Cath Lab Essentials: IVUS & OCT
Different Views of Atherosclerosis

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Presentation-Patient type A

- Name: WJC
- Age: 54 years old
- Professional: former chief executive
- Social hx: wife lives principally in Washington, DC; he has a personal cook in his suburban NY home
- Lifestyle:
  - Occasional use of cigars
  - has had a long-term weight problem
  - likes to play golf
Presentation (cont’d)

- **Examination:**
  - Height: 6 ft 2 in
  - Weight: 220 lb (BMI 28 kg/m²)
  - BP: 150/88 mm Hg
  - Waist circumference: 41 in
  - P: 64 bpm
  - RR: 12 breaths/min

- **Cardiopulmonary exam:** normal
Height: 6 ft 2 in
Weight: 220 lb (BMI 28 kg/m²)
BP: 150/88 mm Hg
Waist circumference: 41 in

Medications:
- amlodipine 5 mg/d

Laboratory results:
- TC: 220 mg/dL
- LDL-C: 140 mg/dL
- HDL-C: 36 mg/dL
- TG: 220 mg/dL
- FBS: 120 mg/dL

Given his fast paced career, WJC enjoys frequenting certain fast food restaurants.
1. Best Doctors/Medical Care
2. Normal Stress Test
3. Coronary Artery Bypass Surgery one year later after stress test
4. Why was this diagnosis not caught earlier?
Patient type B

Normal stress test prior to event

Event probably secondary to Vulnerable Coronary Plaque
Heart attack killed 'Sopranos' star James Gandolfini, friend says

Another Patient

Event probably secondary to Vulnerable Coronary Plaque
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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Most Myocardial Infarctions Are Caused by Low-Grade Stenoses – Patient type B

Coronary stenosis severity prior to MI

- >70% Stenosis: 14%
- 50%-70% Stenosis: 18%
- <50% Stenosis: 68%


Plaque Severity Vs. Stability

- Thick fibrous cap
- Small lipid core
- Lumen

Stable Plaque
- Severe Stenosis

Unstable Plaque
- Mild Stenosis
Stable Plaque

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

thrombus
thin fibrous cap
Large lipid core
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
Coronary CTA
CTA: Positive remodeling (+), Soft plaque (+), Fibrous plaque (+), Calcification (-)

Motoyama et al. JACC 2007

LAD in ACS
IVUS: vessel lumen
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
Culprit lesion with recent MI

Hypertension, flow limiting lesion, superficial “erosion”

Hyperlipidemia, flow-limiting lesion with superficial erosion

Diabetic, early stage lipid necrosis even in a non-flow limiting lesion
Pathological Intimal thickening

Fibrocalcific plaque

Fibrous tissue (dark green)

Fibrofatty tissue (light green)

Necrotic core (red)

Dense calcium (white)

Thick-capped fibroatheroma

Thin-capped fibroatheroma

“vulnerable plaque”
Left: (A) Post-mortem histology demonstrated coronary segment with stent struts but no significant necrotic core.
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.)
Image Orientation

Normal coronary artery
- Uniform silhouette
- 3 layers visible in vessel wall

Data on file at LLI

Imaging catheter
Guidewire shadow
Adventitia
Media
Intima

St. Jude Medical
More control. Less risk.
**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
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

Thrombus

Stent struts

Data on file at LLI
Thrombus – Red (Acute)

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

Red thrombus

Data on file at LLI
OCT Characteristics

Fibrous: Homogeneous, Signal-rich
Lipid: Echolucent, Diffuse Borders
Calcific: Echolucent, Sharp Borders
Combined strengths of OCT and IVUS
Combined strengths of OCT and IVUS
Figure: Morphology of the patient's plaque with IVUS-derived, thin-capped fibroatheroma

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.
Intravascular ultrasound (IVUS)

Optical coherence tomography (OCT)

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

OCT/IVUS: Ideal Combination

- High resolution (2-15 μm)
- Shallow penetration (1-2 mm)
- Combined imaging of Vulnerable Plaque

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