VH IVUS

D. Geoffrey Vince, PhD
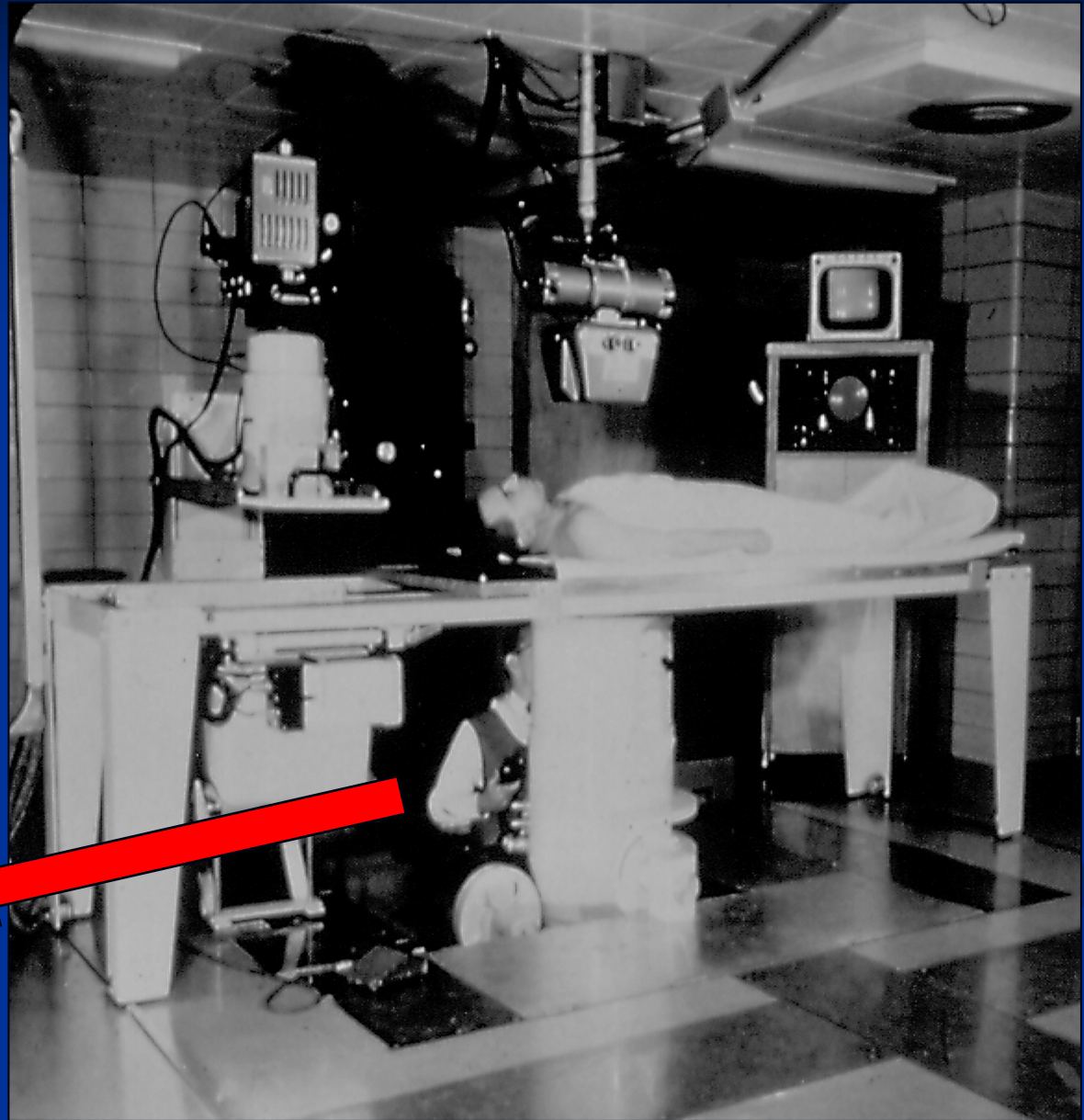
Seoul, Korea, 2005

Cleveland Clinic

- Biggest employer in Cleveland
- 33,000 employees
- 440 acres
    - 180 hectares
- Major cardiac centre

Selective Coronary Angiography
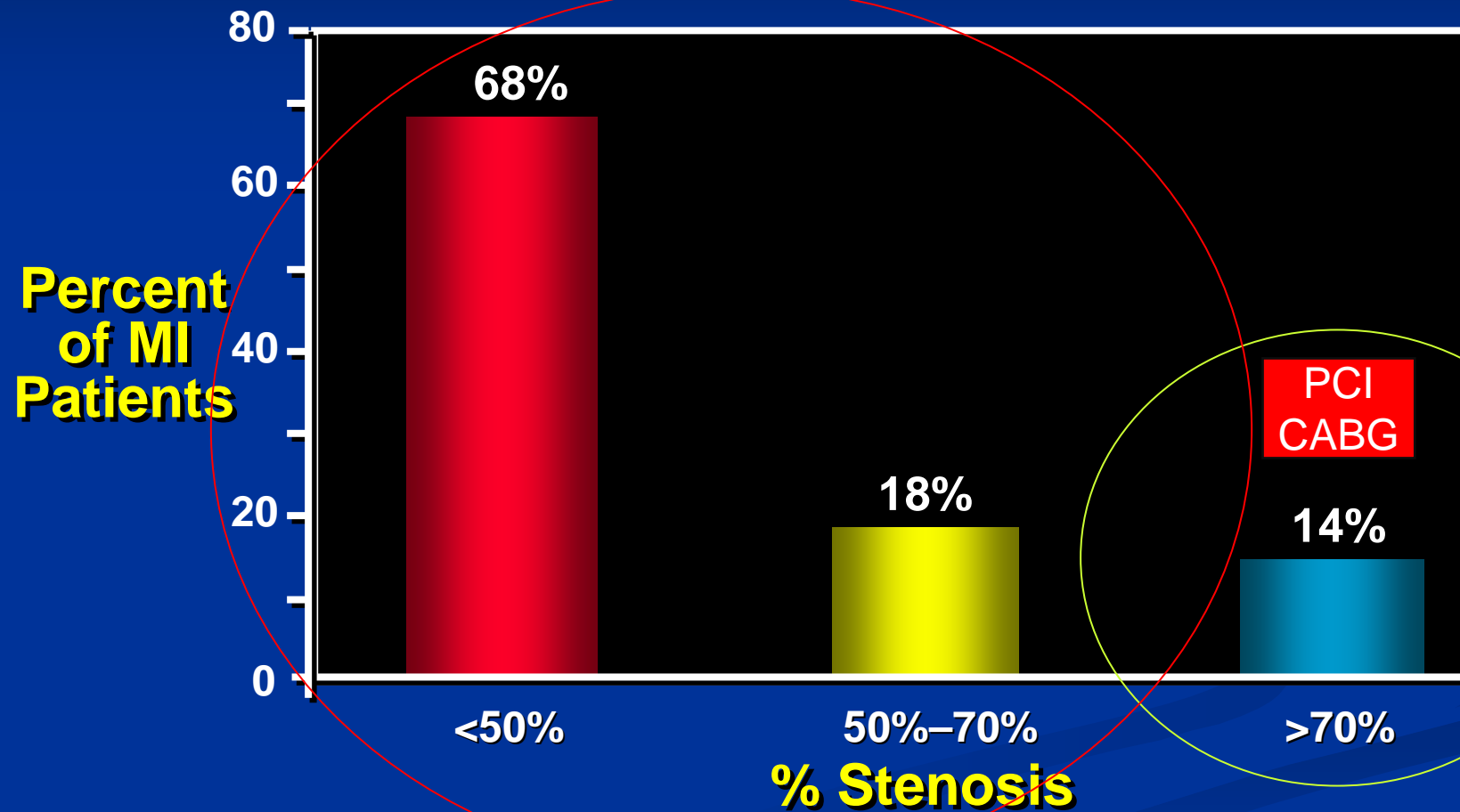
Mason Sones
CCF, 1958

