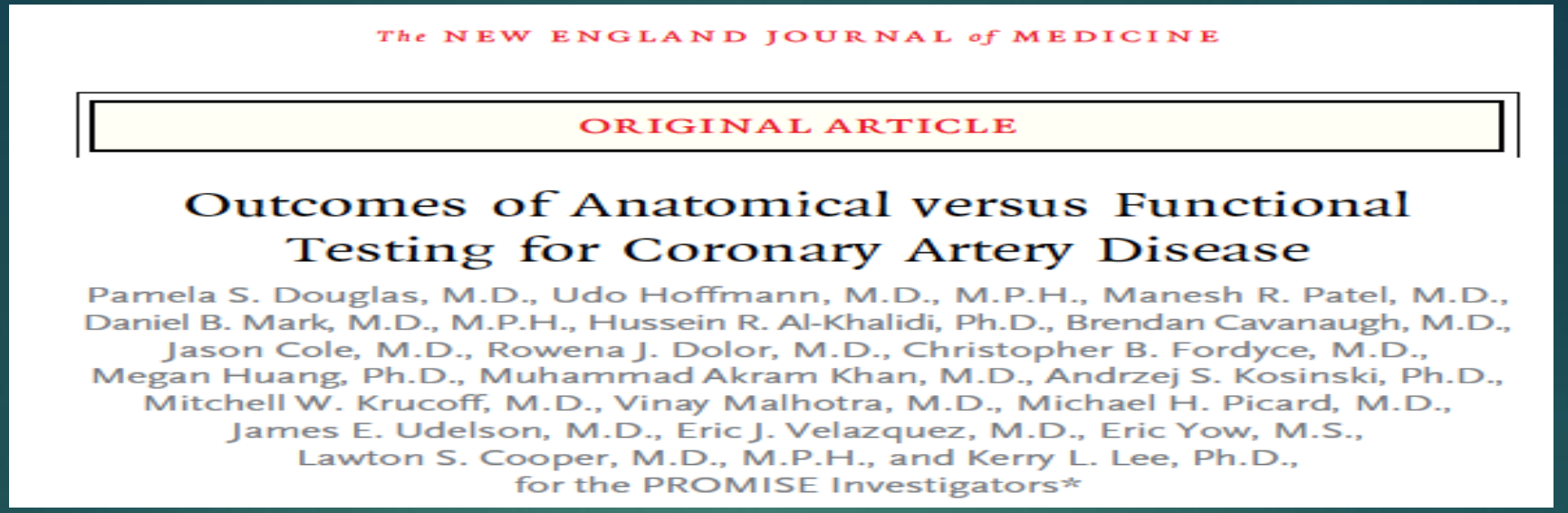
Variable	Univariate HR	95% CI	P-Value	Multivariate HR*	95% CI	P-Value
Non-Obstructive CAD vs. Normal	2.91	2.12-3.99	<0.0001	**2.14**	**1.46-3.14**	**<0.0001**
None/Normal	1	Reference	Reference	1	Reference	Reference
1-Vessel	1.84	1.22-2.77	0.0037	**1.40**	**0.86-2.28**	**0.1766**
2-Vessel	4.46	3.05-6.54	<0.0001	**3.09**	**1.94-4.93**	**<0.0001**
3-Vessel/LM	4.07	2.56-6.45	<0.0001	**3.02**	**1.73-5.27**	**<0.0001**
Segment Involvement Score	1.23	1.17-1.30	<0.0001	**1.17**	**1.10-1.25**	**<0.0001**

*Adjusted for FRS + symptoms

Symptomatic patients

- **The presence and severity of CAD identified on CCTA is associated with the increased use of preventive therapies such as aspirin and statin therapies as well as lifestyle modification.**

- LaBounty TM, AJC 2009;104:873–7.
- Cheezum MK, JACCl Img 2013;6:574–81.
- Orakzai RH, AJC 2008;101:999–1002.



The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

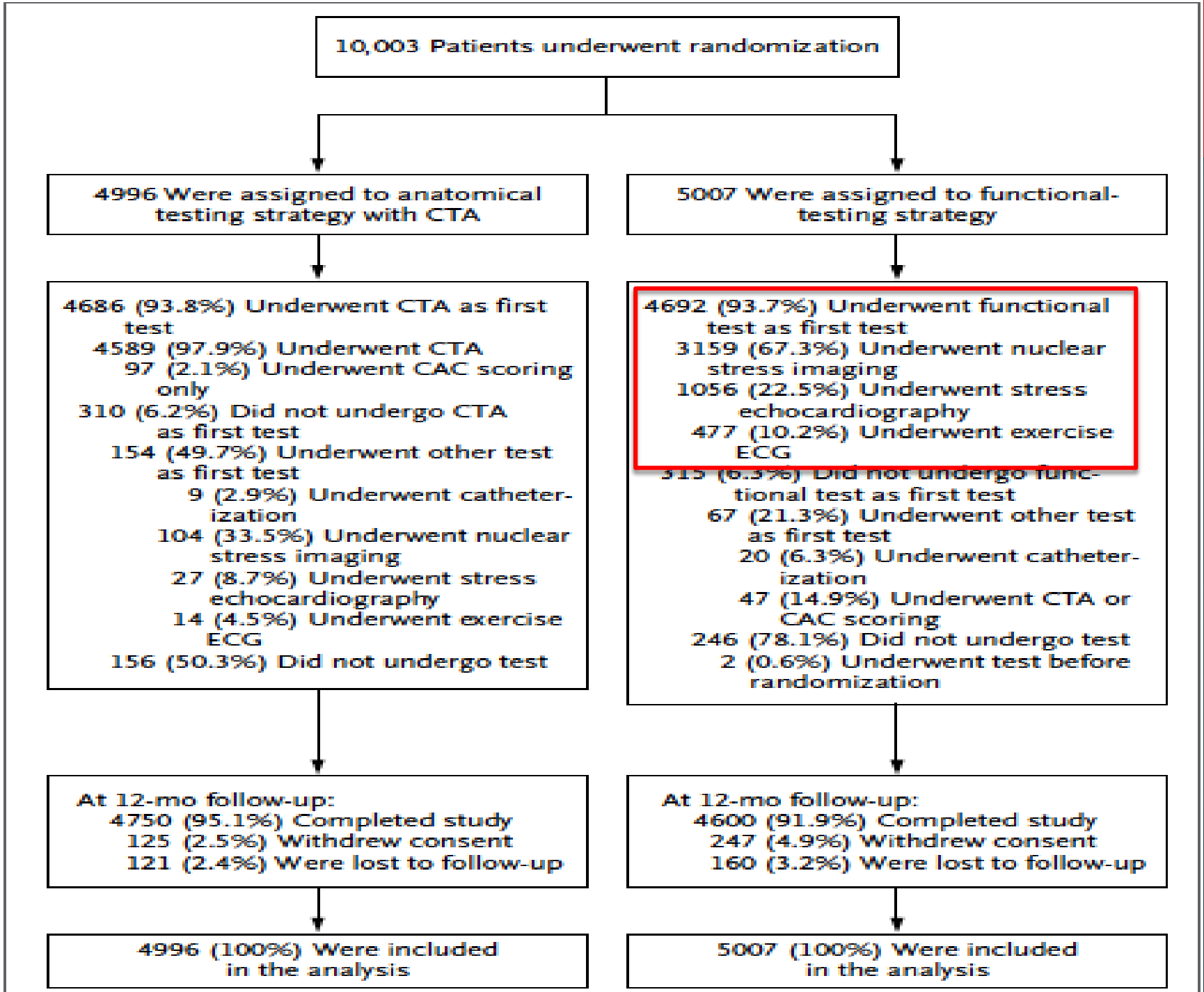
Outcomes of Anatomical versus Functional Testing for Coronary Artery Disease

Pamela S. Douglas, M.D., Udo Hoffmann, M.D., M.P.H., Manesh R. Patel, M.D., Daniel B. Mark, M.D., M.P.H., Hussein R. Al-Khalidi, Ph.D., Brendan Cavanaugh, M.D., Jason Cole, M.D., Rowena J. Dolor, M.D., Christopher B. Fordyce, M.D., Megan Huang, Ph.D., Muhammad Akram Khan, M.D., Andrzej S. Kosinski, Ph.D., Mitchell W. Krucoff, M.D., Vinay Malhotra, M.D., Michael H. Picard, M.D., James E. Udelson, M.D., Eric J. Velazquez, M.D., Eric Yow, M.S., Lawton S. Cooper, M.D., M.P.H., and Kerry L. Lee, Ph.D., for the PROMISE Investigators*

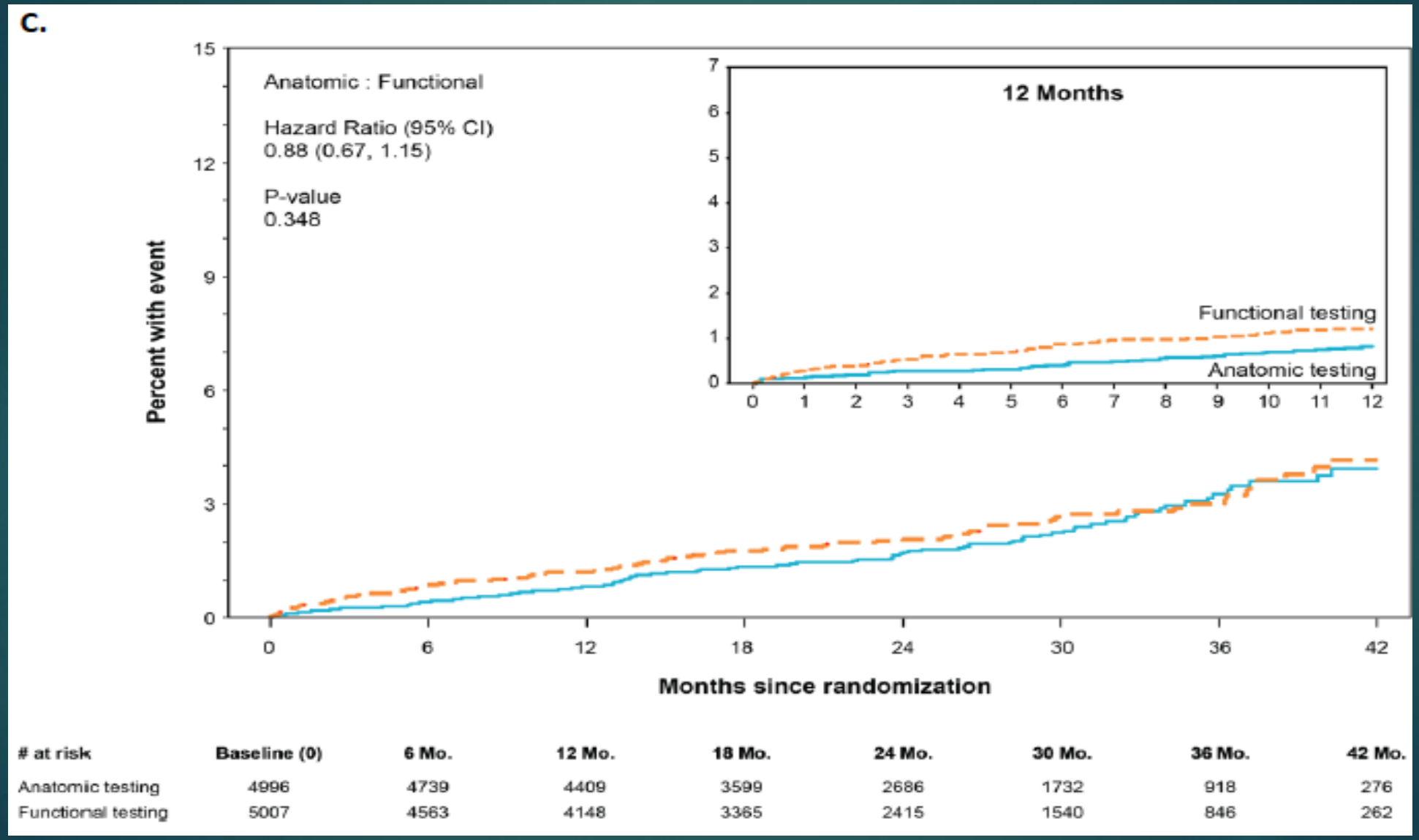
- Symptomatic outpatients without diagnosed CAD whose physicians referred to nonurgent, noninvasive cardiovascular testing for the evaluation of suspected CAD.

