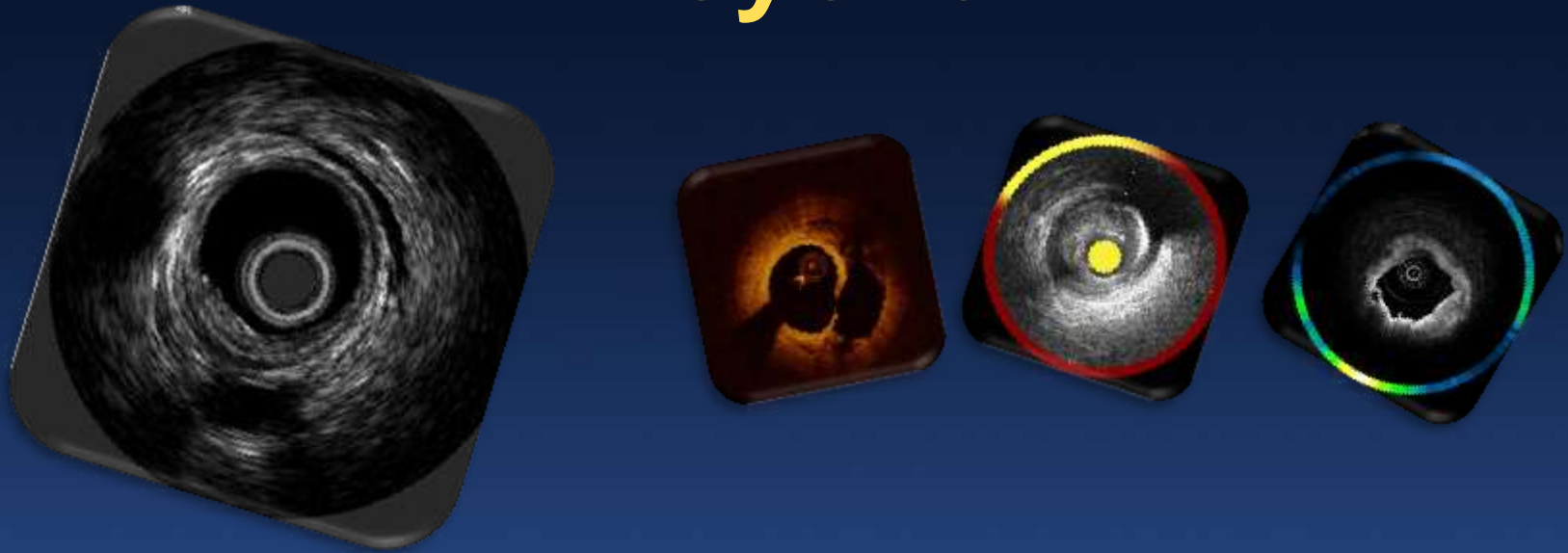


# Beyond IVUS : OCT, NIRS, and Beyond



*Joon Won Kang, RT*

Cardiovascular Center, Anam Hospital  
Korea University Medical Center

# 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions

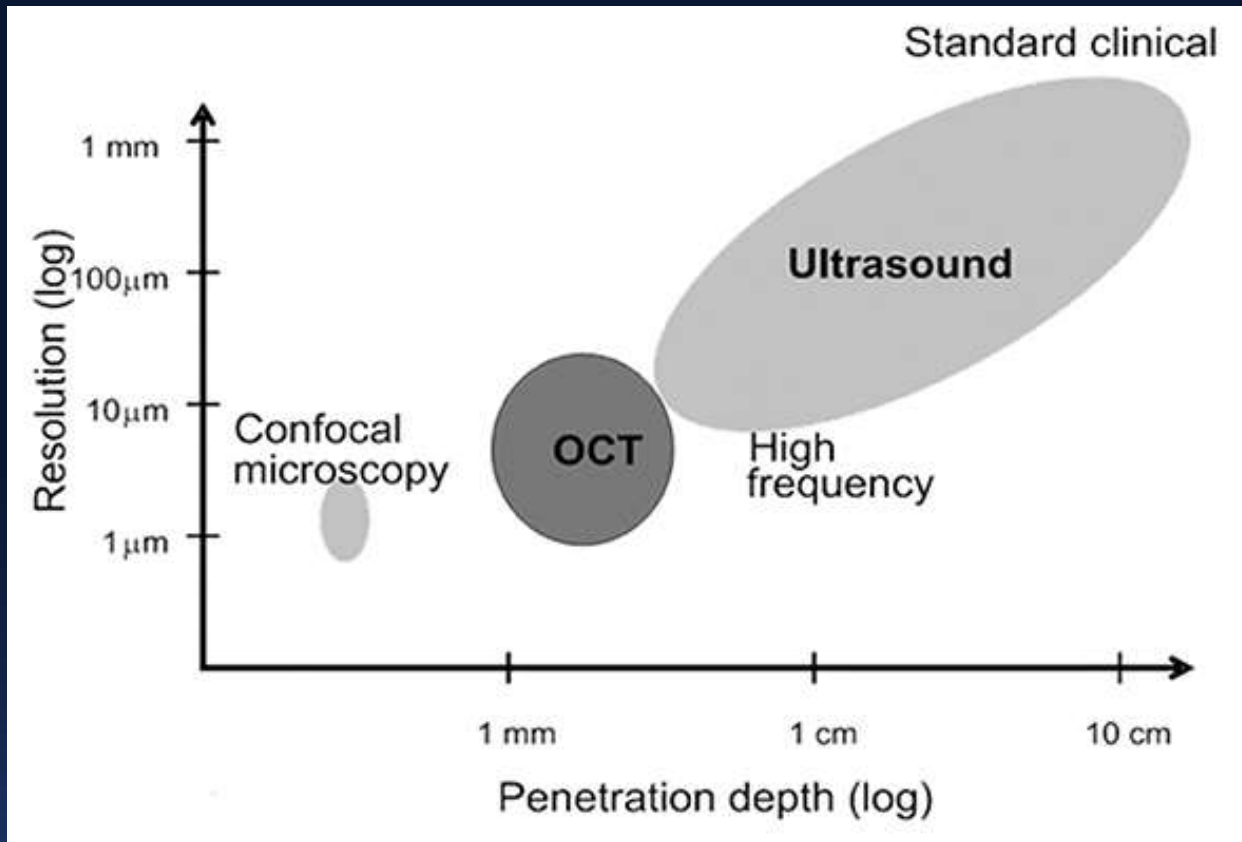
	<b>I</b>	<b>IIa</b>	<b>IIb</b>	<b>III</b>
<b>IVUS</b>		1. Indeterminant LM CAD. 2. Allograftvasculopathy. 3. ISR.	1. Non-left main intermediate. 2. Guide stenting. 3. Mechanism of stent thrombosis.	1.No plan for revasc
<b>OCT</b>	-	-	-	-

Expert consensus statement on the use of fractional flow reserve, intravascular ultrasound, and optical coherence tomography

A consensus statement of the society of cardiovascular angiography and interventions

2014 SCAI  
consensus document

	<b>OCT</b>	<b>IVUS</b>
Definitely beneficial		Determine size of vessel Optimal stent deployment
<b>Probably beneficial</b>	<b>Optimal stent deployment</b> (sizing, apposition, thrombus, dissection) compared with IVUS	<b>LMCA assessment</b>
Possibly beneficial	<b>Plaque morphology</b>	<b>Plaque morphology</b>
No proven value/ discouraged	<b>Non-LMCA lesion severity</b>	<b>Determine lesion significance</b>



Current data...

OCT

IVUS

# Which One is Better ???



**IVUS guided PCI**

**OCT guided PCI**

## **ADAPT DES**

Witzenbichler et al  
Circulation 2014;129:463-70

## **4 Meta-Analysis**

Zhang et al. Eurointervention 2012;8:855-65  
Kersy C et al. Int J Cardiol 2013;170:54-63  
Jang et al. JACC Cardiovasc Inter 2014;7:233-43  
Ahn et al. Am J Cardiol 2014;113:1338-47

## **CLI-OPCI**

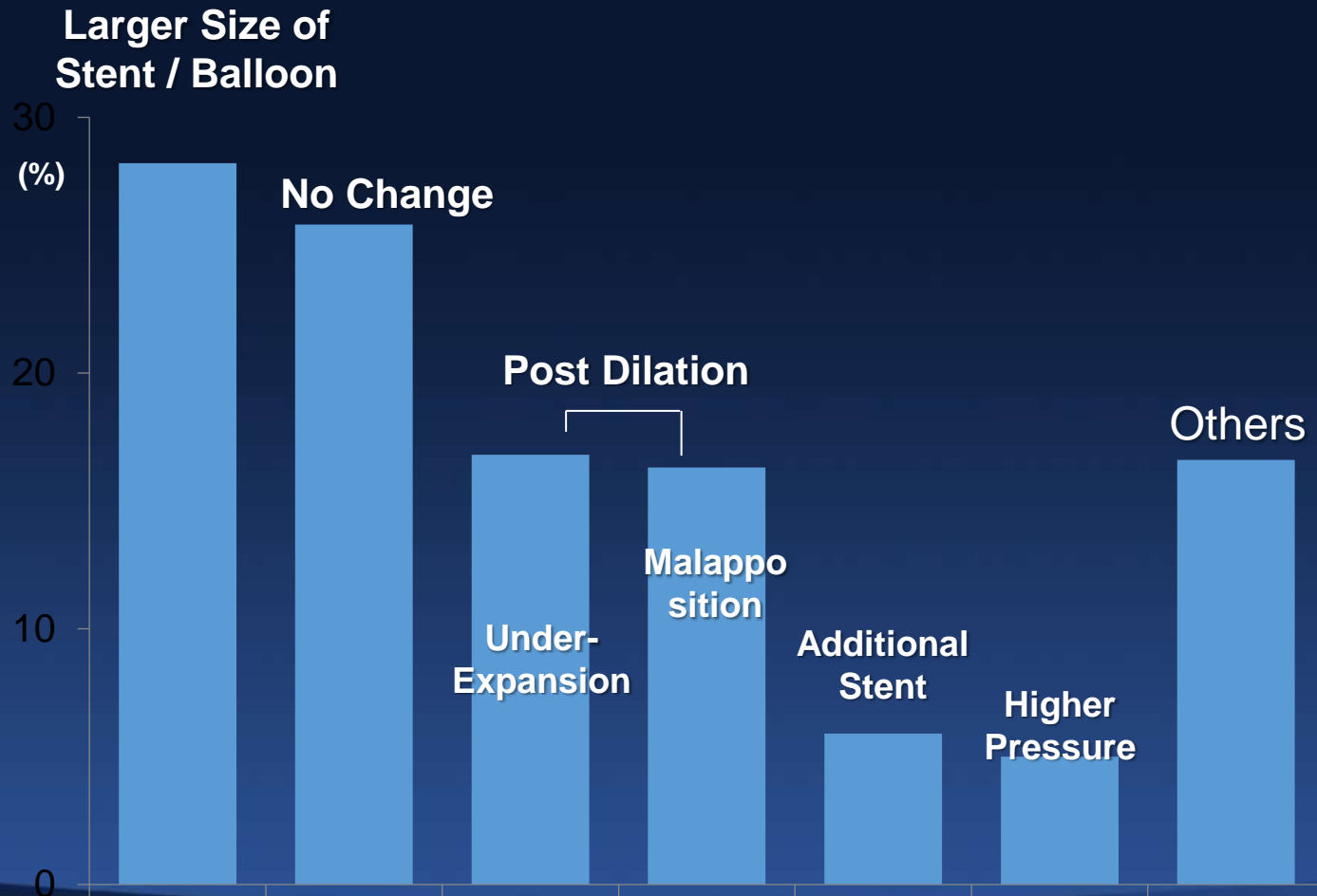
Prati F et al. EuroIntervention 2012;8:823-9

