Imaging Atheroma
The quest for the Vulnerable Plaque

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Coronary Heart Disease Remains the Leading Cause of Death in the U.S, Causing 1 Death Every Minute

1.2 Million Fatal and Non-fatal Heart Attacks Occur Each Year

500,000 have experienced prior events

~ 100,000 occur following stenting

700,000 are first events.
In >50% of sudden coronary deaths there was no prior sign of coronary disease

Sources:www.americanheart.org
Cutlip et al. *Circulation* 2004; 110: 1226–1230

Enormous failure of current methods to diagnosis CAD prior to initial sudden death or MI.

Evolution of Coronary Atherosclerosis

Normal coronary arteries

↓

Asymptomatic atherosclerosis

↓

High-risk (vulnerable) plaque

↓

Thrombosed plaque

ACS

Progression stenosis

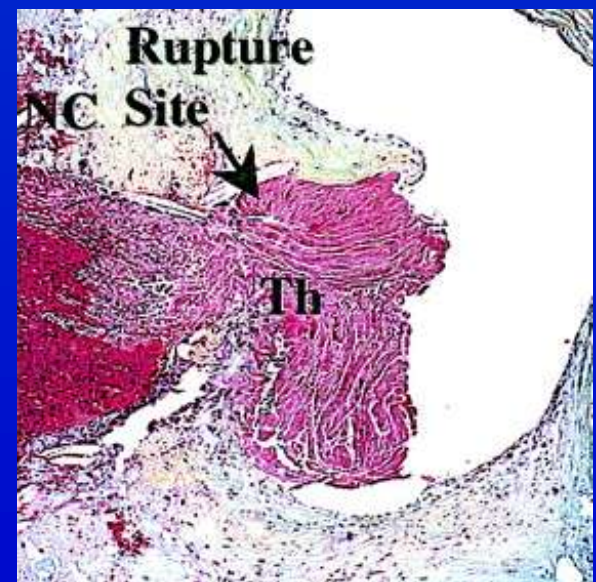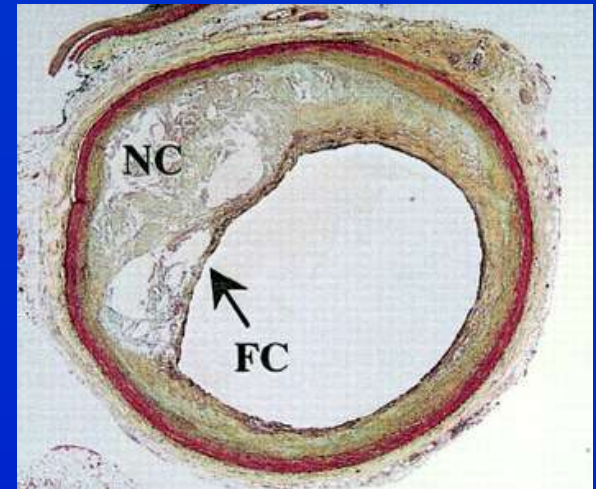↓   ↓

Stable angina   Asymptomatic
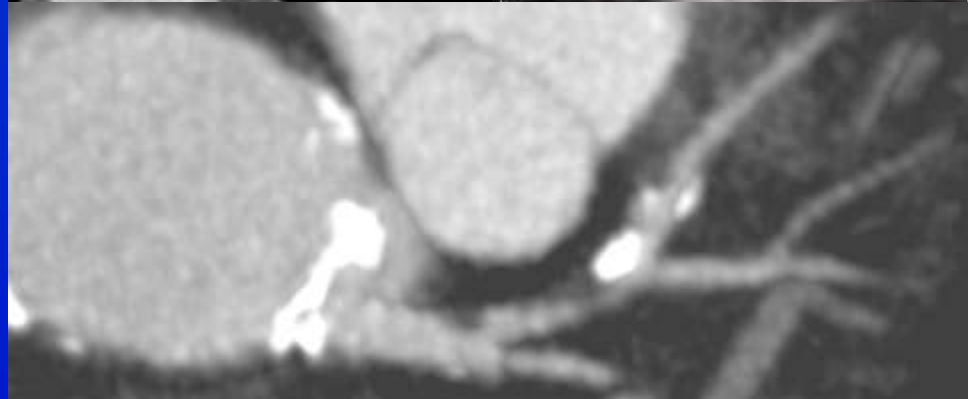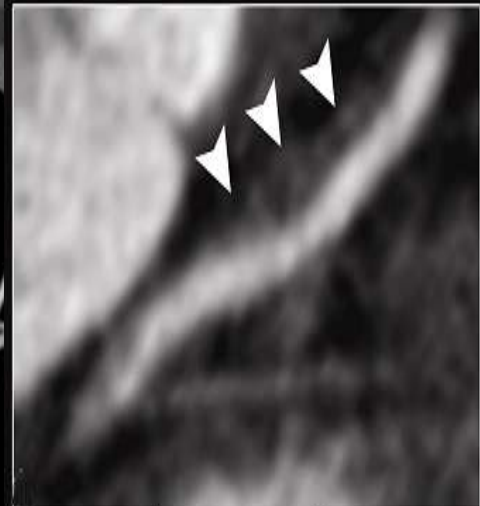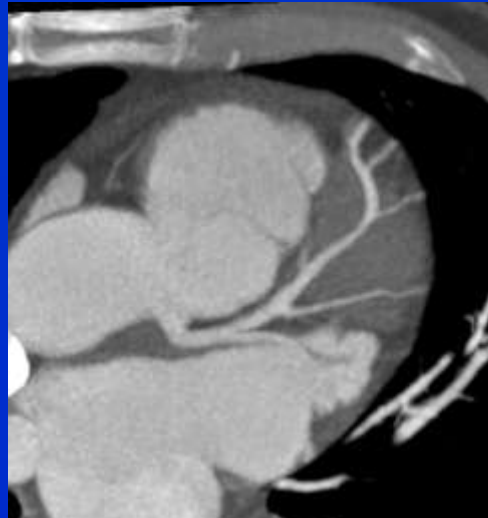
Terminology for high-risk coronary plaques

Vulnerable Plaque

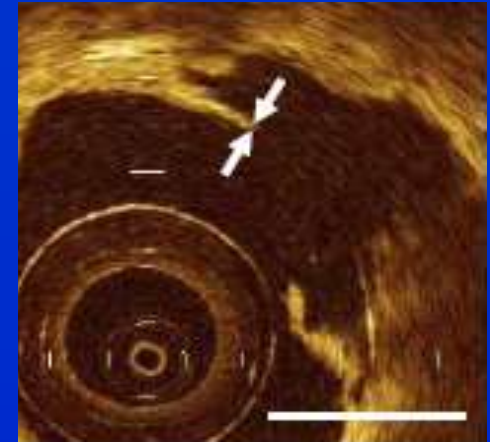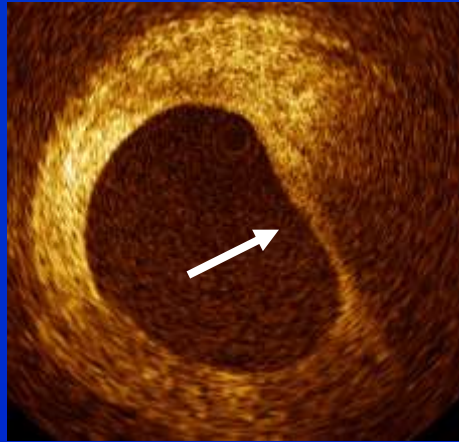## Rupture Prone Plaque

• Large necrotic lipid core

• Thin fibrous cap

• Dense Macrophage infiltration

      (metalloproteinases)

• Progressive matrix degeneration

• Paucity of SMCs

• Angiographically non-significant

• Positive remodelling

• Inflammation

The Elusive Vulnerable Plaque

?

Precursor

Vulnerable Plaque

Ruptured Plaque

?

= ruptured plaque except

No rupture

No erosion

Large lipid core

Thin fibrous cap

inflammation

IVUS : Plaque Composition
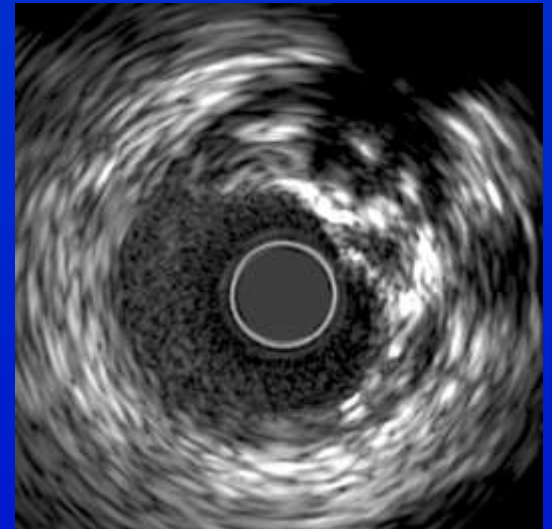
Calcific plaque	Fibrous	Lipid
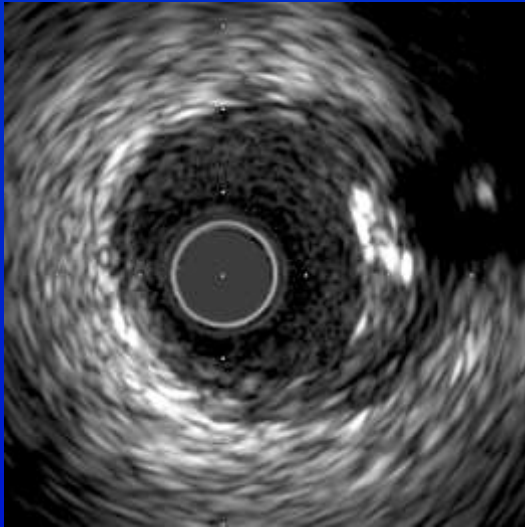
Highly echodense
and shadowing
S 89% / Sp 97%
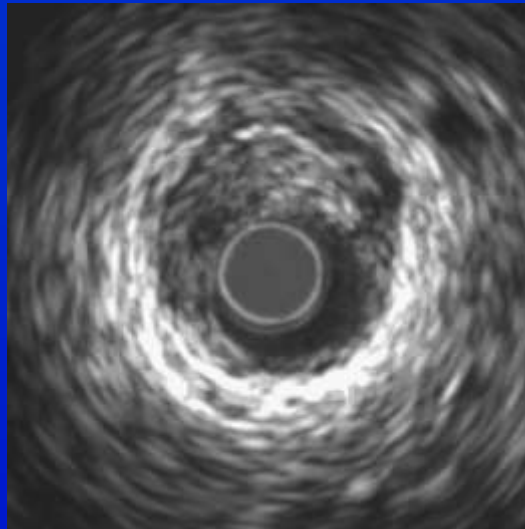
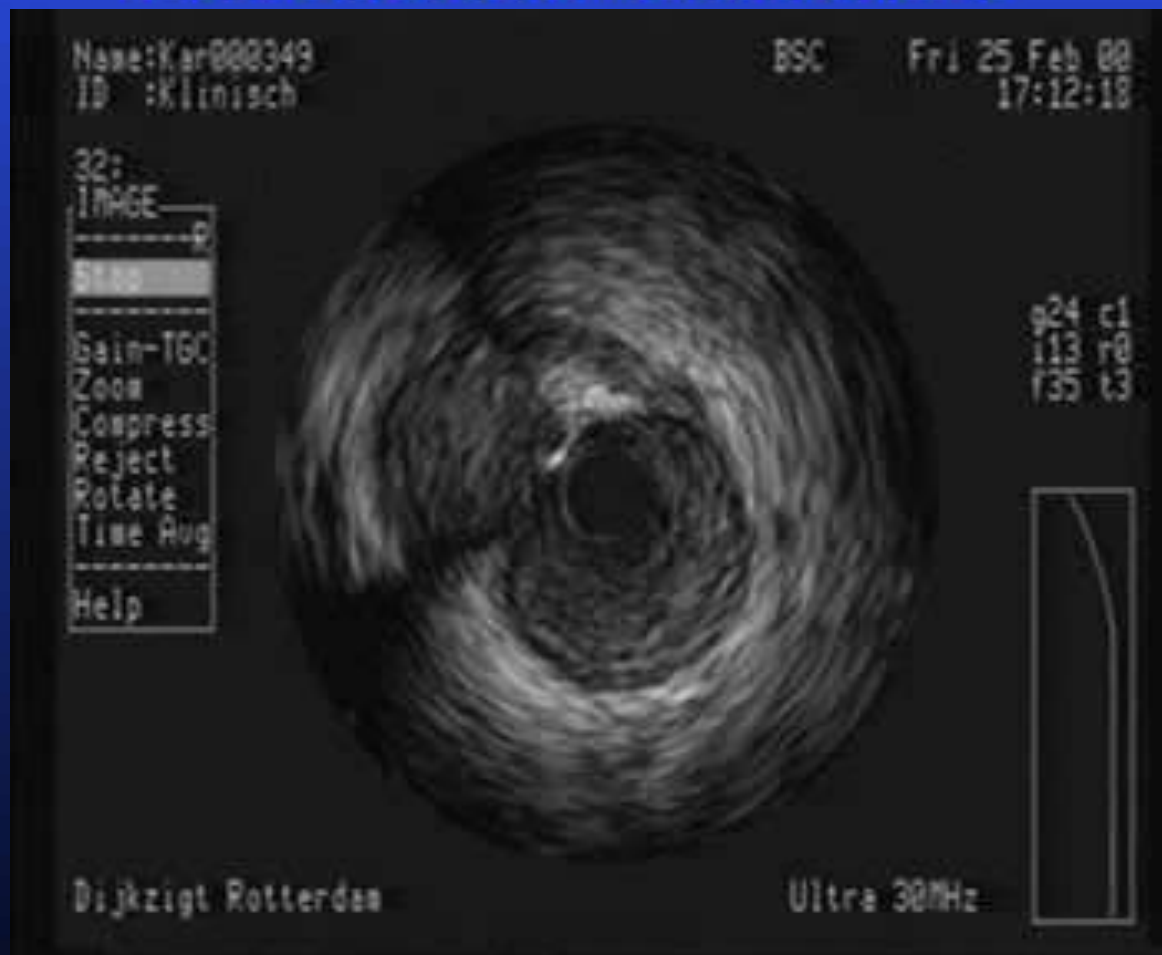Highly echodense
S ? / Sp ?

