“Vulnerable Plaque” features on coronary CT

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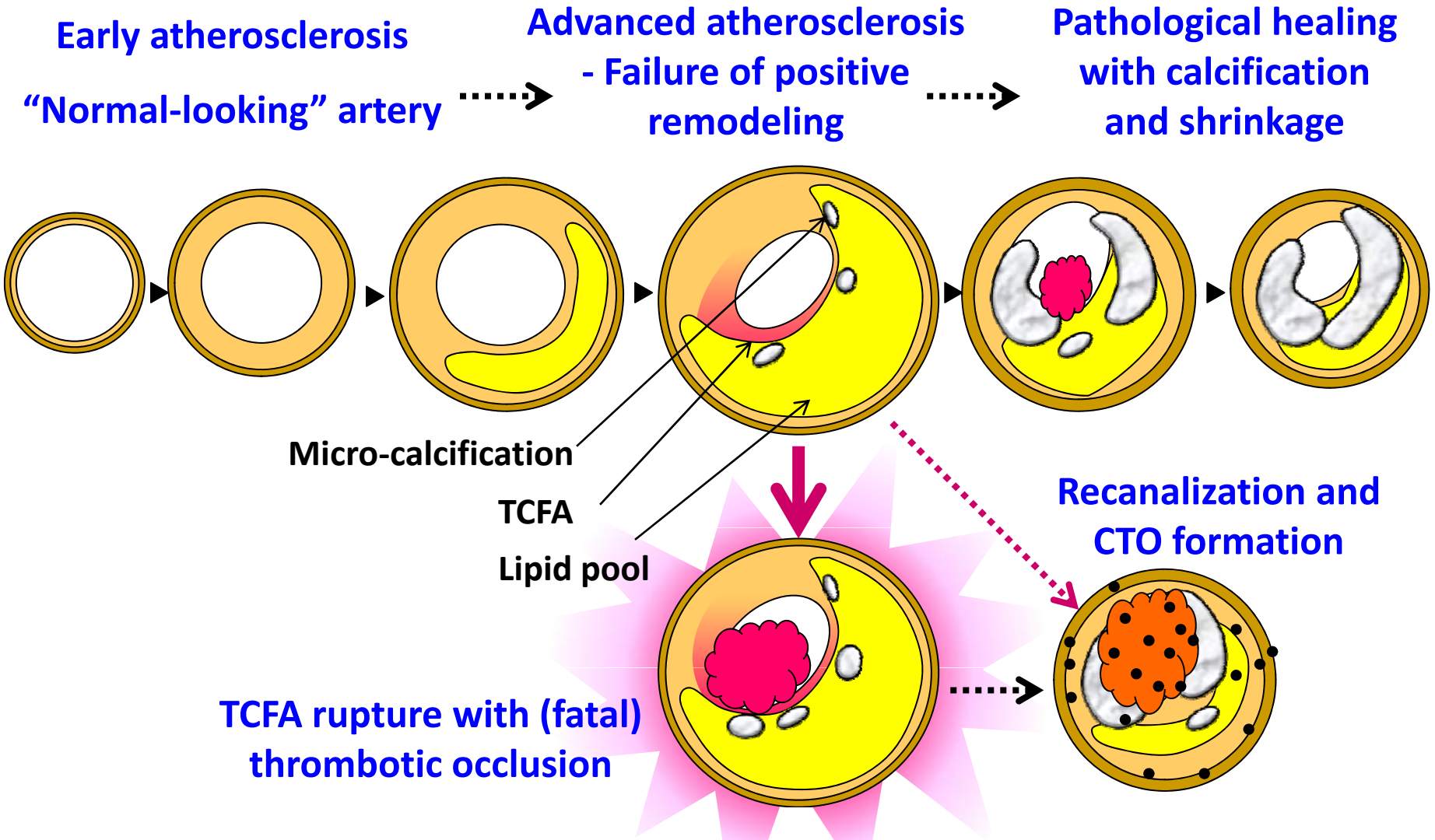
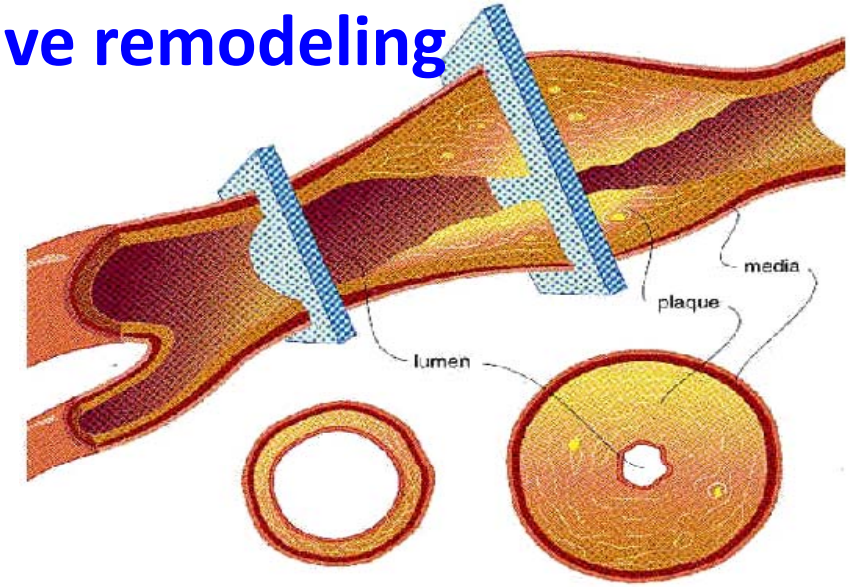
Clinical course of coronary atherosclerosis

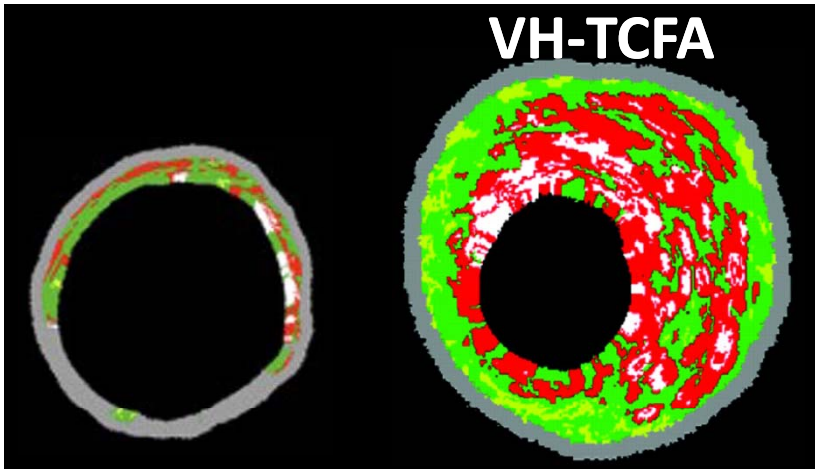


Adapted from Glagov, NEJM 1987; McEvoy, JACC 2010; Voros, JACC IMG 2011

VH-IVUS and OCT show the characteristics of VP validated on pathologic studies

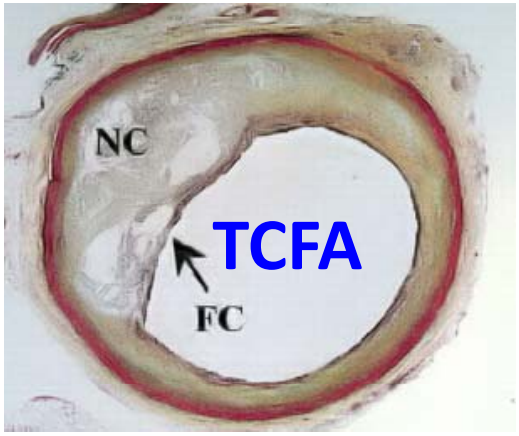
Positive remodeling

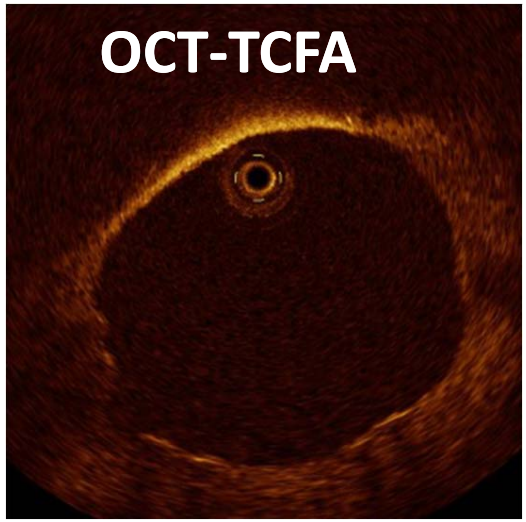




Cherevu, JACC 2007

Necrotic core





Virmani, ATVB 2000

SMC case

1. How the invasive modalities find VP ?
   - Positive remodeling (IVUS)
   - Lipid pool, Necrotic core, TCFA (VH-IVUS, OCT)
   - Microcalcification (IVUS)
   - Vessel stenosis and ischemia (FFR, QCA)

2. Does the same principle apply to the CT ?
   - Not perfect, but CT can show most of the above findings non-invasively.