## **OCT vs IVUS guided PCI**

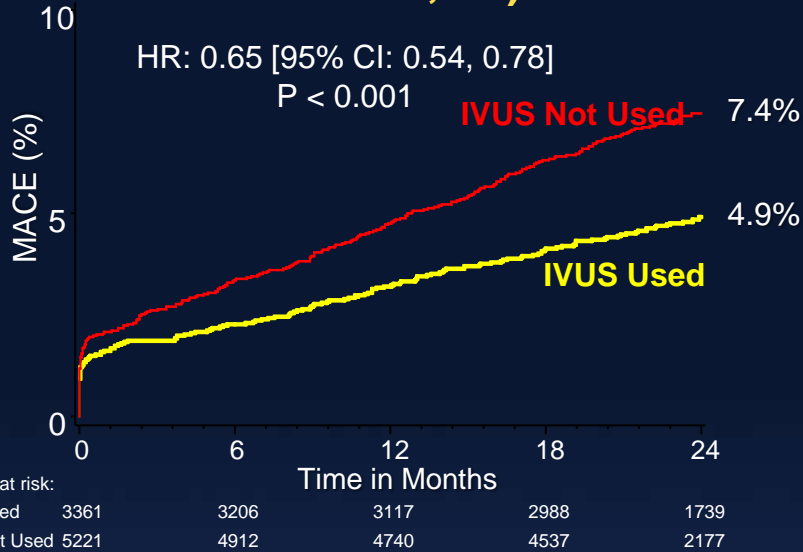
Habara et al.  
Circ Cardiovasc Interv. 2012;5:193-201

# How IVUS changed the procedure?

## ADAPT-DES

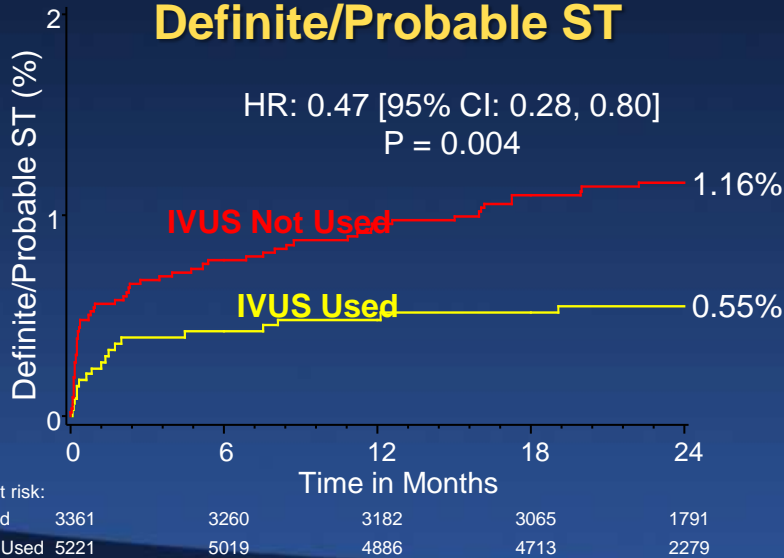


# MACE (Definite/Probable ST, Cardiac Death, MI)

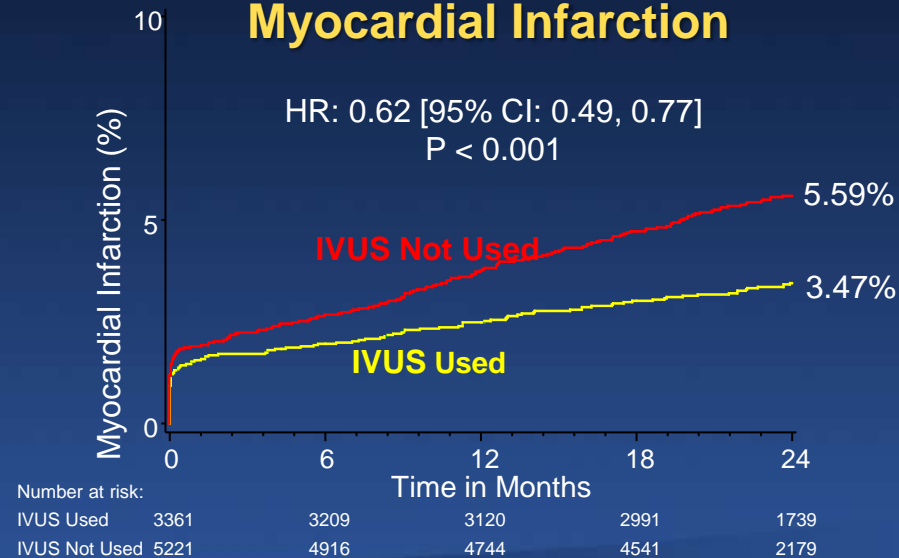


Two year follow-up data from ADAPT-DES (3361 pts treated with IVUS-guidance vs 5221 pts treated with angiographic guidance)

## Definite/Probable ST



## Myocardial Infarction



# New Generation High Frequency IVUS

- **ACIST, 60MHz** (purchased SVMi - has been working on next generation IVUS since 2007)

} Available

- **Boston Scientific, 55MHz**
- **Volcano, FACT**
- **InfraReDx, 50MHz**

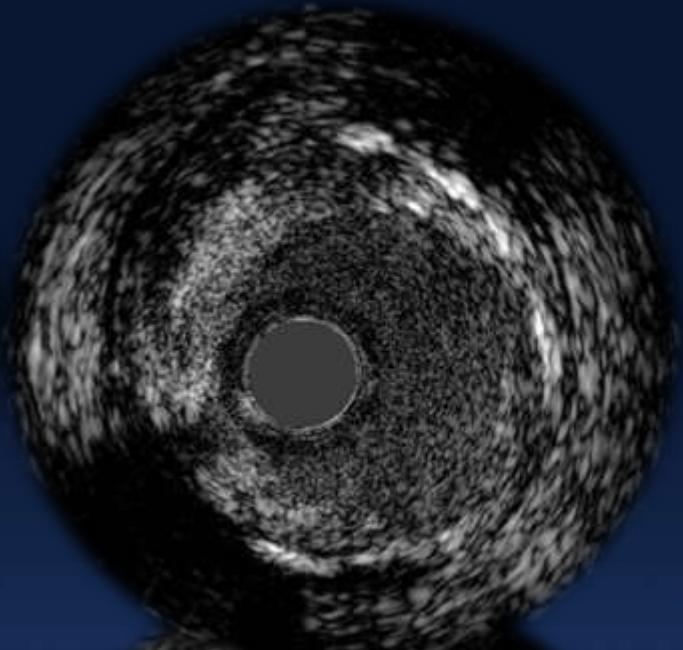
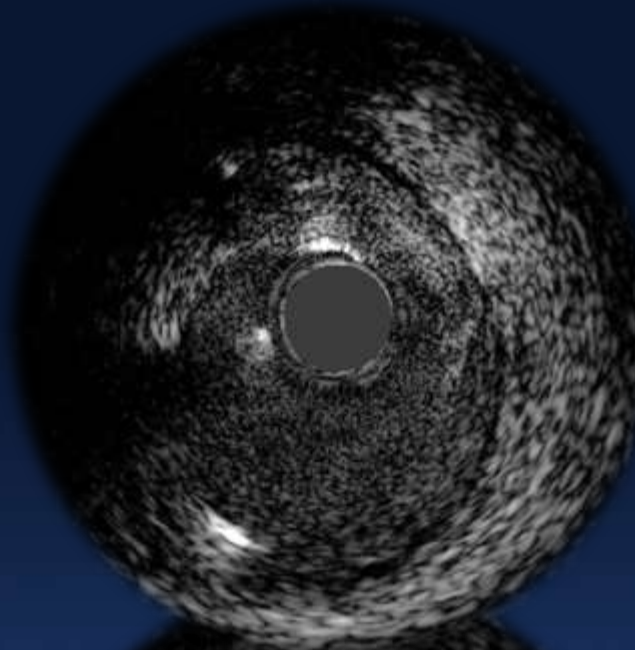
} Under development

<b>Feature</b>	<b>ACIST HDi / Kodama</b>	<b>Boston Scientific</b>	<b>Volcano FACT</b>	<b>InfraReDx</b>	<b>St Jude Medical OCT</b>
Frequency or Wavelength	60 MHz	55 MHz	NA	50 MHz	1.3 $\mu$ m
Axial Resolution	40 $\mu$ m	22 $\mu$ m	<50 $\mu$ m	20 $\mu$ m	15 $\mu$ m
Soft Tissue Penetration	> 2.5 mm	>3.5 mm			0.8-1.2 mm
Pullback Speed (mm/s)	0.5, 1.0, 2.5, 5.0, 10	0.5,1.0		0.5	20
Pullback Length (mm)	130	100		150	75