Coronary Angiography: Luminal Silhouette

Mason Sones
CCF, 1958

Most MIs Arise From Smaller, Non flow-limiting Stenoses

Adapted from Falk et al. *Circulation* 1995; 92:657–671.

Echolucent vs Echogenic

- Previous histological studies have demonstrated that the discrimination of lipid is inconsistent using grayscale images alone.
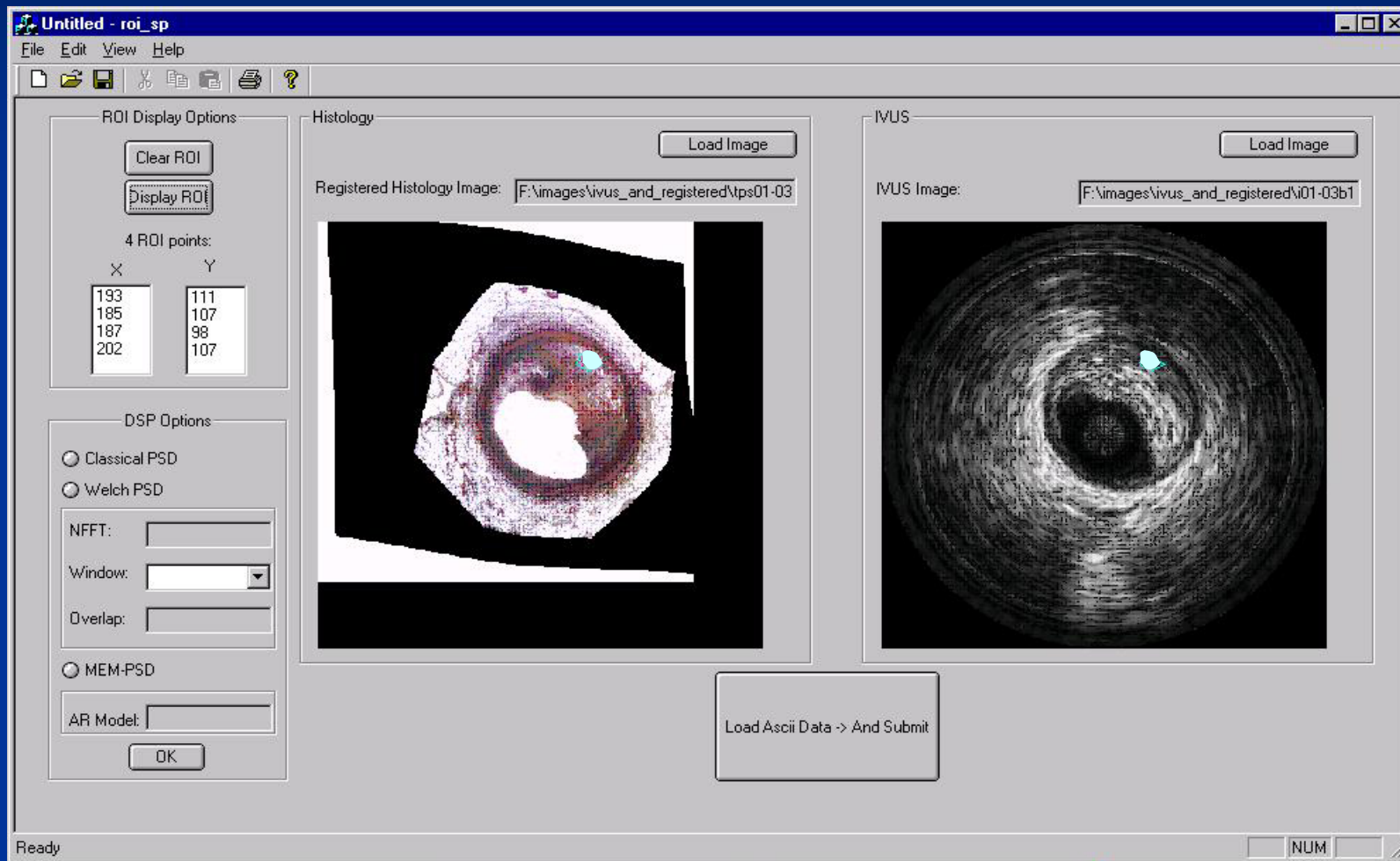
- Is there additional information available?

Images Courtesy of CCF IVUS Core Lab
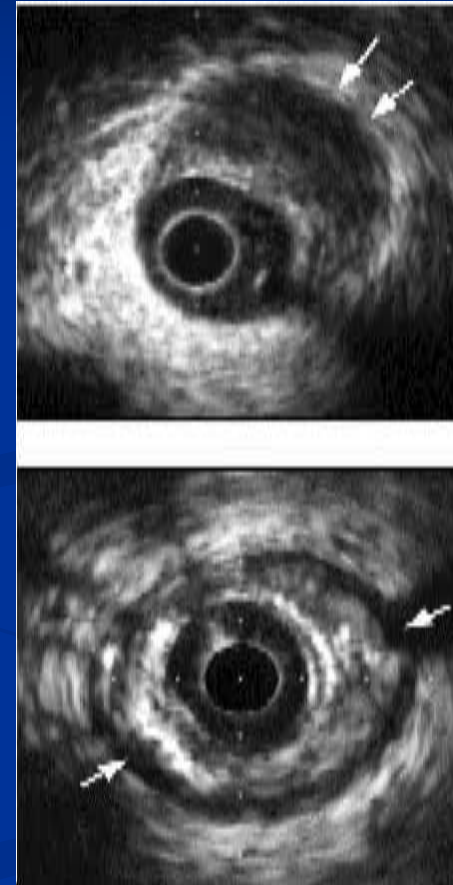
VH IVUS

