



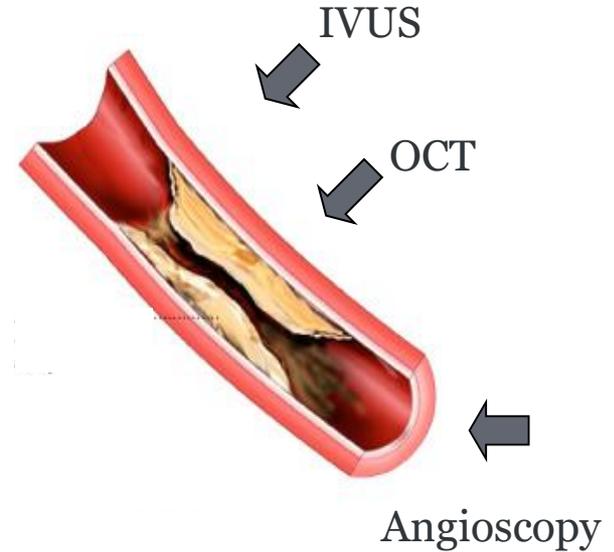
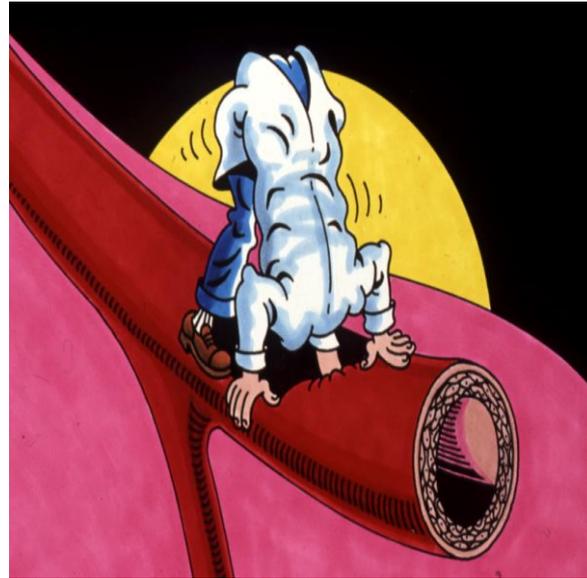
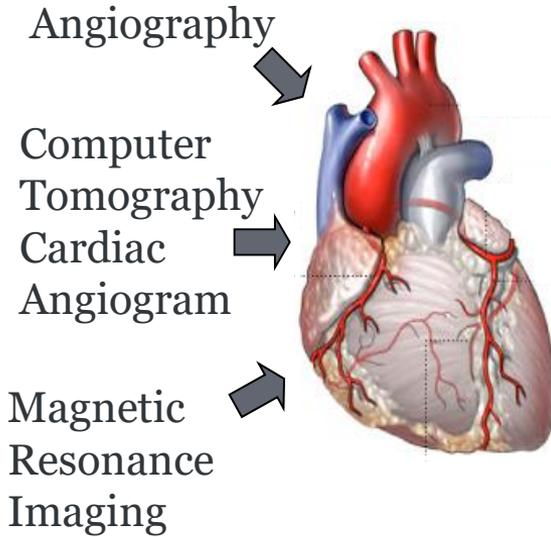
# **Dẫn nhập kỹ thuật chụp cắt lớp kết quang (Introduction to OCT imaging)**

**GS. TS. BS. VÕ THÀNH NHÂN**

**Đại Học Y Dược – BV Vinmec Central Park – LC Hội Tim Mạch Can Thiệp  
TP Hồ Chí Minh**

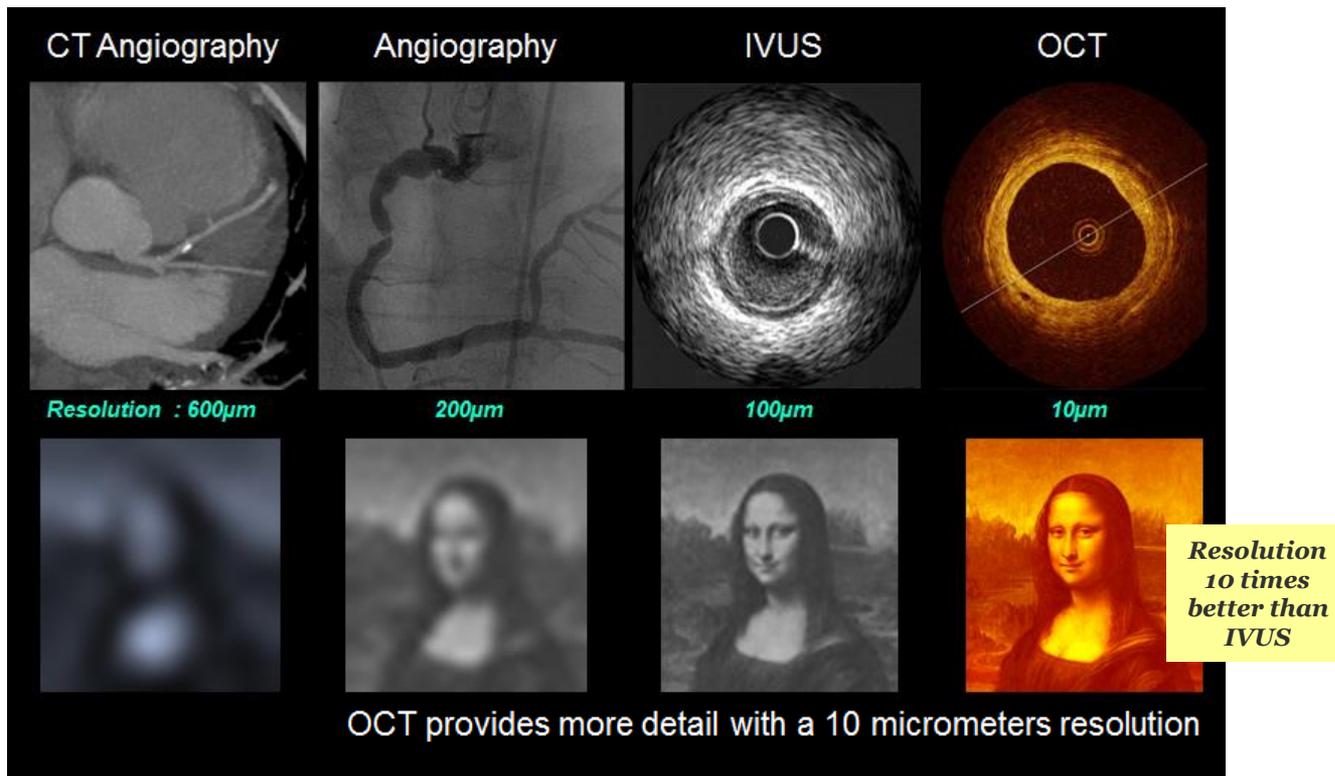
# 1. Principles of Optical Coherence Tomography

# Vascular Imaging Modalities



Seeing from the Inside

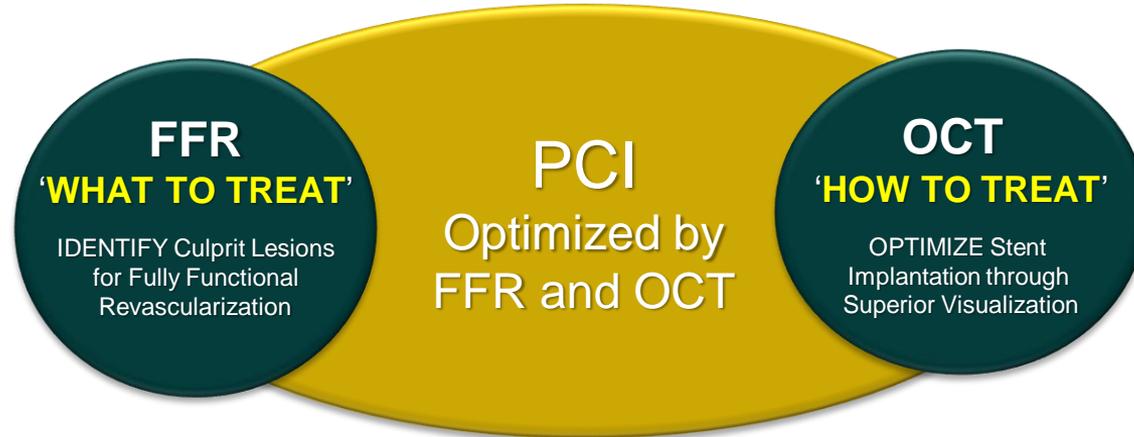
# Time for High Resolution Imaging





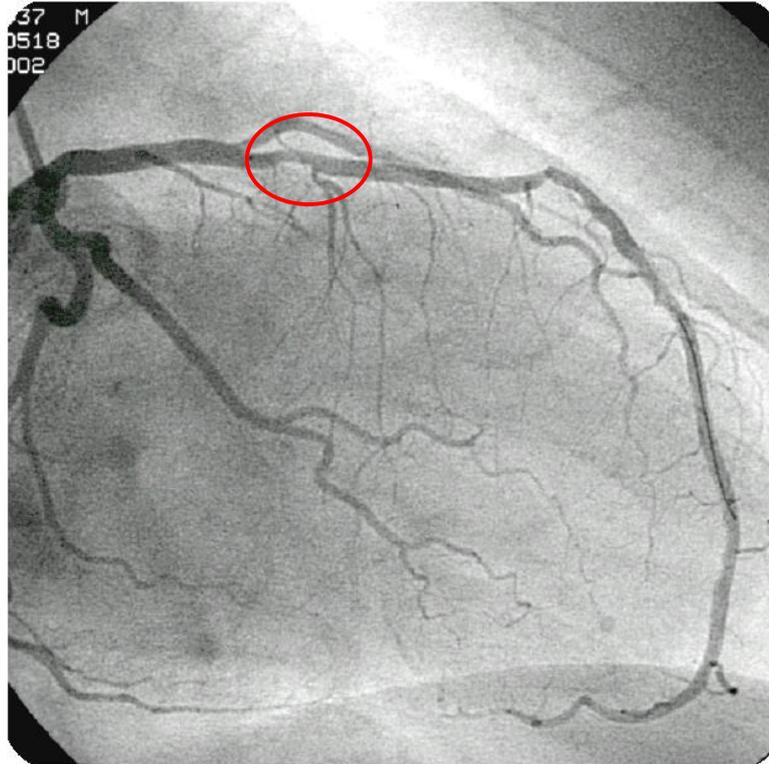
# FFR + OCT = PCI Optimization

FFR guides PCI by **identifying culprit lesions** responsible for ischemia, **ensuring a fully functional revascularization**. Compared to PCI guided with angiography alone, FFR-guided PCI greatly improves outcomes.<sup>1</sup>



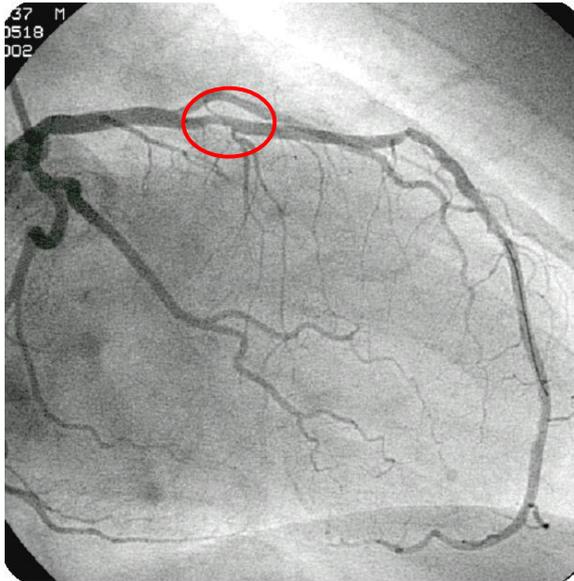
The ultra high resolution of **OCT** makes it the ideal tool to visualize vasculature, **optimize stent implantation, strut coverage, neointimal response** and **follow-up**.<sup>2,3</sup>

# Cine Angiography

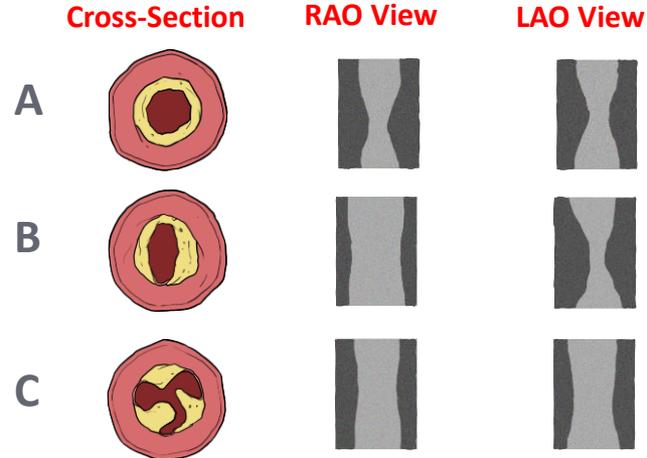


# Limitations of the Cine Angiography for Lesion Assessment

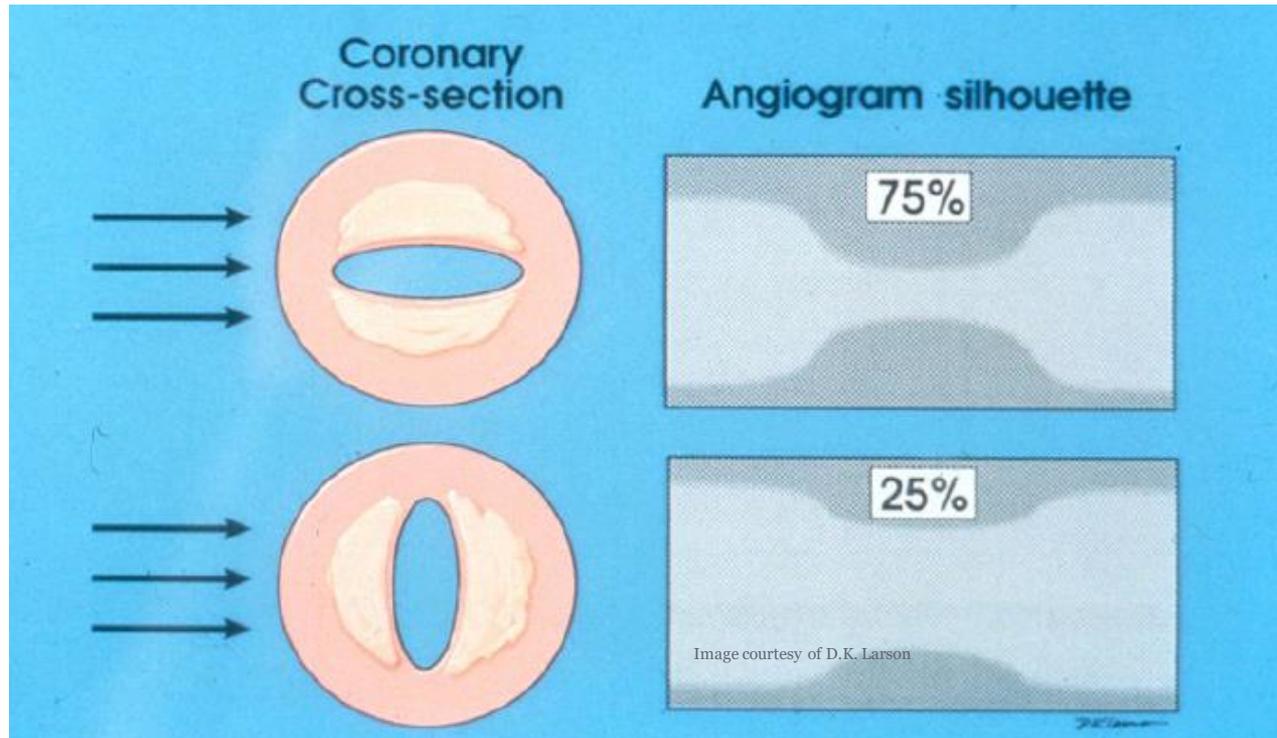
Coronary angiography is restricted to a 2-dimensional representation of the lumen silhouette without providing information about the vessel wall that is the substrate of atherosclerosis.



## Irregular Plaque / Irregular Lumen



# Limitations of Coronary Angiography

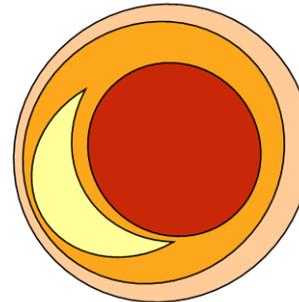
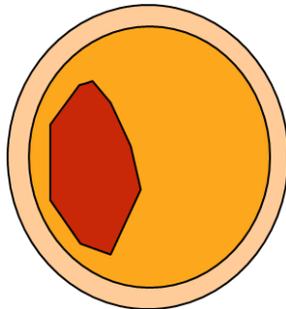
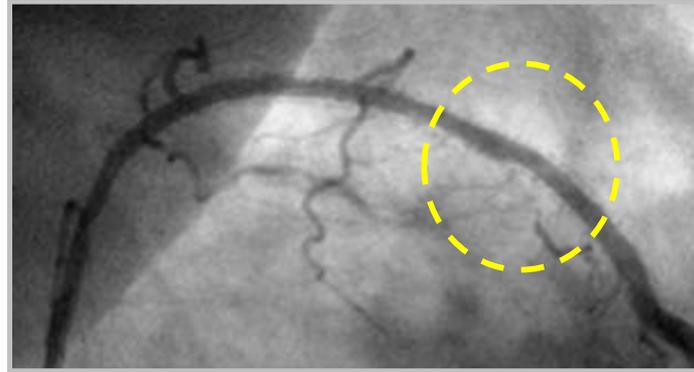
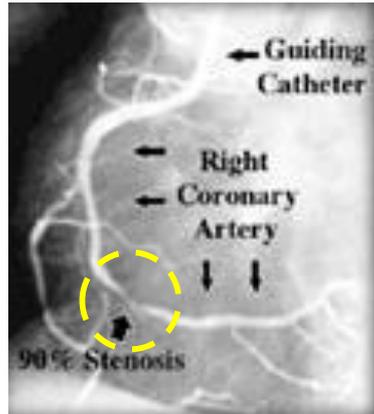


# Limitations of the cine angiography for lesion assessment

Angiography has some other limitations in the assessment of the lesions:

- **Pre-treatment:** Does not give the **components of the plaque**
- **Post Treatment:** Does not say whether the stent or **treatment is optimal**

