Natural History of Vulnerable plaque: Targets for Risk Stratification

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Disclosure Statement of Financial Interest

Within the past 12 months, I or my spouse/partner have had a financial interest/arrangement or affiliation with the organization(s) listed below.

Consultant: 480 Biomedical, Abbott Vascular, Medtronic, and W.L. Gore.

Employment in industry: No

Honorarium: 480 Biomedical, Abbott Vascular, Boston Scientific, CeloNova, Claret Medical, Cordis J&J, Lutonix, Medtronic, Merck, ReCor, Terumo Corporation, and W.L. Gore.

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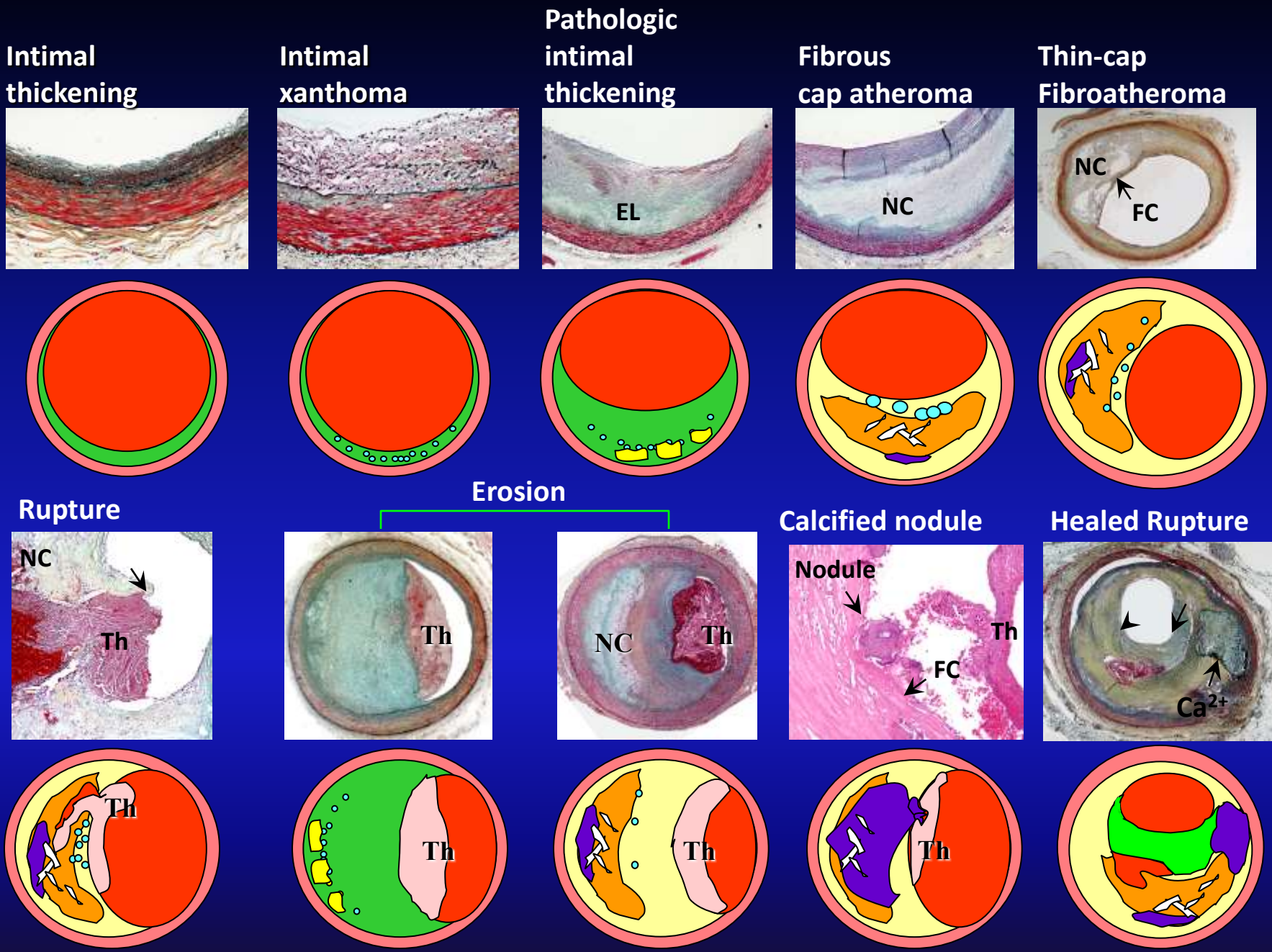
Progression of Human Coronary Atherosclerosis

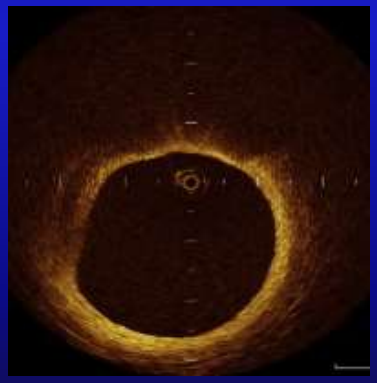


Virmani R, et al. Arterioscler Thromb Vasc Biol 2000;20:1262

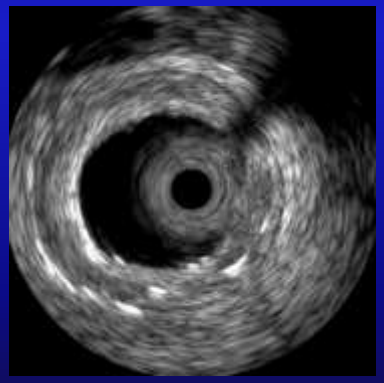
Comparison of Different Imaging Modalities for Assessment of Coronary Artery Disease

	OCT/OFDI	IVUS	MRI	MDCT	CCA
Resolution	10-15µm	150 – 200µm	1 mm	0.5-1 mm	0.5-1 mm
Probe size	140	700	N/A	N/A	N/A
Contact	Yes	Yes	No	No	No
Ionizing radiation	No	No	No	Yes	Yes
Other	Thin cap, macrophage, necrotic core, calcium	Remodeling, plaque burden, calcium	Calcium, remodeling	Remodeling, calcium and soft plaque	Luminogram

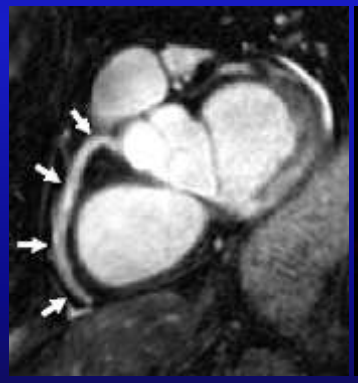
OCT/OFDI



IVUS



MRI



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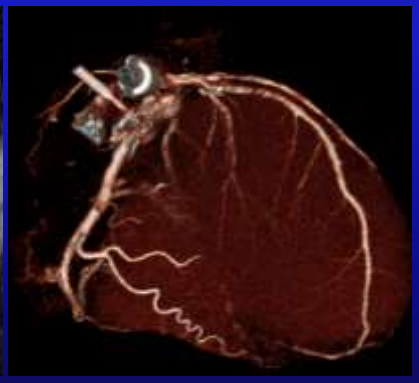
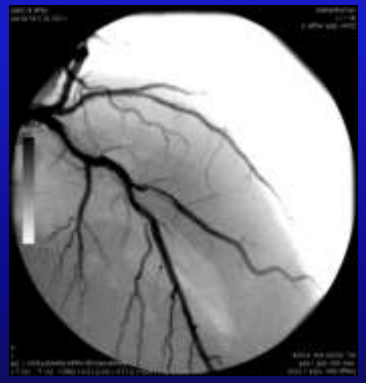


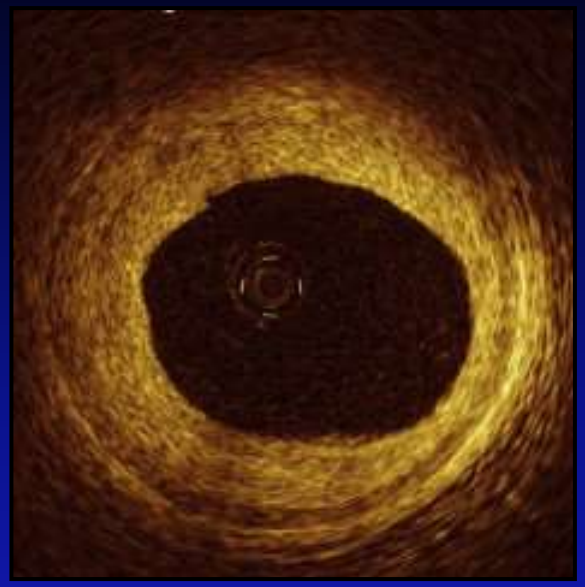
CCA



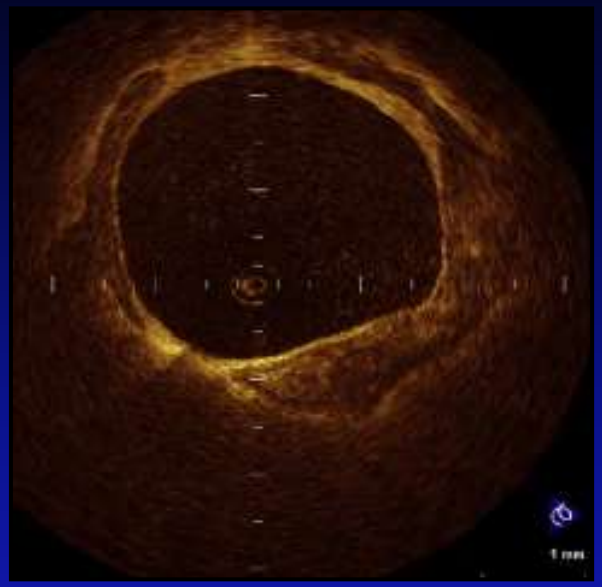
Wessely R, et al. Circulation 2007;116:e78-e80.

OCT Images of Coronary Atherosclerotic Plaques

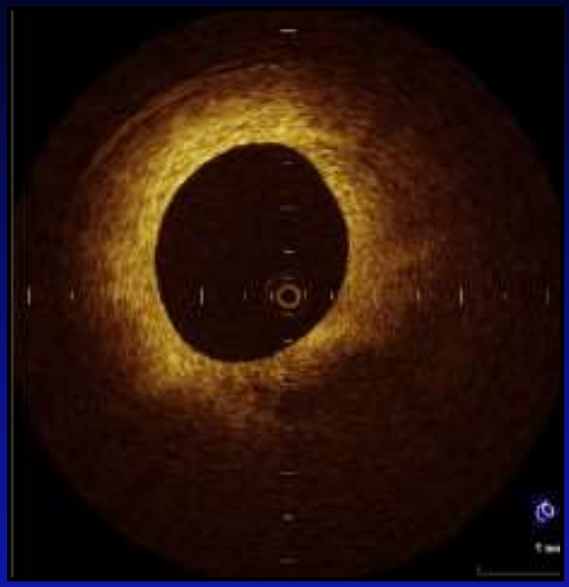
Fibrous plaque



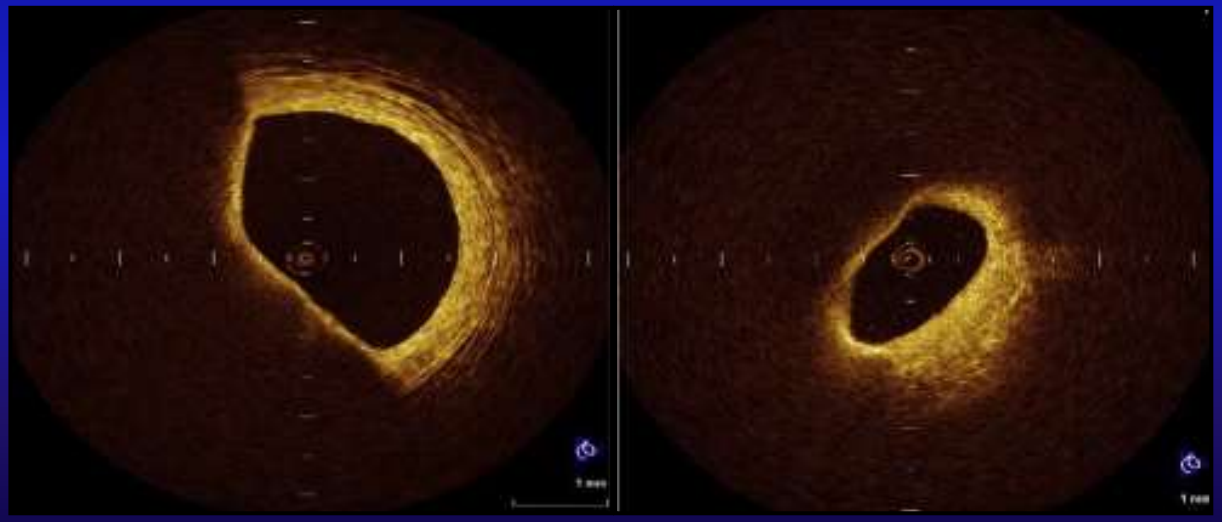
Fibrocalcific plaque



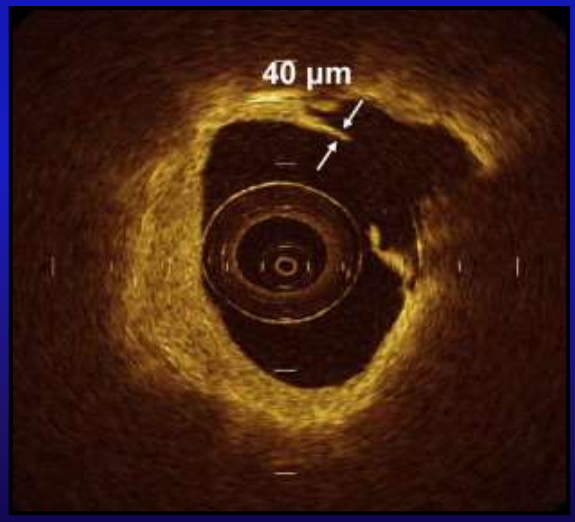
Lipidic plaque



Thin-cap fibroatheromas

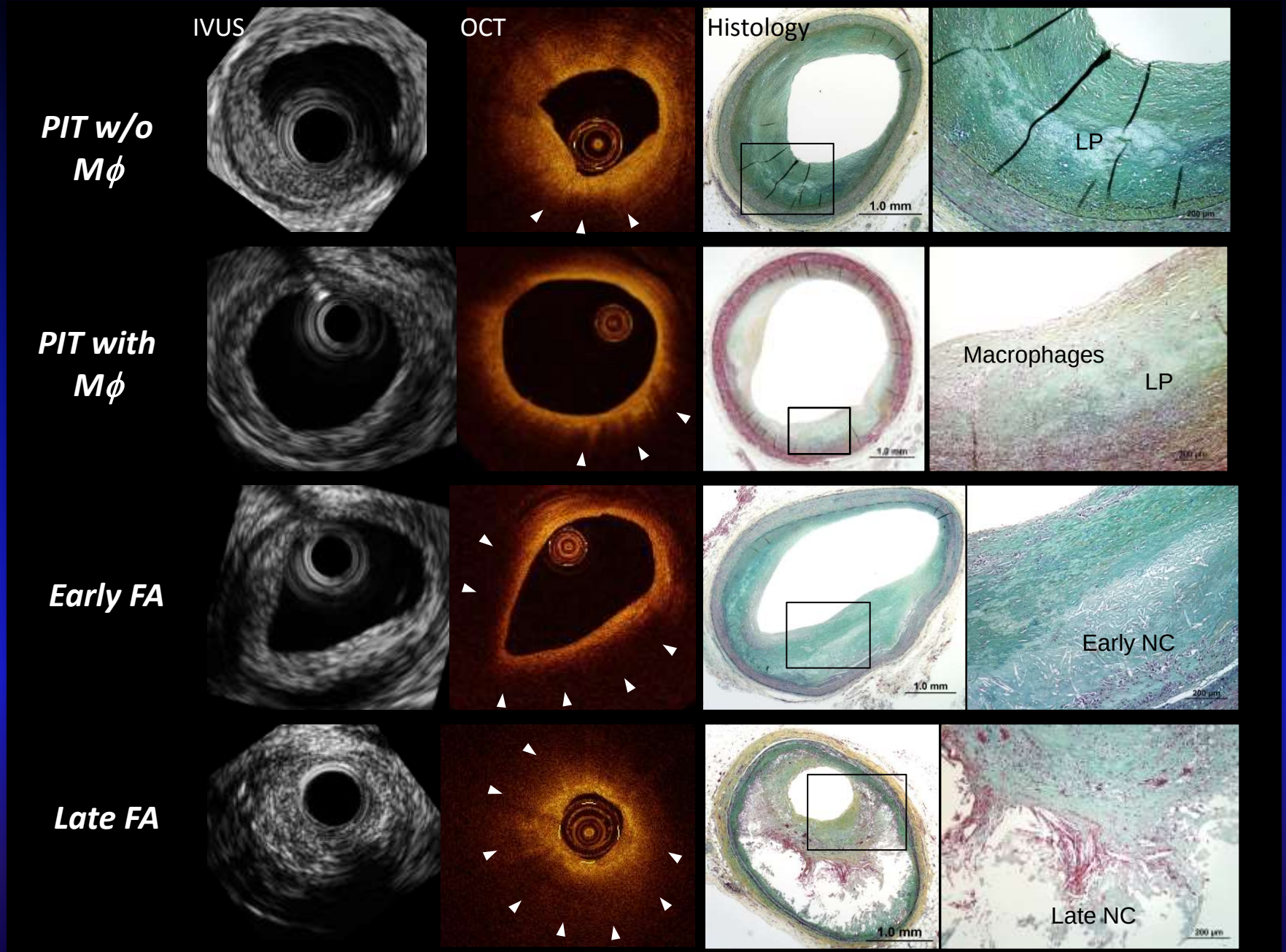


Plaque rupture



Akasaka T, et al. J Cardiol 2010;56:8-14

Plaque Progression: From PIT (LP) to Fibroatheroma (NC)