20MHz signal frequency, but what we get back…

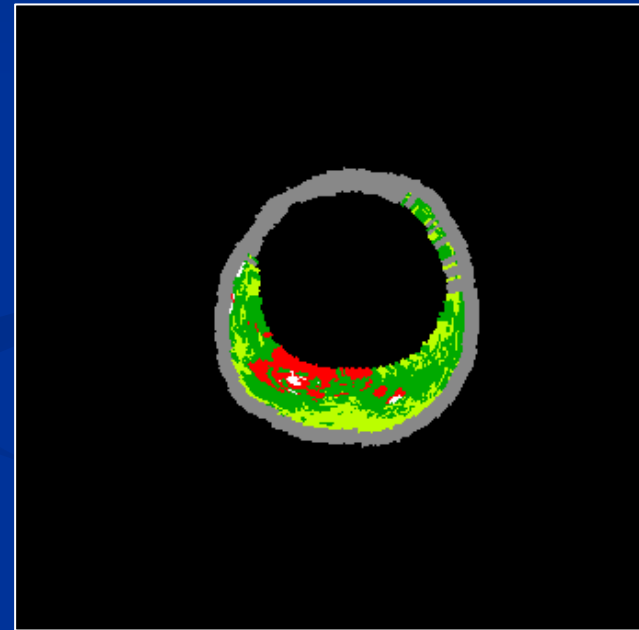Medium frequency   Low frequency   High frequency
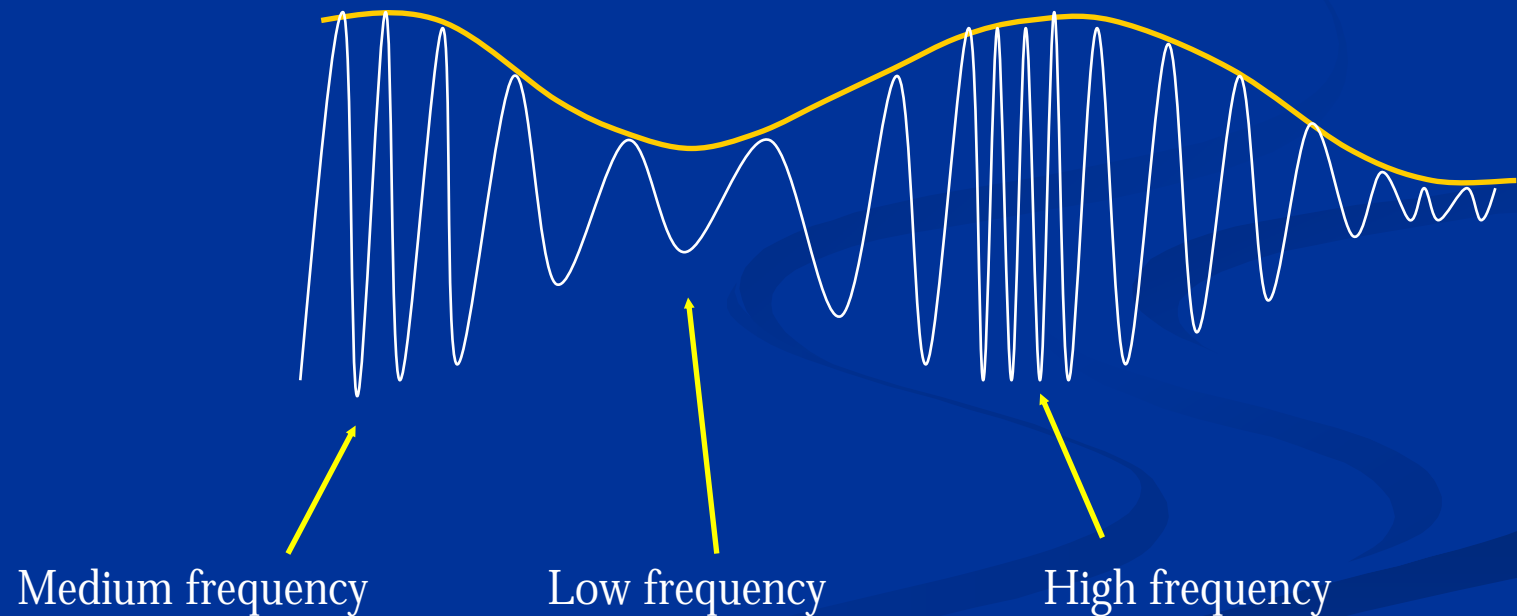
Teaching the Computer
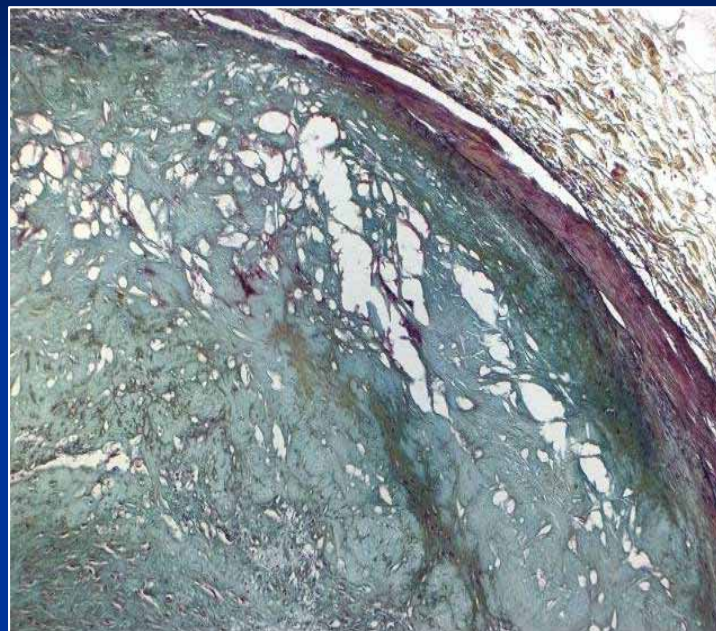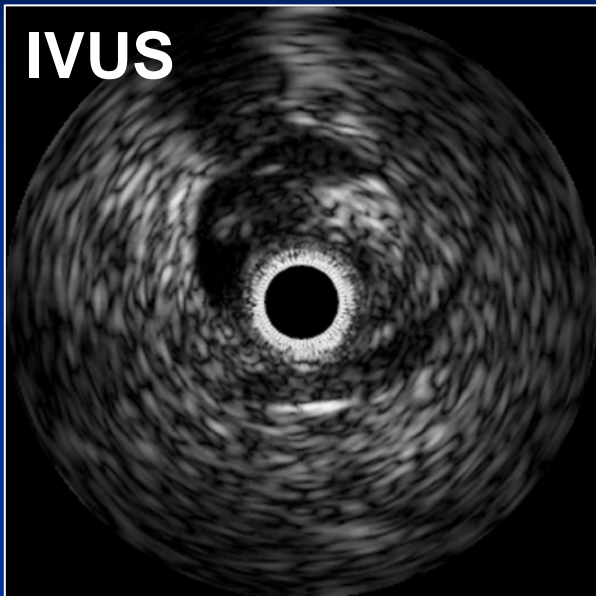
VH IVUS