Case – 54 year old male, sudden resting chest pain

- HT (+), DM (-)
- s/p unstable angina s/p PCI, 2004
  prox LAD 3.5x33mm Cypher

- Aspirin and statin. Clinically stable for 8 year

- Exertional chest pain since 2 days ago

- Coronary CT was performed at ER
- EKG and troponin: negative

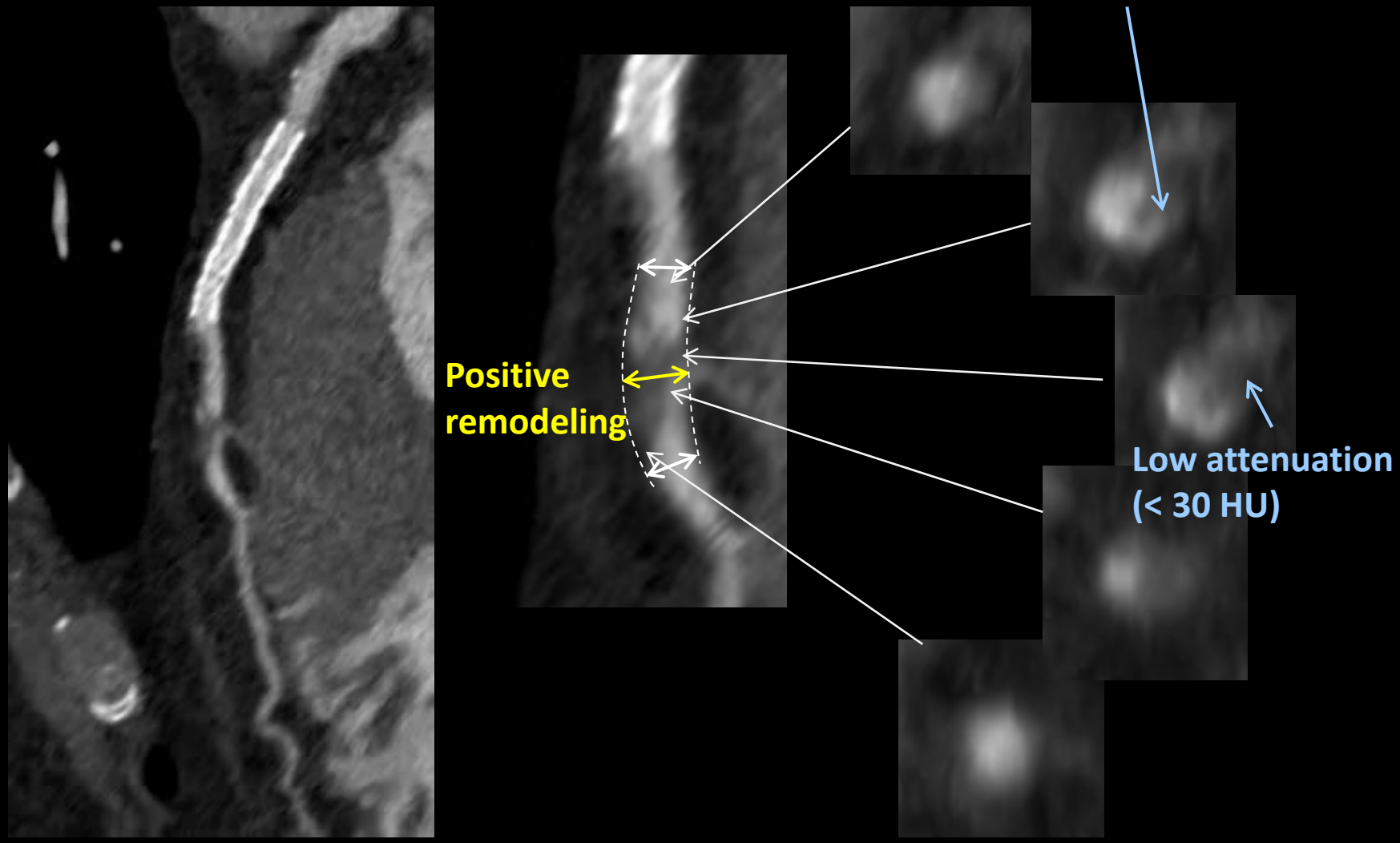
CAG and PCI, 8 years ago

Proximal LAD 90% stenosis

Mid LAD < 25% stenosis

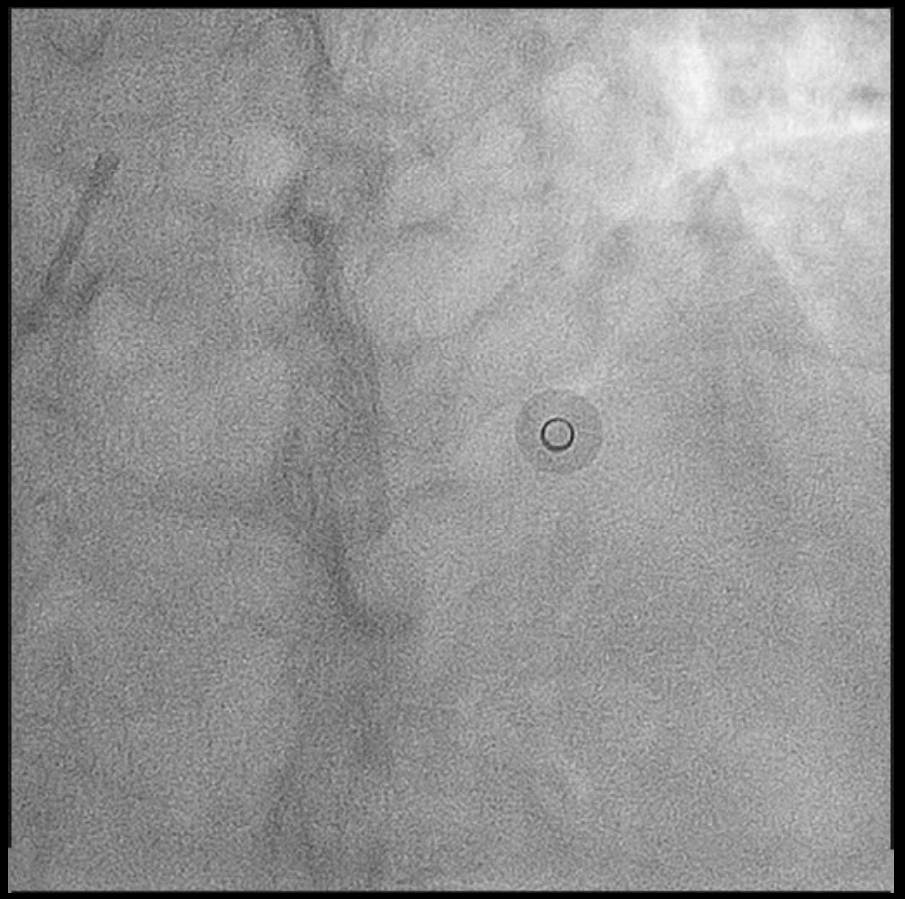
3.5x33mm Cypher, 16 atm in prox LAD

Resting chest pain since 2 days ago



Ventricular fibrillation during preparation → defibrillation

Immediately after wire passage



Red thrombi aspiration

3.0x24mm Biomatrix 16 atm

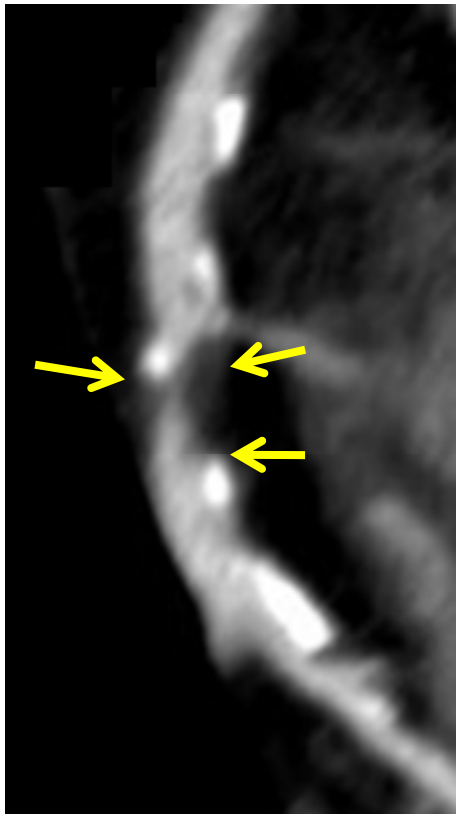
Post-PCI troponin = 1.11 ng/mL (ref. 0.78 ng/mL)

Positive remodeling

Low attenuation plaque

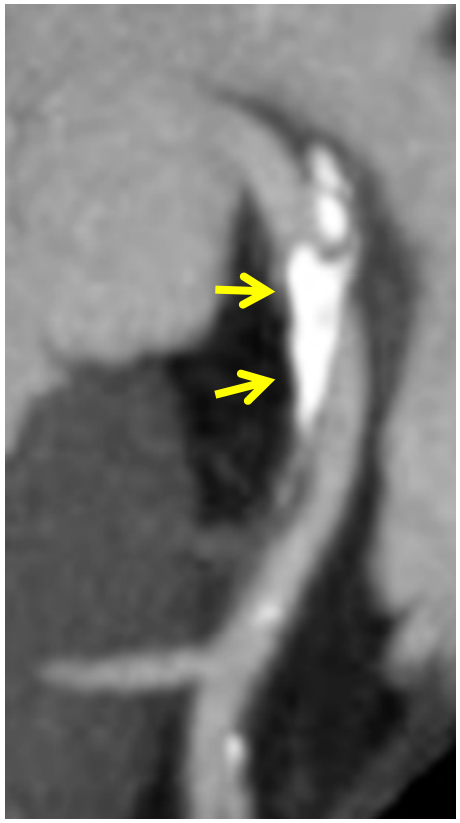
Plaque imaging by coronary CT

Non-calcified plaque



Partially calcified plaque

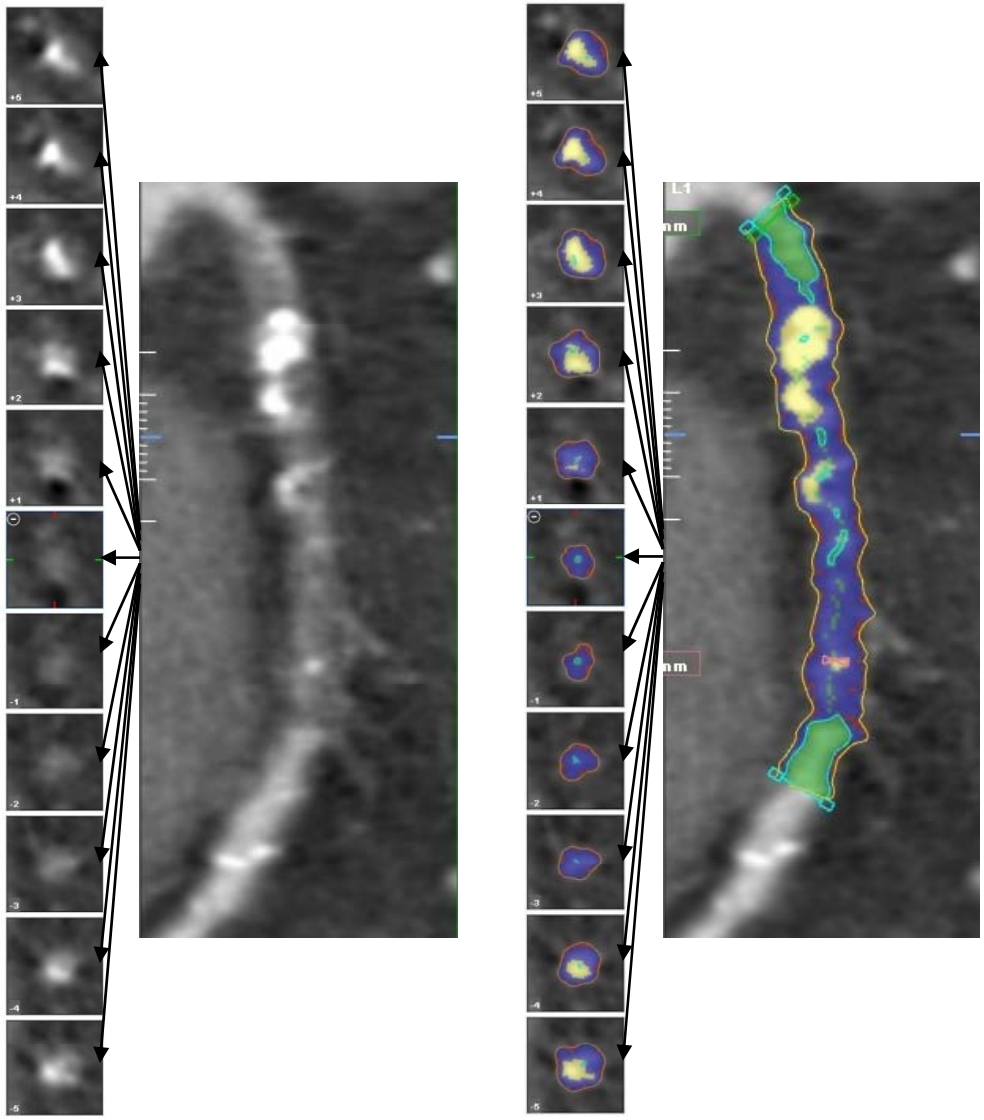
(mixed plaque)



Calcified plaque

SMC educational file

Plaque characterization



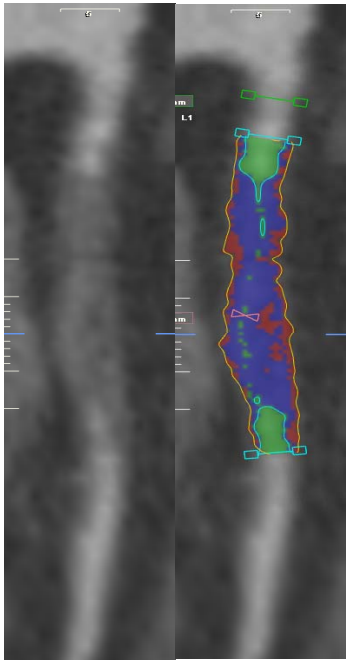
Sureplaque ™

	Calcification	**324 ~ 1684 HU**
	Intermediate	**50 ~ 323 HU**
	Low density	**-100 ~ 49 HU**
	Lumen	**> 270 HU****