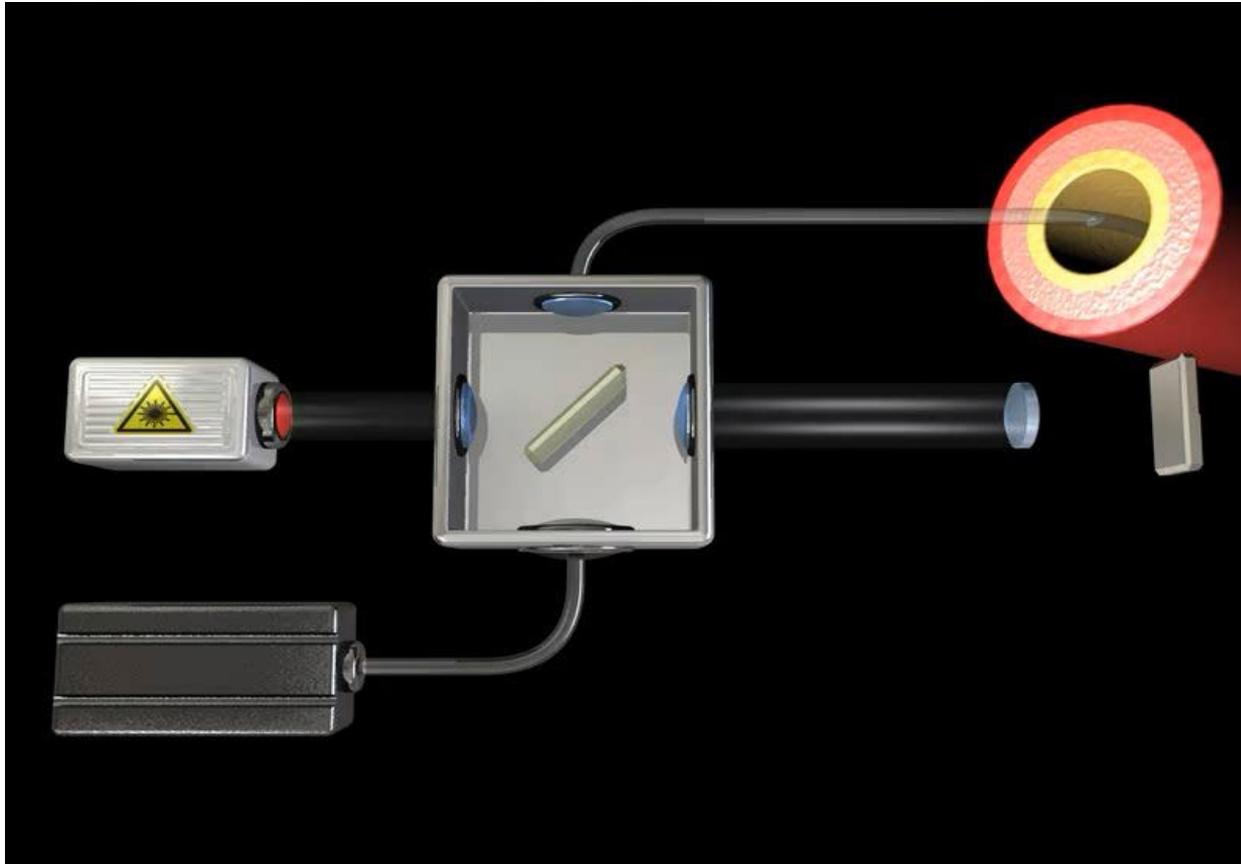
# Coronary Artery Disease: THE DIAGNOSTIC CHALLENGE (FFR and likelihood of ACS)



# What Is OCT?

- Optical coherence tomography (OCT) is an optical imaging modality that uses near-infrared light to create **high-resolution** images of **tissue microstructure**
- **Optical** → of or relating to light (visual)
- **Coherence** → a measure of the **correlation between phases of a wave or waves**
- **Tomography** → method of **producing images from a series of single planes or slices**

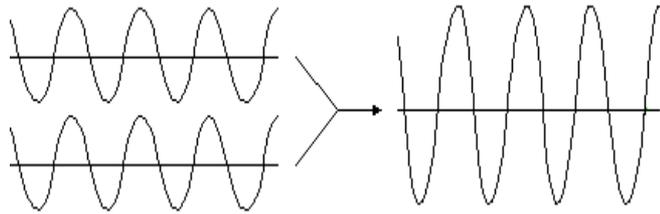
# Frequency Domain OCT: sweeping laser signal, fixed mirror



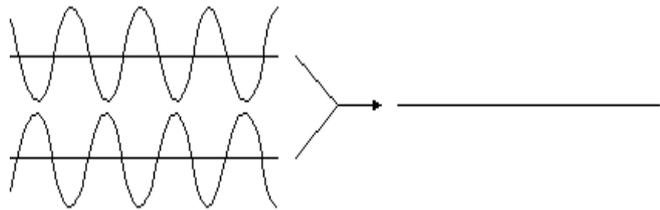
# Physics of OCT

## Interference of Light Waves

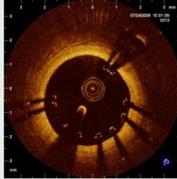
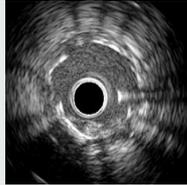
### Constructive Interference



### Destructive Interference



# Performance Comparison: FD-OCT vs. IVUS

|                           | ILUMIEN Optis  | IVUS  |
|---------------------------|--|---|
|                           |  |  |
| Axial Resolution          | 15 – 20 $\mu\text{m}$  | 100 – 200 $\mu\text{m}$   |
| Lateral Beam Width        | 20 – 40 $\mu\text{m}$  | 200 – 300 $\mu\text{m}$   |
| Frame Rate (Engine speed) | 180 frames/s   | 30 frames/s   |
| Pullback Speed            | 18mm/s to 36 mm/s  | 0.5 - 1 mm/s  |
| Max. Scan Dia             | 10 mm (Max. vessel size 5.5)<br>(coronary artery Avg 4 – 4.5 mm)                   | 15 mm   |
| Tissue Penetration        | 1.0 - 2.0 mm   | 4 to 8 mm   |
| Lines per Frame           | 560  | 256   |
| Blood Clearing            | Required   | Not Required  |

**Resolution  
10 times  
better**

**Pullback  
speed 40  
times faster**



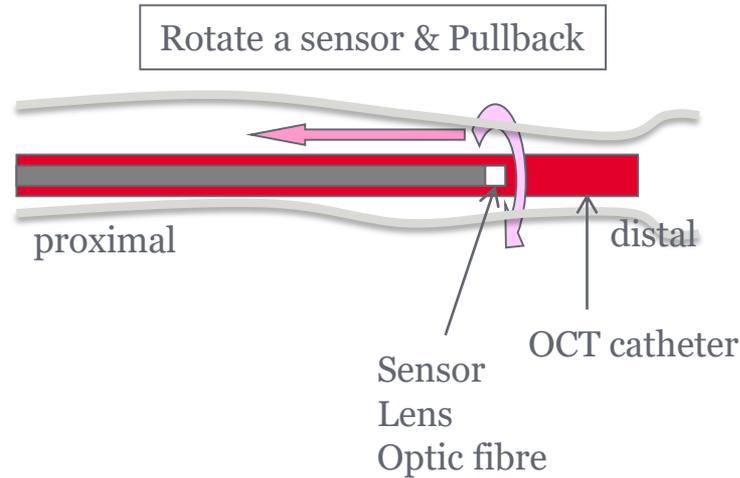
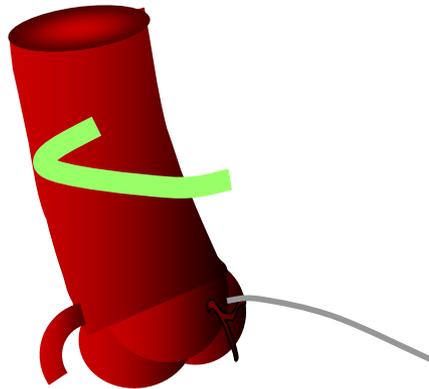
Ref. Gonzalo, N. *Optical Coherence Tomography for the Assessment of Coronary Atherosclerosis and Vessel Response after Stent Implantation*. Rotterdam, the Netherlands: Optima Grafische Communicatie; 2010.

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# Intravascular OCT

Catheter with fibre-optic core used for light delivery

- Fibre rotates to create image frames
- Fibre-optic core pulls back to map vessel segment
- During the pullback, blood clearing is required to get a good image quality.



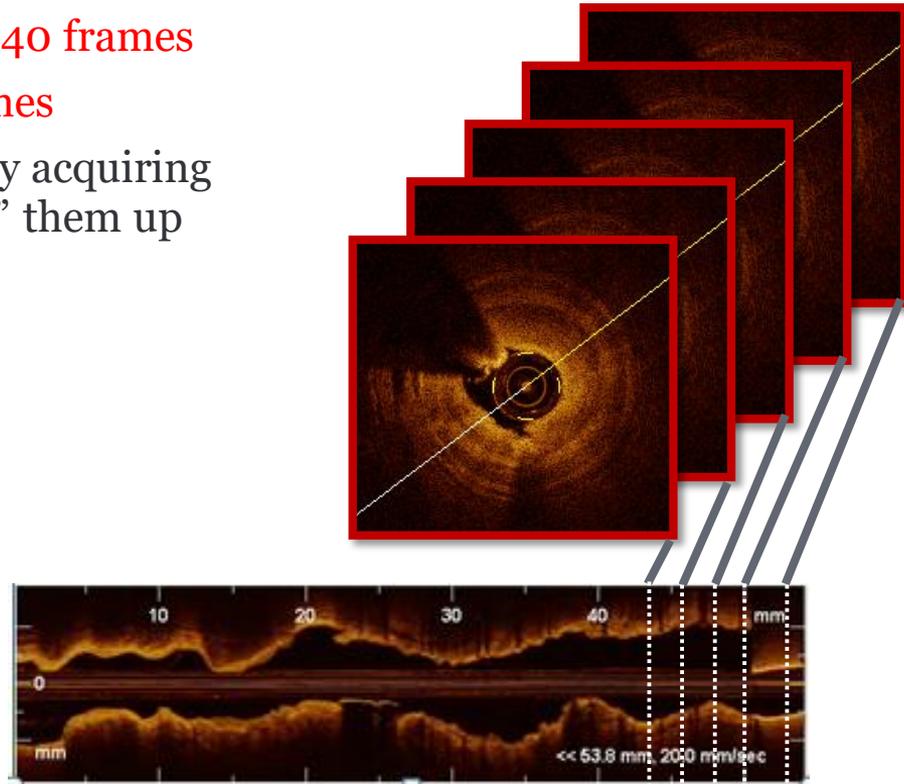
**Better image quality** by:

- (1) Faster rotation
- (2) Slower pullback



# Pullback longitudinal view

- One pullback → 375 frames to 540 frames
- 150k lines to more than 300k lines
- A pullback image is generated by acquiring a series of frames and “stacking” them up



# Image Display

Shown on the OCT system display are two simultaneous views:

Cross-sectional view: **B-mode**

Longitudinal view: **L-mode**

“B-Mode”  
cross-sectional view



“L-Mode”  
longitudinal view

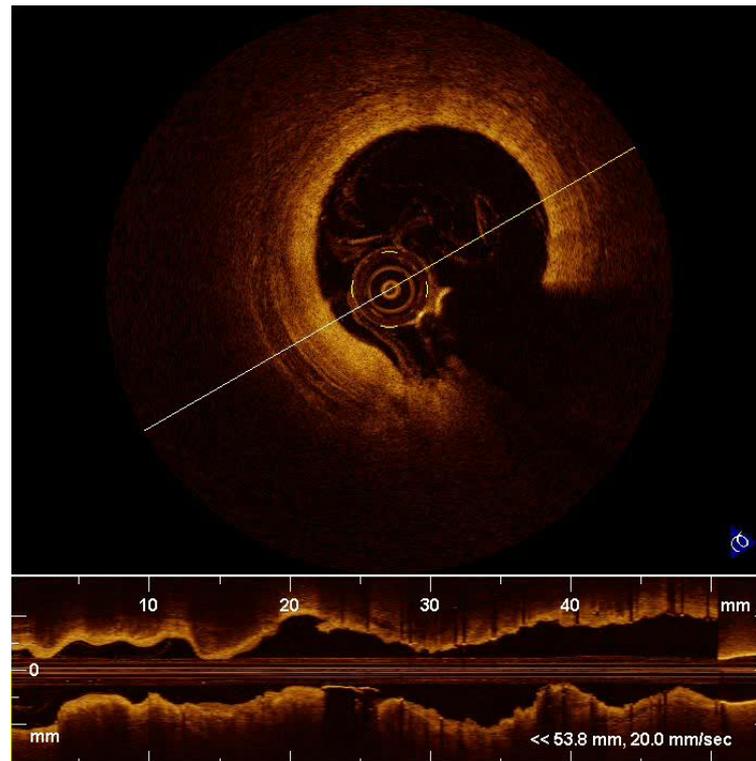


Image courtesy Professor Stephen Lee, Queen Mary Hospital, Hong Kong, 2016

# More Control. Less Risk.

OCT enables the physician

- To comprehensively evaluate a coronary lesions, plan an optimal intervention:
  1. **Anatomical** consideration
  2. Lesion **morphology**
  3. **Landing area**
  4. **Stent diameter, length, type**
- To assess the intervention results and conduct accurate long-term follow-up
  1. Immediate **post-stent evaluation**
  2. Acute finding:
    - **Malapposition**
    - **Expansion**
    - **Edge dissection**

# ILUMIEN™ OPTIS™ PCI Optimisation Tools

- **New Pullback Settings**
  - Survey mode: 75 mm pullback (5 frames/mm)
  - High-resolution mode: 54 mm pullback (10 frames/mm)
- **Lumen Profile Display**
  - Area and Mean Diameter display
  - Automatic minimum lumen area (MLA)
  - Stent planning workflow
- **Real-time 3-dimensional Display**
  - Navigation view
  - Segmented lumen

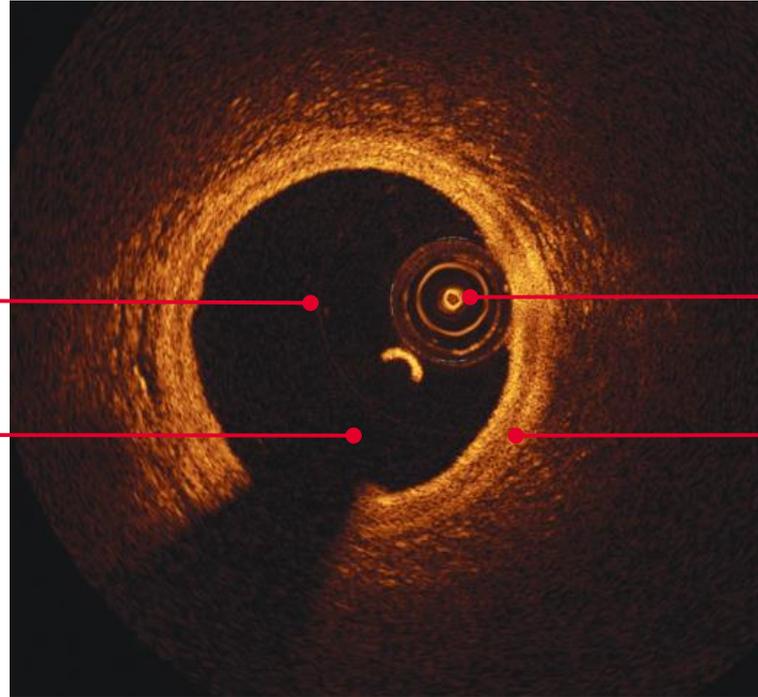


## **2. OCT Image Interpretation**

# Image Orientation—Radial Cross-sectional View

Lumen—cleared  
of blood

Guide wire  
shadow—“Meteor”



Imaging catheter

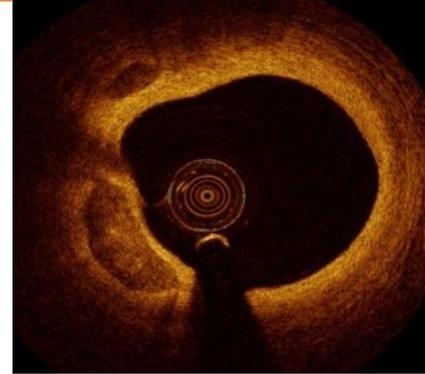
Vessel

# Microstructure Imaging—Simple to Complex

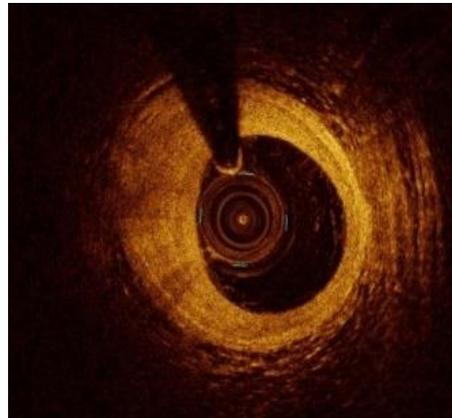
OCT helps to identify different microstructures as well as tissue and plaque morphologies

- **Calcific plaque**
- **Fibrous tissue**
  - Intimal thickening
- **Lipid pools**
- Thrombus
  - Red
  - White
- TCFA
- Plaque ruptures/erosions
- Cholesterol crystals
- Macrophages

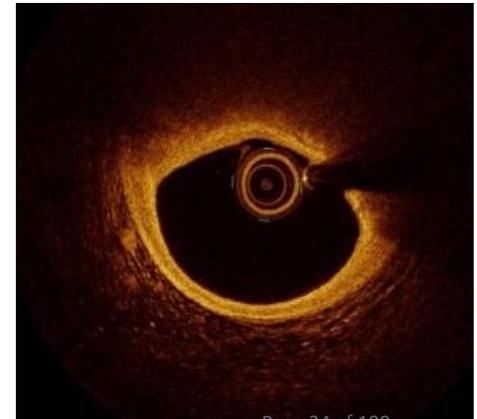
“The Big 3”



**Calcific Plaque**



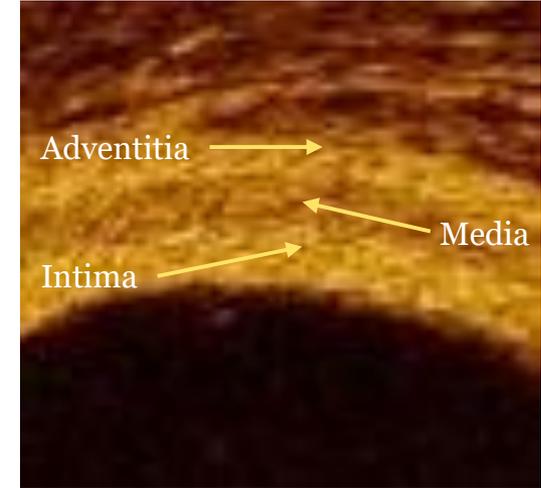
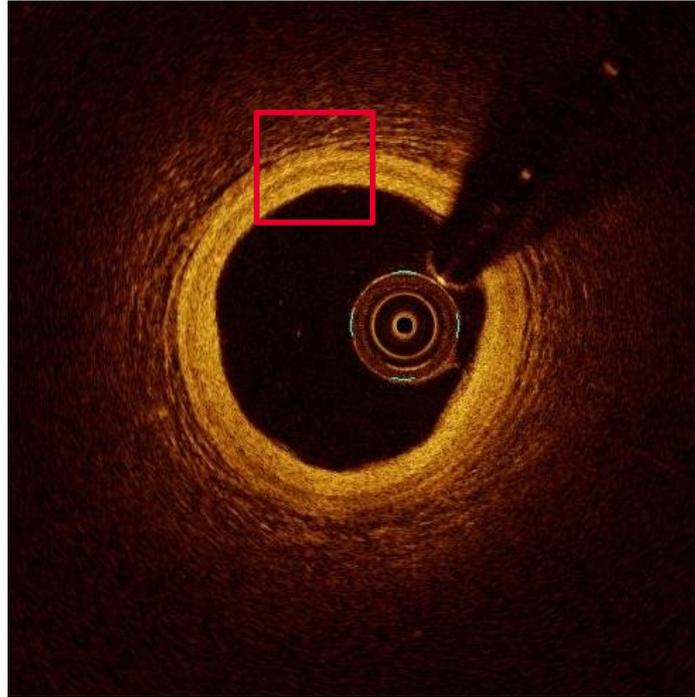
**Fibrous Tissue**