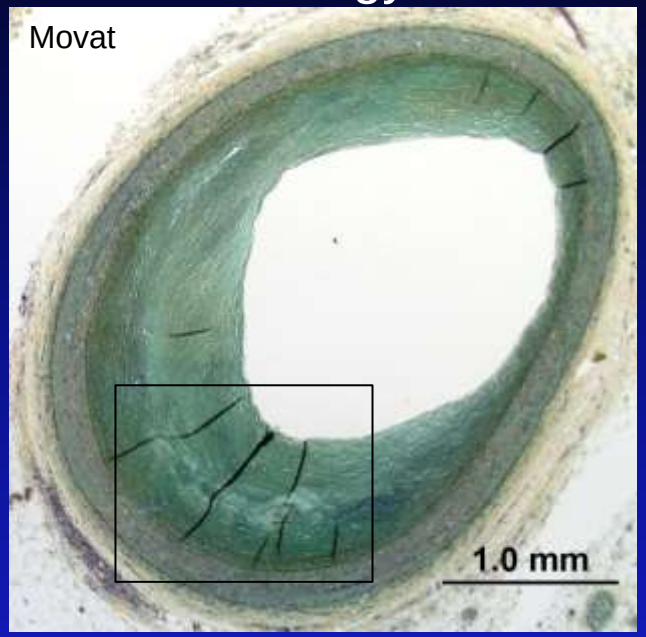


FA=fibroatheroma; LP=lipid pool; NC=necrotic core; PIT=pathologic intimal thickening

Otsuka F. et al. Nat Rev Cardiol. 2014;11:379-89

Pathologic Intimal Thickening (PIT) without Macrophages

Histology



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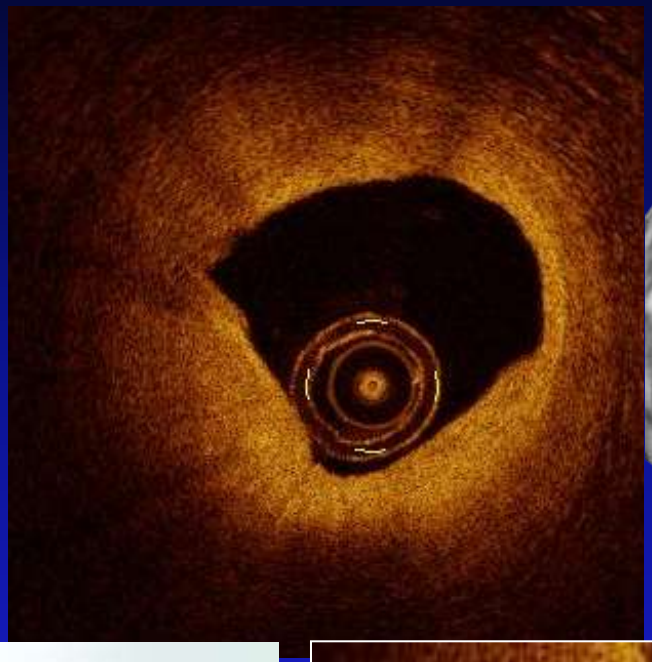
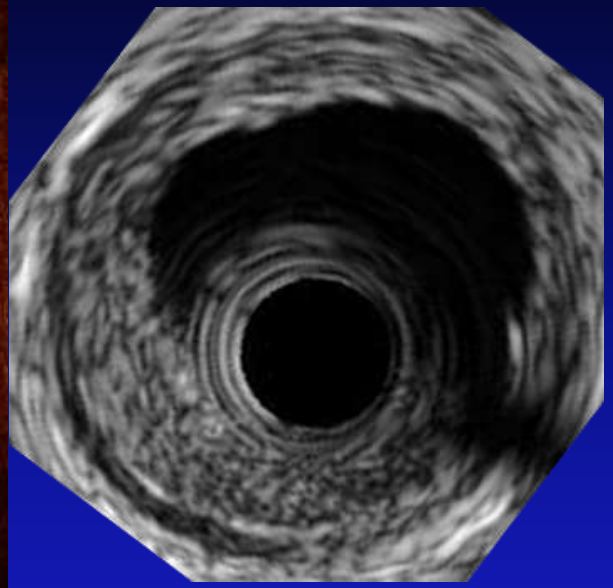


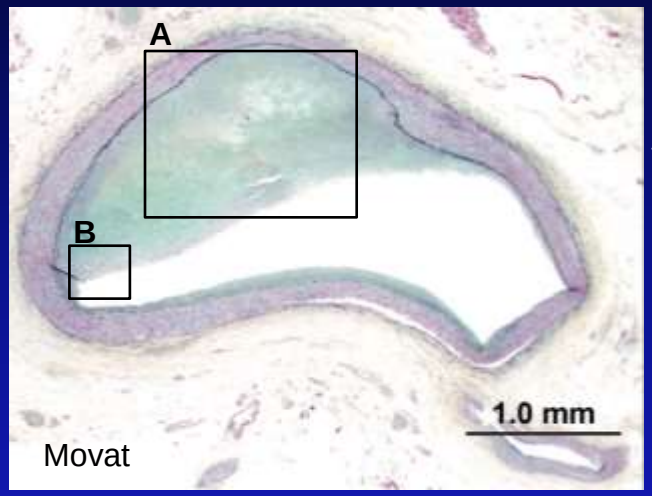
IVUS



Otsuka F. et al. Nat Rev Cardiol. 2014;11:379-89

Pathologic Intimal Thickening (PIT) with Macrophages

Histology



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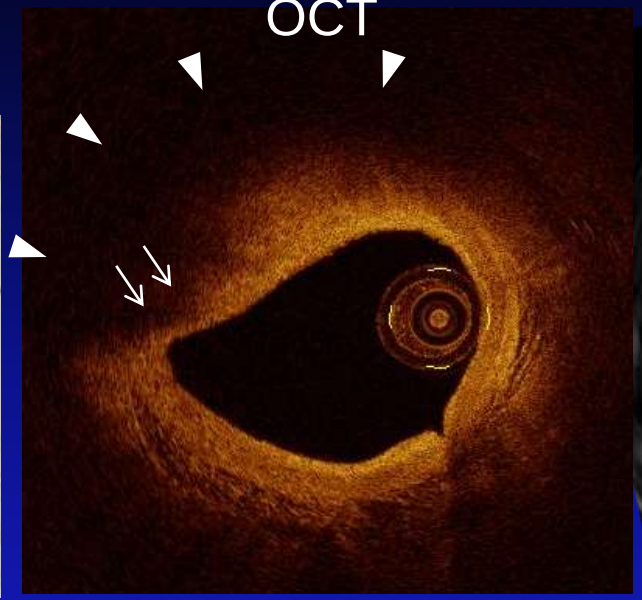

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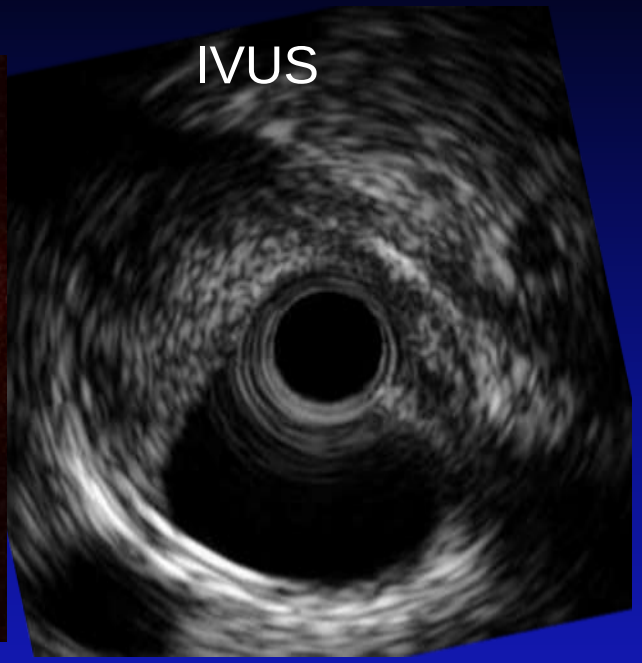
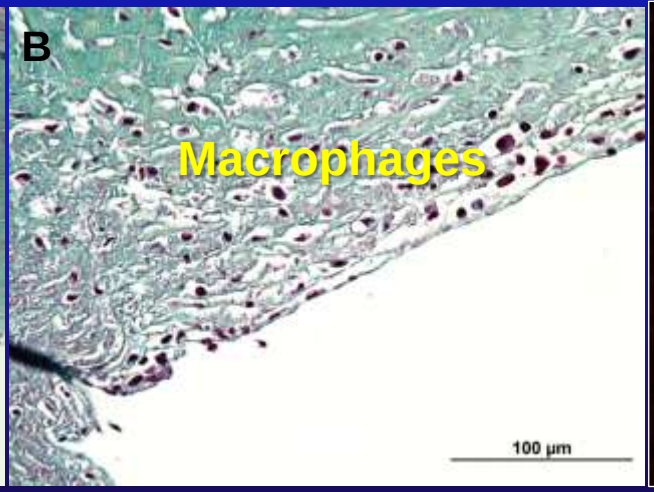
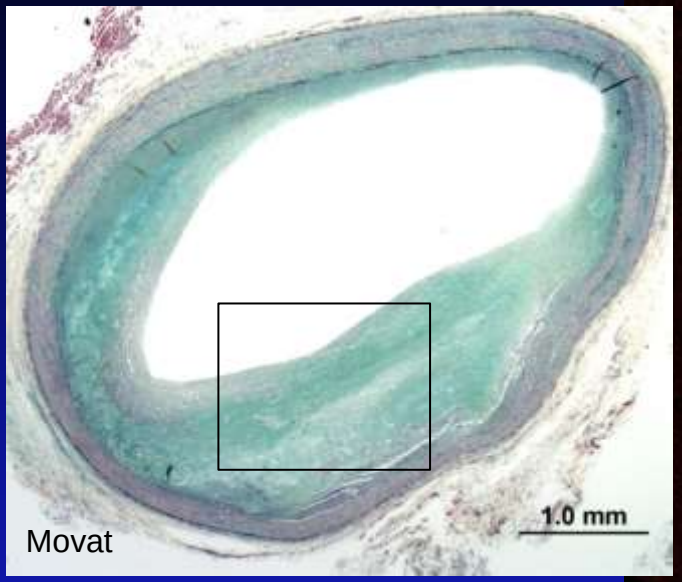




Early Fibroatheroma

Histology



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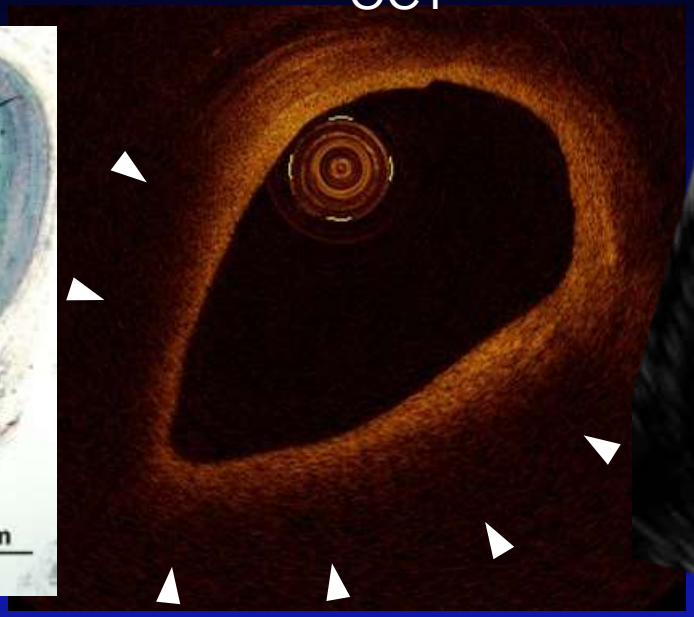

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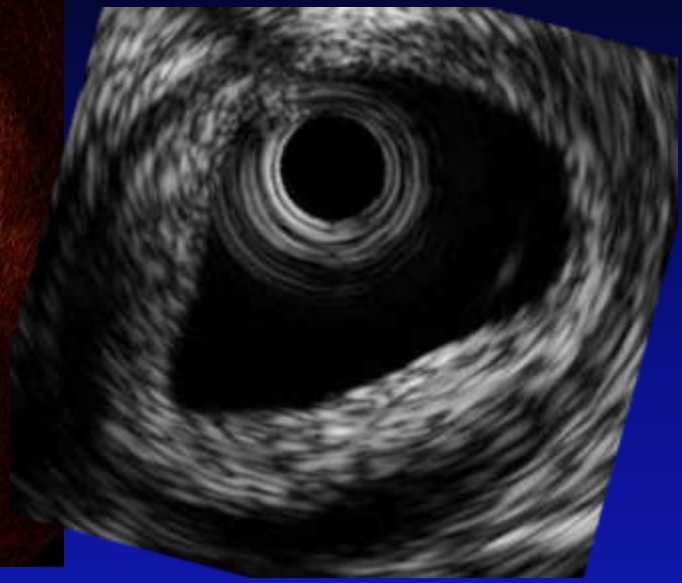
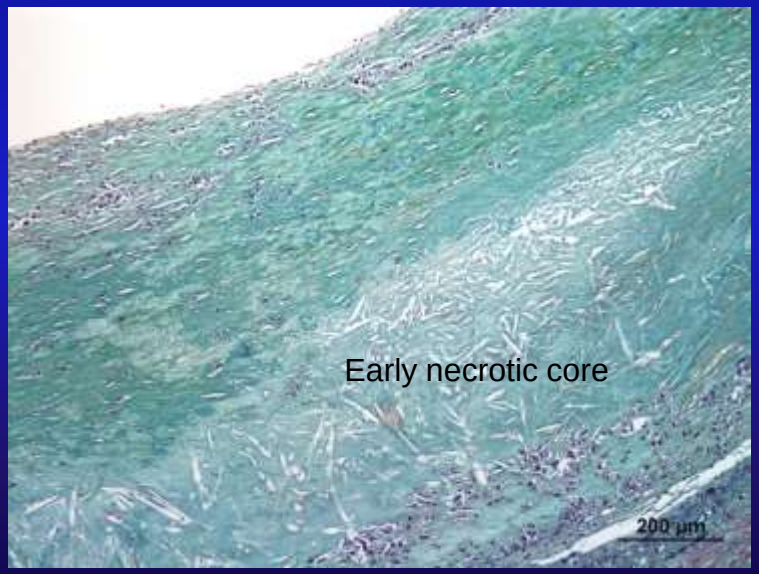
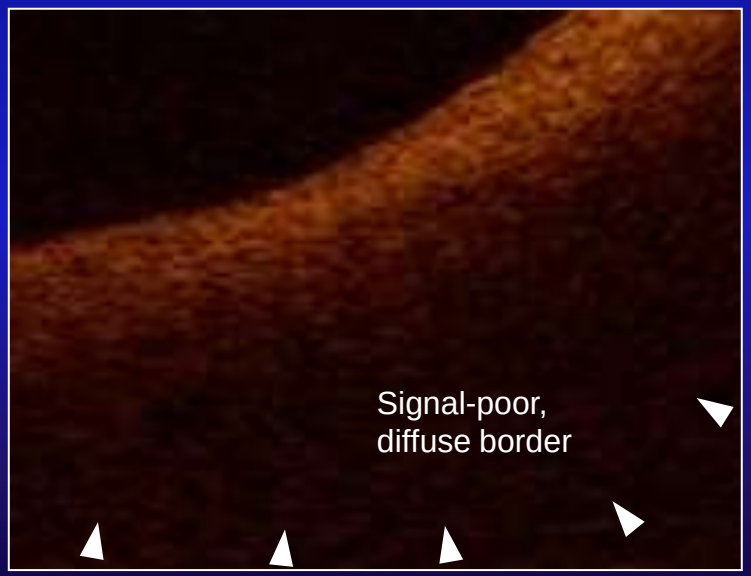


