



IVUS Virtual Histology

Listening through Walls

D. Geoffrey Vince, PhD

The Cleveland Clinic Foundation

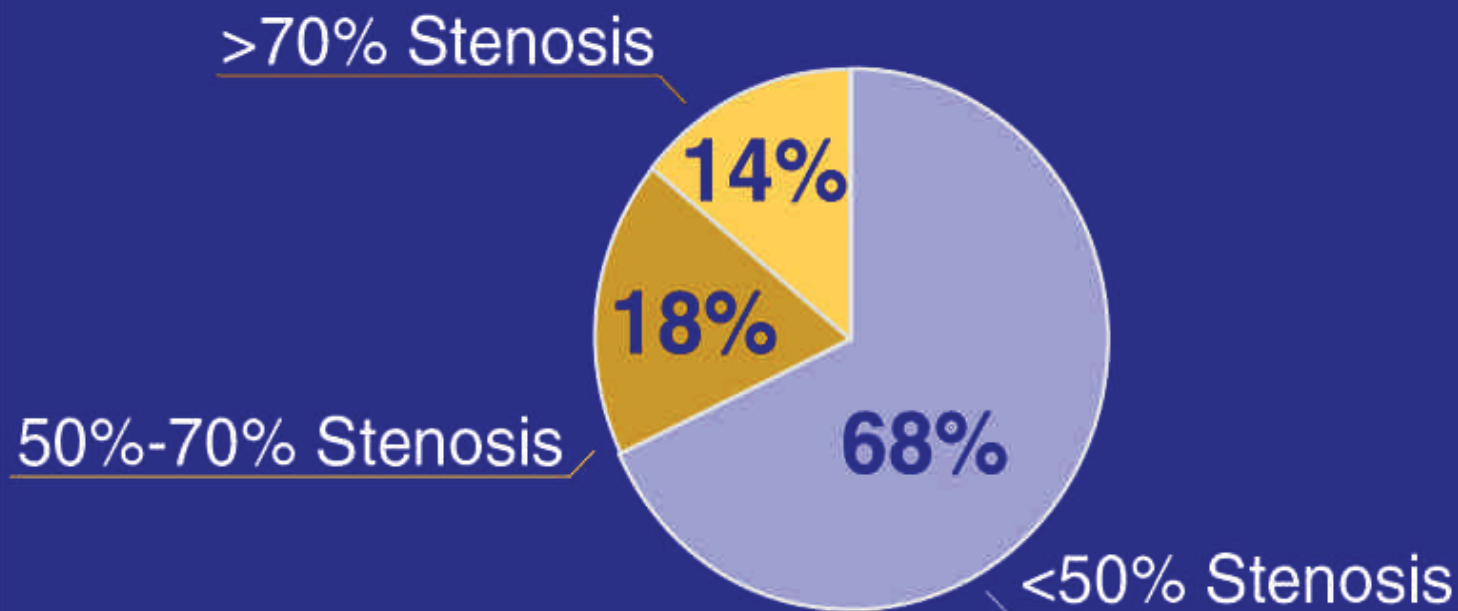
Disclosure

- VH is licenced to Volcano Therapeutics
- Grant funding from Pfizer, Inc.
- Grant funding from Boston-Scientific



Most Myocardial Infarctions are Caused by Low-Grade Stenoses

Coronary stenosis severity prior to MI



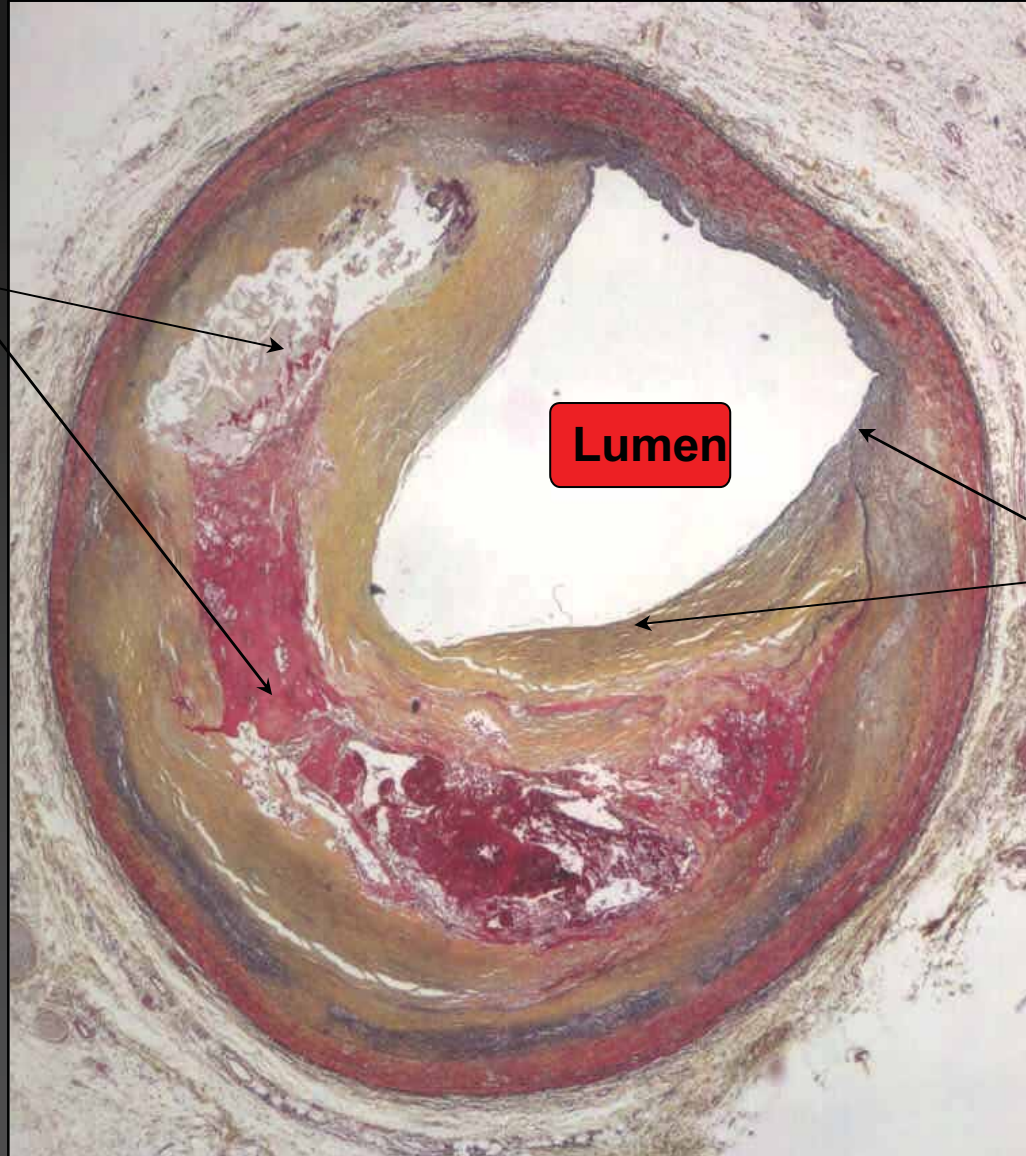
Pooled data from 4 studies: Ambrose et al, 1988; Little et al, 1988; Nobuyoshi et al, 1991; and Giroud et al, 1992. (Adapted from Falk et al. Coronary Plaque Disruption *Circulation* 1995;92:657-671)

