

# **NIR Spectroscopy: Fundamentals and Diagnostic Applications**

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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.

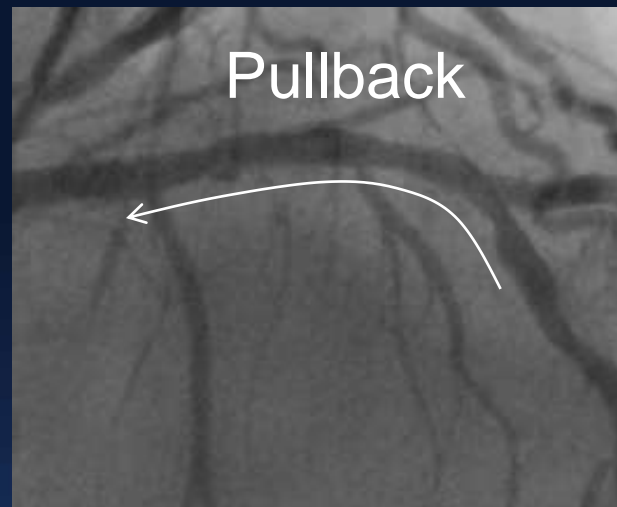
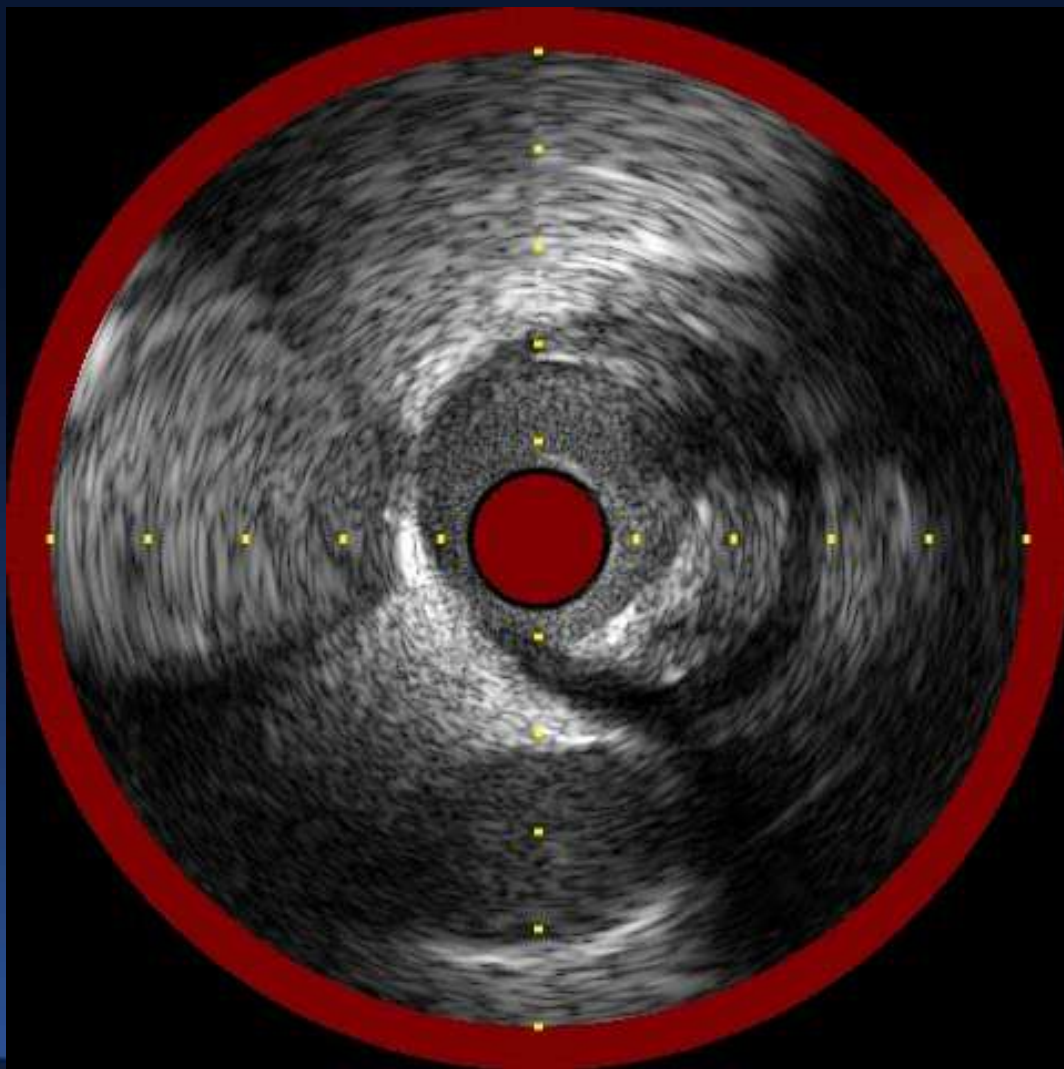
## Affiliation/Financial Relationship

- Grant/Research Support
- Consulting Fees/Honoraria
- Speaker Fee

## Company

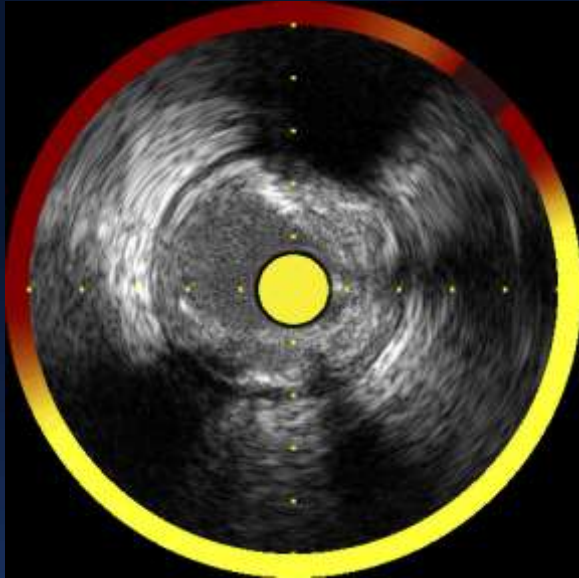
- Boston Scientific Corporation
- Boston Scientific Corporation, ACIST
- Volcano Corporation, St Jude Medical

# NIRS-IVUS Image

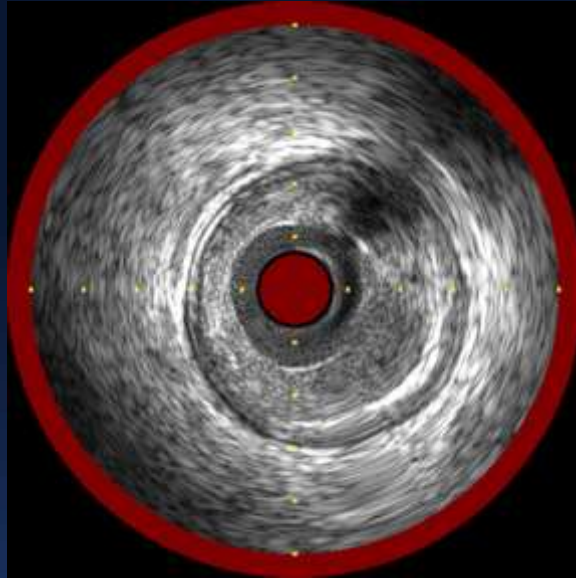


# Detection of Necrotic Core

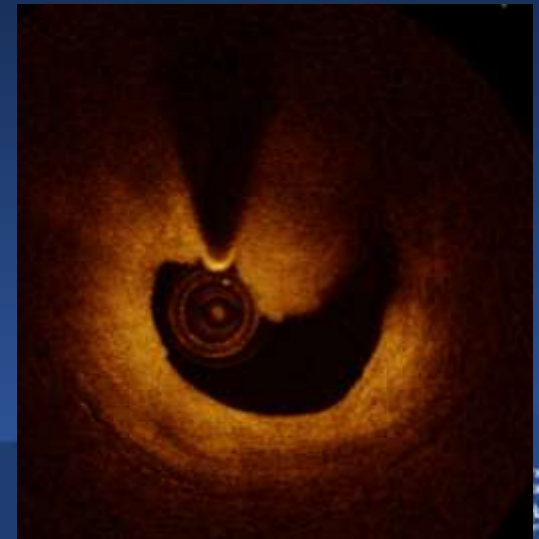
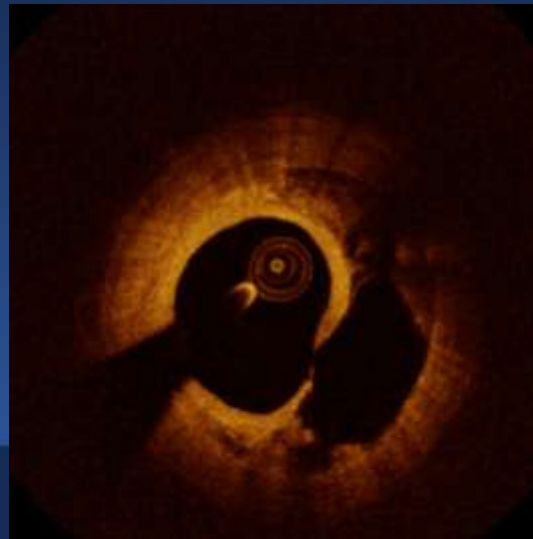
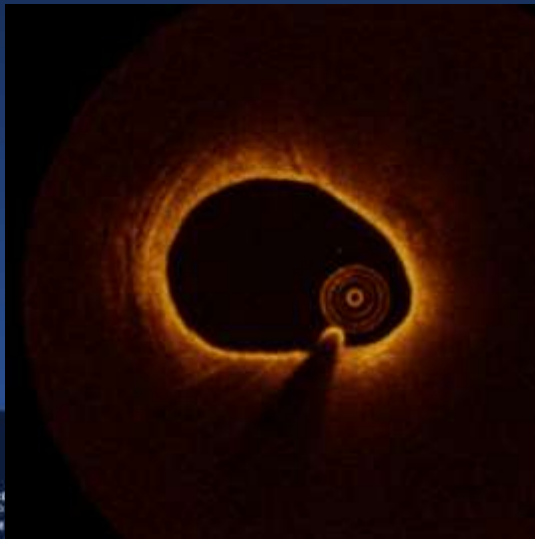
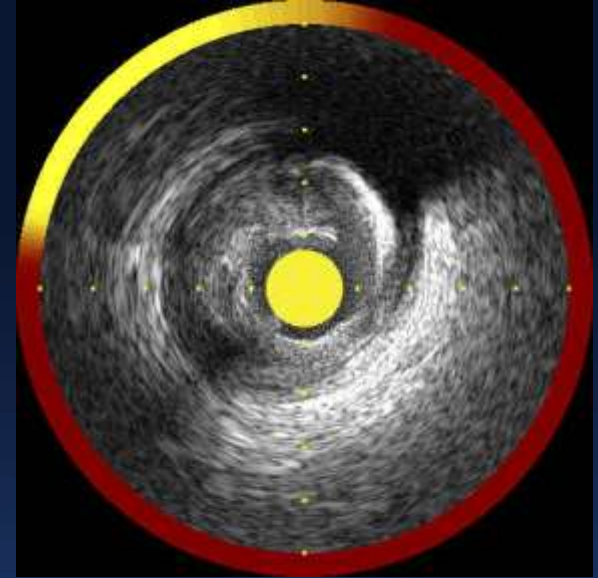
TCFA