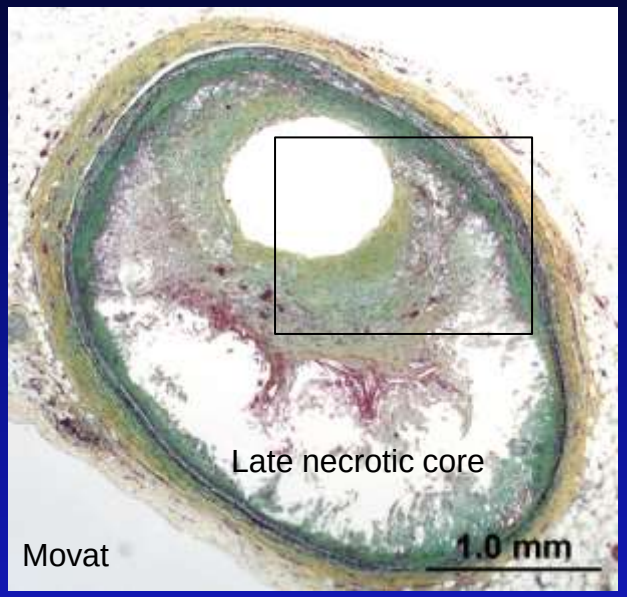




Otsuka F. et al. Nat Rev Cardiol. 2014;11:379-89

Late Fibroatheroma with macrophage infiltration into fibrous cap

Histology



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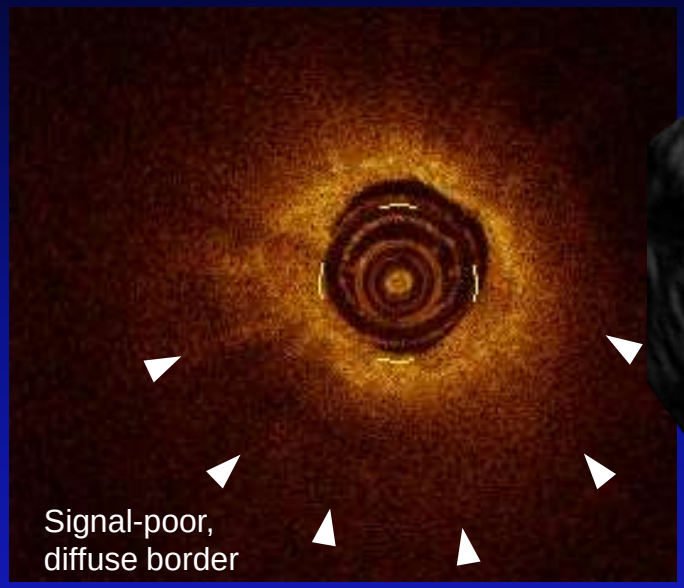

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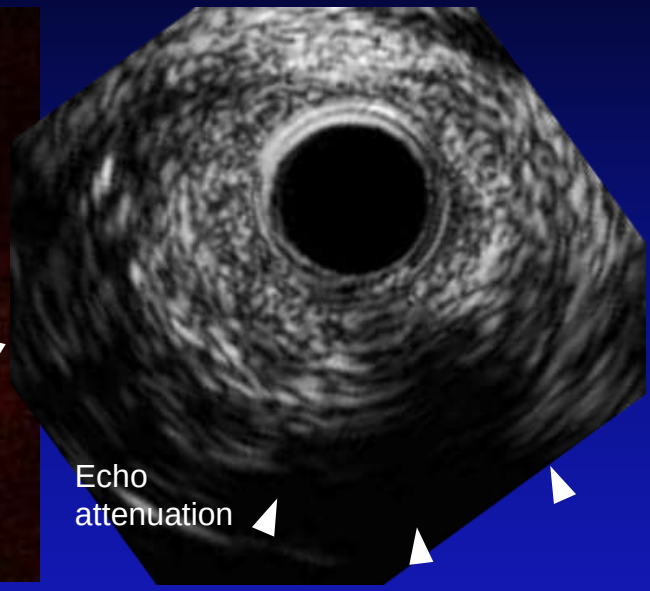

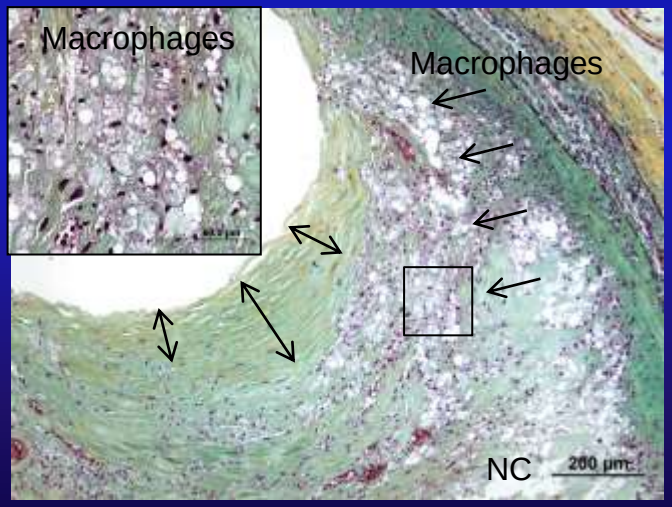

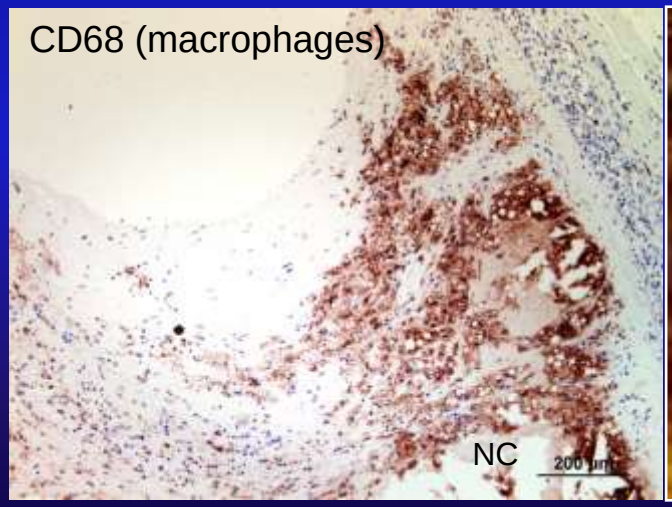

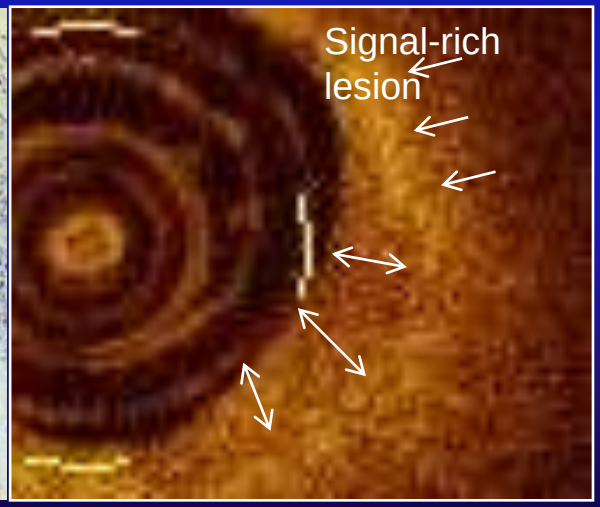

NC=necrotic core

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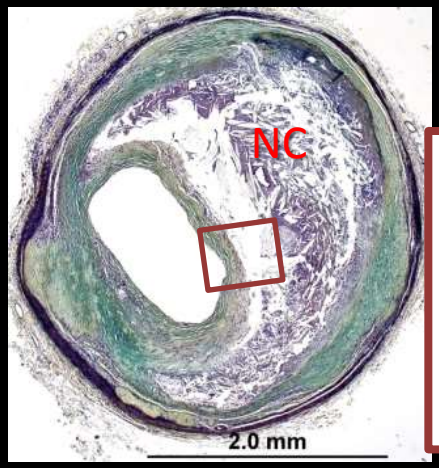
TCFA with Cholesterol Crystals

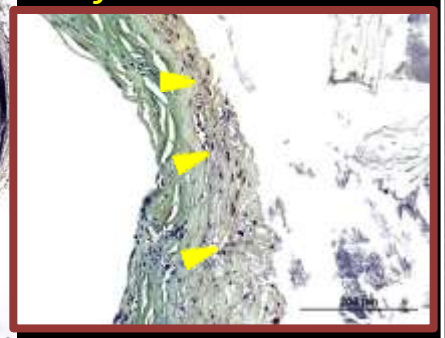
Histology

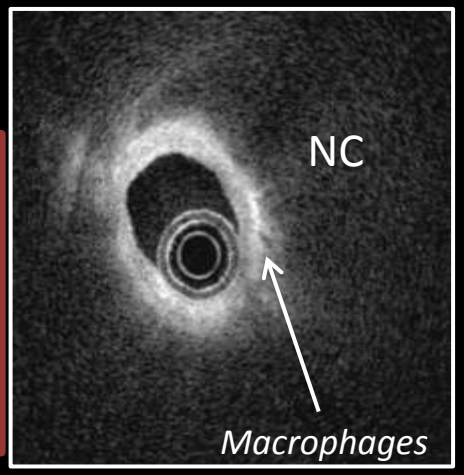
OCT (OFDI)

