Demystifying IVUS Interpretation

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Conflict of Interest

Nicolas W Shammas, MD, MS

Some slides adopted from CATH-SAP, TCT and ACC presentations

**Speaker Bureau:** Janssen, Boehringer Ingelheim, Novartis, Lilly, Esperion

**Consultants/Trainer/Speaker:** Bard/BD, Boston Scientific, Angiodynamics, Phillips, CSI

**Research Grants:** Intact Vascular, Angiodynamics, Boston Scientific, Venture Med Group

[www.mcrfmd.com](http://www.mcrfmd.com)
Angiography Has Limitations

Contrast angiography has been considered the “gold standard” for diagnosis of coronary artery disease. However angiography is only “lumenography” because of several limitations:

1. Severity of calcium
2. Presence of intraluminal thrombus
3. Plaque morphology
4. Vessel diameter particularly in diffuse disease
5. Residual narrowing post-intervention
6. Number and severity of dissections
7. Stent expansion and symmetry post deployment
8. Stent apposition
Intravascular Ultrasound (vs OCT)

Intravascular imaging generates more accurate tomographic imaging of the artery wall and lumen than angiography.

Vascular ultrasound uses the piezoelectric effect.

- Two current systems
  1. Mechanical: a single crystal rotates at high speed to produce image- OPTICROSS (BSc. 60mHz), REVOLUTION (Philips 45 mHz), Acist Medical (Kodama, 60 mHz)
  2. Phased-array—multiple small crystals produce a 360-degree imaging plane. Philips (Volcano) Eagle-Eye, 5 Fr compatible, uses a 0.014-inch guidewire system. 20 MHz. Imaging depth 4-8 mm. Axial and lateral resolution is approximately 100 microns and 200 microns, respectively.

- IVUS imaging is typically accomplished obtained with manual pull back (no length data obtained) or via automated pullback (0.5-1.0 mm/sec). Frame rates are approximately 30 frames/second.

IVUS vs OCT

OCT (St Jude Medical) emits near-infrared light and records the

- Less penetration than IVUS: 1-3 mm
- Axial and lateral resolution: 15 microns and 30 microns, respectively.
- Pullback speed is approximately 30-40 mm/sec
- Frame rates 100 frames/second.
- Inject contrast while pulling back

Limitations of OCT:
- Need to have a blood free medium
- More contrast use
- Limited with depth penetration

Strengths of OCT:
- Higher speed in image acquisition and resolution
- Good for thrombus and calcium
Anatomy of the Vessel wall as seen by IVUS

IVUS: greyscale and cross section: triple-layer

Triple-layer:
- echobright layer nearest to transducer (intima)
- a black layer (media)
- echo-dense layer (adventitia)

(From CathSAP, ACC)
Anatomy of the Arterial wall as seen by IVUS

Stenosis EEL area - stenosis MLA

Atheroma Area=
Plaque-media surface area=

Plaque Burden=
Atheroma Area/
Stenosis EEL area *100

Intima: From endothelial cells to the internal Elastic Lamina

Media: in between the intima and adventitia

Adventitia: Connective tissue

Reference MLA

Plaque Surface Area (PSA)=
Stenosis IEL area - stenosis MLA

Area Stenosis:
Reference EEL area - stenosis MLA

Reference EEL

Reference MLA

Stenosis MLA

Stenosis EEL

Courtesy Nicolas W Shammas, MD
ACC Guidelines for IVUS

CLASS IIa:
1. IVUS is a reasonable option to assess angiographically indeterminant left main CAD (Level of Evidence: B)
2. IVUS and coronary angiography are within reason 4 to 6 weeks and 1-year post cardiac transplantation to rule out donor CAD, detect rapidly progressive cardiac allograft vasculopathy, and provide prognostic information (Level of Evidence: B)
3. IVUS is a reasonable option to determine the mechanism of stent restenosis (Level of Evidence: C)

CLASS IIb:
1. IVUS may be reasonable in assessing non–left main coronary arteries possessing angiographically intermediate coronary stenoses (i.e., 50% to 70% diameter stenosis) (Level of Evidence: B)
2. IVUS may be considered for the guidance of coronary stent implantation, especially in cases of left main coronary artery (LMCA) stenting (Level of Evidence: B)
3. IVUS may be reasonable for the determination of the mechanism of stent thrombosis (Level of Evidence: C)

