Cath Lab Essentials: IVUS & OCT
Different Views of Atherosclerosis

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Glagov Hypothesis and Patient Type A

Luminal obstruction in CAD occurs late

CAD Progression

Artery can compensate for up to 40% plaque volume (lumen size remains constant)


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Artery at maximum expansion: lumen narrows

Plaque Severity Vs. Stability

- **Stable Plaque**
  - Thick fibrous cap
  - Small lipid core
  - Severe Stenosis

- **Unstable Plaque**
  - Thick fibrous cap
  - Large lipid core
  - Mild Stenosis
Stable Plaque

- lumen
- thick fibrous cap
- small lipid core
Unstable Plaque
Ruptured Plaque with Thrombosis

- thrombus
- thin fibrous cap
- Large lipid core
Delayed Healing in Acute MI

Fatal thrombus within a drug-eluting stent located over a lipid core plaque.

Adapted from Nakazawa et al. Circulation 116, No. 16 page II-628.
Coronary Artery Disease
The Imaging Goal
Does the plaque have a lipid core or is it fibrotic?

James E. Muller, MD
CEO, InfraReDx, Inc.
Coronary Calcium makes lesion and lumen diameter difficult to assess
CTA: Positive remodeling (+), Soft plaque (+), Fibrous plaque (+), Calcification (-)

LAD in ACS

Motoyama et al. JACC 2007
IVUS: vessel lumen

A

Proximal Reference

B

3.0 mm

3.1 mm
Diagnose concomitant undiagnosed disease

95% RCA s/p successful PCI; left system angiographically normal
Potentially diagnose stable vs. vulnerable plaques

“Stable” plaque with thick fibrous cap with small lipid core

“Vulnerable” plaque with thin fibrous cap and large lipid core

IVUS-derived TCFA:

(i) plaque burden > 40

(ii) the presence of confluent necrotic core of >10%, and

(iii) no evidence of an overlying fibrous cap as previously described by Rodriguez-Granillo et al.

Pathological Intimal thickening

Fibrocalcific plaque

A

B

Fibrous tissue (dark green)

Fibrofatty tissue (light green)

C

D

Necrotic core (red)

Dense calcium (white)

Thick-capped fibroatheroma

Thin-capped fibroatheroma “vulnerable plaque”
(A) Post-mortem histology demonstrated coronary segment with stent struts but no significant necrotic core.

(B) Co-registered VH-IVUS image showing stent struts mistaken for calcium with necrotic core artefact

NIR Spectroscopy for VP Detection

- Emits near-infrared laser light inside the artery
- Forms an image from how much is absorbed
- Picture of the contents and dimensions of lipids in the vessel walls.
A NIRS Scan Correlates Well to Histologic Findings in Coronary Artery From an 85-Year-Old Male With a History of MI

A Chemogram From a 45-Year-Old Female Who Died of Anoxia

Clinical Case - What Stent Length?

57 yr old male with stable exertional angina
Post Stent

4.0 x 28mm Xience DES
NIR Plaque Characterization Prior to Stenting

CaseCourtesy of Simon Dixon, MD, Beaumont Hospital –

This stenosis has a fibrotic plaque

This stenotic culprit plaque has a large lipid core plaque

This non-stenotic area also has a lipid core plaque

Right Coronary Artery
NIRS-IVUS combination

Post-stenting revealed that the lipid core, represented by the yellow on the Chemogram, was no longer present post-stenting and no-reflow.
Intravascular Ultrasound and Optical Coherence Tomographic Imaging

OCT Resolution = 10 microns

IVUS Resolution = 150 microns
Figure 2. OCT highlights in-stent restenosis in a patient who has just undergone balloon dilatation. (Image courtesy LightLab Imaging.)

Figure 3. Complete tissue coverage between the vessel lumen (dark area) and a half-dozen stent struts (brightest objects) in this OCT image demonstrate good healing. (Image courtesy LightLab Imaging.)
Normal coronary artery
- Uniform silhouette
- 3 layers visible in vessel wall

Image Orientation

- Imaging catheter
- Guidewire shadow
- Adventitia
- Media
- Intima

Data on file at LLI
Thin Cap Fibroatheroma

TCFA was defined as a plaque with fibrous cap <65μm thick. The high resolution of OCT has an ability to identify thin-fibrous cap clearly even if it is less than 100μm.
Guidewire Location

**False lumen**
- In pullback imaging, false lumen diverges from/joins the true lumen
- With OCT identify what is the true vessel wall

Data on file at LLI
Measurements - Restenosis

Area calculations
- % area stenosis
- Minimum and maximum diameter within area

Length calculations
- % diameter stenosis

Measurement of in-stent restenosis

Data on file at LLI

A Area: 2.88 mm²
B Area: 6.98 mm²
C %AS: A/B = 58.74%
D Diameter A: Min=1.65 mm; Mean=1.90 mm; Max=2.23 mm
E Diameter B: Min=2.83 mm; Mean=2.98 mm; Max=3.11 mm
Vessel Wall Damage

Edge dissection

- A disruption of the vessel luminal surface in the edge region

- Easy to interpret using cross-sectional and longitudinal views

Image: Columbia Presbyterian Hospital

Data on file at LLI
Neointimal Hyperplasia

In-stent restenosis

- Thick layer between stent struts and lumen

Data on file at LLI
Thrombosis

Data on file at LLI

Thrombus

Stent struts

Data on file at LLI
Thrombus – Red (Acute)

Thrombus – red
- Absorbs near-infrared light
- High backscatter on surface due to signal attenuation
- Appears as a bright mass
- Shadow (cannot see behind it)

Data on file at LLI
OCT Characteristics

Fibrous
- Homogeneous, Signal-rich

Lipid
- Echolucent, Diffuse Borders

Calcific
- Echolucent, Sharp Borders

500 μm
Combined strengths of OCT and IVUS

OCT

IVUS
Combined strengths of OCT and IVUS
Figure: Morphology of the patient's plaque with IVUS-derived, thin-capped fibroatheroma

Two images are better than One
Integrated hybrid OCT/IVUS from Patel-Chen Labs at UCI
Integrated intravascular OCT/US from Patel-Chen Labs at UCI

* in US image ultrasound pulse ring down effect and the reflection of catheter sheath.

* in OCT image caused by the high back reflection from the interface between the prism and GRIN lens

Scale bar: 0.5mm
Intravascular ultrasound (IVUS)
Optical coherence tomography (OCT)

FD-OCT: (cap thickness)  IVUS: (full thickness of plaque)

Combined imaging of Vulnerable Plaque

High resolution
(2-15 μm)
Shallow penetration
(1-2 mm)

No need for
blood clearance
Deep penetration
(5 mm)
Poor resolution
(50-300 μm)

OCT/IVUS: Ideal Combination
The future of intravascular imaging? Elastography allows us to measure strain patterns in tissues (and vulnerable plaques)

**Fig. 7** PR-ARF-OCE image of human coronary artery. (a) OCT image; (b) PR-ARF-OCE image; (c) histological image (corresponding to across blue line location in (a); and (d) close-up view of the atherosclerotic lesion. Scale bars: 1mm

Z. Chen/P Patel. UC Irvine. Acute radiation force –Optical Coherence elastography
End – questions?

Thanks!