**Lipid Pools**

# Normal or Non-diseased Coronary Anatomy

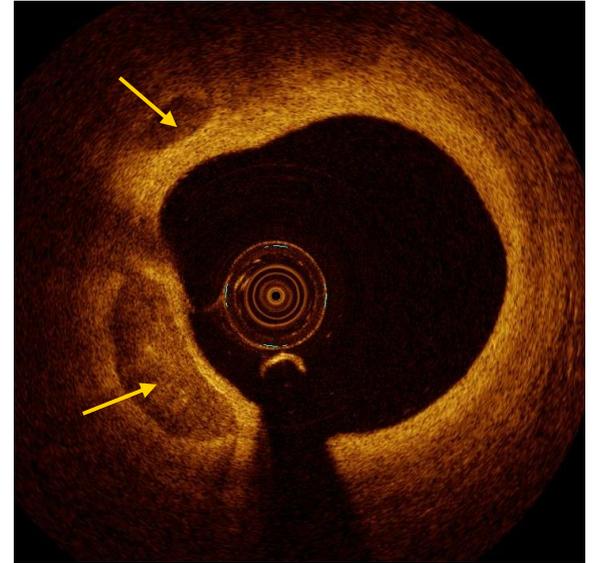
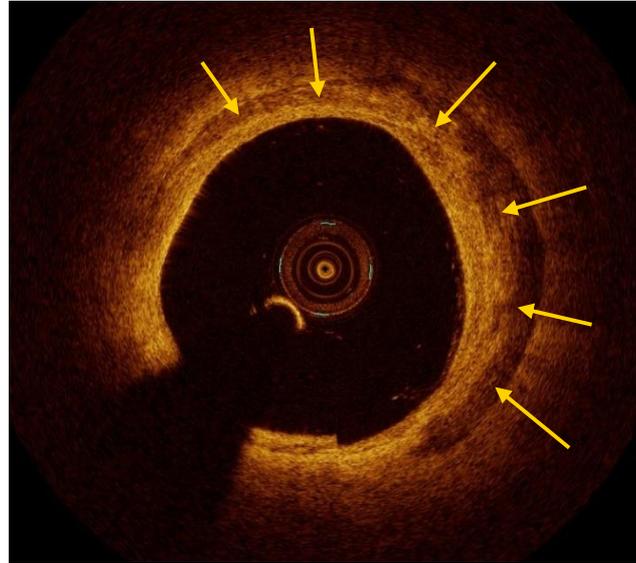
- If there is minimal to no atherosclerosis, the **three layers** of the artery should be visible
- The **Media** appears as a **slightly darker band** than the other two layers



# Calcific Plaque



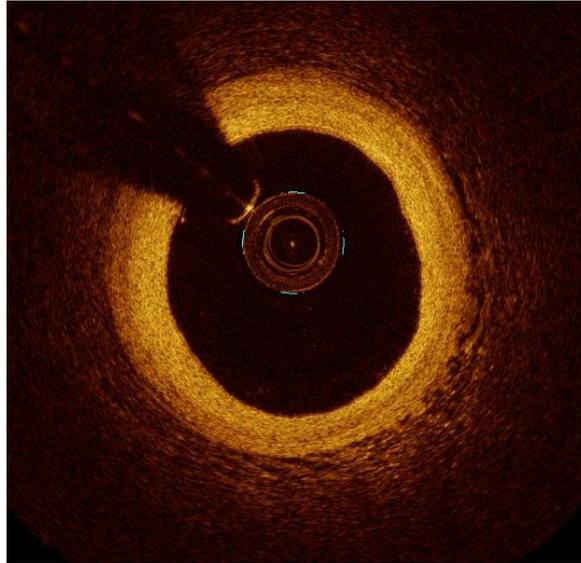
- Heterogeneous appearance
- Low backscatter and low attenuation
- Clear, delineated edges
- “Islands”



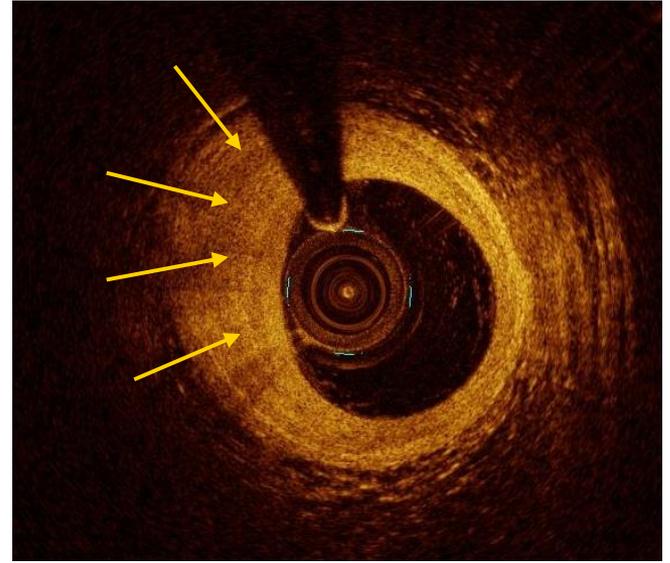
# Fibrous Tissue



- Homogeneous appearance
- High backscatter and low attenuation



Intimal Thickening

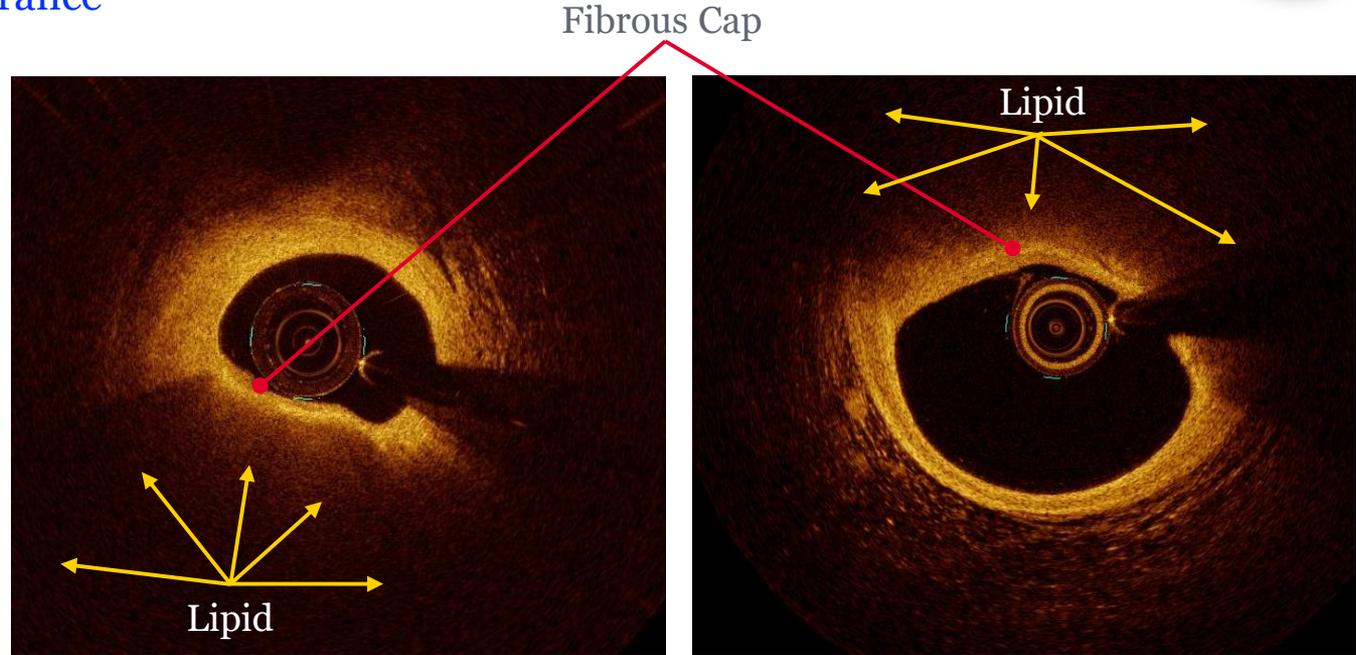
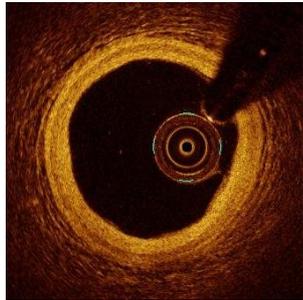


Fibrotic Plaque

# Lipid Pool/Core—Fibrofatty Plaque

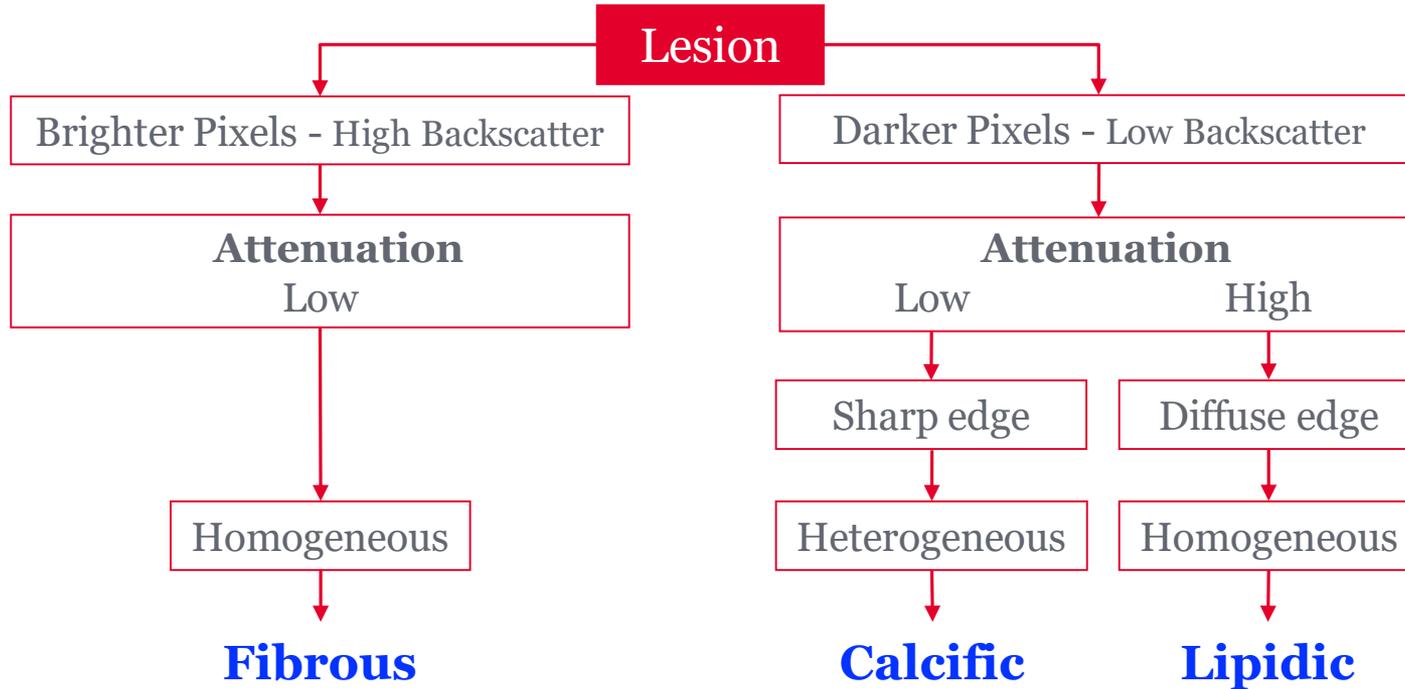


- Homogeneous appearance
- Low backscatter and high attenuation
- Diffuse, “shadowy” edges
- “Murky Water”



Tearney, G., et al., Consensus Standards for Acquisition, Measurement, and Reporting of Intravascular Optical Coherence Tomography Studies A Report From the International Working Group for Intravascular Optical Coherence Tomography Standardization and Validation. JACC Vol. 59, No. 12, 2012.

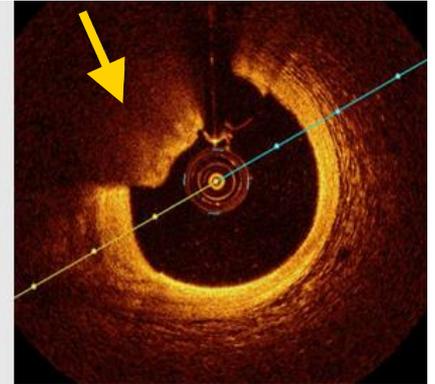
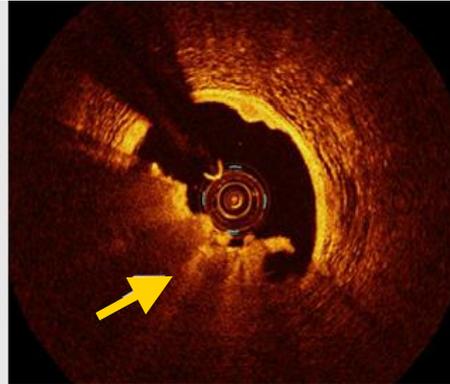
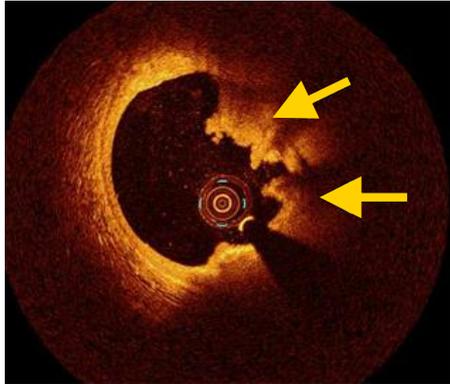
# Major Plaque Characteristics—“The Big 3”



# Red Thrombus



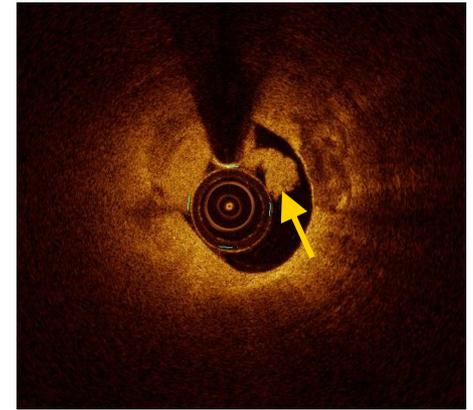
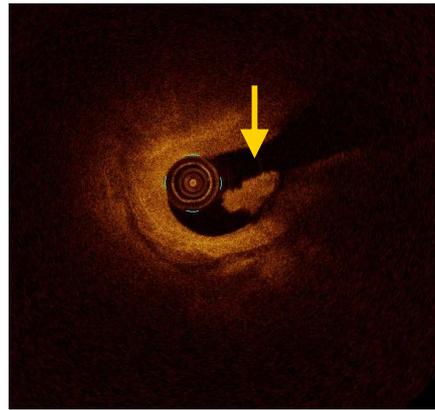
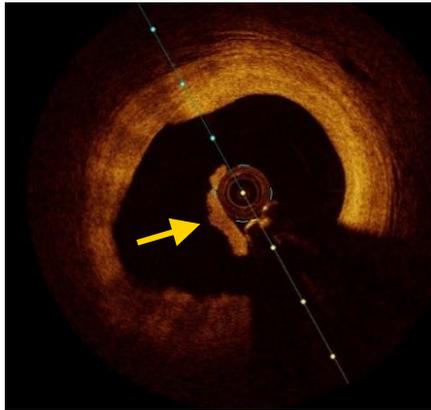
- Red blood cells and fibrin
- **More acute thrombus**
- Absorbs light
- **High backscatter** at leading edge and **high attenuation** beyond leading edge



# White Thrombus



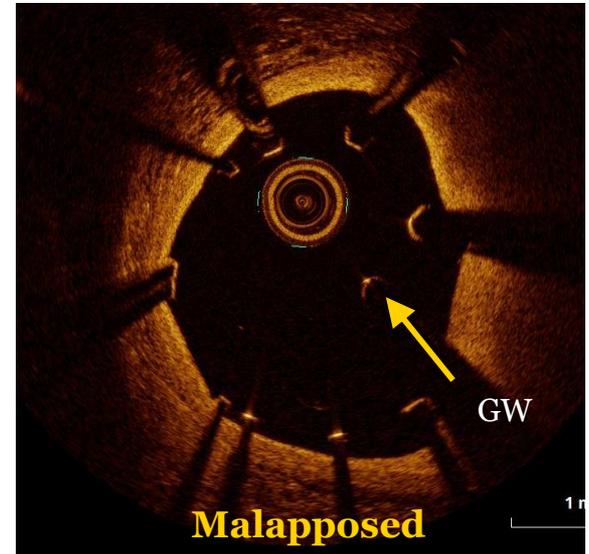
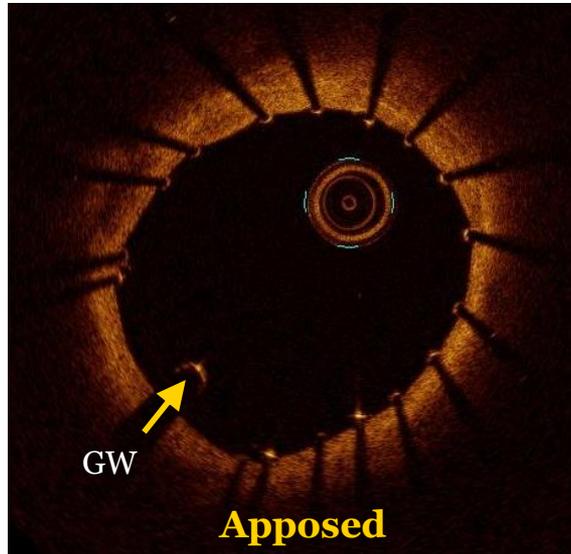
- Platelet rich
- More chronic thrombus
- Homogeneous appearance
- High backscatter throughout and low attenuation



# Metallic Stents



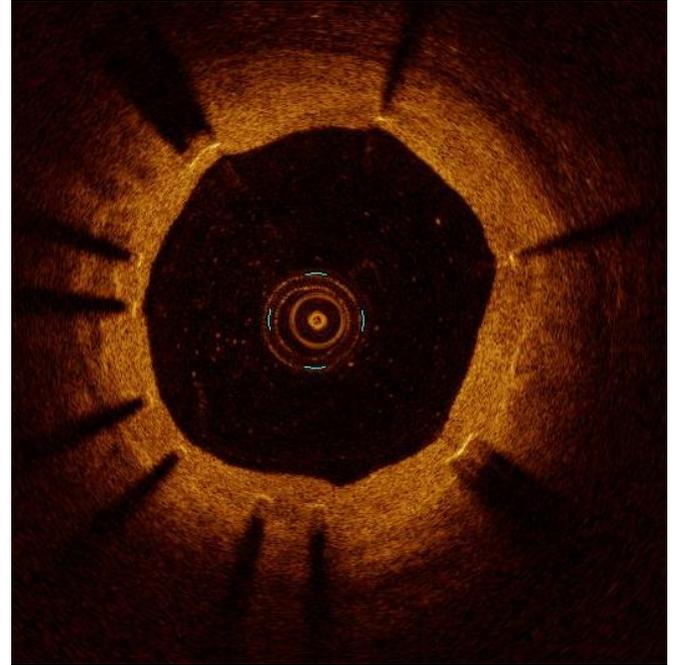
- Similar to the guide wire, each strut has **high backscatter** at the leading edge and a **shadow trailing** it
- GW = Guide wire