CLASS III:
1. IVUS for routine lesion assessment is not a recommendation if revascularization with PCI or CABG is not being contemplated (Level of Evidence: C)
**IVUS** defines a threshold for a significant stenosis to determine the need for catheter-based or surgical intervention

- MLA less than 4 mm$^2$ for most coronary vessels
- MLA less than 6 mm$^2$ for left main (Litro study)

**IVUS** provides accurate lumen CSA measurements to guide stent therapy

Overall good sensitivity but poor specificity & Variable data on optimal cut-point = Cut off should not be use as sole criterion to justify deferring a procedure. FFR guidance for ischemia is recommended
Lesions are classified into 5 main types:

1. Fibrotic
2. Fibrocalcific
3. Pathological intimal thickening (PIT)
4. Thick cap fibroatheroma (ThCFA)
5. VH-thin cap fibroatheroma (VH-TCFA) (presumed high risk)

PROSPECT: Methodology

Virtual histology lesion classification

Lesions are classified into 5 main types
Necrotic Tissue Identification: VHS

**Automatic borders** determine lumen and vessel boundaries

**Automatic measurements** determine lesion MLA, length and plaque burden

VH™ IVUS tissue characterization automatically identifies fibrous, fibro-fatty, dense calcium and necrotic core
Calcified Lesions

CLASS Ila

Rotational atherectomy is reasonable for fibrotic or heavily calcified lesions that might not be crossed by a balloon catheter or adequately dilated before stent implantation. (Level of Evidence: C)

VH-IVUS can identify fibrotic and heavily calcified lesions
IVUS: Low echogenic, Intraluminal, occasionally mobile, irregular border

Courtsey ACC Cath SAP, 2019 and Circulation 2001; 103: 604-16
Calcified lesions

IVUS

OCT
IVUS and Stenting Optimization
IVUS ensures full expansion, full apposition

IVUS confirms full expansion
- no “floating” struts
- drug delivery to the surrounding tissue
- ChromaFlo™ highlights blood motion
Figure 2. Example case for documentary (angiographically guided) stent implantation group: 3.0-mm stent was implanted to address critical narrowing in mid left circumflex artery. Despite acceptable angiographic appearance (A), IVUS demonstrates underdeployment, achieving MSA of only 5.61 mm$^2$ (B) compared with proximal reference segment of 10.40 mm$^2$ (C).
CRUISE: Can Routine Ultrasound Improve Stent Expansion

Target vessel revascularization (TVR) was lower in the IVUS-guided group vs the other two groups.

- QCA reference (mm)
  - IVUS-guided (N=270): 3.03
  - Documentary IVUS (N=229): 2.99

- Min stent CSA (mm²)
  - IVUS-guided (N=270): 7.89
  - Documentary IVUS (N=229): 7.06

- TVR (%)
  - IVUS-guided (N=270): 8.50
  - Documentary IVUS (N=229): 15.30

*Fitzgerald et al. Circulation 2000;102:523-530*
ULTIMATE

A Multicenter, Prospective, Randomized Trial Comparing Intravascular Ultrasound-guided versus Angiography-guided Implantation of Drug-Eluting Stent in All-comers

Jun-Jie Zhang, MD, PhD

Xiaofei Gao, Jing Kan, Zhen Ge, Leng Han, Shu Lu, Nailiang Tian, Song Lin, Qinghua Lu, Xueming Wu, Qihua Li, Zhizhong Liu, Yan Chen, Xuesong Qian, Juan Wang, Dayang Chai, Chonghao Chen, Xiaolong Li, Bill D. Gogas, Tao Pan, Shoujie Shan, Fei Ye, Shao-Liang Chen

NCT02215915
Study Design

1448 all-comer patients

1:1 Randomization

IVUS guidance (n=724)

Angiography guidance (n=724)

Primary endpoint: TVF at 12 months
Major Inclusion Criteria

- Silent ischemia, Stable angina or unstable angina
- Acute myocardial infarction >24 h
- De novo lesion
IVUS-defined Criteria for The Optimal Stent Deployment

1. Minimal lumen CSA in stented segment $>5.0 \text{ mm}^2$, or 90% of distal reference lumen CSA;

2. Plaque burden at the 5-mm proximal or distal to the stent edge $<50$%;

3. no edge dissection involving media with length $>3$mm.
### Baseline Clinical Data