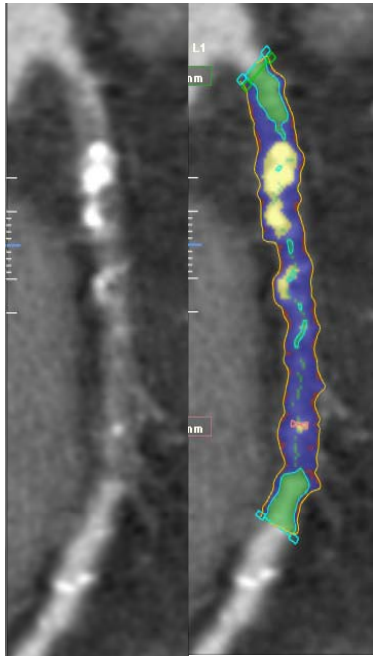
Choi, Circ J 2010

Remodeling pattern of CTO plaque

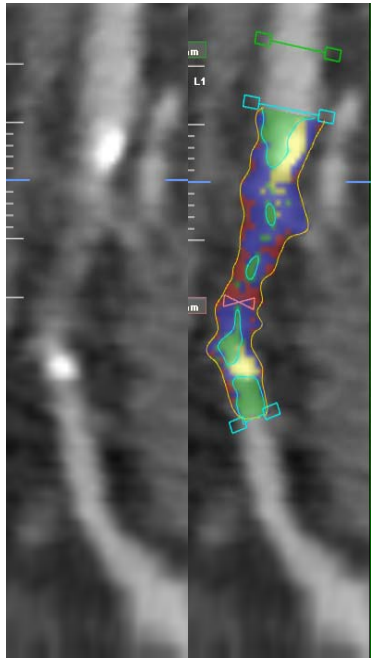
Positive remodeling



Neutral

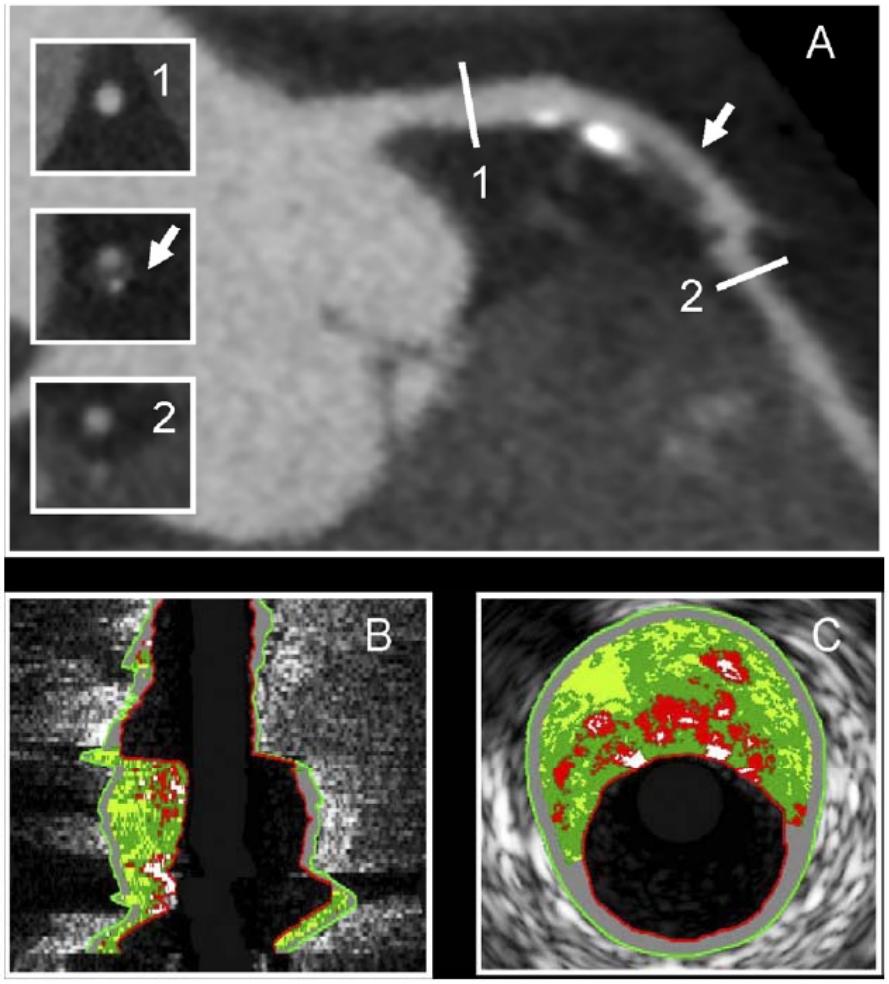


Negative remodeling

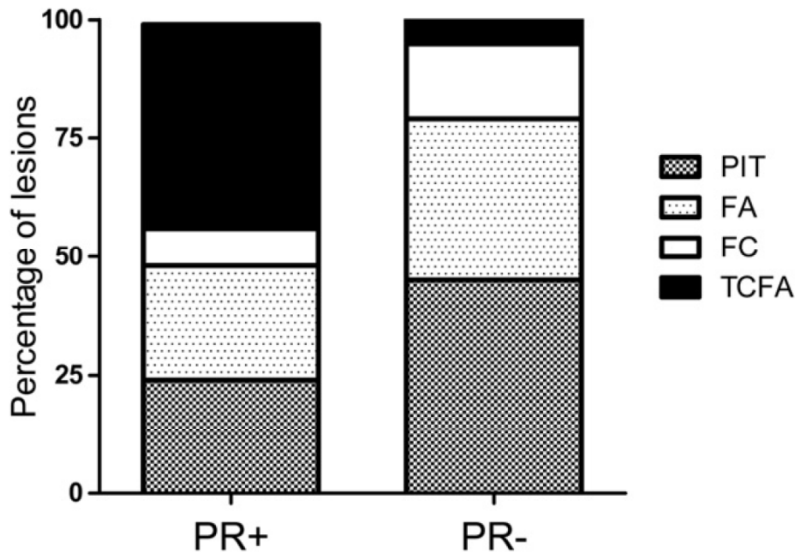


Choi, Circ J 2010

Positive remodeling on CT is associated with necrotic core and VH-TCFA

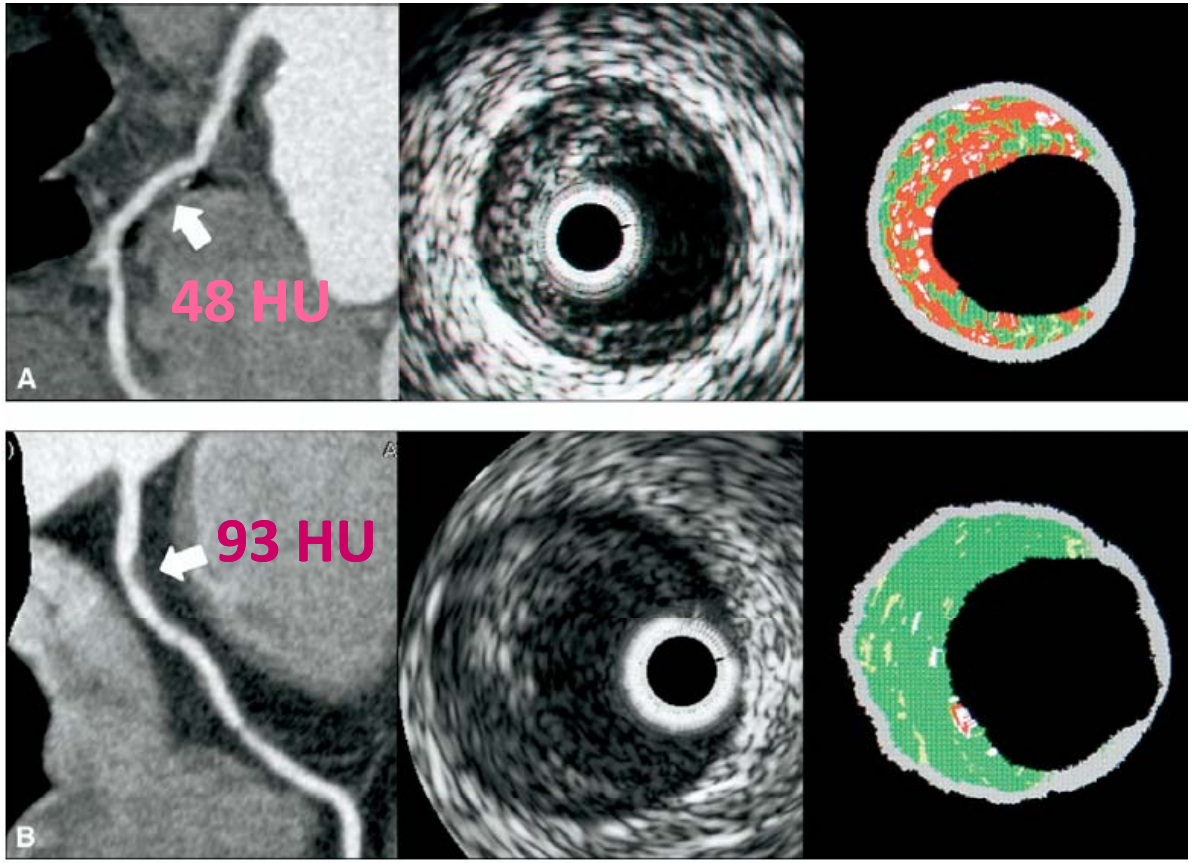


45 patients, 99 plaques

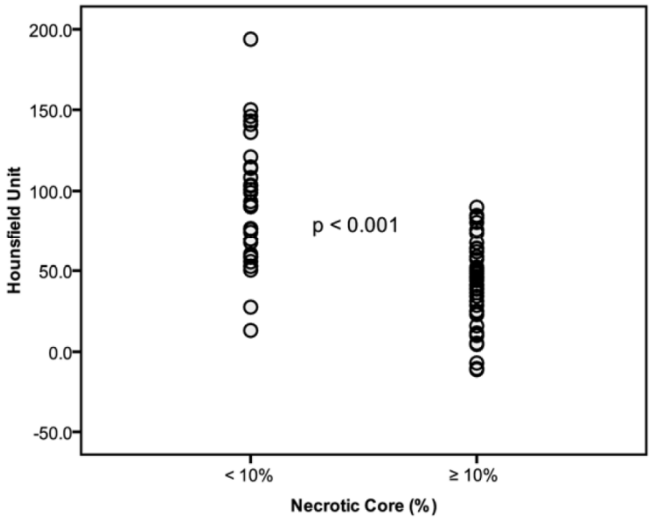


Kroner, Am J Cardiol 2011

Low attenuation plaque on CT → necrotic core on VH-IVUS

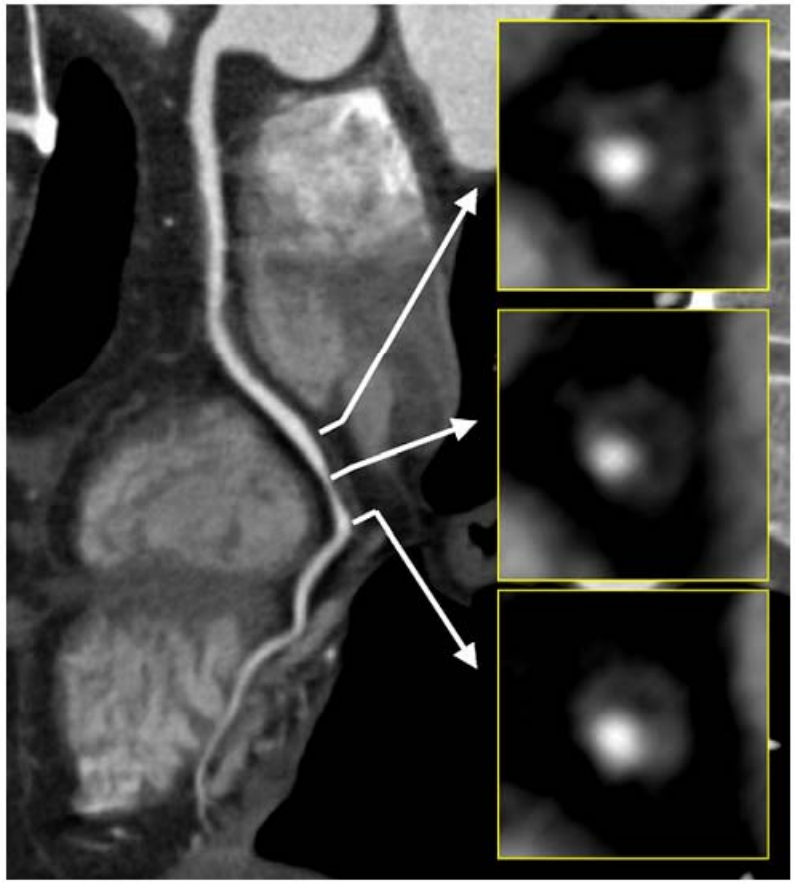


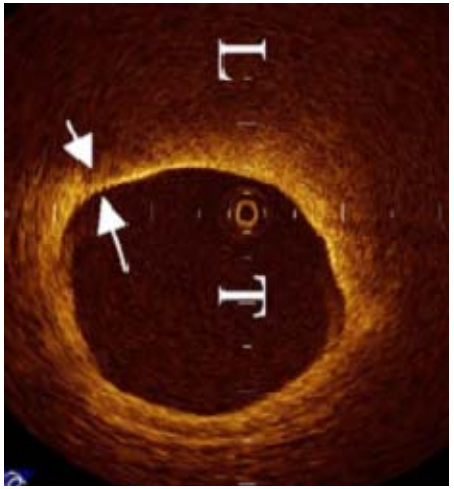
59 patients (21 UA)



Choi BJ, Am J Cardiol 2008

Low attenuation plaque seen as “ring-like enhancement”



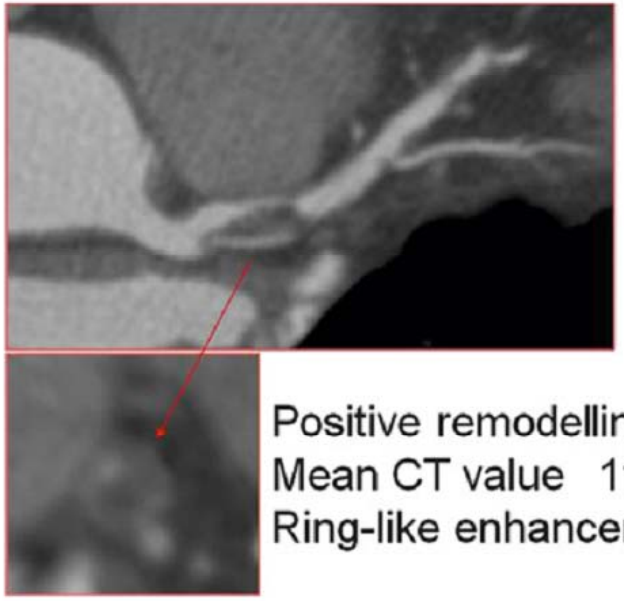


	OCT-TCFA (+)	OCT-TCFA (-)
N	25	80
Ring-like enhancement	**44%**	**4%**
Pos. Remol.	**76%**	**31%**
Plaque HU	**35** HU	**62** HU
Calcium	**44%**	**54%**

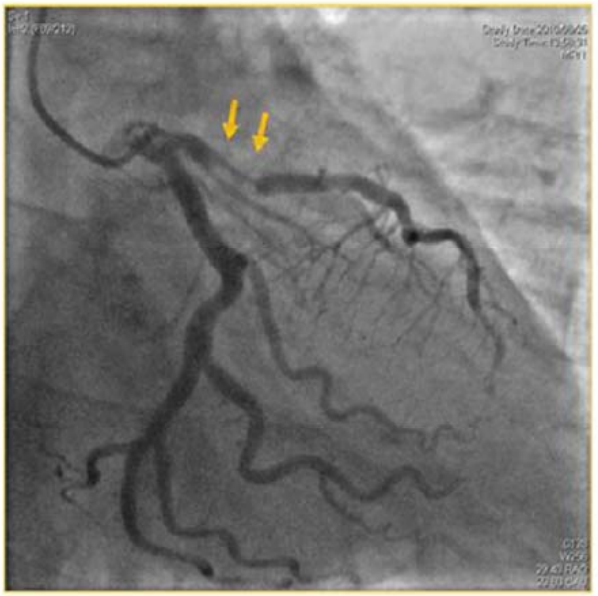
Kashiwagi, JACC IMG 2009

Ring-like enhancement of CT is yellowish plaque

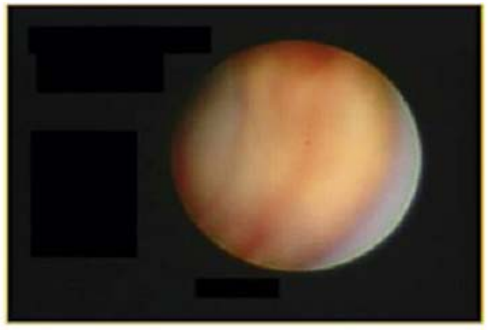
Ring-like enhancement of CT: PPV=0.88, NPV=0.63
for disrupted plaque (yellow color angioscopy)



Positive remodelling
Mean CT value 11HU
Ring-like enhancement

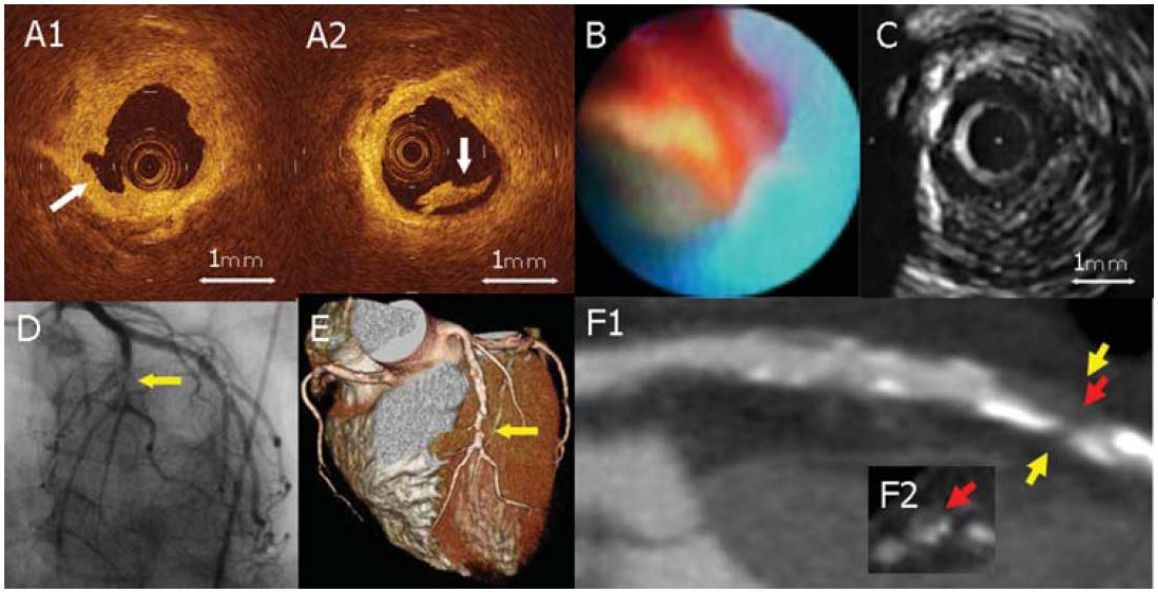


Yellow colour grade 3
Ruptured plaque with thrombus



Nishio, Heart 2011

Low attenuation plaque and spotty calcification are common in ruptured plaque validated by OCT and angioscopy