The “Vulnerable” Coronary Plaque

Necrotic core

Lumen

Fibrous Cap

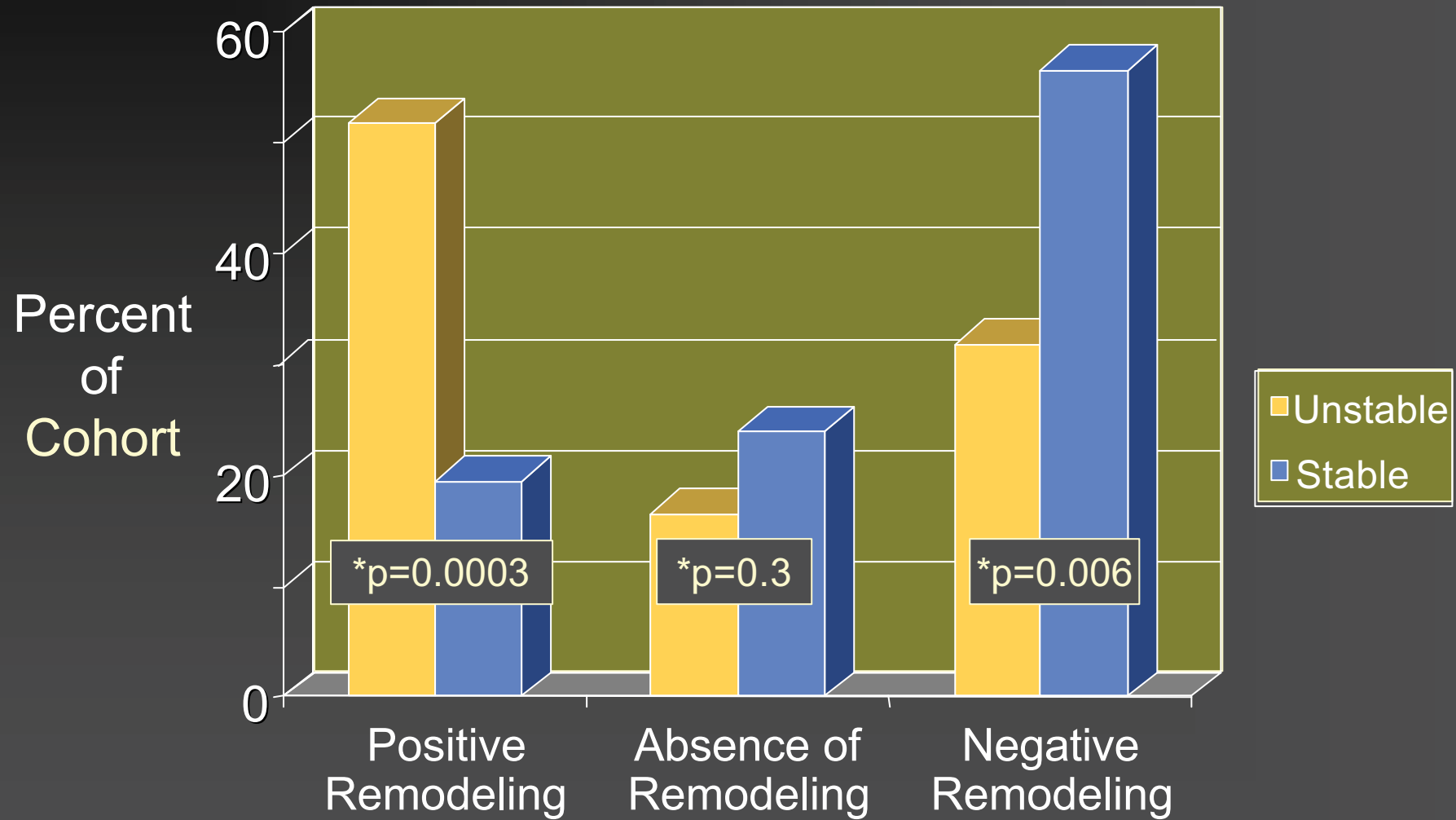


Remodeling and Plaque Vulnerability

- The association between positive arterial remodeling and plaque vulnerability has been demonstrated in vitro and with in-vivo intravascular ultrasound studies.
 - Varnava AM, Mills PG, Davies MJ. Relationship between coronary artery remodeling and plaque vulnerability. *Circulation* 2002;105:939-943
 - Burke AP, Kolodgie FD, Farb A, Weber D, Virmani R. Morphological predictors of arterial remodeling in coronary atherosclerosis. *Circulation* 2002;105:297-303
 - Pasterkamp G, Schoneveld AH, van der Wal AC, Haudenschild CC, Clarijs RJ, Becker AE, Hillen B, Borst C. Relation of arterial geometry to luminal narrowing and histologic markers for plaque vulnerability: The remodeling paradox. *J Am Coll Cardiol* 1998;32:655-62
 - Schoenhagen P, Ziada KM, Kapadia SR, Crowe TD, Nissen SE, Tuzcu EM. Extent and direction of arterial remodeling in stable and unstable coronary syndromes. *Circulation* 2000;101:598-603
 - Yamagishi M, Terashima M, Awano K, et al. Morphology of vulnerable coronary plaque: Insights from follow-up of patients examined by intravascular ultrasound before and acute coronary syndrome. *J Am Coll Cardiol* 2000;35:106-111
 - Kim WY, Stuber M, Börnert P, Kissinger KV, Manning WJ, Botnar RM. Three-Dimensional Black-Blood Cardiac Magnetic Resonance Coronary Vessel Wall Imaging Detects Positive Arterial Remodeling in Patients With Nonsignificant Coronary Artery Disease. *Circulation* 2002;106:296-299



Direction of Remodeling and Clinical Presentation

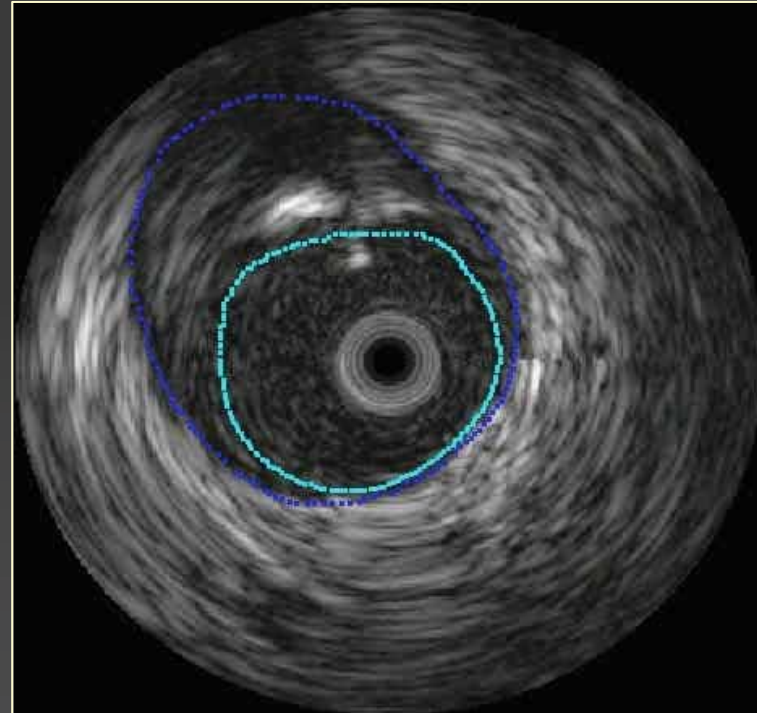
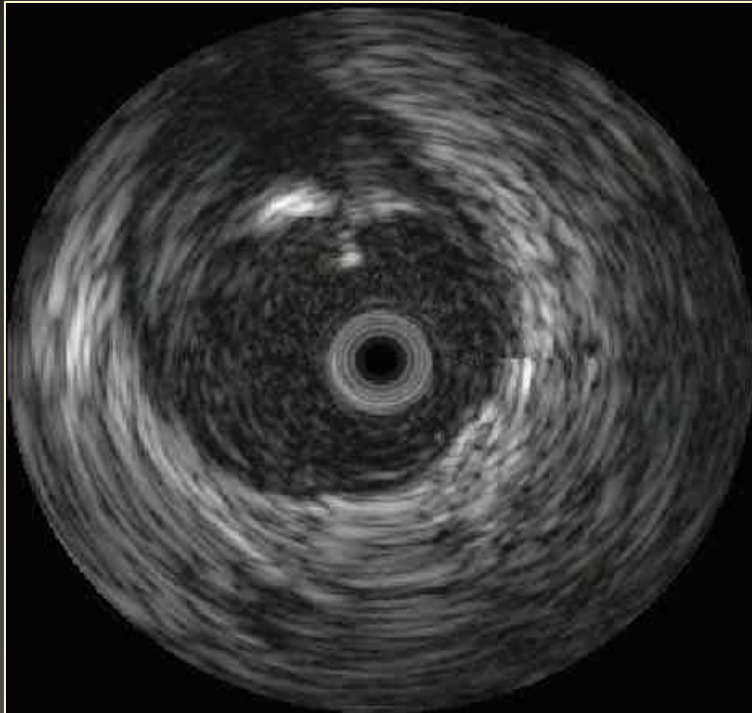