Echolucent zones
S 78%-95% / Sp 30%

Fibrous vs lipid :S 39 -52%

Limitations of angiography
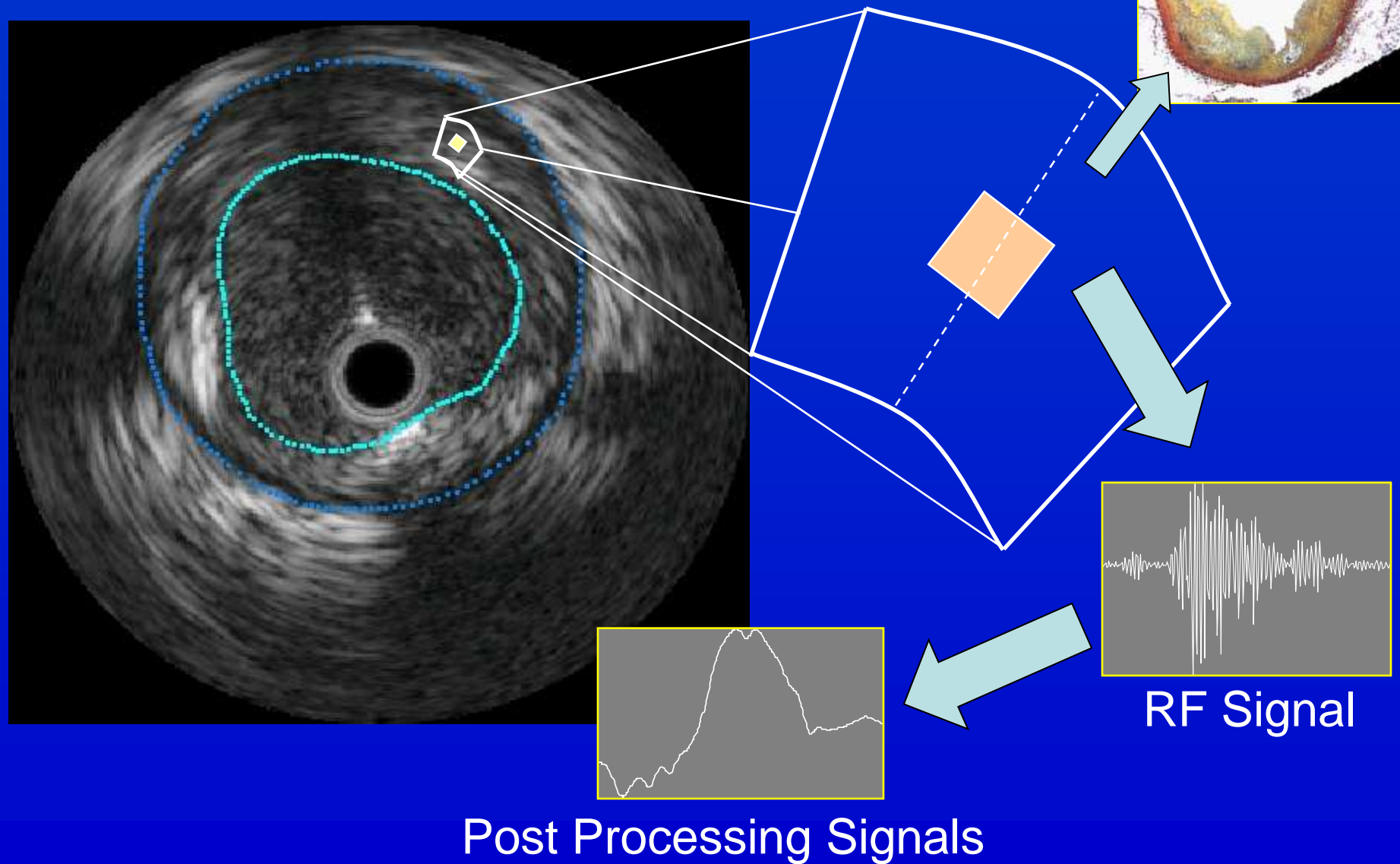## Intravascular Ultrasound

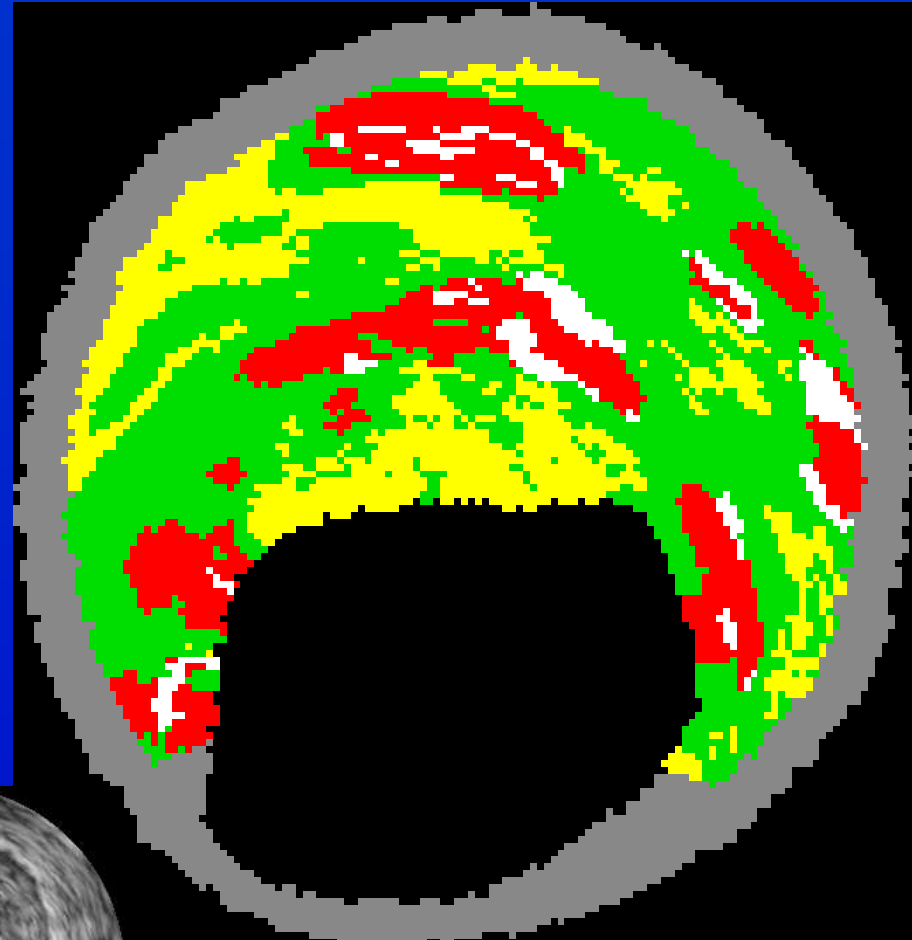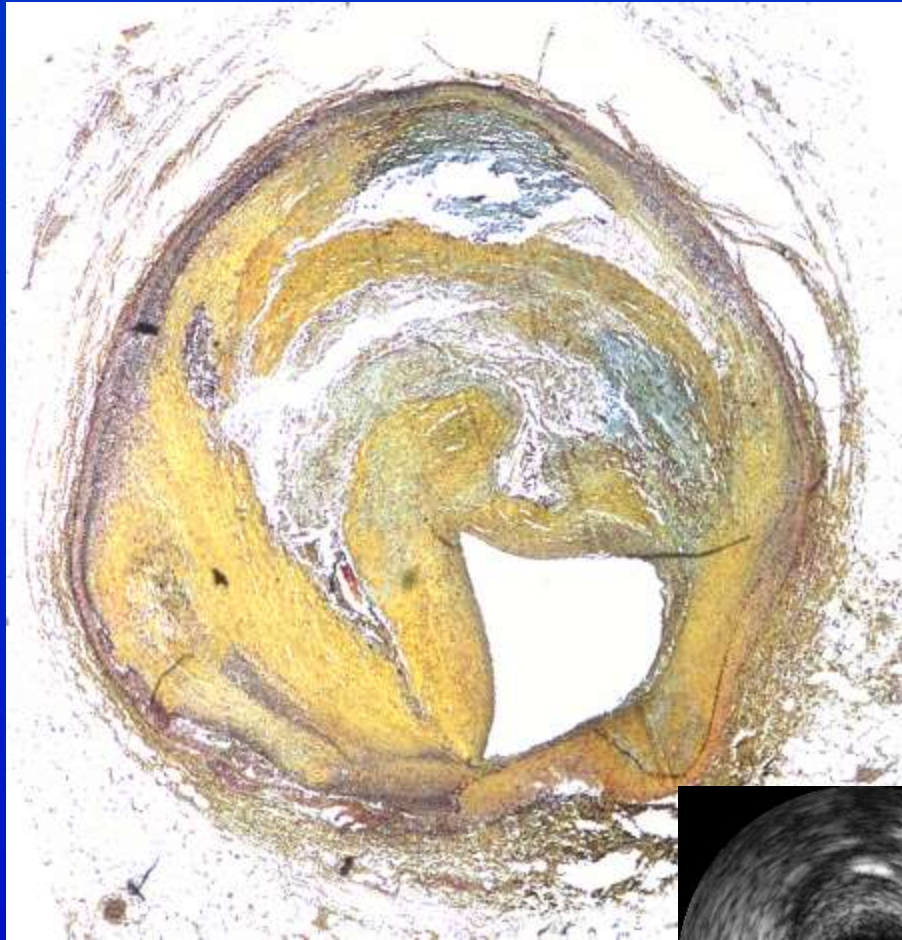**Boston Scientific Ultra 2.9F 30Mhz
pullback speed 0.5mm/sec**

000349

Virtual Histology™ IVUS

RF Signal

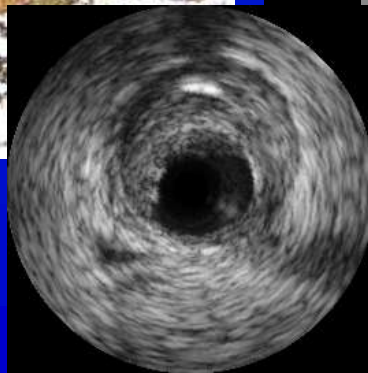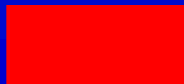Post Processing Signals