<table>
<thead>
<tr>
<th></th>
<th>IVUS guidance (n=724)</th>
<th>Angiography guidance (n=724)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>65.2 ± 10.9</td>
<td>65.9 ± 9.8</td>
<td>0.19</td>
</tr>
<tr>
<td>Male</td>
<td>73.9%</td>
<td>73.2%</td>
<td>0.77</td>
</tr>
<tr>
<td>Hypertension</td>
<td>70.7%</td>
<td>72.0%</td>
<td>0.60</td>
</tr>
<tr>
<td>Diabetes</td>
<td>30.0%</td>
<td>31.2%</td>
<td>0.61</td>
</tr>
<tr>
<td>Current smoker</td>
<td>34.9%</td>
<td>31.5%</td>
<td>0.16</td>
</tr>
<tr>
<td>UAP</td>
<td>67.4%</td>
<td>64.4%</td>
<td>0.22</td>
</tr>
<tr>
<td>AMI</td>
<td>11.2%</td>
<td>14.0%</td>
<td>0.11</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>60.9 ± 7.9</td>
<td>60.3 ± 9.3</td>
<td>0.19</td>
</tr>
</tbody>
</table>
## Core Lab Lesions Data (I)

<table>
<thead>
<tr>
<th>Lesion Location</th>
<th>IVUS guidance (n=962)</th>
<th>Angiography guidance (n=1016)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM</td>
<td>9.9%</td>
<td>8.6%</td>
<td>0.51</td>
</tr>
<tr>
<td>LAD</td>
<td>47.5%</td>
<td>46.7%</td>
<td></td>
</tr>
<tr>
<td>LCX</td>
<td>17.3%</td>
<td>16.8%</td>
<td></td>
</tr>
<tr>
<td>RCA</td>
<td>25.4%</td>
<td>28.0%</td>
<td></td>
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## Core Lab Lesions Data (II)

<table>
<thead>
<tr>
<th>Lesion Type</th>
<th>IVUS guidance (n=962)</th>
<th>Angiography guidance (n=1016)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-vessel disease</td>
<td>52.6%</td>
<td>57.2%</td>
<td>0.08</td>
</tr>
<tr>
<td>B2/C</td>
<td>66.1%</td>
<td>67.7%</td>
<td>0.45</td>
</tr>
<tr>
<td>Bifurcation</td>
<td>23.5%</td>
<td>26.5%</td>
<td>0.13</td>
</tr>
<tr>
<td>CTO</td>
<td>8.8%</td>
<td>9.0%</td>
<td>0.93</td>
</tr>
<tr>
<td>Moderate to severe calcification</td>
<td>25.3%</td>
<td>24.2%</td>
<td>0.59</td>
</tr>
</tbody>
</table>
## Procedural Data (I)

<table>
<thead>
<tr>
<th></th>
<th>IVUS guidance (n=724)</th>
<th>Angiography guidance (n=724)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Per patient, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stent number</td>
<td>2.40±1.55</td>
<td>2.47±1.56</td>
<td>0.39</td>
</tr>
<tr>
<td>Mean stent length, mm</td>
<td>66.42±46.17</td>
<td>66.49±44.36</td>
<td>0.98</td>
</tr>
<tr>
<td>Mean stent diameter, mm</td>
<td>3.15±0.42</td>
<td>2.99±0.38</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Max balloon diameter, mm</td>
<td>3.84±0.52</td>
<td>3.62±0.51</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Max Post-dilation pressure, atm</td>
<td>19.8±3.7</td>
<td>19.2±3.6</td>
<td>0.003</td>
</tr>
</tbody>
</table>
## Procedural Data (II)

<table>
<thead>
<tr>
<th>Per lesion, n (%)</th>
<th>IVUS guidance (n=962)</th>
<th>Angiography guidance (n=1016)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stent number</td>
<td>1.81±0.80</td>
<td>1.76±0.77</td>
<td>0.16</td>
</tr>
<tr>
<td>Mean stent length, mm</td>
<td>49.99±25.10</td>
<td>47.38±22.42</td>
<td>0.02</td>
</tr>
<tr>
<td>Mean stent diameter, mm</td>
<td>3.14±0.51</td>
<td>2.97±0.48</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Max balloon diameter, mm</td>
<td>3.73±0.56</td>
<td>3.51±0.53</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Max post-dilation pressure, atm</td>
<td>19.7±3.7</td>
<td>19.0±3.7</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
## Procedural Data (III)