Vulnerable Plaques

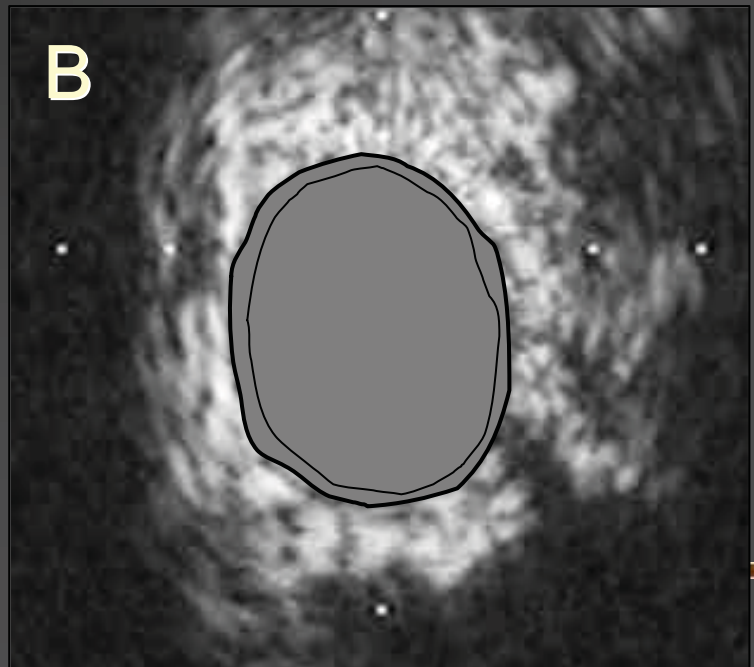
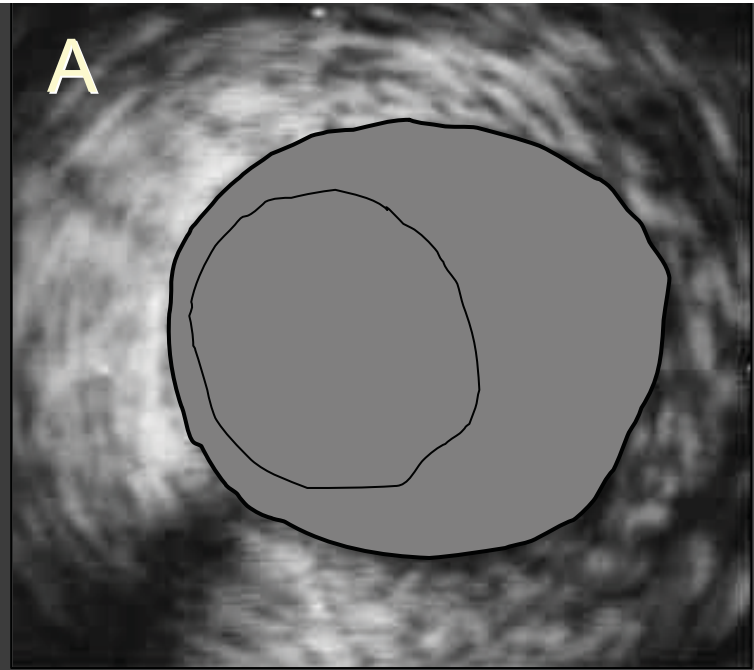
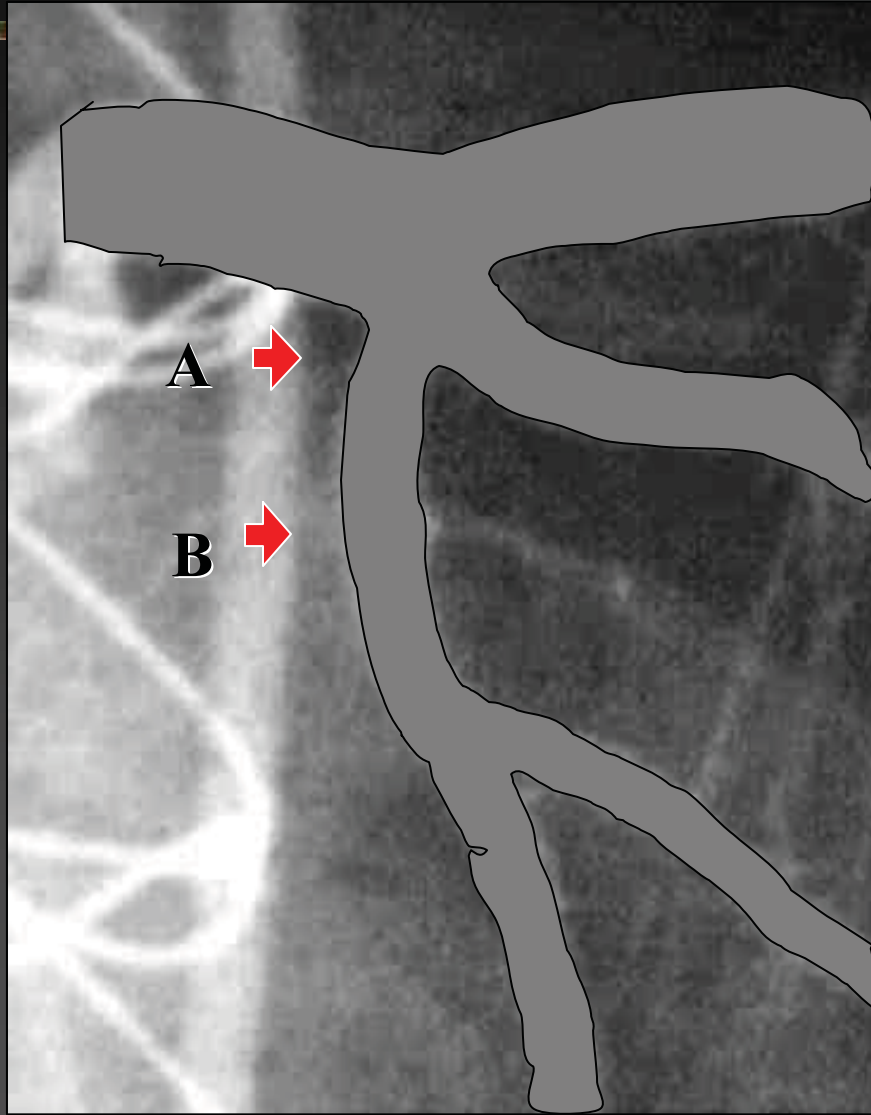
- Geometry and composition may play a role?
 - IVUS provides accurate geometry
 - Composition is a little more difficult



Intravascular Ultrasound



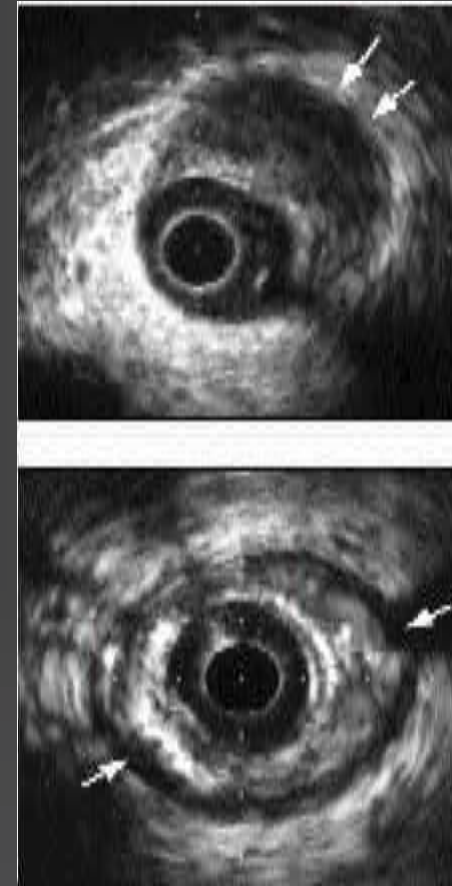
VUS



Echolucent vs Echogenic

Previous histological studies have demonstrated that the discrimination of lipid is inconsistent using video images alone.

- Palmer *et al.* Eur Heart J., 1999
- Peters *et al.* J Am Soc Echocardiogr., 1994
- Peters *et al.* Circulation, 1994