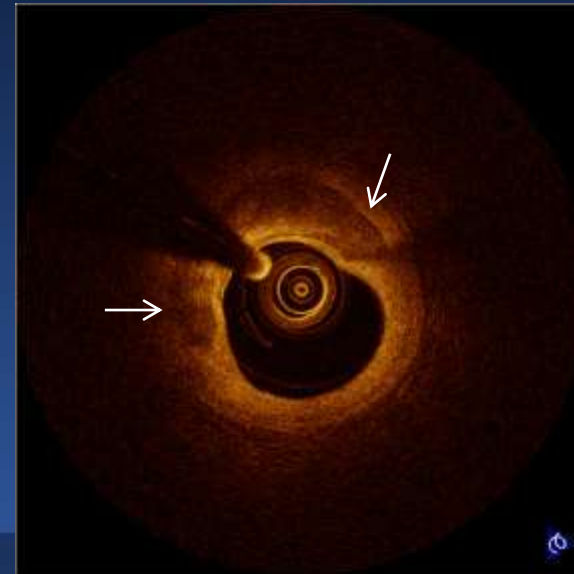
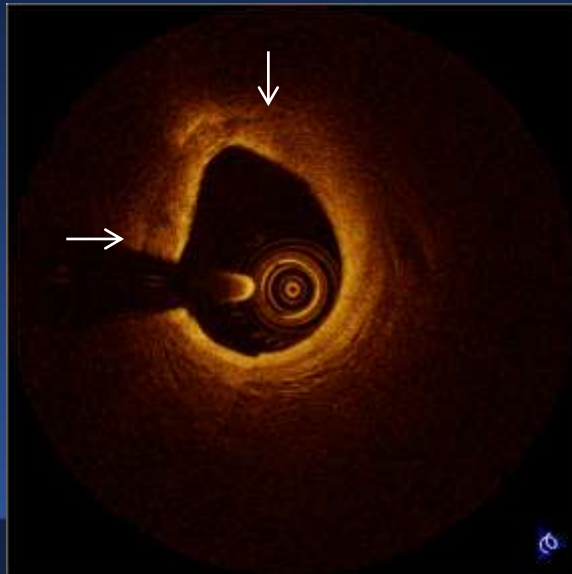
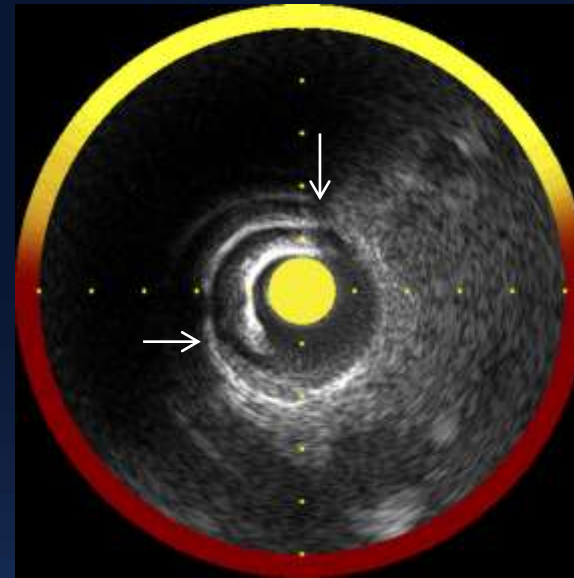
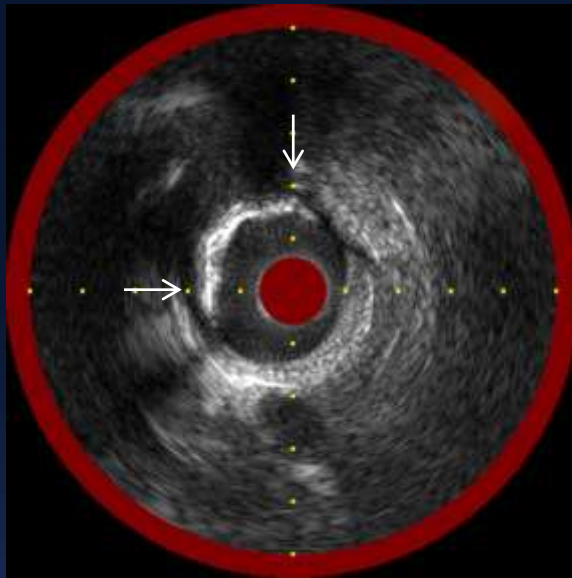
Ruptured plaque



Ruptured plaque with thrombus

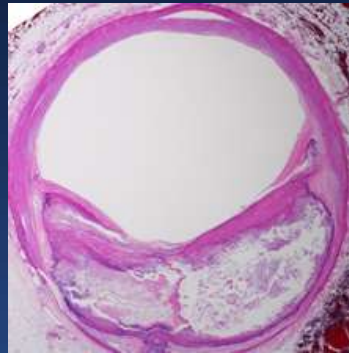
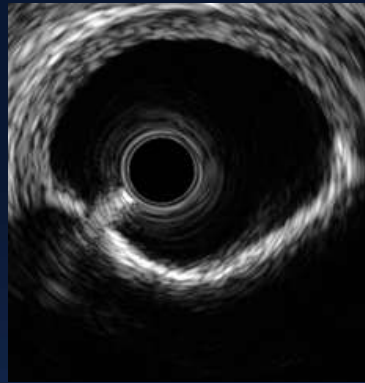


# Different type of Calcified Plaque

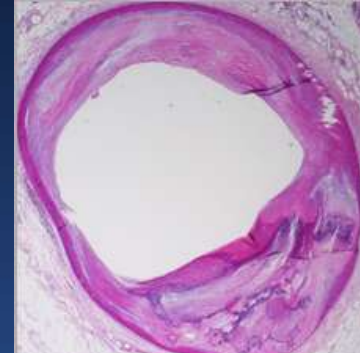
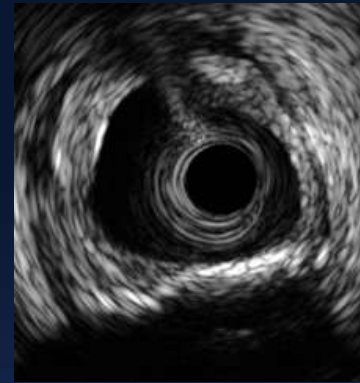


# Different type of Calcified Plaque

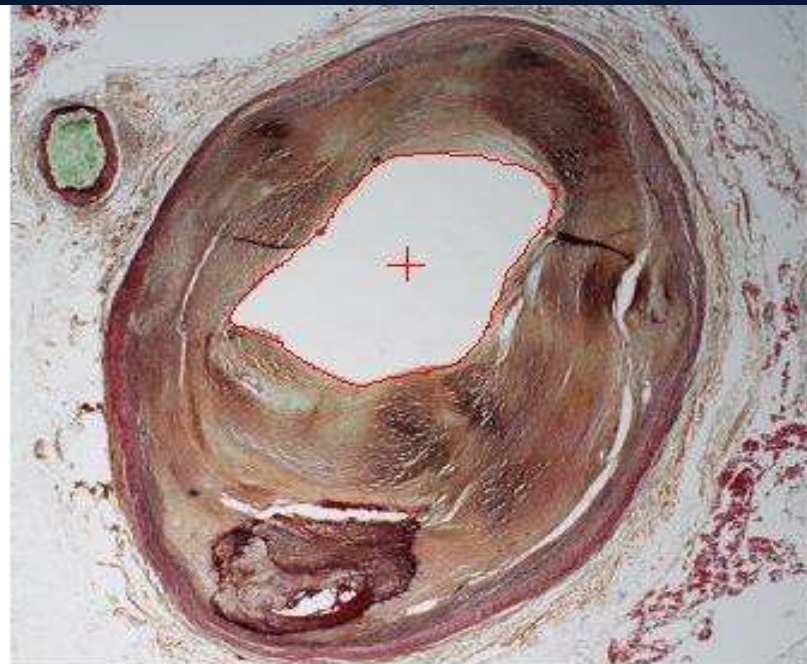
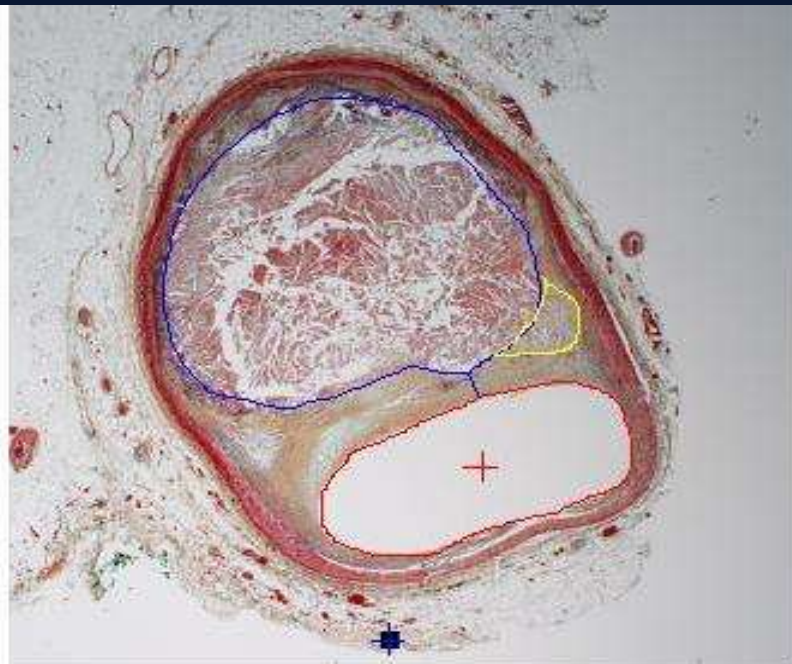
*Necrotic core  
behind calcium*