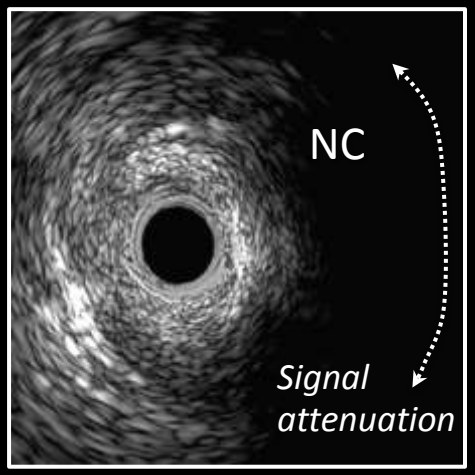
IVUS

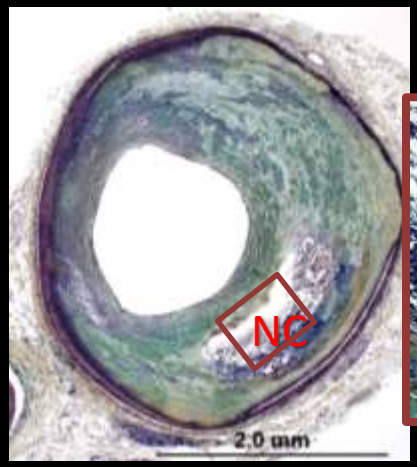


Macrophage infiltration

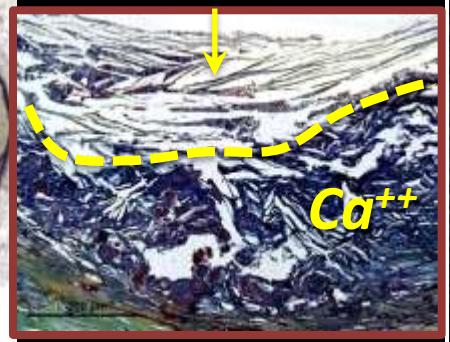


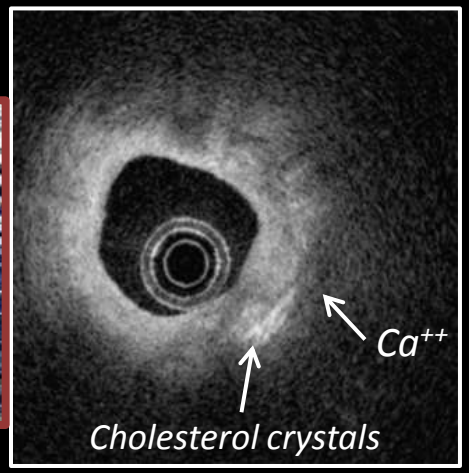


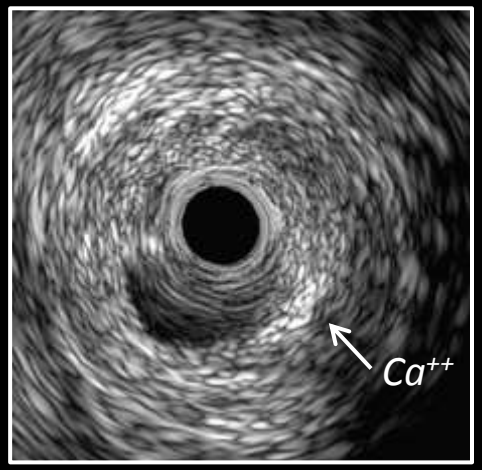




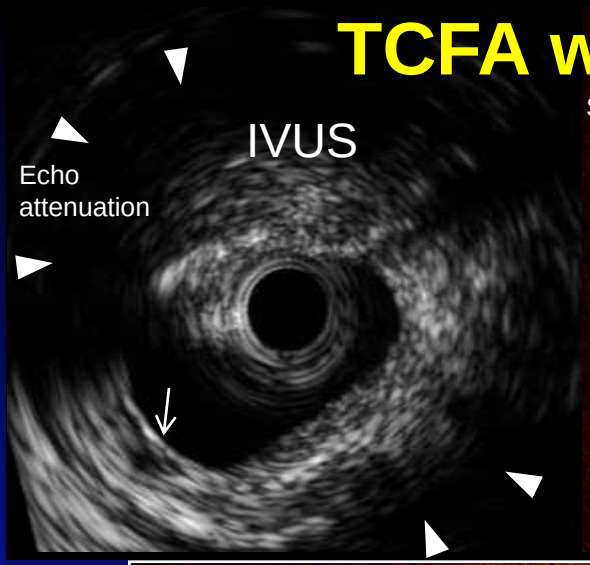
Cholesterol crystals

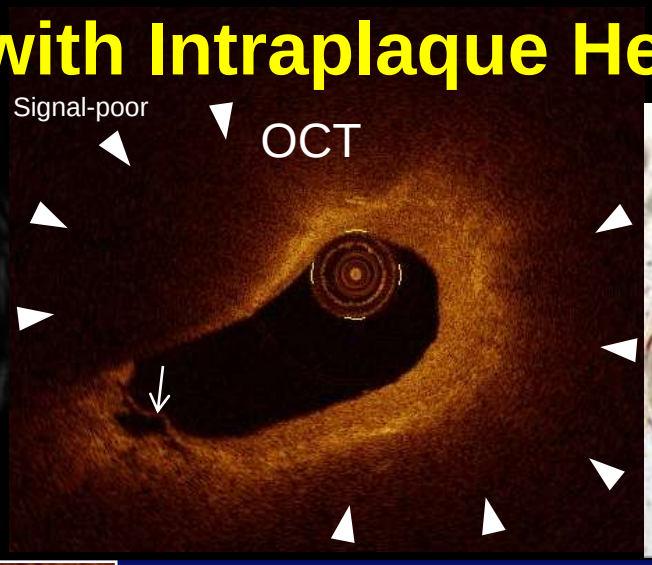


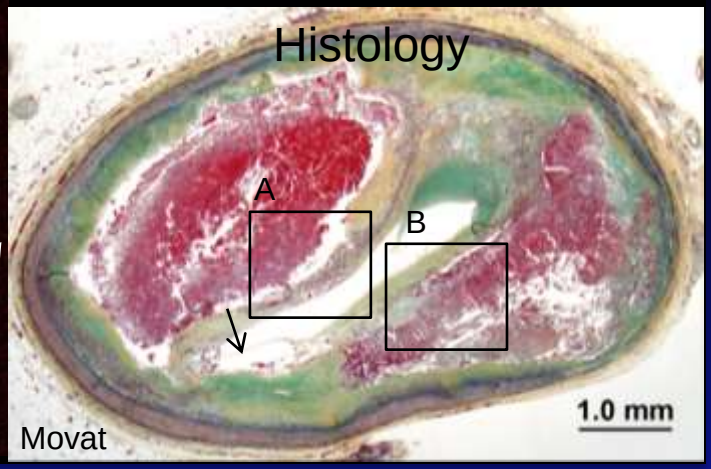


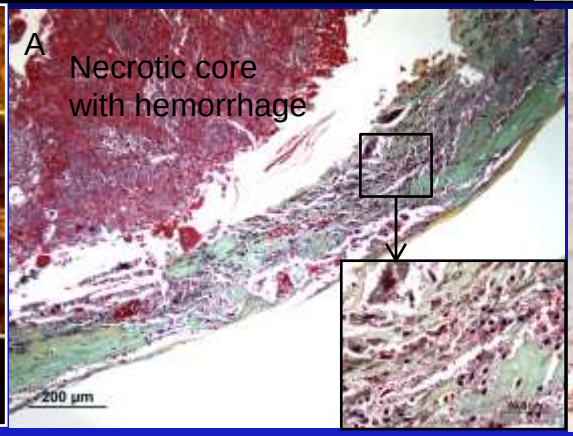


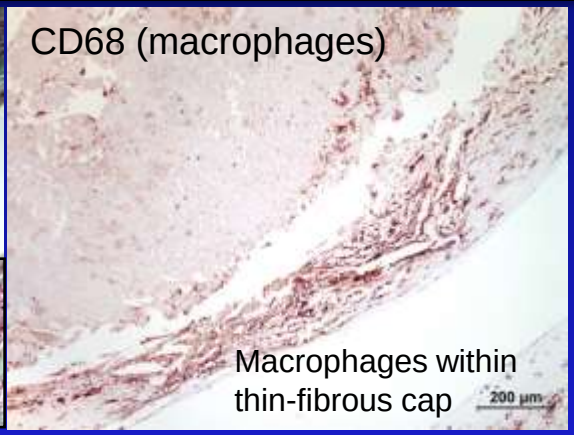
TCFA with Intraplaque Hemorrhage

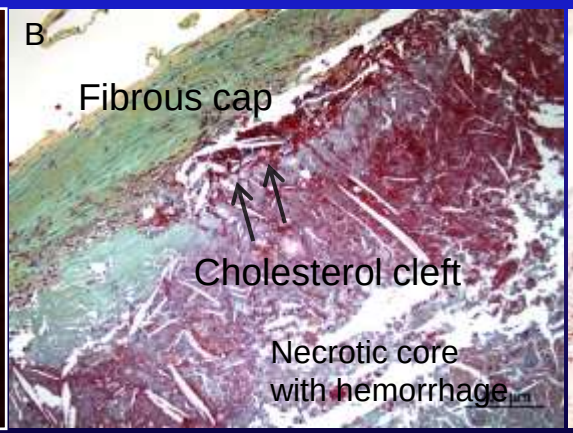


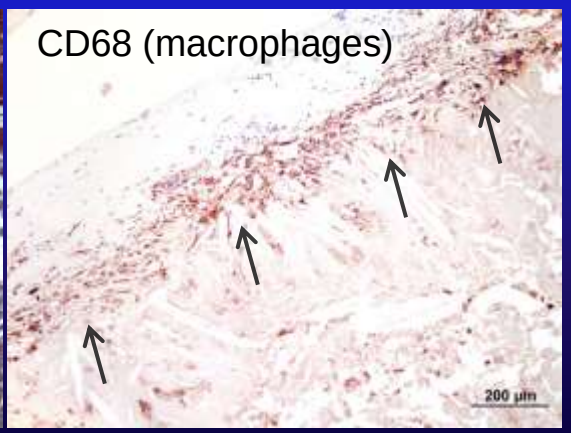








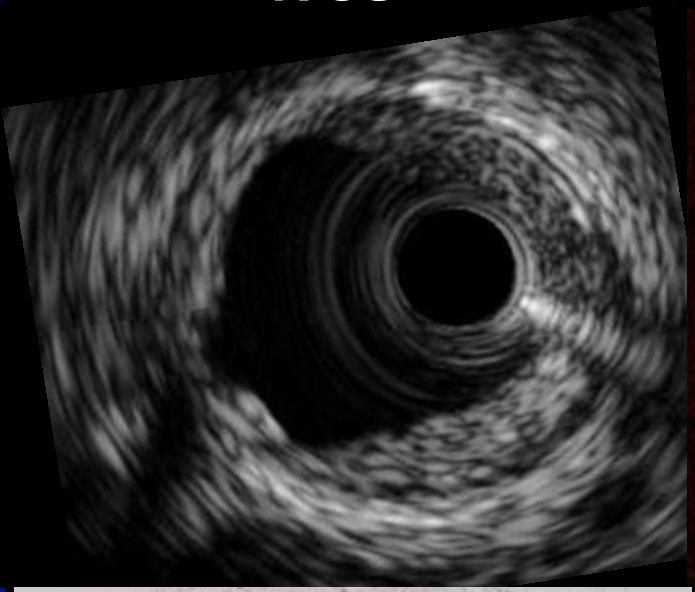




Otsuka F. et al. Nat Rev Cardiol. 2014;11:379-89

TCFA-like Image by OCT

IVUS



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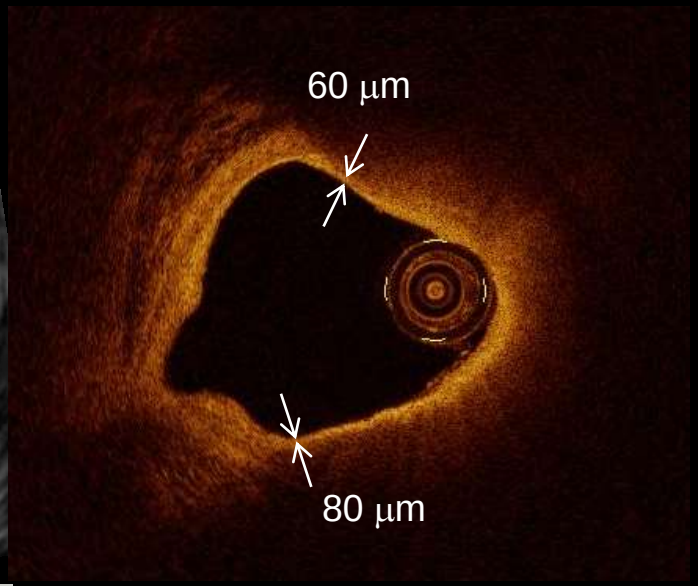
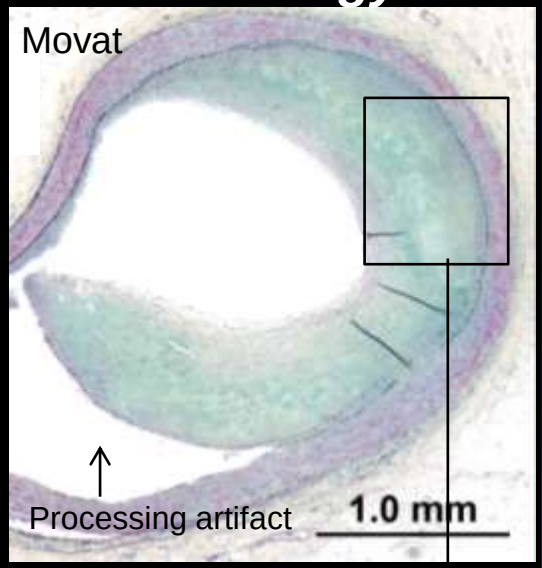
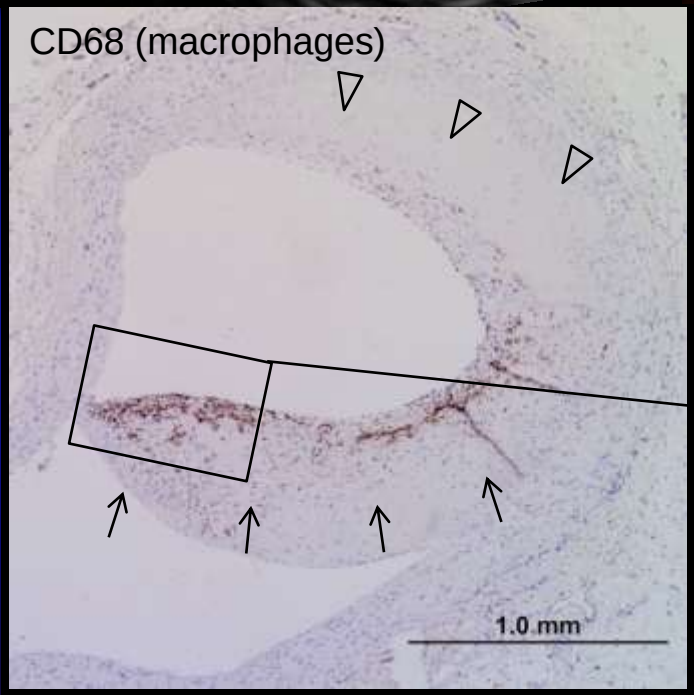
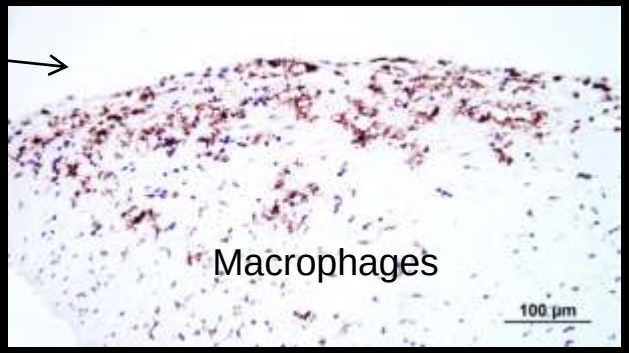


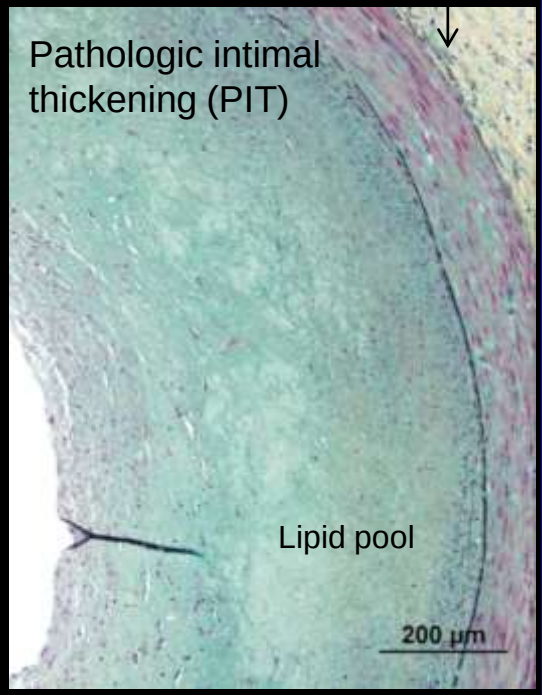
Histology



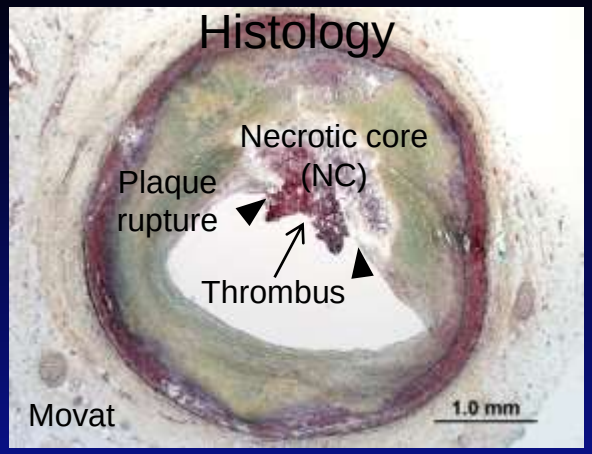


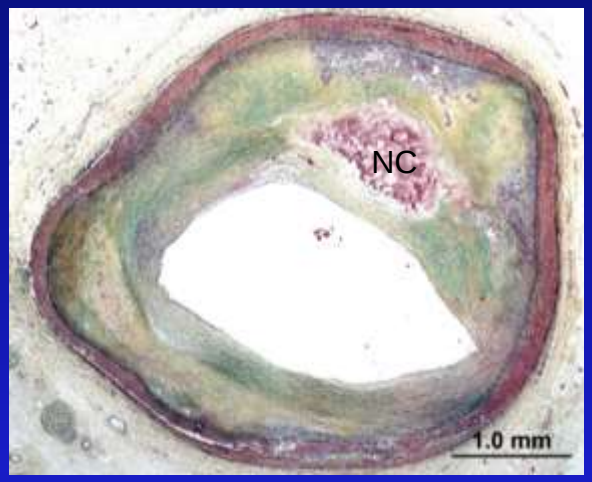
- ✓Superficial macrophages
- ✓Catheter position
  (tangential signal dropout)