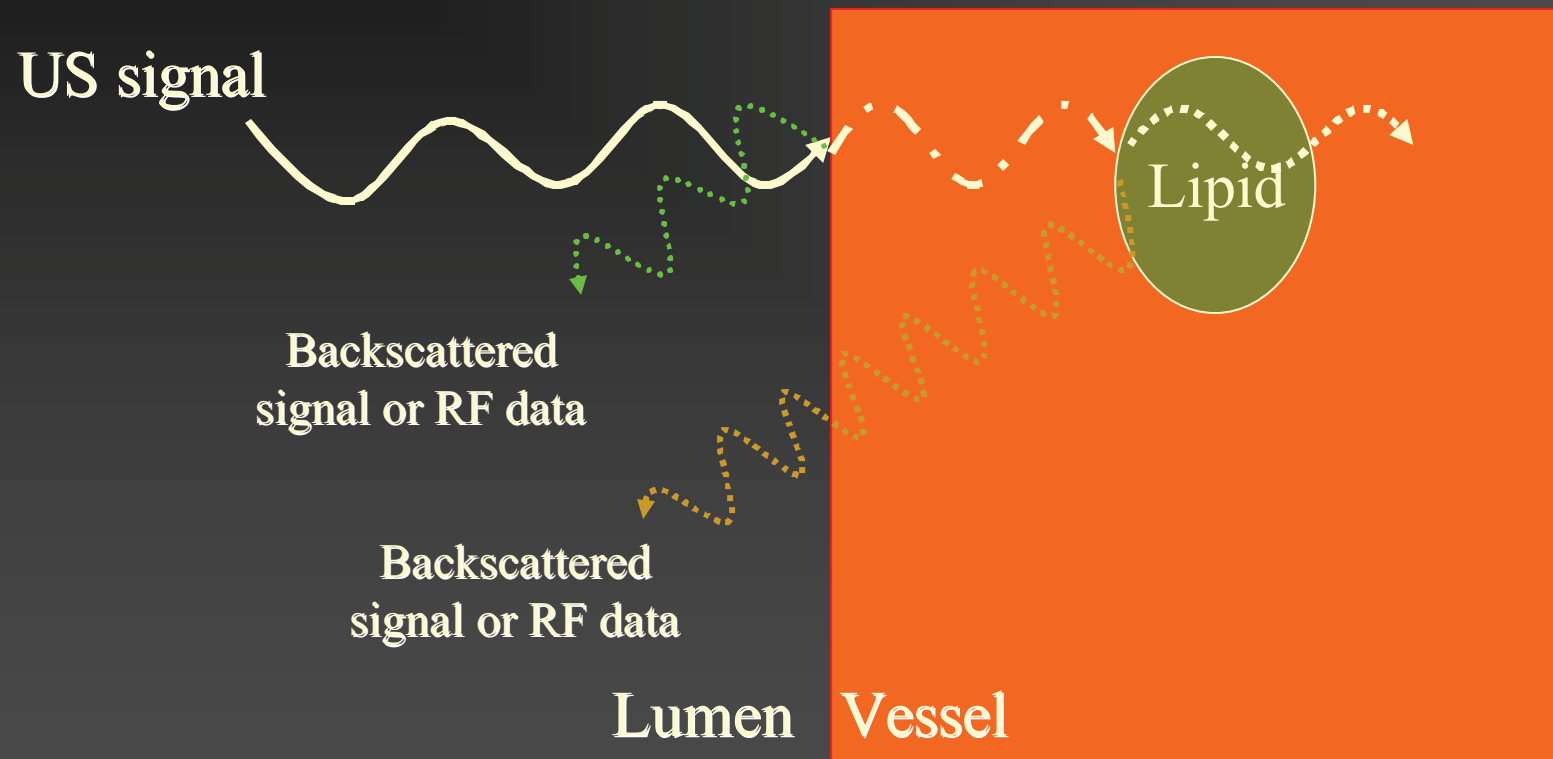


Images Courtesy of CCF IVUS Core Lab



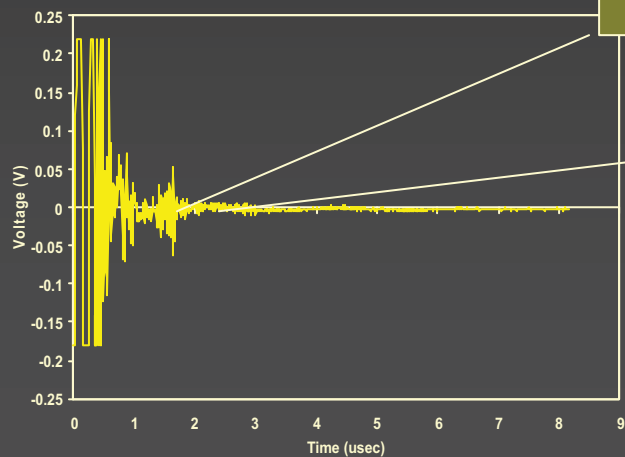
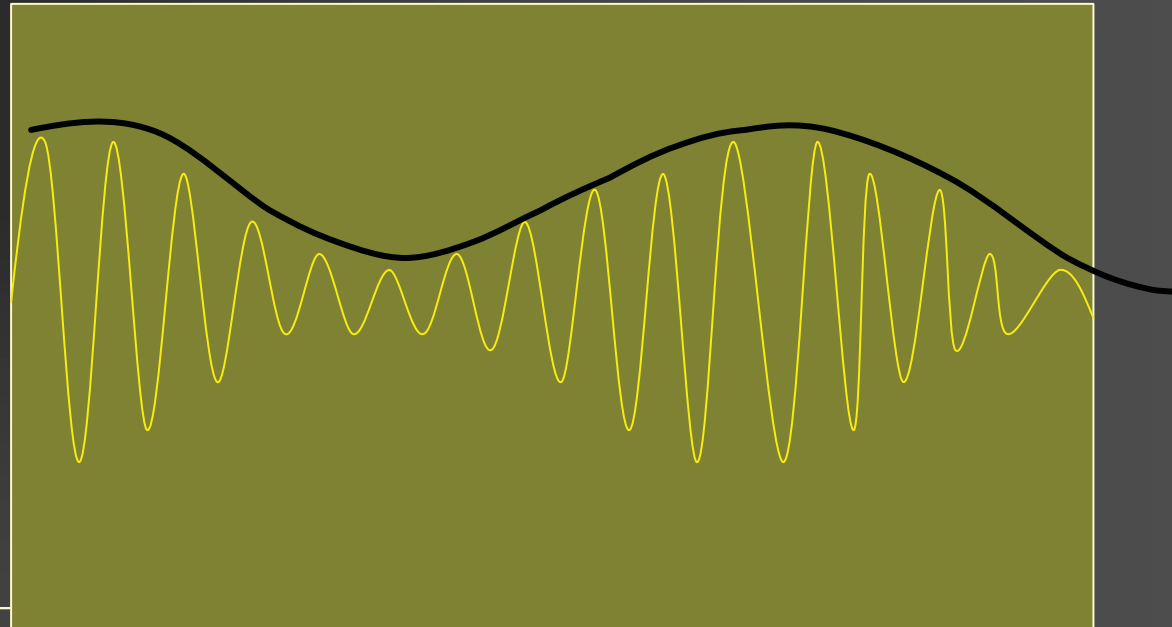
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IVUS – Listening through walls