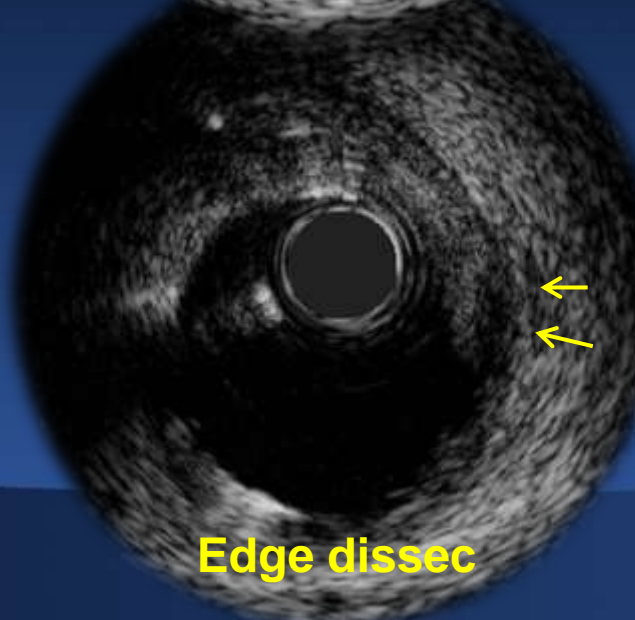


# High Speed Pullback (10mm/sec) with Flushing

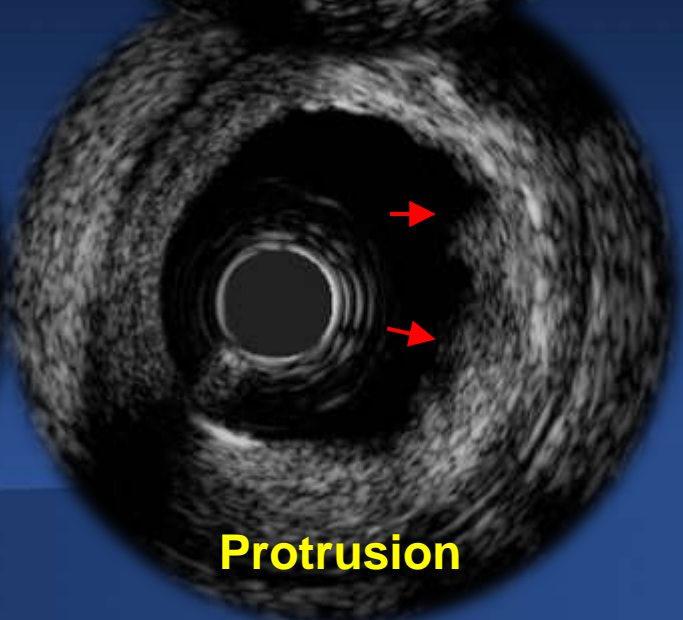
High Speed Pullback  
with Flushing



Normal Pullback



Edge dissec



Protrusion

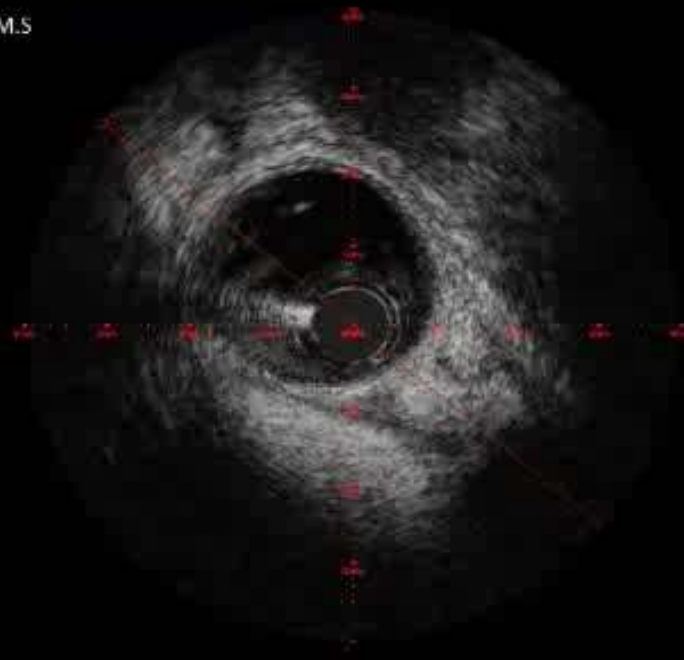
40 MHz  
43 micron axial



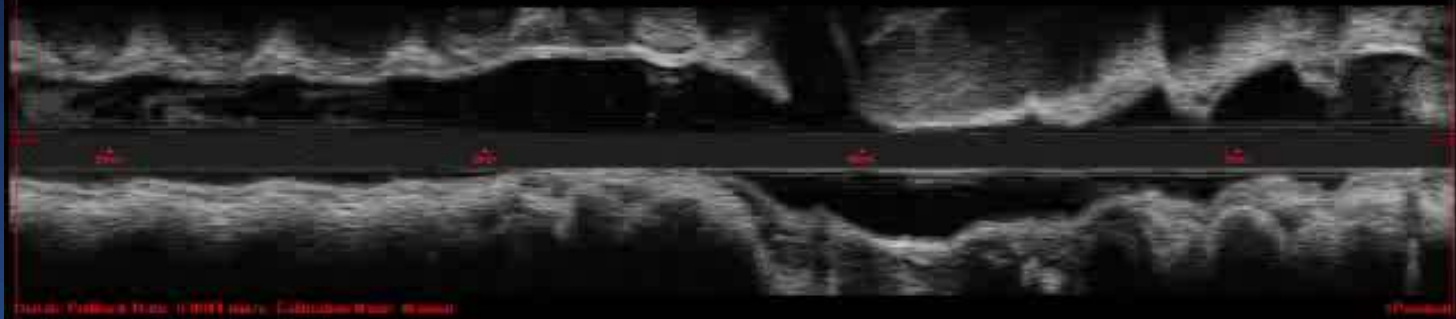
55 MHz  
22 micron axial



DEXTRAN 10PCT 2ML 16MLTOT 5MM.S



SVMI Med Center

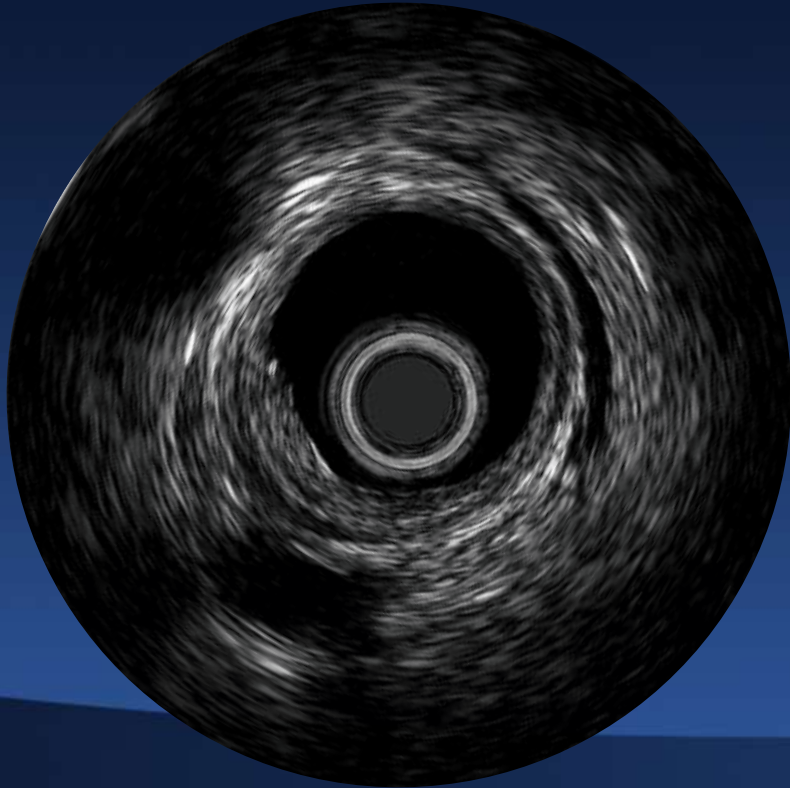


Animal Coronary Artery

# Volcano: FACT

(Focused Acoustic Computed Tomography)

FACT ultrasound transducer intended to generate a “cleaner” signal than traditional piezo electricity, near field **resolution** close to OCT.



# InfraReDx

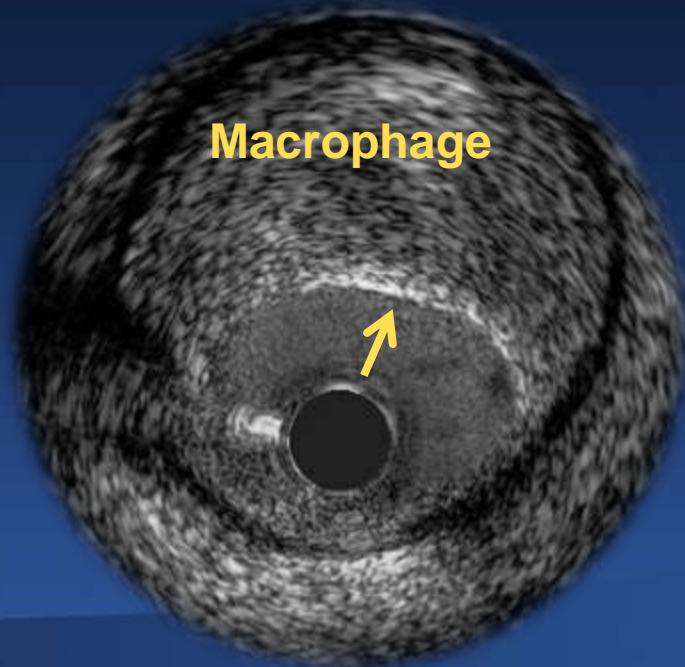
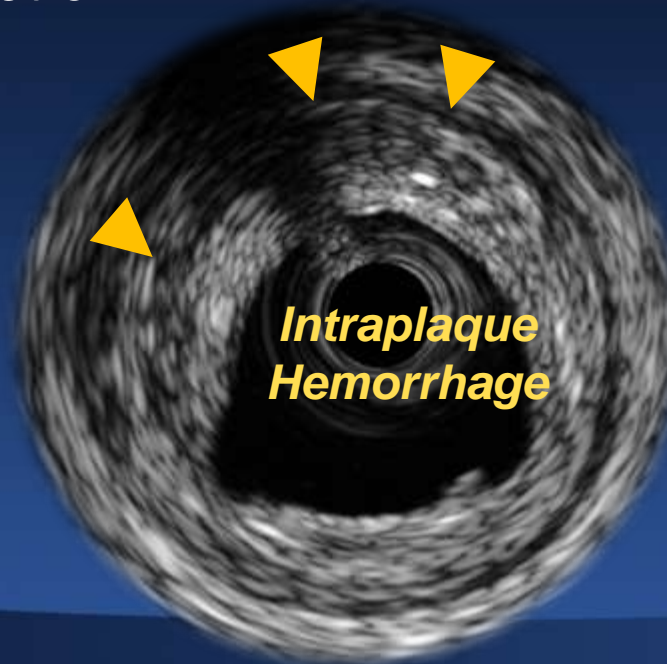
50MHz IVUS Human Coronary Artery