<table>
<thead>
<tr>
<th></th>
<th>IVUS guidance (n=724)</th>
<th>Angiography guidance (n=724)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial access</td>
<td>94.8</td>
<td>96.8</td>
<td>0.07</td>
</tr>
<tr>
<td>2nd generation DES</td>
<td>99.2%</td>
<td>98.8%</td>
<td>0.44</td>
</tr>
<tr>
<td>Post-dilation</td>
<td>96.6%</td>
<td>94.9%</td>
<td>0.11</td>
</tr>
<tr>
<td>Procedural time, min</td>
<td>60.88</td>
<td>45.49</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Contrast volume, ml</td>
<td>178.29</td>
<td>161.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CIN</td>
<td>7.9%</td>
<td>5.8%</td>
<td>0.12</td>
</tr>
<tr>
<td>Complete revas.</td>
<td>73.3%</td>
<td>75.0%</td>
<td>0.47</td>
</tr>
<tr>
<td>Angiographic success</td>
<td>98.0%</td>
<td>97.8%</td>
<td>0.77</td>
</tr>
</tbody>
</table>
## Clinical Outcomes

<table>
<thead>
<tr>
<th></th>
<th>IVUS guidance (n = 724)</th>
<th>Angiography guidance (n = 724)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary endpoint at 30-day</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVF</td>
<td>0.8%</td>
<td>1.9%</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Primary endpoint at 12-month</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVF</td>
<td>2.9%</td>
<td>5.4%</td>
<td>0.019</td>
</tr>
<tr>
<td>Cardiac death</td>
<td>0.7%</td>
<td>1.4%</td>
<td>0.19</td>
</tr>
<tr>
<td>TVMI</td>
<td>1.0%</td>
<td>1.5%</td>
<td>0.34</td>
</tr>
<tr>
<td>Clinically-driven TVR</td>
<td>1.5%</td>
<td>2.9%</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Safety endpoint at 12-month</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definite/probable ST</td>
<td>0.1%</td>
<td>0.7%</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Primary Endpoint
TVF at 12 months

Hazard ratio: 0.530 (95% CI: 0.312, 0.901)
Log-Rank: $P = 0.019$

Cumulative Proportion of TVF (%)

Time (months)

Number at risk
Angiography 724 706 698 685 676
IVUS 724 715 710 704 696

Cardiovascular Research Foundation
TCT2018
Secondary Endpoint
CD-TLR or Definite ST at 12 months

From Lesion-level

Hazard ratio: 0.407 (95% CI: 0.188, 0.880)
Log-Rank: \( P = 0.018 \)

Cumulative Proportion (%)

Time (months)

Number at risk
Angiography 1016 1003 995 979 969
IVUS 962 957 953 946 938
ULTIMATE

Optimal vs. Suboptimal IVUS-guided PCI

TVF at 12 months

Hazard ratio: 0.349 (95% CI: 0.135-0.898)
Log-Rank: \( p = 0.029 \)

Cumulative Proportion of TVF (%)

<table>
<thead>
<tr>
<th>Time (months)</th>
<th>Suboptimal PCI</th>
<th>Optimal PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>0.3</td>
</tr>
<tr>
<td>6</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>9</td>
<td>3.0</td>
<td>8.0</td>
</tr>
<tr>
<td>12</td>
<td>4.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Number at risk:
- Suboptimal: 340, 334, 329, 326, 320
- Optimal: 384, 381, 381, 378, 376

Cardiovascular Research Foundation

tct2018
## On-line IVUS assessment

<table>
<thead>
<tr>
<th></th>
<th>Optimal group</th>
<th>Suboptimal group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients, n (%)</td>
<td>384 (53.0)</td>
<td>340 (47.0)</td>
<td></td>
</tr>
<tr>
<td>Number of lesions, n (%)</td>
<td>578 (60.1)</td>
<td>384 (39.9)</td>
<td></td>
</tr>
<tr>
<td>MSA, mm²</td>
<td>6.09</td>
<td>5.45</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prox. edge plaque burden</td>
<td>37.2%</td>
<td>51.2%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dist. edge plaque burden</td>
<td>24.2%</td>
<td>35.1%</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Conclusion