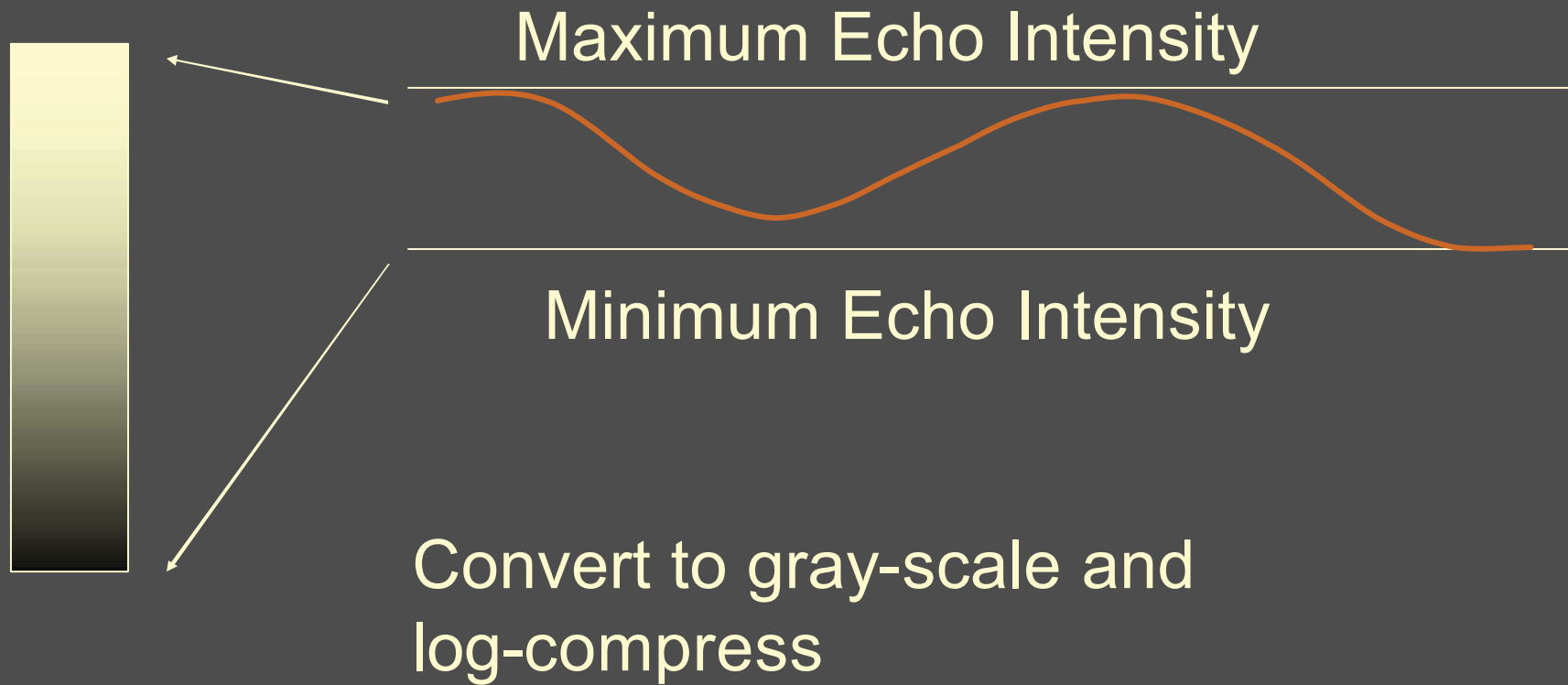


IVUS Image Formation

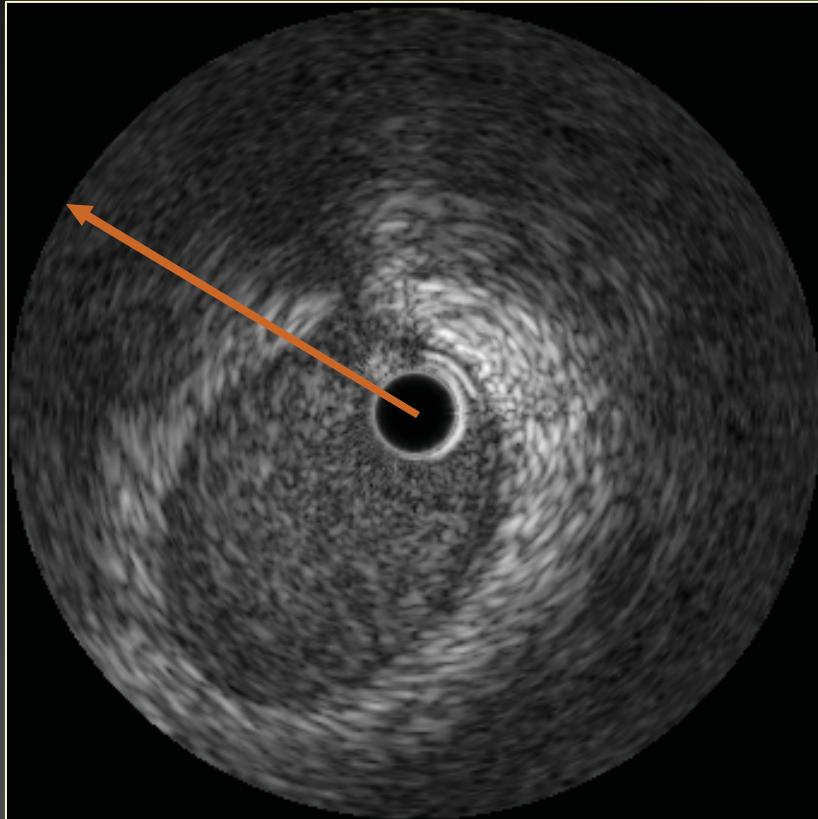
Envelope
Detection



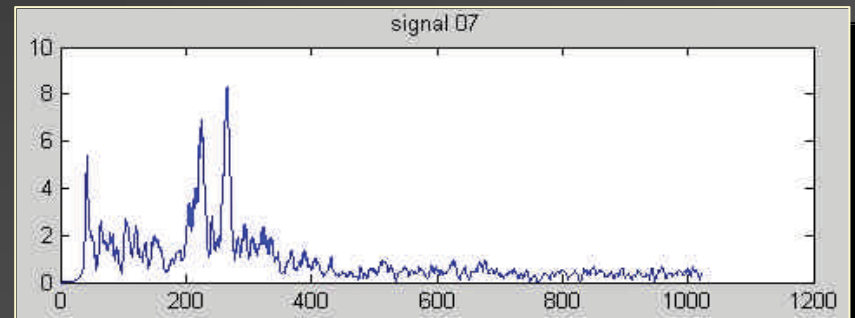
IVUS Image Formation



IVUS Image Formation



Echo intensity lines are scaled and scan converted via bilinear interpolation to make the ultrasonic image



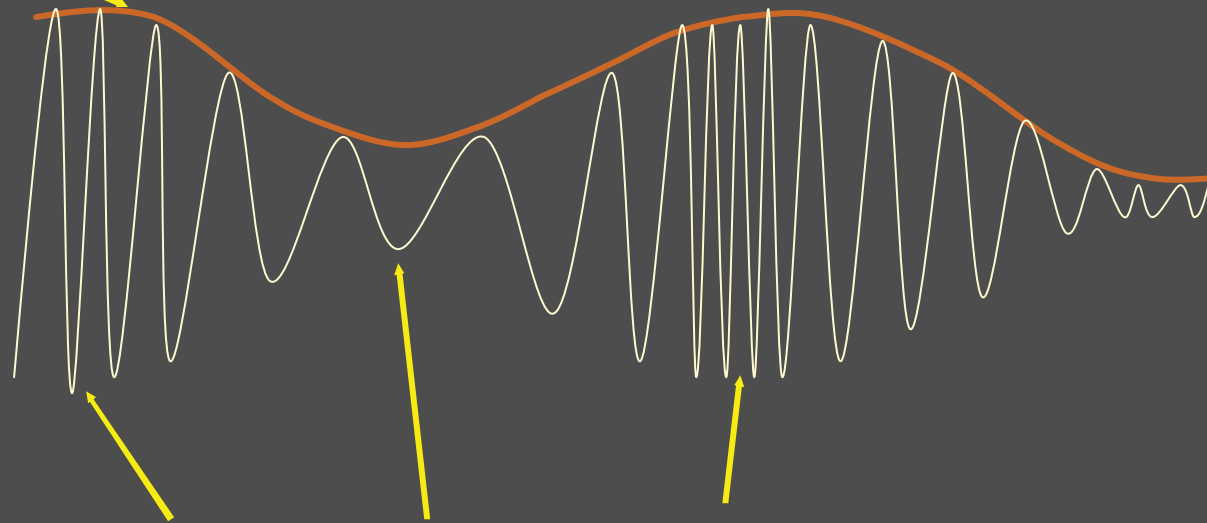
Echo
intensity



Virtual Histology™™ IVUS

Only the envelope amplitude (echo intensity) is used in formation of the gray-scale IVUS image

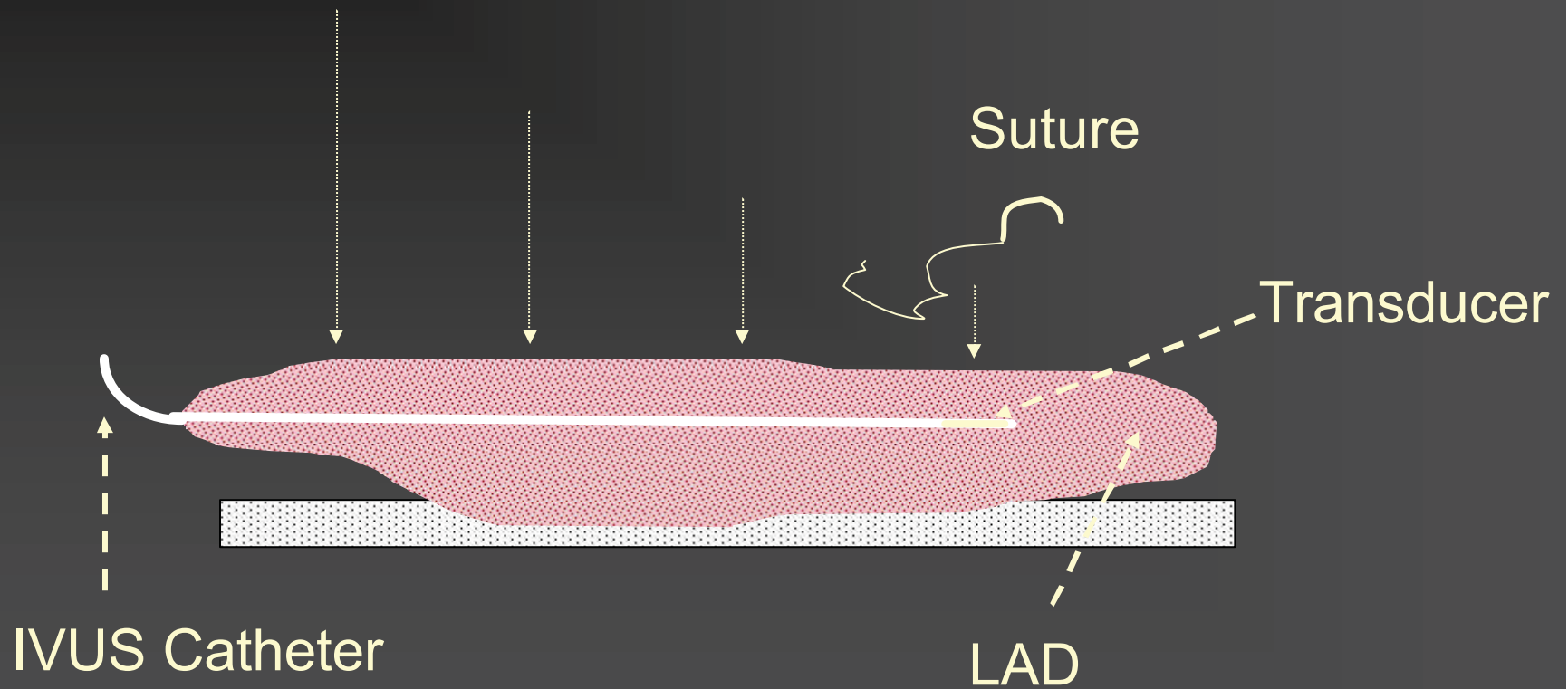
Amplitude AND
Frequency of
Echoes used in
Virtual Histology