- VH IVUS
  - Fibrous Tissue
  - Fibro-fatty
  - Necrotic Core
  - Dense Calcium
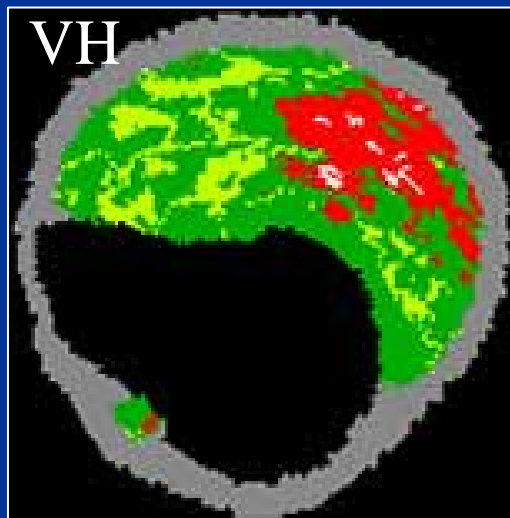- Gated data collection

Nair A, Kuban BD, Tuzcu EM, Schoenhagen P, Nissen SE, Vince DG.
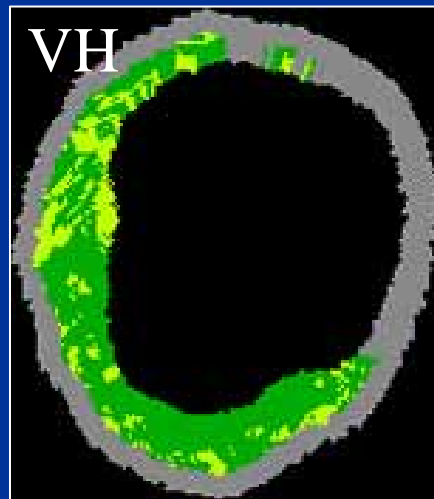*Circulation*, 106: 2200-2206, 2002

CCF 04106b2

IVUS

VH

CCF 04112b3
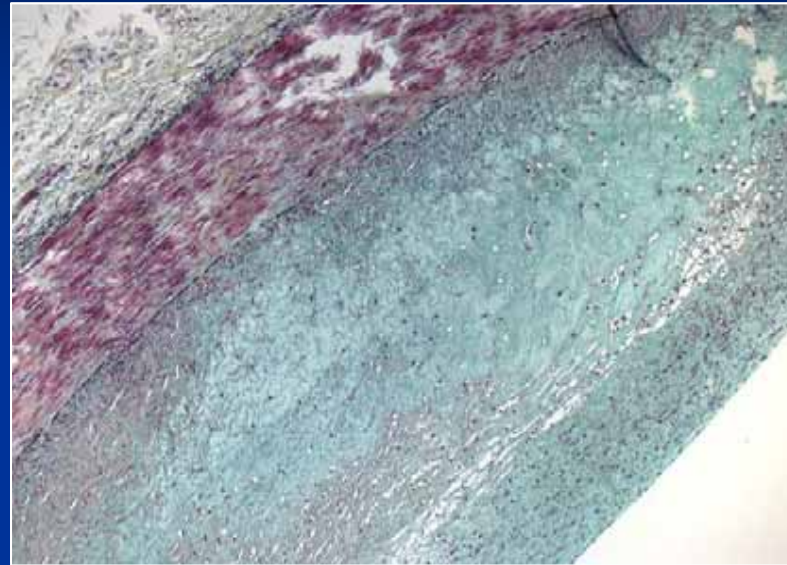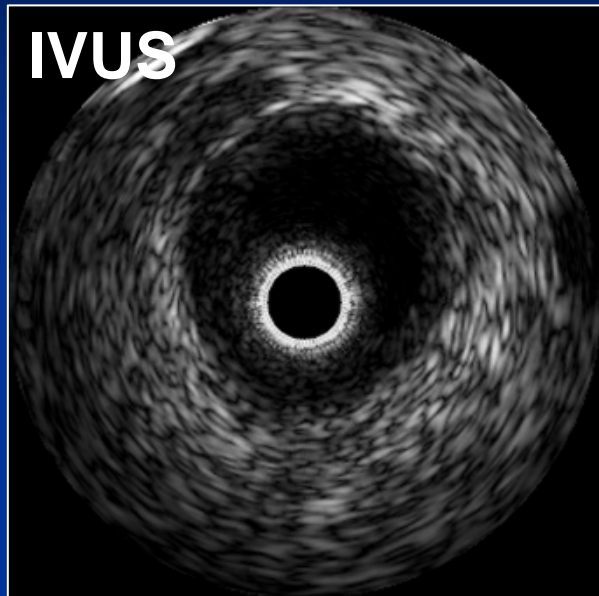
CCF 04114b3
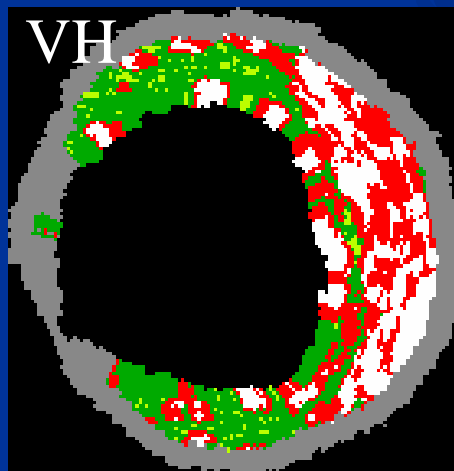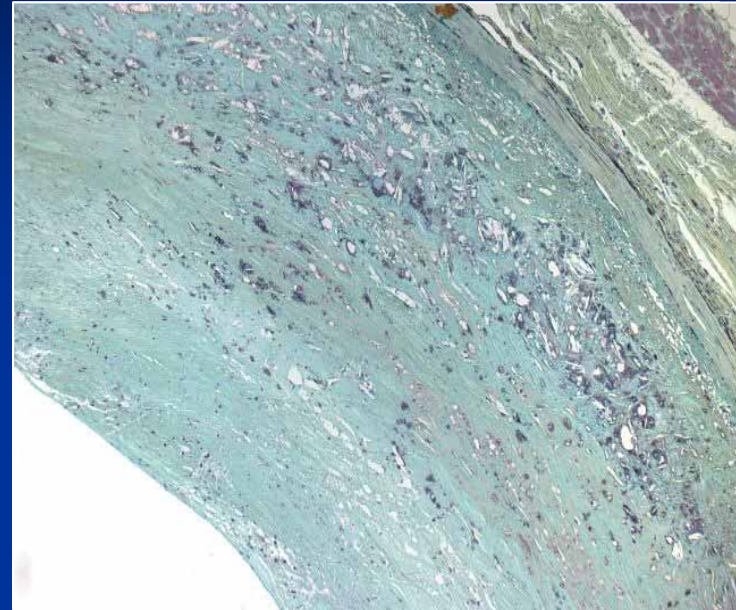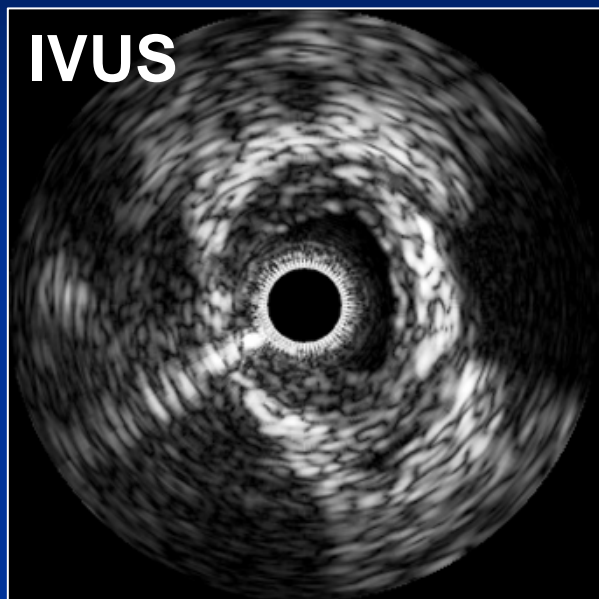
EAGLE EYE DECEMBER 2004 CLASSIFICATION TREE Accuracy Data: Slice by Slice VH & Histology Comparison