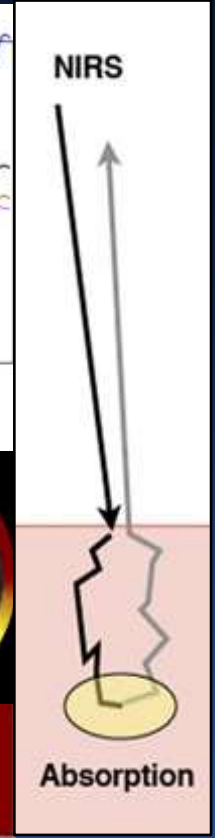
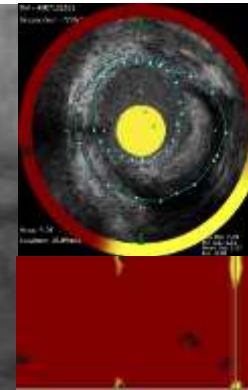
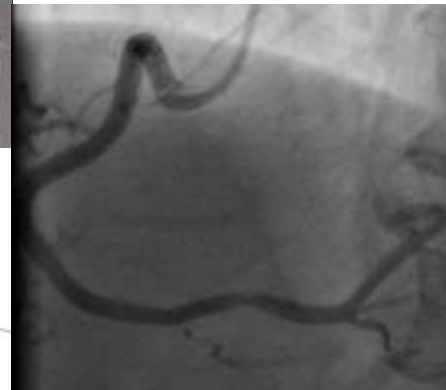
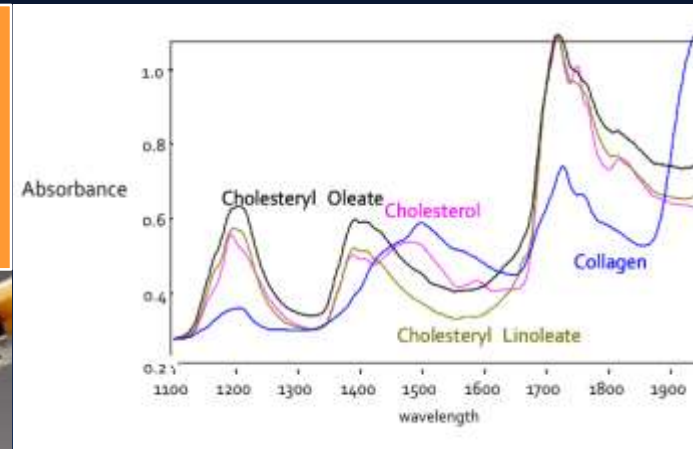
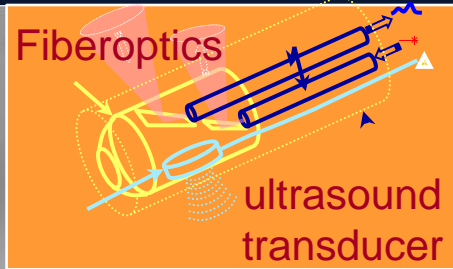
# What we are looking for more?

- *Intraplaque Hemorrhage*
- *Thrombus*
- *Macrophage*
- *Bioabsorbable stent, stent fracture*
- *Edge dissection*

...



# Near-infrared spectroscopy (NIRS-IVUS)



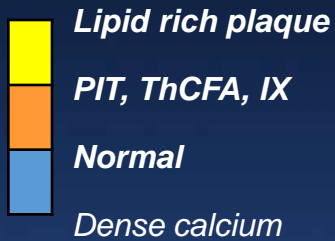
# NIRS: Accuracy vs. Histology

## Ex vivo validation

Chemogram

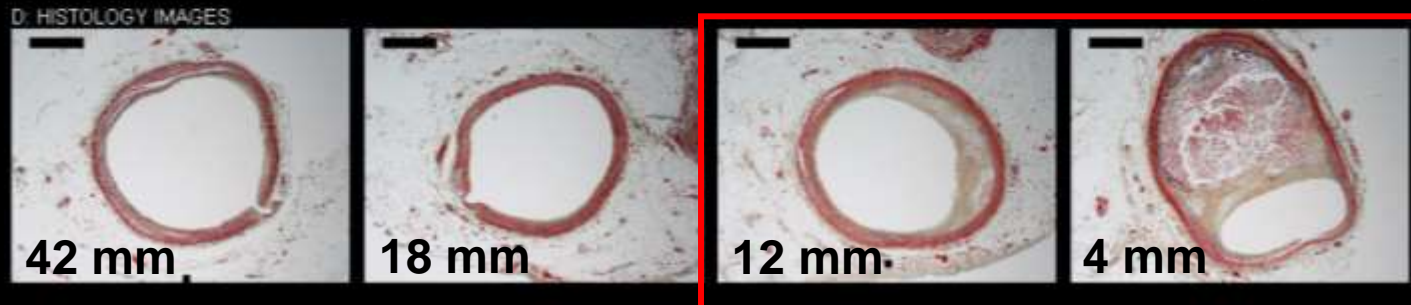


Block chemogram



Histology sections at:

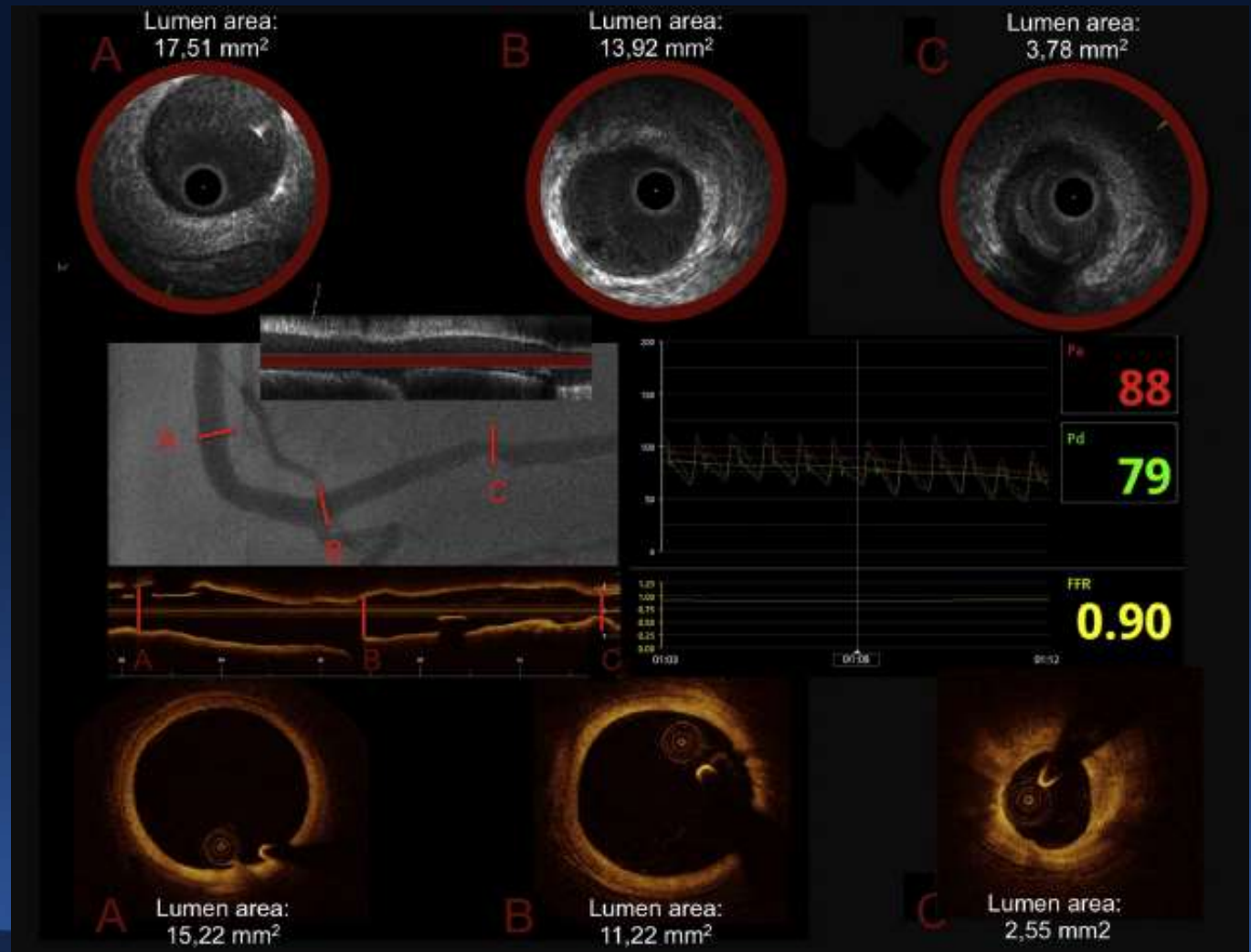
4, 12, 18, 42mm



Proximal

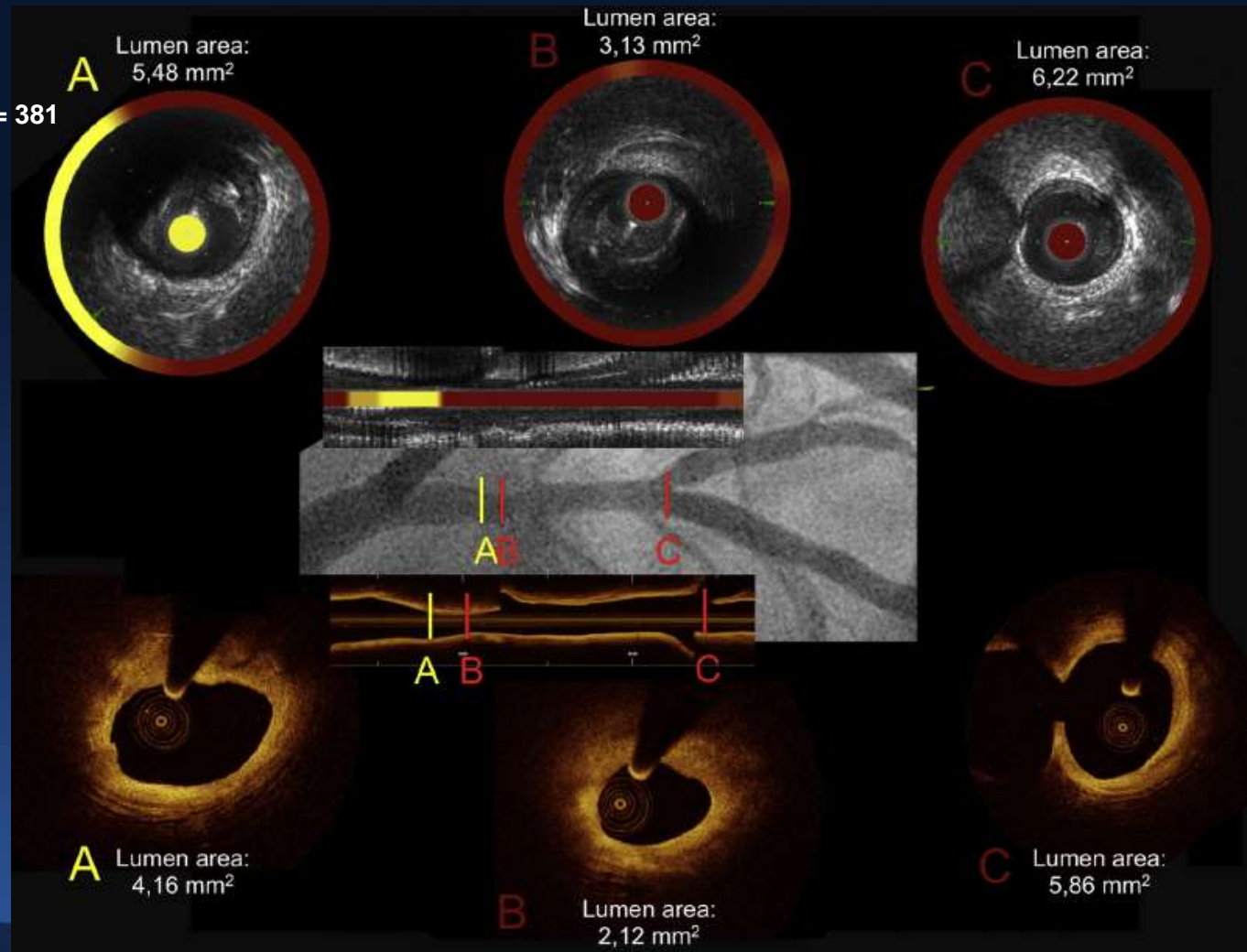
Distal

# Three-vessel coronary artery disease evaluation by multimodality imaging with **NIRS** plus **IVUS** and **OCT**



# Three-vessel coronary artery disease evaluation by multimodality imaging with **NIRS** plus **IVUS** and **OCT**

max LCBI4 mm = 381

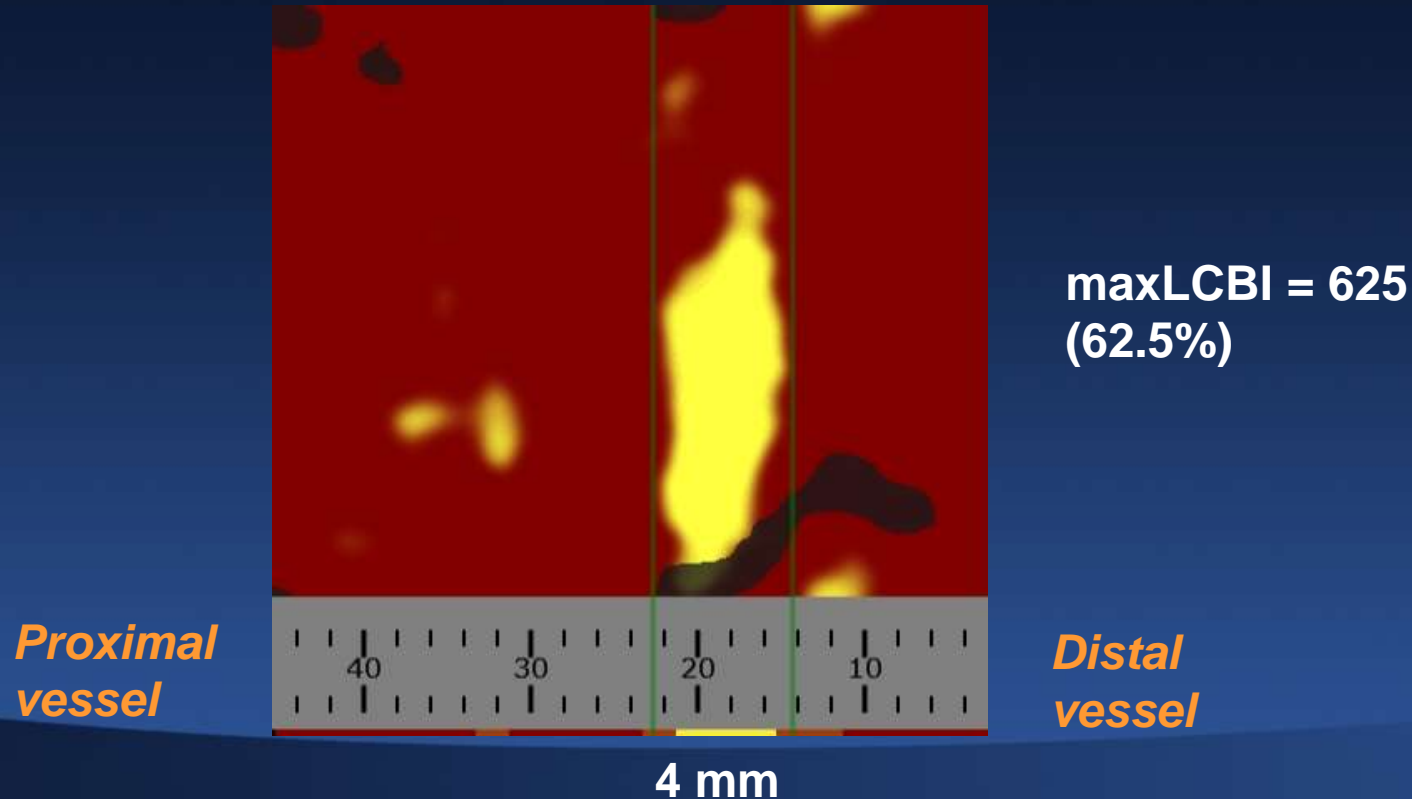




# Quantification of lipid accumulation

LCBI = Lipid Core Burden Index (% yellow pixels of ROI x 10)

**maxLCBI** = the 4 mm segment with highest lipid content

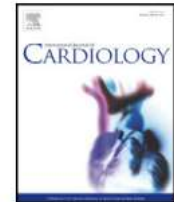


# NIRS-IVUS:

## Serial assesment of pharmacological effects?

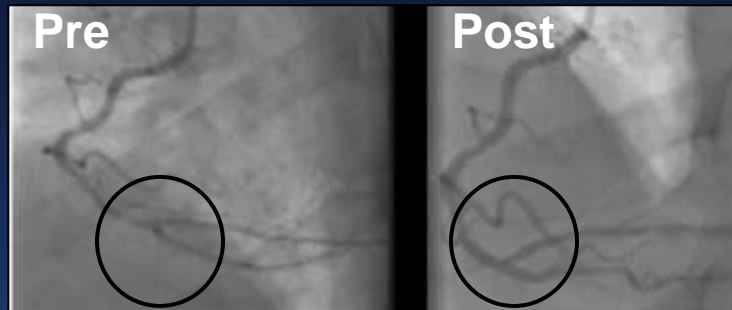


International Journal of Cardiology

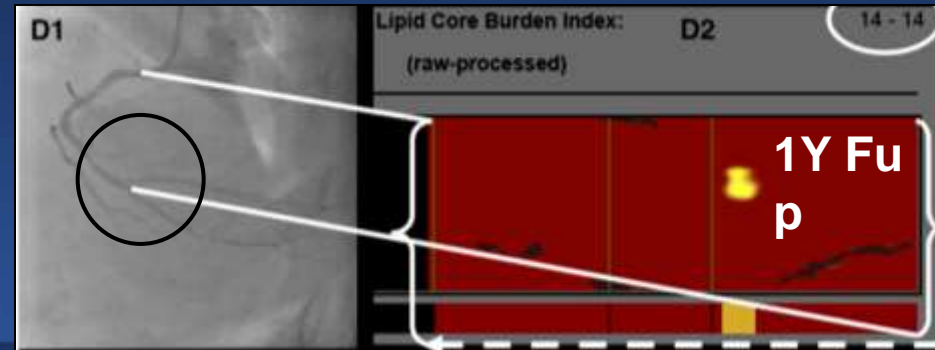
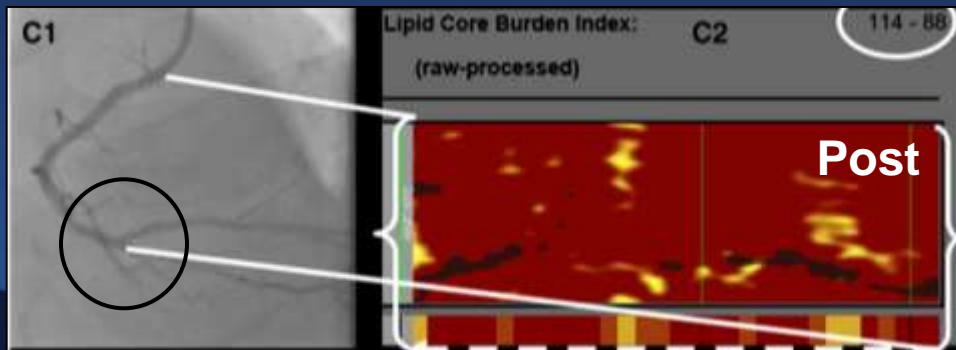


Change in near-infrared spectroscopy of a coronary artery after 1-year treatment with high dose rosuvastatin

- 44 yo male, Inferior MI
- LDL: 72mg/l-HDL: 18mg/l
- Chol/HDL:5.7
- LCBI: 114



- 12-months rosuvast. 40mg
- LDL: 51mg/l-HDL: 23mg/l
- Chol/HDL:3.4
- LCBI: 14

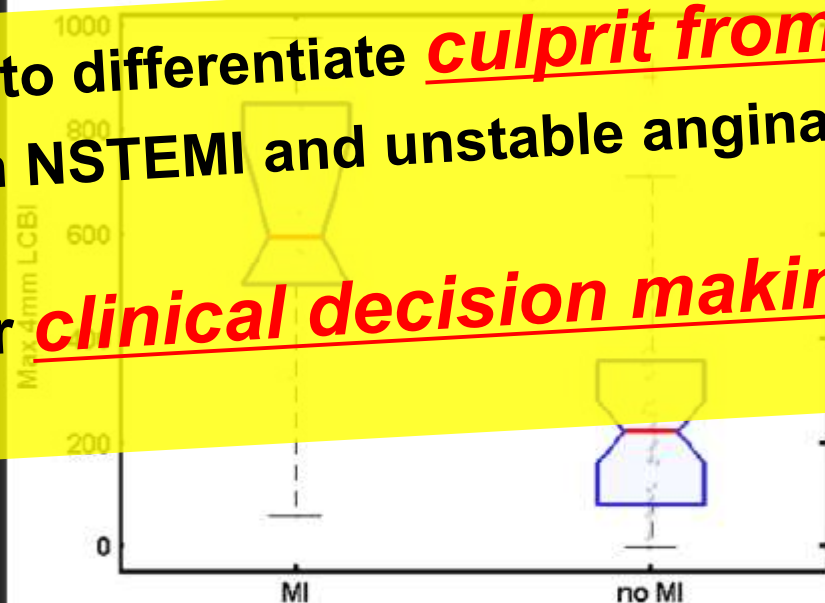


# NIRS useful for clinical decision making

## Detection of Lipid-Core Plaques by Intracoronary Near-Infrared Spectroscopy Identifies High Risk of Periprocedural Myocardial Infarction