# Metallic Stents—Endothelialized

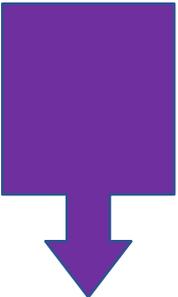


- Neointimal growth over stent struts
- Too much endothelialization or neoatheromas can lead to ISR



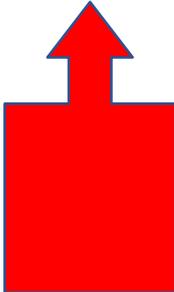
### **3. IVUS and OCT Comparisons**

# IVUS vs OCT



## IVUS

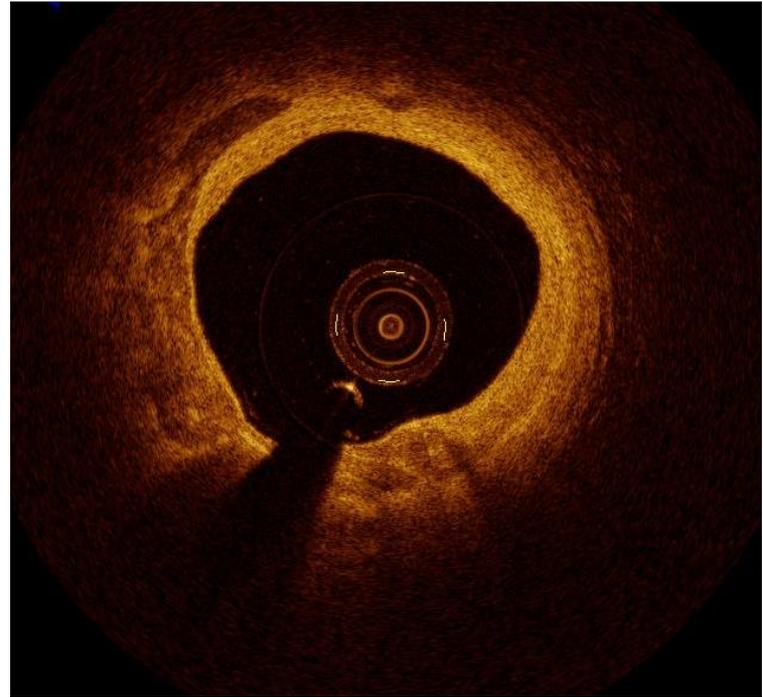
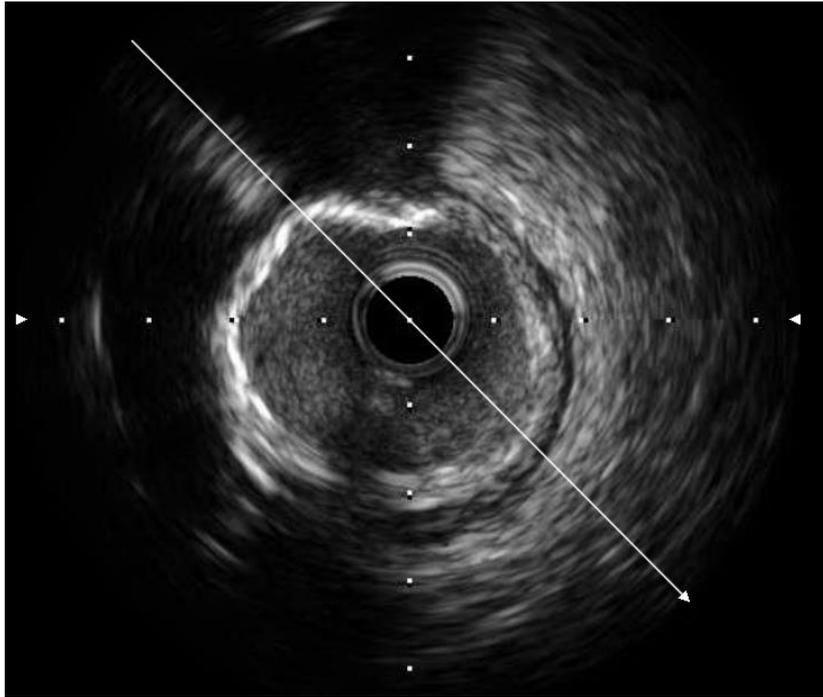
Deeper penetration  
Ostial lesion  
Independent to catheter engagement  
Distal lesion  
During CTO-PCI SVG  
Spontaneous coronary dissection



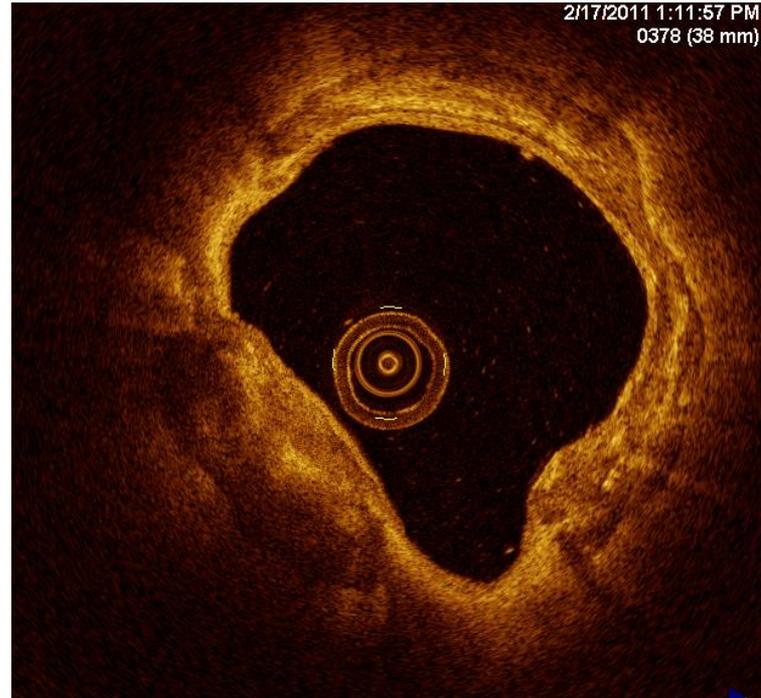
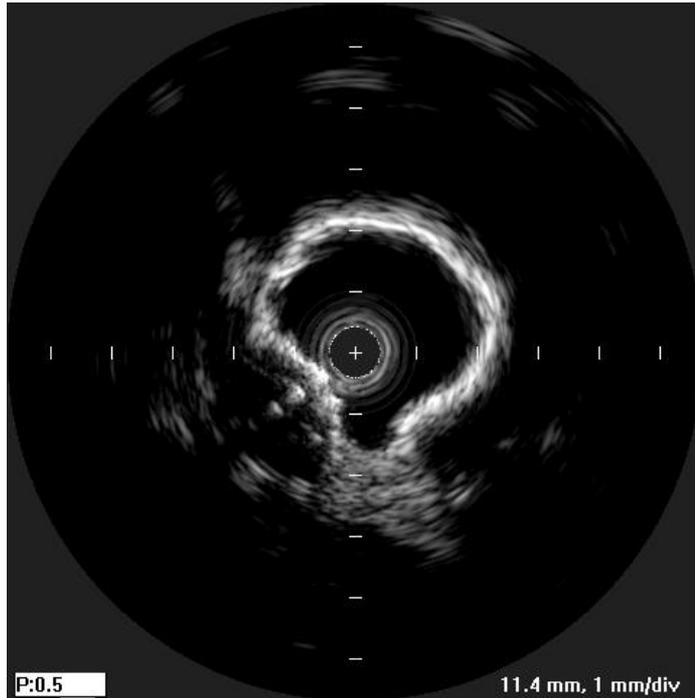
## OCT

Fine resolution to see inner luminal side  
(10-15 $\mu\mu\text{m}$ )  
Very good for thrombus  
Stent apposition  
Tissue prolapse  
Overlap stent  
TCFA  
Calcium nodule  
Intramural/adventitial hematoma

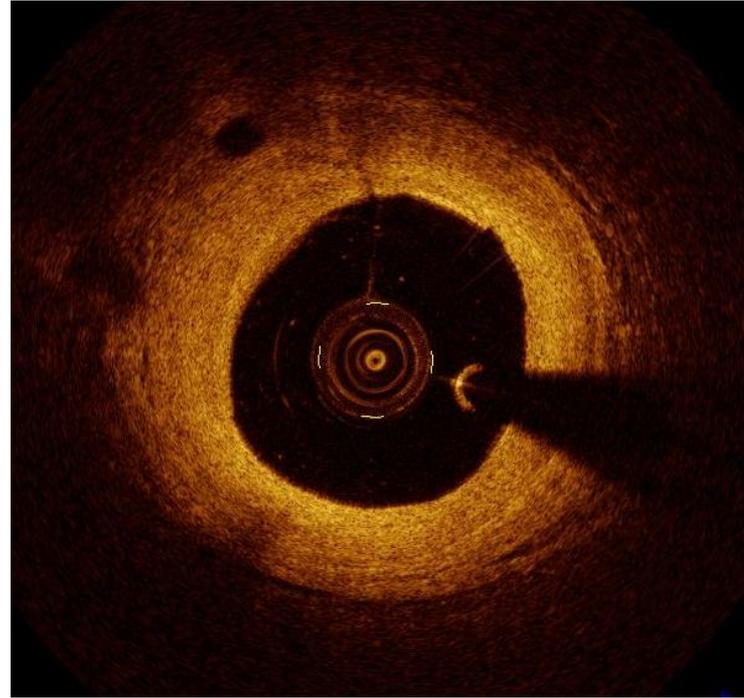
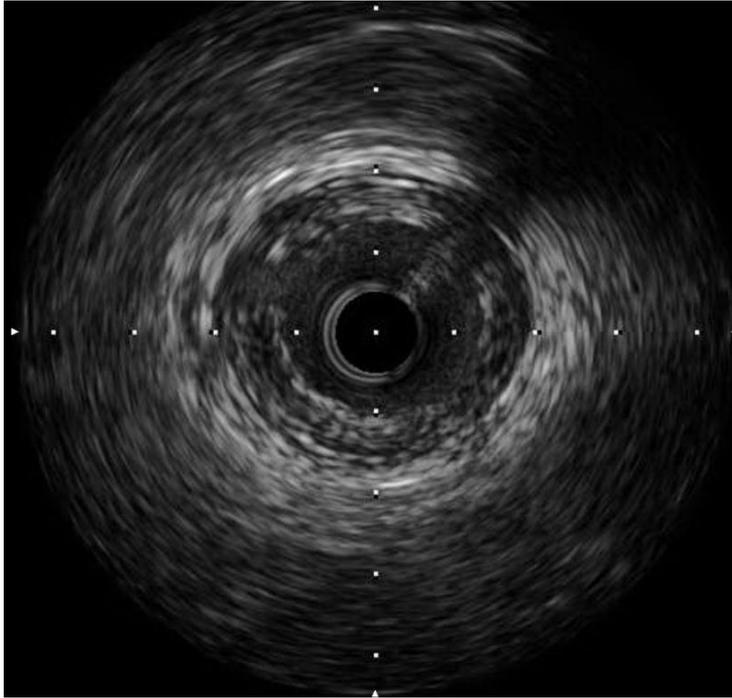
# Calcific and Fibrotic Plaque



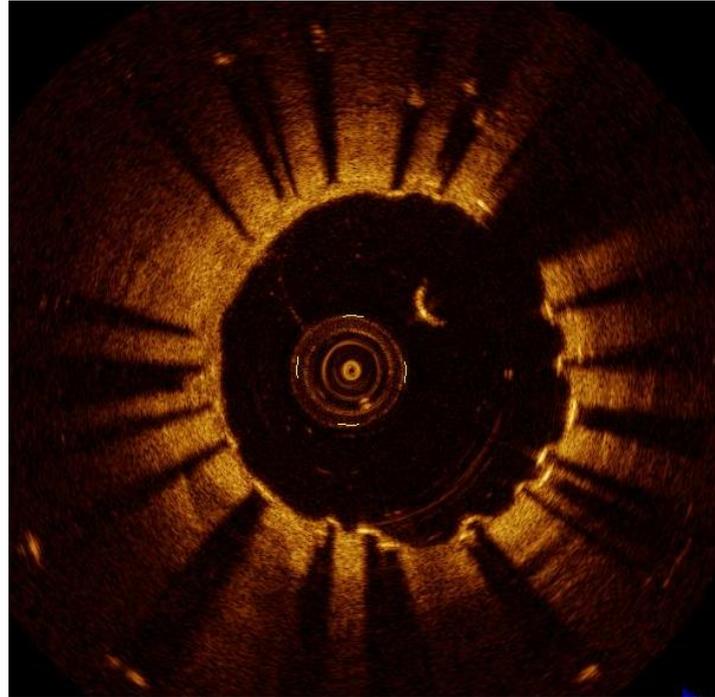
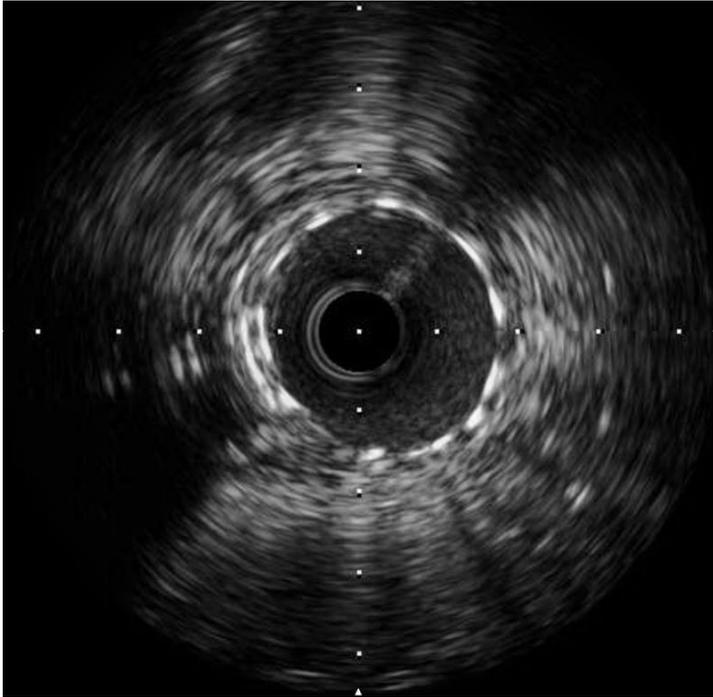
# Calcific Plaque



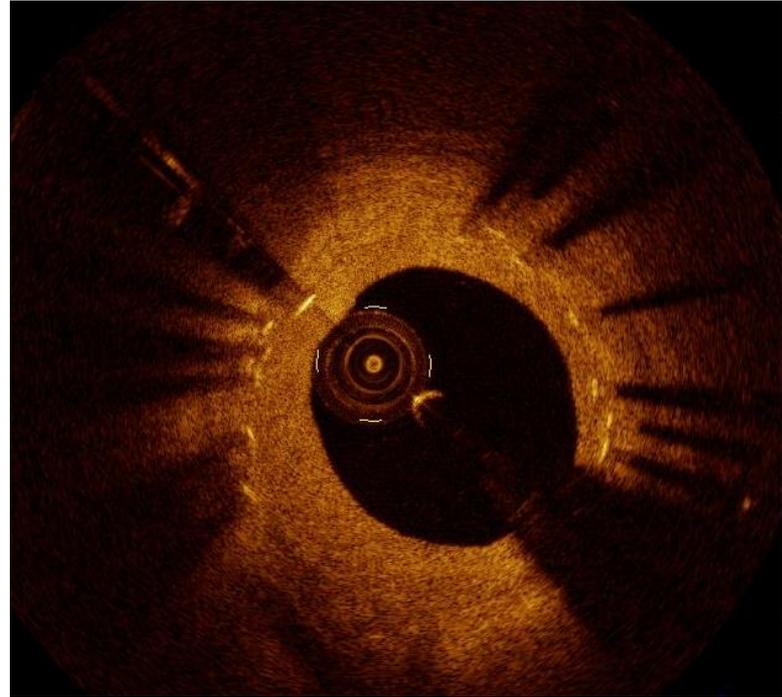
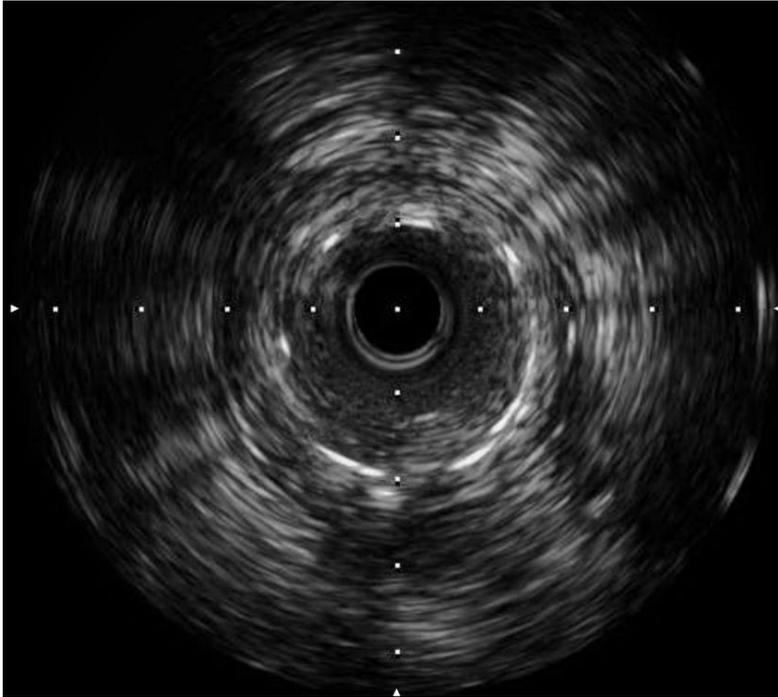
# Fibrotic Plaque



# Post-Stent Implantation—Overlapping Stents



# In-Stent Restenosis



## **4. OCT Fundamentals for Good Imaging**

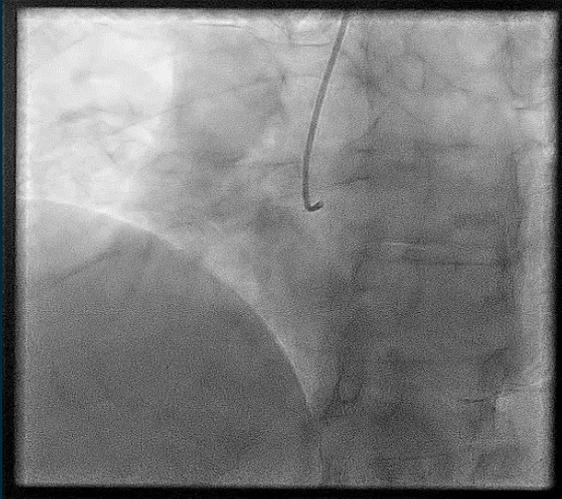
# Remember the 4 Ps

- **Position**  
Ensure your target segment is between the Lens and Proximal markers
- **Purge**  
Clear the blood from the catheter lumen, if present
- **Puff**  
Inject a small amount of flush media through the guide catheter, during Live View, to ensure you are obtaining adequate clearance
- **Pullback**  
Enable to start the imaging process