  Relative reduction of 20% in the primary end point in the CTA group, as compared with the functional-testing group, assuming an event rate of 8% in the functional-testing group

Enrollment, Randomization, and Follow-up

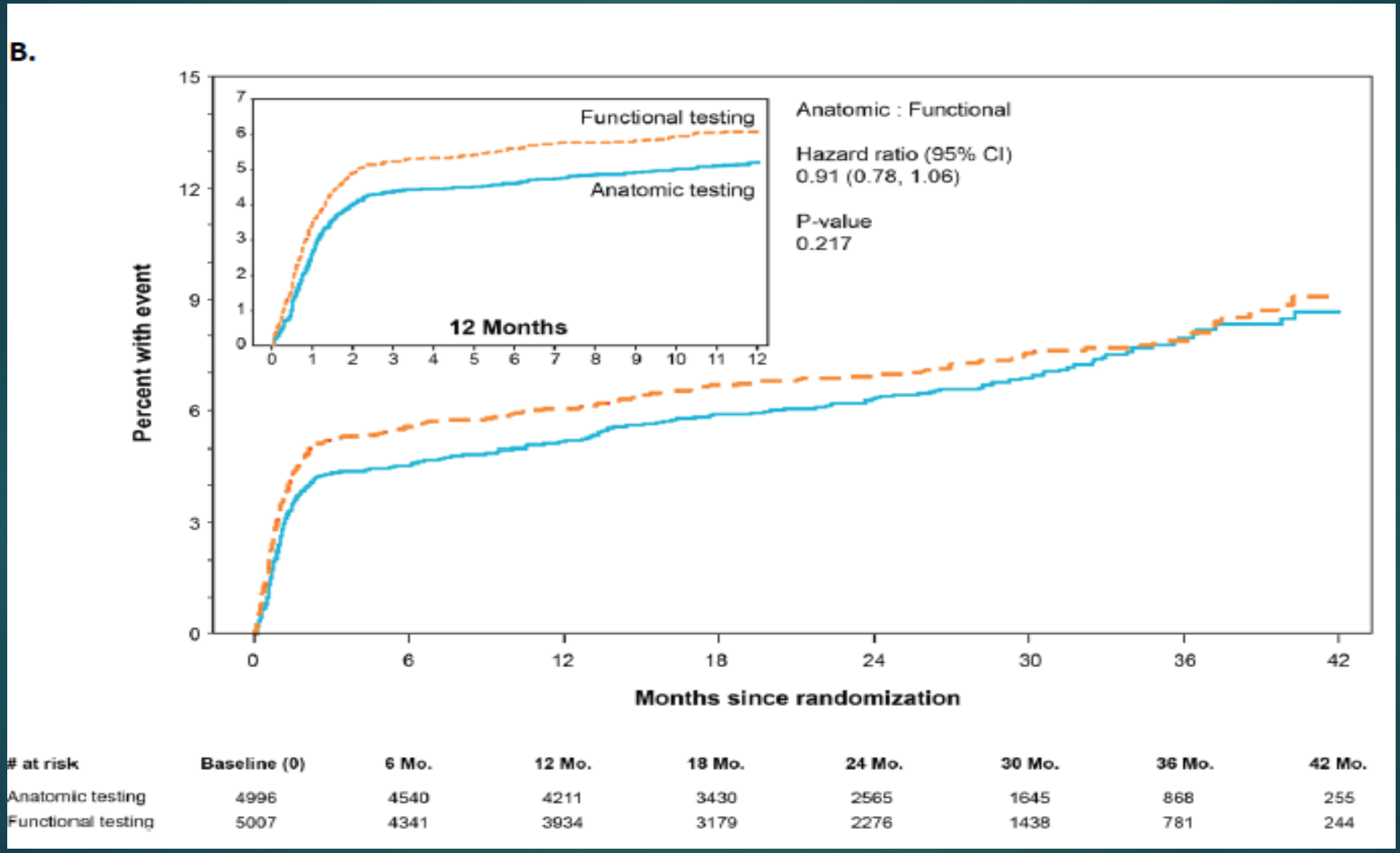


Death or non-fatal MI



# at risk	Baseline (0)	6 Mo.	12 Mo.	18 Mo.	24 Mo.	30 Mo.	36 Mo.	42 Mo.
Anatomic testing	4996	4739	4409	3599	2686	1732	918	276
Functional testing	5007	4563	4148	3365	2415	1540	846	262

Primary endpoint + ICA without obstructive CAD



# at risk	Baseline (0)	6 Mo.	12 Mo.	18 Mo.	24 Mo.	30 Mo.	36 Mo.	42 Mo.
Anatomic testing	4996	4540	4211	3430	2565	1645	868	255
Functional testing	5007	4341	3934	3179	2276	1438	781	244

Conclusions:

- Coronary CTA is a viable alternative to functional stress testing to assess symptomatic, intermediate risk patients for whom testing is currently recommended.

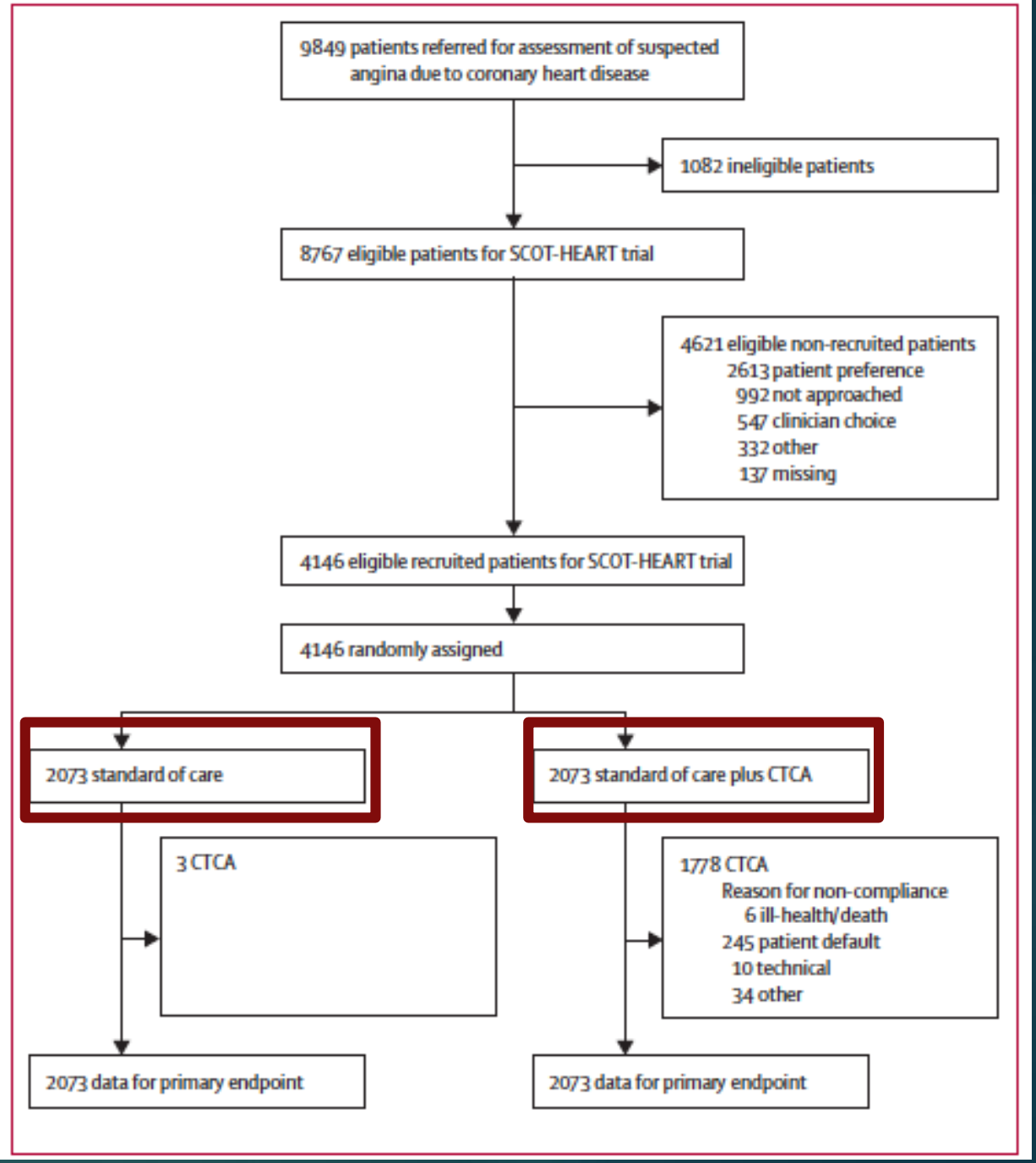
- An initial strategy with CTA was associated with a significant lower rate of invasive catheterization without obstructive CAD as compared to a functional strategy.