James A. Goldstein, MD; Brijeshwar Maini, MD; Simon R. Dixon, MBChB; Emmanouil S. Brilakis, MD, PhD; Cindy L. Grines, MD; David G. ... Daniel H. Steinberg, MD; Kendrick A. Shunk, MD, PhD; Giora We ... Annapoorna Kini, MD; Samin K. Sharma, MD; Michael J. Hend ... Sean P. Madden, PhD; James E. Muller, MD; Gregg W. Slagter

Maximum 4mm LCBI and Peri-procedural MI Status



maxLCBI<sub>4mm</sub> >400 by NIRS is able to differentiate culprit from non-culprit segments in both NSTEMI and unstable angina. We already find NIRS useful for clinical decision making in NSTEMI patients

**Conclusions**—NIRS provides rapid, automated detection of extensive LCPs to predict periprocedural MI, presumably due to embolization of plaque contents during PCI. (Interv. 2011;4:429-437.)

**Key Words:** distal embolization ■ lipid-core plaque ■ plaque characterization ■ near-infrared spectroscopy ■ periprocedural myocardial infarction ■ percutaneous coronary intervention

# New developments and trends in OCT

- OCT-derived FFR
- Super high speed Heartbeat OCT
- Spectroscopic OCT (SOCT)
- Multimodality imaging: OCT +
  - IVUS
  - Near-infrared spectroscopy (NIRS)
  - Near-infrared autofluorescence (NIRAF)
  - Near-infrared exogenous fluorescence (NIRF)
- $\mu$ OCT - Cellular level resolution

# • OCT-derived FFR



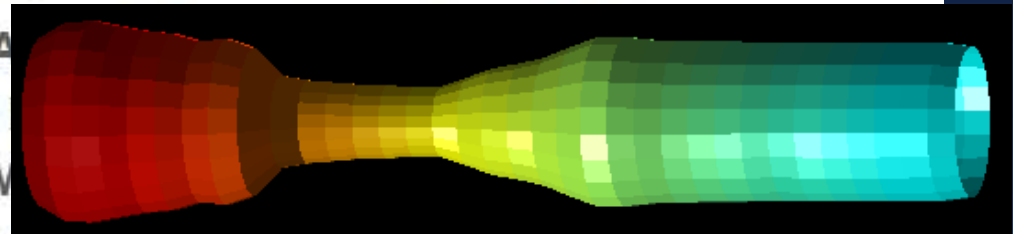
Journal of the American College of  
Cardiology

Volume 63, Issue 12, Supplement 2, 1 April 2014, Pages A1775



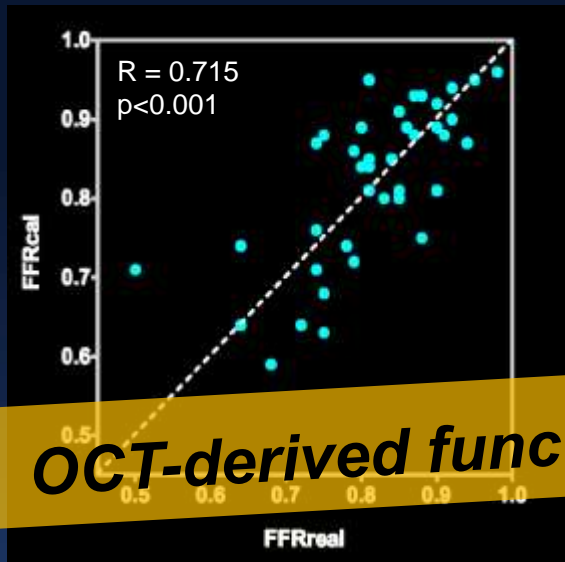
TCT@A  
DER  
TOM  
ASS  
Sun-Joo Jang, Jung-Min Ahn, Seung-Jung Park, Wang-Yuhl Oh  
Korea A  
hology, Daejeon, South Korea  
Asan Medical Center, Seoul, South Korea

Available online 27 March 2014

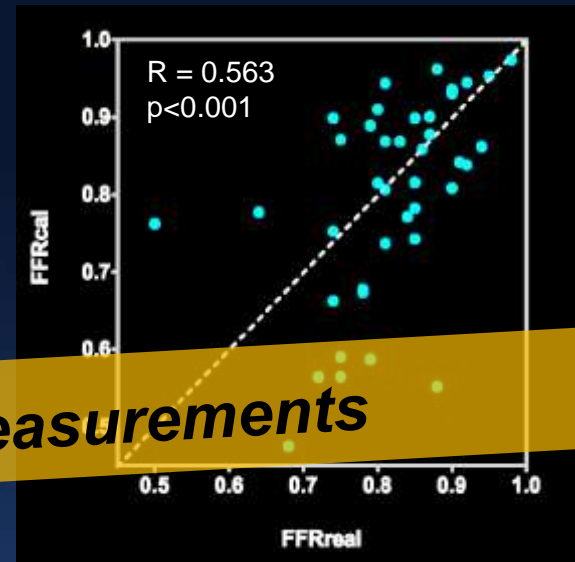


# Diagnostic Performance for $FFR \leq 0.80$

## In Laminar Flow



## In Turbulent Flow



**OCT-derived functional measurements**

	Derivation set (n=21)	Validation set (n=21)	Total patients (n=42)
Sensitivity, %	75	67	71
Specificity, %	92	100	96
Positive Predictive Value, %	86	100	92
Negative Predictive Value, %	86	80	83
Accuracy, %	86	86	86

	Derivation set (n=21)	Validation set (n=21)	Total patients (n=42)
Sensitivity, %	83	75	79
Specificity, %	80	85	82
Positive Predictive Value, %	63	75	69
Negative Predictive Value, %	92	85	88
Accuracy, %	81	81	81

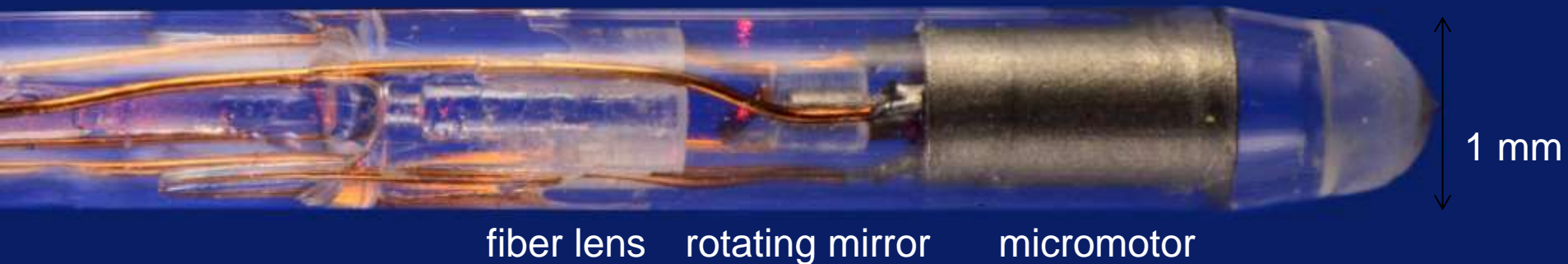
# Super high speed Heartbeat OCT

Cardiac motion artifacts in IVOCT pullback imaging



Faithful 3D matching, biomechanics, even less flush needed...