## **5. MLD MAX OCT Algorithm**

# Diagnostic Angiography

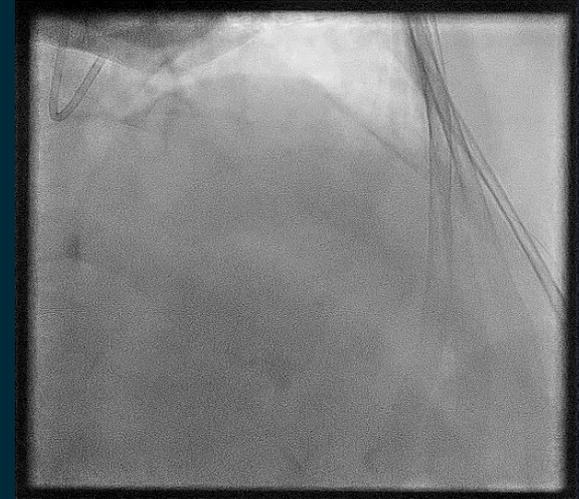
- Syntax Score 22 (MACCE CABG vs PCI, P=0.43)
- Patient elects to undergo PCI



RCA



Circumflex



LAD

Case courtesy of Dr. Ziad A. Ali

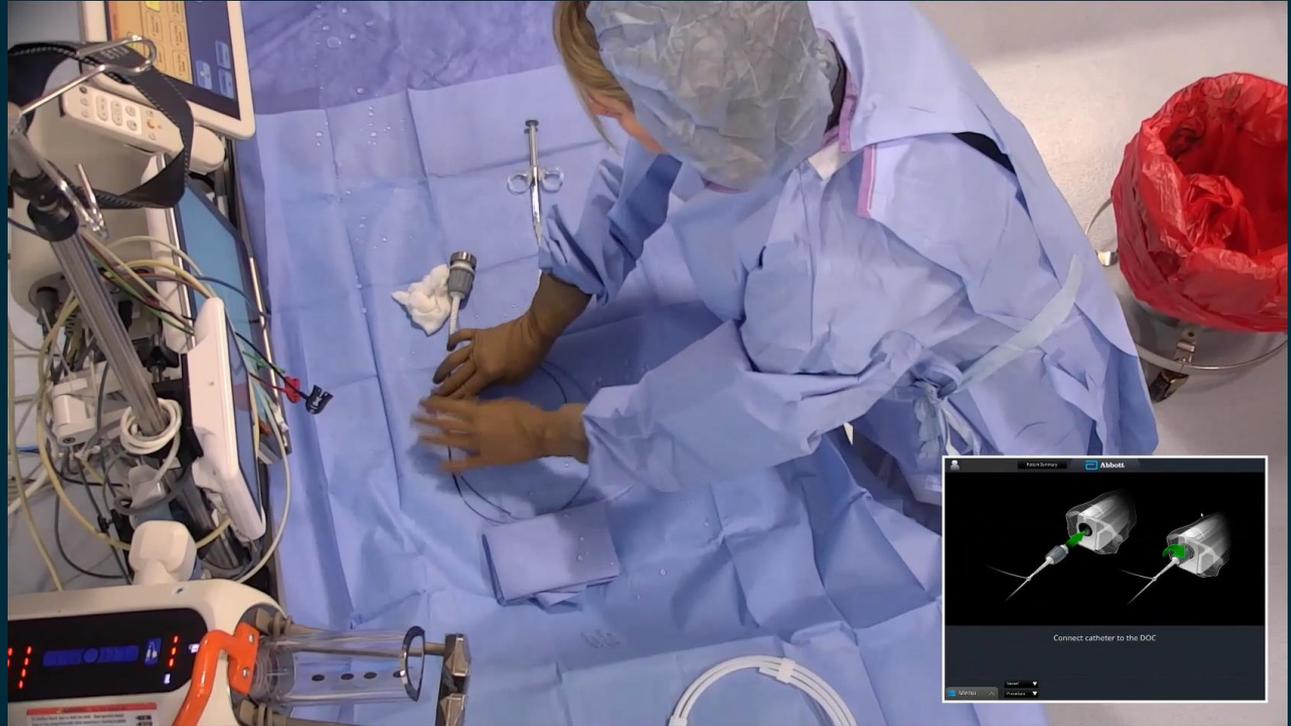
**See Important Safety Information referenced within.**

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# OCT-Guided PCI: Setup

- Connect syringe
- Purge catheter
- Drape DOC
- Connect catheter



Refer to Instructions For Use (IFU) for additional information.

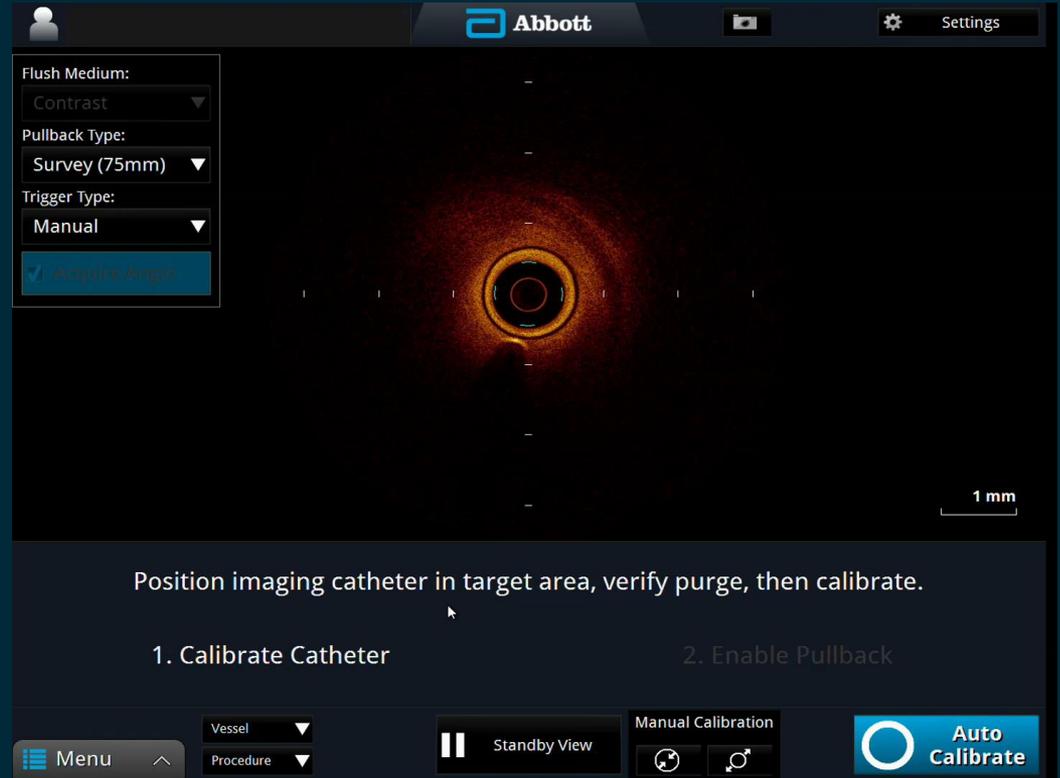
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# Pullback: The 4 P's

- **Position** – catheter distal to lesion
- **Purge** – catheter lumen
- **Puff** – to evaluate clearance
- **Pullback** – image acquisition



Refer to Instructions For Use (IFU) for additional information.

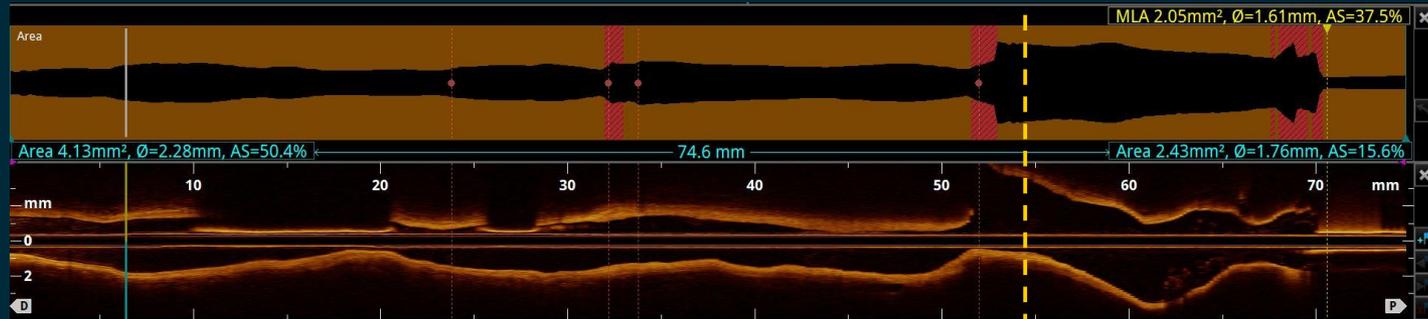
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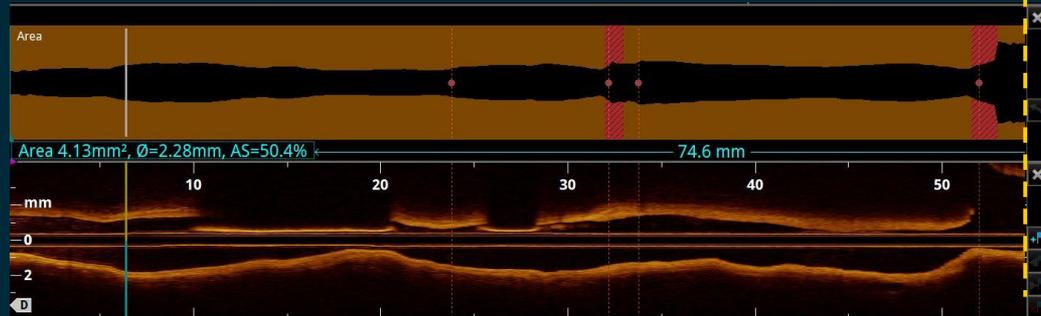
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# Pullback Type

**Survey-mode acquisition:** 75 mm, 5 frames/mm - 2.1 Sec



**High-resolution acquisition:** 54 mm, 10 frames/mm - 3.0 Sec



Useful for:

- Bifurcation re-crossing
- Stent fracture assessment

Refer to Instructions For Use (IFU) for additional information.

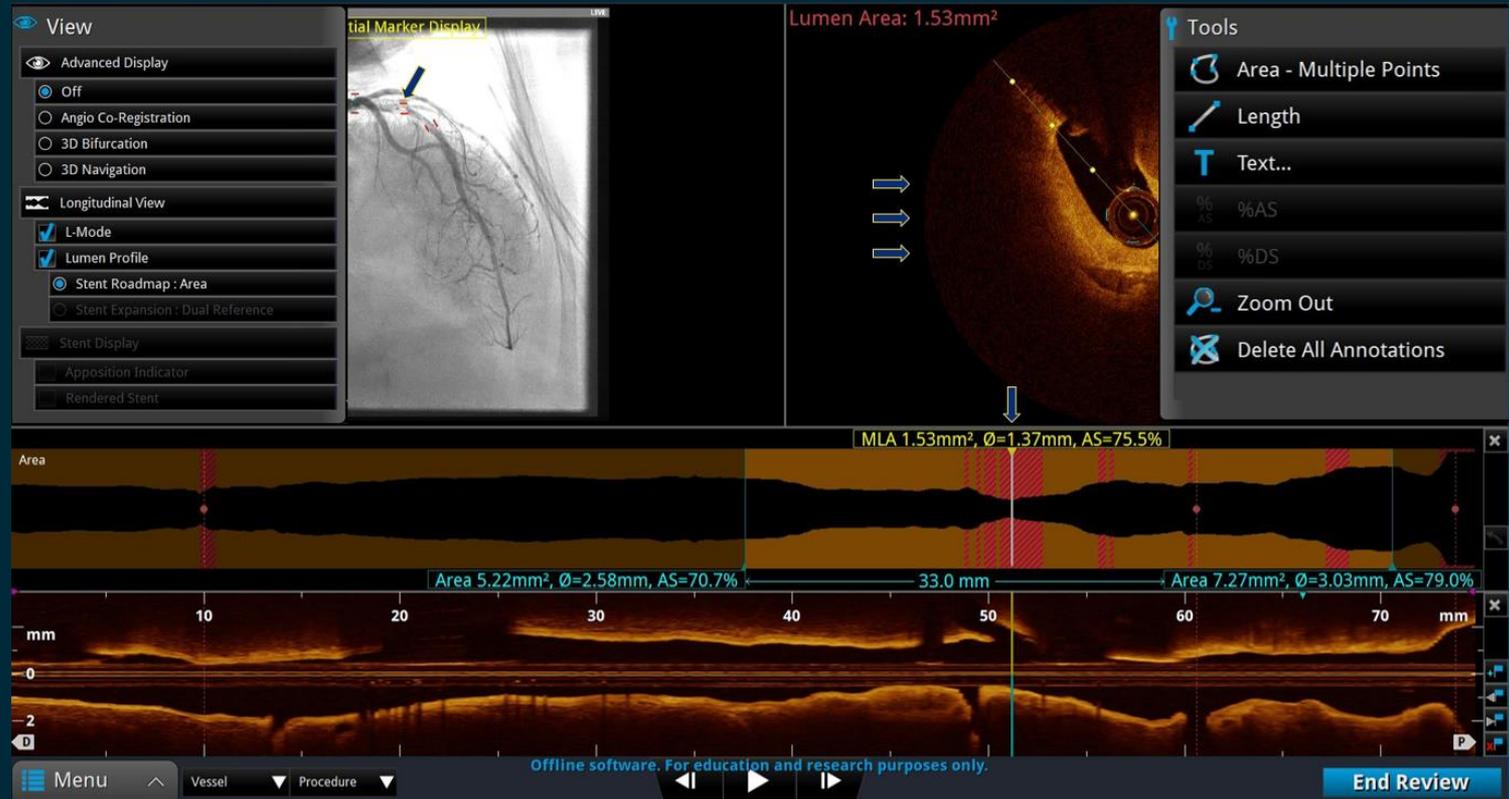
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# User Interface



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# Modern OCT Guided PCI Workflow | MLD MAX

Each OCT run serves a separate purpose. The **pre-PCI run helps determine the PCI strategy**, and the **post-PCI run allows for optimization of the stent as needed**.

Pre-PCI OCT | Strategize

MMORPHOLOGY

LENGTH

DIAMETER

Post-PCI OCT | Optimize

MEDIAL DISSECTION

APPOSITION

EXPANSION

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# Pre-PCI OCT-Guidance

Pre-PCI OCT | Strategize

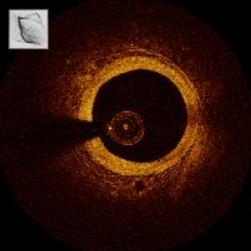
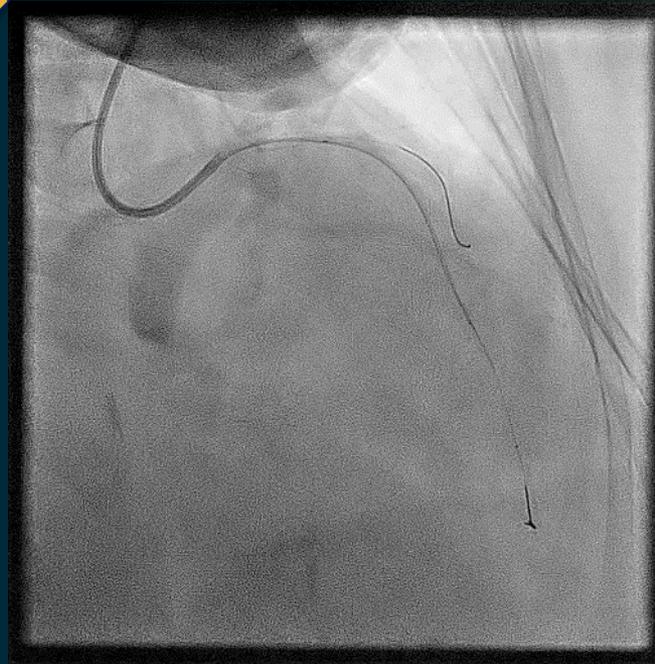
MMORPHOLOGY



LLENGTH



DDIAMETER



**OCT Pullback**  
12:30:27  
Vessel:  
Procedure:  
Comment: **OPTIMIZE-pre**

 Review

Case courtesy of Dr. Ziad A. Ali

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## SECTION 1

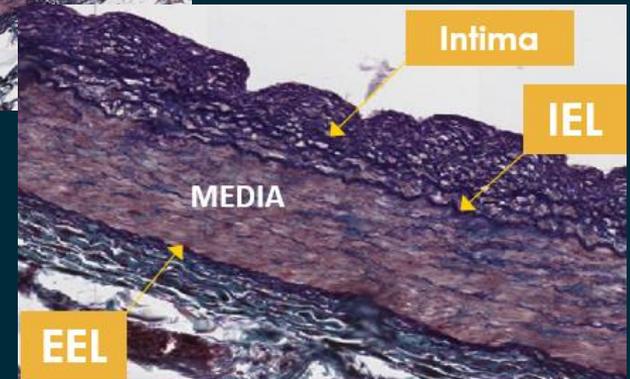
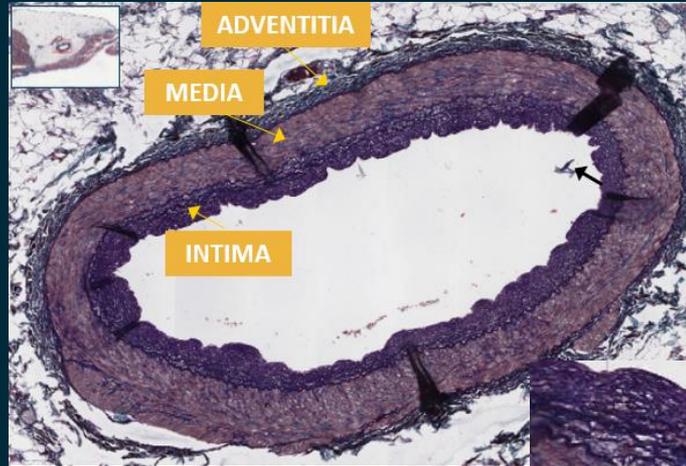
# Morphology

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# Normal Artery Morphology

- **Intima** = hard sponge
- **IEL** = rubber band
- **Media** = soft rope
- **EEL** = rubber band
- **Adventitia** = mesh



Shlofmitz, E. et al. Algorithmic Approach for OCT Guided Stent Implantation During PCI. Intervent Cardiol Clin 7 (2018) 329-344.