In the present multicenter randomized trial, IVUS-guided DES implantation in all-comers resulted in lower incidence of TVF at 12 months, compared with angiography guidance, particularly for patients who had an IVUS-defined optimal procedure.
ADAPT DES

8,575 pts prospectively enrolled
No clinical or anatomic exclusion criteria
Successful and uncomplicated PCI with ≥1 DES

Pre-Specified IVUS vs. No IVUS Substudy

IVUS: 3349 pts
No IVUS: 5234 pts

Clinical F/U at 30 days, 1 year, 2 years
How IVUS Changed The Procedure

IVUS used pre PCI in 7%
IVUS pre and post PCI in 63%

PCI strategy modified in 74% of all IVUS guided pts

- Larger stent or balloon: 38
- Higher inflation pressure: 23
- Longer stent: 22
- Additional post-dil: 13
- Additional stent: 8

Circulation 2014; 129:463-70
Clinical Outcomes

Confidence 36
Confidential. For internal training purposes only. Do not distribute.

Circulation 2014; 129:463-70

Graphs showing clinical outcomes with Kaplan-Meier curves for definite or probable ST (ST %) and MACE (%). HR: 0.53 [95% CI: 0.31, 0.90], P = 0.02. HR: 0.67 [95% CI: 0.51, 0.87], P = 0.002.
IVUS-XPL TRIAL

1400 pts with “long” (≥28 mm) lesions randomly assigned to IVUS vs Angio guidance. 1º outcome: MACE

<table>
<thead>
<tr>
<th>Event</th>
<th>IVUS</th>
<th>Angio</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACE</td>
<td>2.9%</td>
<td>5.8%</td>
<td>0.48 (0.28 – 0.83)</td>
</tr>
<tr>
<td>Cardiac Death</td>
<td>0.4%</td>
<td>0.7%</td>
<td>0.60 (0.14 – 2.52)</td>
</tr>
<tr>
<td>Target lesion related MI</td>
<td>0%</td>
<td>0.1%</td>
<td>N/A</td>
</tr>
<tr>
<td>TLR</td>
<td>2.5%</td>
<td>5.0%</td>
<td>0.51 (0.28 – 0.91)</td>
</tr>
<tr>
<td>Stent Thrombosis</td>
<td>0.3%</td>
<td>0.3%</td>
<td>1.0 (0.14 – 7.1)</td>
</tr>
</tbody>
</table>

Hong SJ et al. JAMA 2015: 314:2155-2163
Underexpansion vs Malapposition
Stent Expansion

Maximal Stent Expansion: \((\pi \times r^2)\)

- 3.5 mm stent: 100% expansion = 9.6 mm²
- 3.0 mm stent: 100% expansion = 7.1 mm²
- 2.75 mm stent: 100% expansion = 5.9 mm²
- 2.5 mm stent: 100% expansion = 4.9 mm²
when performing IVUS guided PCI, costs as well as benefits increase. The increased benefits measured as cost savings resulting from less restenosis outweigh the cost increase from performing the IVUS guided PCI as opposed to CAG guided PCI.”

Gaster et al. Scan Cardiovasc J 2001;35:80-5
IVUS and Plaque Morphology
The PROSPECT Trial

700 pts with ACS
UA (with ECGΔ) or NSTEMI or STEMI >24º
undergoing PCI of 1 or 2 major coronary arteries
at up to 40 sites in the U.S. and Europe

Metabolic S.
• Waist circum
• Fast lipids
• Fast glu
• HgbA1C
• Fast insulin
• Creatinine

PCI of culprit lesion(s)
Successful and uncomplicated

Formally enrolled

Biomarkers
• Hs CRP
• IL-6
• sCD40L
• MPO
• TNFα
• MMP9
• Lp-PLA2
• others

PI: Gregg W. Stone
Sponsor: Abbott Vascular; Partner: Volcano
## PROSPECT: Primary Endpoint

### MACE attributable to rapid angiographic progression of a non-culprit lesion*

- Cardiac death
- Cardiac arrest
- Myocardial infarction
- Unstable angina
  - Requiring revascularization
  - Requiring rehospitalization
- Increasing angina
  - Requiring revascularization
  - Requiring rehospitalization

MACE during FU were adjudicated by the CEC as attributable to culprit lesions (those treated during or before the index hospitalization) or non culprit lesions (untreated areas of the coronary tree) based on angiography (+ECGs, etc.) at the time of the event; events occurring in pts without angiographic follow-up were considered indeterminate in origin. Rapid lesion progression = ↑ in QCA DS by >20% from baseline to FU.
PROSPECT 82910-012: 52 yo ♂