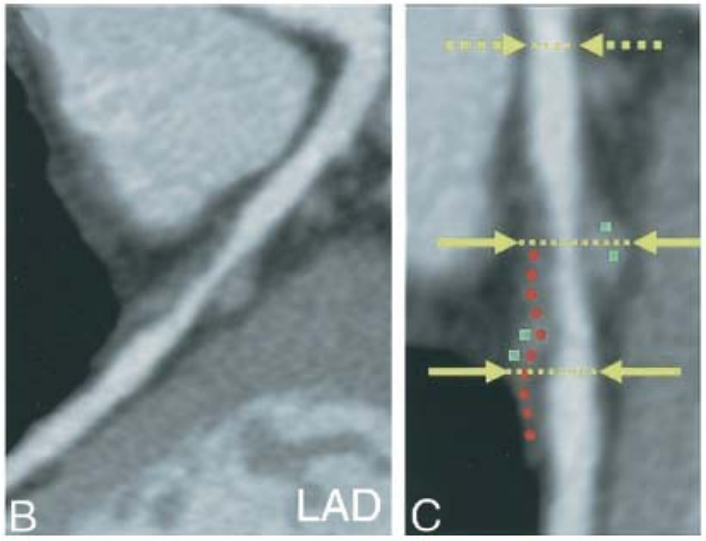
Ozaki, Eur heart J 2011

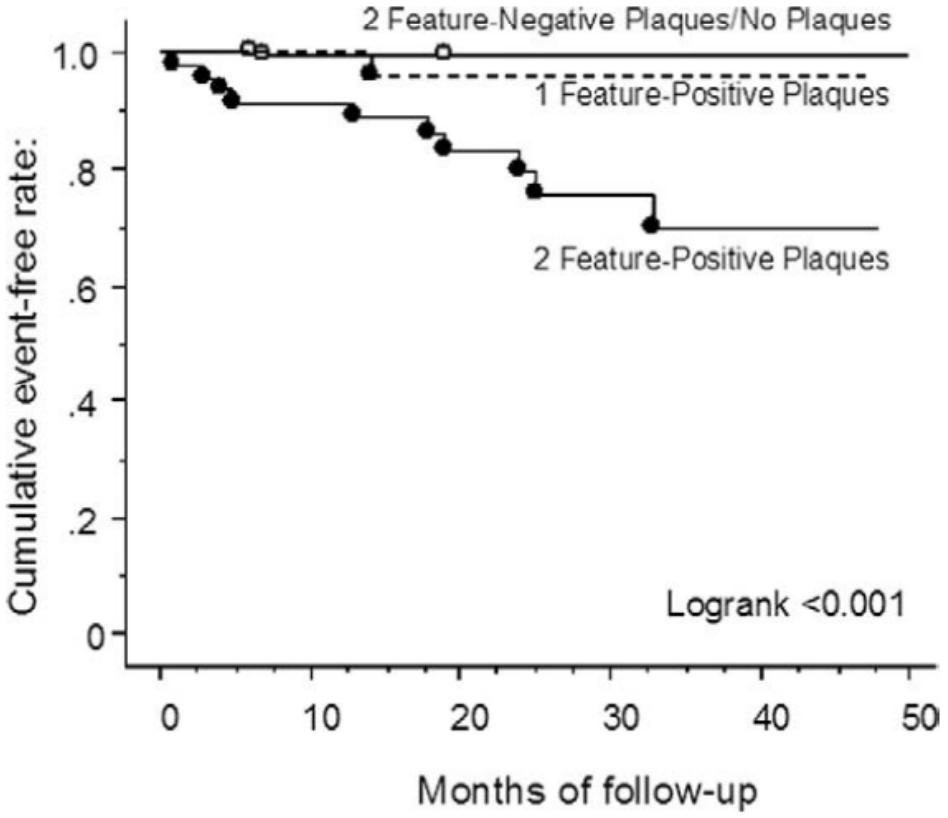
		Ruptured TCFA	Intact TCFA	Stable angina
OCT	TCFA	92%	20%	9%
Angioscopy	Yellow plaque	84%	70%	55%
IVUS	Remodeling index	1.14	1.00	0.95
CT	**NCP (< 30 HU)**	**88%**	40%	18%
	Spotty calcification	**80%**	20%	23%

Plaque characteristics of CT predicts future cardiovascular event

N = 1059, 2 year follow-up

Positive remodeling (PR) and **low attenuation plaque** (LAP) → **22.2% ACS event**





Motoyama, JACC 2009

Calcification

Case: 56 year old asymptomatic male

- Physically active and good shape
- Stage I hypertension, otherwise no risk factors
- Lab test (lipid, CRP): normal

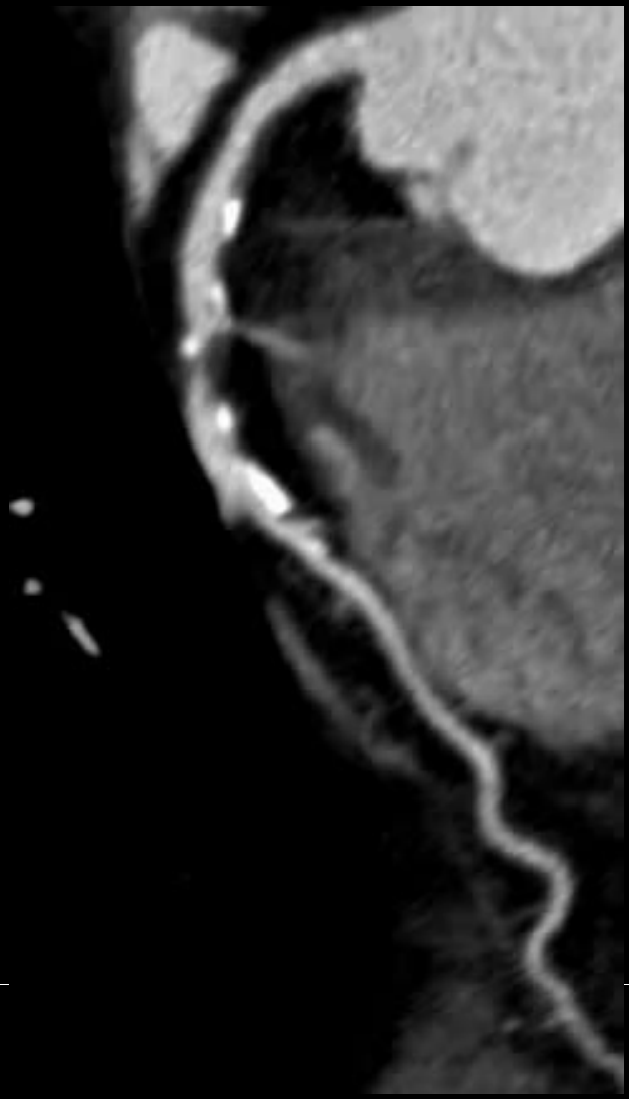
- **Coronary CT** done in health screening center
  - **mid LAD 70% stenosis**
  - Calcium score (Agatston) = **342**

- Cardiac catheterization was recommended

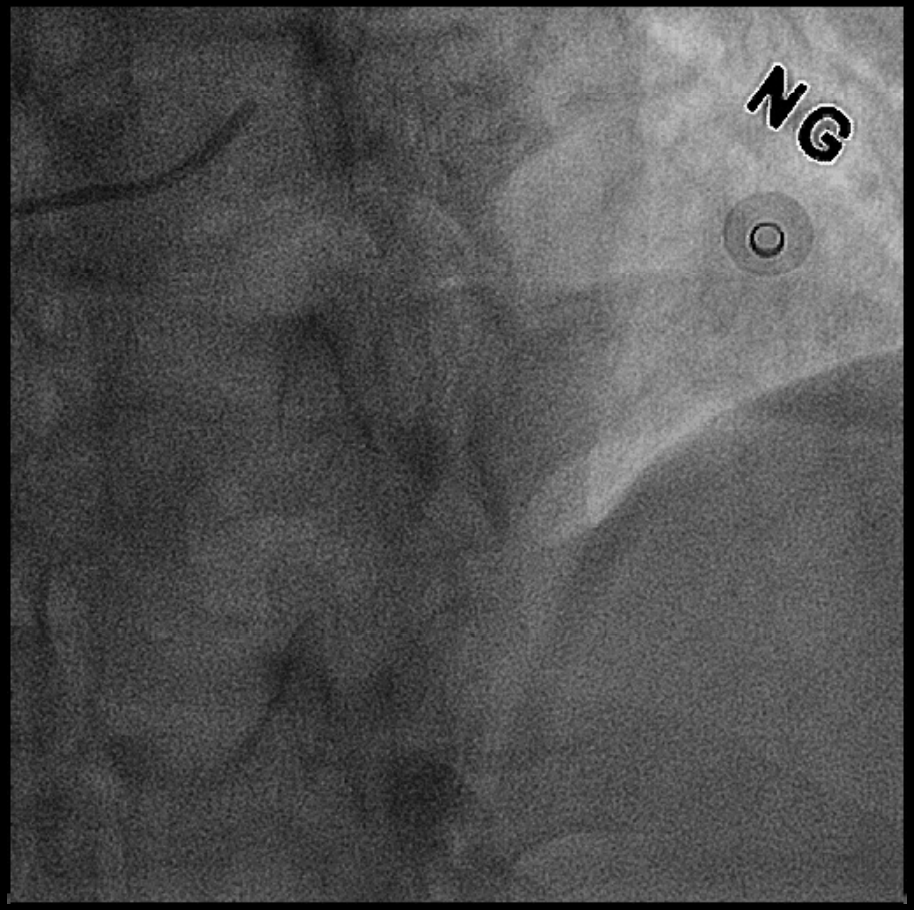
Partilally calcified plaque with >70% stenosis at mid LAD