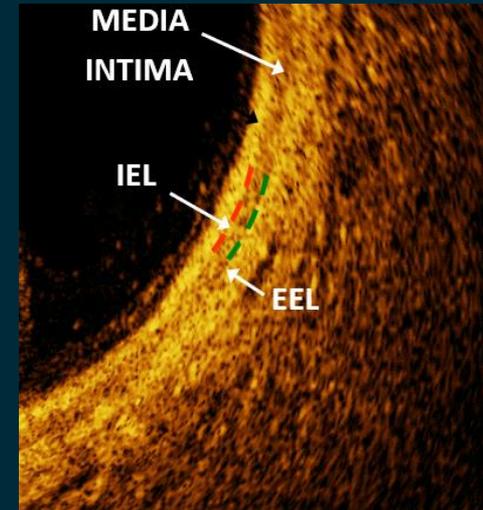
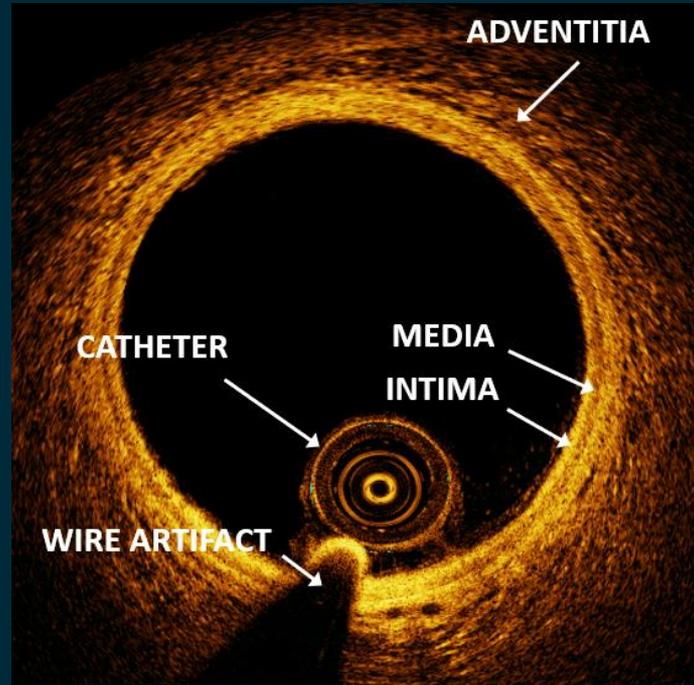
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# Normal Artery Morphology on OCT

- **Intima** = hard sponge
- **IEL** = rubber band
- **Media** = soft rope
- **EEL** = rubber band
- **Adventitia** = mesh



Shlofmitz, E. et al. Algorithmic Approach for OCT Guided Stent Implantation During PCI. *Intervent Cardiol Clin* 7 (2018) 329-344.

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# OCT Image Interpretation

Can the EEL (rope) and Adventitia (mesh) be visualized?

YES

NO

Normal Artery  
Fibrous Plaque

Is the signal change in the lumen or the wall?

Lumen

Wall

High Attenuation  
(light absorbed)

Low Attenuation  
(light refracted)

High Attenuation

Low Attenuation

Red Thrombus

White Thrombus

Lipid

Calcium

Could you draw a line  
around the signal change?

Shlofmitz, E. et al. Algorithmic Approach for OCT Guided Stent Implantation During PCI. *Intervent Cardiol Clin* 7 (2018) 329-344.

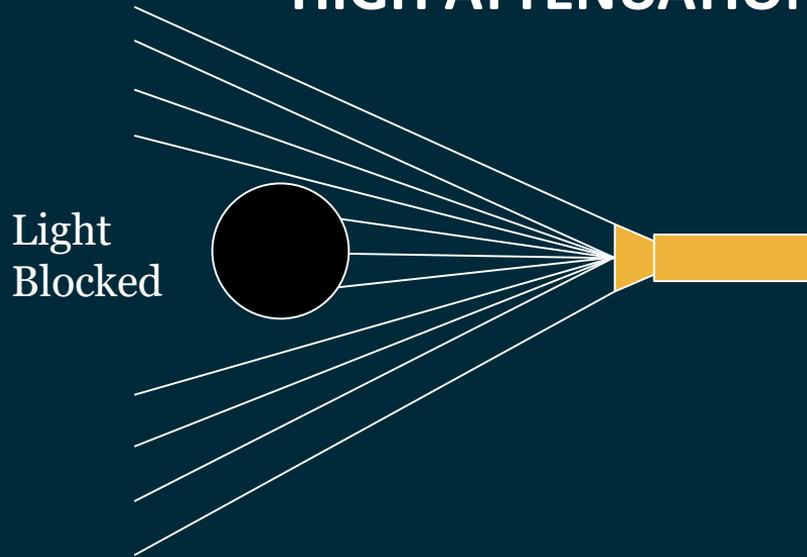
See Important Safety Information referenced within.

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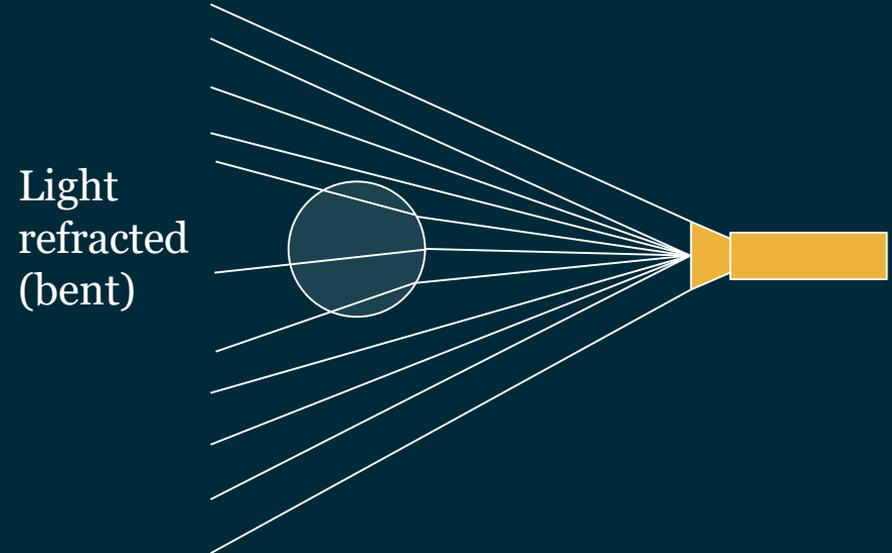
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# OCT Signal Attenuation

## HIGH ATTENUATION



## LOW ATTENUATION



Courtesy of Dr. Ziad A. Ali

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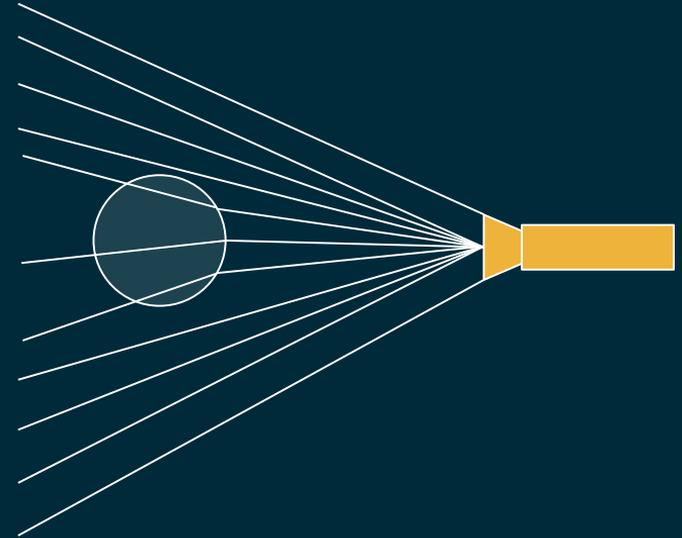
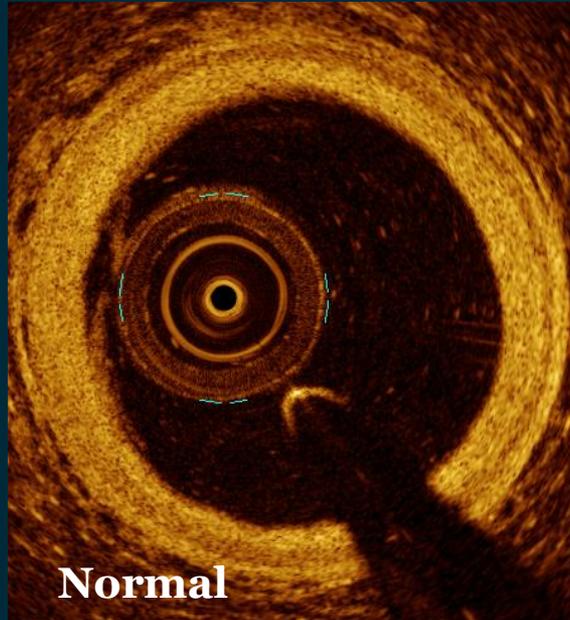
# OCT Image Interpretation

Can the EEL and Adventitia be visualized?

Yes



Normal Artery  
Fibrous Plaque



Courtesy of Dr. Ziad A. Ali

See Important Safety Information referenced within.

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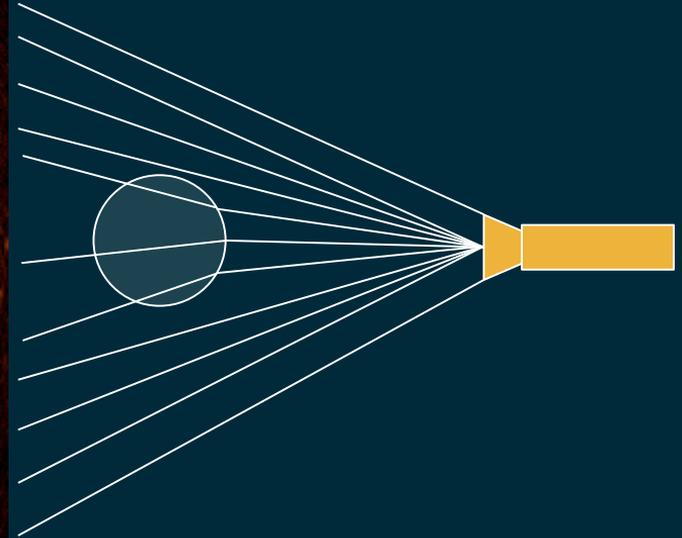
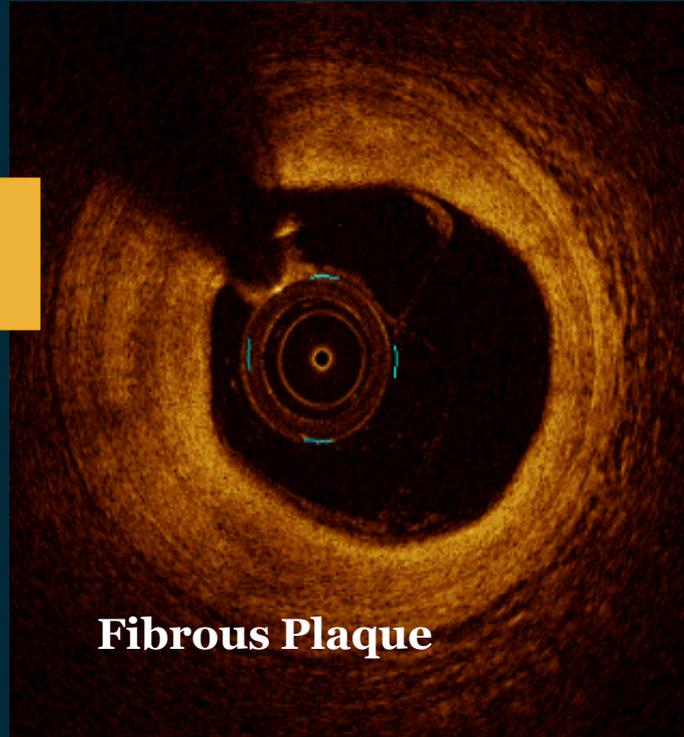
# OCT Image Interpretation

Can the EEL and Adventitia be visualized?

Yes



Normal Artery  
Fibrous Plaque



Courtesy of Dr. Ziad A. Ali

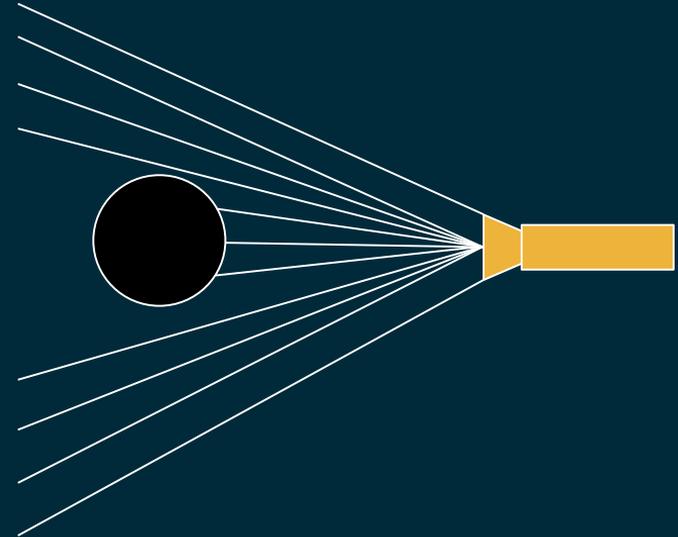
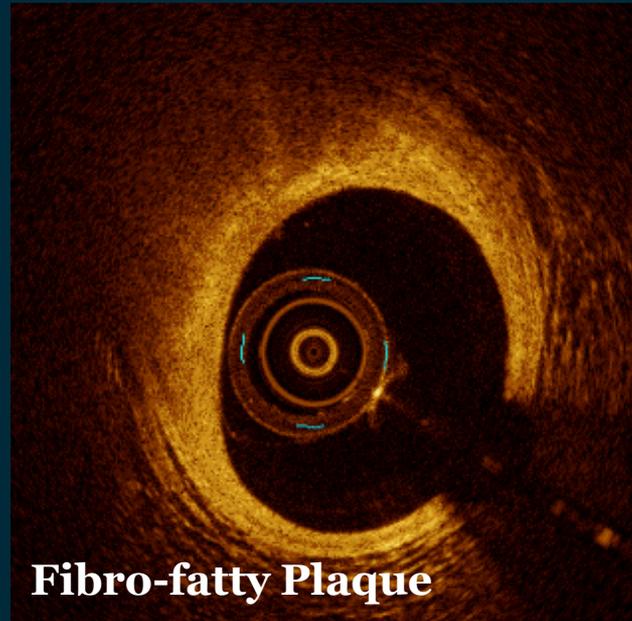
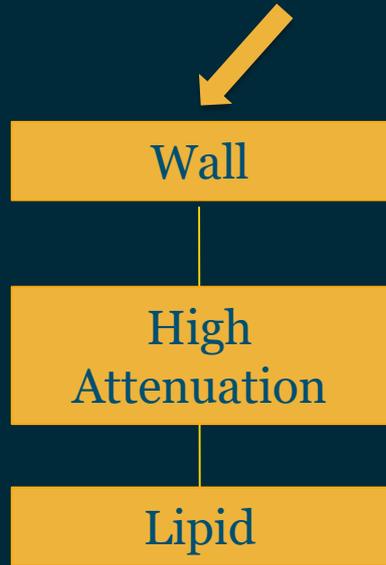
See Important Safety Information referenced within.

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# OCT Image Interpretation

Is the signal change in the lumen or the wall?



Courtesy of Dr. Ziad A. Ali

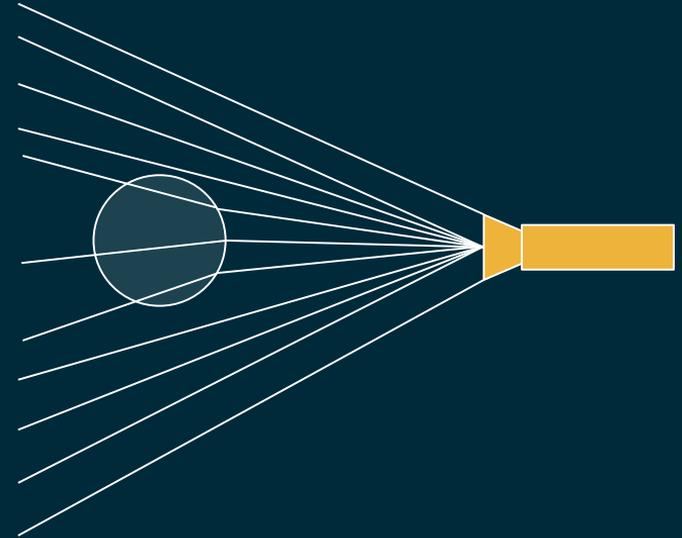
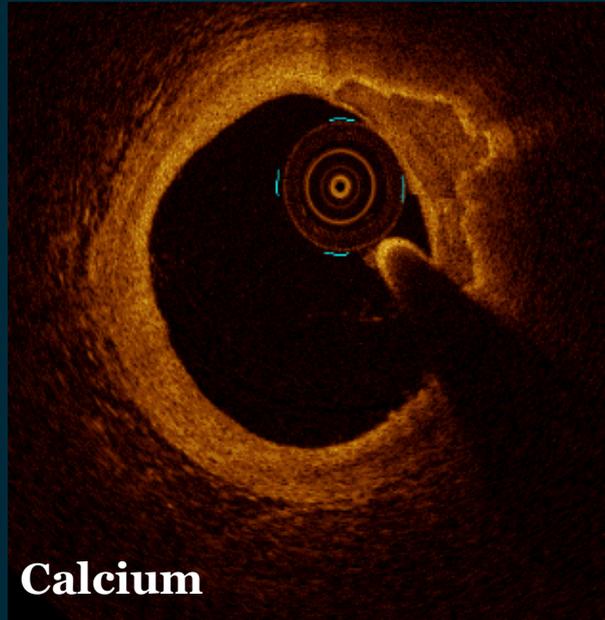
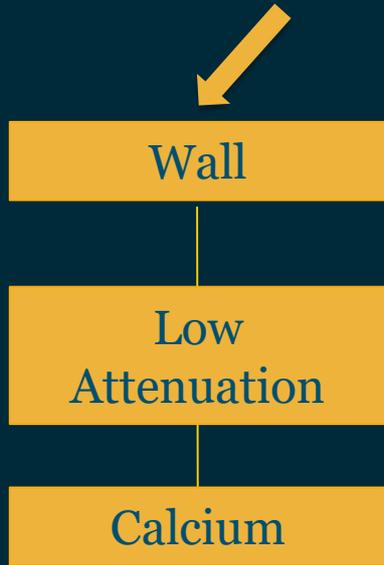
See Important Safety Information referenced within.

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# OCT Image Interpretation

Is the signal change in the lumen or the wall?