	Sensitivity (%)	Specificity (%)	Predictive Accuracy (%)
Fibrous Tissue (n= 97)	84.5	97.7	92.1
Fibro Fatty (n= 58)	77.6	93.5	89.5
Necrotic Core (n= 36)	83.3	92.2	90.8
Dense Calcium (n= 37)	97.3	96.9	96.9

Reproducibility

One EagleEye and collect 10 images
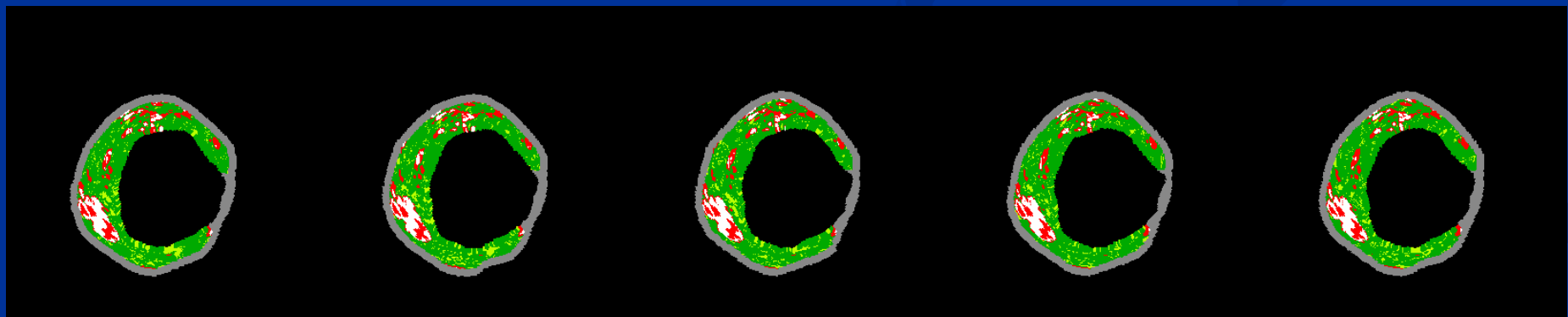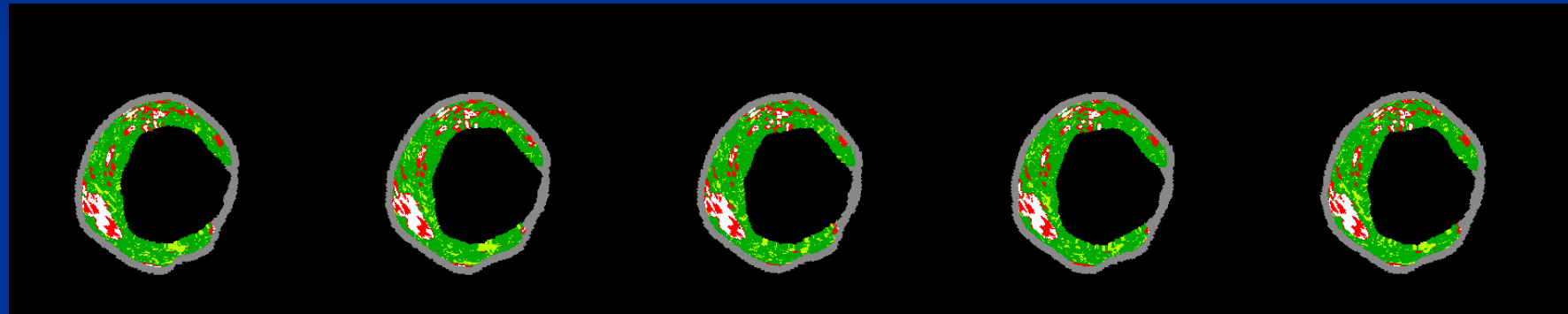
Predicted Plaque Composition with pullback one and two

REPRODUCIBILITY

Pullback	n of sites	DC (mm^2)	FT (mm^2)	FF (mm^2)	NC (mm^2)
1	19	0±0	1.3±0.8	0.3±0.2	0.01±0.01
2	19	0±0	1.5±0.7	0.3±0.2	0.02±0.03
1	37	0.005±0.008	1.4±0.8	1.2±0.7	0.008±0.001
2	37	0.001±0.005	1.3±0.7	1.1±0.6	0.005±0.02
1	14	0.04±0.07	5.6±0.6	0.6±0.1	0.1±0.1
2	14	0.04±0.04	6.3±1.0	0.9±0.1	0.1±0.1
1	27	0.00±0	3.3±0.8	0.6±0.1	0.08±0.06
2	27	0.02±0.05	2.9±0.6	0.9±0.1	0.08±0.07
1	27	0.01±0.02	3.6±0.4	0.8±0.2	0.1±0.09
2	27	0.05±0.05	3.9±0.4	0.6±0.2	0.1±0.07

Matched pairs;