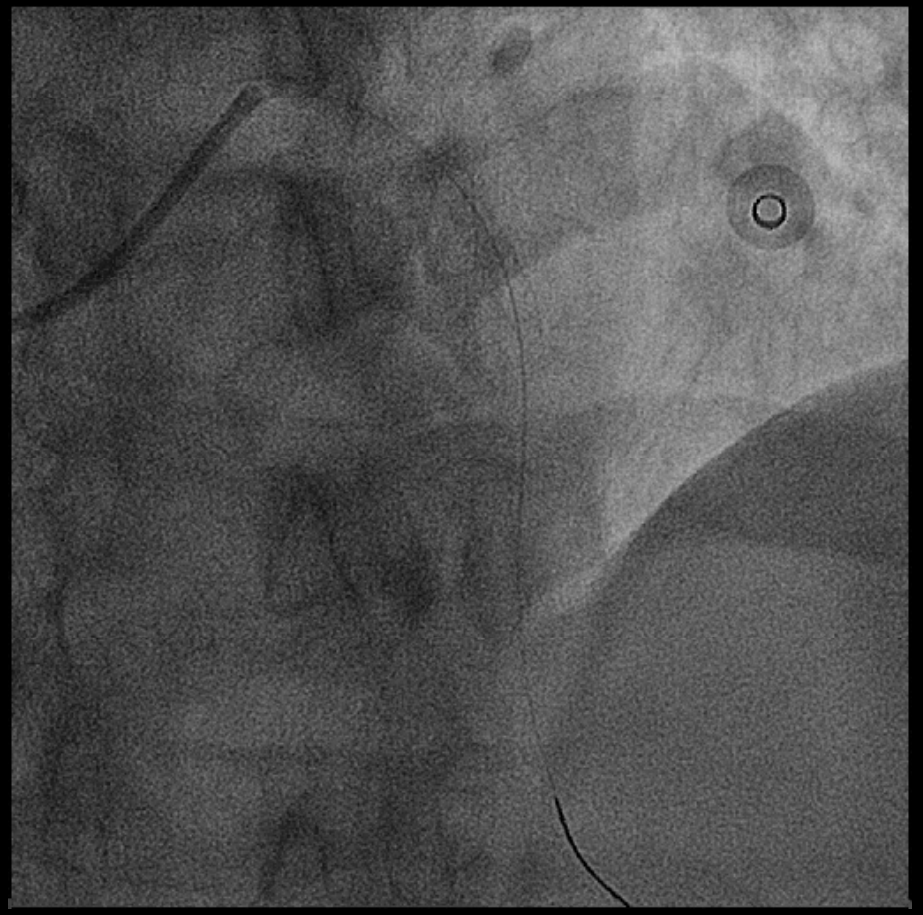
MIP

CPR



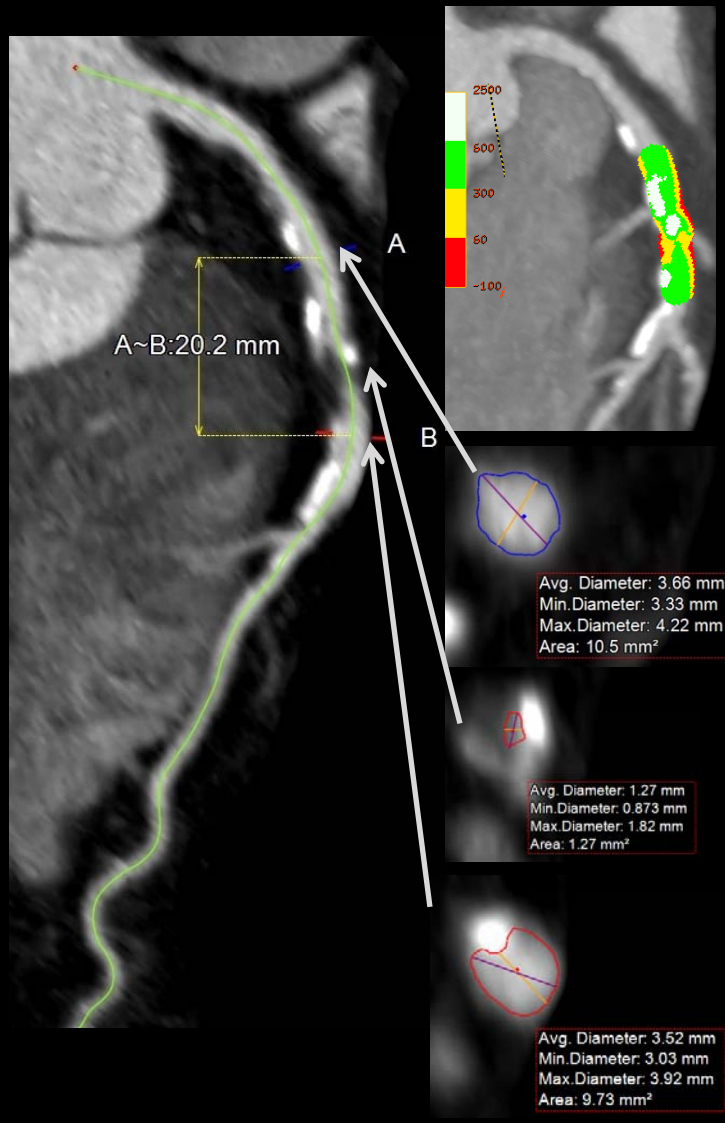
CAG





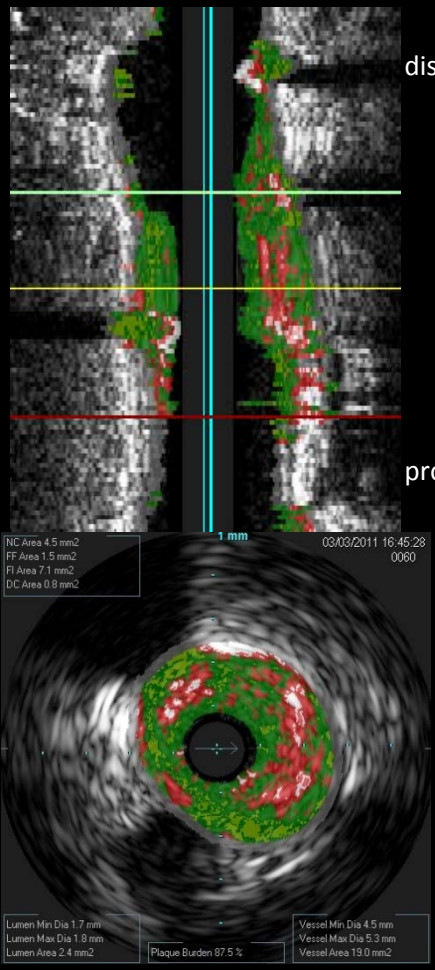
3.5x23 mm Biomatrix, 18 atm

CT color code map



Lipid intensity = 15.2%

VH-IVUS color code map



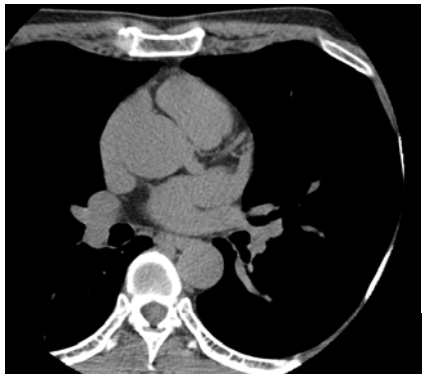
Plaque burden = 88%

Necrotic core = 32%

CAC score predicts coronary risk better than clinically determined risk

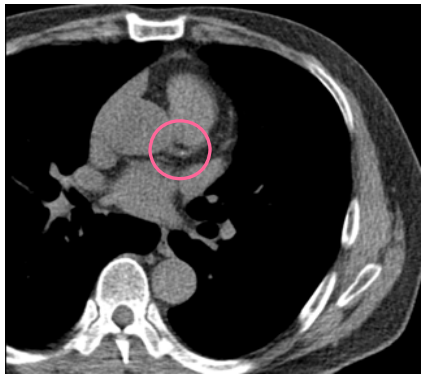
Risk prediction is ~ x4 better than clinical risk score, and additive to clinical risk score

CAC score and risk of major coronary event (MI or CHD death)



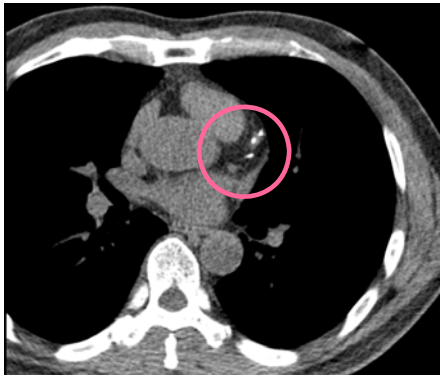
CAC = 0

Hazard ratio = 1
(standard)



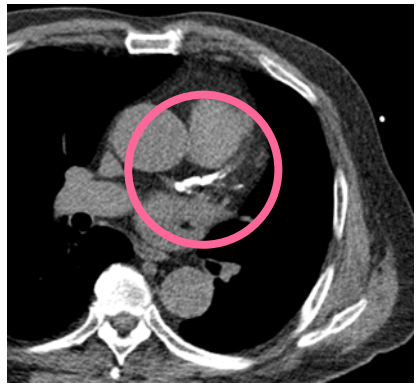
CAC = 65

Hazard ratio ~ 4



CAC = 342

Hazard ratio ~ 7



CAC = 1019

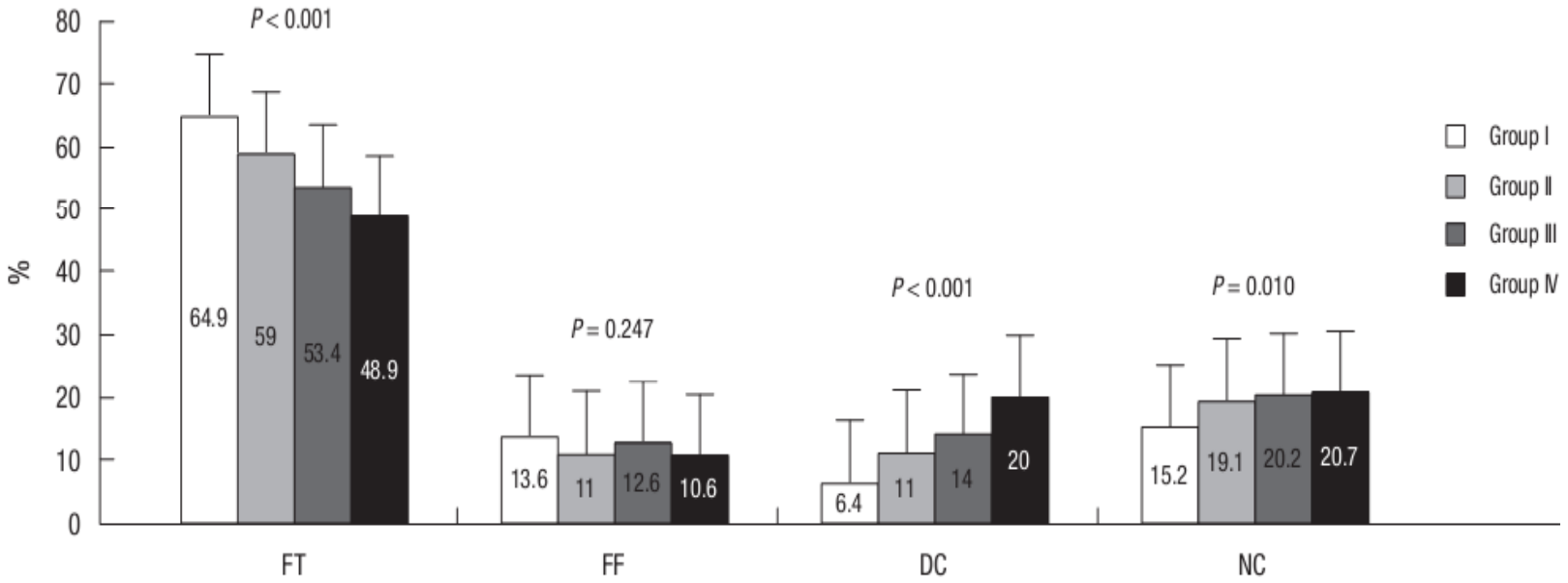
Hazard ratio > 7

MESA study, Detrano, NEJM 2008

Higher CAC, more vulnerable plaques

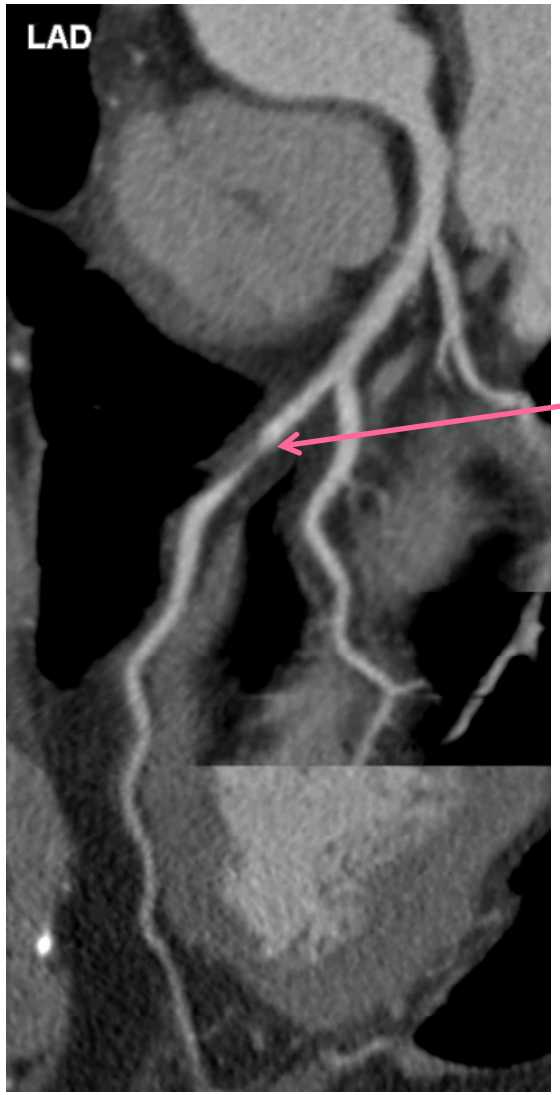
CT and VH-IVUS of 172 patients.

Higher volume% of dense calcium (DC) and necrotic core (NC) of VH-IVUS in group with higher CAC (group IV; CACS > 400)



Choi YH, JKMS 2011

Zero calcium score does NOT guarantee the absence of coronary artery plaque, especially in symptomatic patients



Non-calcified plaques with significant stenosis

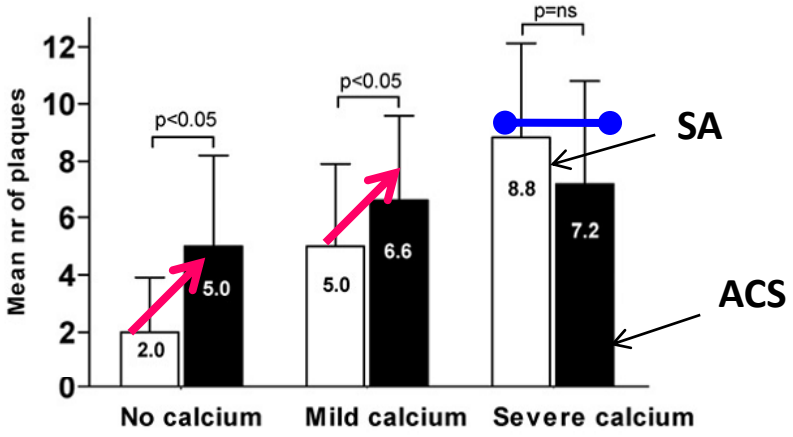
HYW 234697261

YBK 21272025

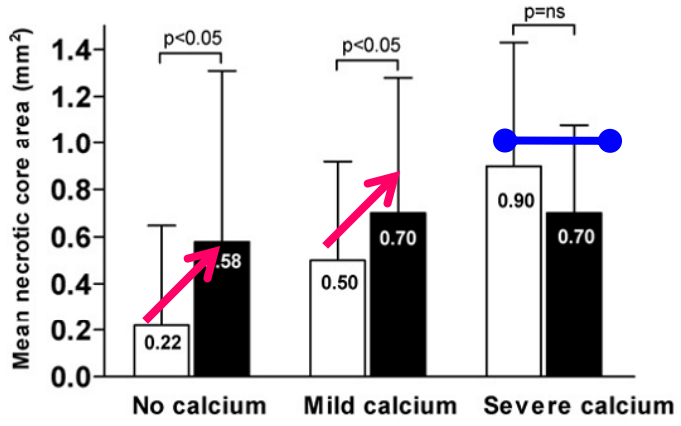
Ref: Gottlieb, JACC 2010

CAC score=0 does not exclude the presence of VP: Higher plaque burden and increased vulnerability in patients with ACS

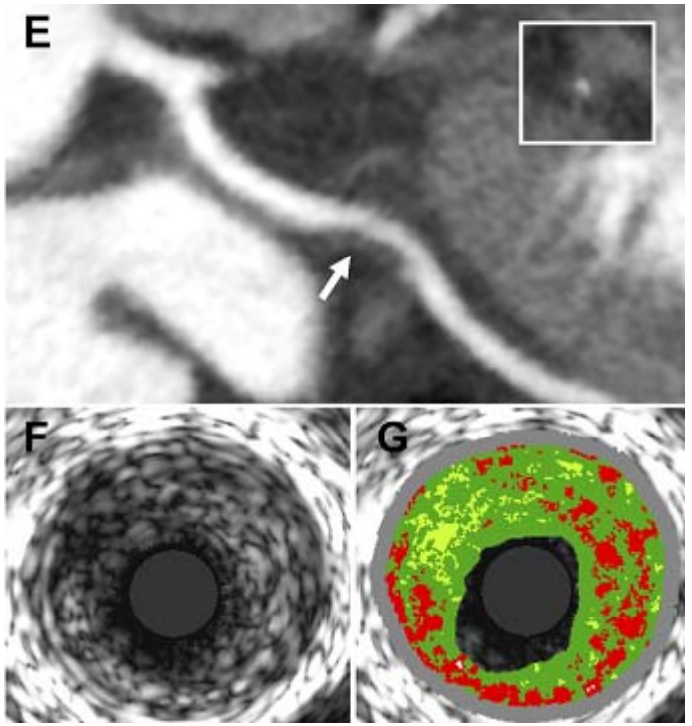
Higher number of plaque in ACS with CAC=0