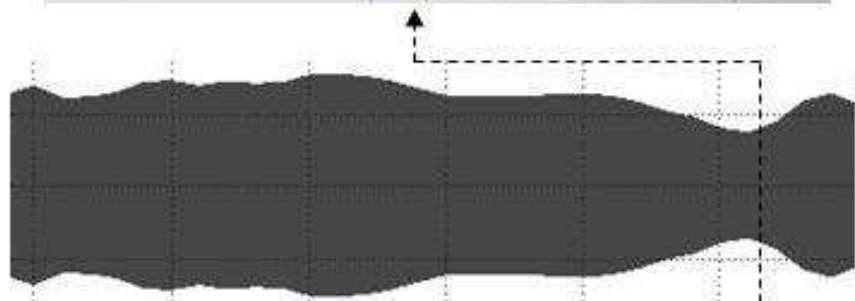
*Calcium Only*



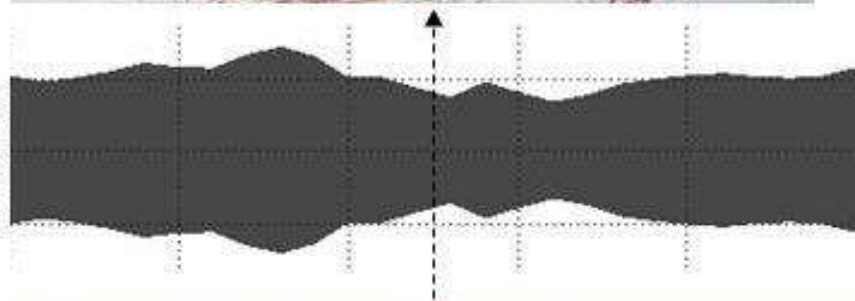
# NIR can Distinguish Lipid-rich from Fibrotic Plaques