## Heartbeat OCT catheter



# Heartbeat OCT: True 3D motionless IVOCT

40 mm/s pullback

158 frames per second

81 kHz A-line rate



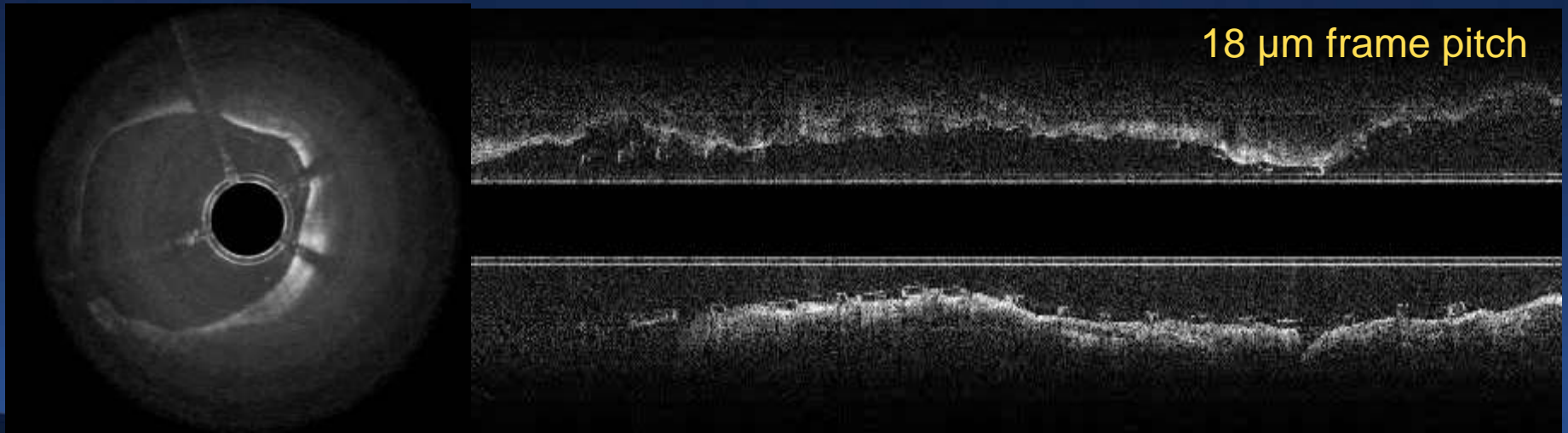
> 100 mm/s pullback

> 3000 frames per second

> 1.5 MHz A-line rate

***Speed (Heartbeat OCT)***

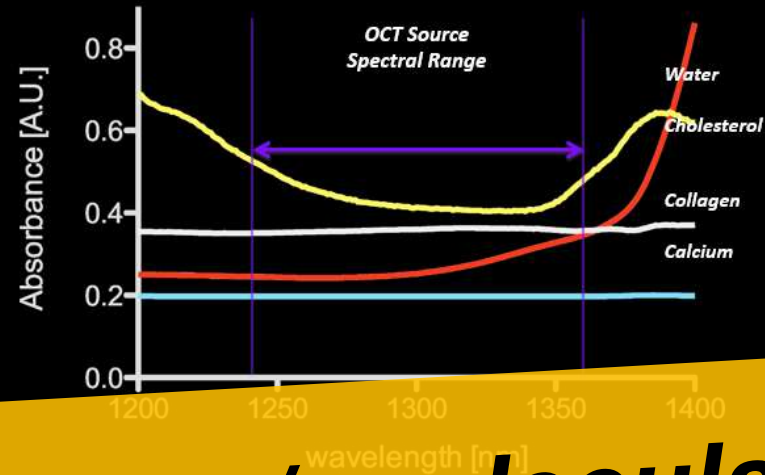
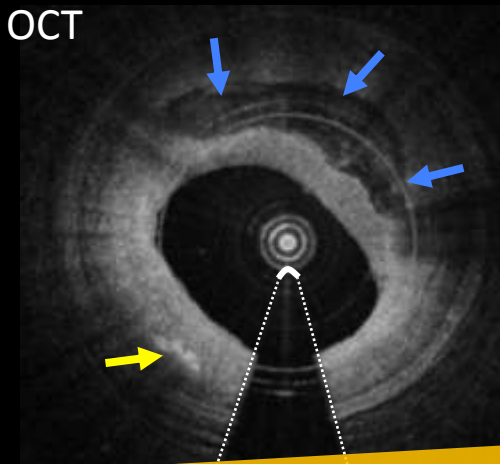
Faithful 3D matching, biomechanics, even less flush needed...





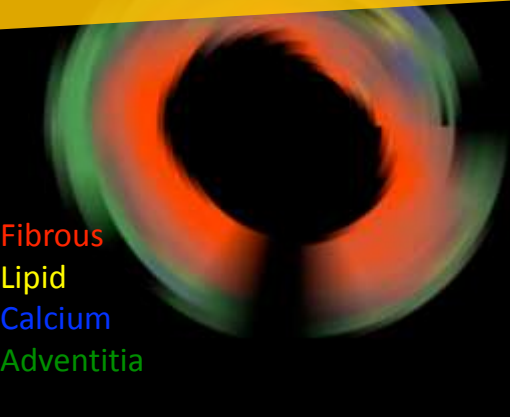
# Spectroscopic OCT (SOCT)

OCT



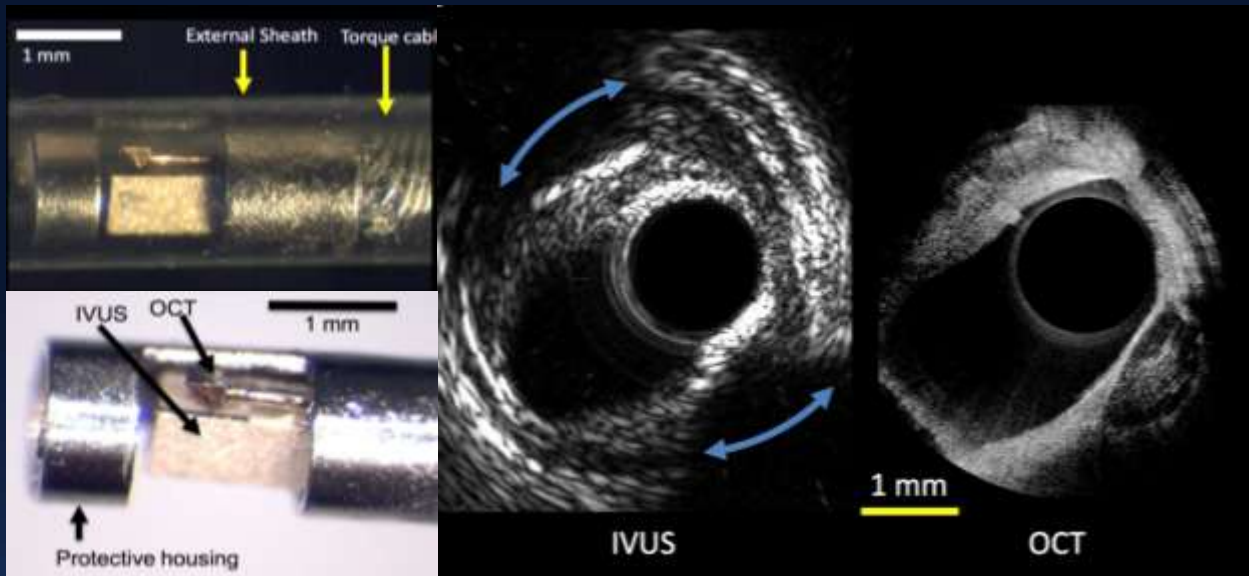
SOCT

## Composition / molecular

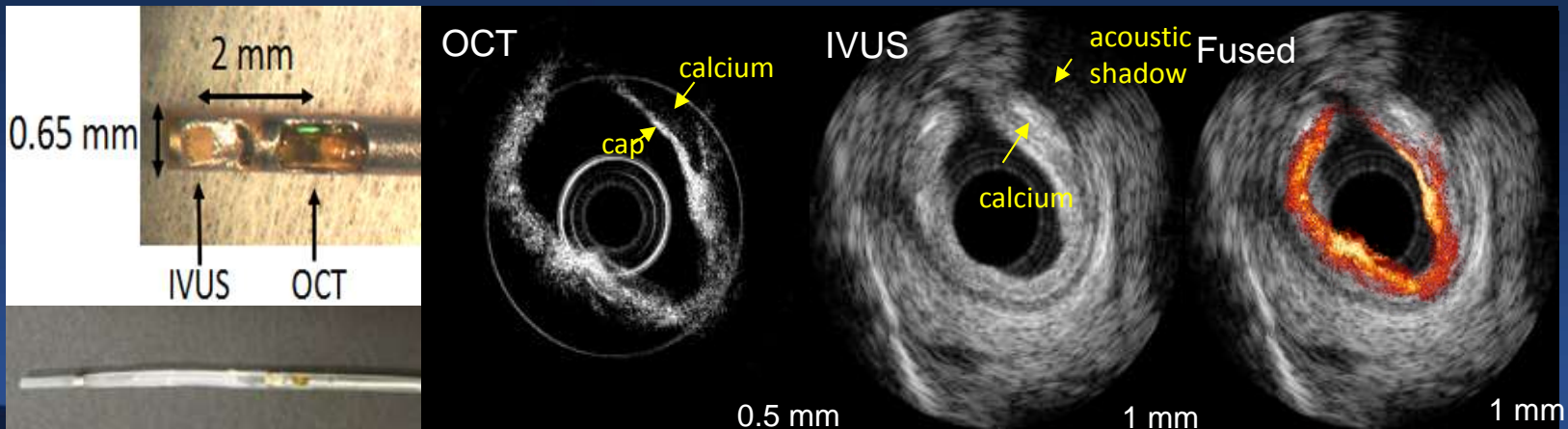


Probability of lipid or other plaque chemicals (collagen, adventitial fat, etc.) determined by classification algorithms

# Multimodality imaging: OCT + IVUS



Images courtesy of  
Brian Courtney,  
[University of Toronto](#)

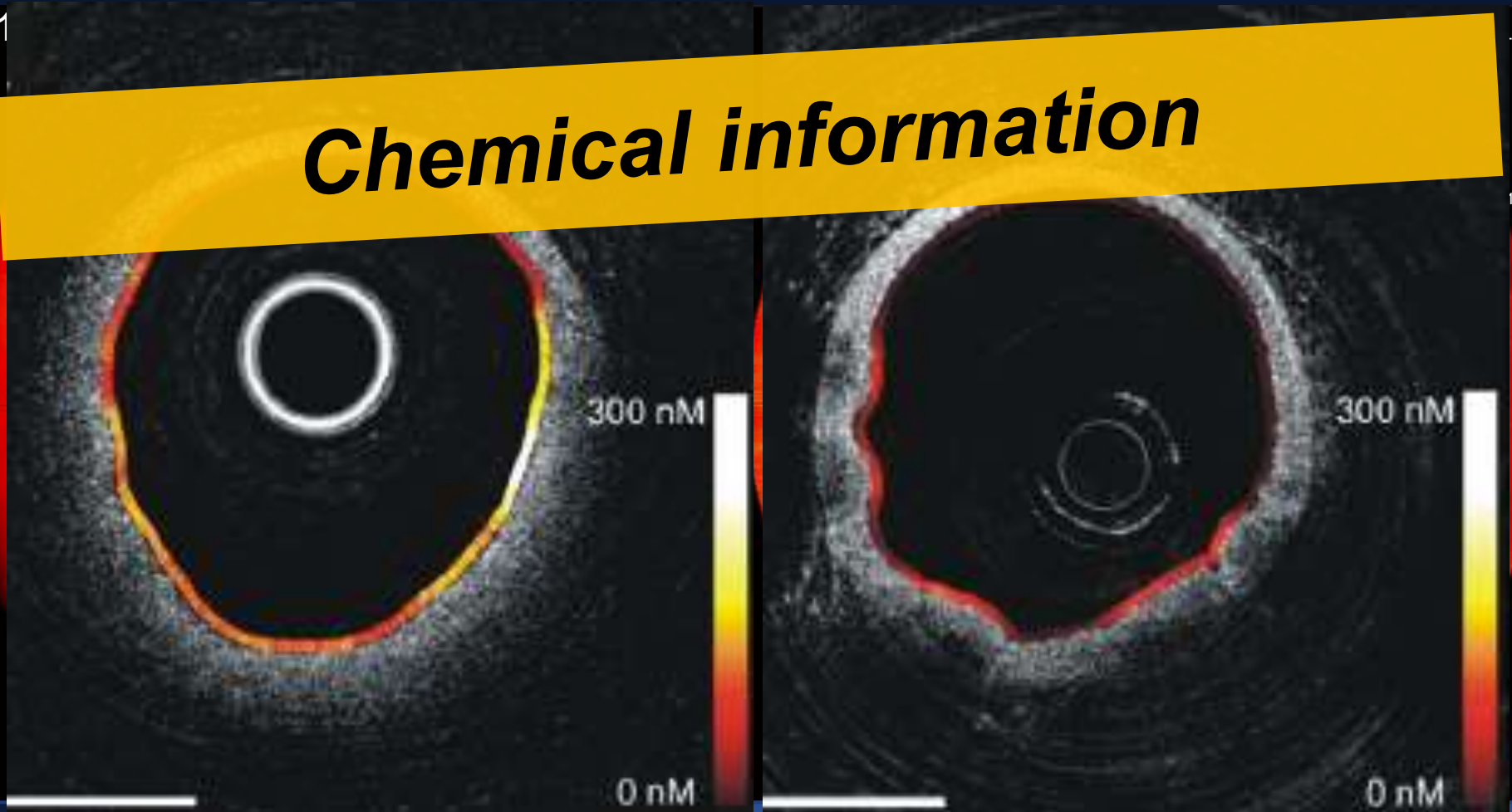


Slide courtesy of Zhongping Chen, [UC Irvine](#)