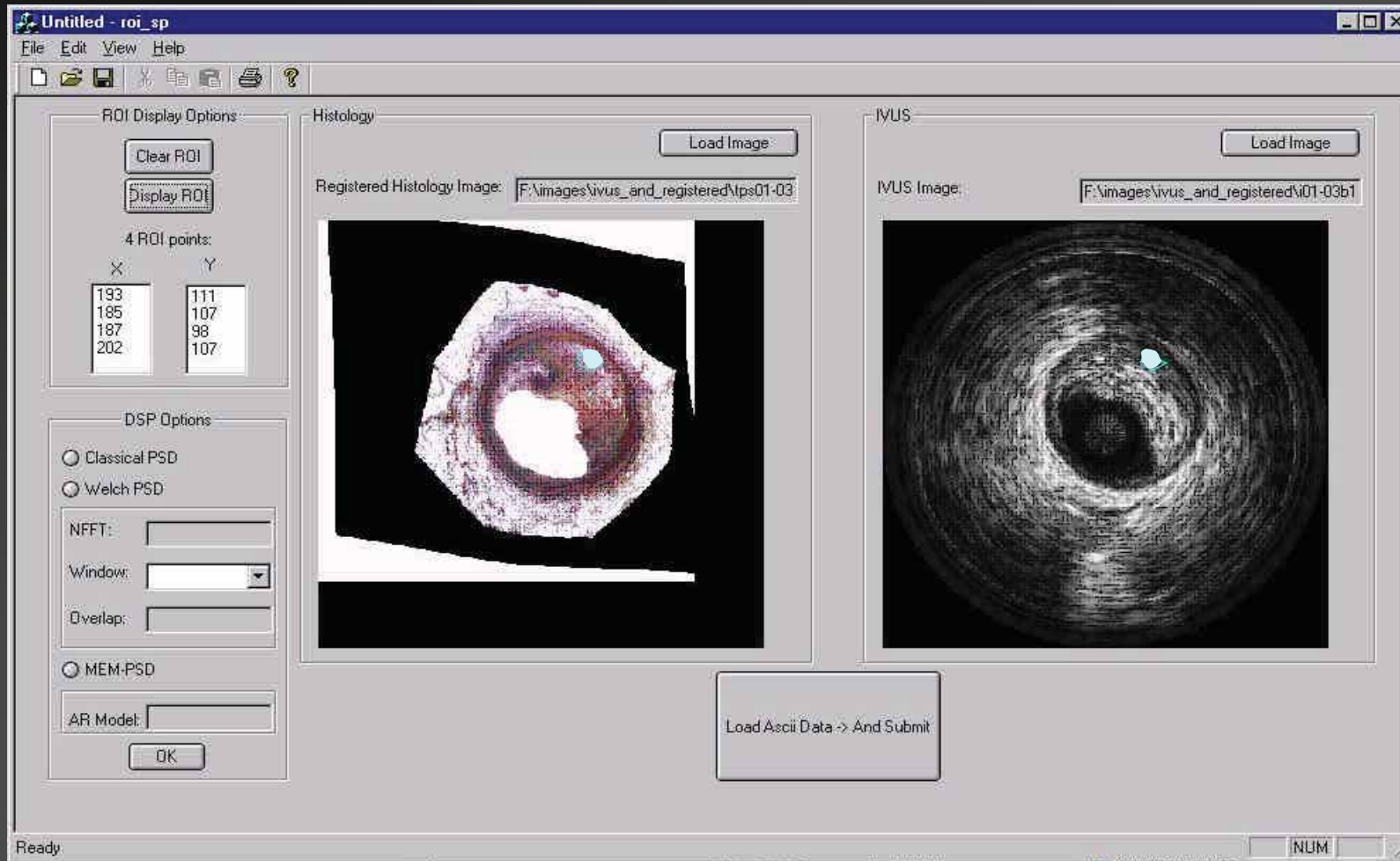
Frequency of echo signal can also vary, depending on the tissue



Data Collection



Teaching the Computer



Virtual Histology™ IVUS

- Do the different frequencies correspond to different types of tissue??
 - Calcium
 - Fibrous
 - Fibro-lipidic
 - Lipid core



Geometrical Measurements

- Number of Frames:
- Average Lumen Cross-Sectional Area:
- Average Vessel Cross-Sectional Area:
- Average Plaque+Media Cross-Sectional Area:
- Average Percent Occlusion:
- Lumen Volume:
- Vessel Volume:
- Plaque Volume:
- Frame Position
- For every frame:
 - Lumen Cross-Sectional Area
 - Lumen Perimeter Length
 - Lumen Maximum Diameter
 - Lumen Minimum Diameter
 - Lumen Eccentricity (Min/Max)
 - Plaque Cross-Sectional Area
 - Plaque Maximum Thickness
 - Plaque Minimum Thickness
 - Plaque Eccentricity (Min/Max)
 - Percent Occlusion
 - **Remodelling Index**
 - And more!!

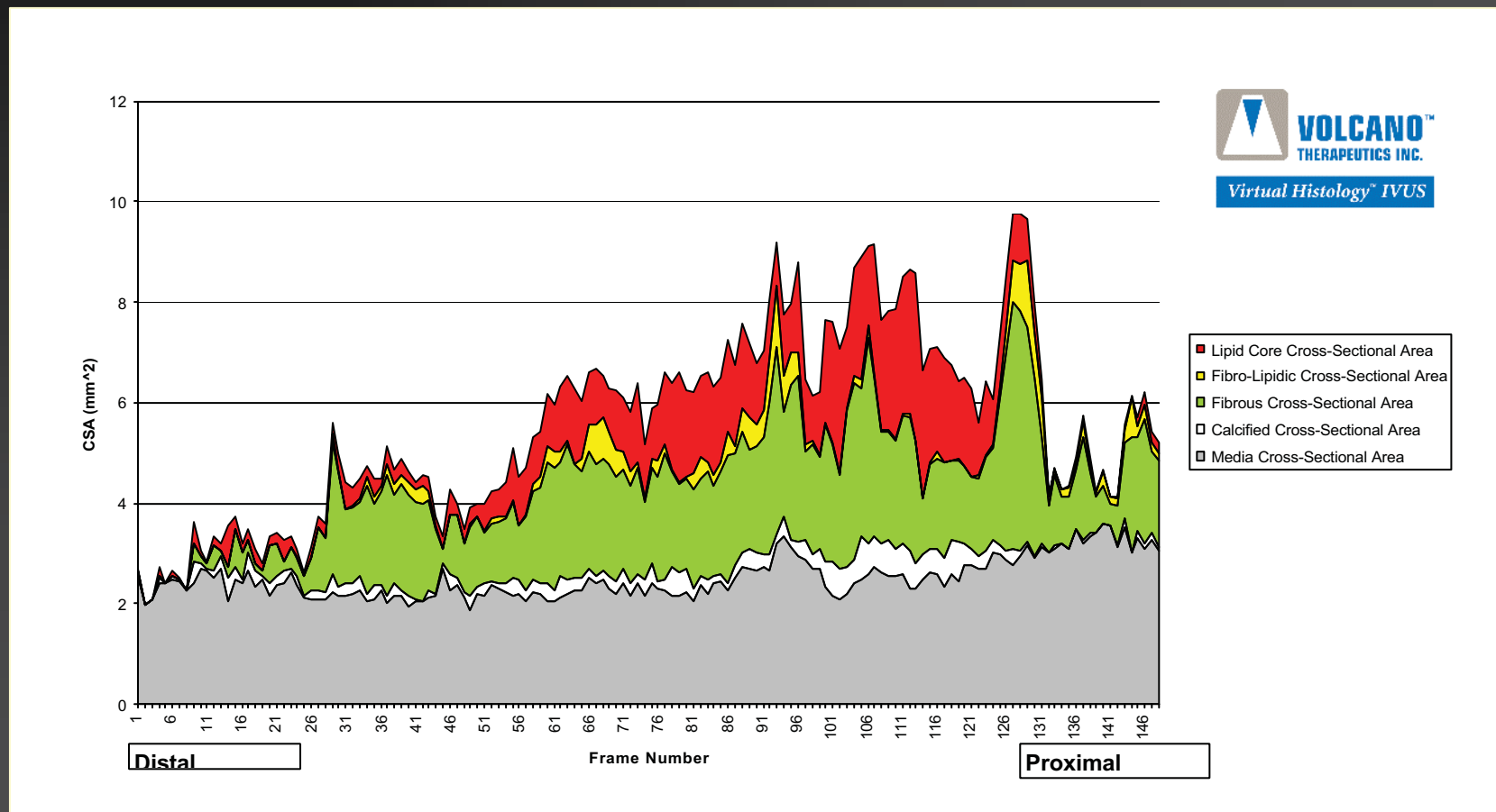


Compositional Measurements

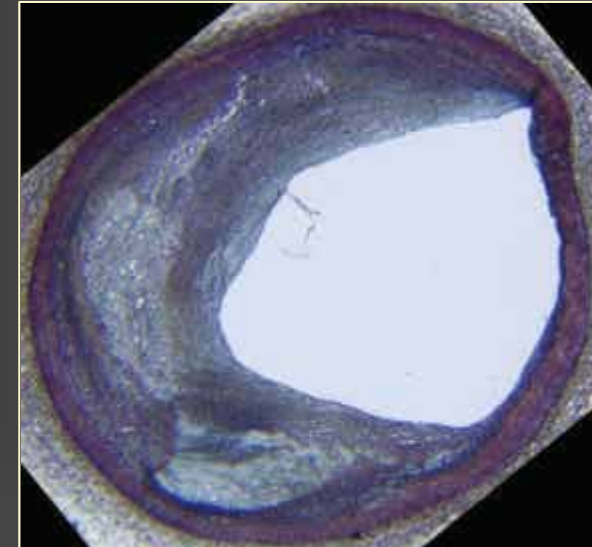
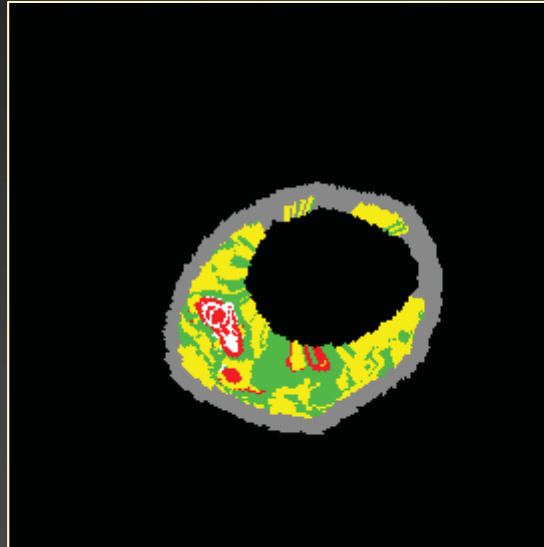
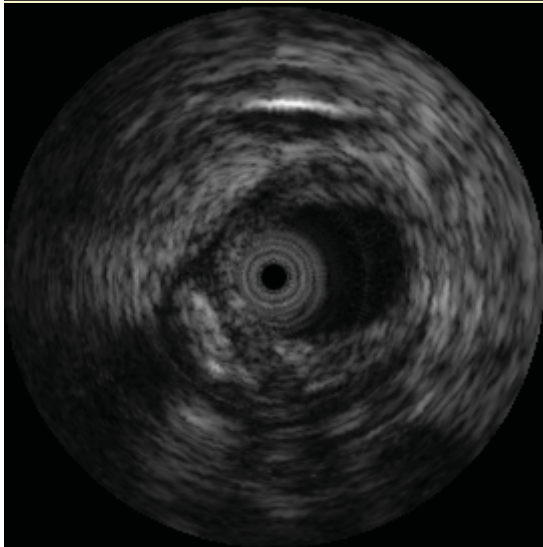
- Average Fibrous Cross-Sectional Area:
- Average Fibro-Lipidic Cross-Sectional Area:
- Average Calcified Cross-Sectional Area:
- Average Lipid Core Cross-Sectional Area:
- Average Media Cross-Sectional Area:
- Fibrous Volume:
- Fibro-Lipidic Volume:
- Calcified Volume:
- Lipid Core Volume:
- For every frame:
 - Calcified Cross-Sectional Area
 - Calcified %
 - Fibrous Cross-Sectional Area
 - Fibrous %
 - Fibro-Lipidic Cross-Sectional Area
 - Fibro-Lipidic %
 - Lipid Core Cross-Sectional Area
 - Lipid Core %