IVUS  
DIAMETER



IVUS  
DIAMETER



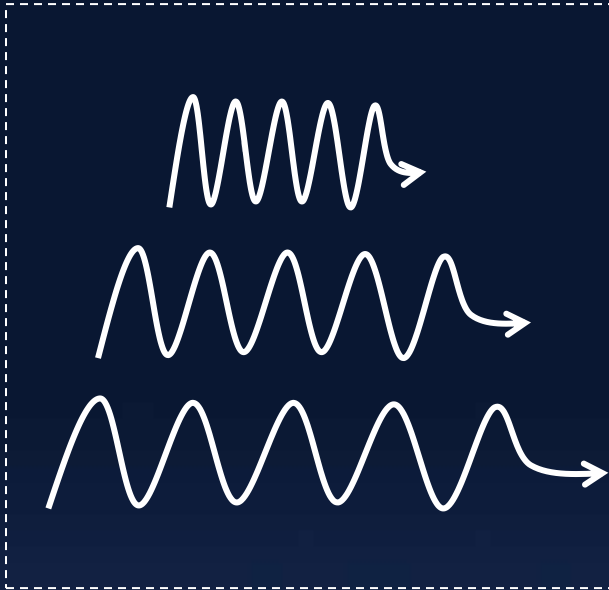
CHEMOGRAM



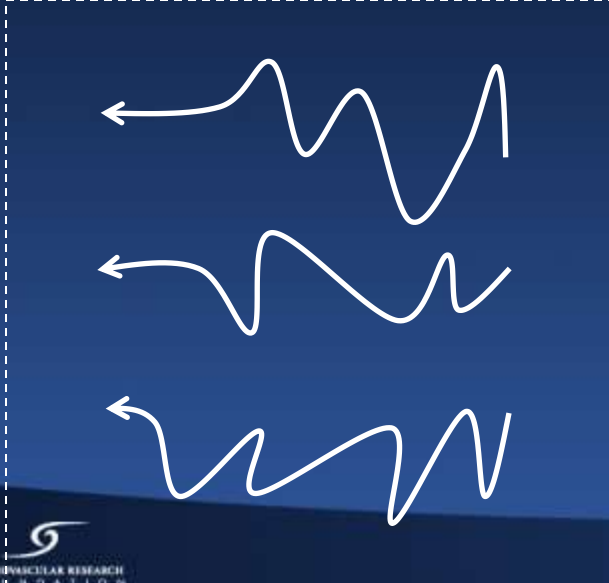
CHEMOGRAM



# Original Wave

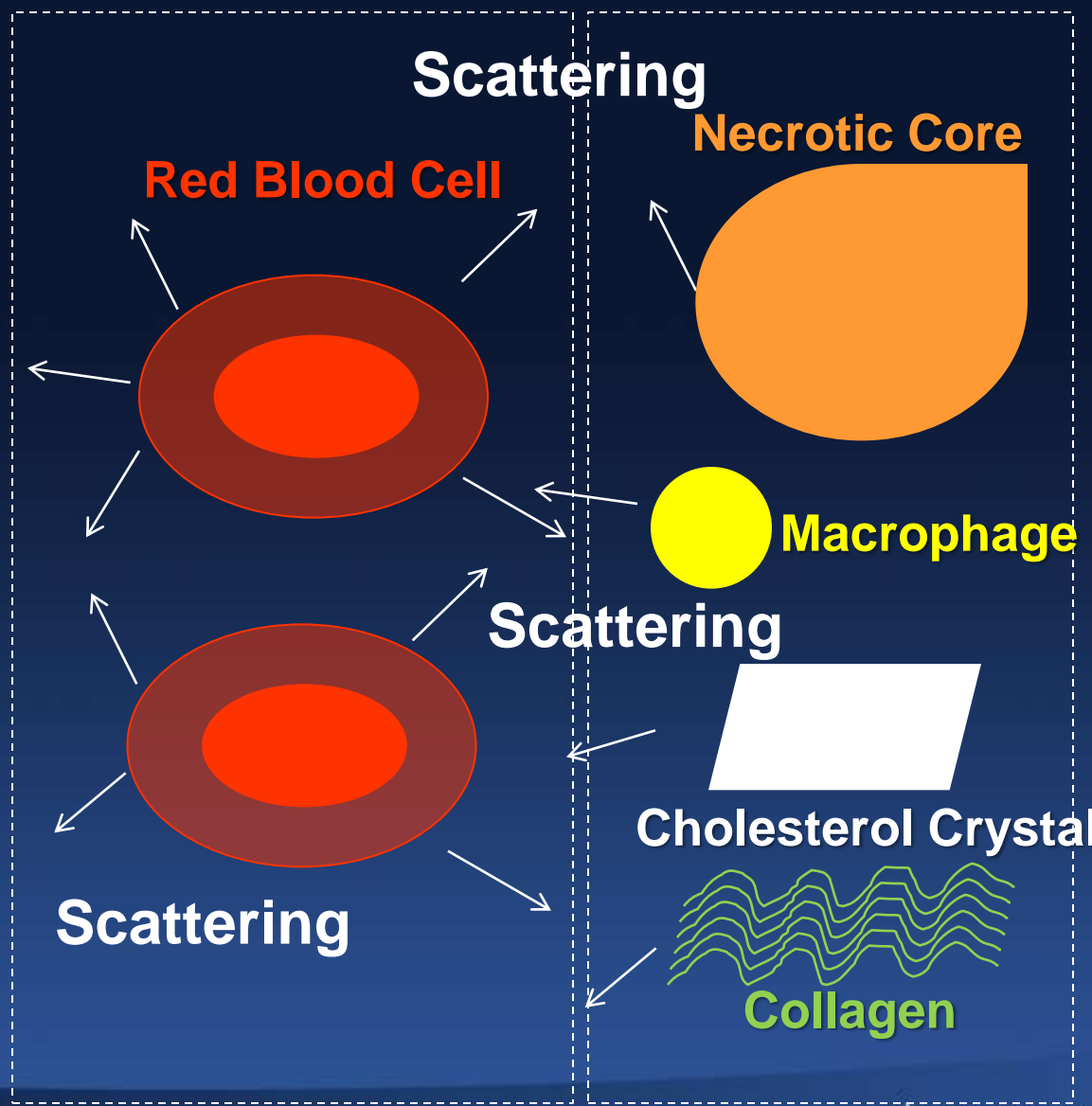


# Returned Wave

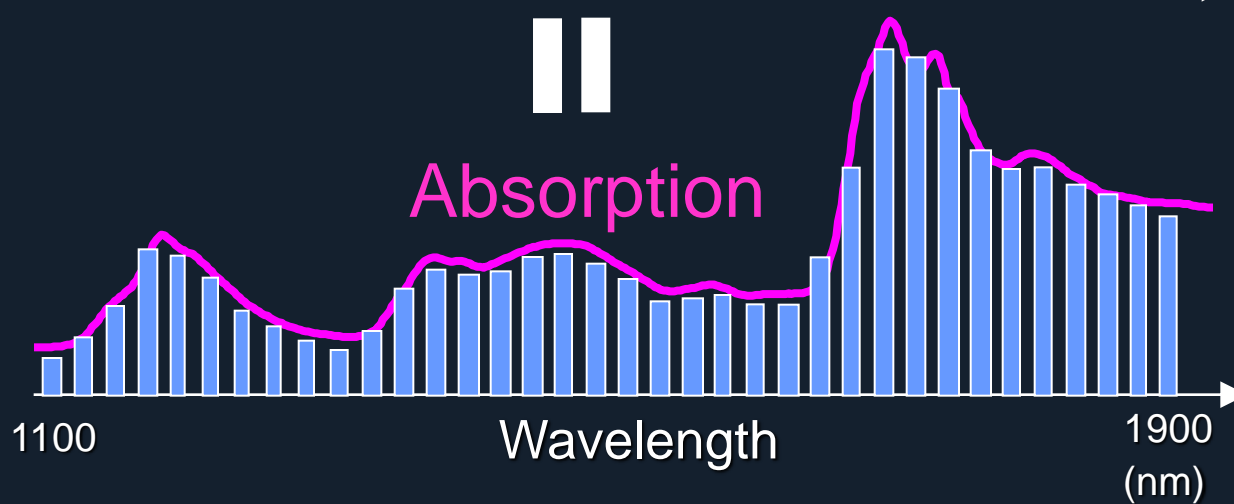
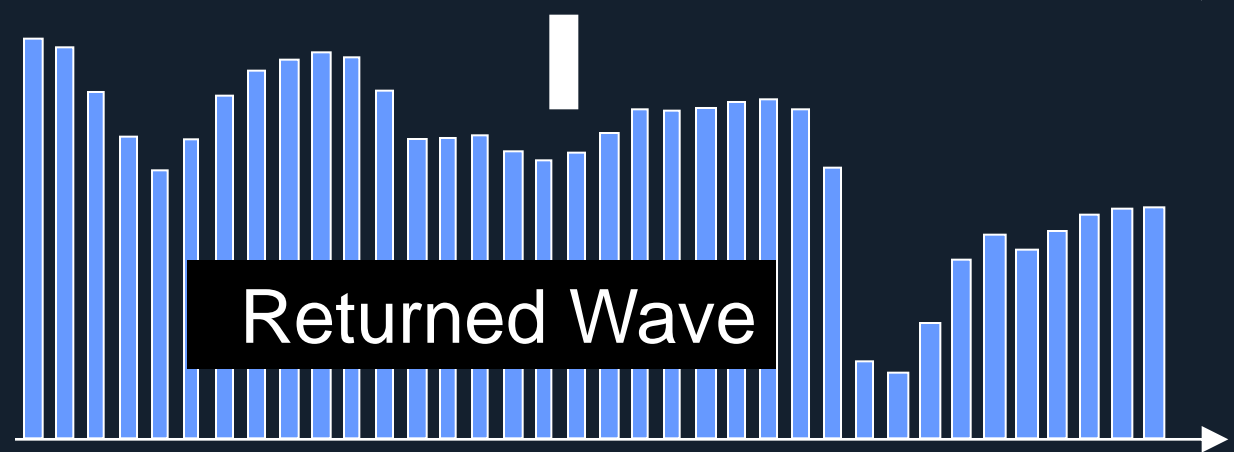
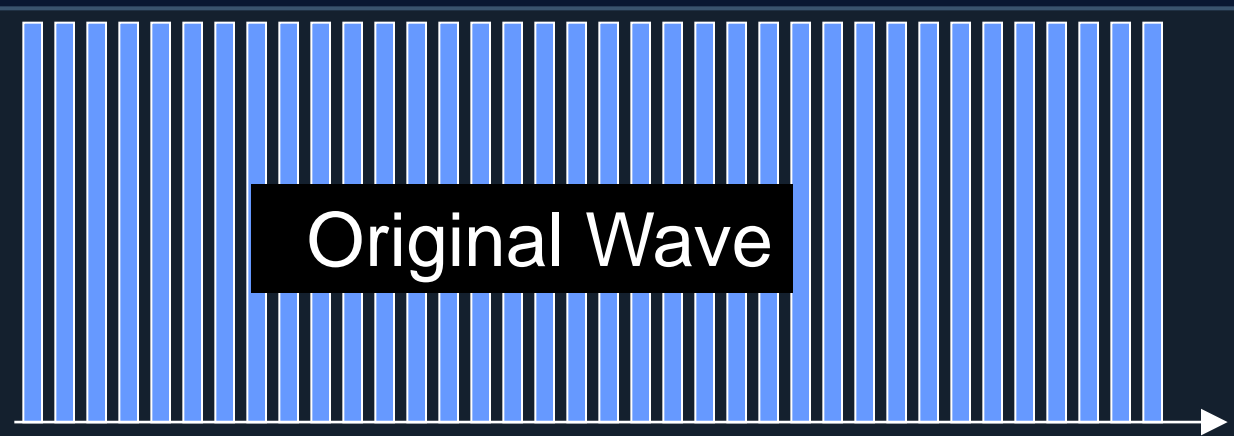
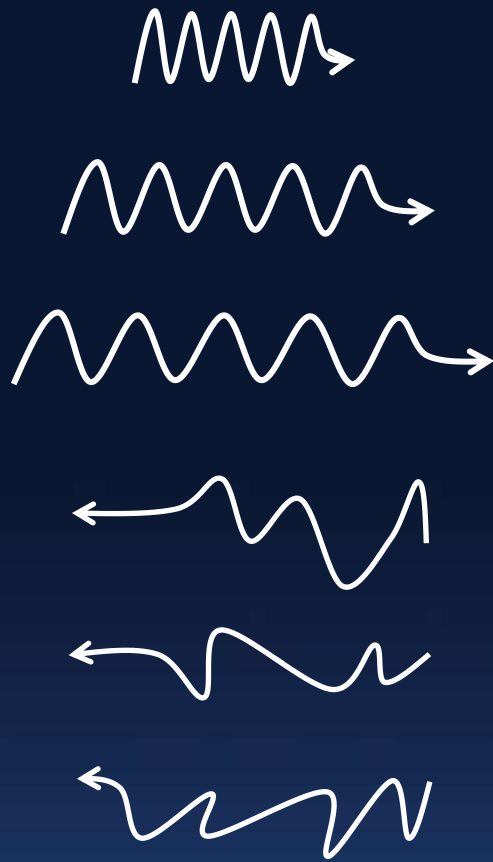


## Blood

## Vessel Wall

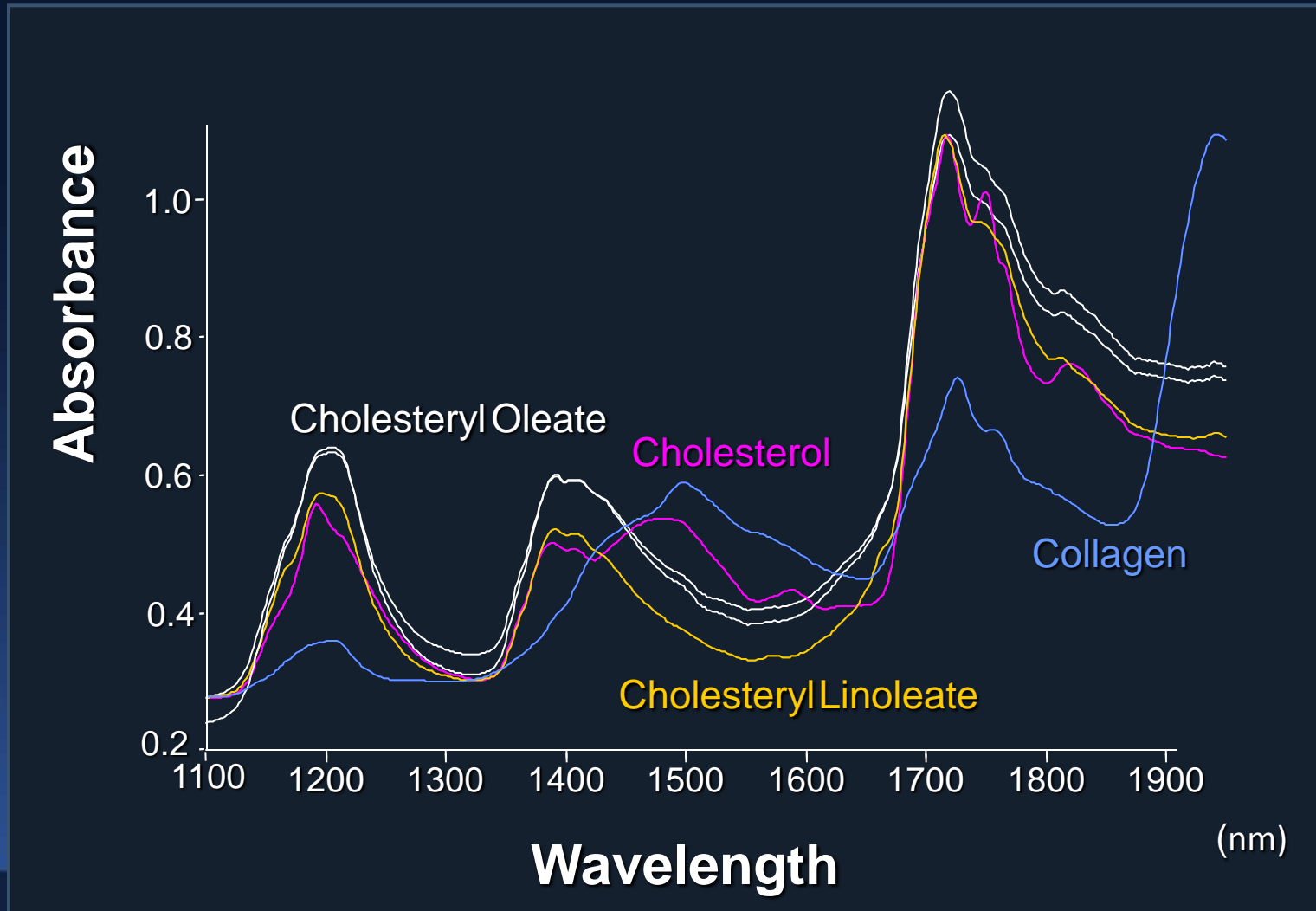






# NIR Spectroscopy

- Necrotic Core  $>0.2\text{mm}$  thick,  $>60^\circ$ , Cap  $<0.45\text{mm}$



# Process of NIR Spectroscopy

1. What kind of tissue?

Tissue



2. Near Infrared

Tissue



3. Absorption Pattern from this tissue



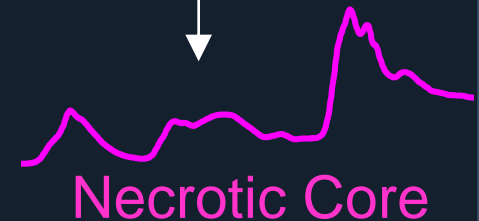
4. How similar?