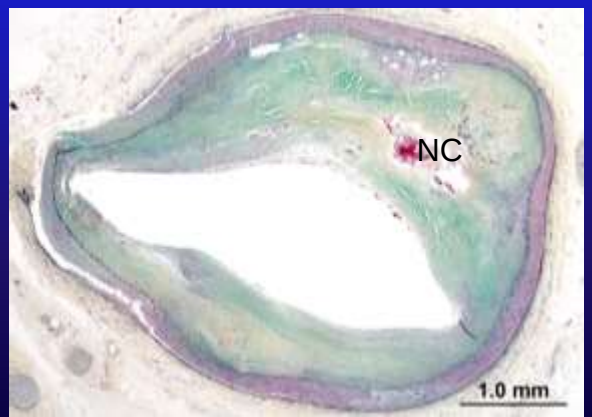


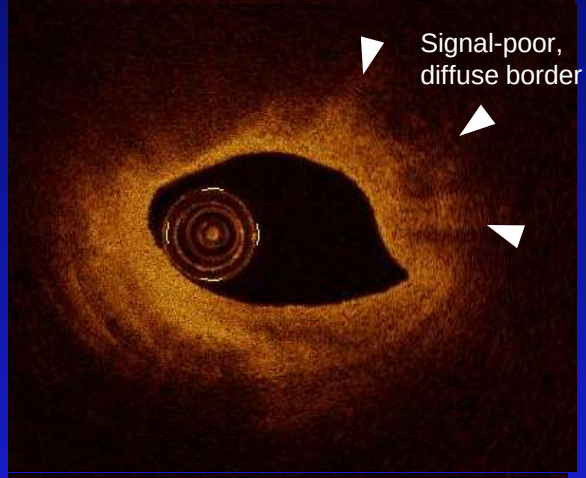


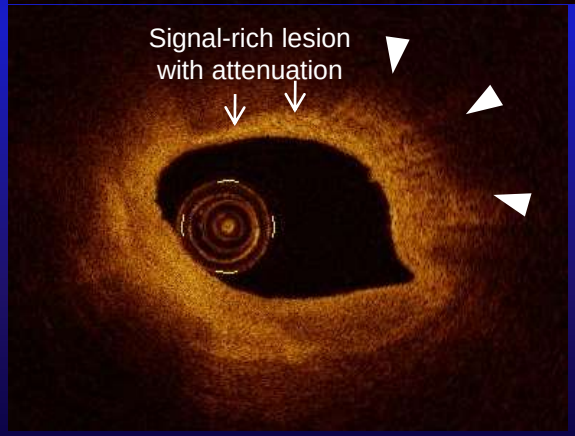
Plaque Rupture

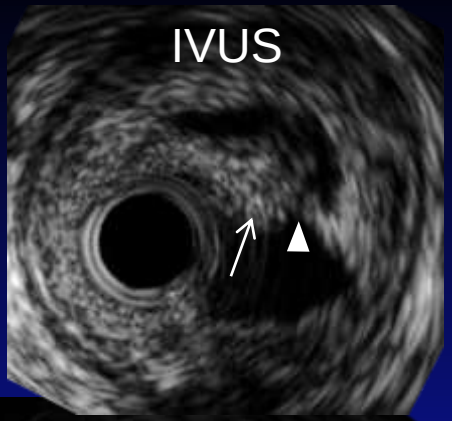


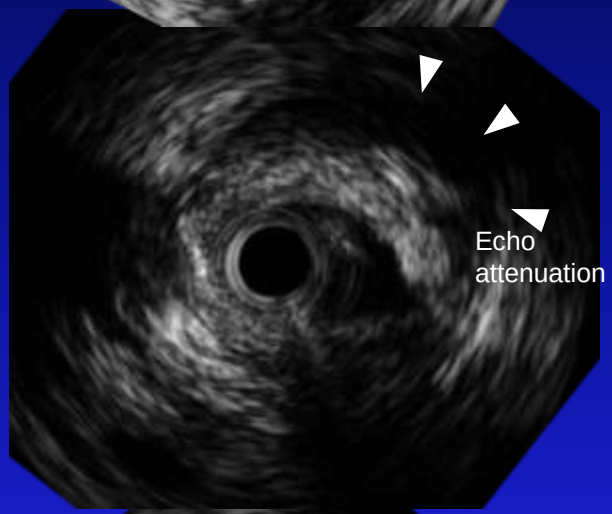


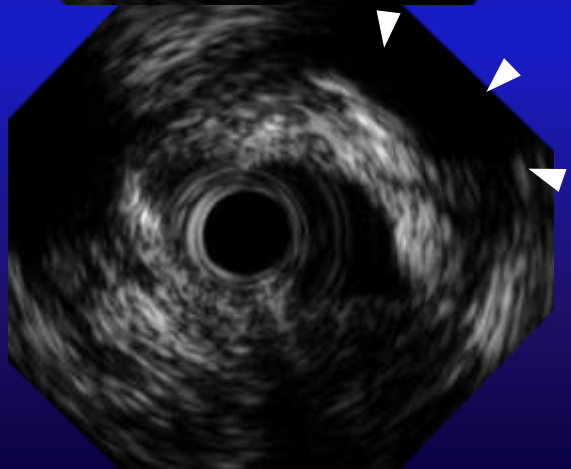










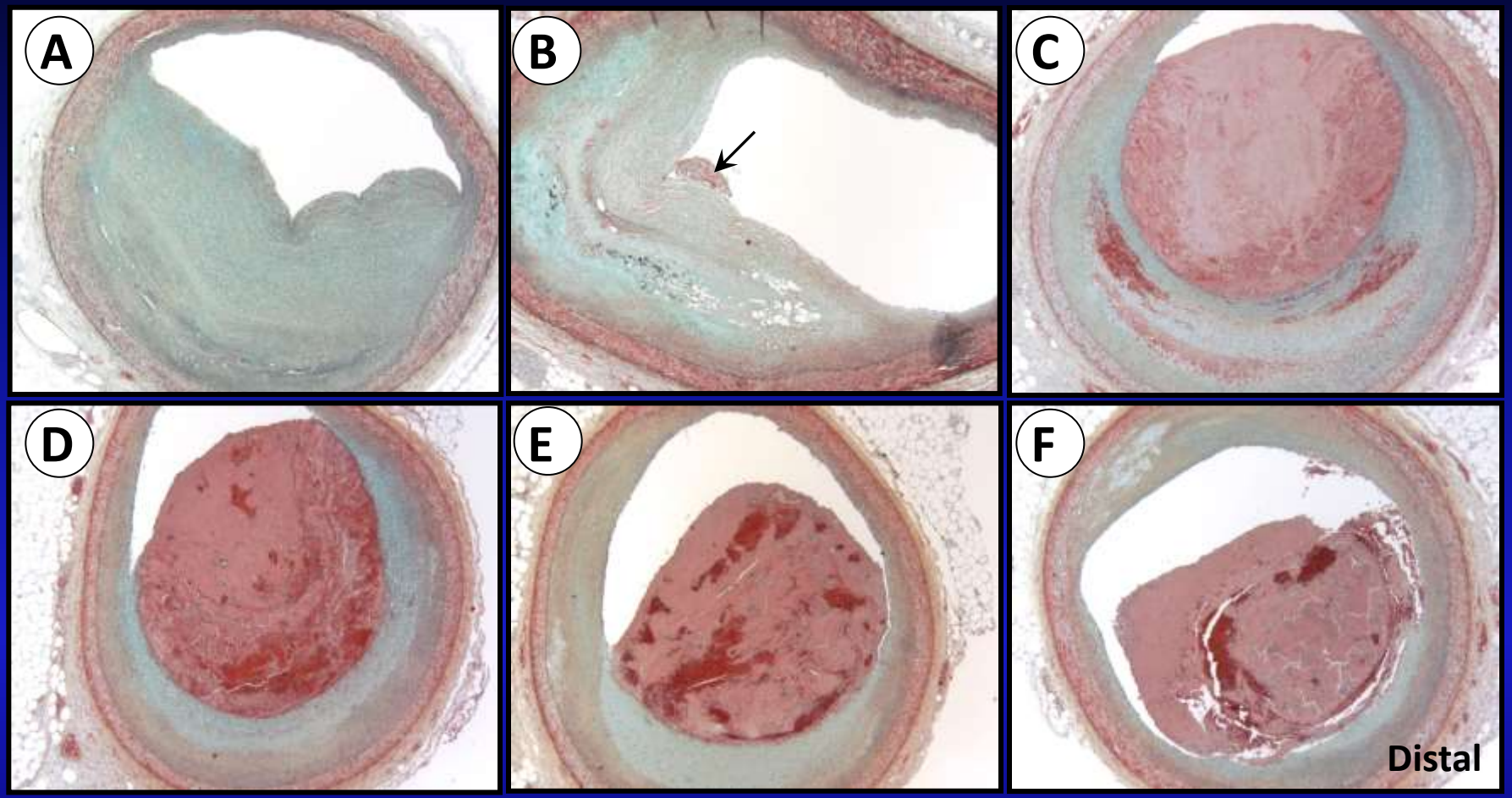


Otsuka F. et al. Nat Rev Cardiol. 2014;11:379-89

Serial Sections of Coronary Plaque Erosion

38F, Sudden Coronary Death Victim

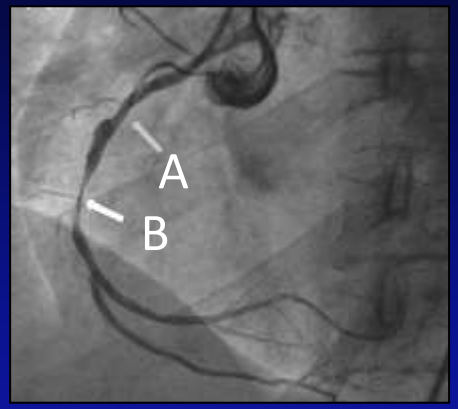
Proximal LAD ⟶



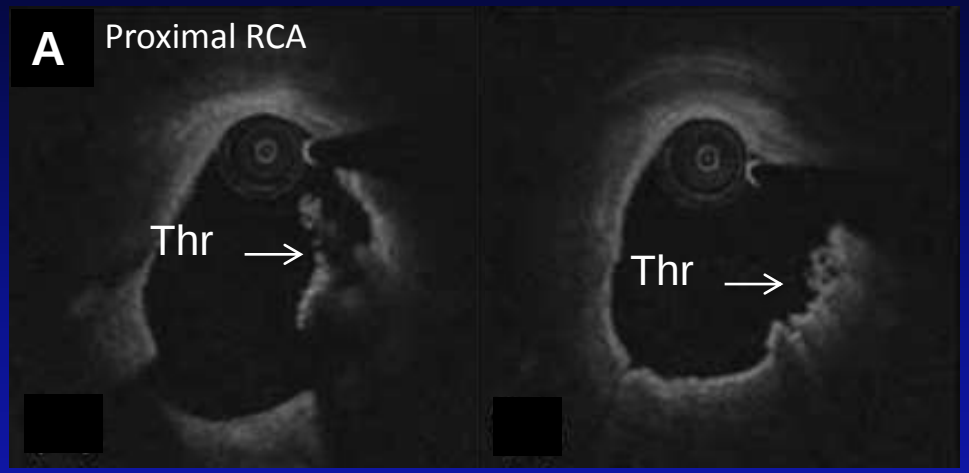
Plaque erosion accounts for 30-35% of coronary thrombi in sudden coronary death. The underlying plaque in erosions consists of PIT or fibroatheroma, which is rich in smooth muscle cells in a proteoglycan matrix, and there is an absence of endothelial lining. The erosion lesions are infrequently calcified.

Can plaque erosion be identified by OCT/OFDI?

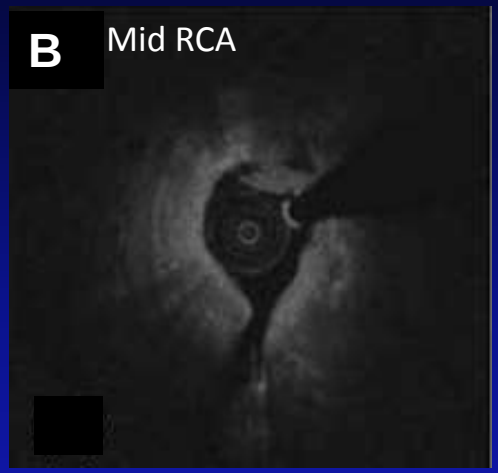
51F presented with STEMI

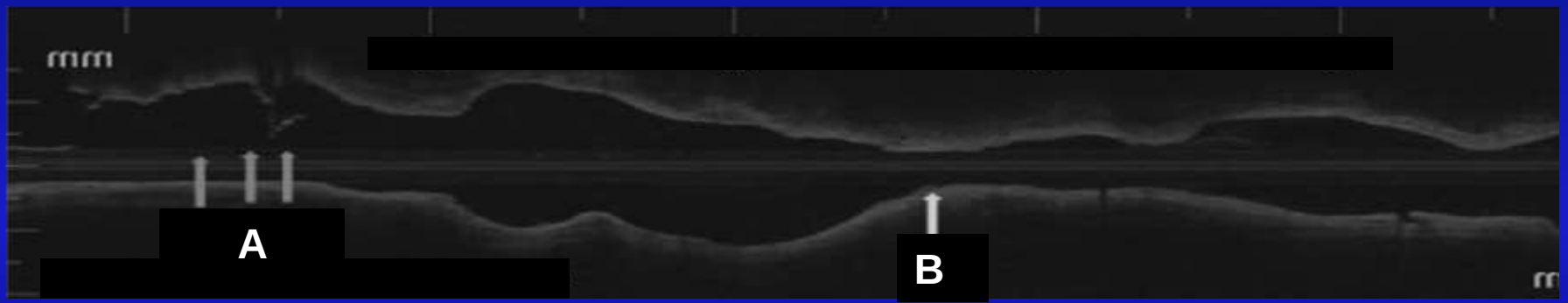


Luminal thrombus without plaque rupture



Sub-occlusive thrombus



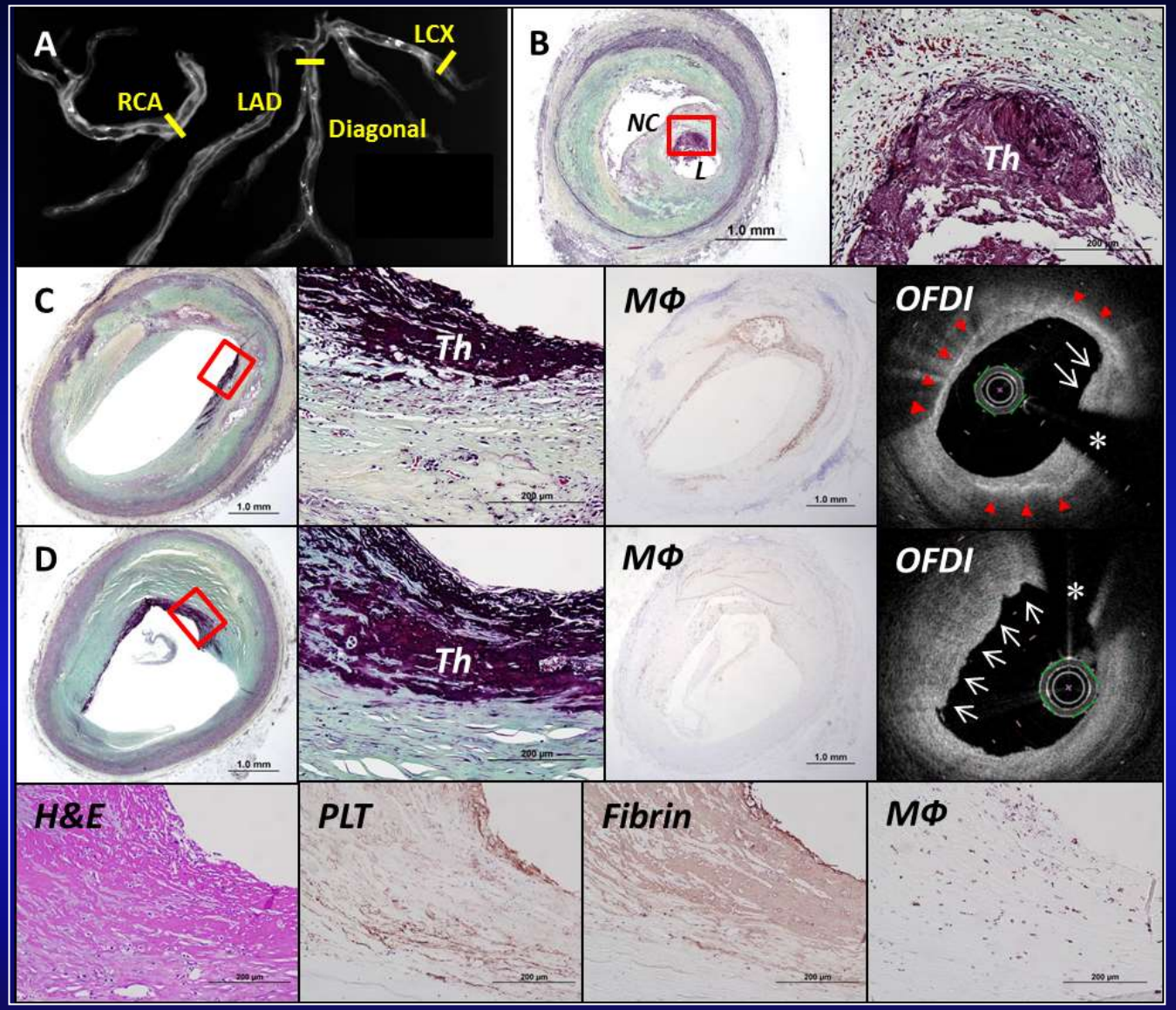


Fineschi M, J Cardiovasc Med 2013 [Epub ahead of print]

- Thrombus may obscure the underlying plaque morphology.
- Currently, no distinct morphological features of erosion-prone plaques have been identified.