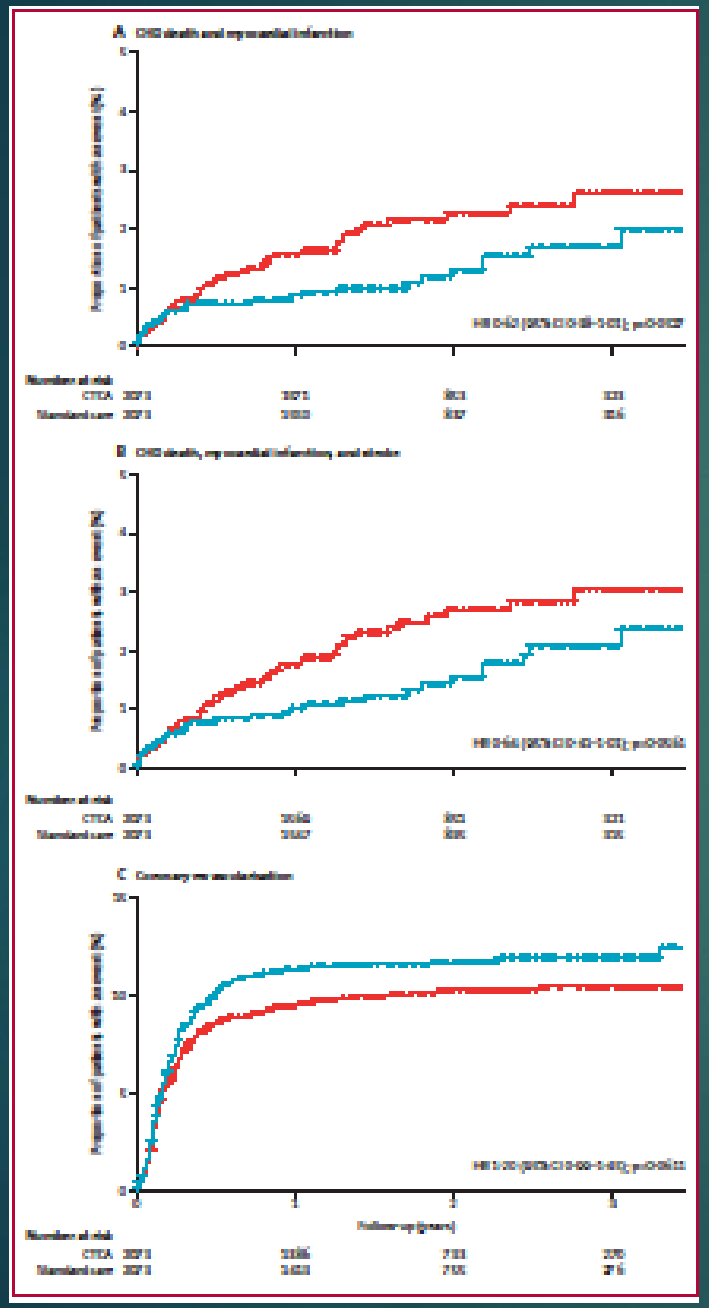
CT coronary angiography in pa
due to coronary heart disease
parallel-group, multicentre tri

*The SCOT-HEART investigators**

	All participants	Standard care and	Standard care
Stress electrocardiograph			
Performed	3517 (85%)	1764 (85%)	1753 (85%)
Normal	2188 (62%)	1103 (63%)	1085 (62%)
Inconclusive	566 (16%)	284 (16%)	282 (16%)
Abnormal‡	529 (15%)	264 (15%)	265 (15%)
Further investigation	1315 (32%)	633 (31%)	682 (33%)
Stress imaging			
Radionuclide	389 (9%)	176 (9%)	213 (10%)
Other	30 (1%)	16 (1%)	14 (1%)

Median follow-up 1.7 years





	All participants (n=4146)	Standard care and CTCA (n=2073)	Standard care (n=2073)	HR (95% Wald confidence limits)	p value*
CHD death† and myocardial infarction	68 (1·6%)	26 (1·3%)	42 (2·0%)	0·616 (0·378–1·006)	0·0527
CHD death†, myocardial infarction, and stroke	79 (1·9%)	31 (1·5%)	48 (2·3%)	0·644 (0·410–1·012)	0·0561
Non-fatal myocardial infarction	57 (1·4%)	22 (1·1%)	35 (1·7%)	0·627 (0·367–1·069)	0·0862
Non-fatal stroke	12 (0·3%)	5 (0·1%)	7 (0·2%)	0·727 (0·228–2·315)	0·5900
All-cause death	37 (0·9%)	17 (0·8%)	20 (1·0%)	0·860 (0·450–1·642)	0·6468
Cardiovascular death†	11 (0·3%)	4 (0·2%)	7 (0·3%)	0·574 (0·167–1·971)	0·3776
Non-cardiovascular death	26 (0·6%)	13 (0·6%)	13 (0·6%)	1·006 (0·466–2·172)	0·9879
Coronary revascularisation‡	434 (10·7%)	233 (11·2%)	201 (9·7%)	1·198 (0·992–1·448)	0·0611
Percutaneous coronary intervention	344 (8·3%)	184 (8·9%)	160 (7·7%)	1·190 (0·963–1·472)	0·1075
Coronary artery bypass graft surgery	99 (2·4%)	54 (2·6%)	45 (2·2%)	1·218 (0·819–1·812)	0·3304
Hospitalisation for chest pain§	511 (12·3%)	247 (11·9%)	264 (12·7%)	0·928 (0·780–1·104)	0·3993
Cardiac chest pain	145 (3·5%)	76 (3·7%)	69 (3·3%)	1·115 (0·805–1·545)	0·5130
Non-cardiac chest pain	391 (9·4%)	183 (8·8%)	208 (10·0%)	0·864 (0·708–1·054)	0·1498

	Standard care and CTCA		Standard care	
	Cancellation	New	Cancellation	New
Investigations				
Stress imaging	121	5	0	6
Invasive coronary angiography	29	94	1	8
Total	150	99	1	14
Medical treatments				
Preventive treatment	77	293	8	84
Antianginal treatment	112	82	6	11
Total	189	375	14	95

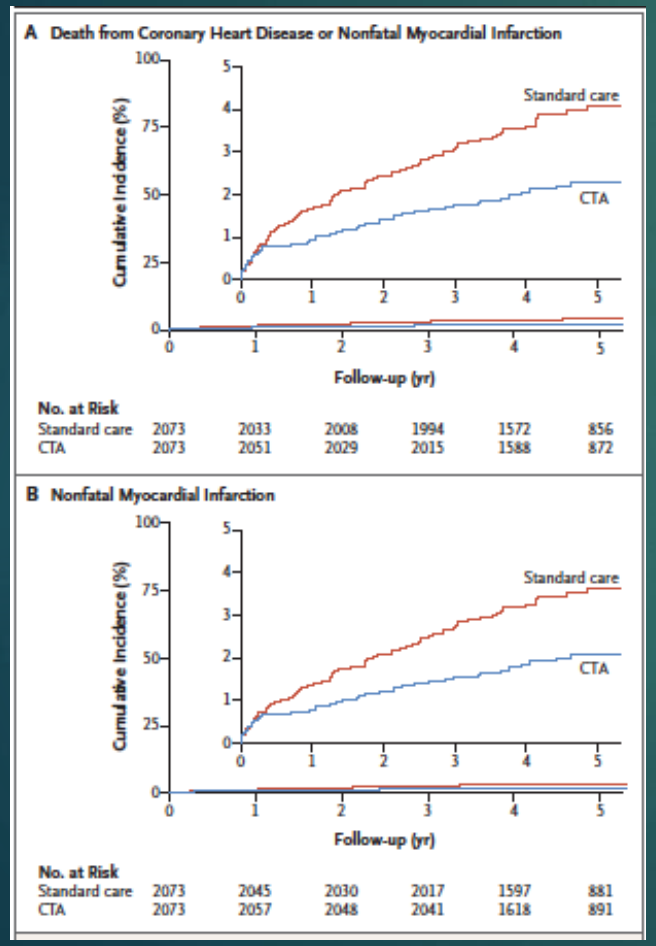
CTCA=CT coronary angiography.

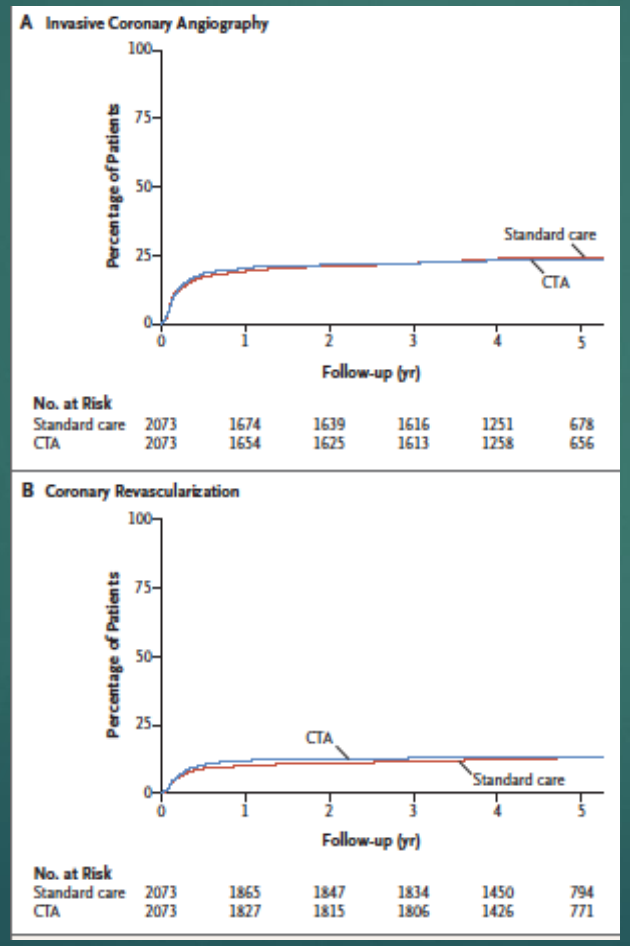
***Table 4*: Changes in investigations and treatments at 6 weeks**

ORIGINAL ARTICLE

Coronary CT Angiography and 5-Year Risk of Myocardial Infarction

The SCOT-HEART Investigators*





The use of CTA in addition to standard care in patients with stable CP resulted in a significantly **lower** rate of CV death or nonfatal MI at 5 years than standard care alone, **without** resulting in a significantly higher rate of coronary angiography or coronary revascularization

- In the SCOT-HEART and PROMISE trials, the use of CTA resulted in a higher rate of detection of obstructive CAD, as confirmed by ICA, than standard care alone (SCOT-HEART trial) or functional testing (PROMISE trial).
- Invasive coronary angiography and coronary revascularization are more likely to be used appropriately in patients who receive a correct diagnosis of coronary heart disease
- Patients who receive a correct diagnosis are also more likely to receive appropriate preventive therapies and may have greater motivation to implement healthy lifestyle modifications.
- In addition, the SCOT-HEART trial encouraged initiation of secondary prevention strategies in patients with nonobstructive coronary artery disease.