Histopathology and VH
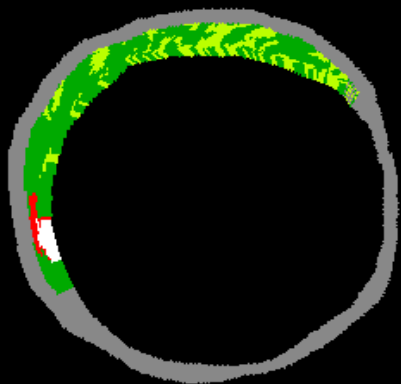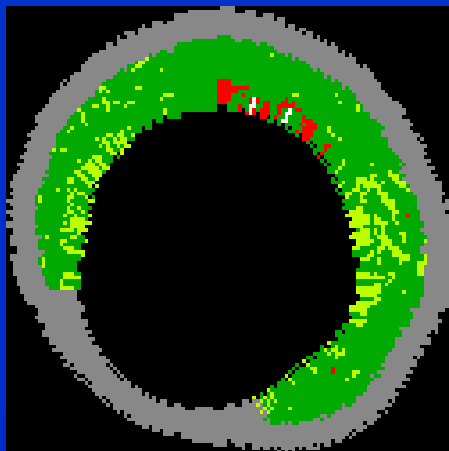
Sens 85%-95%   Spec. 80%-90%
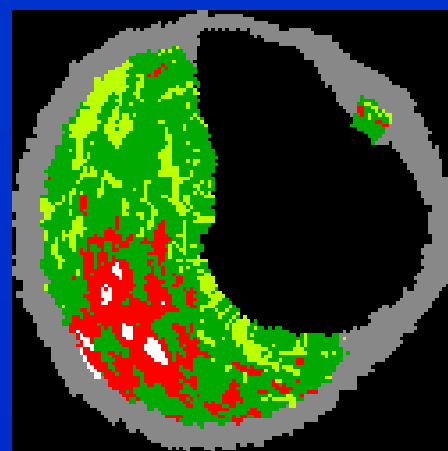
CALCIUM

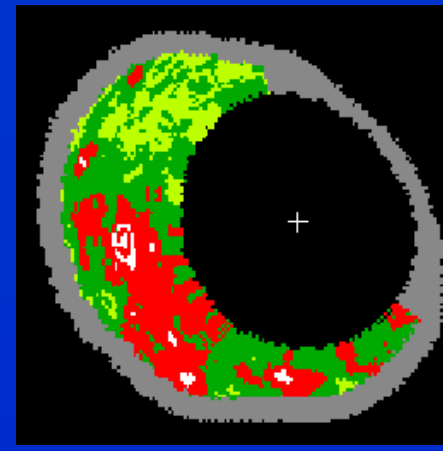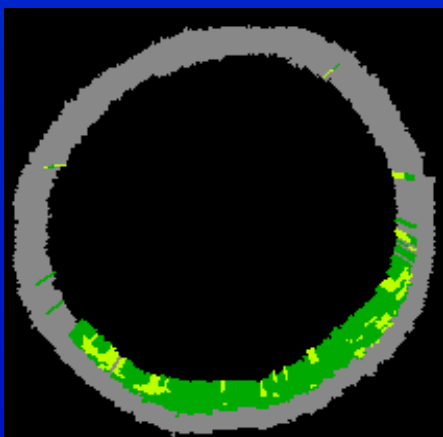NECROTIC CORE

FIBROUS

FIBROFATTY

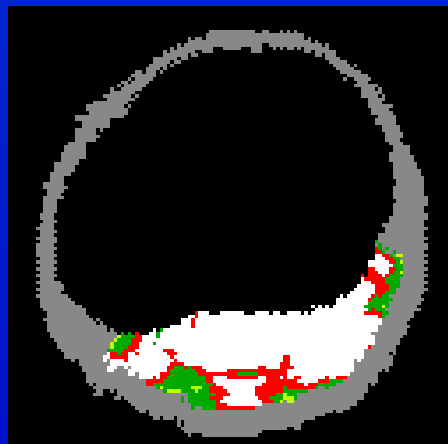Pathological intimal thickening

Fibrotic

Fibroatheroma

Thin cap Fibro atheroma

Adaptative intimal thickening

Fibrocalcific
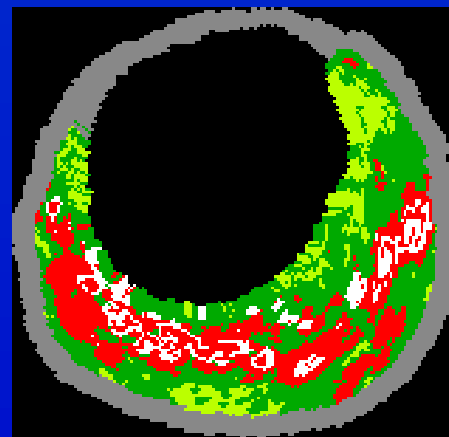
Calcified FA
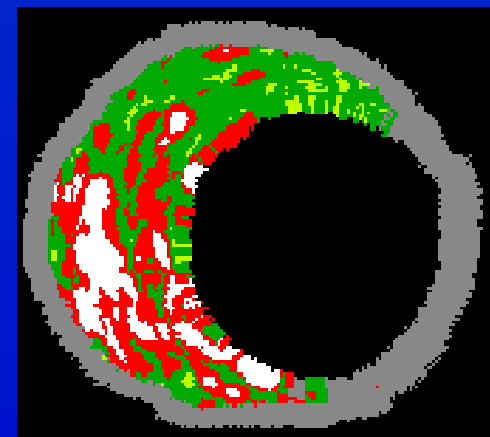
Calcified TCFA

Atheroma heterogeneity

Definition of IVUS-Derived Thin-Cap Fibroatheroma (IDTCFA)

1. **Focal (adjacent to non-TCFA)**
2. **Necrotic core ≥10%**
3. **In direct contact with the lumen**
4. **Percent area obstruction ≥40%**

VH Legend

MEDIA	M
FIBROTIC	FT
FIBROFATTY	FF
DENSE CALCIUM	
NECROTIC CORE	NC

• Per 3 consecutive frames with four characteristics
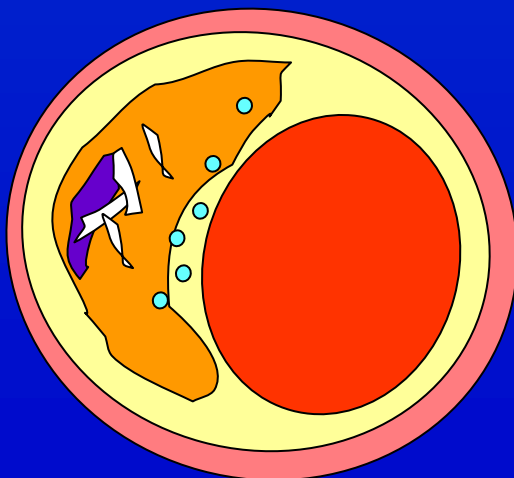
Histology legend

- NECROTIC CORE
- COLLAGEN
- CALCIFIED PLAQUE
- MACROPHAGE FOAM CELLS
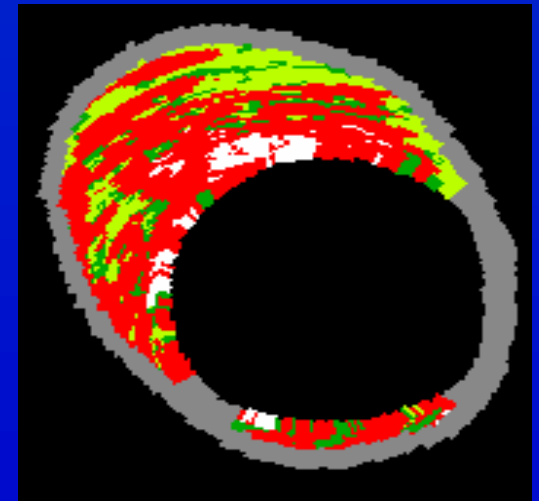
Rodriguez-Granillo GA. In vivo intravascular derided thin-cap fibroatheroma detection using ultrasound radiofrequency data analysis. J Am Coll Cardiol.. 2005;46:2038-42.

Incidence of IDTCFA lesions in non-culprit coronary vessels (n= 55)

	IDTCFA	IDTCFA/cm
Stable (N=32)	1.0 (0.0,2.8)	0.2 (0.0,0.7)
ACS (N=23)	3.0 (0.0, 5.0)	0.7 (0.0,1.3)
p value	0.018	0.031

Continuous variables are presented as medians (25th, 75th percentile) or means ± SD when indicated.

Rodriguez JACC 2005;46:2038.

Clustering of IDTCFA along the coronaries

Total lesions = 99

p=0.008

35.4 %
31.3 %
19.2 %
14.1 %

IDTCFA

Percent

40
35
30
25
20
15
10
5
0

0-10   11-20   21-30   ≥31

Distance from the ostium (mm)

Rodriguez-Granillo J Am Coll Cardiol.
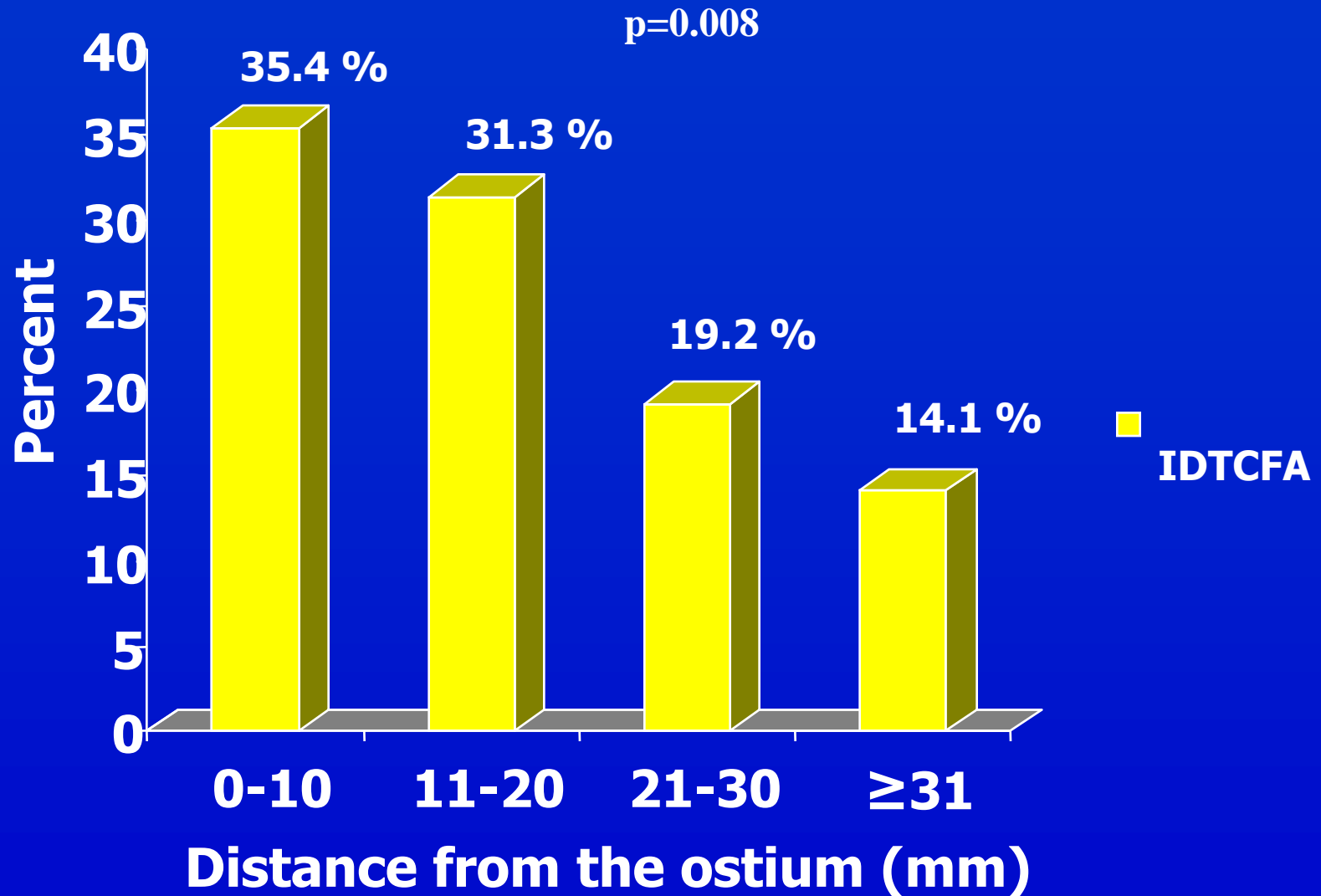
Optical Coherence Tomography OCT

OCT relies on light echo's.