Higher NC area in ACS with CAC=0



CT and VH-IVUS study, N=112 (53 SA, 59 ACS)



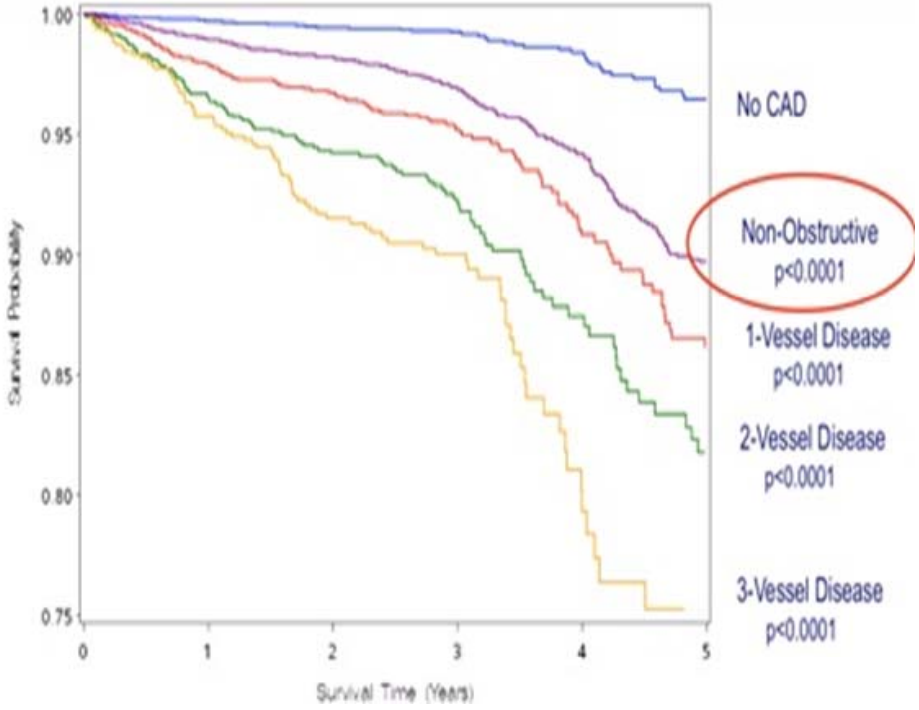
Van Velzen, AJC 2011

Stenosis and semiquantitative extent of coronary artery plaque predicts all-cause mortality

CONFIRM registry: 21,111 consecutive patients (59±13 yr, 57% male)

without known CAD in 10 international centers followed for 2.6±1.7 yr

for all cause mortality (N = 704, 3.4%)



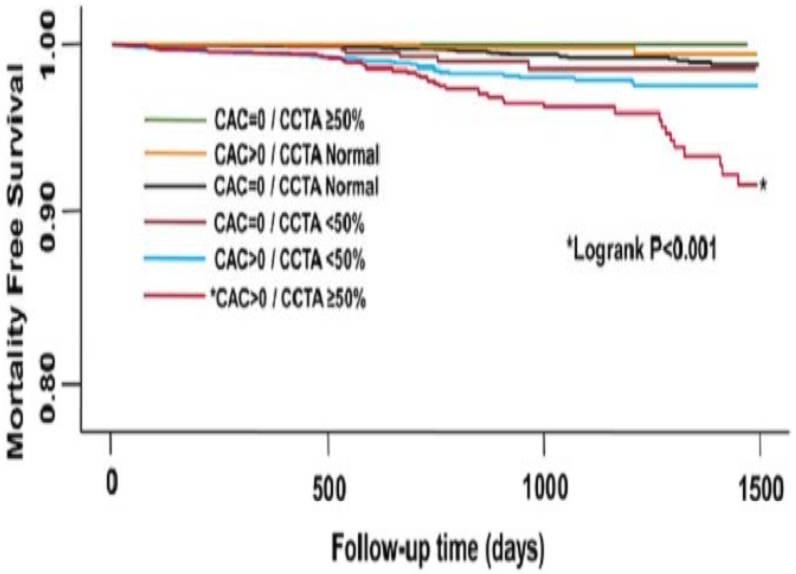
Min, JACC 2011

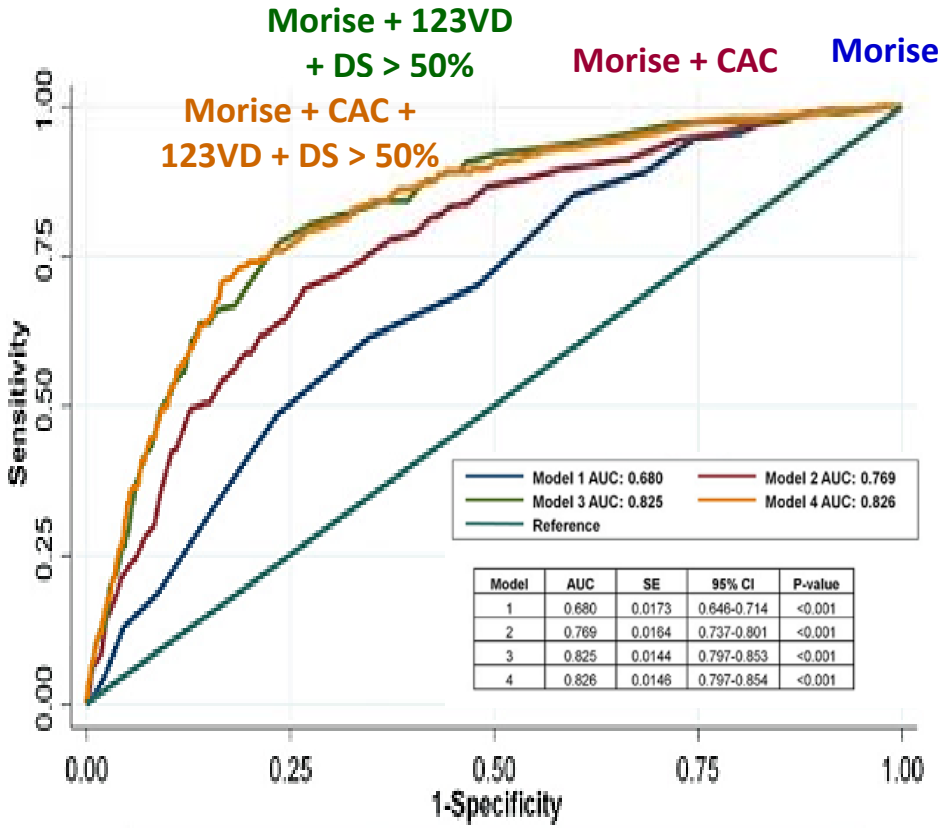
CAC score is not additive: CONFIRM registry

Symptomatic patients without known CAD, N=10,037, follow-up median 2.1 year

CT stenosis is **additive** to **clinical risk score** (Morise, Am J Med 1997)

CAC score was **not additive** to **CT stenosis + clinical risk score**



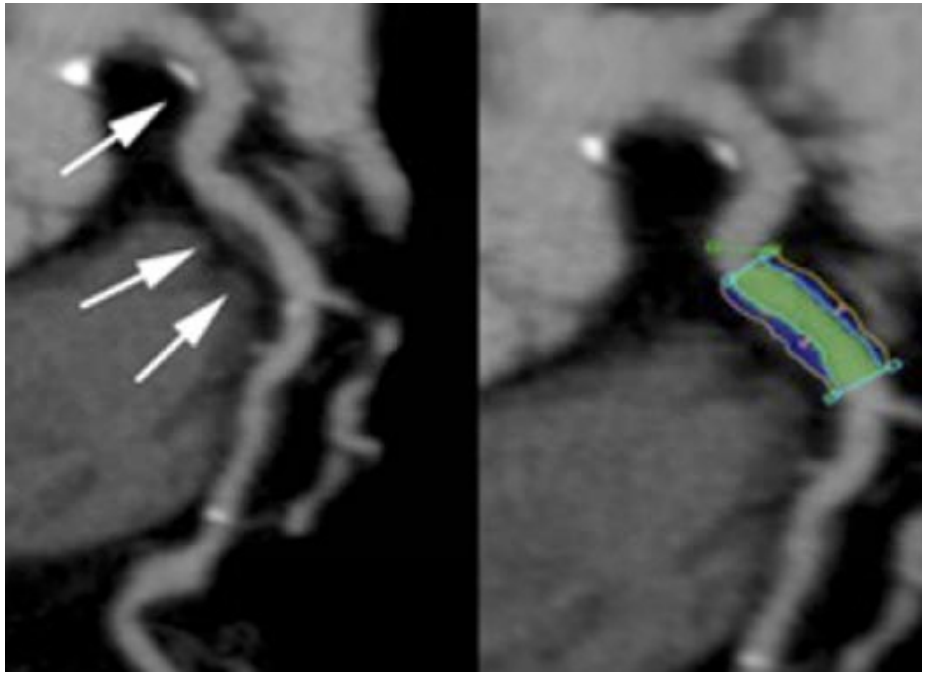


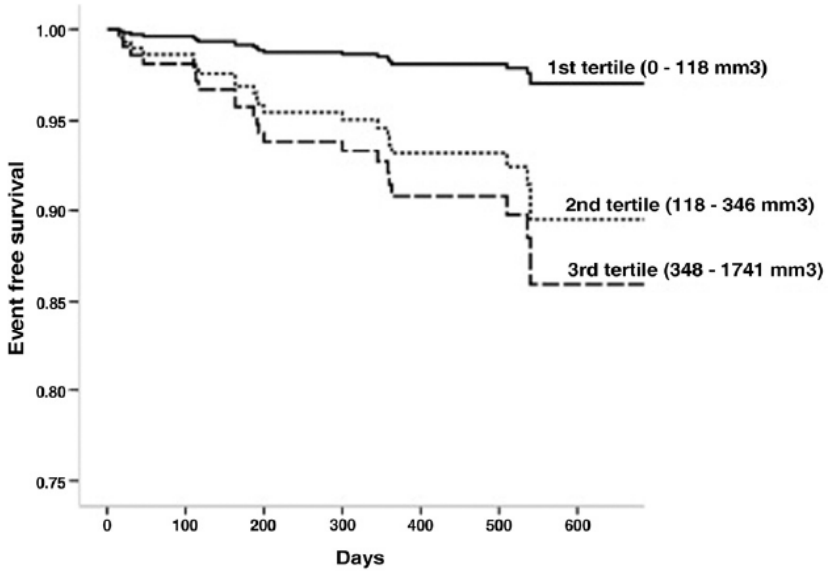
Villines, JACC 2011

Volume of non-calcified plaque in patients with ACS (NSTEMI) predicts future cardiovascular event

N = 312, 16 months follow-up

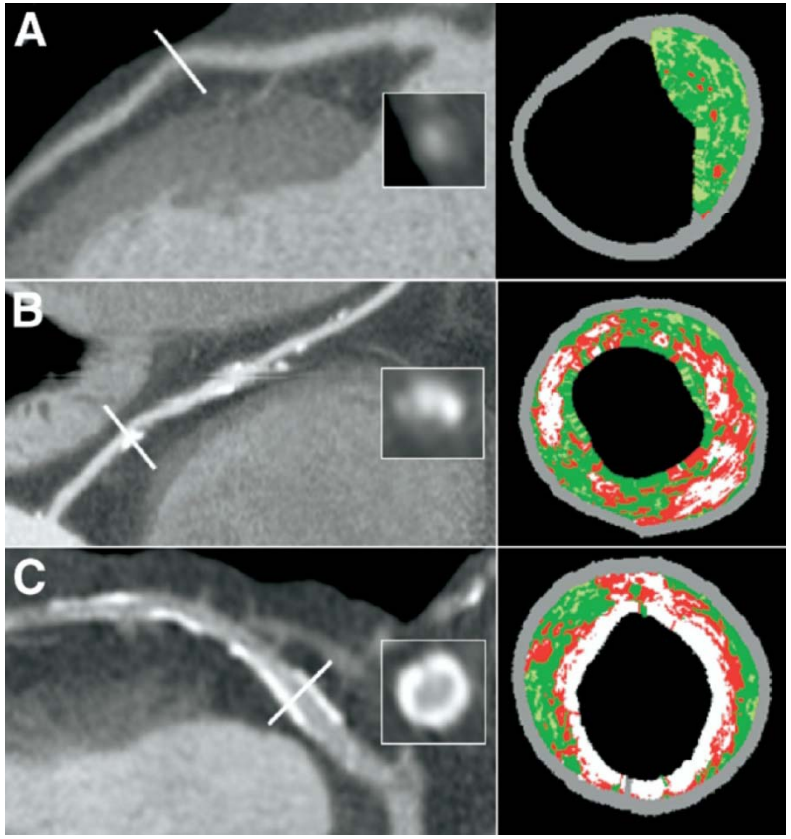
Total volume of non-calcified plaque (but not CAC score nor calcium in non-culprit lesion) predicted future event, and was additive to clinical risk predictors