Courtesy of Dr. Ziad A. Ali

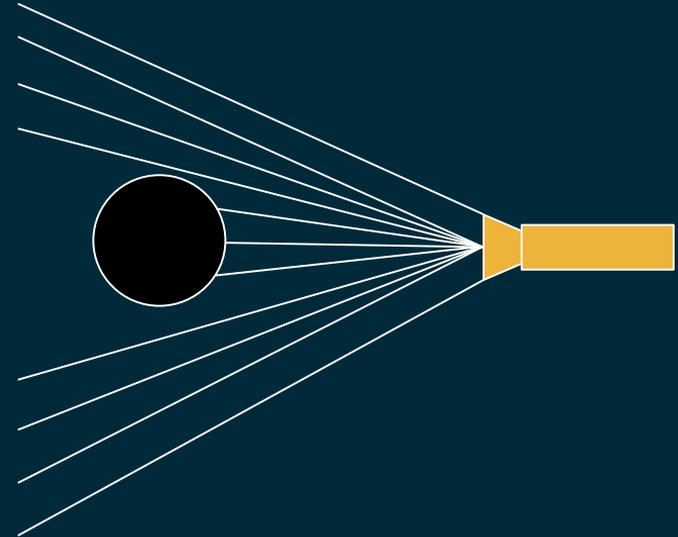
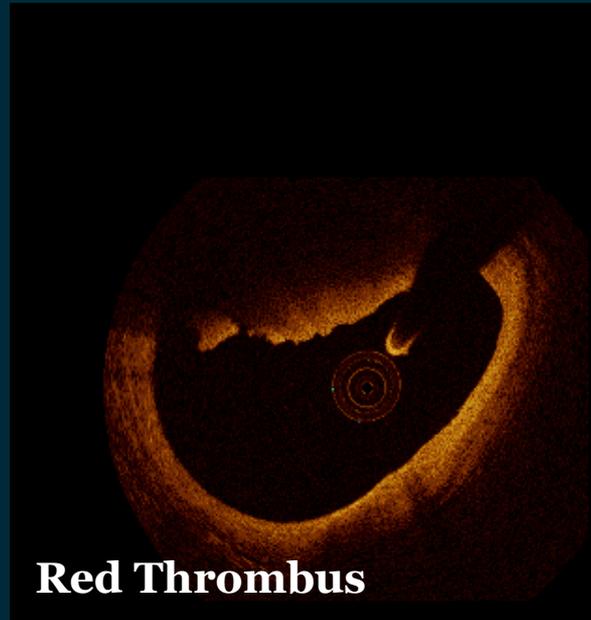
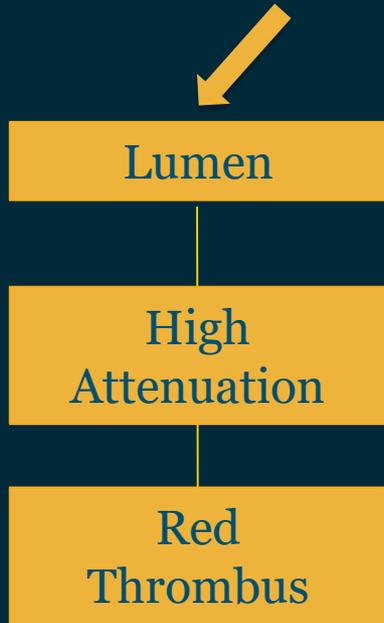
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# OCT Image Interpretation

Is the signal change in the lumen or the wall?



Courtesy of Dr. Ziad A. Ali

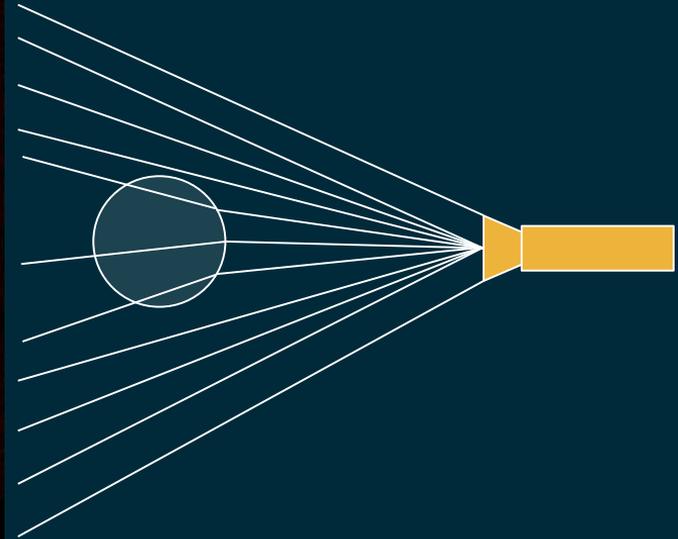
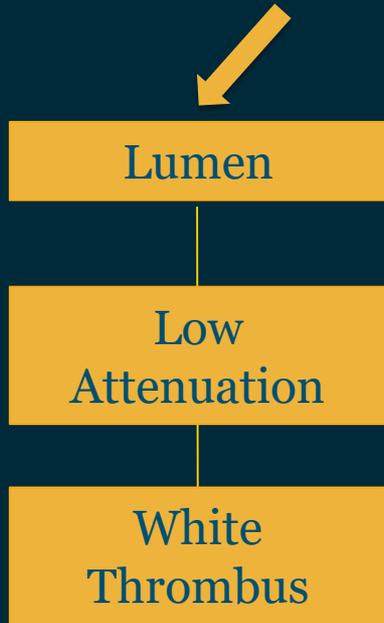
See Important Safety Information referenced within.

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# OCT Image Interpretation

Is the signal change in the lumen or the wall?



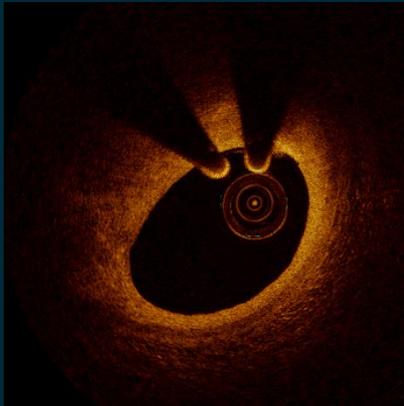
Courtesy of Dr. Ziad A. Ali

See Important Safety Information referenced within.

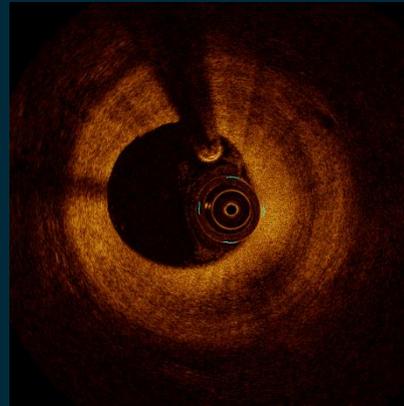
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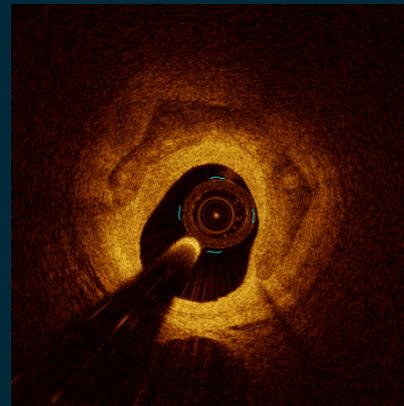
# Morphology Guided Lesion Preparation



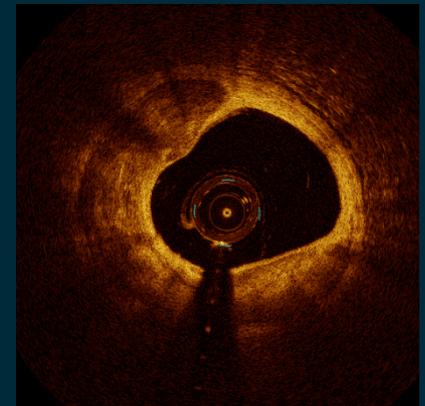
Lipidic



Fibrotic



Mild/Moderate Ca<sup>2+</sup>



Severe Ca<sup>2+</sup>

**DIRECT STENTING<sup>1</sup>**

**COMPLIANT BALLOON<sup>2</sup>**

**NON-COMPLIANT BALLOON<sup>3</sup>**

**ATHERECTOMY OR IVL<sup>4</sup>**

1. Taylor, A., et al. Efficacy and Safety of Direct Stenting in Coronary Angioplasty, *J. Invasive Cardiology*, 2000; 12(11); 2. Romagnoli, E., et al. Drug Eluting Stenting, *JACC Cardiovascular Interventions*, 2008; 1(1): 21-31; 3. Seyithanoglu, B., Compliant vs Non-compliant balloons. A Prospective Randomised Study, 1998; 39(1): 45-54; 4. Toney, M., Current Status of Rotational Atherectomy, *JACC Cardiovascular Interventions*, 2014; 7(4): 345-354.

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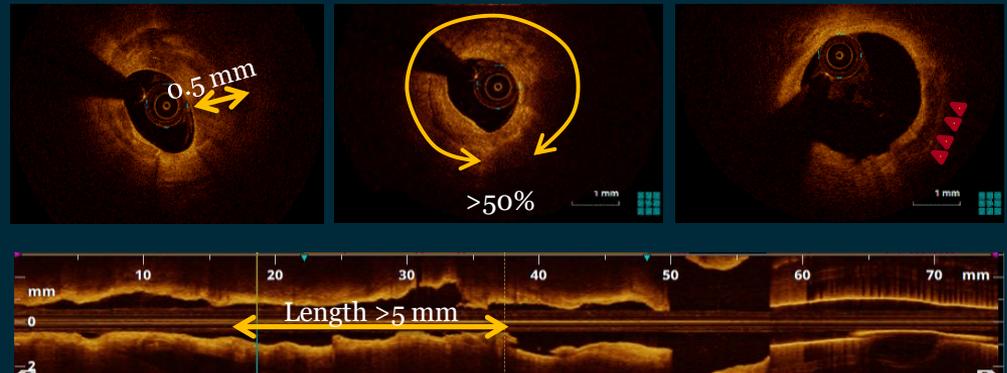
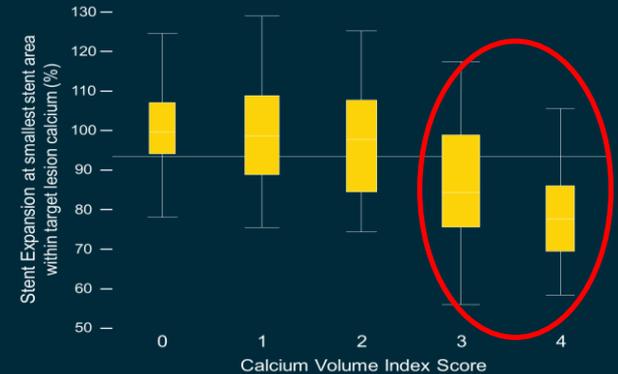
# Influence of Ca<sup>2+</sup> on Stent Expansion by OCT

## OCT-Based Calcium Volume Index Score<sup>1</sup>

|                                   |   |
|-----------------------------------|---|
| 1. Maximum Calcium Angle (°)      | $\leq 90^\circ$ ▶ 0 point<br>$90^\circ < \text{Angle} \leq 180^\circ$ ▶ 1 point<br>$> 180^\circ$ ▶ 2 points |
| 2. Maximum Calcium Thickness (mm) | $\leq 0.5 \text{ mm}$ ▶ 0 point<br>$> 0.5 \text{ mm}$ ▶ 1 point   |
| 3. Calcium Length (mm)            | $\leq 5.0 \text{ mm}$ ▶ 0 point<br>$> 5.0 \text{ mm}$ ▶ 1 point   |
| <b>Total score</b>                | <b>0 to 4 points</b>  |

## Rule of 5's

- 0.5 mm thickness
- 5.0 mm long
- 50% vessel arc



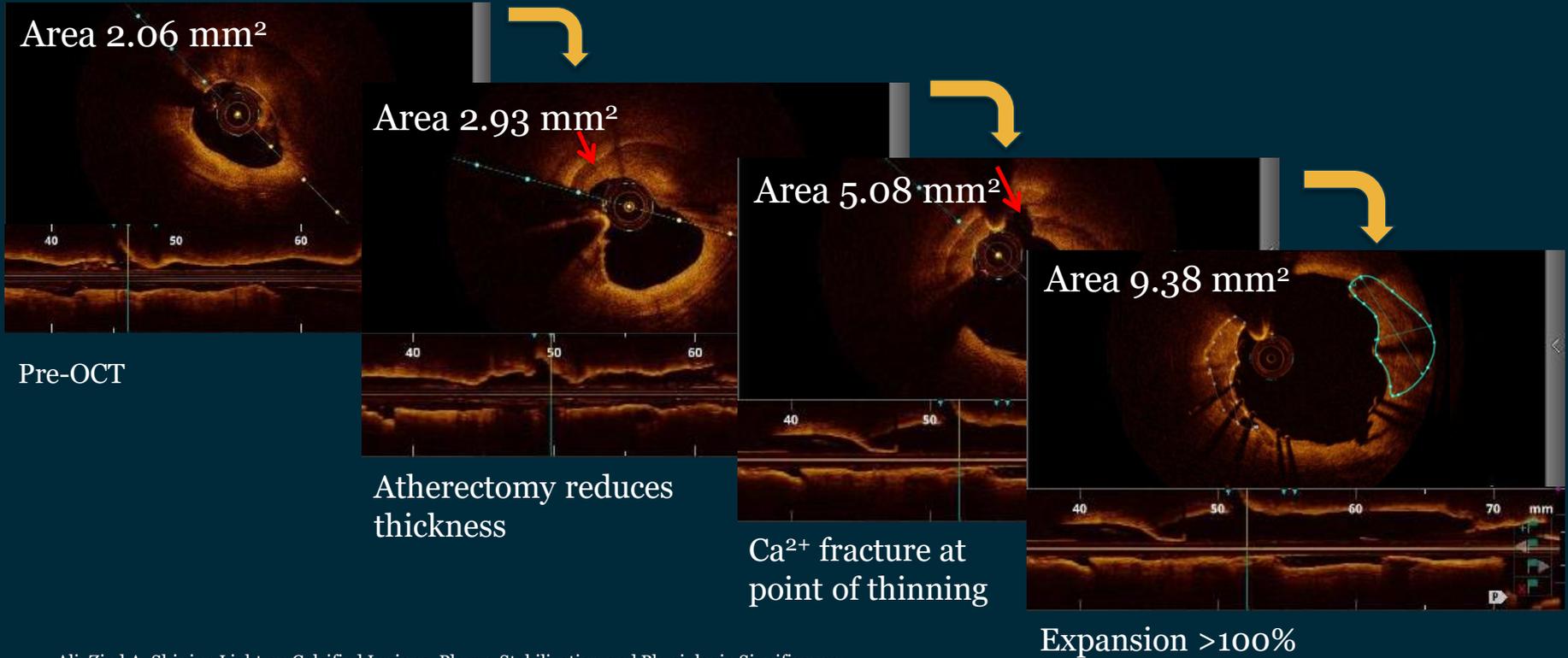
1. Fujino, A. et al. A new optical coherence tomography-based calcium scoring system to predict stent under expansion. *EuroIntervention*, April 2018; 13(18):e2182-e2189.

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# Ca<sup>2+</sup>-Dependent Lesion Preparation



Ali, Ziad A. Shining Light on Calcified Lesions, Plaque Stabilization and Physiologic Significance: New Insights from Intracoronary OCT. *EuroIntervention*, vol. 13, no. 18, 2018, pp. 2105–2108.

See Important Safety Information referenced within.

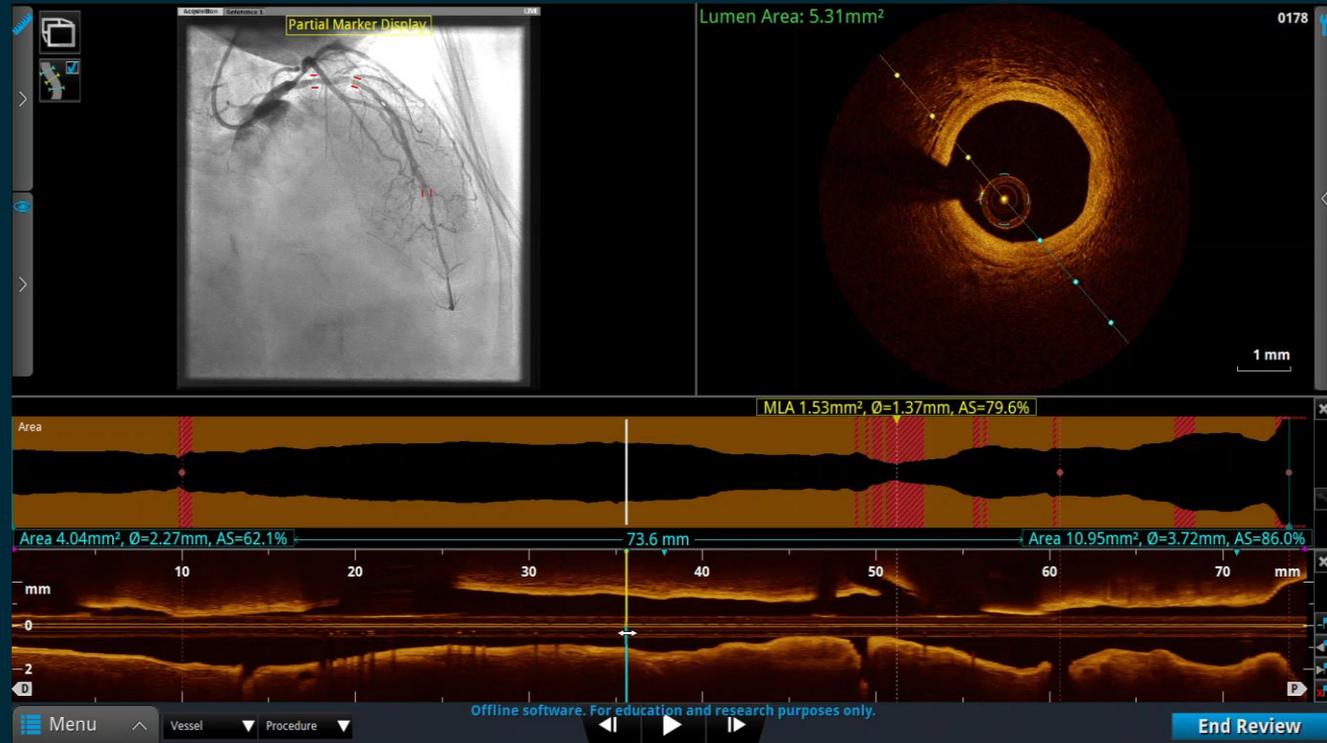
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# OCT-Guided Morphology Assessment

## Identify:

- Normal or fibrous edges
- Severe  $\text{Ca}^{2+}$



Case courtesy of Dr. Ziad A. Ali

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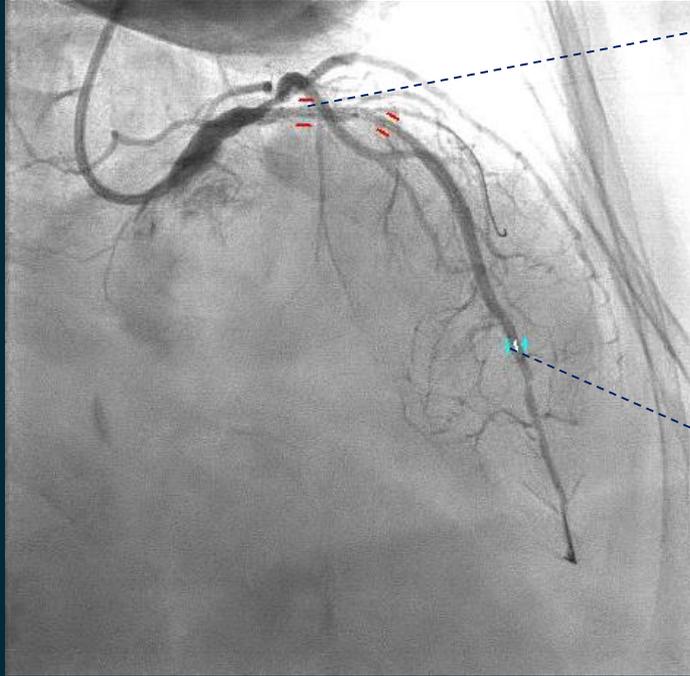
## SECTION 2