Every tissue has it own specific backscatter of light echo

SLED*

Broadband source

Fiber-optic beamsplitter

Detector

Scanning reference mirror

Amplifier → Bandpass filter → Computer
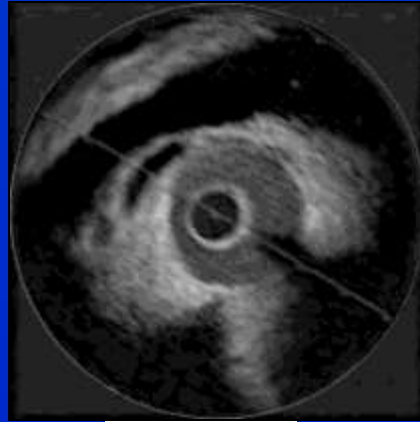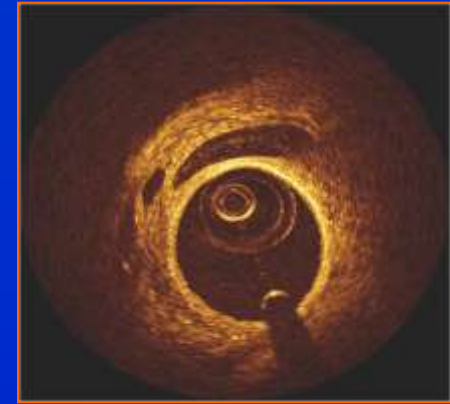
Penetration depth ~ 2mm
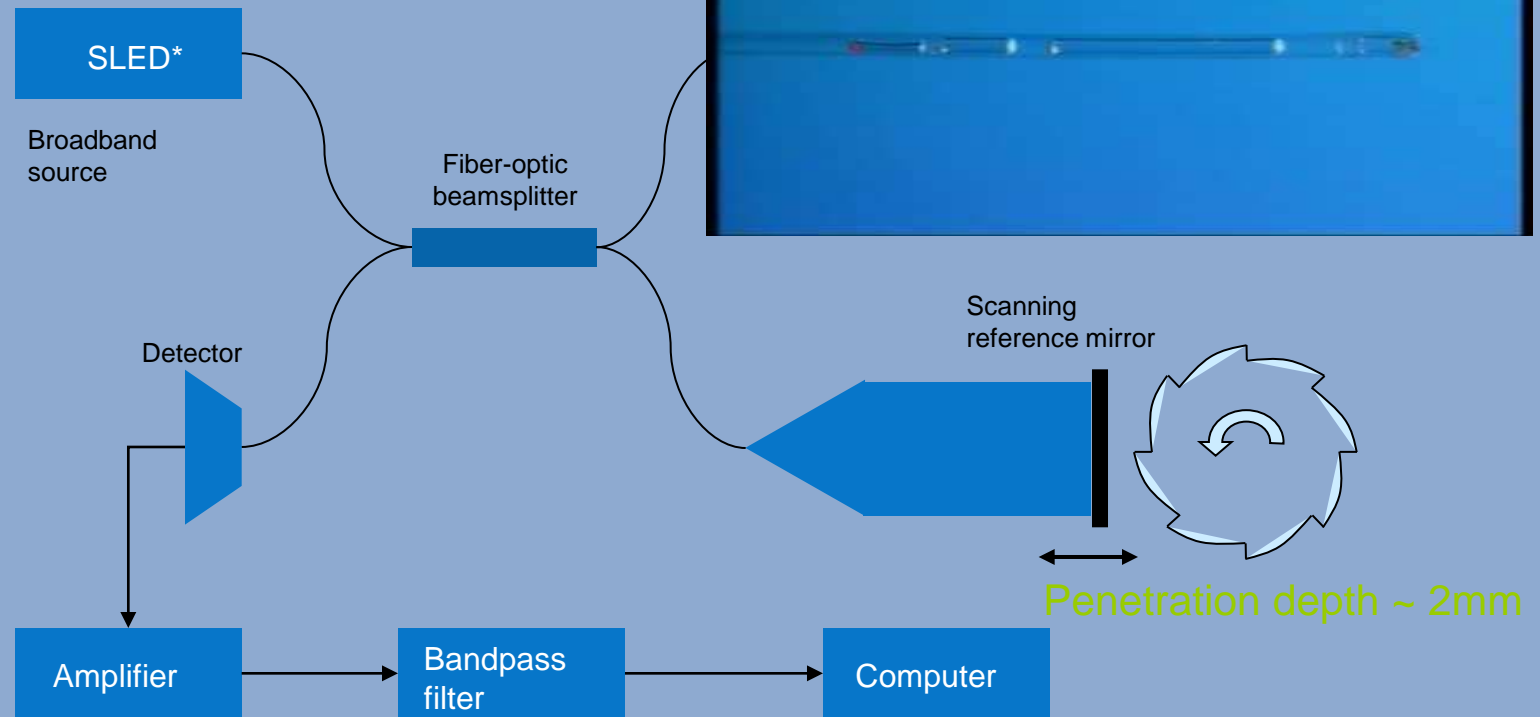
OCT Imaging

Pullback from distal to proximal in the coronary vessel, with contrast injection to induce a blood free field of view during 4 sec. pullback

IVUS and Optical Coherence Tomography

IVUS

OCT

		IVUS	OCT
Resolution	*(axial)*	100 - 150 μm	10 - 15 μm
	(lateral)	150 - 300 μm	25 - 40 μm
Max. depth of penetration		4 - 8 mm	1 – 1.5 mm

OCT normal coronary vessel three layered appearance

Three-Layer Appearence

"intima" 0.07mm
"media" 0.13mm
"adventitia"

Prati EHJ 2010;31:401
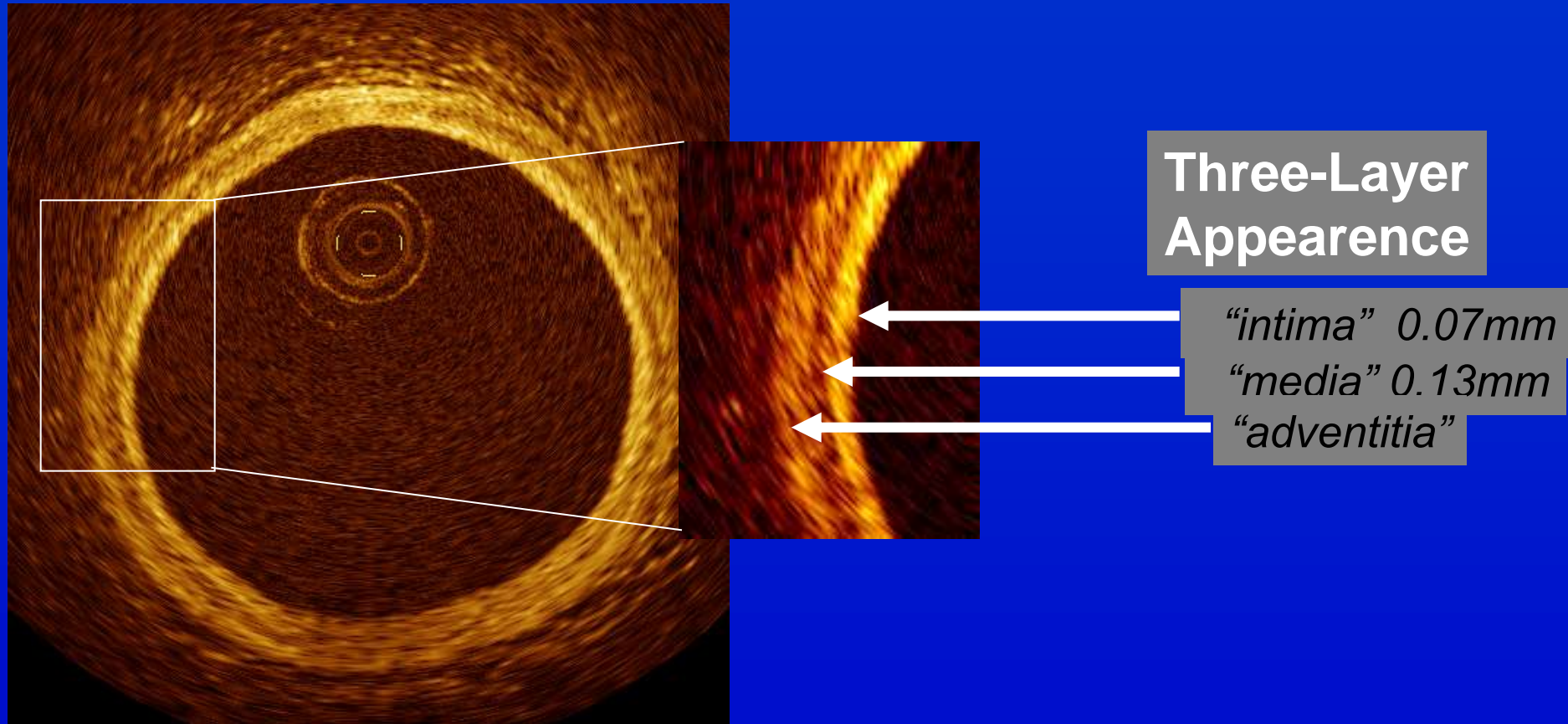
OCT intimal thickening as bright homogeneous layer
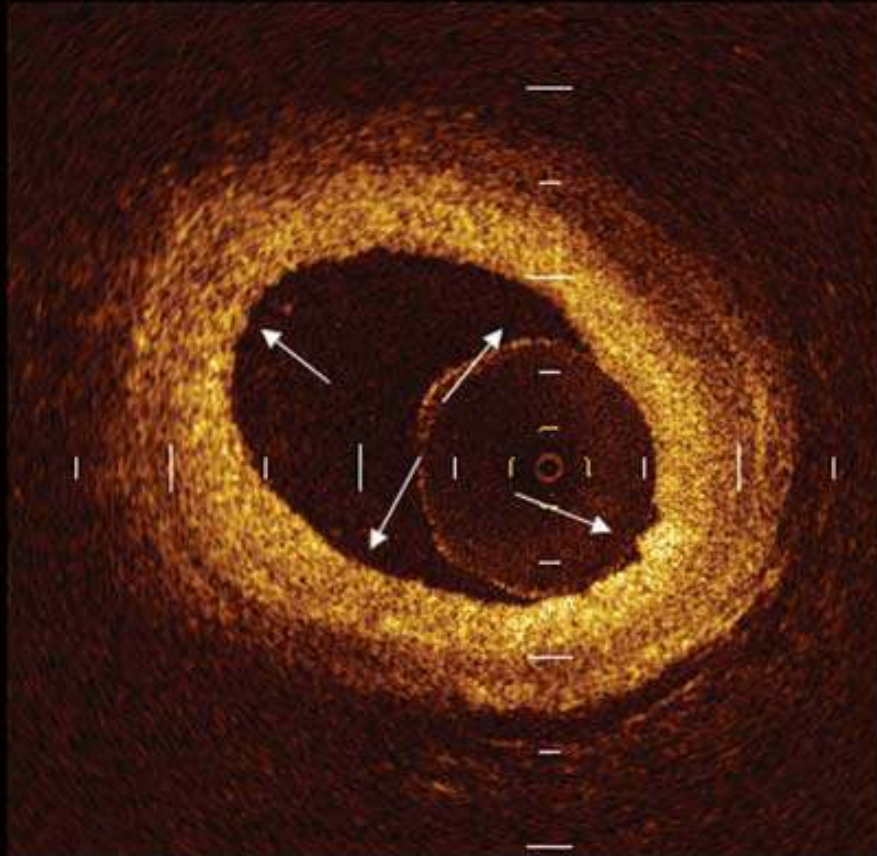
diffuse
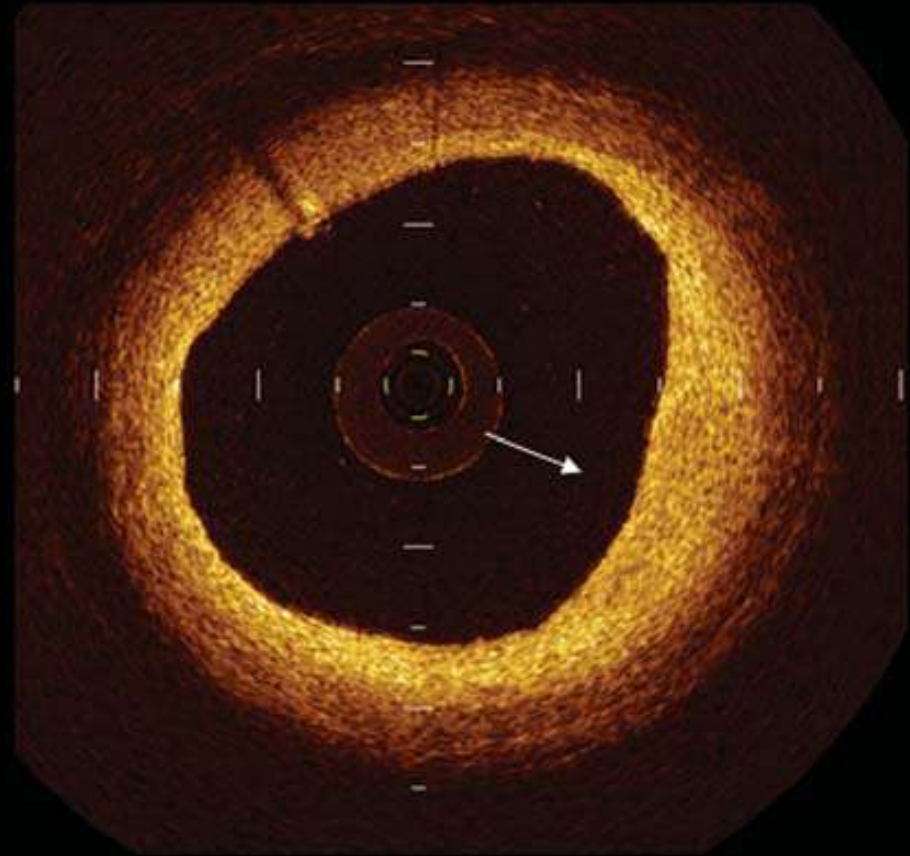
localized