Mean difference	0.014	0.09	0.02	0.006

Limitations

- Spatial accuracy
    - 100μm resolution expressed in 200μm blocks
- Invasive method
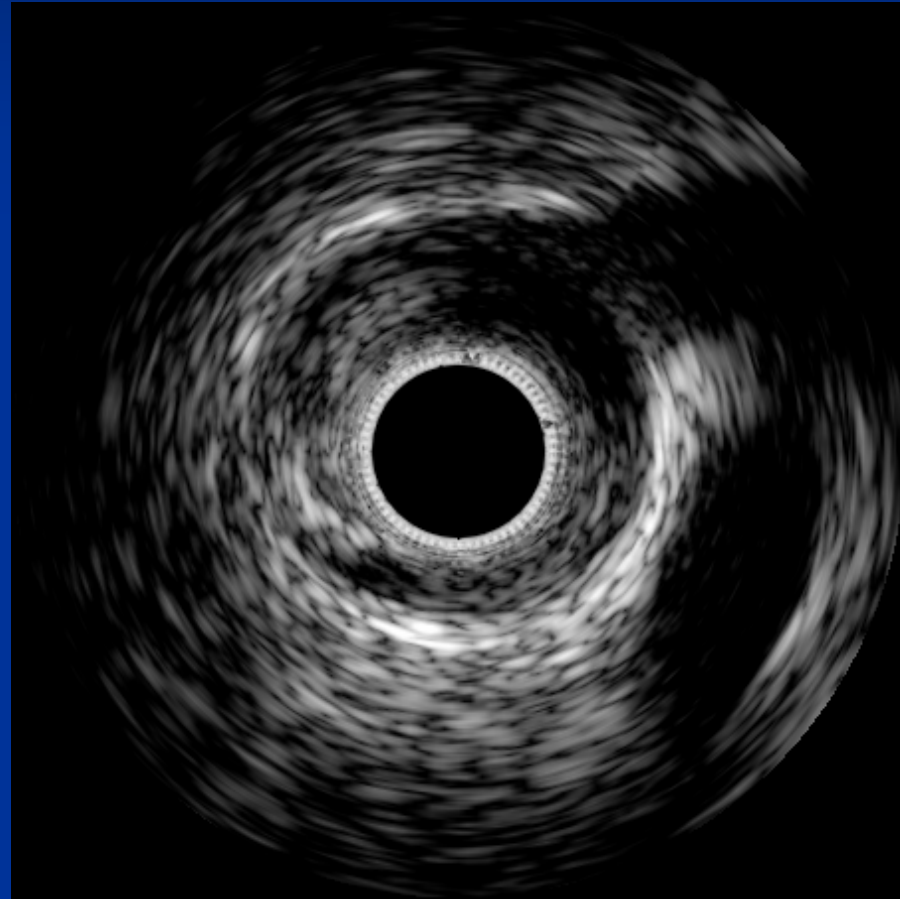   - Fast
    - High resolution

- Seeing behind calcium
    - Investigate SNR
    - Plastic embedded tissue
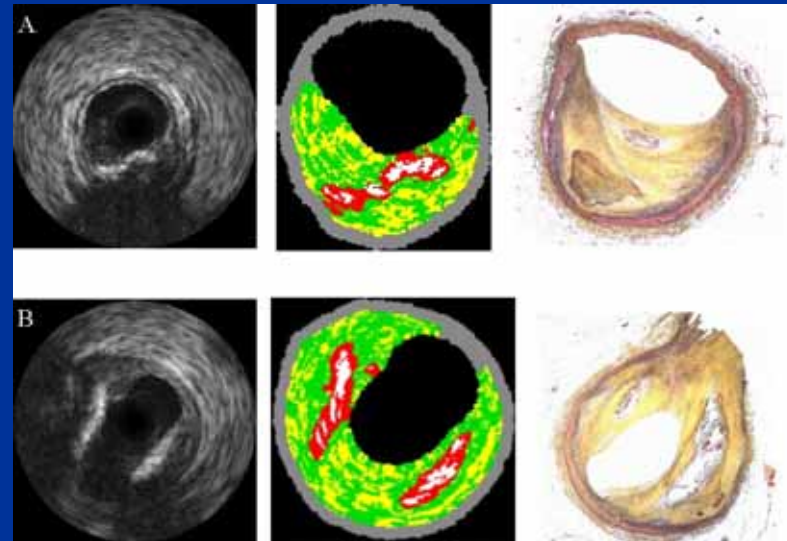
For True Real Time we Need Automatic Borders?

Future Technology

- Fully-automatic
  - Really difficult!!

Future Technology

$$E_{contours} = \int_0^1 \left(\alpha(s) E_L(s) + \beta(s) E_M(s) + \gamma(s) E_P(s) \right) ds$$

$$\left| \begin{array}{l} \left(V_{j-2,MAB,n \bmod N} - V_{j-2,lumen,n \bmod N} \right) - \\ 2 \left(V_{j-1,MAB,n \bmod N} - V_{j-1,lumen,n \bmod N} \right) + \\ \left(V_{j,MAB,n \bmod N} - V_{j,lumen,n \bmod N} \right) \end{array} \right|^2$$

$$\left| V_{(n-1) \bmod N} - 2V_{n \bmod N} + V_{(n+1) \bmod N} \right|^2$$
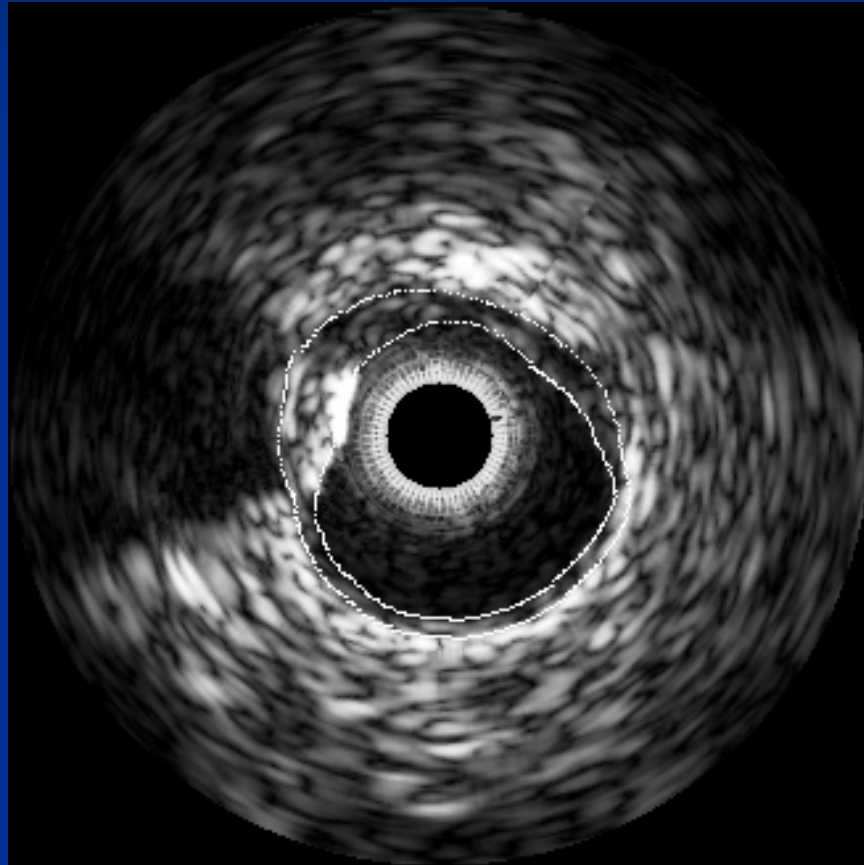
$$\left| V_{(n-1) \bmod N} - V_{n \bmod N} \right| + \left| V_{n \bmod N} - V_{(n+1) \bmod N} \right|$$