5. Probability for Necrotic Core

XX%

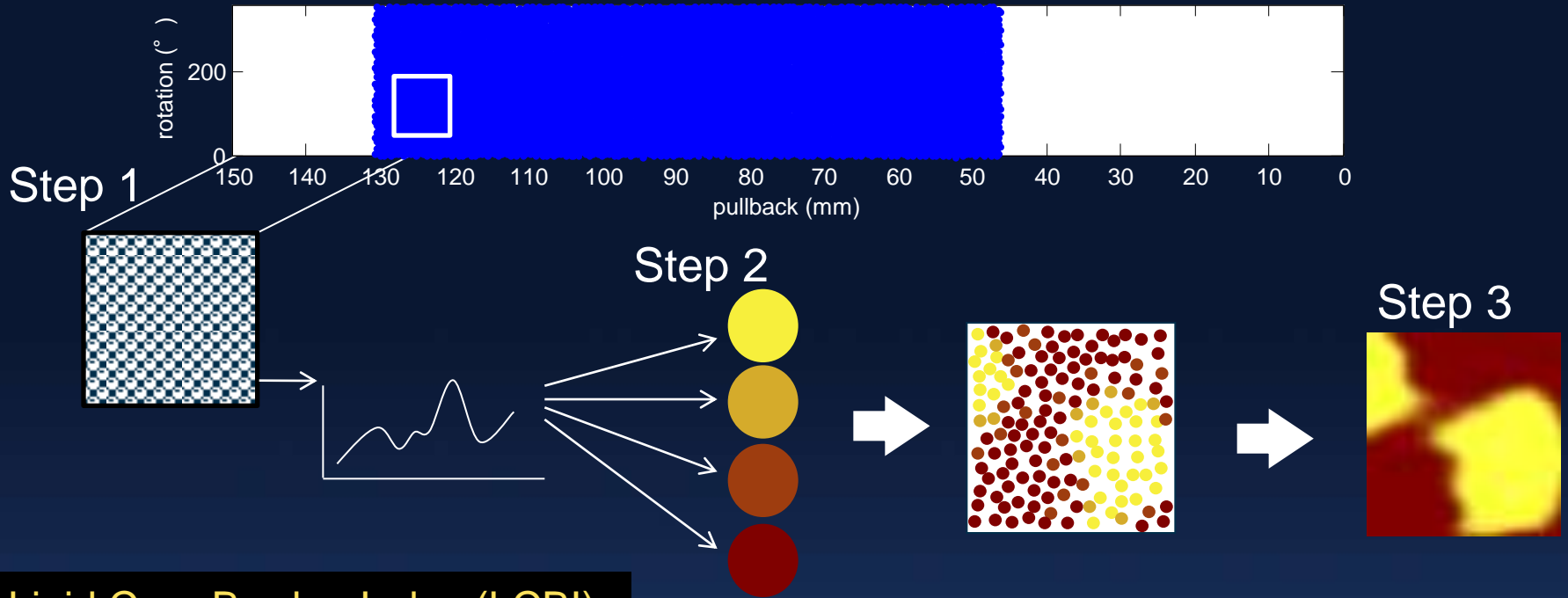


Collagen

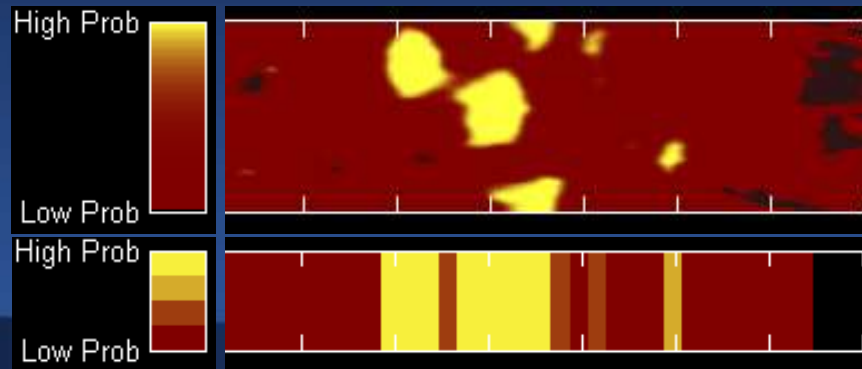


Necrotic Core

# Near Infrared Spectroscopy

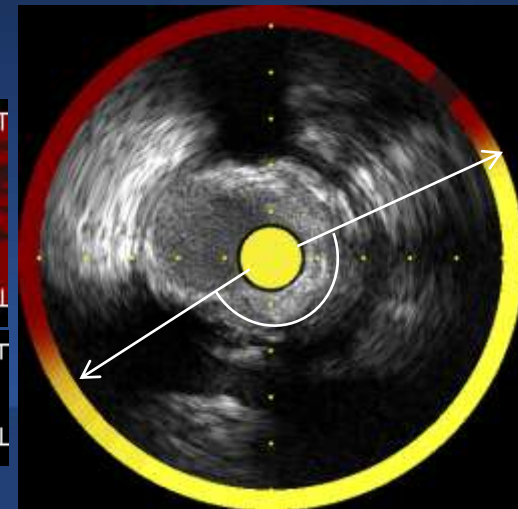


**Lipid Core Burden Index (LCBI)**  
 = Yellow pixel / All variable pixel  
 × 1000

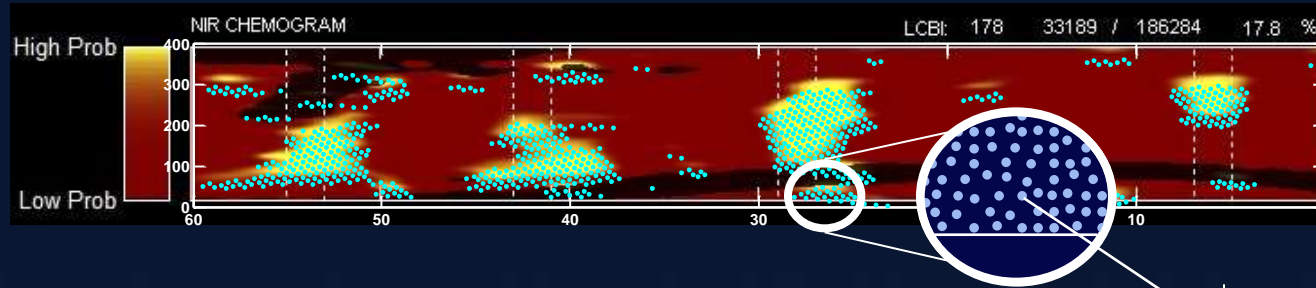


Proximal

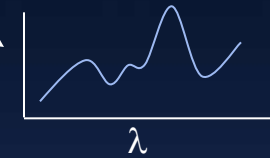
Distal



# Formation of the Cap Thickness Prediction Image



Spectra acquired at discrete pullback and rotation positions



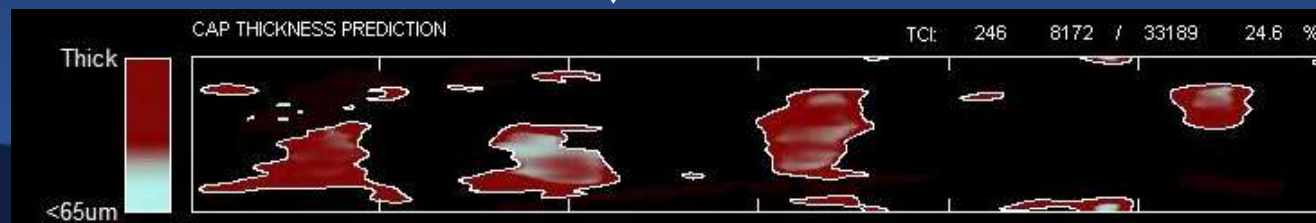
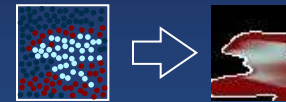
LCP Spectra transformed into posterior probability of thin cap presence



0→1

Probability mapped to a color

Pixels formed into an image



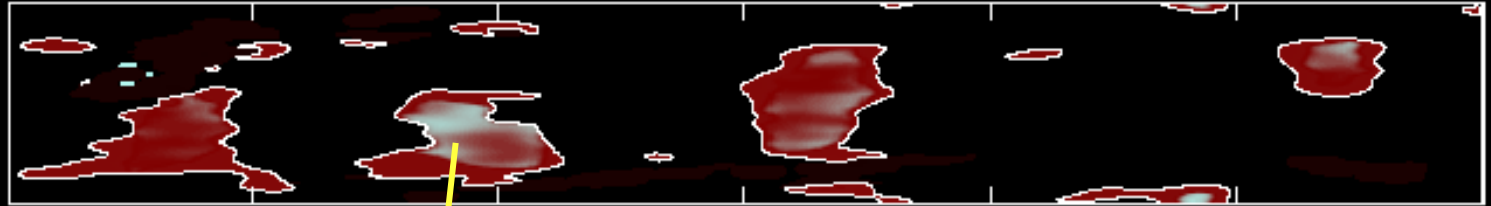
CAP THICKNESS PREDICTION

TCI: 246 8172 / 33189 24.6 %

Thick



<65um



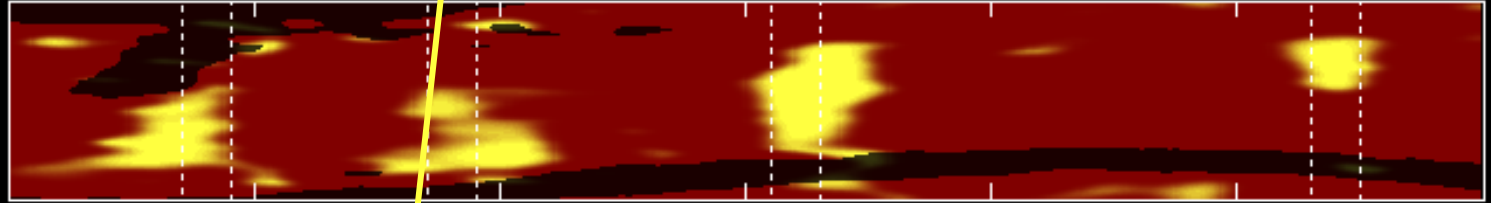
NIR CHEMOGRAM

LCBI: 178 33189 / 186284 17.8 %

High Prob



Low Prob



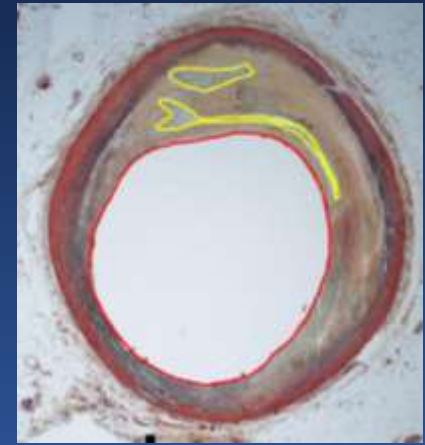
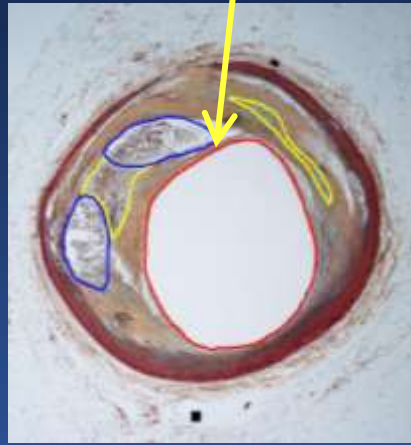
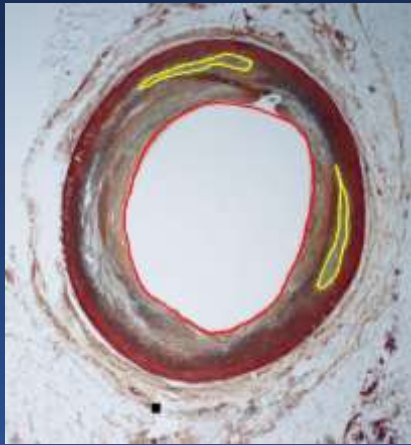
60 50 40 30 20 10 0