OCT Ca ++ and dissection

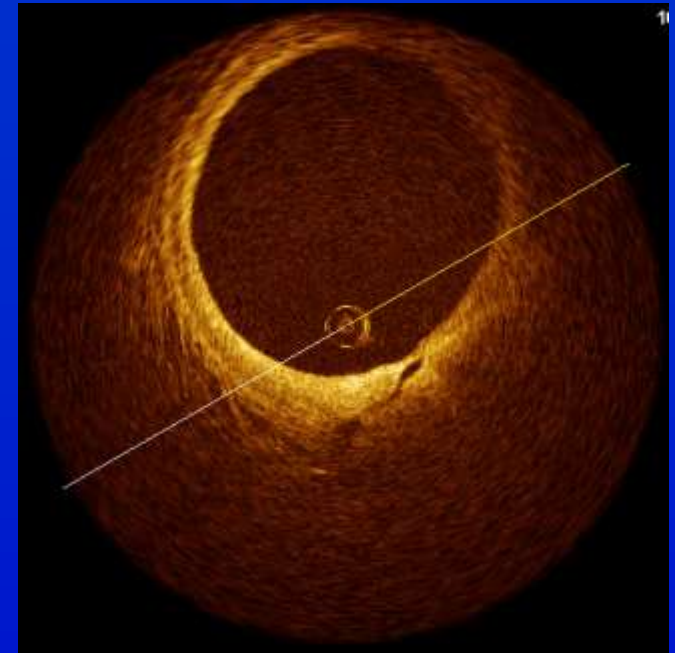Calcium
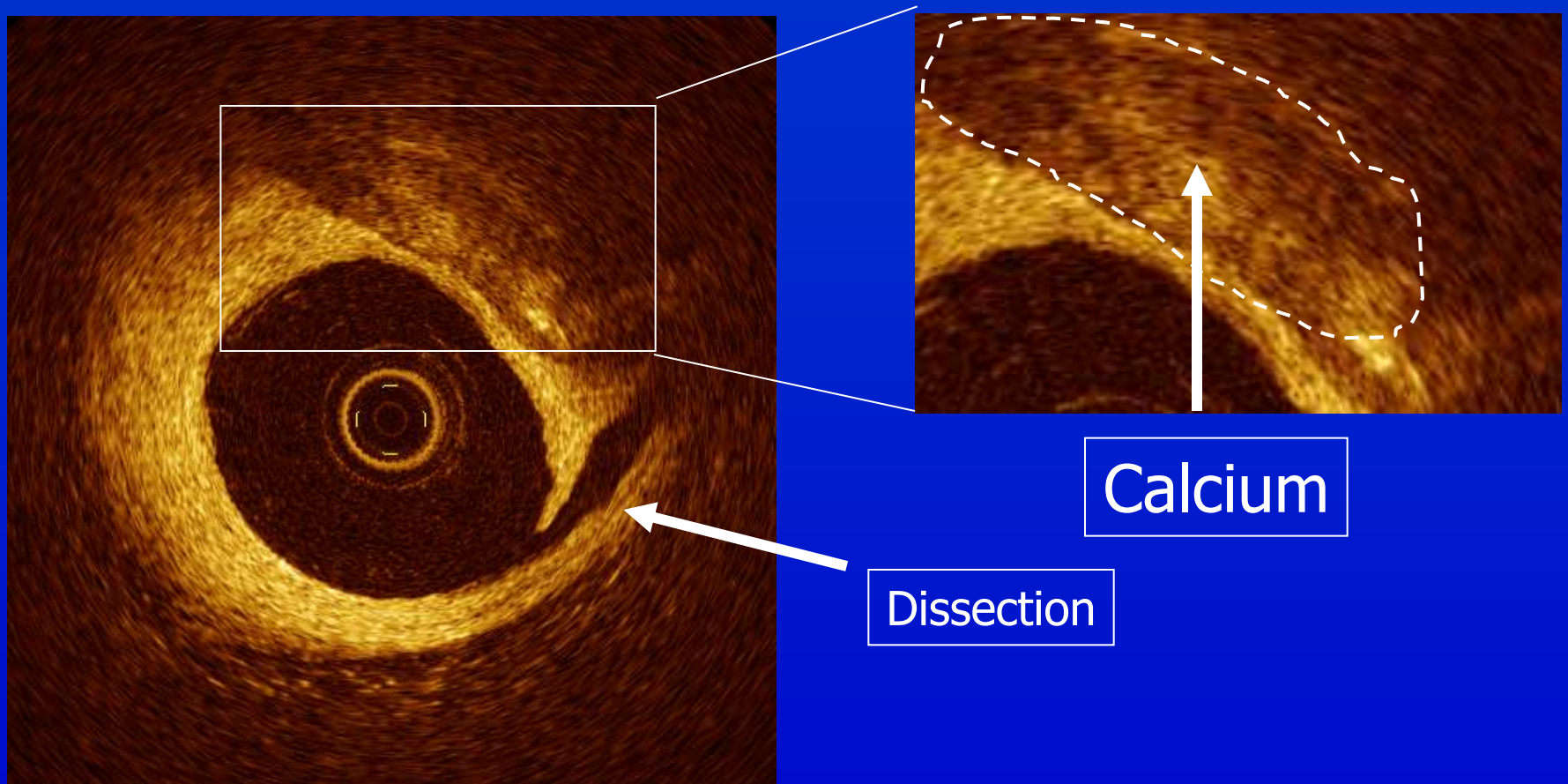
Dissection

Optical Coherence Tomography
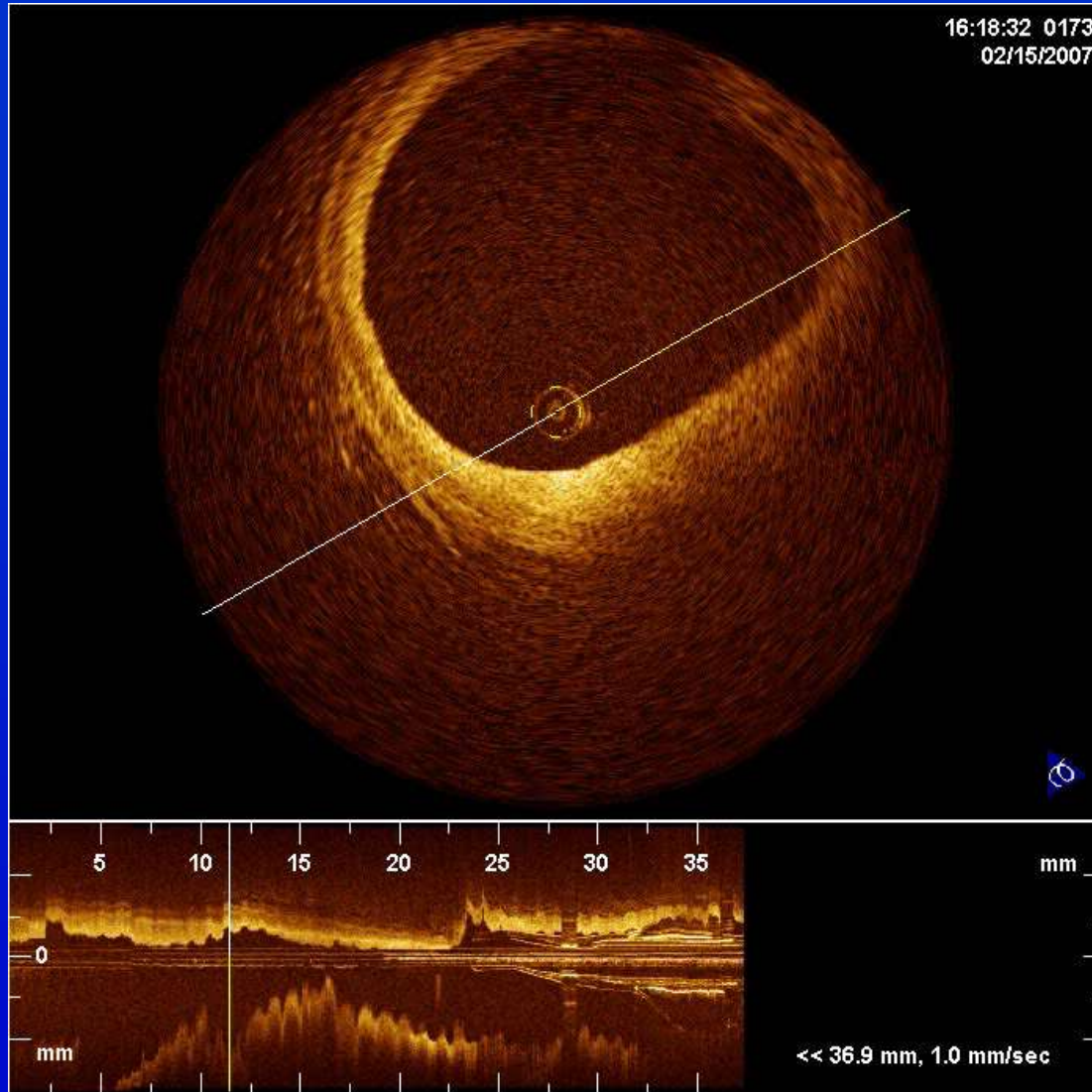
Vasovasorum