Volume Plots



Ex-Vivo Validation Virtual Histology™

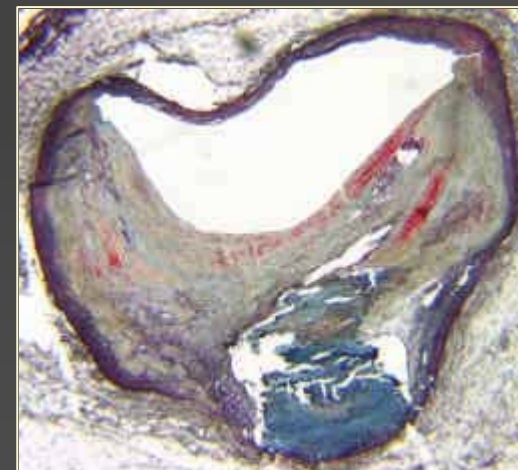
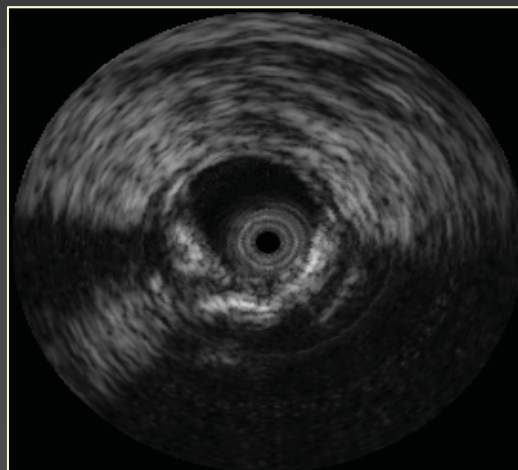


Fibrous; Fibro-lipidic; Lipidic-necrotic; Calcium



Ex-vivo validation

	Fibrous (n=101)	Fibro-Lipidic (n=56)	Calcified (n=50)	Lipidic-Necrotic (n=70)
VH Accuracy	79.7%	81.2%	89.5%	85.5%

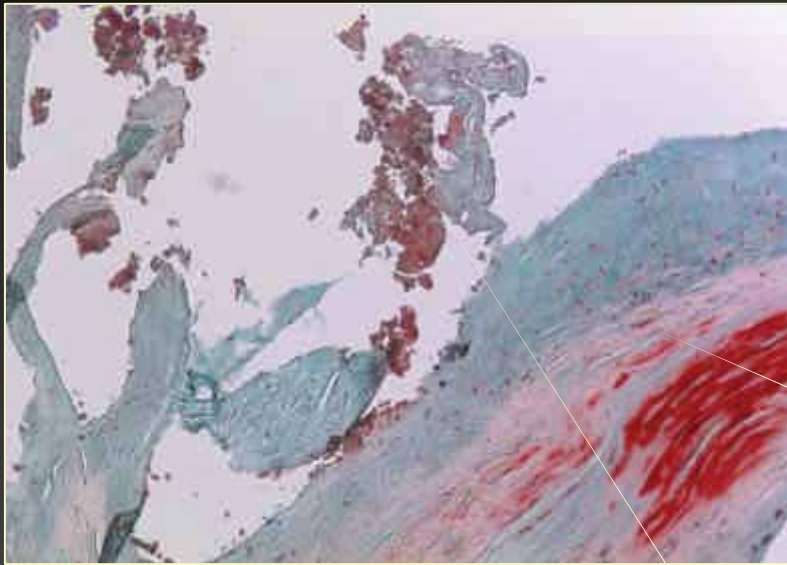


Accurate – *in vivo* validation

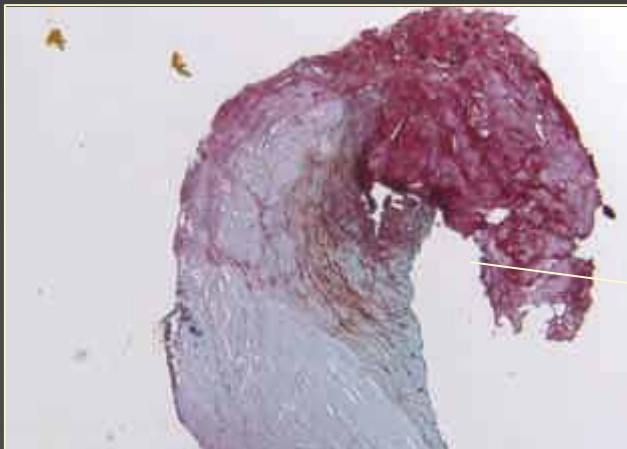
- Test accuracy of VH in patients
 - Dr Columbo, Italy
 - Drs Suzuki and Kato, Japan
- IVUS followed by DCA
 - Guidant flex-cut
 - Fox Hollow
- Histology
 - True “gold-standard”



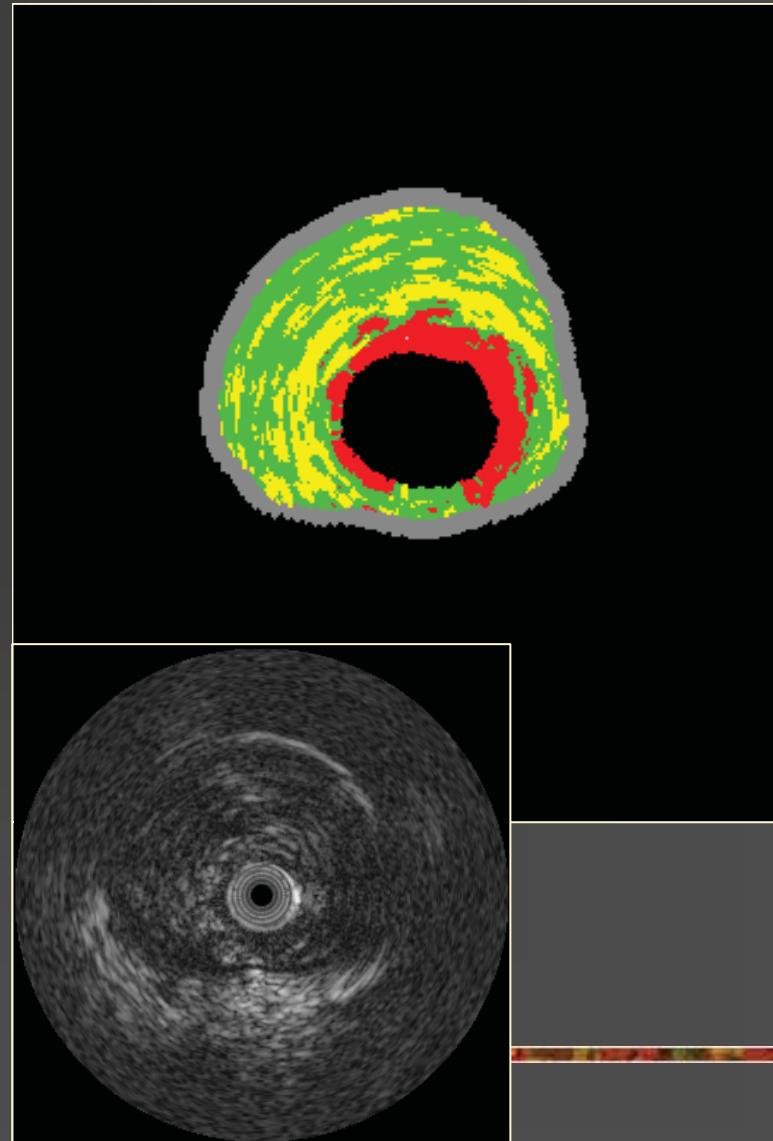
In vitro vs In vivo histo (ZC)