52mm

42mm

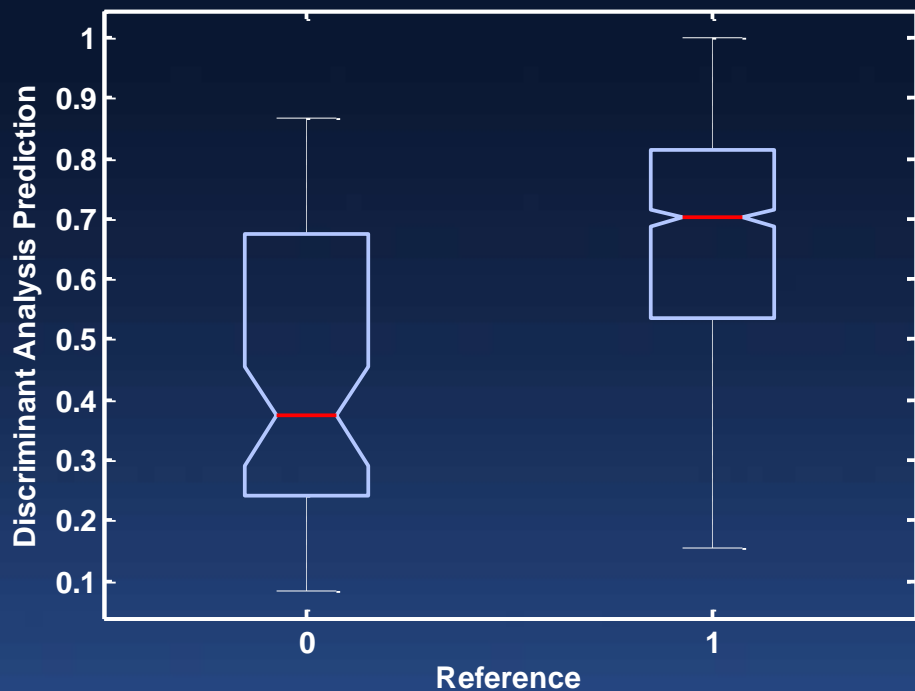
28mm

6mm

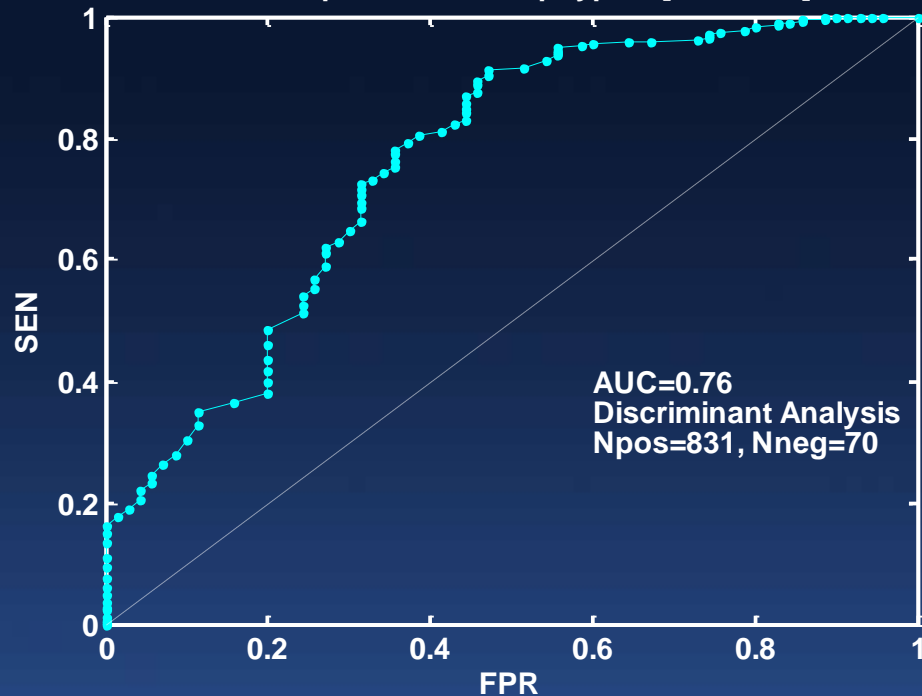


# Ability to Predict Thin Cap (<0.065mm)

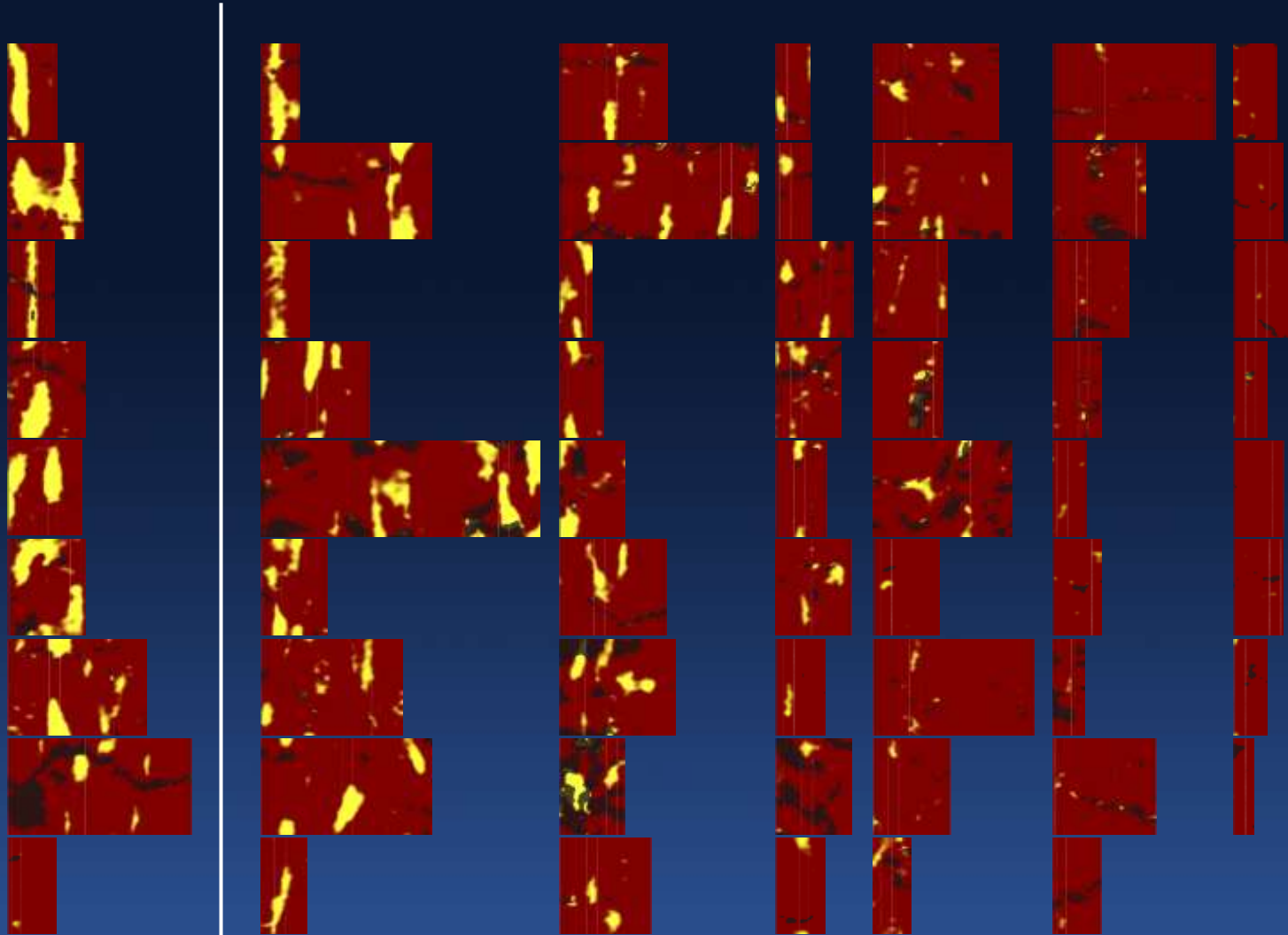
Capmeth=min, Neg=Cap<0.065mm,  
Pos=Cap>0.065mm, CapTypes=[LCNCCC]



Capmeth=min, Neg=Cap<0.065mm,  
Pos=Cap>0.065mm, CapTypes=[LCNCCC]



# NIRS and post-PCI MI



MI

No MI

Goldstein et al. Circ Intv 2011



# Near-Infrared Spectroscopy and Inadequate Flow



■ STEMI 
 ■ NSTEMI/UAP 
 ■ Stable AP

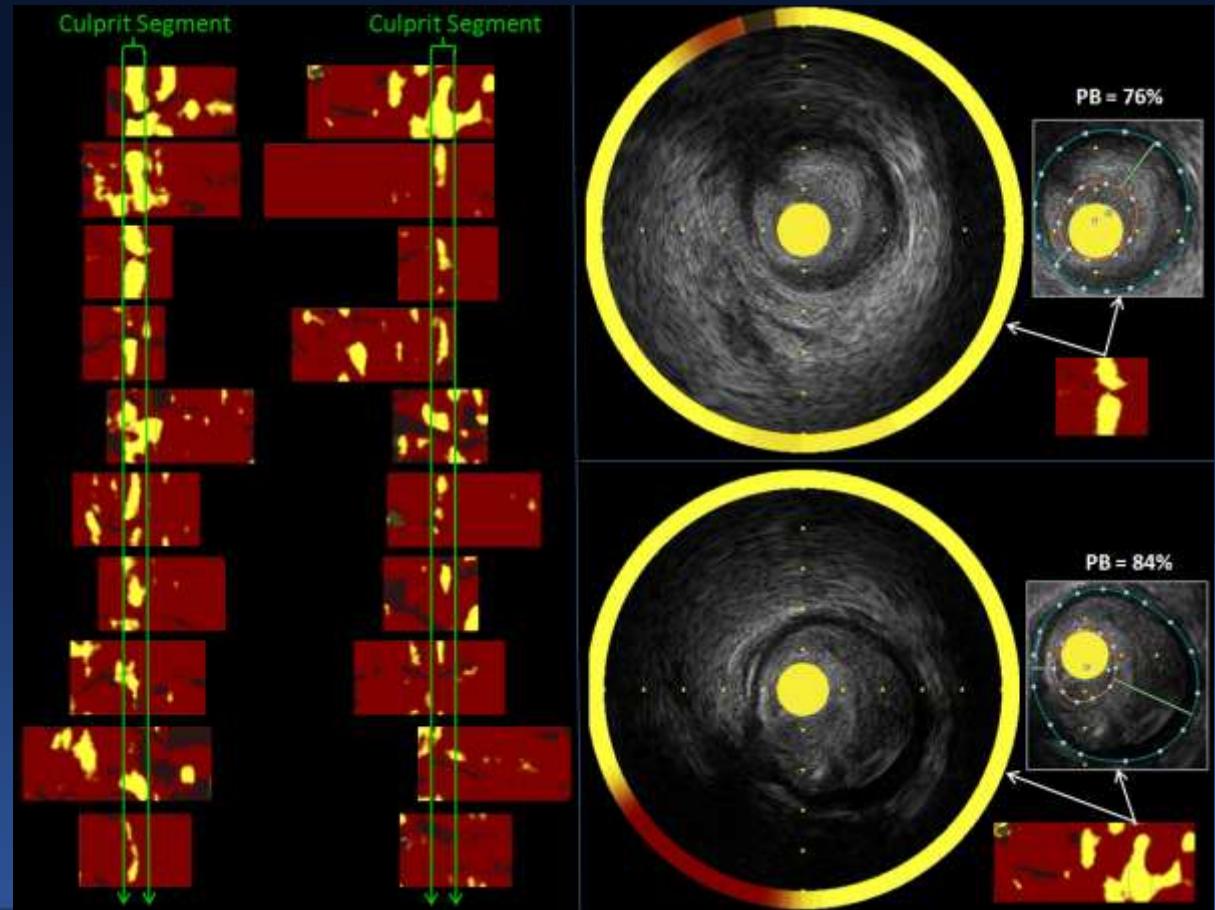
Author	# of pt	Symptom	Morphological Predictor	Endpoint
<b>Goldstein</b>	<b>62</b>	<span style="color: blue;">■</span> <span style="color: gray;">■</span>	LCB I max4mm $\geq$ 500	Trop or CK-MB $>$ 3UNL
<b>Raghunathan</b>	<b>30</b>	<span style="color: red;">■</span> <span style="color: blue;">■</span> <span style="color: gray;">■</span>	Lesion LCBI 145 vs 110	CK-MB $>$ UNL

Goldstein et al Circ Cardiovasc Interv 2011;4:429-37, Raghunathan D et al. AJC 2011;107:1613-8

# Is there a characteristic signal of lesions that cause STEMI?

Near infrared spectroscopy (InfraReDx) was performed immediately after infarct artery recanalization in 20 pts with STEMI

The NIRS chemograms of all 20 STEMI pts. The culprit segments contain LCP in 19 cases (95%), all with large plaque burden.