OCT culprit lesion ACS
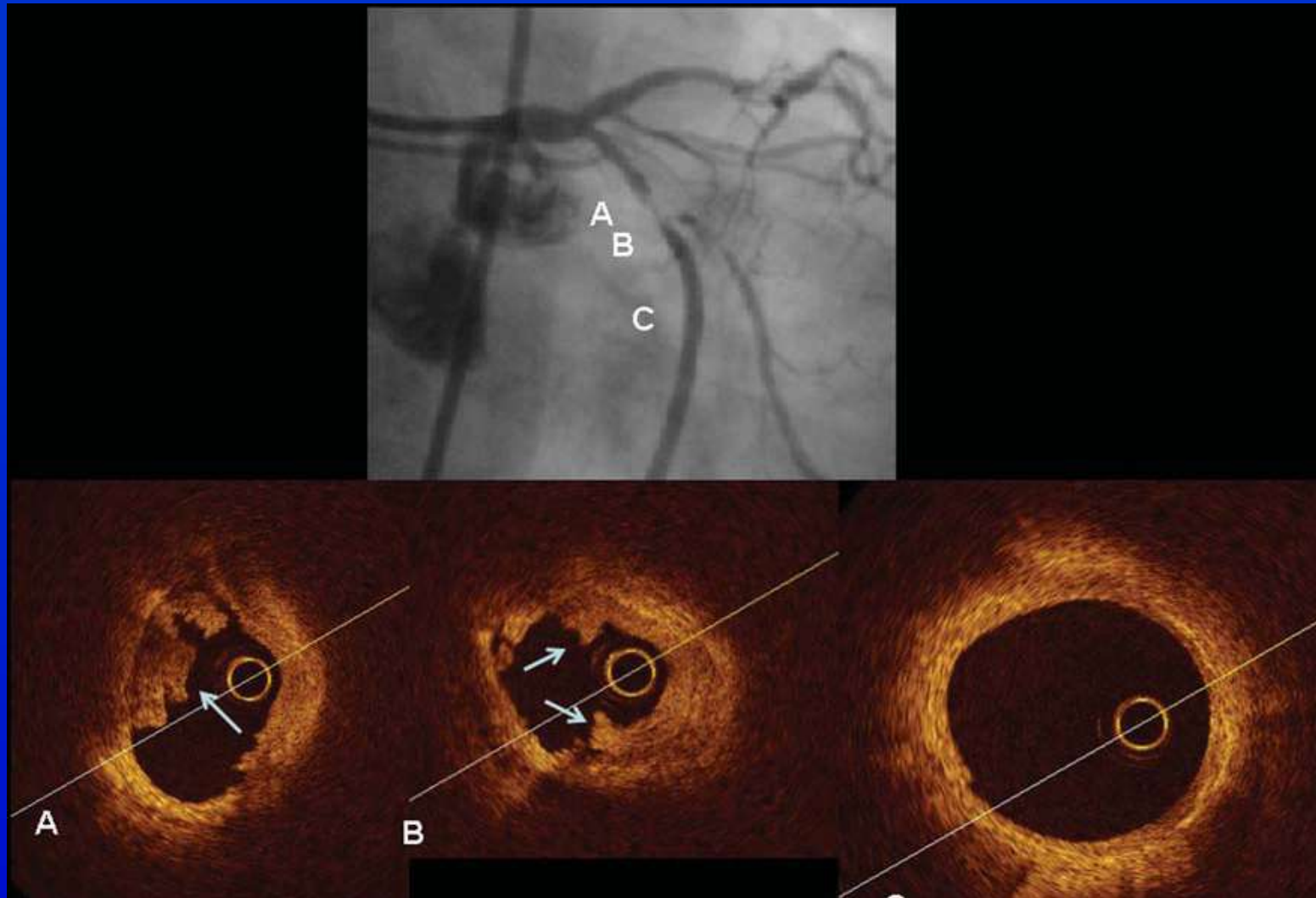
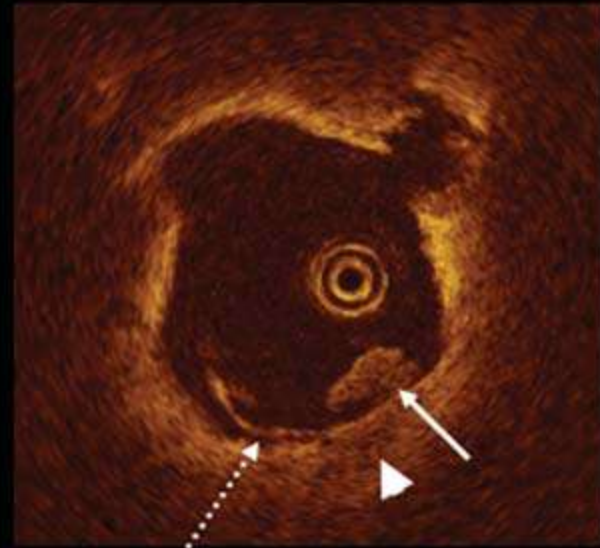**Intracoronary thrombus**   **Normal reference**

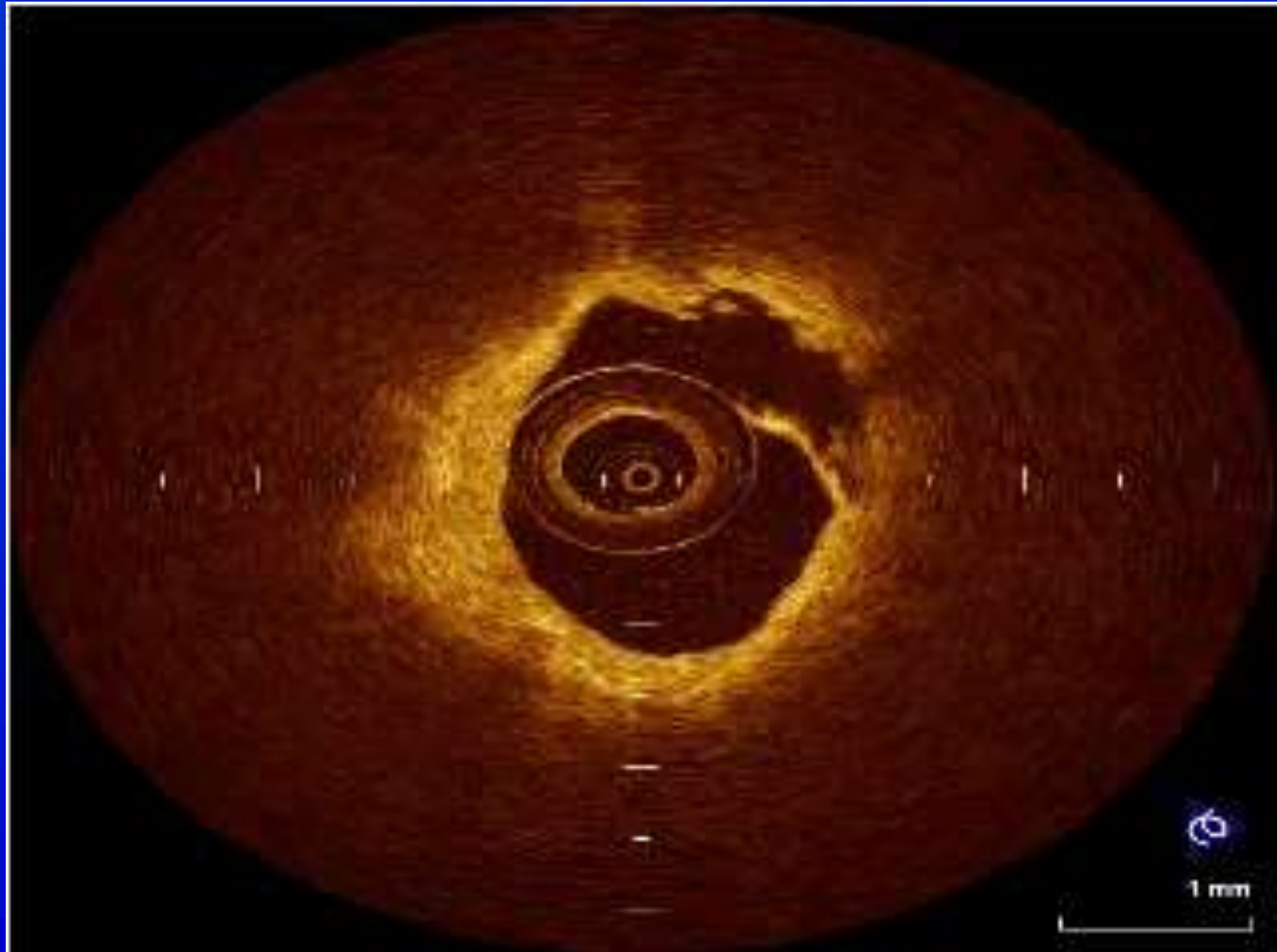# OCT culprit lesion Stable Angina

Non-significant lesion

Mild dissection
Thrombus
Lipid pool

ODFI Plaque Rupture
optical domain frequency imaging

Incidental findings, 73 yo man, 9 month post stenting, with 2 weeks crescendo angina