New major recommendations in 2019

Basic testing, diagnostics, and risk assessment	
Non-invasive functional imaging for myocardial ischaemia or coronary CTA is recommended as the initial test for diagnosing CAD in symptomatic patients in whom obstructive CAD cannot be excluded by clinical assessment alone.	I
It is recommended that selection of the initial non-invasive diagnostic test be based on the clinical likelihood of CAD and other patient characteristics that influence test performance, local expertise, and the availability of tests.	I
Functional imaging for myocardial ischaemia is recommended if coronary CTA has shown CAD of uncertain functional significance or is not diagnostic.	I
Invasive angiography is recommended as an alternative test to diagnose CAD in patients with a high clinical likelihood and severe symptoms refractory to medical therapy, or typical angina at a low level of exercise and clinical evaluation that indicates high event risk. Invasive functional assessment must be available and used to evaluate stenoses before revascularization, unless very high grade (>90% diameter stenosis).	I
Invasive coronary angiography with the availability of invasive functional evaluation should be considered for confirmation of the diagnosis of CAD in patients with an uncertain diagnosis on non-invasive testing.	IIa
Coronary CTA should be considered as an alternative to invasive angiography if another non-invasive test is equivocal or non-diagnostic.	IIa
Coronary CTA is not recommended when extensive coronary calcification, irregular heart rate, significant obesity, inability to cooperate with breath-hold commands, or any other conditions make good image quality unlikely.	III

CLINICAL RESEARCH Clinical Trial

The CT-STAT (Coronary Computed Tomographic Angiography for Systematic Triage of Acute Chest Pain Patients to Treatment) Trial

- **Objective: Comparing safety, cost & efficacy of CCTA vs. MPI in acute chest pain, low risk patients**
- **16 ED sites ; TIMI scores < 4**
- **CCTA (n=361) vs. MPI (n=338)**

Goldstein et al. JACC 2011

CLINICAL RESEARCH | Clinical Trial

The CT-STAT (Coronary Computed Tomographic Angiography for Systematic Triage of Acute Chest Pain Patients to Treatment) Trial

- CCTA: Diagnostic time (median 2.9h)
- MPI: Diagnostic time (median 6.3h)

} 54% reduction in time to Dx for CCTA

- CCTA: Cost - 2137$
- MPI: Cost - 3458$

} 38% lower cost for CCTA

- No difference in MACE (0.8 vs. 0.4 %, p = 0.29)

Goldstein et al. JACC 2011

ORIGINAL ARTICLE

CT Angiography for Safe Discharge of Patients with Possible Acute Coronary Syndromes

ACRIN

- **CTA vs. standardized ER triage for ACP evaluation**
- **1392 low risk patients (TIMI risk scores of 0–2)**

<u>CTA in comparison to SOC resulted in</u>:

- **Shorter mean hospital stay (18h vs 25 h)**
- **Higher rate of direct ED discharge (49% vs. 23%)**
- **3-fold greater rate of detection of CAD (9% vs. 3.5%)**

Litt et al. NEJM 2012

ACRIN

- **No significant difference between the CTA and SOC groups in use of ICA (5.1% vs. 4.2%) or in the rate of revascularization (2.7% vs. 1.3%).**
- **0 % adverse events among the 640 patients with negative coronary CTA**

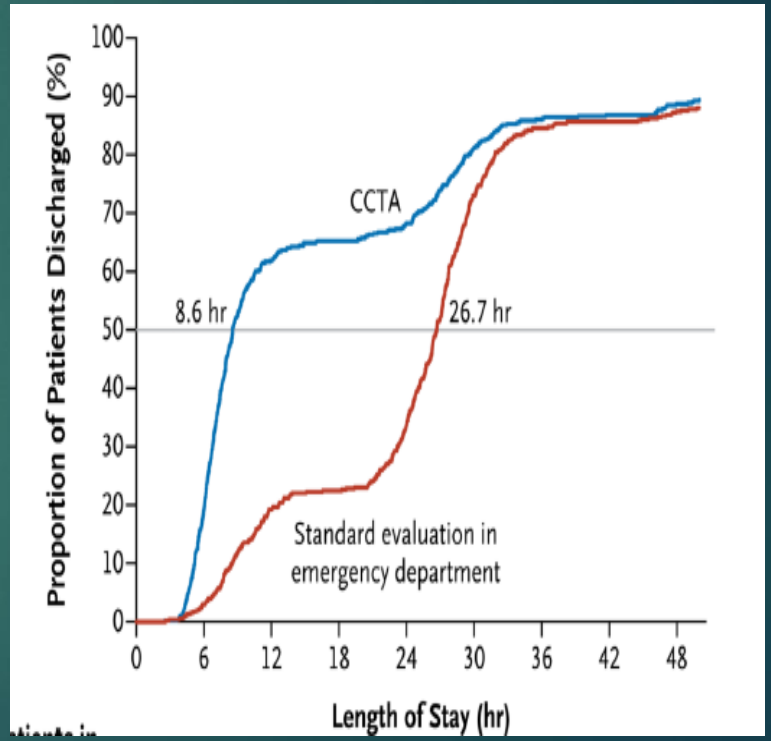
CTA-based strategy for low–intermediate risk patients presenting with possible ACS allows expedited & safe ED discharge

Coronary CT Angiography versus Standard Evaluation in Acute Chest Pain

Udo Hoffmann, M.D., M.P.H., Quynh A. Truong, M.D., M.P.H., David A. Schoenfeld, Ph.D., Eric T. Chou, M.D., Pamela K. Woodard, M.D., John T. Nagurney, M.D., M.P.H., J. Hector Pope, M.D., Thomas H. Hauser, M.D., M.P.H., Charles S. White, M.D., Scott G. Weiner, M.D., M.P.H., Shant Kalanjian, M.D., Michael E. Mullins, M.D., Issam Mikati, M.D., W. Frank Peacock, M.D., Pearl Zakroysky, B.A., Douglas Hayden, Ph.D., Alexander Goehler, M.D., Ph.D., Hang Lee, Ph.D., G. Scott Gazelle, M.D., M.P.H., Ph.D., Stephen D. Wiviott, M.D., Jerome L. Fleg, M.D., and James E. Udelson, M.D., for the ROMICAT-II Investigators

ROMICAT II

- **Comparative effectiveness study - CTA vs. standardized ED triage**
- **1000 ACP patients**
- **TIMI scores did not limit entry criteria**



Hoffman et al. NEJM 2012

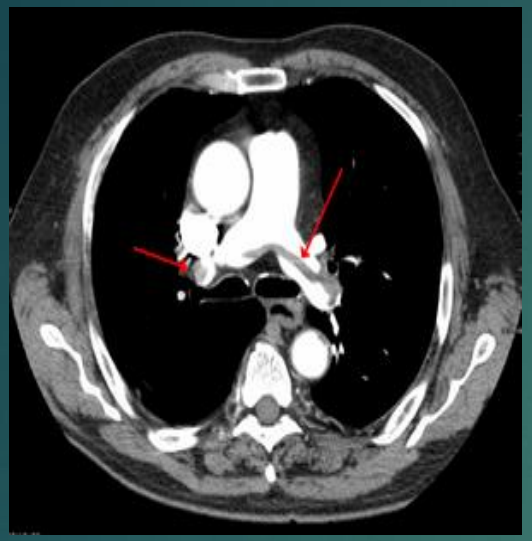
ROMICAT II

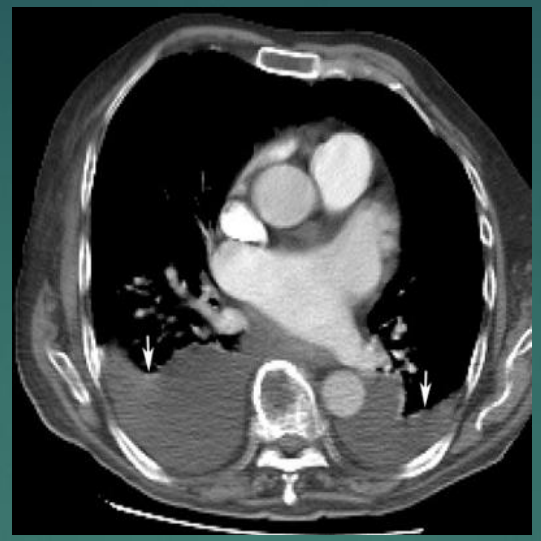
Coronary CTA as compared with SOC :

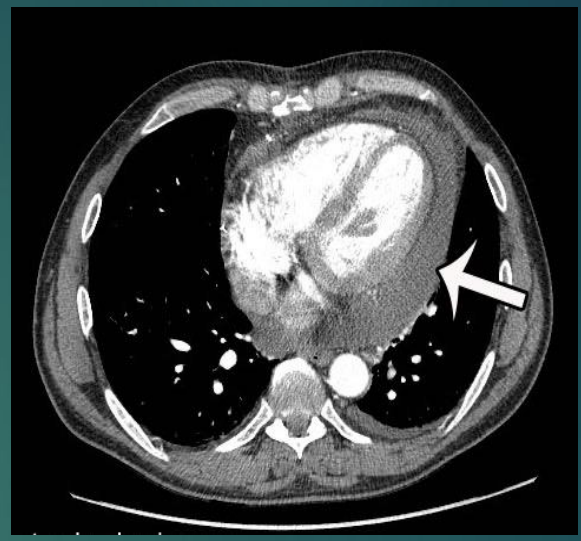
- **Reduced median LOS (8.6 h vs. 26.7 h; p <0.001)**
- **Reduced time to diagnosis (5.8 h vs. 21.0 h; p < 0.001)**
- **Increase in direct discharge (47% vs. 12%; p < 0.001)**
- **MACE: CCTA vs. SOC (0.4% vs. 1.2%)**
- **Costs of care including hospital costs were similar between coronary CTA and SOC ($4026 vs. $3874)**

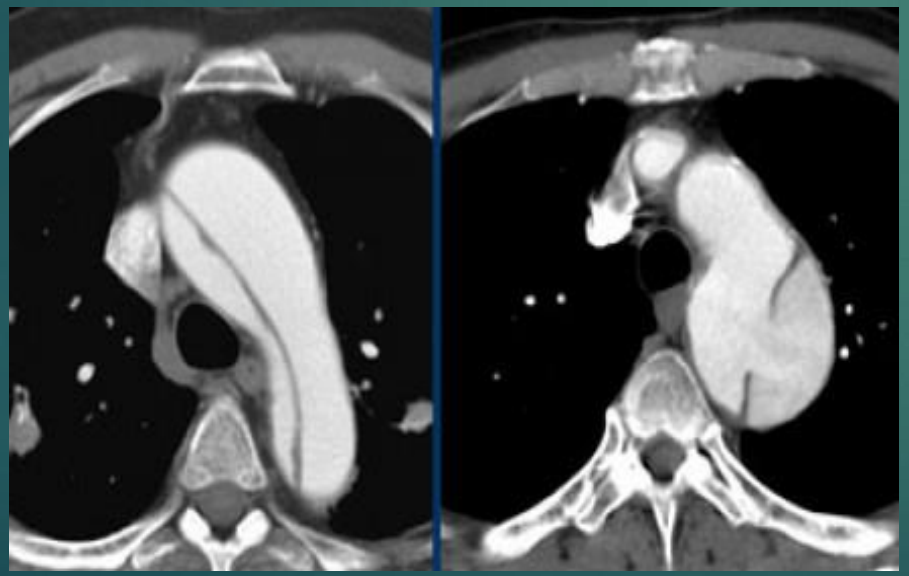
Hoffman et al. NEJM.2012

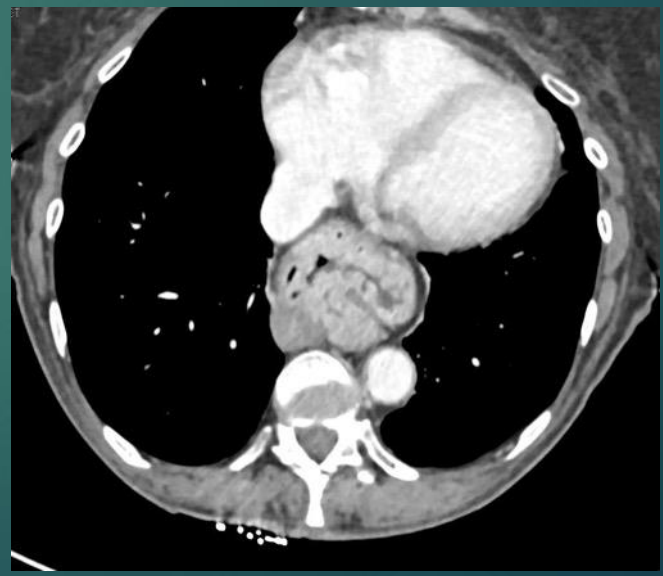
<u>In summary</u> - in low-to-intermediate-risk patients with ACP, use of coronary CTA is safe and results in shorter length of stay and shorter time to diagnosis.