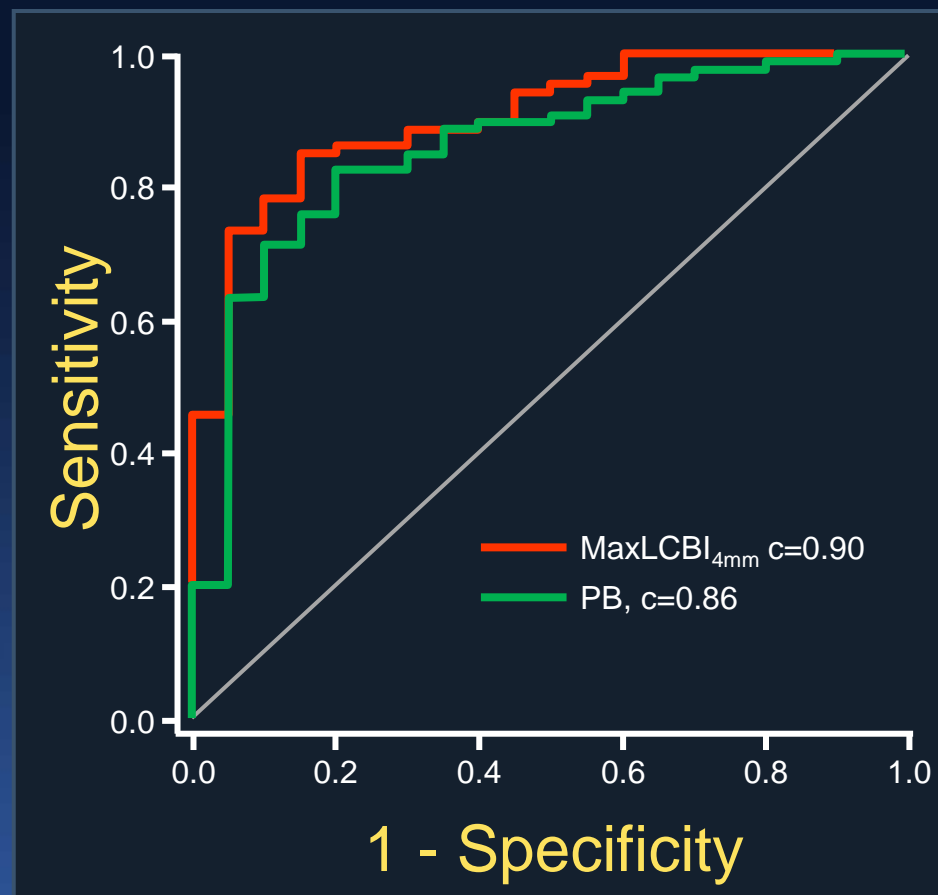


# Is there a characteristic signal of lesions that cause STEMI?

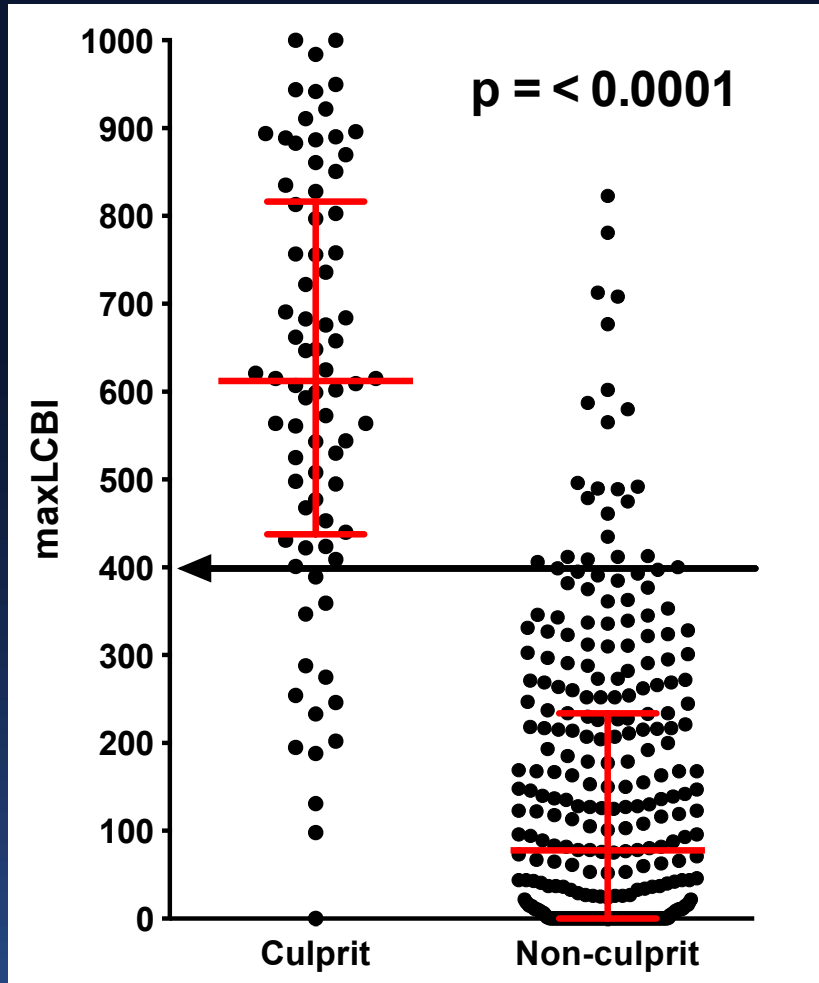
Near infrared spectroscopy (InfraReDx) was performed immediately after infarct artery recanalization in 20 pts with STEMI

Ability of NIRS (maxLCBI<sub>4mm</sub>) and IVUS (plaque burden and calcification) to distinguish the culprit segment from non-culprit segments of the STEMI culprit vessel:

- AUC for maxLCBI<sub>4mm</sub> = 0.90
- AUC for plaque burden = 0.86



# STEMI culprit vs. non-culprit segments



*Mann-Whitney U test*  
*Median  $\pm$  interquartile range*

STEMI culprit lesions:  
 $\text{maxLCBI}_{4\text{mm}} = 612 (438-817)$

Non-culprit lesions:  
 $\text{maxLCBI}_{4\text{mm}} = 78 (0-234)$

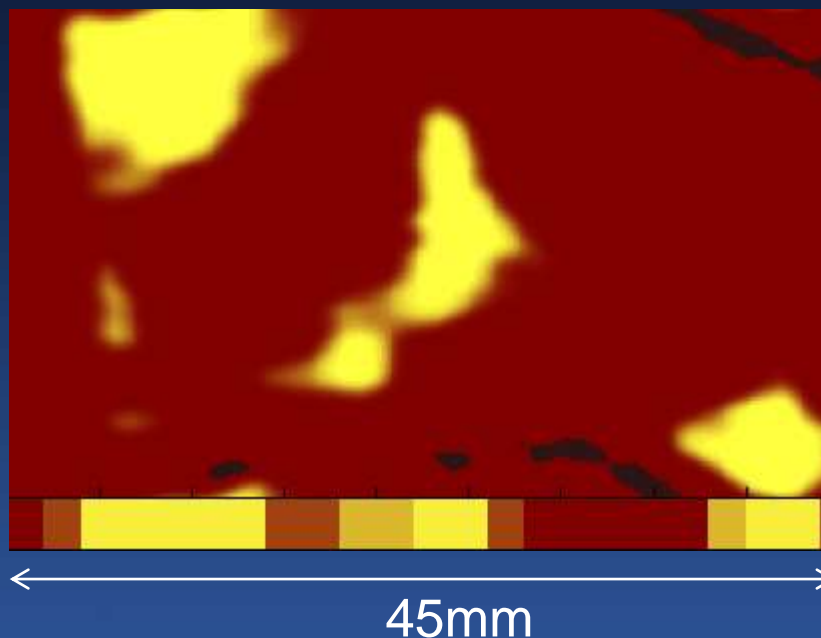
$\text{MaxLCBI}_{4\text{mm}} > 400$  was present  
at the STEMI culprit site in  
**63 of the 78 cases**

$\text{MaxLCBI}_{4\text{mm}} > 400$  was present  
at the non-culprit site in  
**22 of the 304 segments**

# Relationship between Lipid Rich Plaque detected by NIRS and Outcomes

- Prospective Single Center Study, 206 patients (ACS47%)
- Primary Endpoint: Composite of all-cause mortality, non-fatal ACS, stroke and unplanned PCI during one-year FU
- >40mm non culprit segment of NIRS

Lipid Core  
Burden Index  
(LCBI)=188

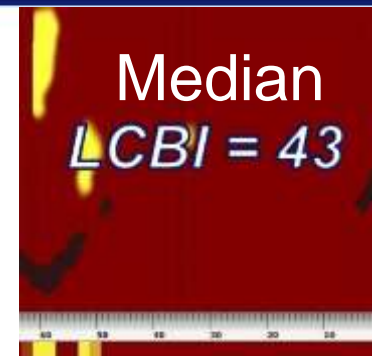
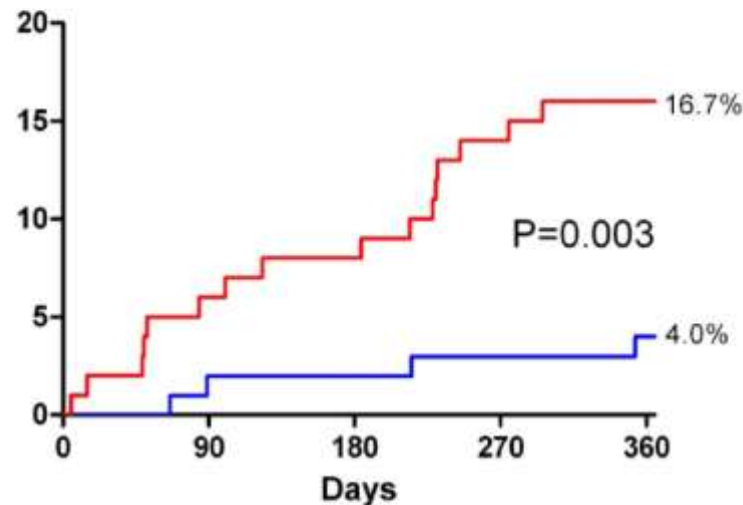