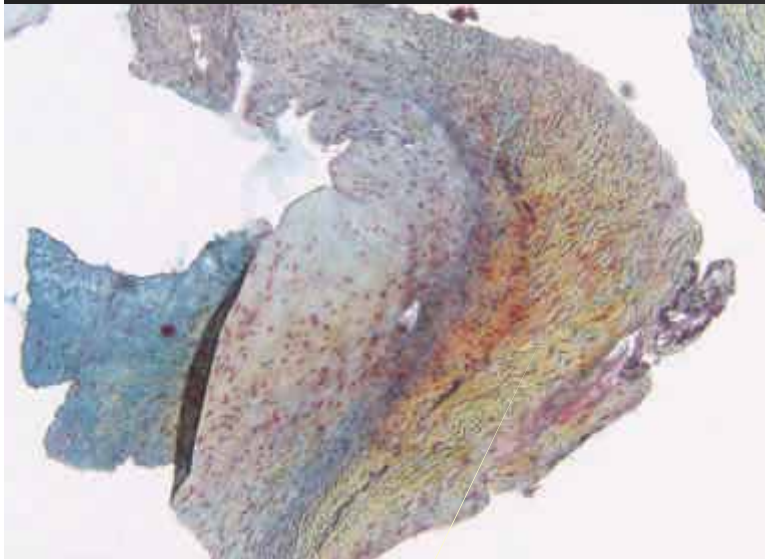
fibrous



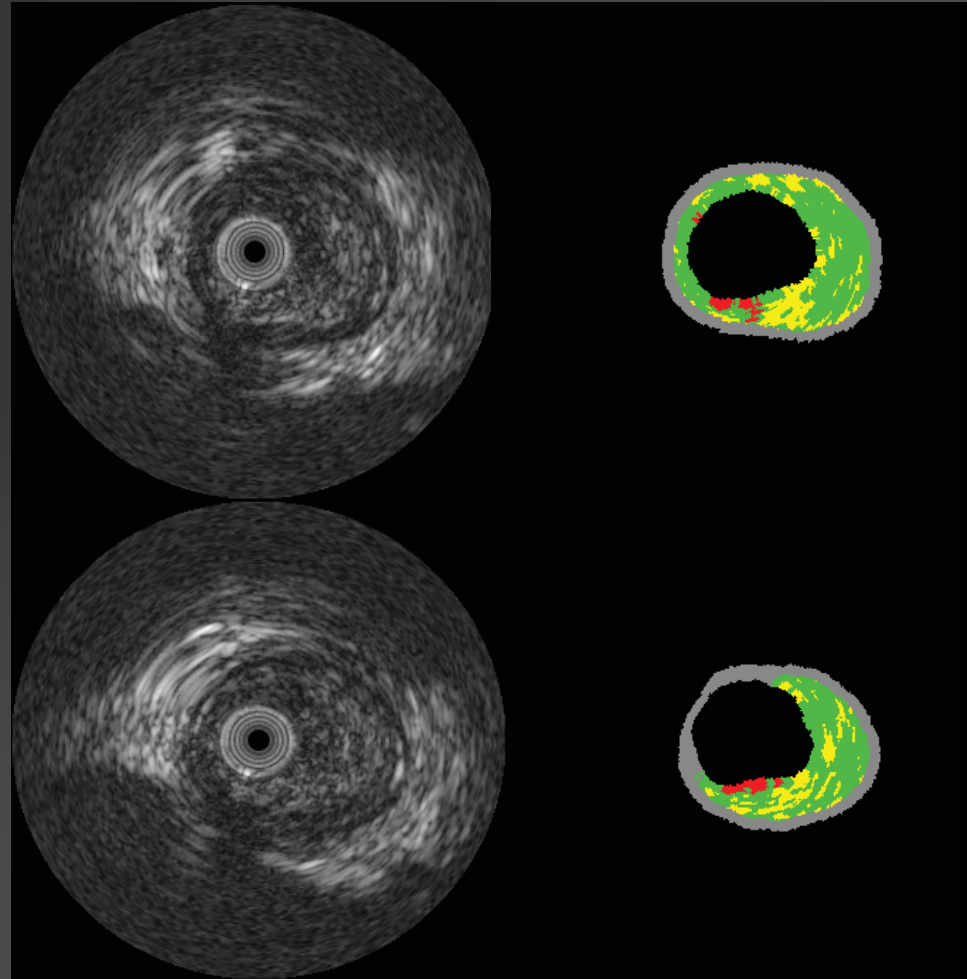
Lipidic
necrosis



In vitro vs in vivo histo (GB)

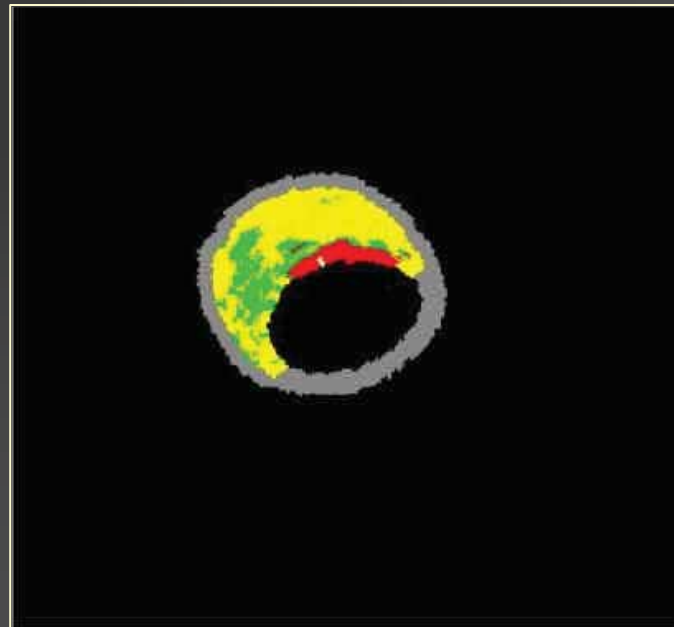
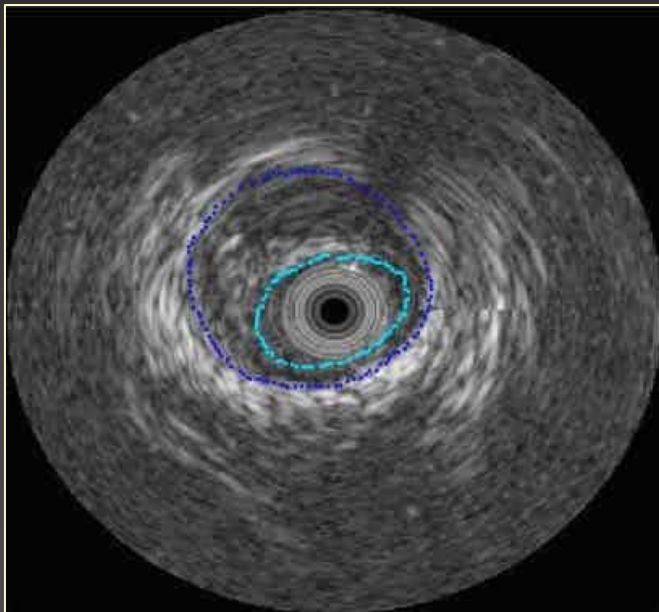


Fibrous



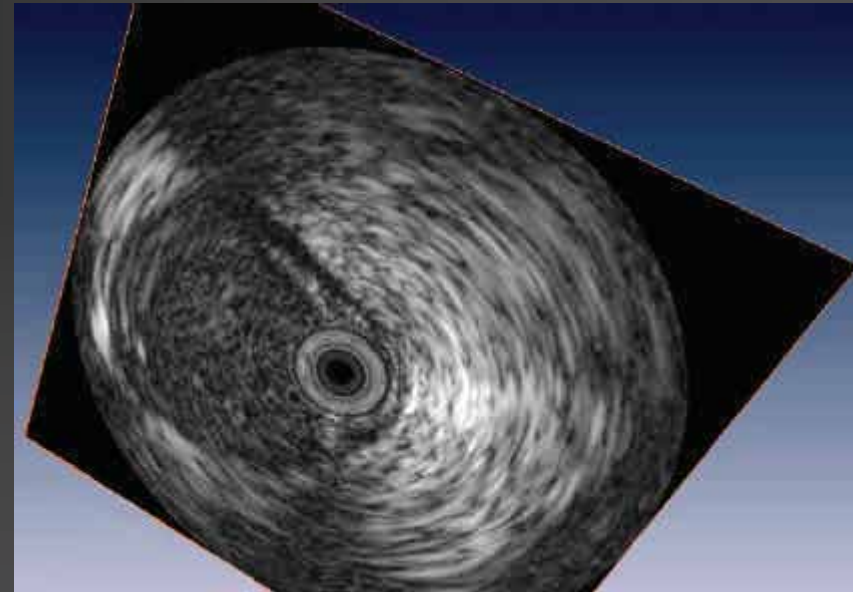
IVUSLab Analysis System

- Provides data on vessel geometry
- Provides Virtual Histology™



Future studies

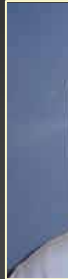
- VH built into IVUS system
 - EagleEye tree in Q2, 2004
 - “Real-time” capabilities
 - Automatic border detection
- Interface & Display



Team Cleveland



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D



BS
BS



cki, BEng
ekar, BS