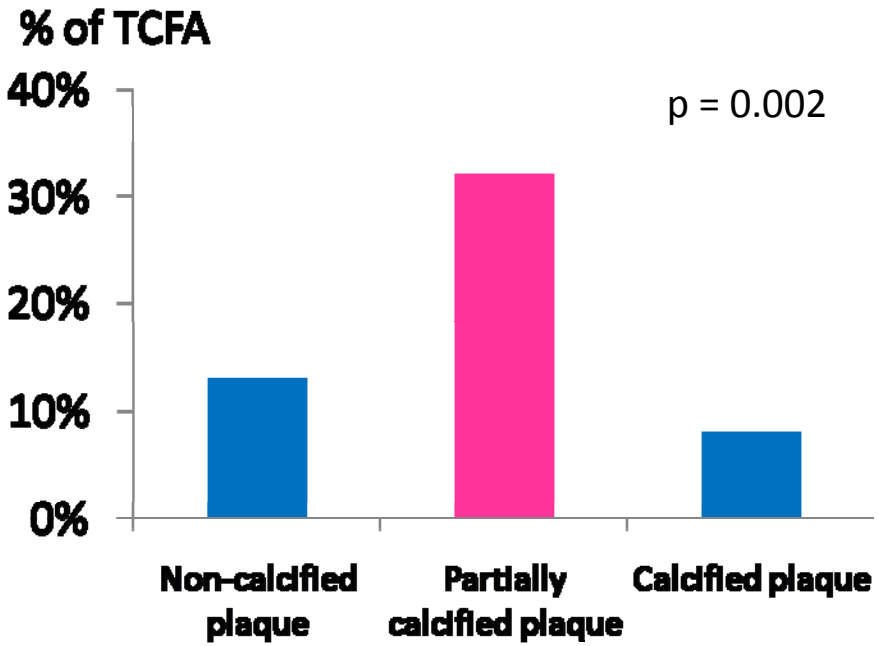


Kristensen, JACC 2011

Partially calcified plaque: highest frequency of VH-TCFA



N=50, CT and VH-IVUS



Pundziute, JACC Int 2008

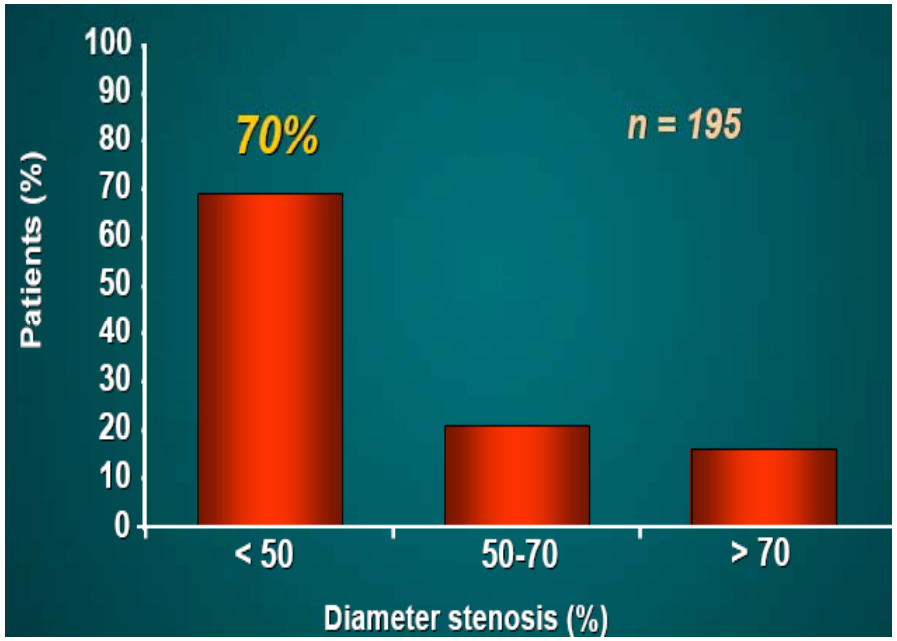
Stenosis

Paradigm shift: more stenotic, more risky

1996

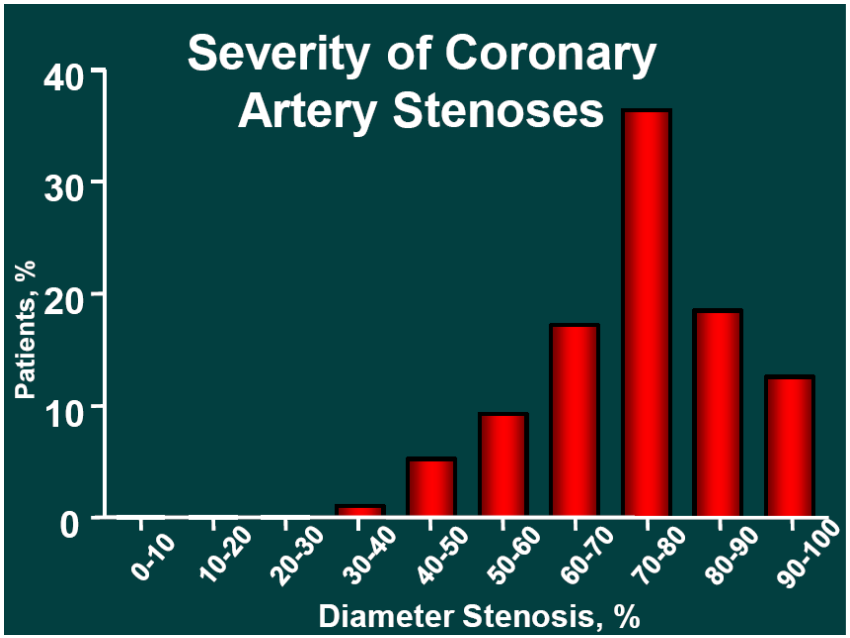
2007

Most of ACS at insignificant stenoses (< 50%)



Smith, AHA 1996

Most of ACS at significant stenoses (> 50%)



Frobert, CCI 2007

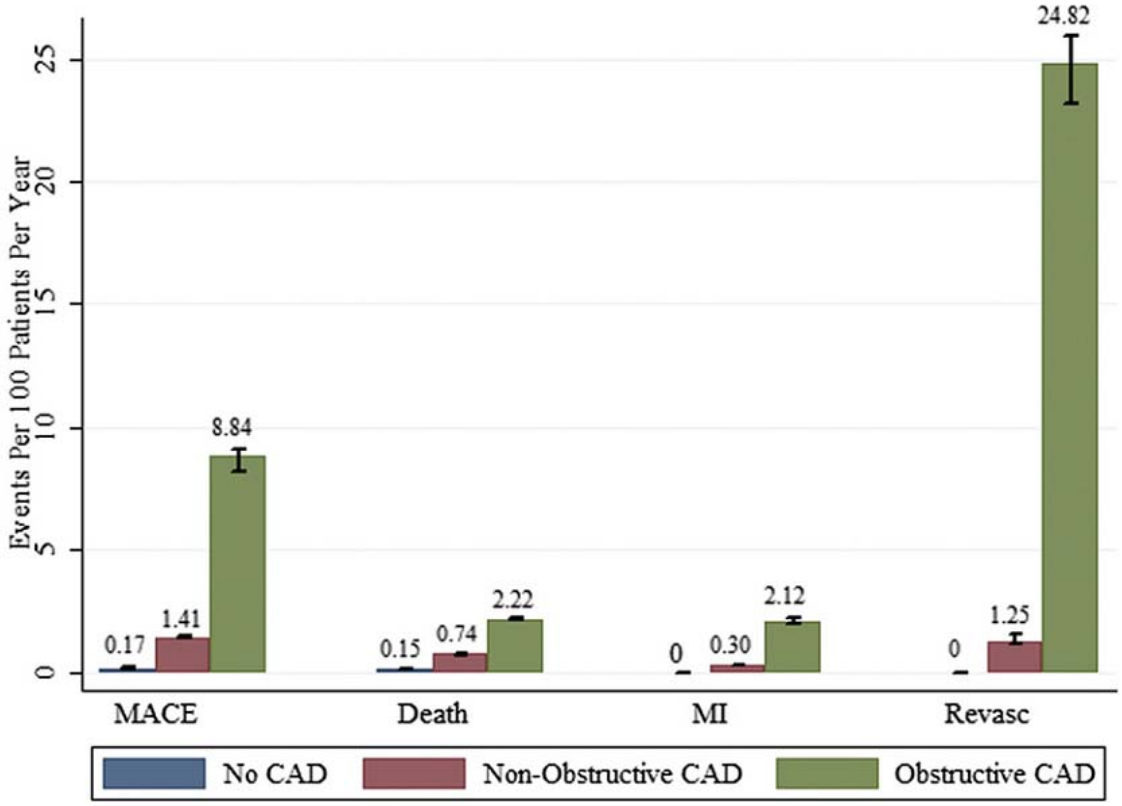
Mild stenoses have excellent long-term prognosis

Clinical study	Follow-up period	Publication
DEFER	5 year	Pijls, JACC 2010
Left Main registry	5 year	Hamilos, Circulation 2009
FAME	2 year	Tonino, NEJM 2009
PROSPECT	3 year	Stone, NEJM 2011

Prognostic value of >50% stenosis on CCTA

Meta-analysis of 18 studies (EBCT, 16-, or 64-slice MDCT) with follow-up > 3 month (median 20 months), N= 9592

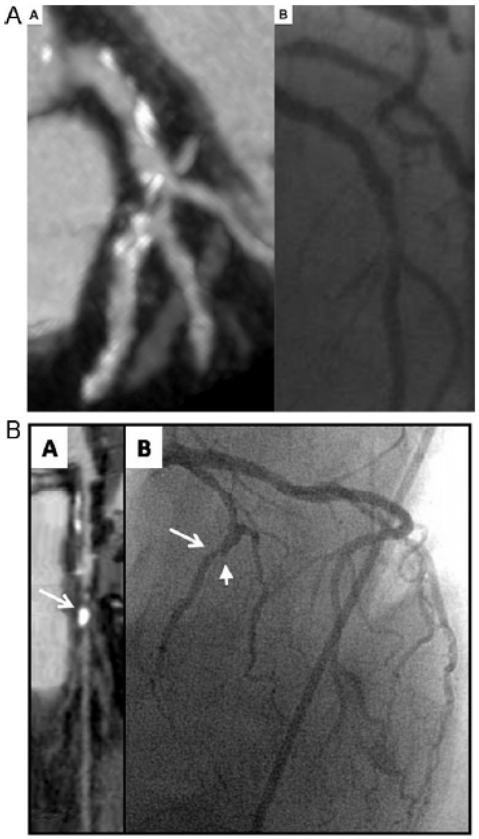
-LR=0.008, +LR=1.7, sensitivity=0.99, specificity=0.41

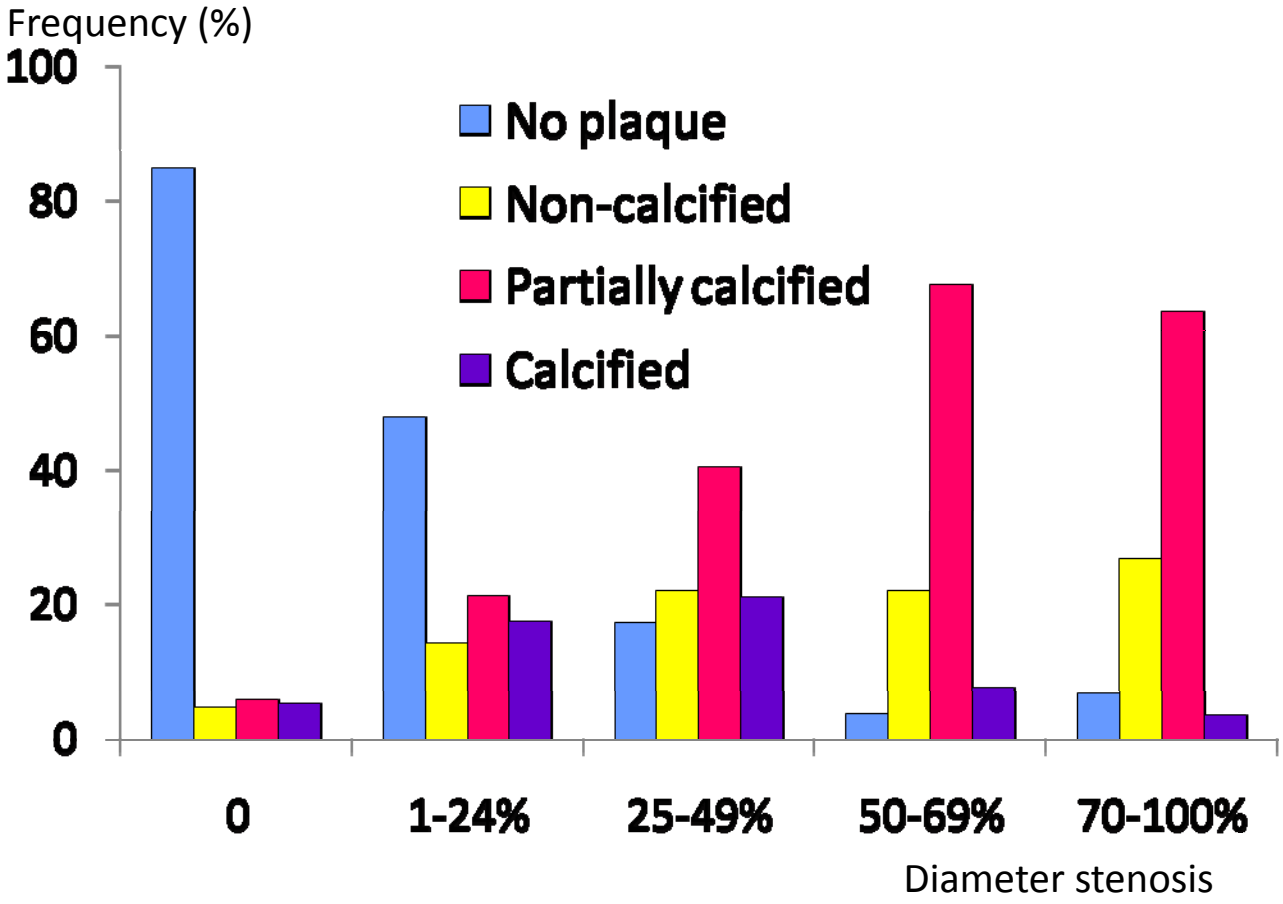


Hulten, JACC 2011

Partially calcified plaque is the most stenotic plaque (even more than calcified plaque)

Prospective mulicenter ACCURACY study. Segment-based analysis of plaque composition to stenosis severity, 2954 segments from 230 subjects