2/13/06: NSTEMI, PCI of MLAD
2/6/07 (51 weeks later): NSTEMI attributed to LCX

Index 2/13/06

Event 2/6/07

QCA PLCX DS 28.6%

QCA PLCX DS 71.3%
PROSPECT: MACE

<table>
<thead>
<tr>
<th></th>
<th>Time in Years</th>
<th>All</th>
<th>Culprit lesion (CL) related</th>
<th>Non culprit lesion (NCL) related</th>
<th>Indeterminate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>697</td>
<td>697</td>
<td>697</td>
<td>697</td>
</tr>
<tr>
<td>Number at risk</td>
<td>1</td>
<td>557</td>
<td>590</td>
<td>543</td>
<td>534</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>506</td>
<td>543</td>
<td>553</td>
<td>553</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>480</td>
<td>518</td>
<td>521</td>
<td>583</td>
</tr>
</tbody>
</table>

MACE (%) at Each Time Point:
- ALL: 0% (0 years), 13.2% (1 year), 18.1% (2 years), 20.4% (3 years)
- Culprit lesion (CL) related: 0% (0 years), 7.9% (1 year), 11.4% (2 years), 12.9% (3 years)
- Non culprit lesion (NCL) related: 0% (0 years), 6.4% (1 year), 9.4% (2 years), 11.6% (3 years)
- Indeterminate: 0% (0 years), 0.9% (1 year), 1.9% (2 years), 2.7% (3 years)
**PROSPECT: Multivariable Correlates of Non Culprit Lesion Related Events**

Independent predictors of lesion level events by logistic regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR [95% CI]</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{PB}_{\text{MLA}} \geq 70%)</td>
<td>4.99 [2.54, 9.79]</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>VH-TCFA</td>
<td>3.00 [1.68, 5.37]</td>
<td>0.0002</td>
</tr>
<tr>
<td>MLA ≤4.0 mm(^2)</td>
<td>2.77 [1.32, 5.81]</td>
<td>0.007</td>
</tr>
<tr>
<td>Lesion length ≥11.6 mm</td>
<td>1.97 [0.94, 4.16]</td>
<td>0.07</td>
</tr>
<tr>
<td>(\text{EEM}_{\text{MLA}} &lt; 14.3 \text{ mm}^2)</td>
<td>1.30 [0.62, 2.75]</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Variables entered into the model: Minimal luminal area (MLA); plaque burden at the MLA (\(\text{PB}_{\text{MLA}}\)); external elastic membrane at the MLA (\(\text{EEM}_{\text{MLA}}\)) <median; lesion length ≥ median (mm); VH-TCFA.
PROSPECT: VH-TCFA and Non Culprit Lesion Related Events

Lesion HR

<table>
<thead>
<tr>
<th>Lesion</th>
<th>HR</th>
<th>CI</th>
<th>P value</th>
<th>Prevalence*</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCFA</td>
<td>3.84</td>
<td>(2.22, 6.65)</td>
<td>&lt;0.0001</td>
<td>51.2%</td>
</tr>
<tr>
<td>TCFA + MLA ≤4.0mm²</td>
<td>6.41</td>
<td>(3.35, 12.24)</td>
<td>&lt;0.0001</td>
<td>17.4%</td>
</tr>
<tr>
<td>TCFA + PB ≥70%</td>
<td>10.77</td>
<td>(5.53, 21.00)</td>
<td>&lt;0.0001</td>
<td>11.0%</td>
</tr>
<tr>
<td>TCFA + PB ≥70% + MLA ≤4mm²</td>
<td>10.81</td>
<td>(4.30, 27.22)</td>
<td>&lt;0.0001</td>
<td>4.6%</td>
</tr>
</tbody>
</table>

*Likelihood of one or more such lesions being present per patient. PB = plaque burden at the MLA
Summary

Intracoronary Imaging – Applications

- Pre-PCI
  - Lumen geometry
  - Plaque composition
  - Stent sizing
  - Stent positioning

- Post-PCI
  - Stent fracture
  - Acute malapposition
  - Acute malexpansion
  - Lumen geometry (dissection)