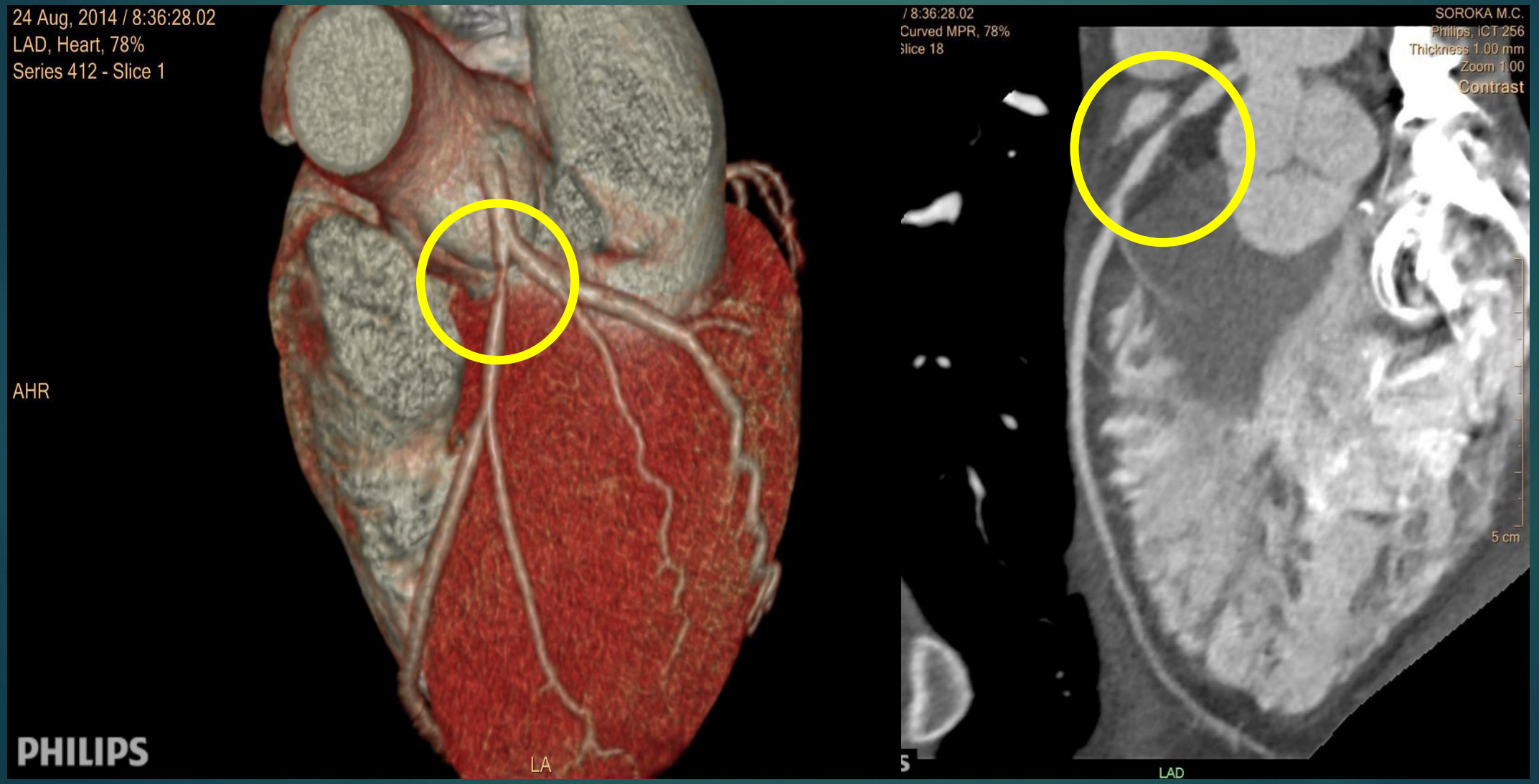




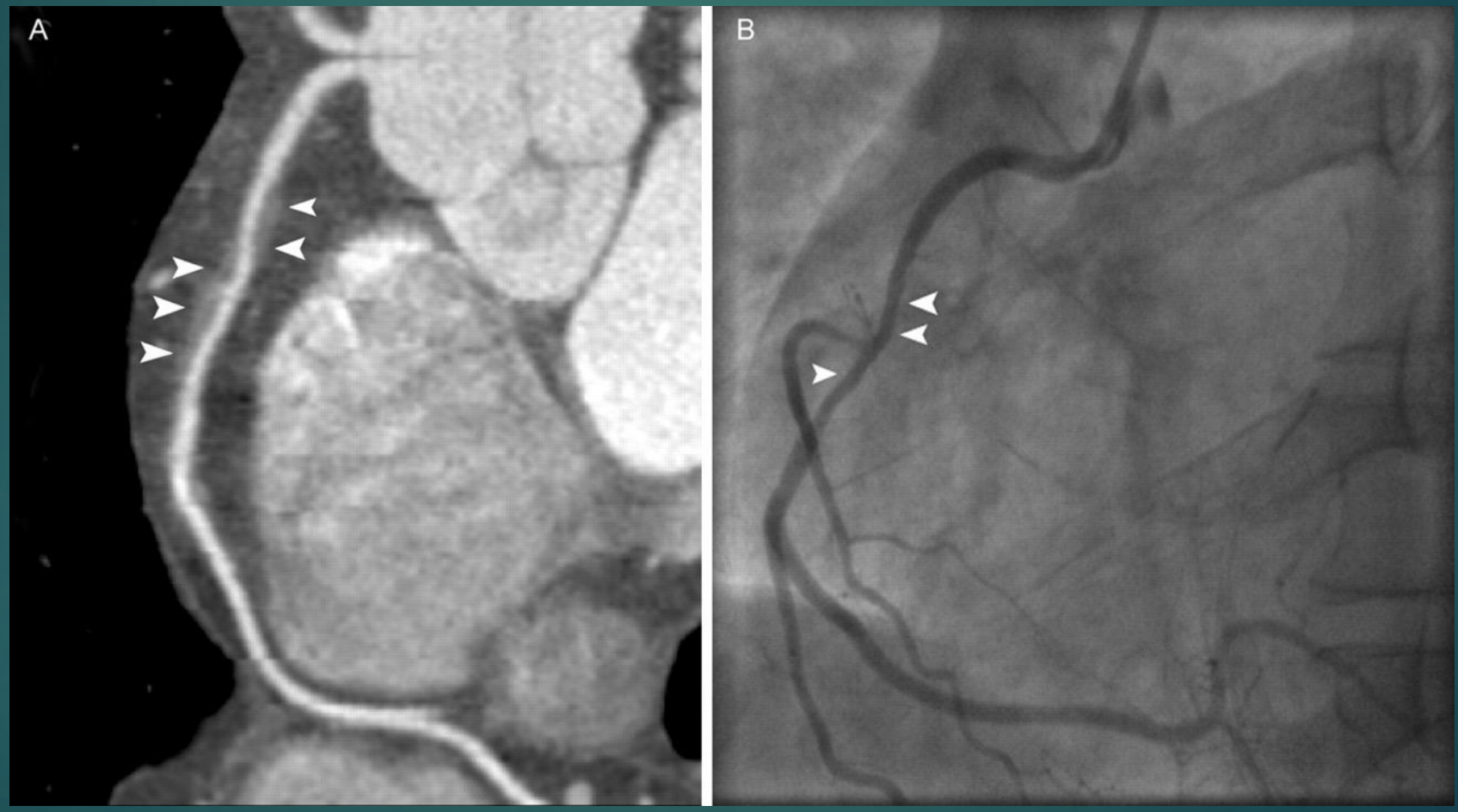




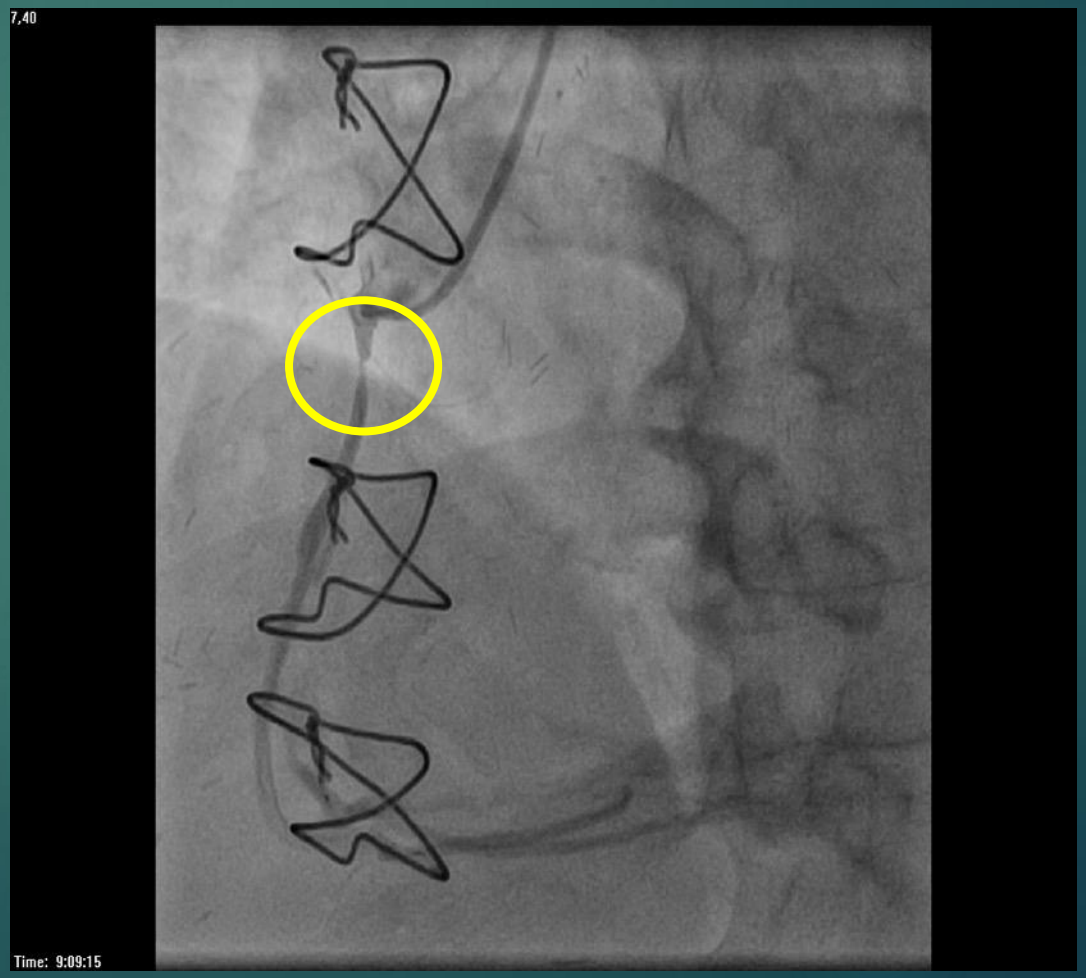
- בן 36, דיסליפידמי, סיפור משפחתי. ארוע של סינקופה לאחר מאמץ.
- מבחן מאמץ תקין עם הגעה לדופק מטרה.