P. Barlis et al: Eur Heart J 2008
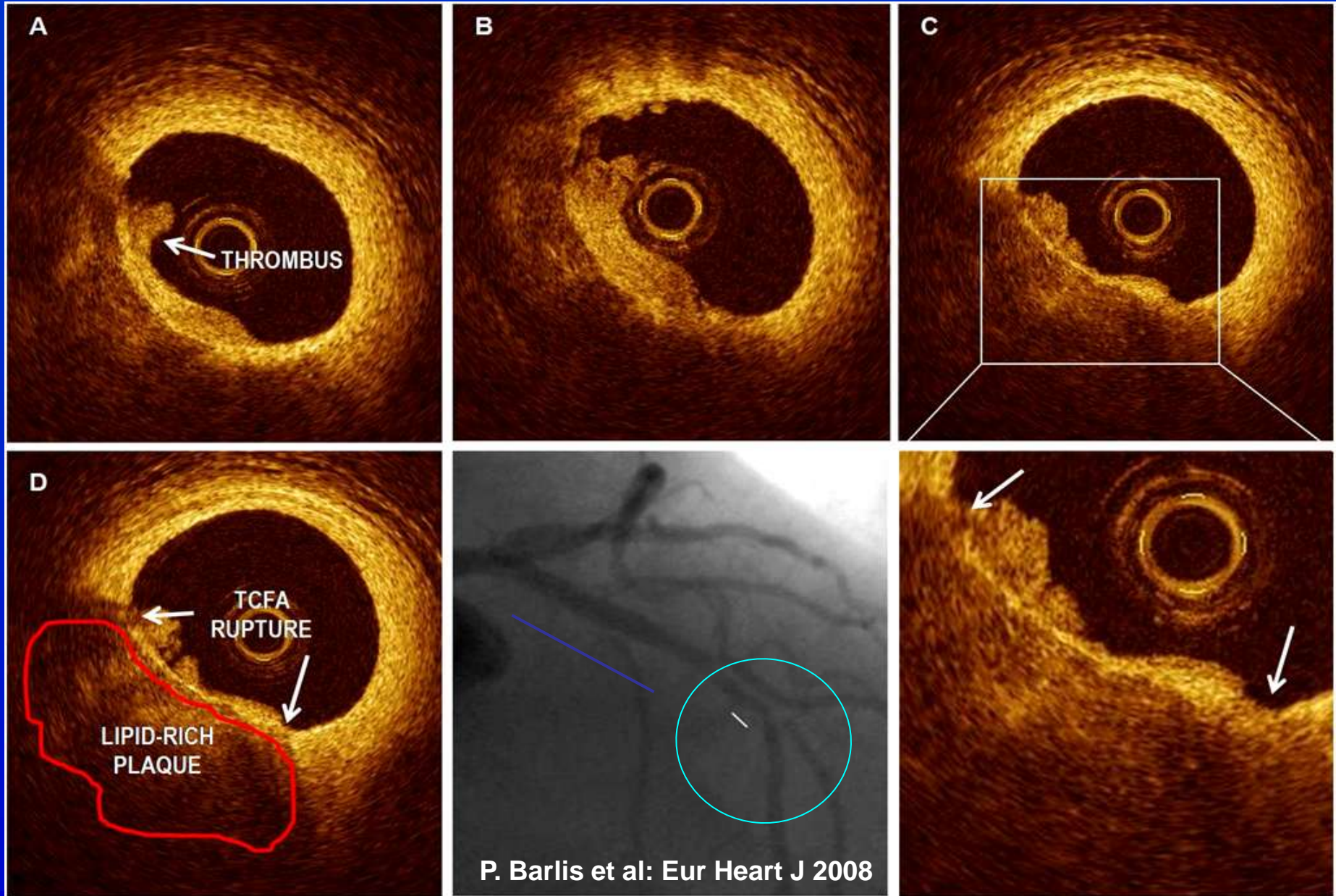
OCT lipid pool with thin fibrous cap

Vulnerable Plaque ?
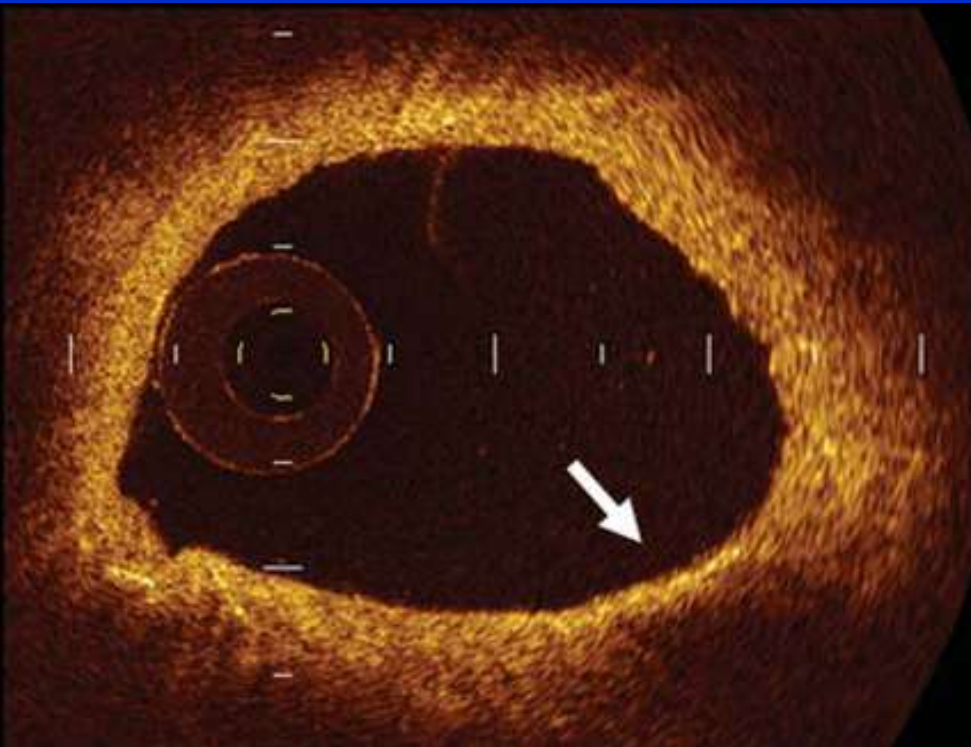
OCT   TCFA (vulnerable plaque)
Thin Cap Fibro-Atheroma

OCT definition of TCFA

- Signal-rich fibrous cap
- Covering signal-poor lipid/nectrotic core
- Cap thickness < 0.2mm
- Extent: > 45° vessel circumference
- At least 5 consecutive frames

Cap thickness: 0.19±0.05mm

Atherosclerotic Intima 5 years after BMS

Normal intima

Calcified nodule

Cholesterol crystals

Intima with lipid pool

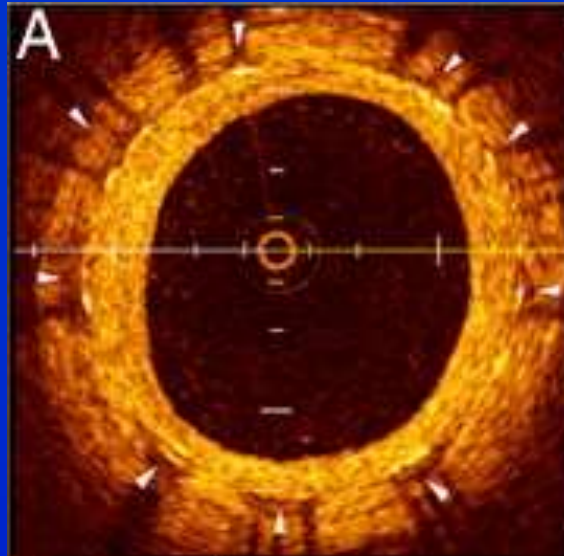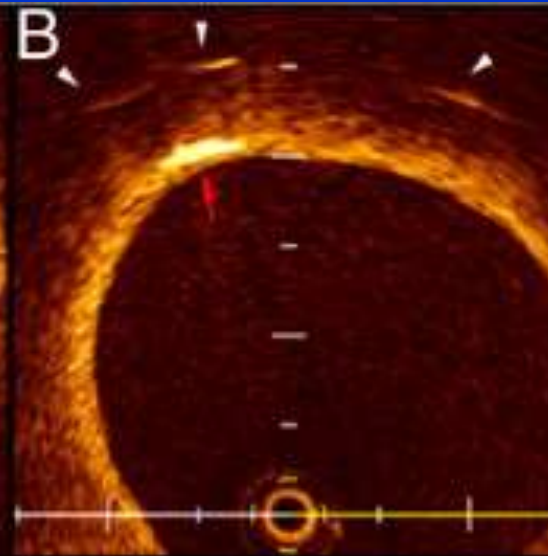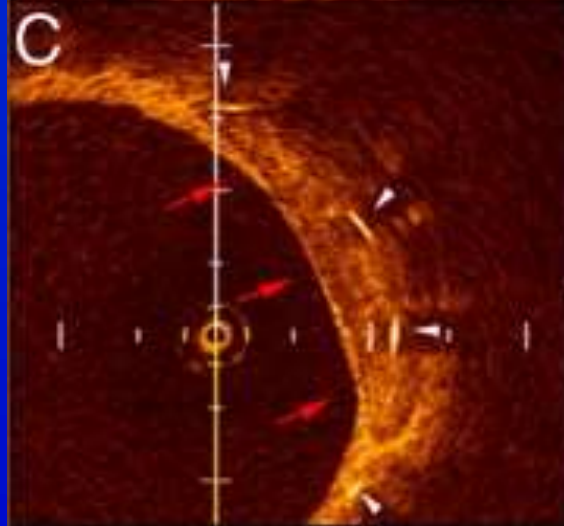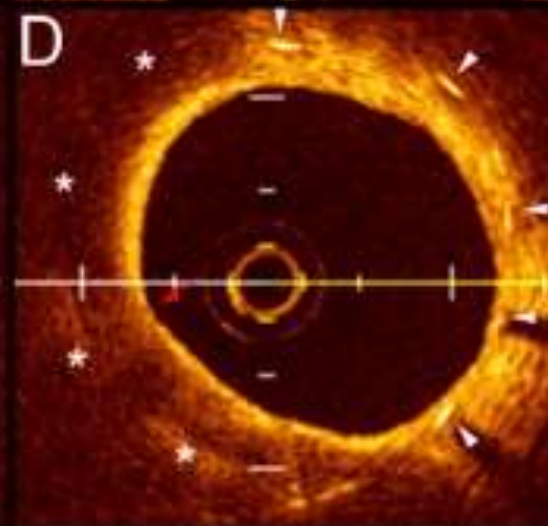# Feasibility of combined use of intravascular ultrasound radiofrequency data analysis and optical coherence tomography for detecting thin-cap fibroatheroma

Takahiro Sawada[1], Junya Shite[1]*, Hector M. Garcia-Garcia[2], Toshiro Shinke[1], Satoshi Watanabe[1], Hiromasa Otake[1], Daisuke Matsumoto[1], Yusuke Tanino[1], Daisuke Ogasawara[1], Hiroyuki Kawamori[1], Hiroki Kato[1], Naoki Miyoshi[1], Mitsuhiro Yokoyama[1], Patrick W. Serruys[2], and Ken-ichi Hirata[1]

[1]Division of Cardiovascular Medicine, Department of Internal Medicine, Kobe University Graduate School of Medicine, 7-5-1 Kusunoki-cho, Chuo-ku, Kobe, Hyogo, 650-0017, Japan; and [2]Thoraxcenter, Erasmus MC, Rotterdam, The Netherlands

Aims   To evaluate the feasibility of the combined use of virtual histology (VH)-intravascular ultrasound (IVUS) and optical coherence tomography (OCT) for detecting *in vivo* thin-cap fibroatheroma (TCFA).

Feasibility of combined use of IVUS-VH and OCT for detecting thin-cap fibroatheroma.
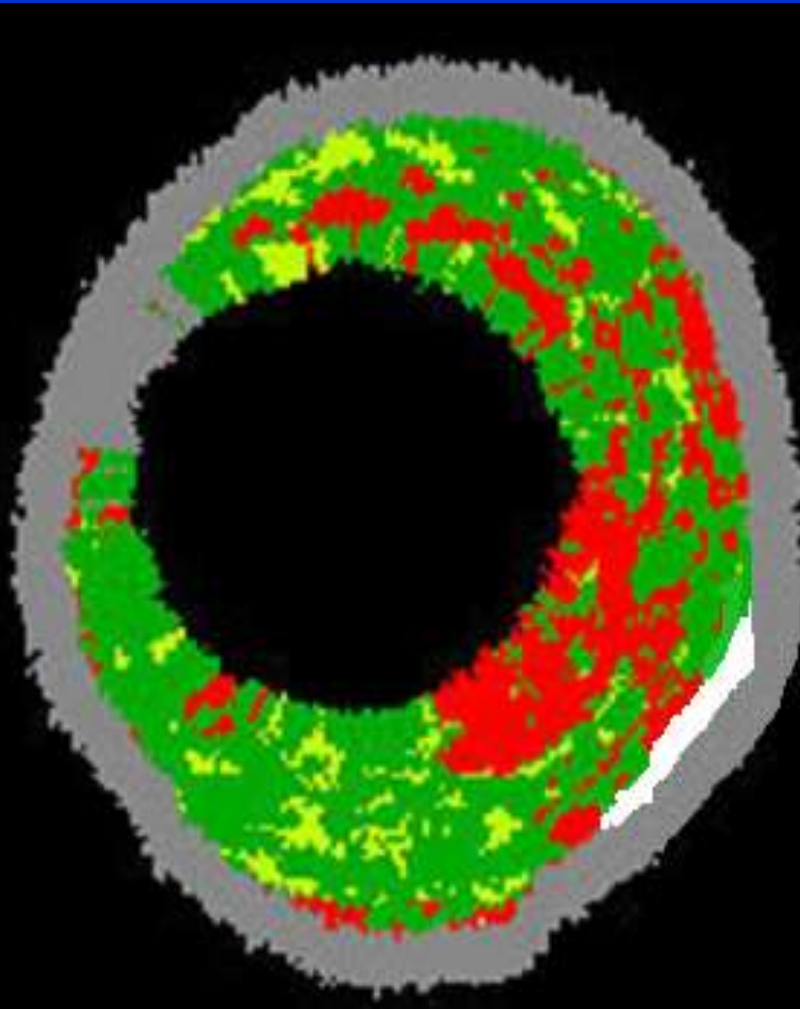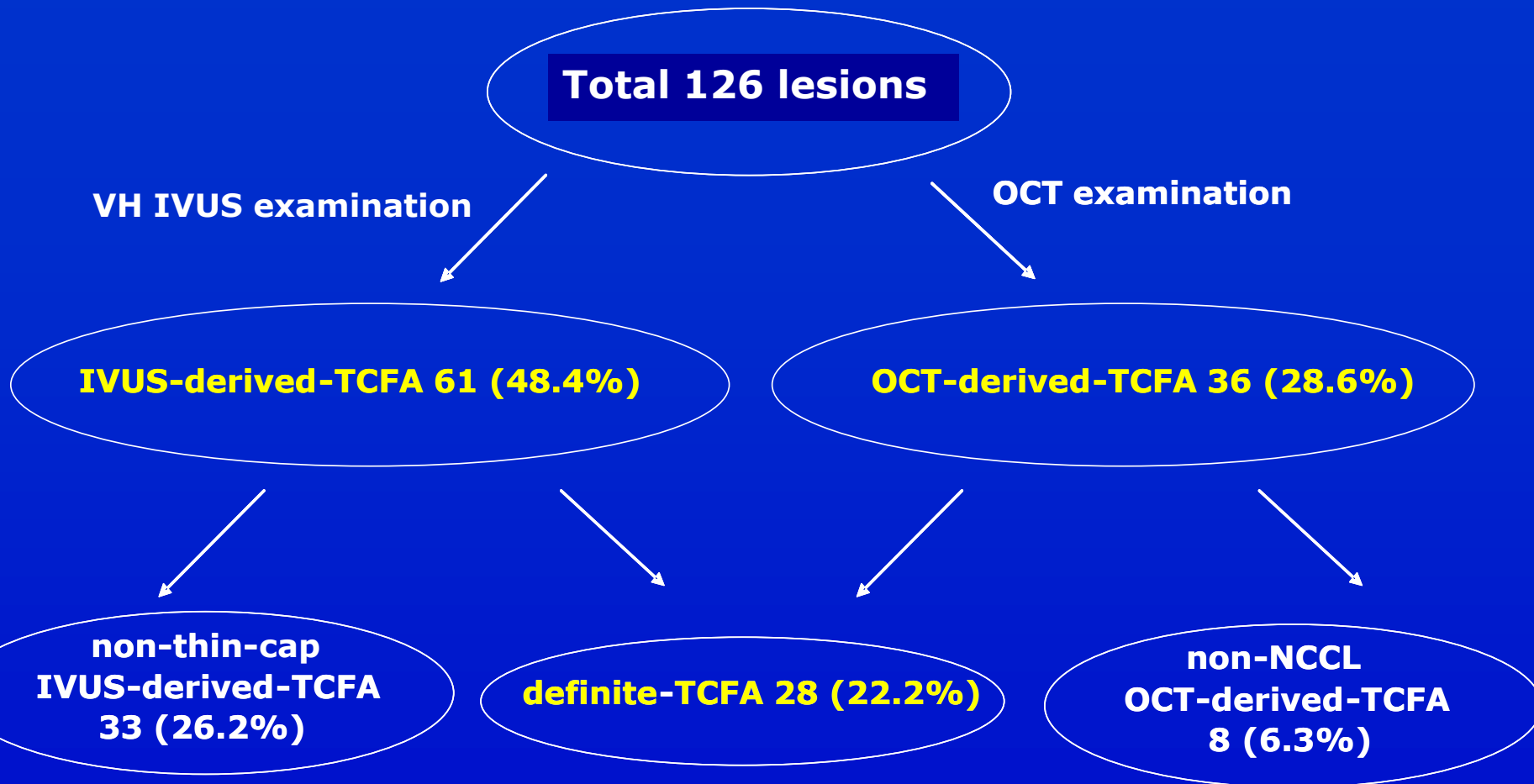

fib.fatty 55.8%; NC 22%

Cap thickness 40 microns

Feasibility of combined use of IVUS-VH and OCT for detecting thin-cap fibroatheroma:56 pts