Multiple Simultaneous Plaque Erosion in 3 Coronary Arteries

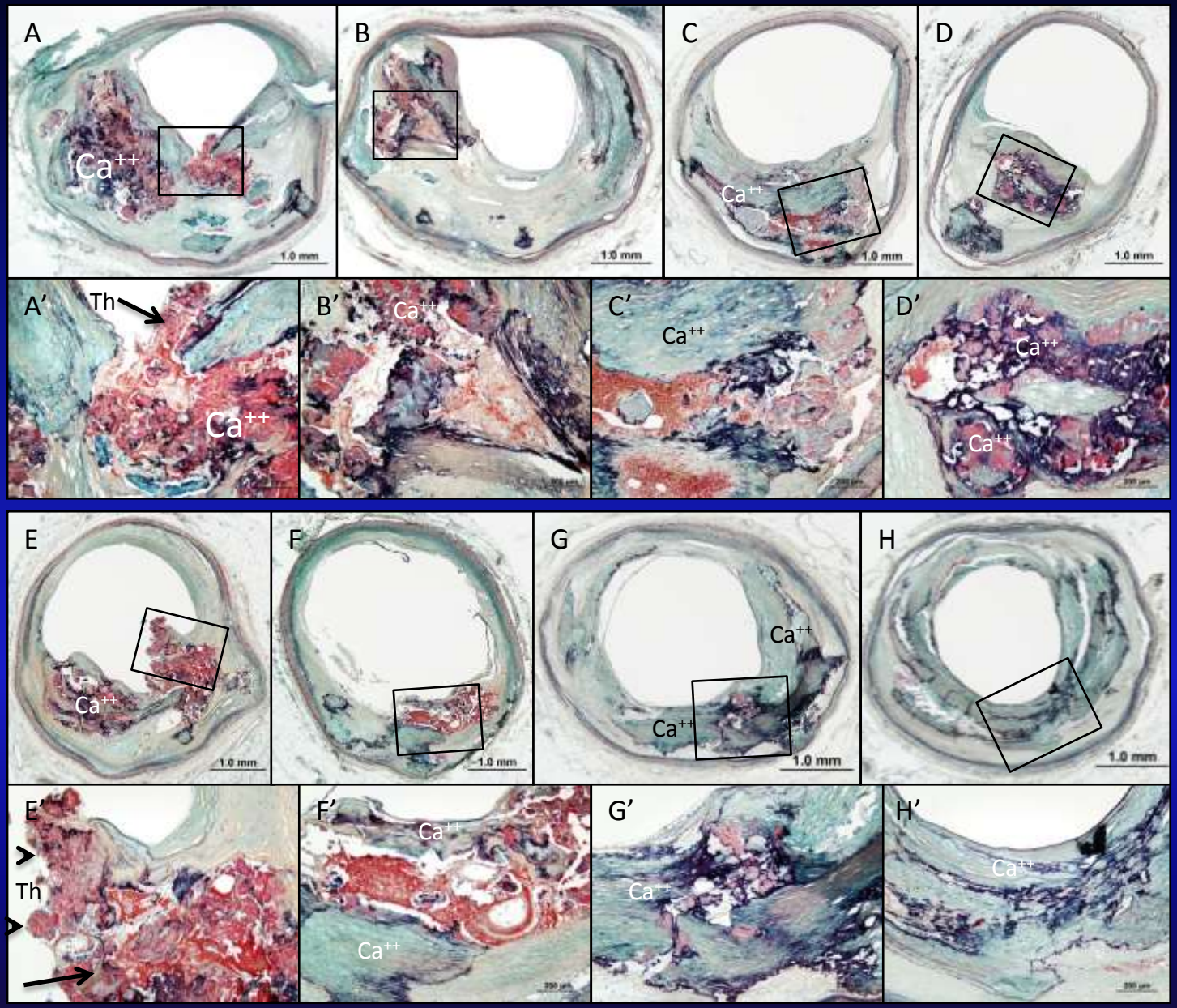
34-year-old man with history of smoking and untreated hyperlipidemia who had suffered from epigastric pain and was found dead at home.



Yahagi K, et al. JACC Cardiovasc imaging. 2014;7:1172-4

Calcified Nodule

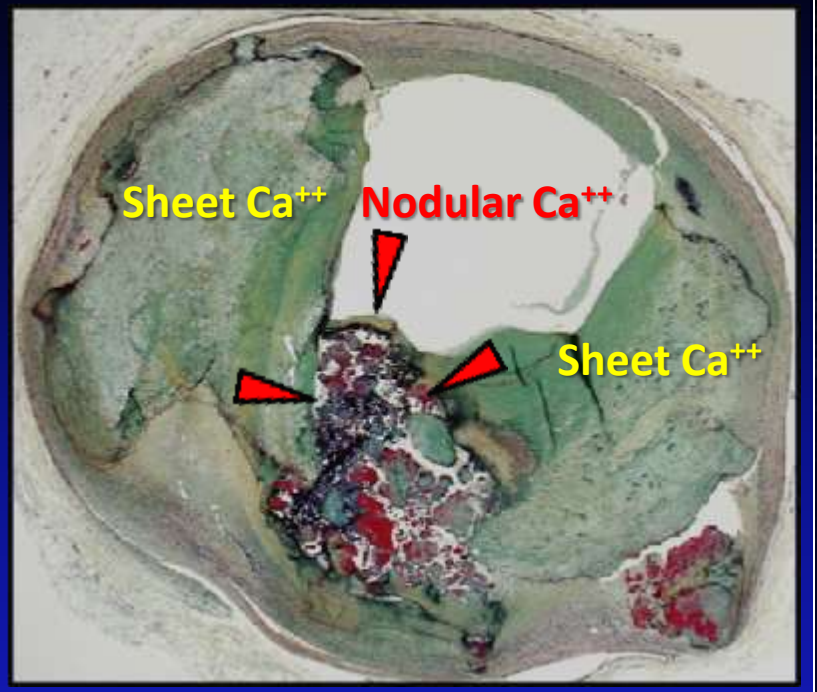
67M, Prediabetic, BMI=41.1, Mid RCA

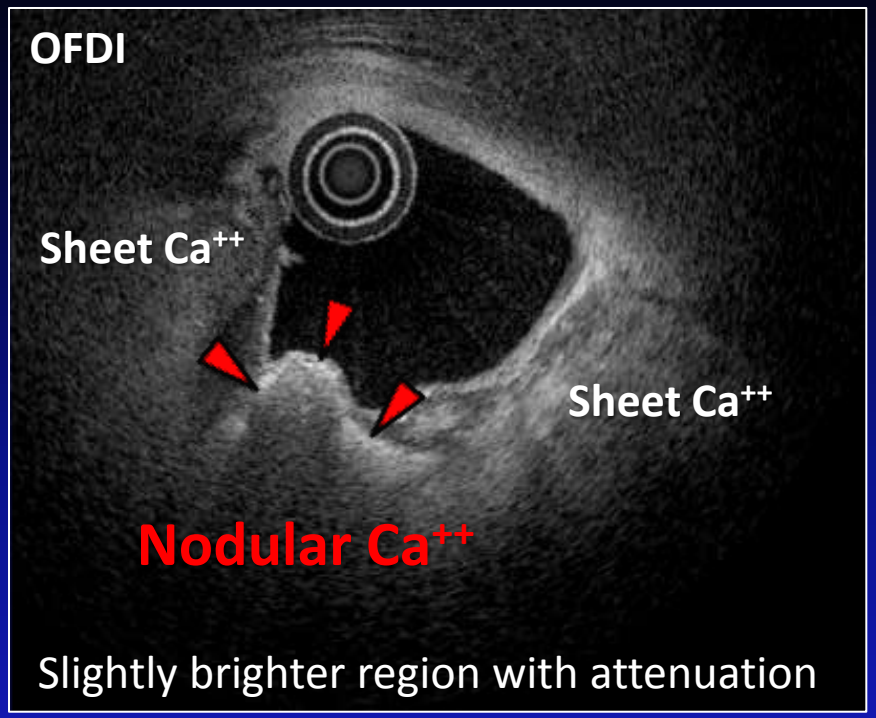


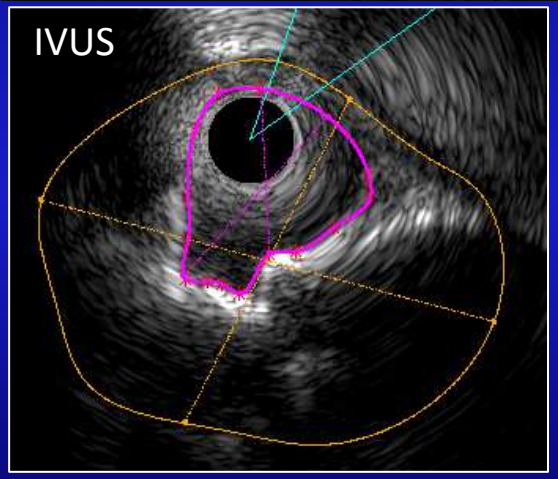
- The least frequent lesion of coronary thrombi (2-7%) in sudden coronary death
- Protruding into the lumen
- Accompanied by heavy sheet calcification
- Fibrin is often present between the calcified spicules

- ✓ Calcified nodule → with thrombus
- ✓ Nodular calcification → without thrombus

Nodular Calcification and Calcified Nodule on OCT/OFDI

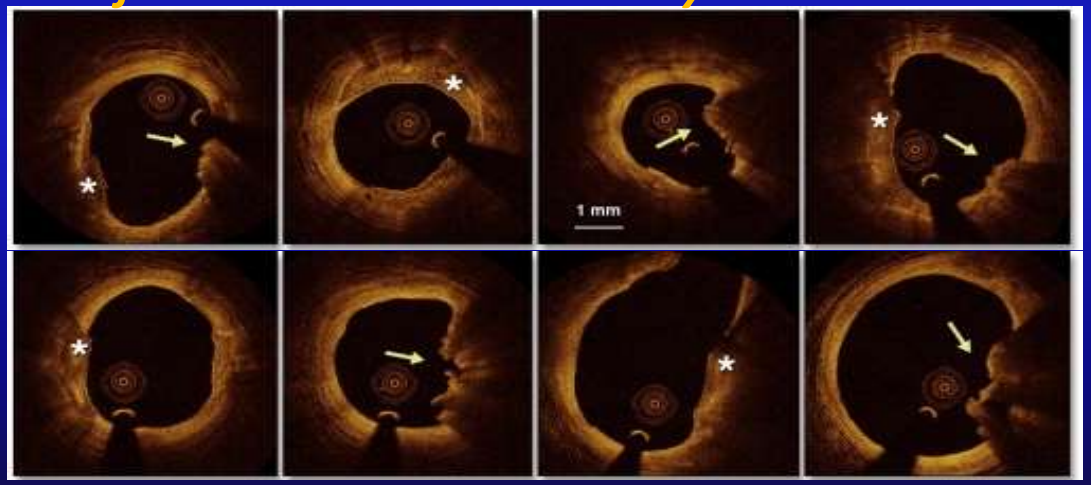






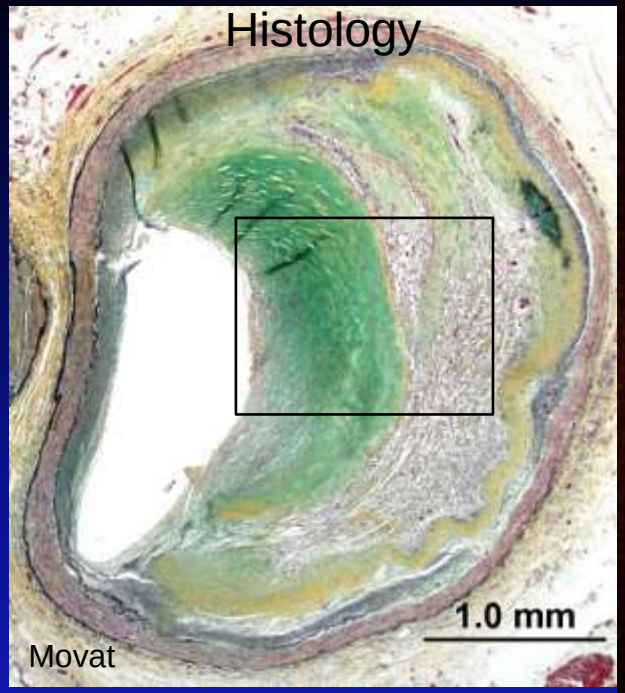
However, the precursor lesions of calcified nodule remain to be clarified.

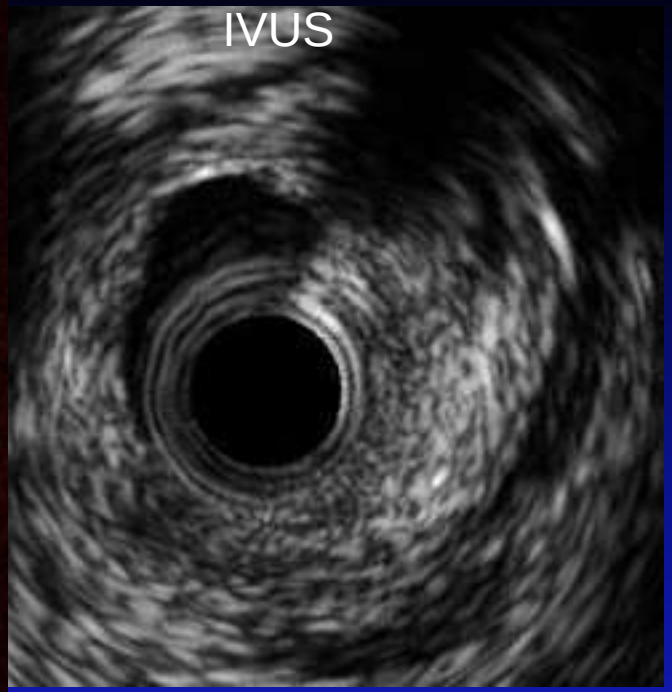
Calcified Nodule as Detected by OCT

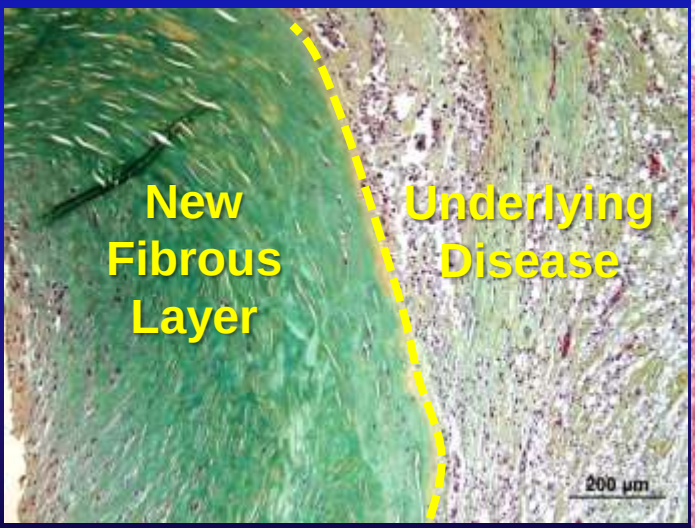


Karanasos A, et al. JACC: Cardiovascular Imaging 2012;5:1071-1072

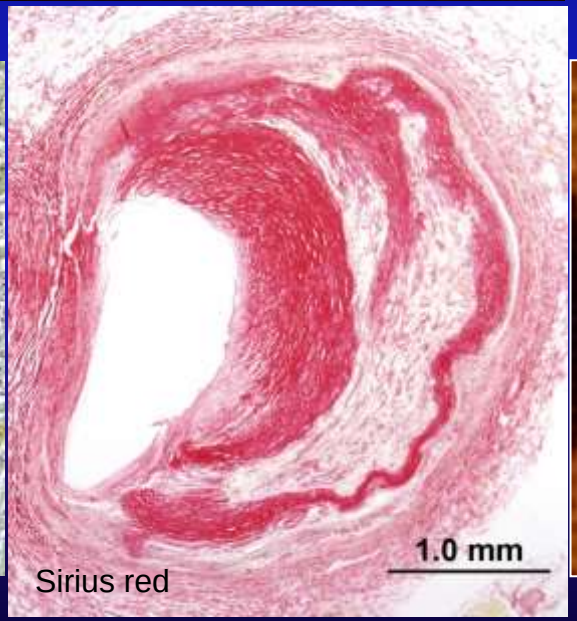
Healed Plaque Rupture and New Fibrous Cap