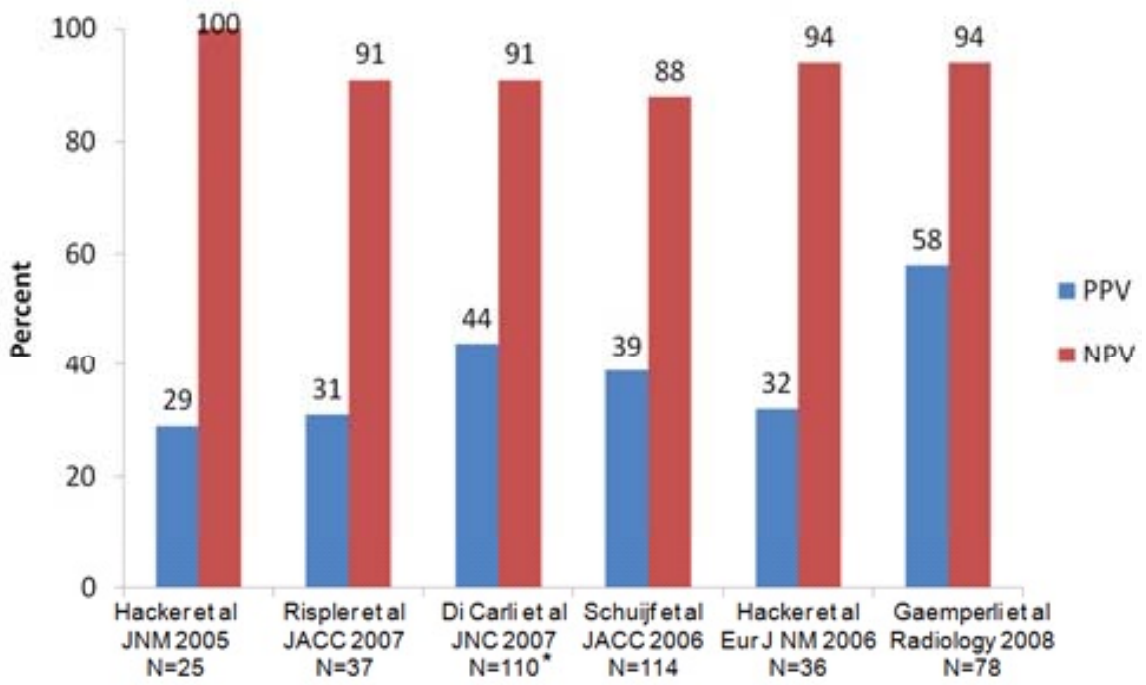


Min, Atherosclerosis 2011

Stenosis is POOR indicator of ischemia

Only 1/3 ~ 1/2 of significant stenosis is hemodynamically significant

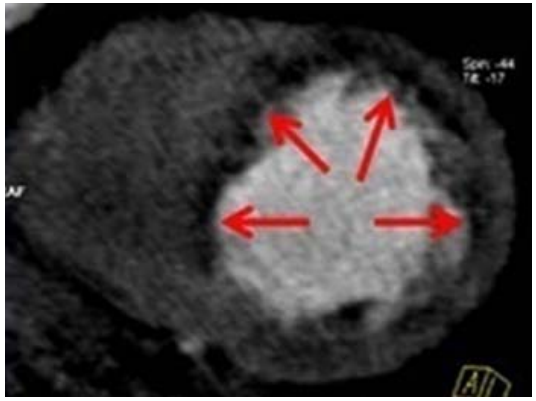
Prevalence of ischemia in vessels with stenosis ≥ 50%



Blankstein, Nature Review Cardiology, 2010

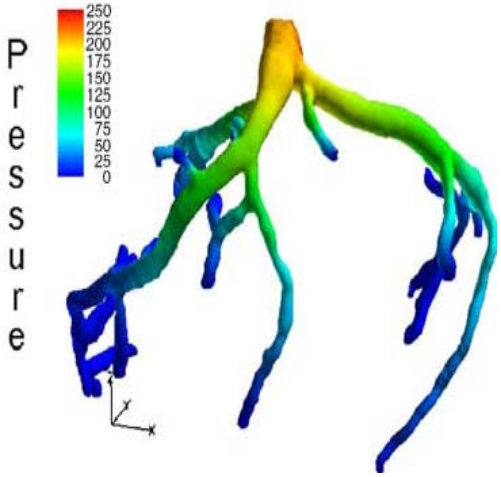
Beyond anatomical stenosis: Evaluation of myocardial ischemia by CT

Myocardial stress perfusion



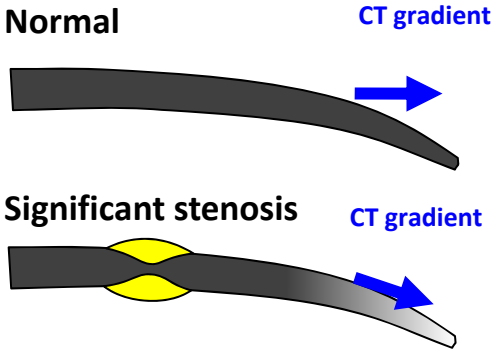
Feuchtner , Circ Img 2011
Ho , JACC Img 2010
Ko , Eur Heart J 2011

Computational fluid dynamics



Koo, JACC 2011

Intraluminal attenuation gradient



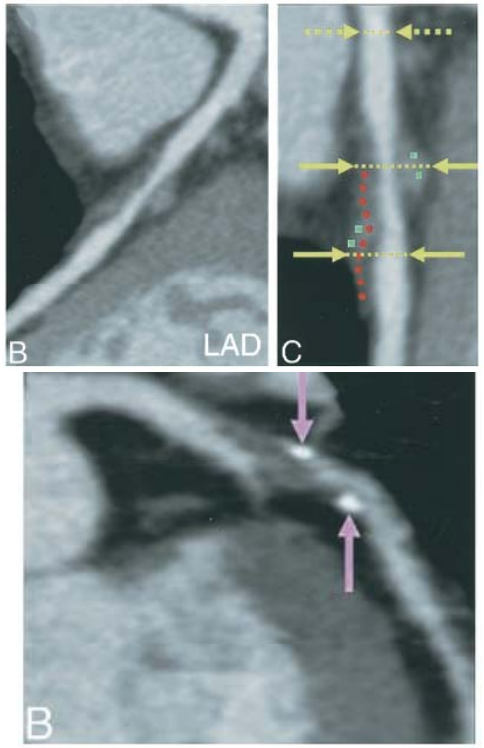
Choi, JACC Img 2011
Chow, JACC 2010
Steigner, Circ Img 2009

CT vs SPECT: VP-CT causes ischemia

Non-calcified plaque of 70-90% stenosis in proximal or mid of major coronary artery, N=49

Comparison of CT analysis and **SPECT**

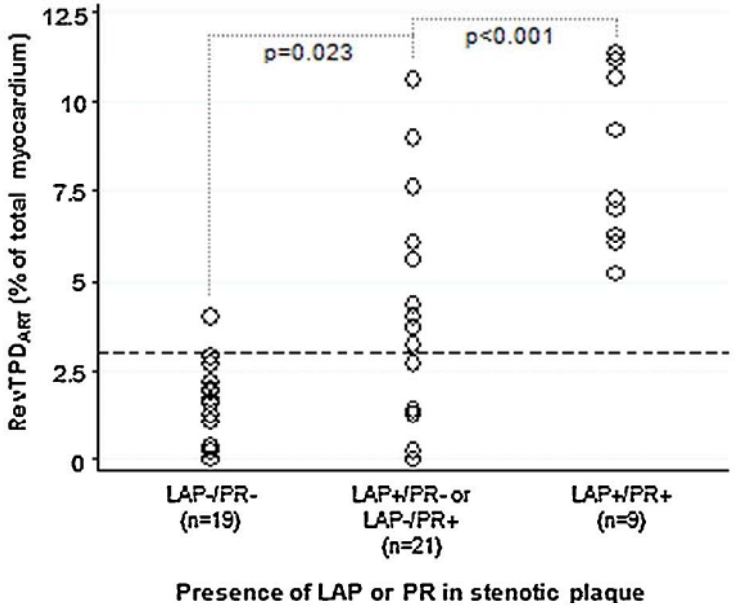
Higher frequency of **low attenuation plaque (LAP), spotted calcification (SC)**, and **positive remodeling (PR)** in plaque with larger perfusion defect



Positive remodeling

Lower attenuation (< 30 HU)

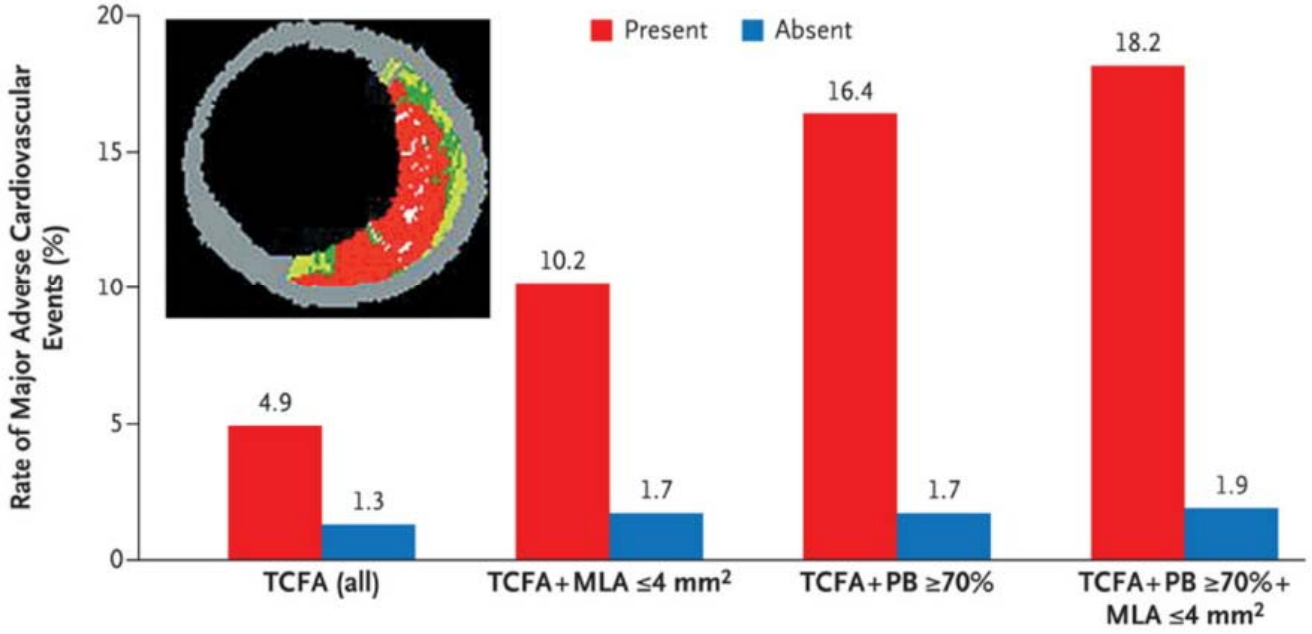
Spotty calcification



Shmilovich, Atherosclerosis 2011

PROSPECT study

Plaques with the **narrower lumen**, the **higher plaque burden**, the higher **'bad' plaque** burden likely to cause an acute vascular event

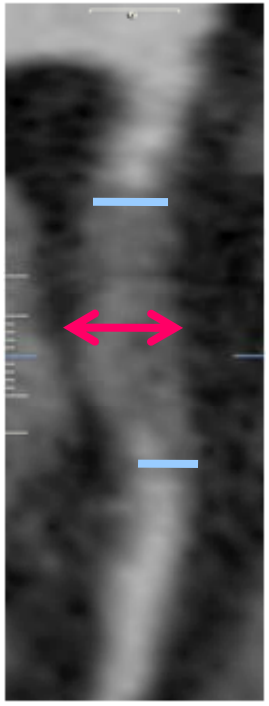


Lesion hazard ratio (95% CI)	3.90 (2.25–6.76)	6.55 (3.43–12.51)	10.83 (5.55–21.10)	11.05 (4.39–27.82)
P value	<0.001	<0.001	<0.001	<0.001
Prevalence (%)	46.7	15.9	10.1	4.2

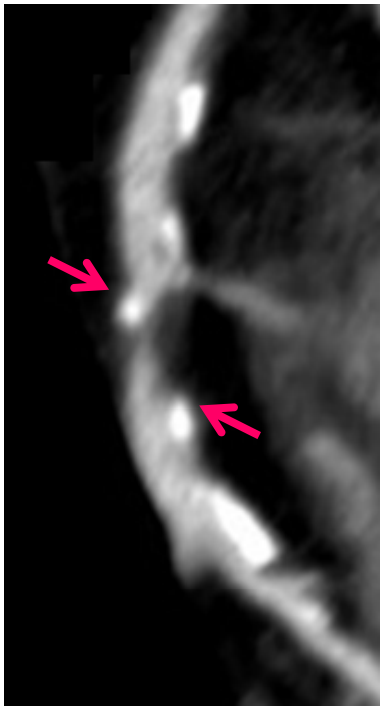
Stone, PROSPECT study, NEJM 2010

Plaque characteristics of coronary CT shown to be related to clinical event, or VP characteristics validated by VH-IVUS or OCT

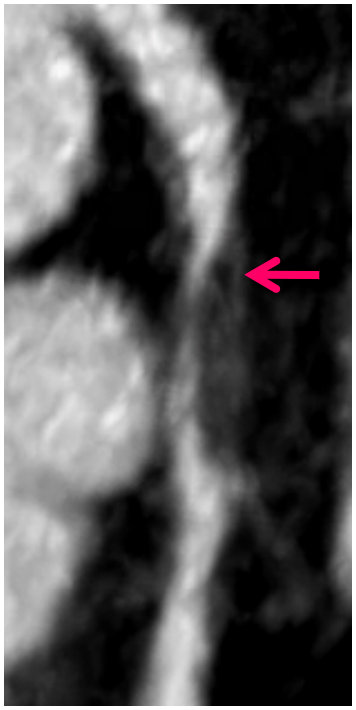
Severe stenosis



Positive remodeling



Partially calcified or “Spotty” calcification



Low attenuation plaque (< 30 HU)

SMC case files

Based on Shmilovich, Berman, Cheng, SNM 2010