Imaging Atheroma
The quest for the Vulnerable Plaque

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Coronary Heart Disease Remains the Leading Cause of Death in the U.S, Causing 1 Death Every Minute

1.2 Million Fatal and Non-fatal Heart Attacks Occur Each Year

- 500,000 have experienced prior events
- 700,000 are first events. In >50% of sudden coronary deaths there was no prior sign of coronary disease
- ~ 100,000 occur following stenting

Sources: www.americanheart.org

Enormous failure of current methods to diagnosis CAD prior to initial sudden death or MI.
Evolution of Coronary Atherosclerosis

- Normal coronary arteries
- Asymptomatic atherosclerosis
- High-risk (vulnerable) plaque
- Thrombosed plaque
- ACS
- Progression stenosis
- Stable angina
- Asymptomatic

Terminology for high-risk coronary plaques

EHJ 2004;25: 1-6
Vulnerable Plaque

Rupture Prone Plaque

- Large necrotic lipid core
- Thin fibrous cap
- Dense Macrophage infiltration (metalloproteinases)
- Progressive matrix degeneration
- Paucity of SMCs
- Angiographically non-significant
- Positive remodelling
- Inflammation
The Elusive Vulnerable Plaque

Precursor = ruptured plaque except
- No rupture
- No erosion

Vulnerable Plaque
- Large lipid core
- Thin fibrous cap
- Inflammation

Ruptured Plaque
**IVUS: Plaque Composition**

**Calcific plaque**
- Highly echodense and shadowing
- $S \ 89\% / Sp \ 97\%$

**Fibrous**
- Highly echodense
- $S \ ? / Sp \ ?$

**Lipid**
- Echolucent zones
  - $S \ 78\%-95\% / Sp \ 30\%$

**Fibrous vs lipid:** $S \ 39 \ -52\%$
Limitations of angiography
Intravascular Ultrasound

Boston Scientific Ultra 2.9F 30Mhz
pullback speed 0.5mm/sec
Virtual Histology™ IVUS

Post Processing Signals

RF Signal
Histopathology and VH

Sens 85%-95%  Spec. 80%-90%
Atheroma heterogeneity

Pathological intimal thickening
Fibrotic
Fibroatheroma
Thin cap Fibro atheroma

Adaptative intimal thickening
Fibrocalcific
Calcified FA
Calcified TCFA

Atheroma heterogeneity
Definition of IVUS-Derived Thin-Cap Fibroatheroma (IDTCFA)

1. Focal (adjacent to non-TCFA)
2. Necrotic core ≥10%
3. In direct contact with the lumen
4. Percent area obstruction ≥40%

- Per 3 consecutive frames with four characteristics

## Incidence of IDTCFA lesions in non-culprit coronary vessels (n= 55)

<table>
<thead>
<tr>
<th></th>
<th>IDTCFA</th>
<th>IDTCFA/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable (N=32)</td>
<td>1.0 (0.0,2.8)</td>
<td>0.2 (0.0,0.7)</td>
</tr>
<tr>
<td>ACS (N=23)</td>
<td>3.0 (0.0, 5.0)</td>
<td>0.7 (0.0,1.3)</td>
</tr>
<tr>
<td>p value</td>
<td>0.018</td>
<td>0.031</td>
</tr>
</tbody>
</table>

Continuous variables are presented as medians (25th, 75th percentile) or means ± SD when indicated.
Clustering of IDTCFA along the coronaries

Total lesions = 99

Distance from the ostium (mm)

- 0-10: 35.4%
- 11-20: 31.3%
- 21-30: 19.2%
- ≥31: 14.1%

p=0.008

Rodriguez-Granillo  J Am Coll Cardiol.
Optical Coherence Tomography (OCT)

OCT relies on light echo’s.
Every tissue has its own specific backscatter of light echo

- SLED*
- Broadband source
- Fiber-optic beamsplitter
- Detector
- Amplifier
- Bandpass filter
- Computer
- Scanning reference mirror

Penetration depth ~ 2mm
OCT Imaging

Pullback from distal to proximal in the coronary vessel, with contrast injection to induce a blood free field of view during 4 sec. pullback.
IVUS and Optical Coherence Tomography