Total 126 lesions

VH IVUS examination

OCT examination

IVUS-derived-TCFA 61 (48.4%)

OCT-derived-TCFA 36 (28.6%)

non-thin-cap IVUS-derived-TCFA 33 (26.2%)

definite-TCFA 28 (22.2%)

**non-NCCL OCT-derived-TCFA 8 (6.3%)**

Feasibility of combined use of IVUS-VH and OCT for detecting thin-cap fibroatheroma.

Conclusion

"Neither modality alone is sufficient for detecting TCFA. The combined use of OCT and VH-IVUS might be a feasible approach for evaluating TCFA".
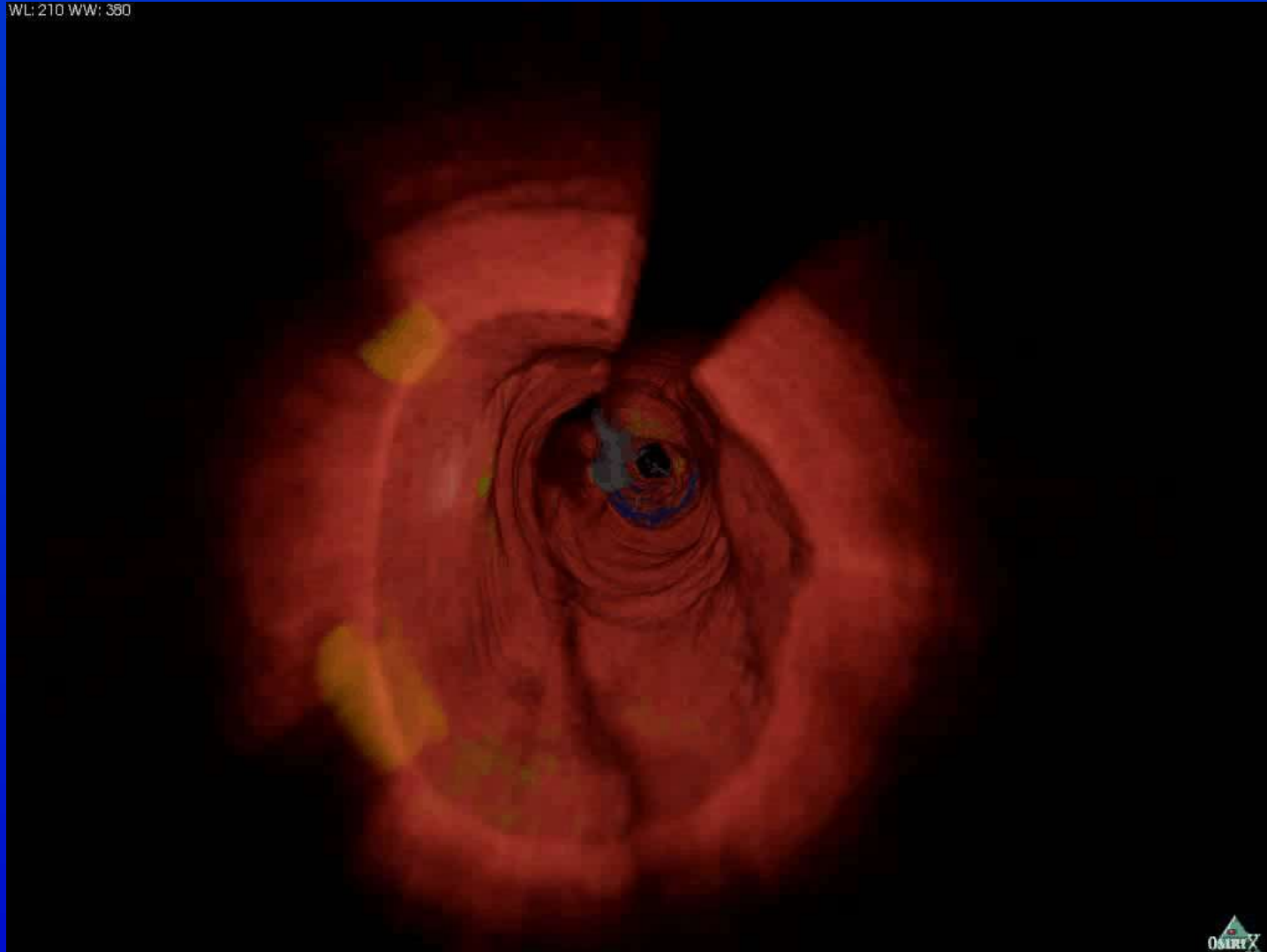
Histology Fly Through

Virtual pullback distal to proximal through 1 cm diseased coronary vessel
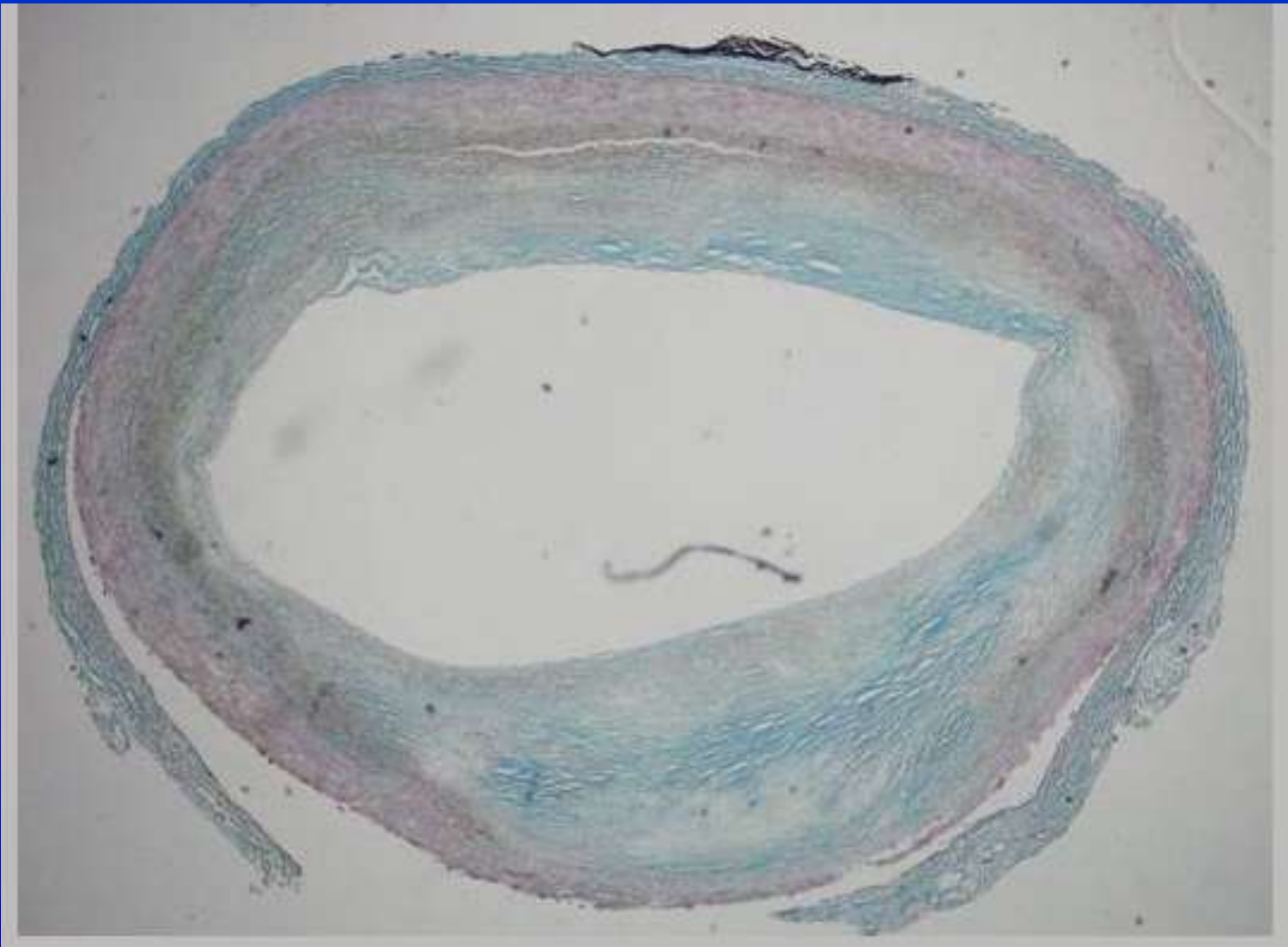
ODFI Fly Through

Courtesy Dr Tearney MGH USA

Algorithm to detect high-risk plaque in a high-risk patient

High-risk patient

Clinical presentation

Acute coronary syndrome
Younger < 60 yrs
Diabetes
Troponin positive

Biological marker
hsCRP↑

Presence of plaque

Non-invasive MSCT

Calcific plaque
Non-calcific plaque
Total coronary plaque burden

High-risk plaque

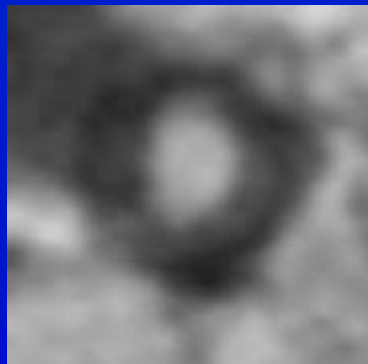**Invasive techniques**

ICUS
Palpography
Thermography
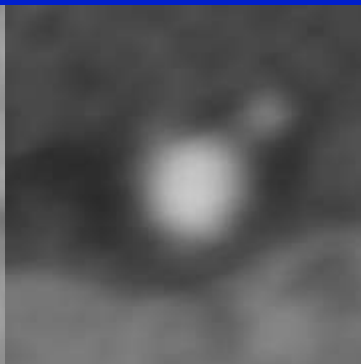OCT

CT: PLAQUE CHARACTERIZATION
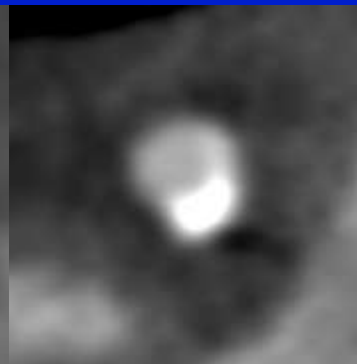## HIGH-RISK PLAQUE: WHERE ?

Non-obstructive noncalcific   **Obstructive mixed**   **Normal or ?**   **Non-obstructive calcific**   **Obstructive non-calcific**

Identification Vulnerable Plaque

Work in Progress

Sofar elusive

Combination non-invasive and invasive coronary Imaging

High Risk Patients

THANK YOU