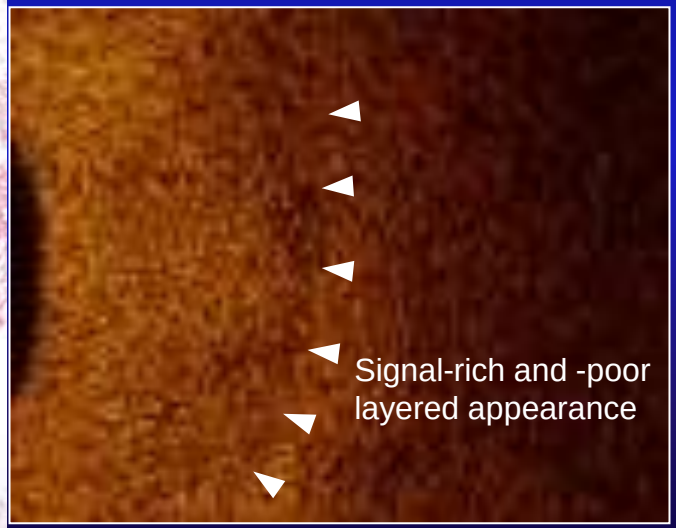




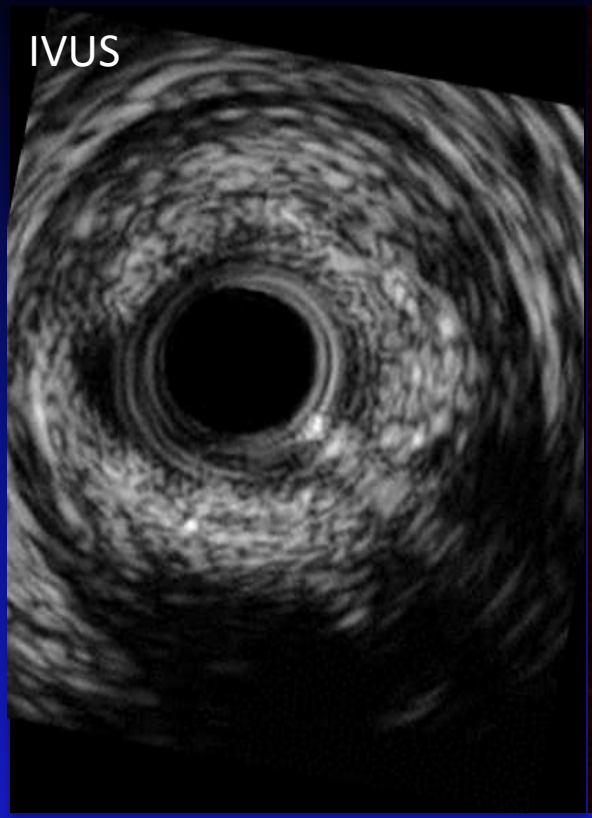


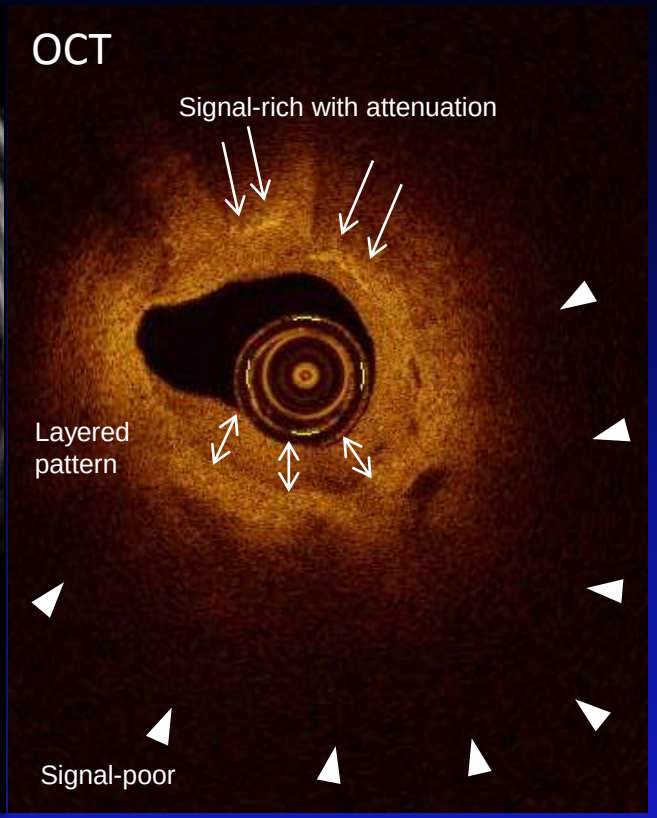
NC=necrotic core

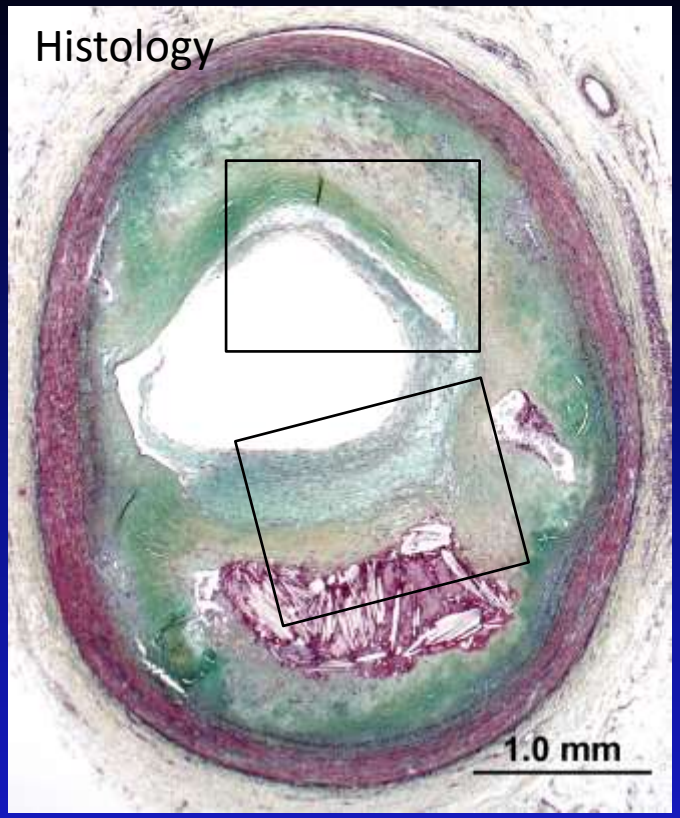


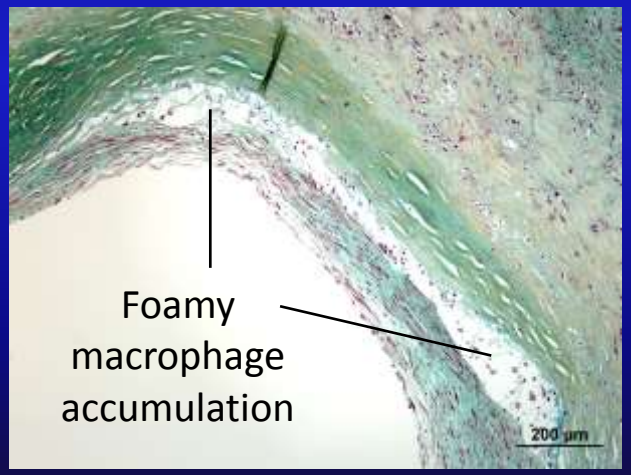


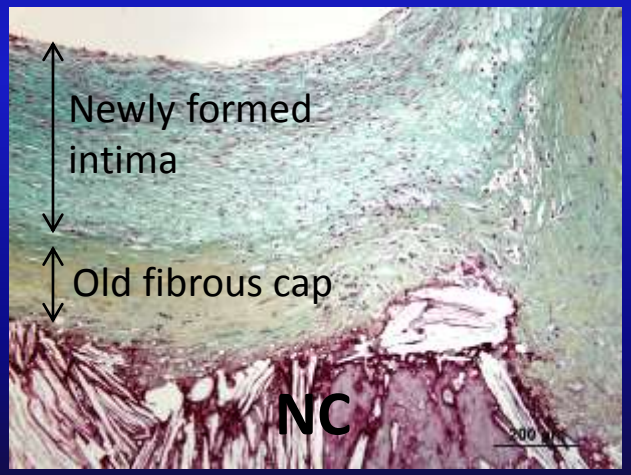
Healed Plaque Rupture

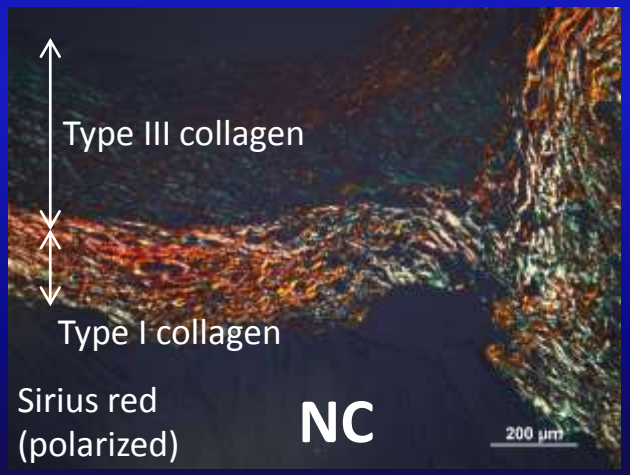






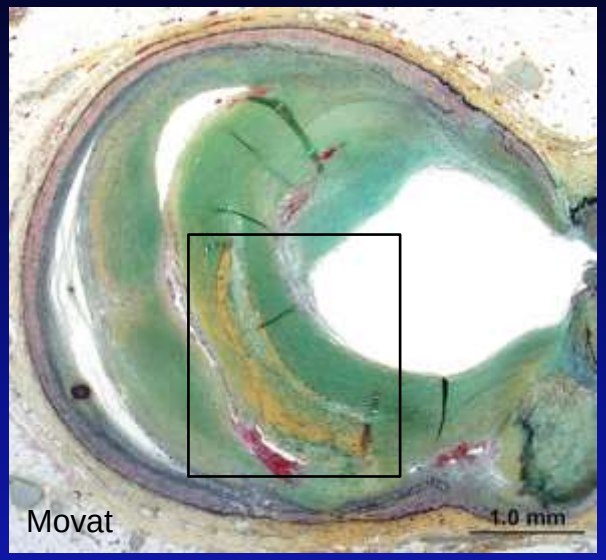




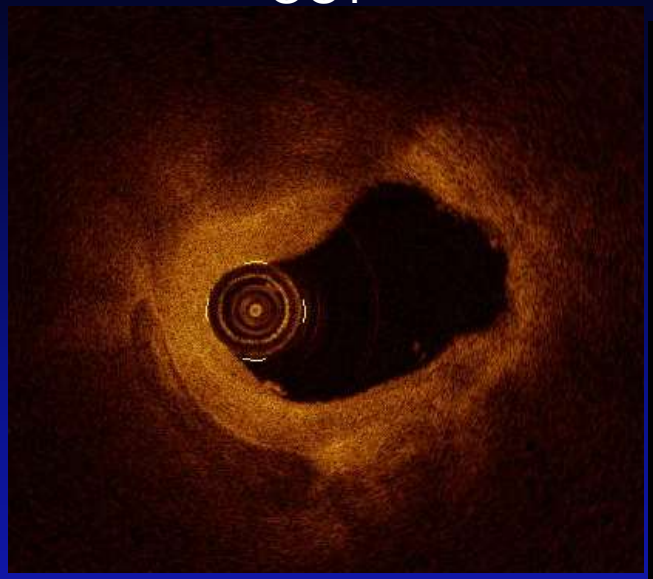


Fibrocalcific Plaque

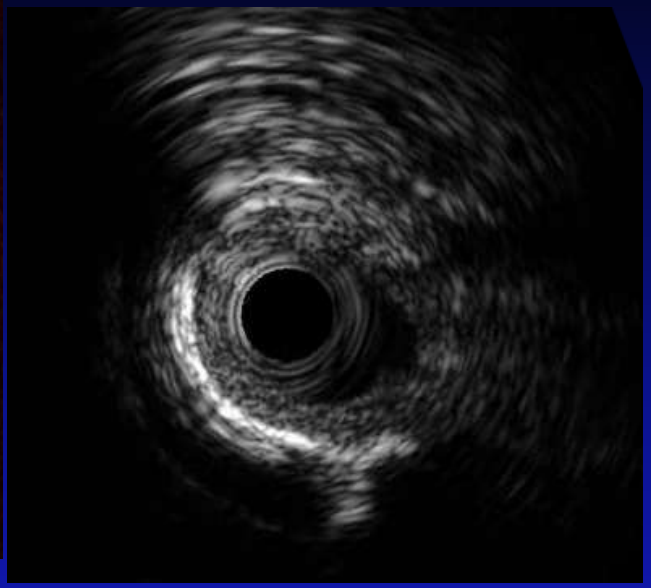
Histology

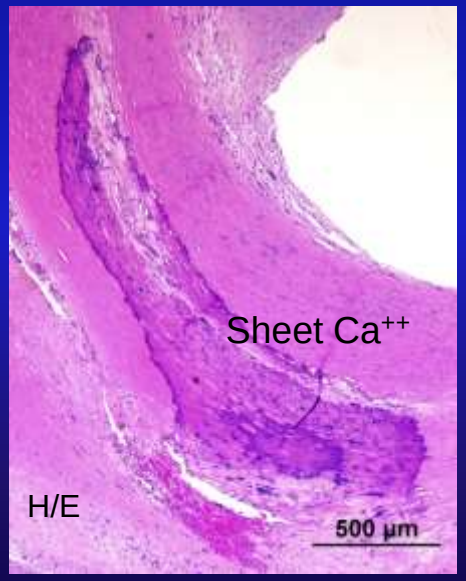


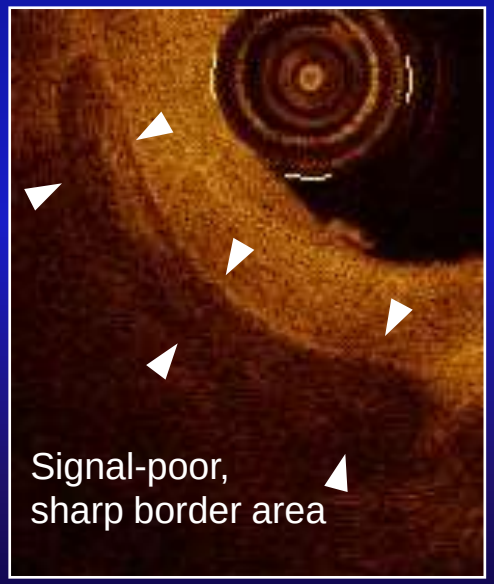
OCT

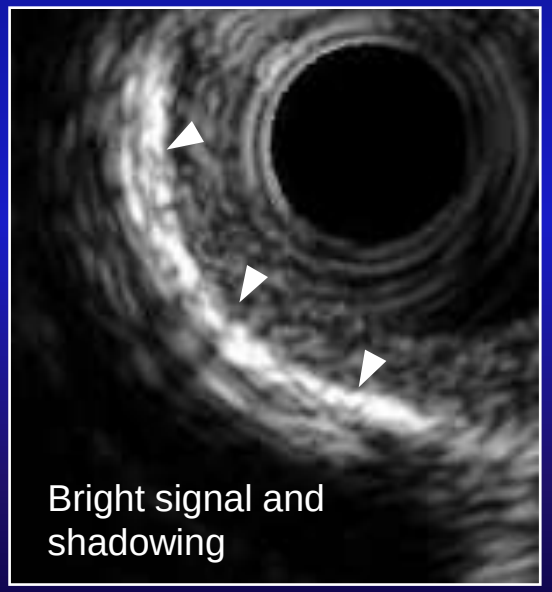


IVUS

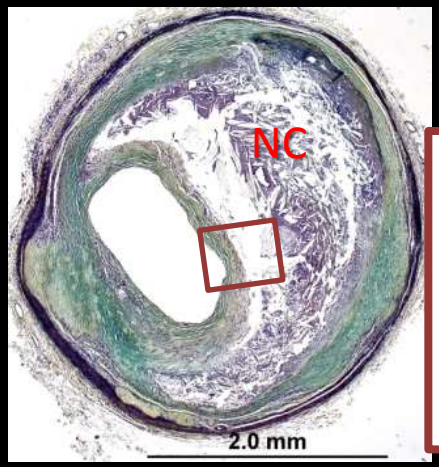


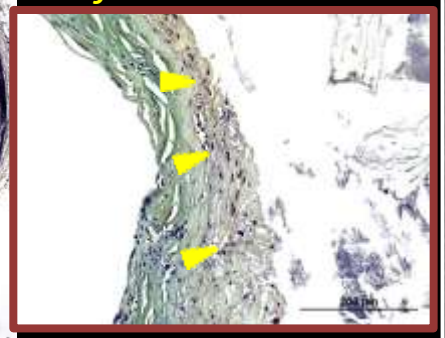


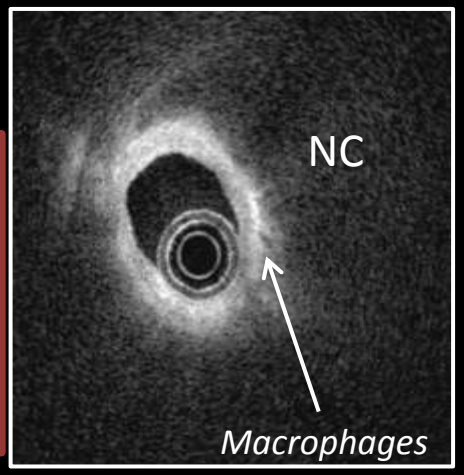


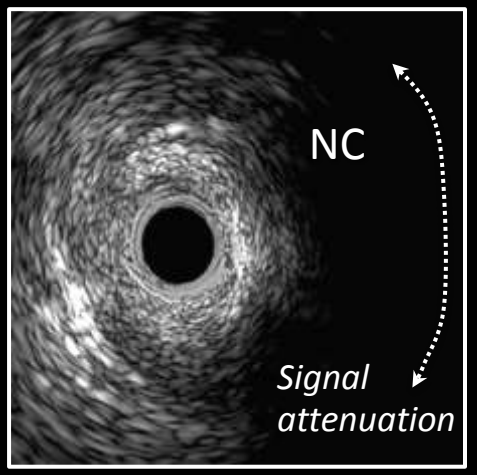


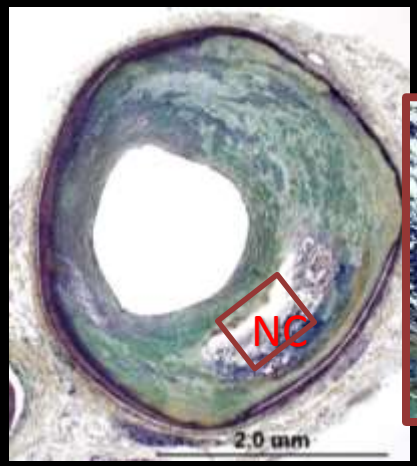
OFDI Can Detect Macrophage and Cholesterol Crystal

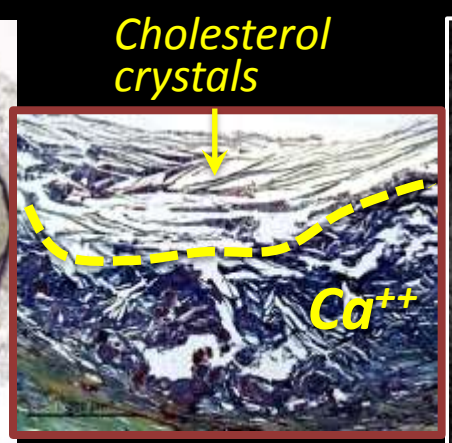


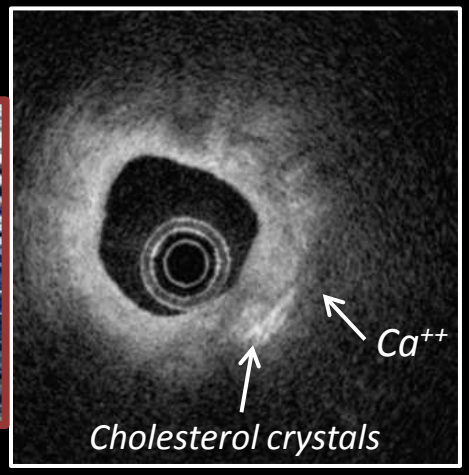


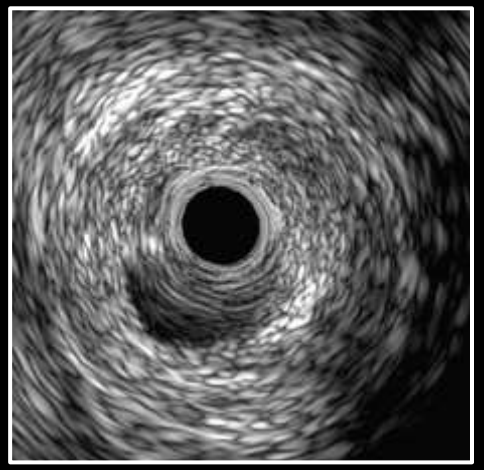




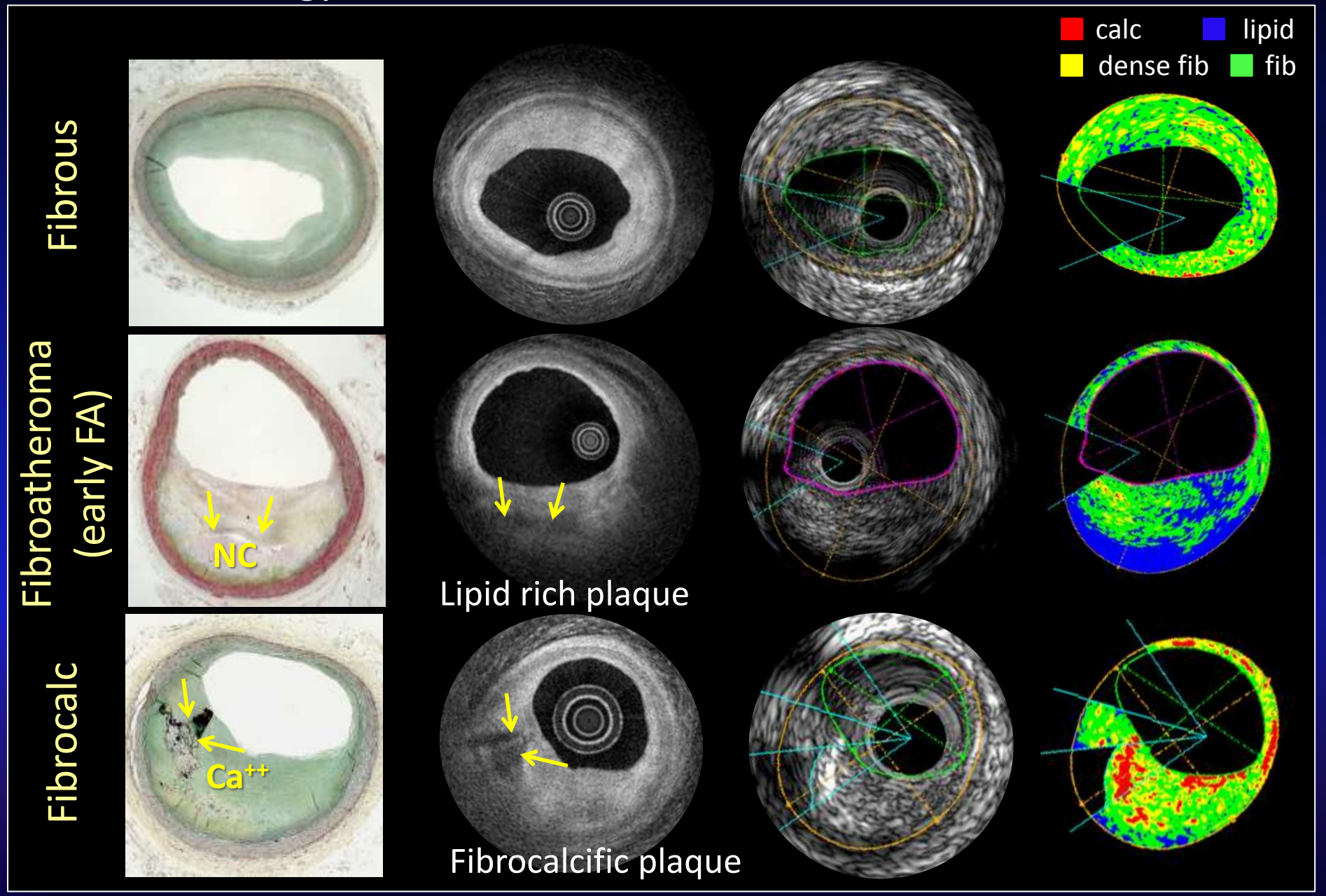








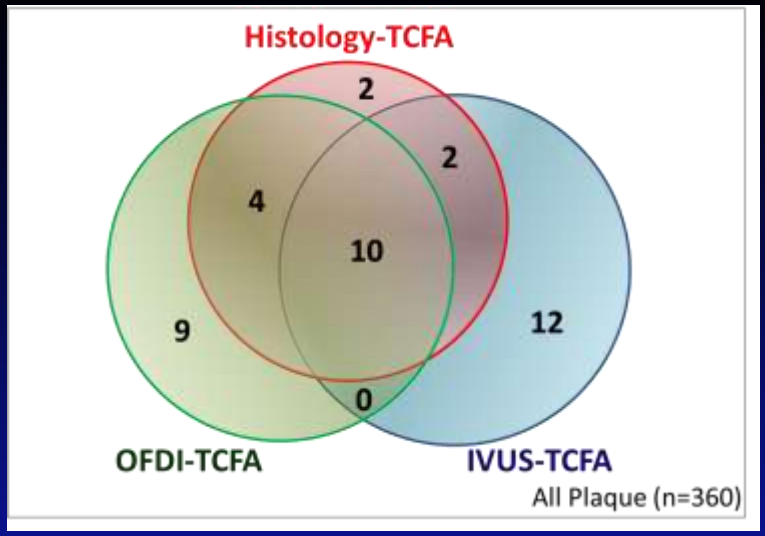
Terumo OFDI Study: Co-registration with Histology



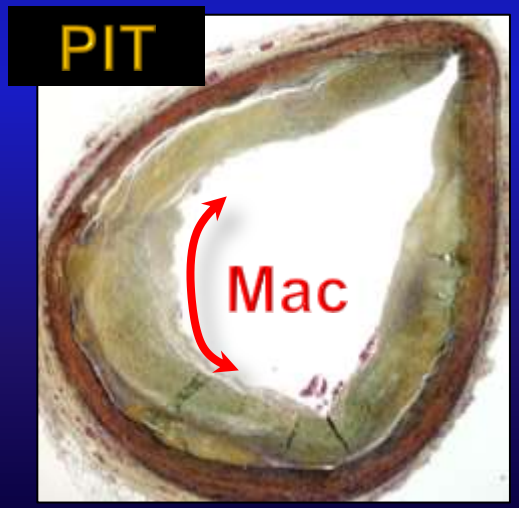
Detection of Plaque Morphology by OFDI

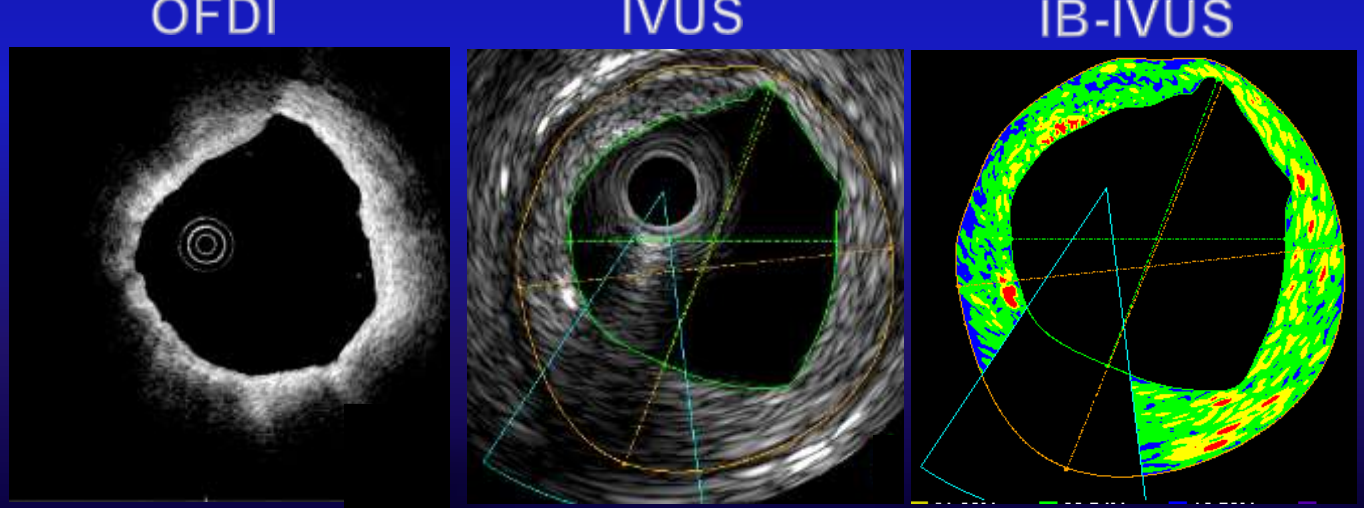
360 histologic cross-sections from 27 human coronary arteries

		OFDI			
		Fib	Lipid	TCFA	Fibrocalc
Histology	Fib	85	0	0	2
	PIT	66	39	**3**	17
	Th-FA	4	60	**5**	2
	TCFA	1	2	14	1
	Fibrocalc	0	11	1	47