**IVUS**

- **Resolution**
  - (axial) 100 - 150 μm
  - (lateral) 150 - 300 μm

- **Max. depth of penetration**
  - 4 - 8 mm

**OCT**

- **Resolution**
  - 10 - 15 μm
  - 25 - 40 μm

- **Max. depth of penetration**
  - 1 – 1.5 mm
OCT normal coronary vessel
three layered appearance

“intima” 0.07mm
“media” 0.13mm
“adventitia”
OCT intimal thickening as bright homogeneous layer

diffuse

localized

Prati EHJ 2010;31:401
OCT Ca ++ and dissection

Calcium

Dissection
Optical Coherence Tomography

Vasovasorum
OCT culprit lesion ACS

Intracoronary thrombus

Normal reference
OCT culprit lesion Stable Angina

Non-significant lesion

Mild dissection
Thrombus
Lipid pool
ODFI Plaque Rupture
optical domain frequency imaging
Incidental findings, 73 yo man, 9 month post stenting, with 2 weeks crescendo angina

P. Barlis et al: Eur Heart J 2008
OCT lipid pool with thin fibrous cap

Vulnerable Plaque?
OCT  TCFA (vulnerable plaque)
Thin Cap Fibro-Atheroma

Cap thickness: 0.19±0.05mm

OCT definition of TCFA
- Signal-rich fibrous cap
- Covering signal-poor lipid/nectrotic core
- Cap thickness < 0.2mm
- Extent: > 45° vessel circumference
- At least 5 consecutive frames
Atherosclerotic Intima 5 years after BMS

Normal intima

Calcified nodule

Cholesterol crystals

Intima with lipid pool

Takano JACC 2010;55:26
Feasibility of combined use of intravascular ultrasound radiofrequency data analysis and optical coherence tomography for detecting thin-cap fibroatheroma

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Aims

To evaluate the feasibility of the combined use of virtual histology (VH)-intravascular ultrasound (IVUS) and optical coherence tomography (OCT) for detecting in vivo thin-cap fibroatheroma (TCFA).
Feasibility of combined use of IVUS-VH and OCT for detecting thin-cap fibroatheroma.

fib. fatty 55.8%; NC 22%

Cap thickness 40 microns

Eur Heart J. 2008 Apr 7
Feasibility of combined use of IVUS-VH and OCT for detecting thin-cap fibroatheroma: 56 pts

Total 126 lesions

IVUS-derived-TCFA 61 (48.4%)

OCT-derived-TCFA 36 (28.6%)

non-thin-cap IVUS-derived-TCFA 33 (26.2%)

definite-TCFA 28 (22.2%)

non-NCCL OCT-derived-TCFA 8 (6.3%)

VH IVUS examination

OCT examination

Eur Heart J. 2008 Apr 7
Feasibility of combined use of IVUS-VH and OCT for detecting thin-cap fibroatheroma.

Conclusion

“Neither modality alone is sufficient for detecting TCFA. The combined use of OCT and VH-IVUS might be a feasible approach for evaluating TCFA”.
Histology Fly Through

Virtual pullback distal to proximal through 1 cm diseased coronary vessel
ODFI Fly Through

Artery Wall
Lipid
Calcium
Macrophages
Stent
Guide Wire

Courtesy Dr Tearney MGH USA
Algorithm to detect high-risk plaque in a high-risk patient

Clinical presentation
- Acute coronary syndrome
  - Younger < 60 yrs
  - Diabetes
  - Troponin positive
- Biological marker: hsCRP↑

Non-invasive MSCT
- Calcific plaque
- Non-calcific plaque
- Total coronary plaque burden

Presence of plaque

Invasive techniques
- ICUS
- Palpography
- Thermography
- OCT

High-risk patient

High-risk plaque
CT: PLAQUE CHARACTERIZATION

HIGH-RISK PLAQUE: WHERE?

Non-obstructive noncalcific    Obstructive mixed    Normal or?    Non-obstructive calcific    Obstructive non-calcific
Identification Vulnerable Plaque

Work in Progress

Sofar elusive

Combination non-invasive and invasive coronary Imaging

High Risk Patients
THANK YOU