Nonobstructive Plaque Visualization



- בן 66, סוכרתי. תעוקה מספר חודשים לאחר ניתוח מעקפים.
- צנתור – מעקפים עורקיים לעורק הקדמי היורד ולענף מרגינלי – חסומים.
- המעקף הורידי לעורק הימני לא הודגם.



RCA originating from LAD

איזה מן ההיגדים הבאים נכון לגבי ביצוע בדיקת CT של הלב?

1. Calcium score הינה הבדיקה הראויה לביצוע בגבר בן 65, לאחר אוטם שריר הלב בעברו, אשר פונה למיון עם כאב חריף בקדמת החזה.
2. Coronary CT angiography נחשבת בדיקה ראויה באשה בת 30 עם כאב דוקר בקדמת החזה מזה שבועיים, ללא קשר ברור למאמץ.
3. Coronary CT angiography הינה בדיקת הסקר המומלצת לנבדקים ללא סימפטומים אך עם גורמי סיכון למחלה כלילית
4. אחת הדרכים להפחתת כמות הקרינה בבדיקת CCTA הינה לבצע סריקה באמצעות prospective gating
5. CCTA הינה בדיקת הבחירה להערכת תפקוד מסתמי הלב

מה לא נכון לגבי CTA של העורקים הכליליים:

1. מספק הדמיה מדויקת של מעקפים לעורקים כליליים.
2. הערכה טובה של תומכנים בעורקים הכליליים מעל קוטר של 3 מ"מ
3. מתאים לאבחון קריש בחללי הלב
4. רגישות CTA לאבחון מחלה כלילית חסימתית נמוכה יותר בהשוואה למיפוי לב.

מה לא נכון לגבי cardiac CT?

1. הסיכוי להערכת יתר של חומרת היצרויות בעורקים הכליליים גבוה יותר מאשר תת הערכה.
2. מומלץ לבצע את הבדיקה במטופלים עם סבירות נמוכה עד בינונית למחלה כלילית.
3. הסתיידויות בעורקים הכליליים גורמות להערכת יתר של חומרת ההיצרות.
4. סריקת הלב לשם הערכה של העורקים הכליליים מתבצעת בדרך כלל בשלב הסיסטולה.

Coronary CT Angiography - סיכום

- מטרת הבדיקה – שלילה של מחלת לב כלילית חסימתית (50%< מקוטר העורק) :

  בעיקר בנבדקים ללא מחלת לב כלילית ידועה עם –

  - סבירות נמוכה עד בינונית לקיום מחלה כלילית חסימתית

- אוכלוסית יעד:
  - כאב בחזה / Effort dyspnea
  - ירידה בלתי מוסברת בתפקוד הלב
  - כאשר Stress test אינו חד משמעי (מבחן מאמץ, אקו במאמץ, מיפוי לב)
  - לפני ניתוח לב לא כלילי – הפרעה מסתמית או האאורטה החזית

Implications of CAD diagnosis

- Coronary plaque on CTA is associated with adverse events
- CTA is associated with intensification in preventive therapies and modification of CVD risk factors.

Coronary CTA uniquely identifies patients who have non-obstructive atherosclerosis and who will benefit from medical therapy

** Cheezum et al JACC Cardiovasc Imaging. 2013*
***Hulten et l Circ Cardiovasc Imaging. 2014*

התוויות נוספות לביצוע CCTA

- הערכה של העורקים הכליליים - "צנתור וירטואלי"
- טרשת עורקים – קיום מחלה טרשתית, חומרת הצרויות, הרכב הטרשת
- אנומליות במוצא העורקים הכליליים
- הערכה לאחר התקנת סטנט / לאחר ניתוח מעקפים (פטנטיות של מעקפים)
- אנטומיה של ורידי הריאה – לפני ביצוע אבלציה של פרפור פרוזדורים (PVI)
- לפני החלפה של מסתם אאורטלי בגישה מילעורית – TAVI - הערכה של מסתם אאורטלי, האאורטה העולה וכלי דם פריפריים
- הערכה של תהליכים תופסי מקום ומומים בלב
- תפקוד שריר הלב, נפח מדורי הלב (כאשר אקו באיכות ירודה, MRI לא זמין)

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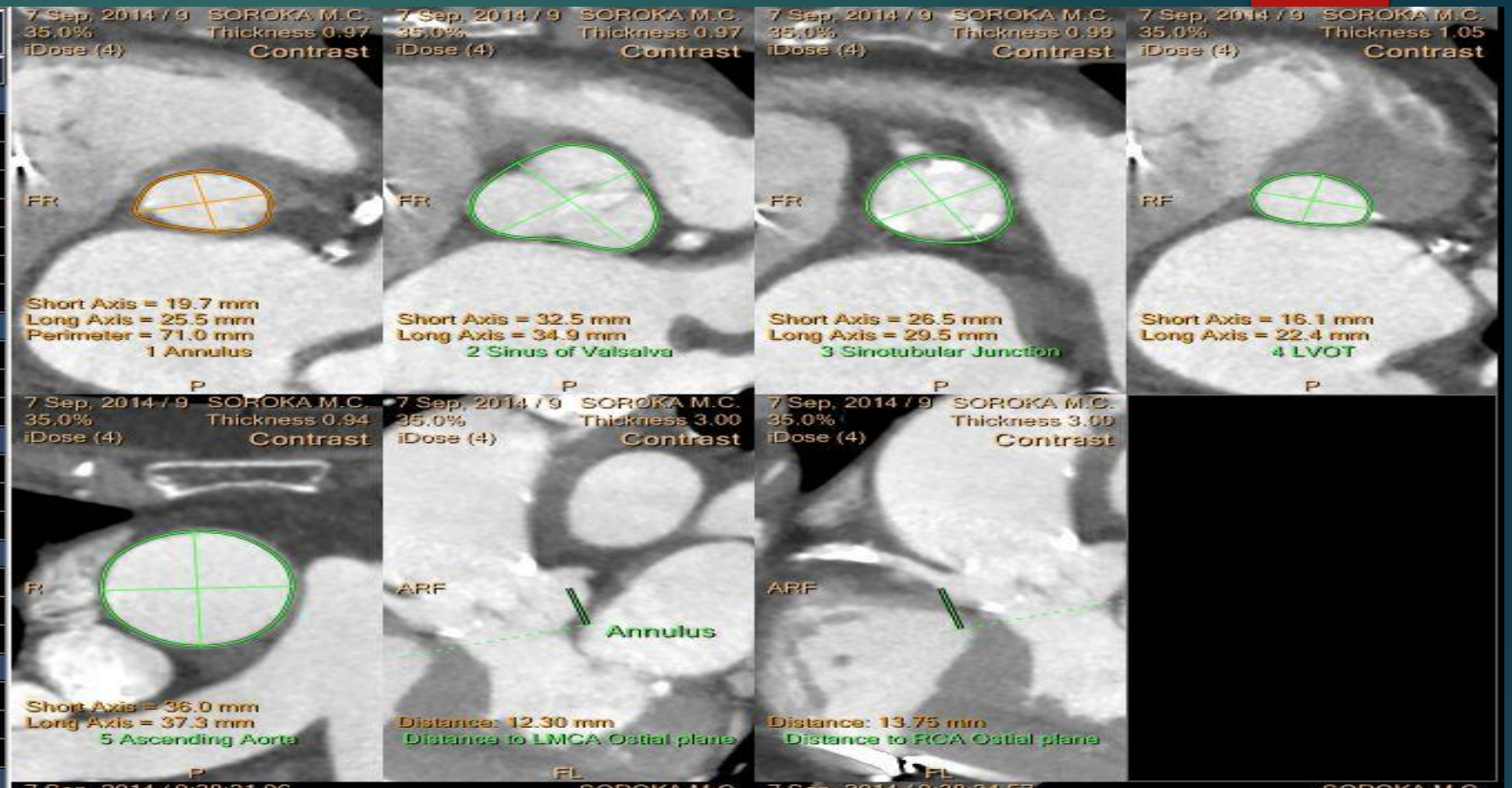
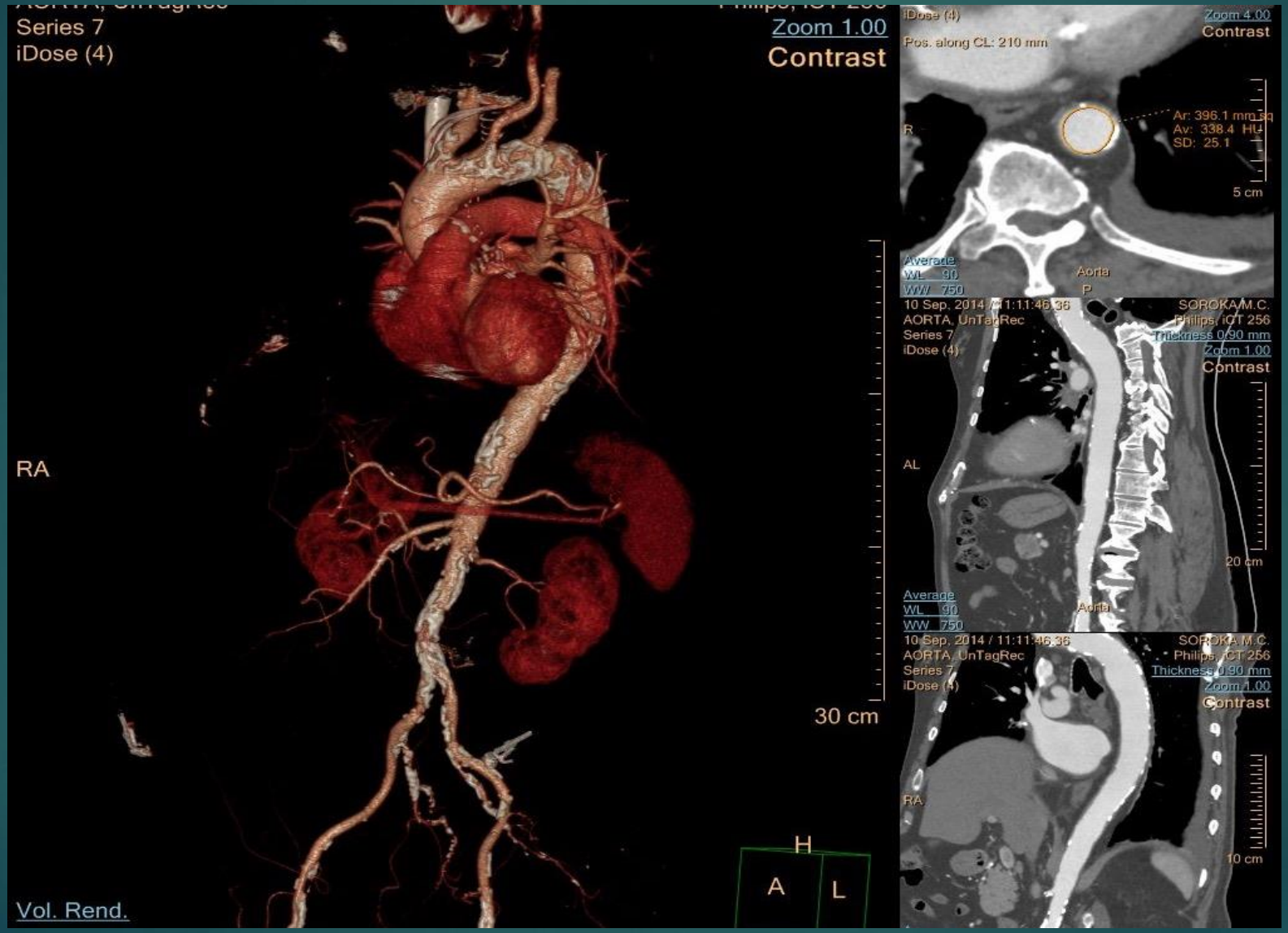
Valvular and perivalvular assessment