# Relationship between Lipidic Plaque detected by NIRS and Outcomes

Primary endpoint



Cumulative Rate of  
All-Cause Mortality, Stroke,  
Non-fatal ACS or unplanned PCI  
(excl. definite CLR events)



— LCBI ≥ median  
— LCBI < median

No. at Risk

LCBI < Median	101	99	99	97	91
LCBI ≥ Median	102	94	92	86	83

Adjusted HR: **4.04** 95% CI: 1.3-12.3 P=0.01

# Two/Three Vessel CAD

(n= 87)

After stenting the target vessel  
The non-target lesion underwent FFR

FFR $\leq$ 0.8  $\rightarrow$  IVUS, NIRS

Randomized

## Standard

n = 43

Continue statin the patient was taking  
Dual antiplatelet therapy for 1 year

## Aggressive

n = 44

Rosuvastatin 40 mg daily  
Dual antiplatelet therapy for 1 year

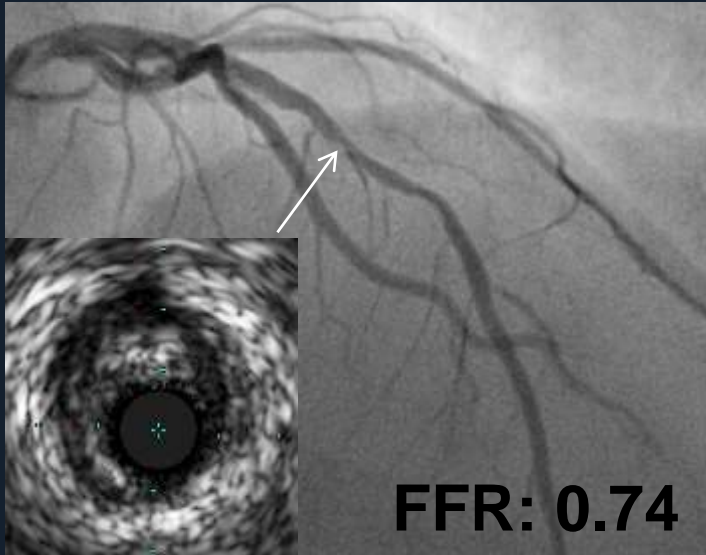
Follow up Cath (6-8 weeks)  
FFR, IVUS and NIRS repeated.  
If FFR  $\leq$ 0.8, lesion stented and imaging repeated.  
If FFR > 0.8 the patient was treated medically.

Imaging data analyzed by CRF Core Lab  
Data analysis for primary outcome analyzed by MSH independent Core Lab

# Case Example

*Yellow*

## Baseline



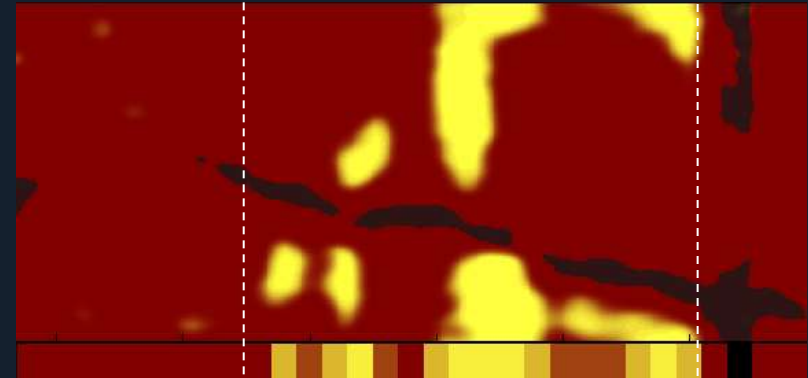
Plaque Area  
5.6mm<sup>2</sup>

FFR: 0.74

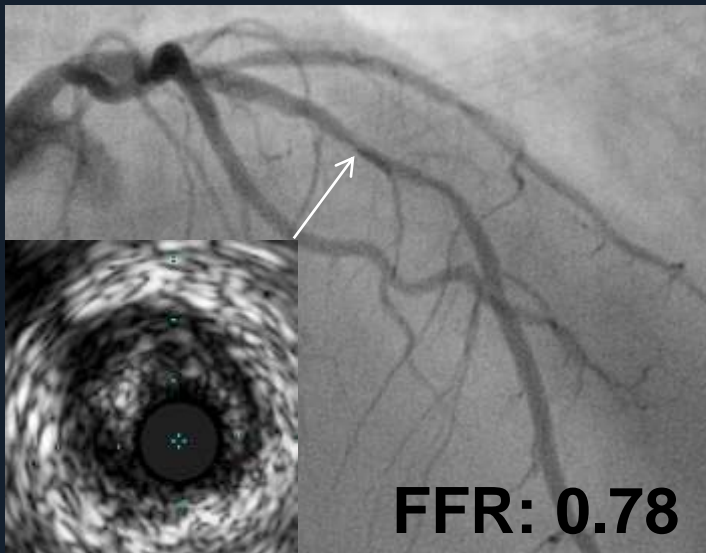
Lesion LCBI: 259

Max10mm LCBI: 511

Max4mm LCBI: 802



## Follow-up



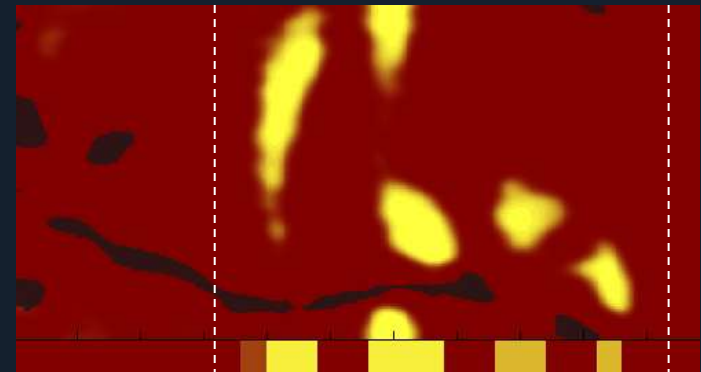
Plaque Area  
5.5mm<sup>2</sup>

FFR: 0.78

Lesion LCBI: 177

Max10mm LCBI: 289

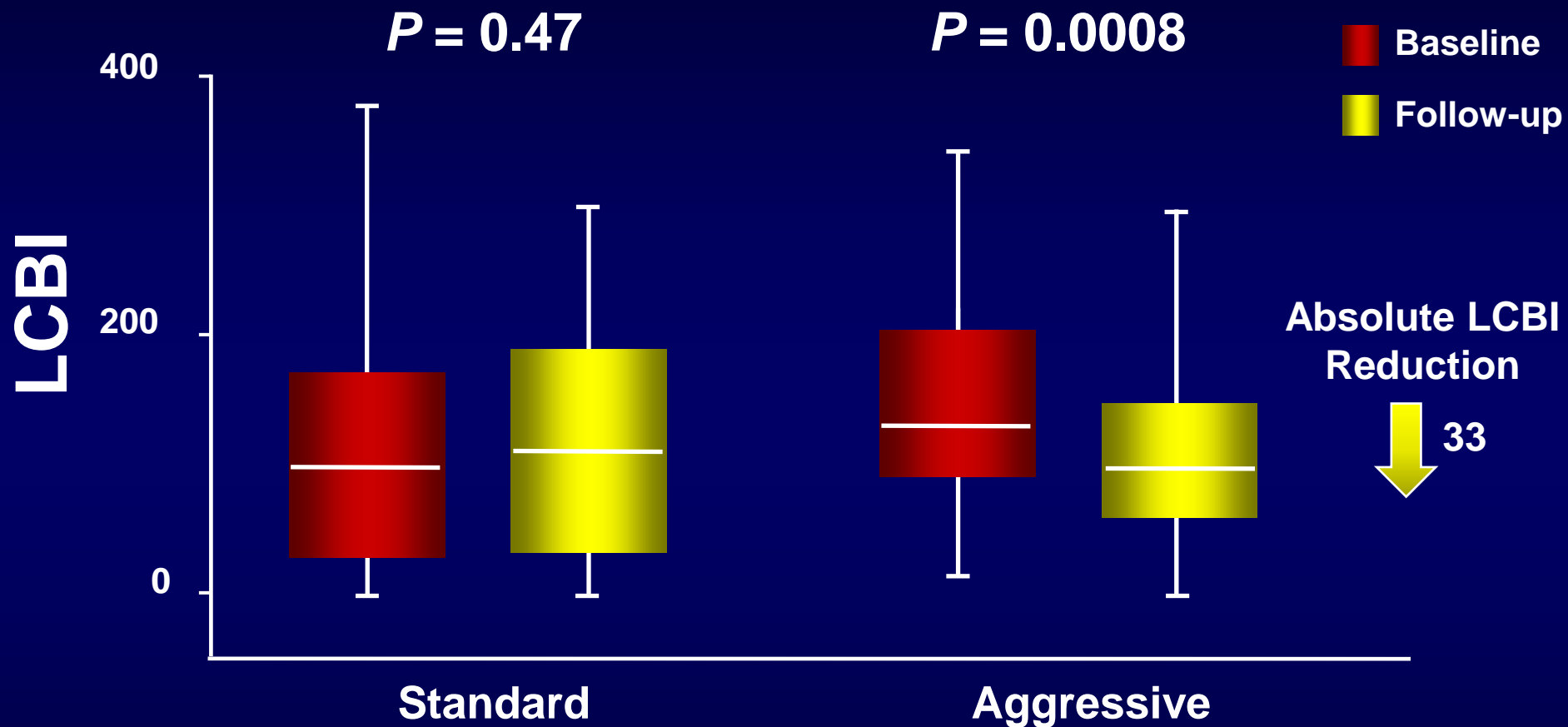
Max4mm LCBI: 474





# Paired Analysis – Lesion LCBI

*Yellow*



Variable	Standard (n = 43)	Aggressive (n = 44)	P
Percent atheroma volume	0.26%	0.24%	0.98

# Take Home Message

- 1. NIRS uses scattering through blood and diagnose a distribution of lipid contents using absorption pattern which is unique for tissue components.**
- 2. NIRS can...**
  - 1. predict the lesions with distal embolization**
  - 2. differentiate the culprit lesions in STEMI compared to non-culprit lesions.**
  - 3. predict future event based on the lipid contents in the coronary arteries.**
  - 4. evaluate the efficacy of short-term drug efficacy on the lipidic plaques.**