- Late F/U
  - Endothelial healing and strut coverage
  - Late stent malapposition
  - Stent fracture
  - Neoatherosclerosis
  - In-stent restenosis
  - Stent thrombosis
IVUS in peripheral interventions
NHLBI Dissection Classification

A. Minor radiolucent areas
B. Linear dissection
C. Contrast outside the lumen
D. Spiral dissection
E. Persistent filling defects
F. Total occlusion w/o distal antegrade flow

Angio Images adjudicated by core laboratory
Dissections Impact Clinical Outcomes After POBA

Hazard ratio for restenosis vs Dissection Severity (NHLBI)²

<table>
<thead>
<tr>
<th></th>
<th>HR</th>
<th>[95% CI]</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1.58</td>
<td>[0.79, 3.16]</td>
<td>0.193</td>
</tr>
<tr>
<td>A</td>
<td>1.00</td>
<td>(Ref)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1.81</td>
<td>[0.88, 3.73]</td>
<td>0.108</td>
</tr>
<tr>
<td>C</td>
<td>4.45</td>
<td>[1.22, 16.2]</td>
<td>0.024</td>
</tr>
<tr>
<td>D</td>
<td>6.37</td>
<td>[2.99, 13.6]</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>E</td>
<td>22.9</td>
<td>[7.33, 71.6]</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>F</td>
<td>297</td>
<td>[34.9, 2527]</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

1Fujihara, J Endovasc Ther 2017
2National Heart, Lung, and Blood Institute PTCA Registry 1985
Primary Patency After POBA of SFA

Fujihara et al. J Endovasc Ther 2017
NHLBI Dissections: No dissections seen

IVUS Dissections (iDissection classification): 5 dissections noted
The iDissection Grading System

Depth of dissection

• A: Intima
• B: Media
• C: Adventitia

Extent (circumference) of dissection:

1: arc of injury < 180°
2: arc of injury ≥ 180°
### Number of Dissections

<table>
<thead>
<tr>
<th></th>
<th>Post-Atherectomy</th>
<th>Post-Adjunctive PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVUS</td>
<td>46</td>
<td>39</td>
</tr>
<tr>
<td>Angiography</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>

**Ratio:**
- Post-Atherectomy: 5.75/1
- Post-Adjunctive PTA: 3.55/1

4 to 6 times more dissections are identified with IVUS over angiography post-intervention.
### Severity of Dissections

<table>
<thead>
<tr>
<th></th>
<th>Post-Atherectomy</th>
<th>Post-Adjunctive PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IVUS</td>
<td>Angiography</td>
</tr>
<tr>
<td>A1 – C1</td>
<td>40</td>
<td>6 (13%)</td>
</tr>
<tr>
<td>A2 – C2</td>
<td>6 (13%)</td>
<td>7</td>
</tr>
<tr>
<td>A – C</td>
<td>7</td>
<td>1 (12%)</td>
</tr>
<tr>
<td>D – F</td>
<td>1 (12%)</td>
<td></td>
</tr>
</tbody>
</table>

Wider dissections are frequently present post-atherectomy. The total number of dissections appear less after adjunctive PTA, wider dissections are more frequent at least numerically.

Shammas, J Invasive Cardiol 2018
Baseline / Severely Calcified Right Common Femoral Artery / Post laser /DCB / Final Results

Courtesy Nicolas W Shammas, MD
Optimal Vessel Sizing and Understanding Dissections in Infrapopliteal Interventions: Data From the iDissection Below the Knee Study

Nicolas W. Shammas, MD, MS¹, W. John Shammas, MBA¹, Susan Jones-Miller, MS¹, James T. Torey, PA-C², Ehrin J. Armstrong, MD³, Qais Radaideh, MD, MS¹, and Gail A. Shammas, BS, RN¹

Conclusion: In addition to underestimating the infrapopliteal vessel diameter by $-25\%$, angiography underappreciated the presence and severity of post-intervention dissections vs IVUS, particularly in the OA+PTA group.
Take Home Points

1. IVUS reduces MACE events in the coronaries when used routinely
2. Technique is important
3. Interpreting images correctly is critical and improves with experience
4. Plaque morphology can identify vulnerable plaques. Although routine treatment of non-culprit vulnerable plaques has not been yet validated, it may trigger an intensification of preventative therapy
5. Emerging applications in the periphery include vessel sizing, and dissection severity in both IP and Fempop segments
Thank You!!!