# Multimodality imaging: OCT + NIRS

(Near-infrared spectroscopy)

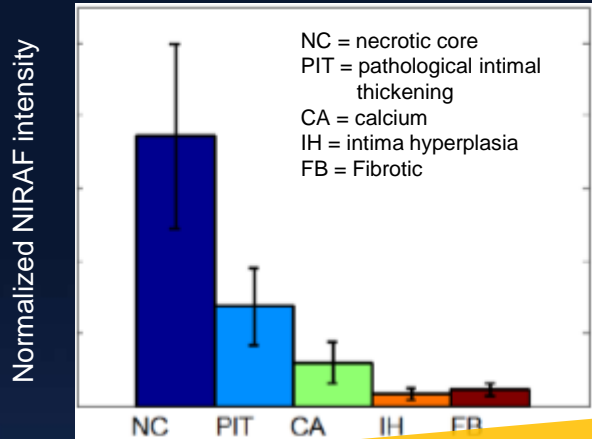
**Chemical information**



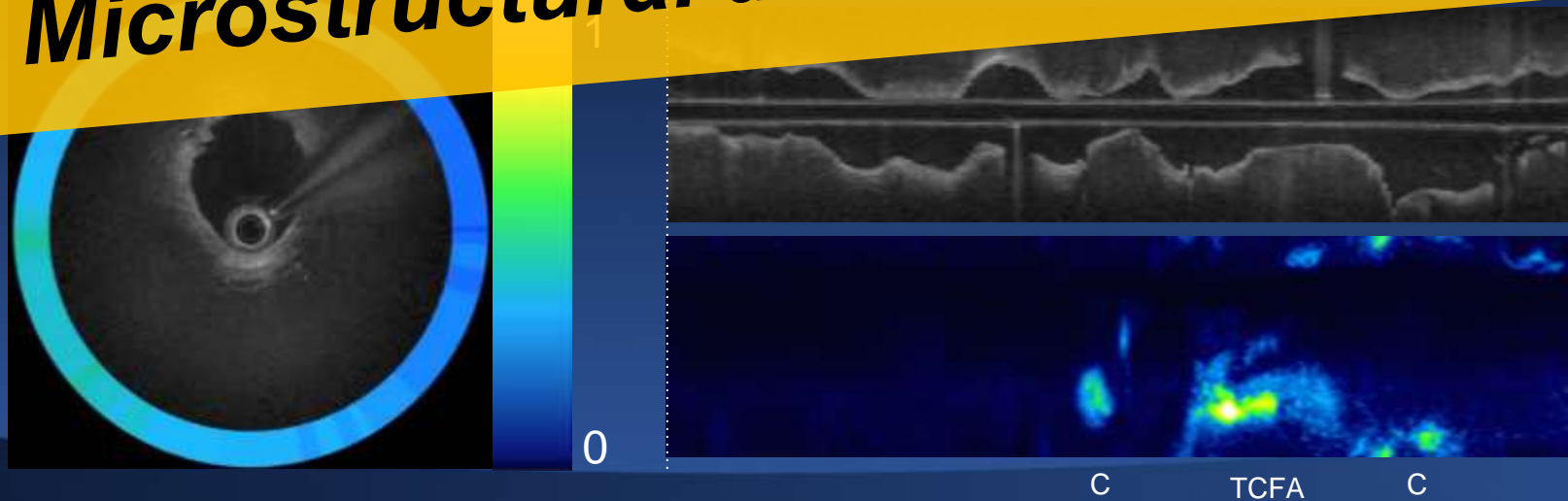
OCT-NIRS catheter has *two* optical fibers

# Multimodality imaging: OCT + NIRAF

(Near-infrared autofluorescence)



## Microstructural and Necrotic Cores



# Multimodality imaging: OCT + NIRF

*(Near-infrared fluorescence)*

## Targeted molecular imaging

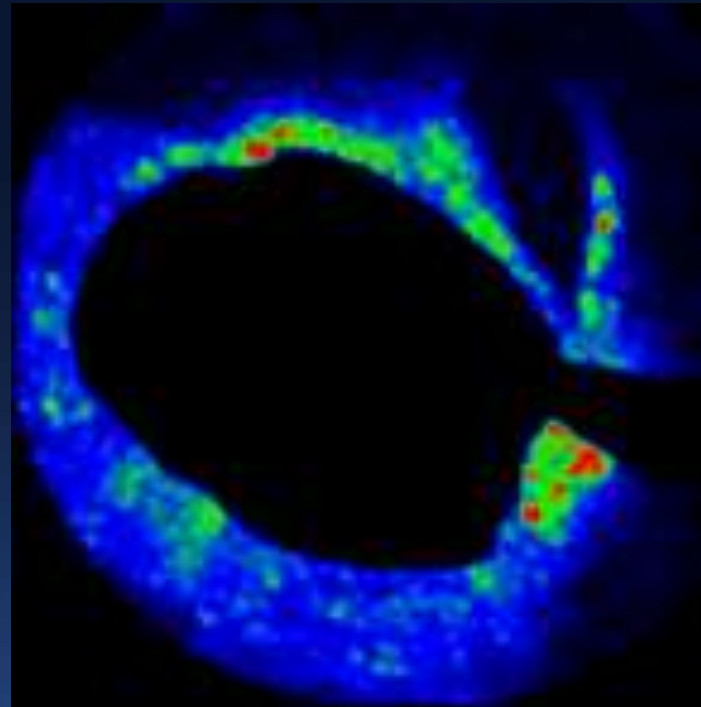
Inflammation

Enzymatic activity

Fibrin

## Dye injected intravenously

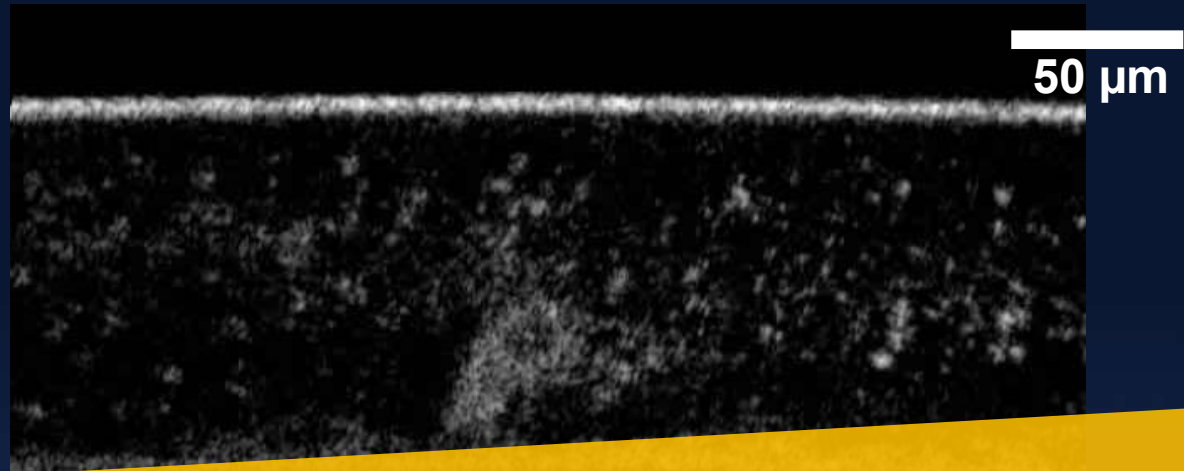
(Indocyanine green : ICG)



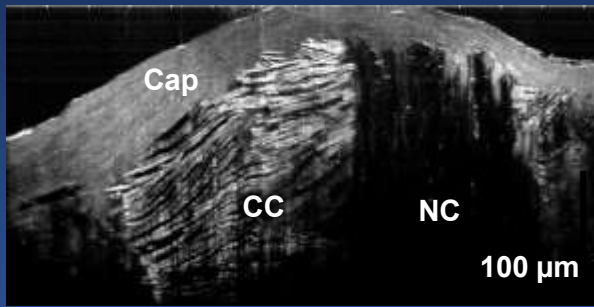
Future is bright for intravascular optical imaging

# $\mu$ OCT - Cellular level resolution

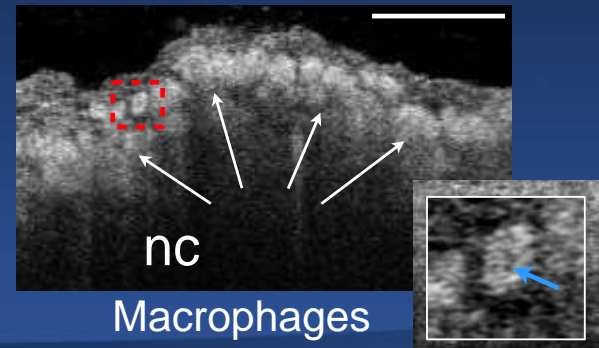
Flowing Blood



**Cellular 1  $\mu$ m resolution**



Necrotic Core Cholesterol Crystals



Macrophages

# Conclusion

1. New generation of high definition of IVUS will provide **better resolution** with clinically enough penetration
2. Clinically useful **easier diagnosis** such as under-expansion and dissection will be expected
3. Understanding of **plaque vulnerability** (intraplaque hemorrhage, macrophage, thrombus) would be promising

# Conclusion

4. NIRS is highly accurate to detect **lipid core plaque** in human coronary arteries
5. Next generation OCT will increase our **capabilities** to **evaluate the coronary wall** beyond microstructure
6. Higher technology to visualize cell level morphology and complementary imaging, which allow us to **understand vulnerable plaque** more details



**Which One is Better ???**



**Improve outcomes of PCI !!!**