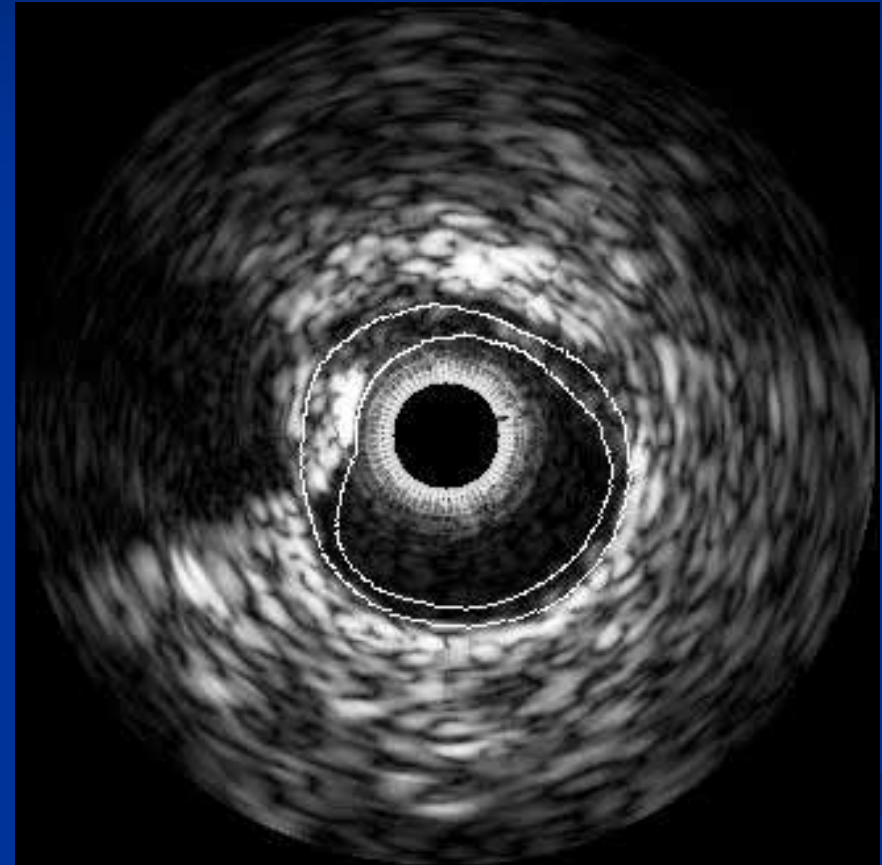$$\frac{\min_{RF} - G_{RF}}{\max_{RF} - \min_{RF}}$$

Future Technology

- Why not use VH to find borders
  - Find "blood"
  - Find "plaque"
  - Where blood ends and plaque starts is the lumen border