# Length

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# Identify Landing Zones



Traditional 2-D Angiogram



OCT 3-D Lumenogram

Courtesy of Dr. Ziad A. Ali

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# Identify Landing Zones

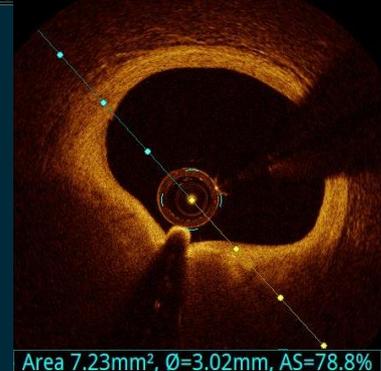
- |   |   |   |   |
|---|---|---|---|
| <p>1) Scroll reference vessel markers to distal “normal” OCT lumenogram</p> | <p>2) Is this a safe place to land the distal stent edge?<br/><i>The more visible the EEL the safer your landing zone</i></p> | <p>3) Scroll reference vessel markers to proximal “normal” OCT lumenogram</p> | <p>4) Is this a safe place to land the proximal stent edge?<br/><i>The more visible the EEL the safer your landing zone</i></p> |
|---|---|---|---|



- 5) Adjust the length to an available DES size at the “more normal” reference



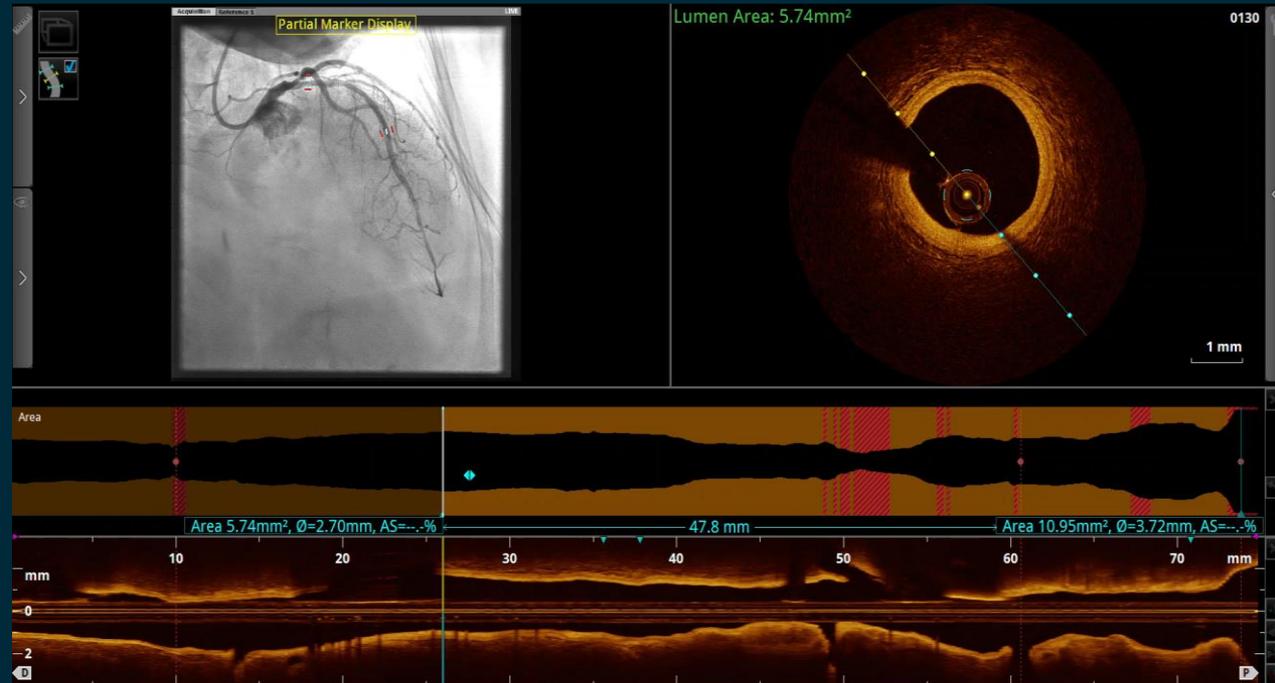
Lesion length 33 mm



# OCT-Guided Length

## Identify:

- “Normal” reference segments
- Adjusted DES size



Case courtesy of Dr. Ziad A. Ali

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## SECTION 3

# Diameter

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# OCT Stent Sizing Algorithm

PRE-PCI OCT



Can the EEL be identified at the **distal** reference segment to allow vessel diameter measurement?

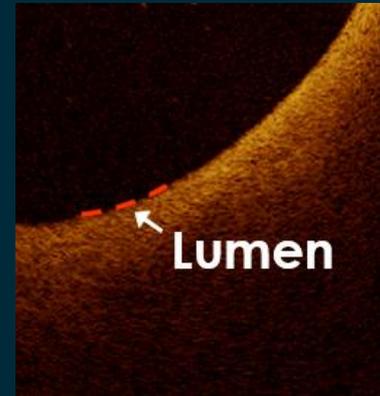
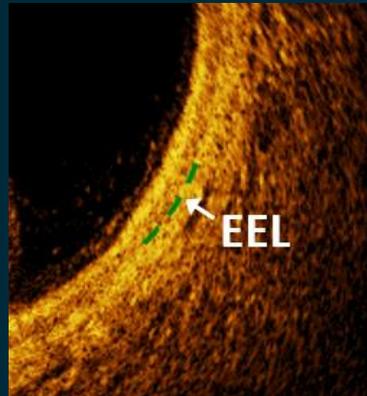
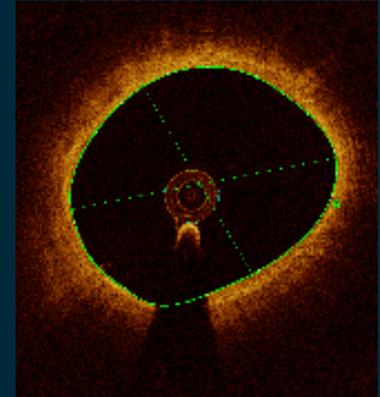
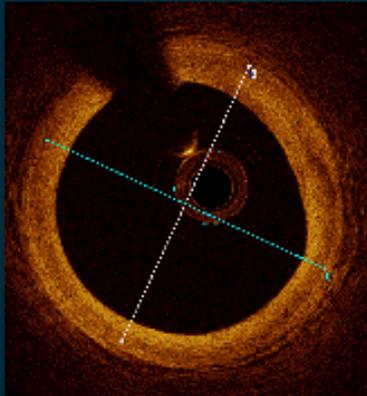
YES



Stent diameter decided by OCT measurement of **mean EEL to EEL diameter rounded down** to nearest stent size<sup>1</sup>

NO

Stent diameter decided by OCT measurement of **mean lumen diameter rounded up** to nearest stent size<sup>2</sup>



1. Ali, Z., et al., ILUMIEN III Study, Lancet Journal, 2016; 1-11. 2. Shlofmitz, E. et al. Algorithmic Approach for OCT Guided Stent Implantation During PCI. Intervent Cardiol Clin 7 (2018) 329-344.

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# OCT Post-Dilatation Balloon Sizing Algorithm

PRE-PCI OCT



Can the EEL be identified at the proximal and distal reference segment to allow vessel diameter measurement?

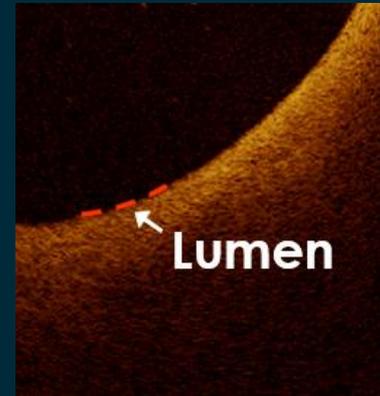
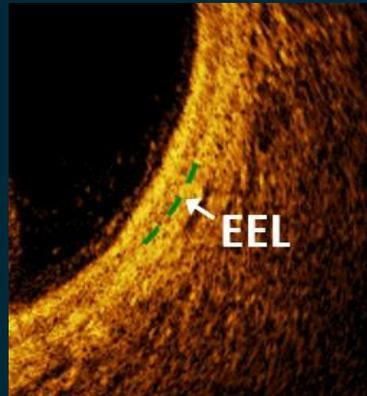
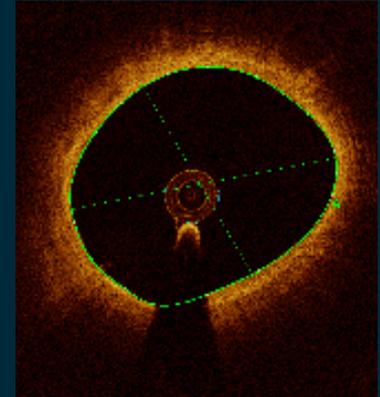
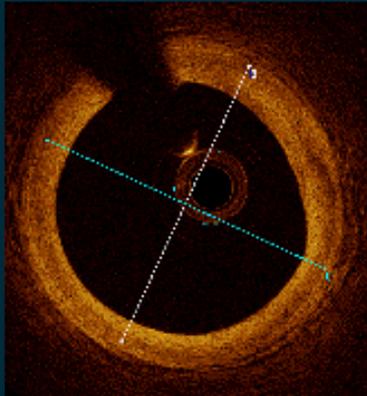
YES



Balloon diameter decided by OCT measurement of **mean EEL to EEL diameter rounded down** to nearest balloon size<sup>1</sup>

NO

Balloon diameter decided by OCT measurement of **mean lumen diameter rounded up** 0.25-0.50 mm<sup>2</sup>



1. Ali, Z., et al., ILUMIEN III Study, Lancet Journal, 2016; 1-11. 2. Shlofmitz, E. et al. Algorithmic Approach for OCT Guided Stent Implantation During PCI. Intervent Cardiol Clin 7 (2018) 329-344.

See Important Safety Information referenced within.

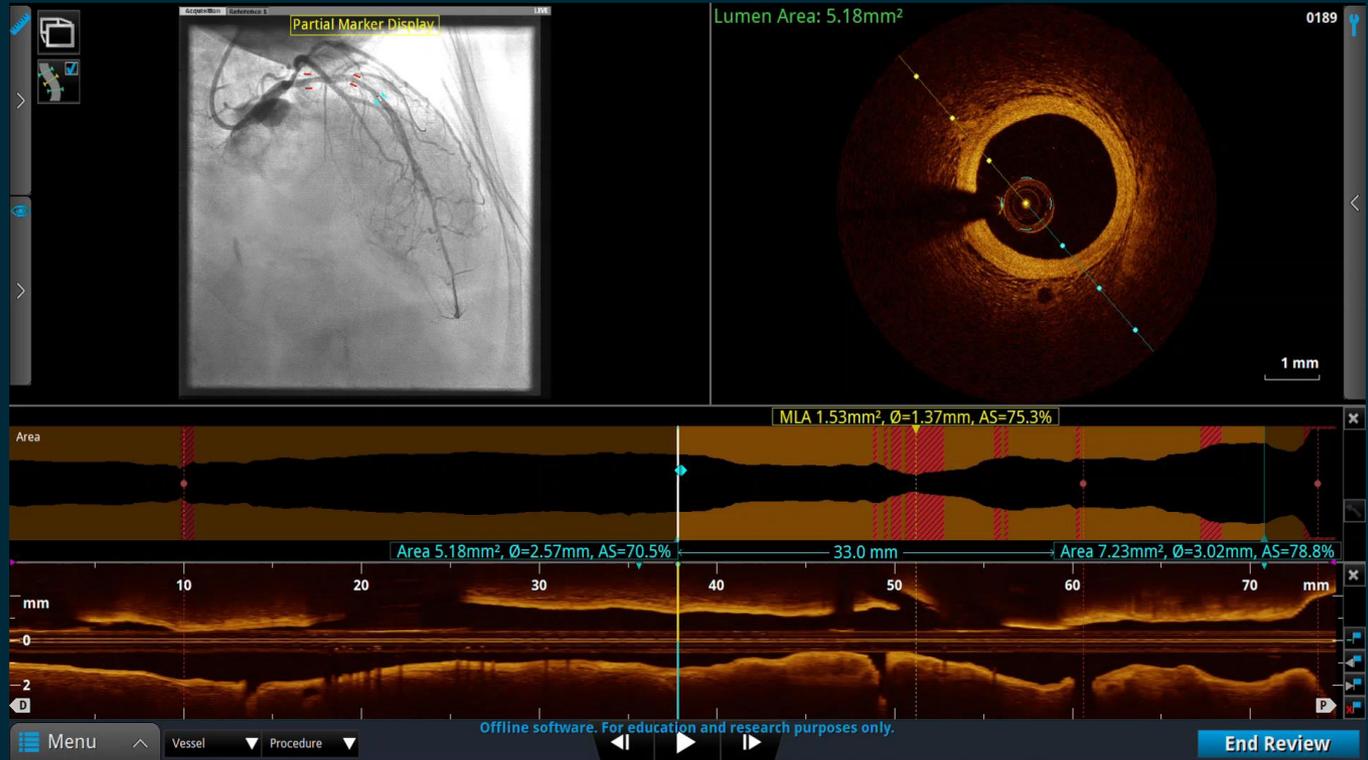
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# OCT-Guided Diameter

## Measure:

- EEL-EEL, if possible
- Mean lumen diameter, if no EEL-EEL



Case courtesy of Dr. Ziad A. Ali

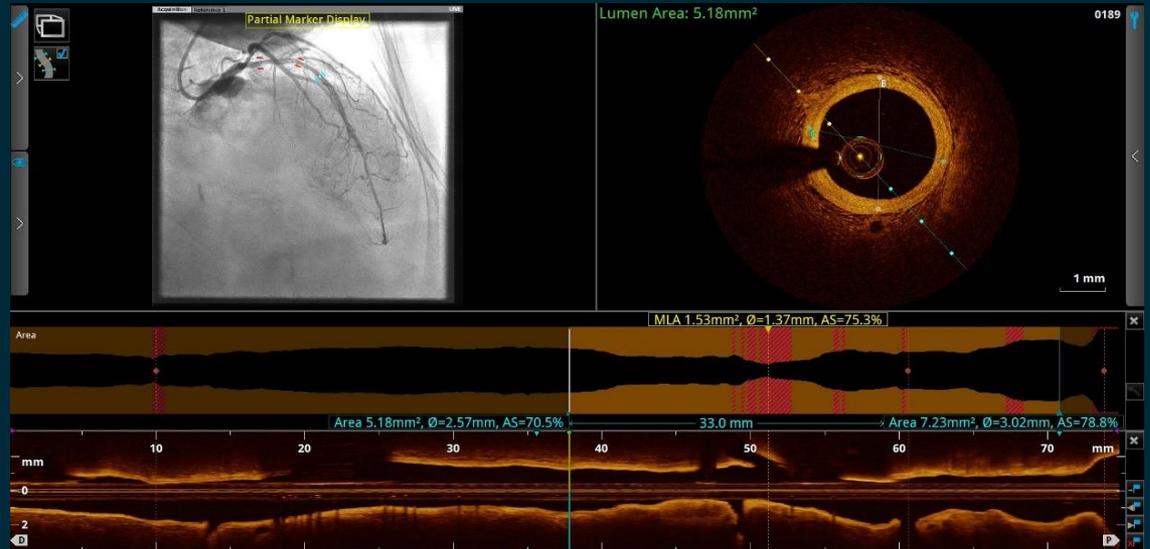
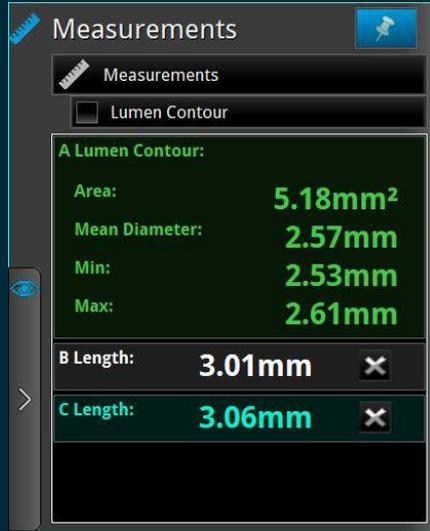
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# OCT Guided Stent / Balloon Sizing – Distal Reference

- At the LAD distal reference the vessel wall can be measured
- Mean EEL = 3.04 mm
- Round **down** to nearest stent size = 3.0 mm



Ali, Z., et al., ILUMIEN III Study, Lancet Journal, 2016.

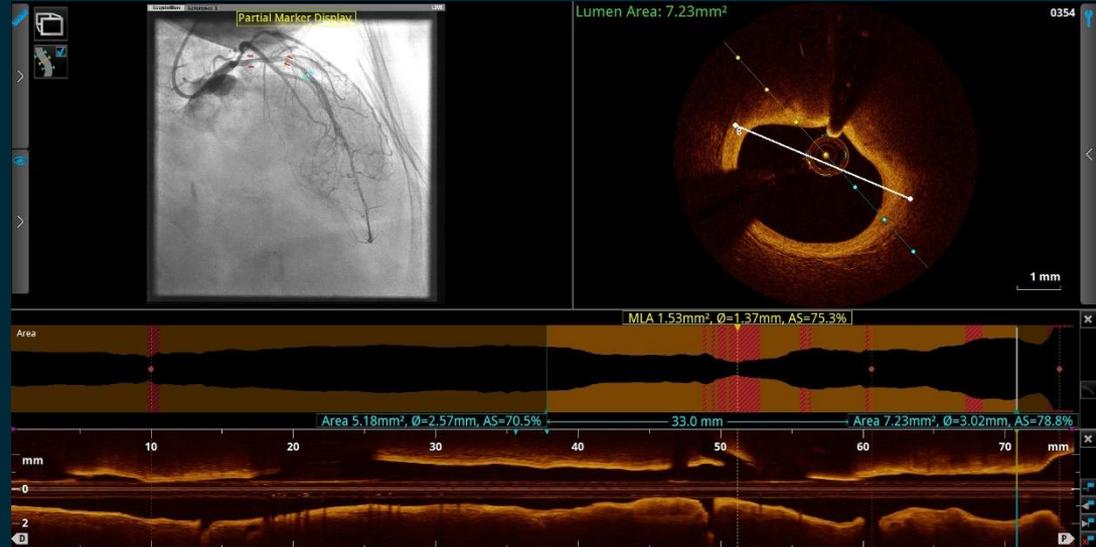
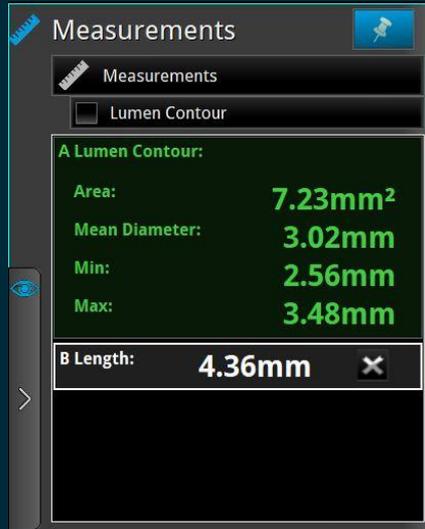
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# OCT Guided Post-Dilatation Balloon Sizing - Proximal

- At the LAD proximal reference the vessel wall can be measured. EEL = 4.36 mm
- Round **down** to nearest balloon size for post-dilatation (if necessary) = 4.00 mm
- At the LAD proximal reference if the vessel wall can not be measured. MLD = 3.02 mm
- Round **up** to nearest balloon size for post-dilatation (if necessary) = 3.50 mm



Ali, Z., et al., ILUMIEN III Study, Lancet Journal, 2016.

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XIN CẢM ƠN QUÝ ĐỒNG NGHIỆP.