Measurements table	
Measurement	Value
Annulus	
Short Axis	19.7 mm
Long Axis	25.5 mm
Area	393.9 mm²
Perimeter	71.0 mm
Effective diameter based on a...	22.4 mm
Effective diameter based on p...	22.6 mm
(Long Axis + Short Axis) / 2	22.3 mm
Sinus of Valsalva	
Short Axis	32.5 mm
Long Axis	34.9 mm
(Long Axis + Short Axis) / 2	32.9 mm
Sinotubular Junction	
Short Axis	26.5 mm
Long Axis	29.5 mm
(Long Axis + Short Axis) / 2	28.0 mm
LVOT	
Short Axis	16.1 mm
Long Axis	22.4 mm
(Long Axis + Short Axis) / 2	19.3 mm
Ascending Aorta	
Short Axis	36.0 mm
Long Axis	37.3 mm
(Long Axis + Short Axis) / 2	36.6 mm
Distance to RCA Ostial plane	
Distance	13.7 mm
Distance to LMCA Ostial plane	
Distance	12.3 mm



PHILIPS

TAVI – Peripheral & access assessment



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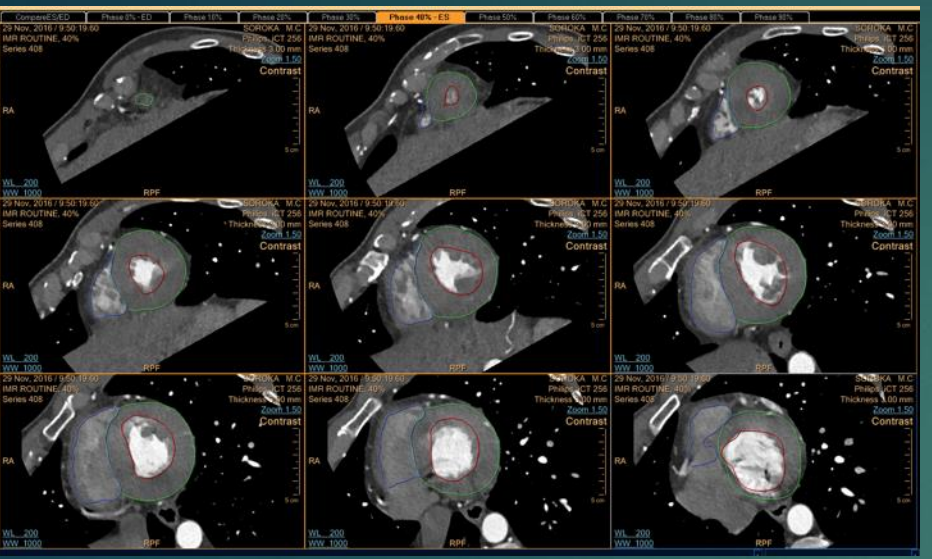
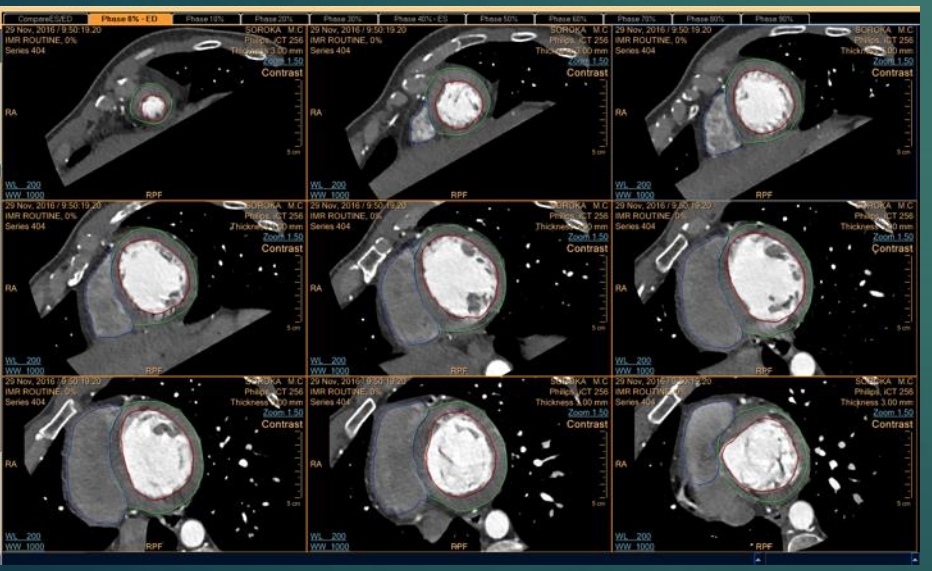
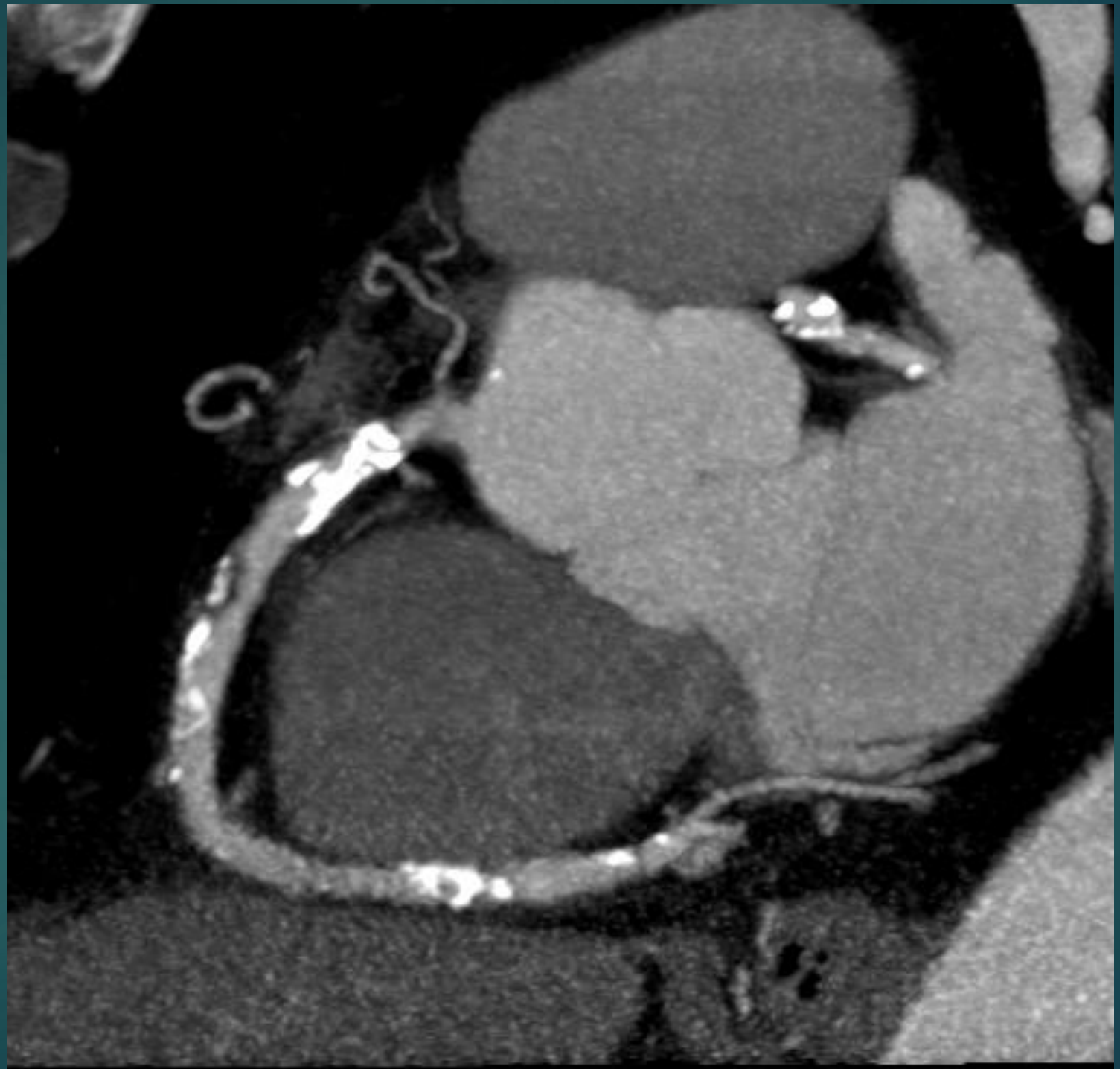
Left ventricle – volumes Ejection fraction, mass





CCTA – מגבלות:

- פרפור פרוזדורים מהיר
- הסתיידויות כליליות קשות (Dense calcifications)
- סטנטים (קוטר קטן מ- 2.5 מ"מ)
- כלי דם קטנים (קוטר תחת 1.5 מ"מ)
- אי ספיקת כליות (GFR<45ml/min)
- חשיפה לקרינה