  - Find "plaque"
  - Find "adventitia"
  - Where plaque ends and adventitia starts is the external border
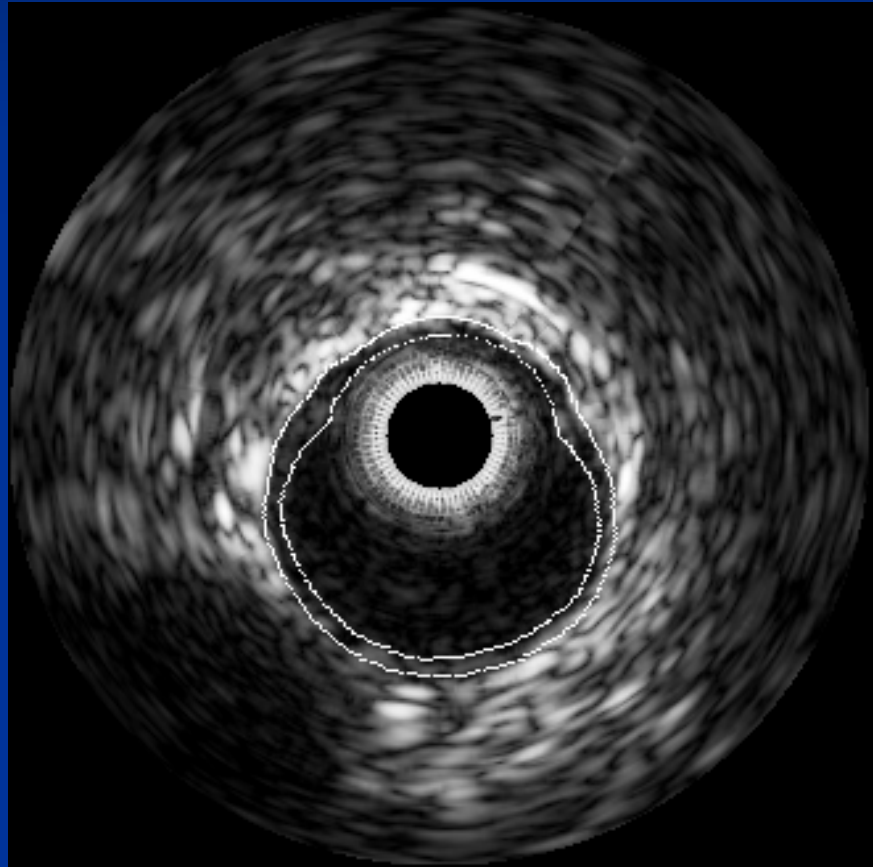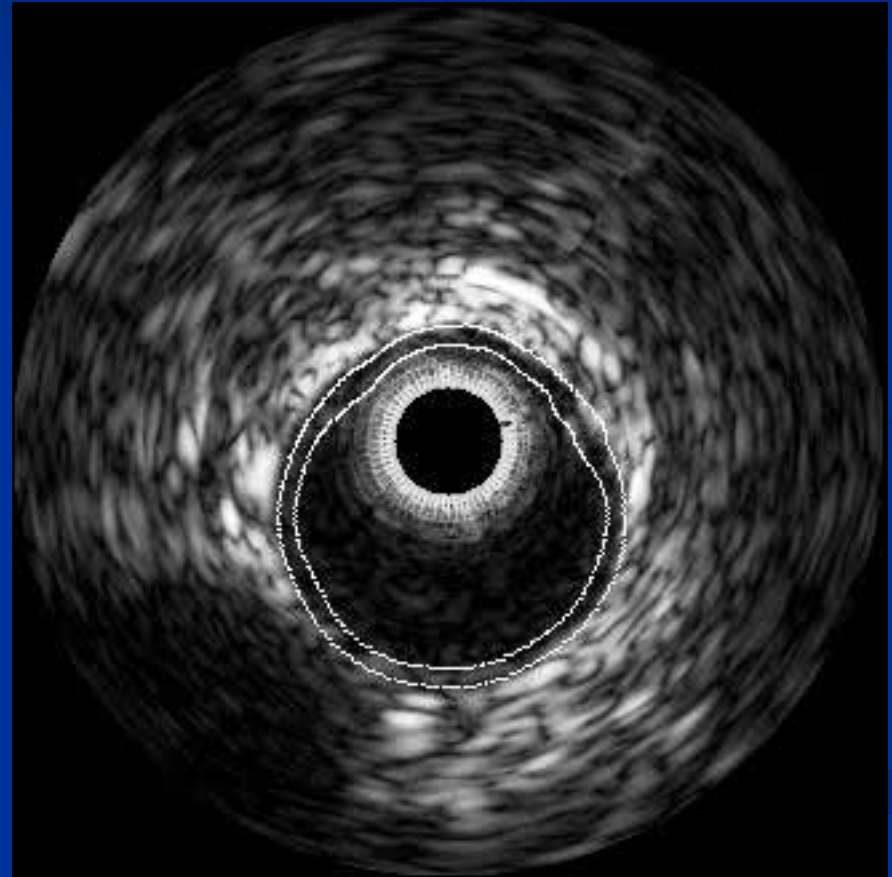- Use border detection algorithm to refine border
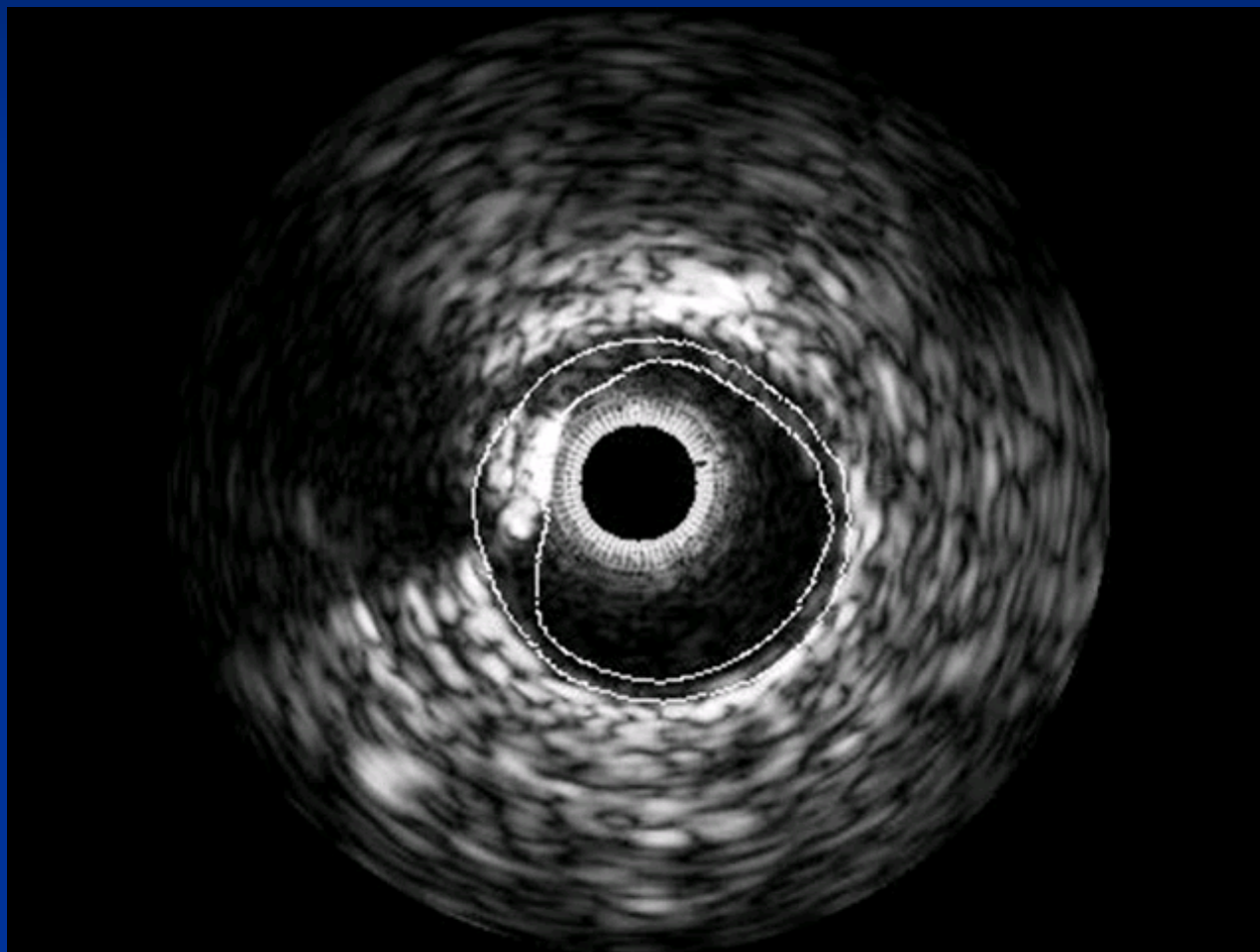
Examples

Manual Tracing

Automated Detection

Examples

Manual Tracing   **Automated Detection**

Real-time Border Detection

Fully - Automated Lumen Border Detection

(n = 1183)**	Lumen CSA (mm²)	Lumen Min DIA (mm)	Lumen Max DIA (mm)	Lumen Mean DIA (mm)
Avg (± stdev)	0.42 (± 2.3) 3.4% (± 16.4%)	0.02 (± 0.49) -1.1% (±8.7%)	0.17 (± 0.63) 3.6% (± 10.3%)	0.09 (± 0.54) 1.2% (± 7.4%)

** 7 pullbacks of RF data – no user interaction – compared to expert observer

Fully - Automated EEL Border Detection

(n = 1183)**	EEL CSA (mm^2)	EEL Min DIA (mm)	EEL Max DIA (mm)	EEL Mean DIA (mm)
Avg (± stdev)	-0.9 (± 7.4) -8.8% (± 22.8%)	-0.26 (± 1.0) -8.8% (± 11.0%)	-.01 (± 1.1) -1.6% (± 14.2%)	-0.13 (±1.0) -5.3% (± 10.5%)

** 7 pullbacks of RF data – no user interaction – compared to expert observer

Future and Current Work

- Validation
  - Further *ex vivo*
  - Atherectomy
- New groups:
  - Thrombus
  - Stents
- New catheters
- Non-invasive VH ??