TCFA detection	PPV (95% CI)	NPV (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	Diagnostic accuracy
OFDI alone	60.9% (38.8 - 79.5%)	98.8% (96.8 - 99.6%)	77.8% (51.9 - 92.6%)	97.4% (94.9 - 98.7%)	96.4%
IB-IVUS alone	50.0% (29.6 - 70.4%)	98.2% (96.0 - 99.3%)	66.7% (41.1 - 85.6%)	96.5% (93.8 - 98.1%)	95.0%
Combination of OFDI and IB-IVUS	**100.0% (65.5 - 100.0%)**	97.7% (95.4- 98.9%)	55.6% (31.3 - 77.6%)	100.0% (98.6 - 100.0%)	97.8%





Summary: What we cannot see with current imaging

OCT/OFDI provides high resolution images and is considered to be the best tool in identifying detailed structures of coronary plaques.

◎ Well identified
○ Identified with limitation
△ May not be identified

➢ Coronary thrombosis

◎ Plaque rupture
○ Erosion
○ Calcified nodule (△ Nodular calcification)

} The precursor lesions remain to be determined.

➢ Plaque progression

△ Lipid pool (PIT) vs. necrotic core (fibroatheromas)
○ Extracellular matrix (collagen, proteoglycan etc.)
◎ Foamy macrophages
○ TCFA (but need to differentiate it from superficial macrophages and TSD)
△ Intraplaque hemorrhage
○~△ Healed rupture
△ Macrophage subtype
△ Smooth muscle cell phenotype

➢ Vascular responses to stents

◎ Strut coverage and apposition
○ Hypersensitivity reaction
○~△ Fibrin deposition
○~△ Organized thrombus
○ In-stent neoatherosclerosis (macrophages, necrotic core)
△ Regenerated endothelium

Further innovation is definitely needed!

CVPath

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