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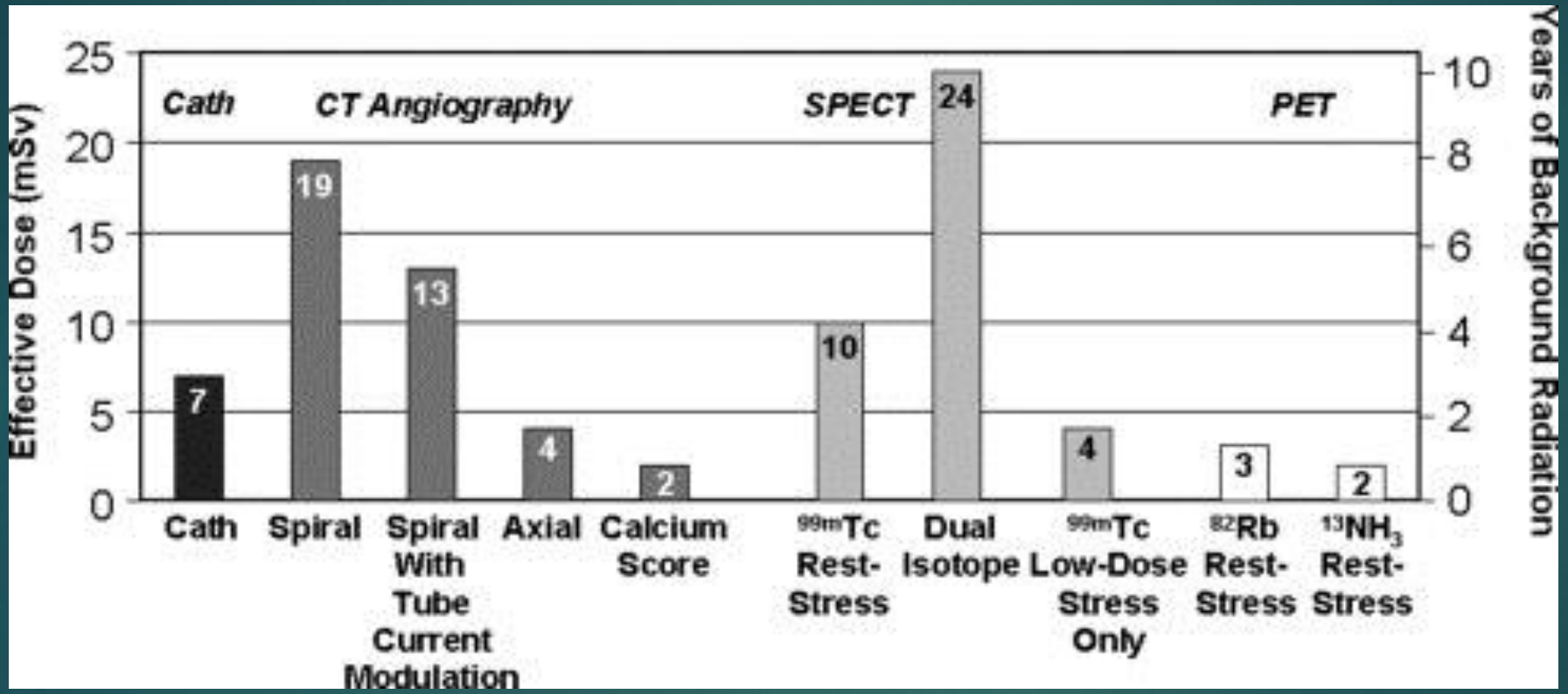
- אי ספיקת כליות (GFR<45ml/min)
- רגישות ליוד (קלה / קשה)

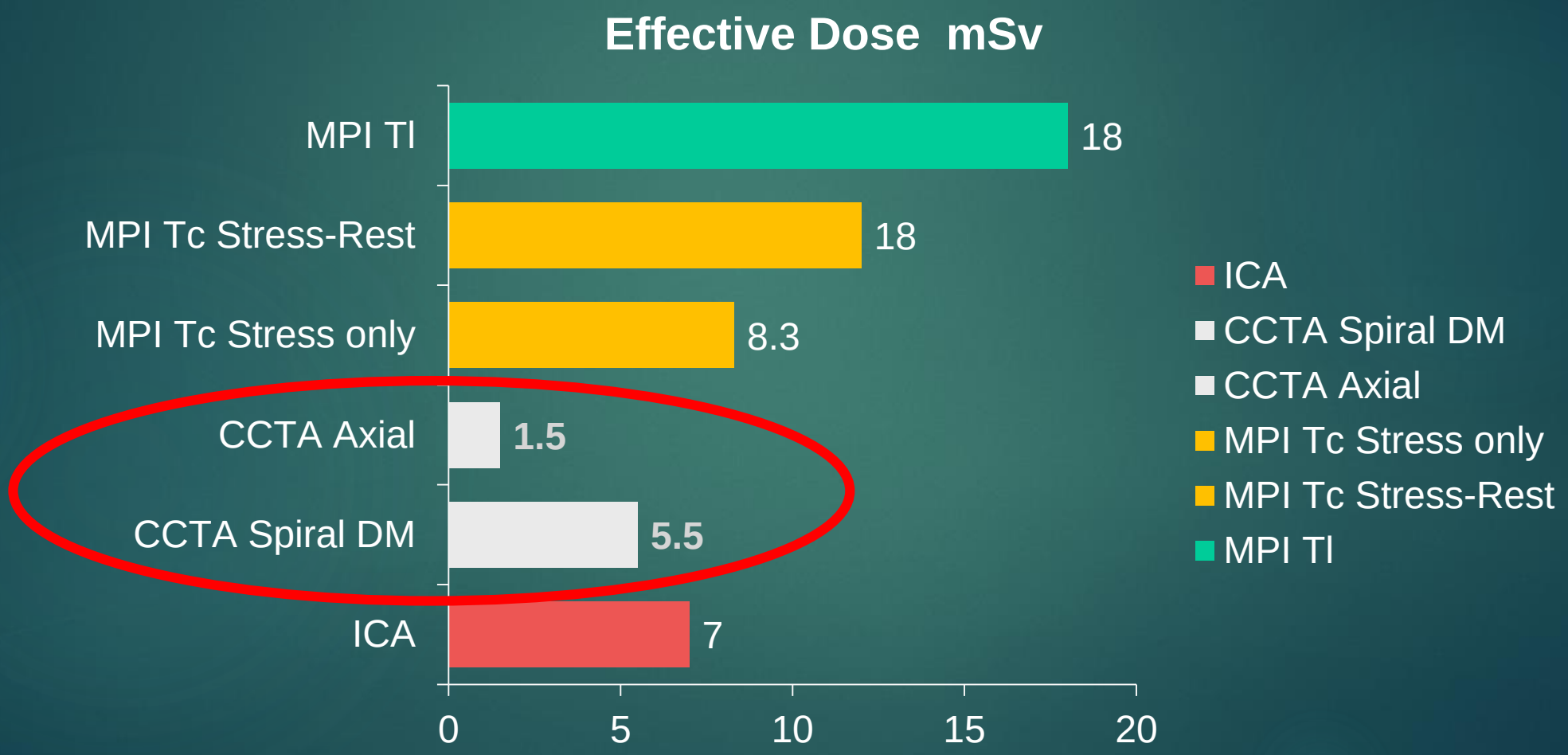
- חשיפה לקרינה
- מידע אנטומי בלבד

Radiation Exposure



Einstein AJ, JACC Vol. 59, No. 6, 2012

Radiation Exposure



Ultra-low radiation exposure

- Advanced scan features
- Iterative reconstruction algorithms

Image quality of ultra-low radiation exposure coronary CT angiography with an effective dose <0.1 mSv using high-pitch spiral acquisition and raw data-based iterative reconstruction

Schuhbaeck A. et al. Eur Radiol 2012

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Accuracy of Coronary CT Angiography Using a Submillisievert Fraction of Radiation Exposure

Comparison With Invasive Coronary Angiography

Julia Stehli, MD,* Tobias A. Fuchs, MD,* Sacha Bull, MD,* Olivier F. Clerc, MD,* Mathias Possner, MD,* Ronny R. Buechel, MD,* Oliver Gaemperli, MD,*† Philipp A. Kaufmann, MD*

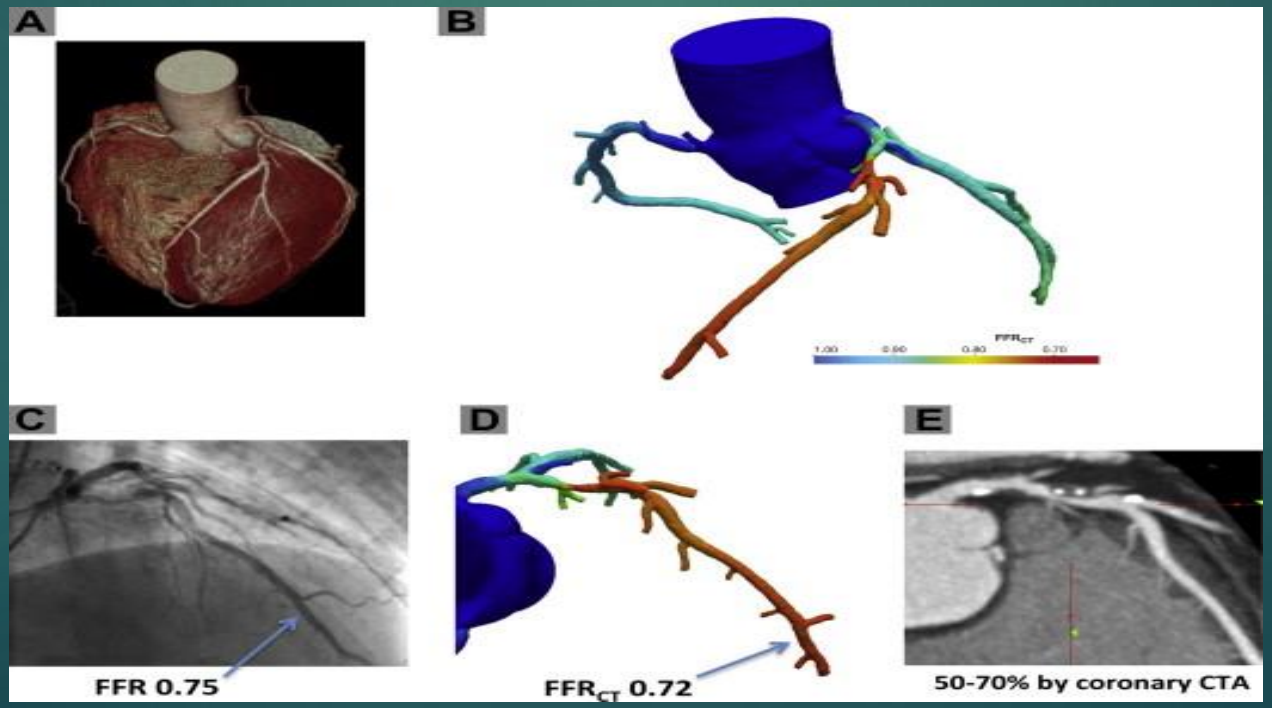
Anatomy vs. Physiology - Relationship between luminal stenosis and ischemia is complex

- Future prospective : Combining anatomy & physiology

A single noninvasive test with high diagnostic performance for both anatomy and lesion- specific ischemia would provide a major advantage in assessment of CAD

Combining Anatomy & Physiology

- **CT Perfusion (CTP) – dual scan, adenosine infusion**
- **FFRCT - computational fluid dynamics to derive physiologic data from CT, without additional imaging or medications.**



THANK YOU