IVUS and PCI: Pre-intervention Lesion Assessment

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Most of the concepts used in IVUS-guided intervention are no different from those used in angiography-guided intervention. However, unlike angiography, IVUS is actually able to make precise measurements and assess lesion morphology.

- Weigh potential problems (i.e. LM disease, significant proximal or distal disease)
- Assess lesion severity
- Assess unusual lesion morphology (i.e., aneurysms, calcium, thrombi, in-stent restenosis, etc.)
- Measure vessel size
- Measure lesion length
- Determine and fine-tune the final result of interventions
- Assess complications
Assessment of Lesion Severity
Validation of IVUS Assessment of Ischemia Producing Stenosis (Doppler FloWire and SPECT)

<table>
<thead>
<tr>
<th></th>
<th>IVUS MLA ≥ 4.0mm²</th>
<th>IVUS MLA &lt;4.0mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFR &lt; 2.0</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>CFR ≥ 2.0</td>
<td>39</td>
<td>4</td>
</tr>
</tbody>
</table>

*Diagnostic accuracy = 92%. Abizaid et al, AJC 1998;82:42-8*

<table>
<thead>
<tr>
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<th>IVUS MLA ≥ 4.0mm²</th>
<th>IVUS MLA &lt;4.0mm²</th>
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</thead>
<tbody>
<tr>
<td>+ Spect</td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td>- Spect</td>
<td>20</td>
<td>1</td>
</tr>
</tbody>
</table>

*Diagnostic accuracy = 93%. Nishioka et al, JACC 1999;33:1870-8*
Validation of IVUS Assessment of Ischemia Producing Stenosis (Pressure Wire)

Comparison of IVUS and pressure wire (measurement of fractional flow reserve: $\text{FFR}_{\text{myo}}$)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS &gt;70%</td>
<td>100%</td>
<td>68%</td>
</tr>
<tr>
<td>MLD &lt;1.8mm</td>
<td>100%</td>
<td>66%</td>
</tr>
<tr>
<td>MLA &lt;4.0mm²</td>
<td>82%</td>
<td>56%</td>
</tr>
<tr>
<td>Length &gt;10mm</td>
<td>41%</td>
<td>80%</td>
</tr>
</tbody>
</table>

$T_{\text{akagi, et al.}}$ *Circulation* 1999;100:250-5

IVUS Criteria for a ‘Significant’ Stenosis

• Based on the studies comparing IVUS to flow wire, pressure wire, or SPECT thallium and based on studies with clinical outcome - most feel that a lumen area less than 4.0 mm$^2$ in a proximal epicardial artery excluding the Left Main (and SVGs) is a flow limiting stenosis
Clinical Follow up in 357 intermediate lesions in 300 pts deferred intervention after IVUS imaging

- Death/MI/TLR @ (mean) 13 mos = 8% overall (2% death/MI and 6% TLR)
- Death/MI/TLR @ (mean) 13 mos = 4.4% in lesions with MLA >4.0mm²
- Only independent predictor of death/MI/TLR was IVUS MLA (p=0.0041)
- Independent predictors of TLR were DM (p=0.0493) and IVUS MLA (p=0.0042)

Event-Free Survival Curve of Patients with Intermediate Lesions and Deferred Procedures

Event-free survival (%)

- MLA >4.0 mm²
  - 92.0%
- FFR >0.75
  - 89.0%

On pre-intervention IVUS, 404 pts with 436 arteries had 500 lesions with an IVUS minimum lumen area <4.0mm². 28% (140/500) had an angiographic DS<50%. Predictors of these lesions were

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Odds Ratio</th>
<th>p</th>
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<tbody>
<tr>
<td>Multiple lesions in same artery</td>
<td>2.7</td>
<td>0.0003</td>
</tr>
<tr>
<td>Right coronary artery</td>
<td>1.7</td>
<td>0.03</td>
</tr>
<tr>
<td>Lesion maximum lumen diameter</td>
<td>9.5/1mm</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lesion plaque burden</td>
<td>0.44/10%</td>
<td>0.0001</td>
</tr>
<tr>
<td>Mean reference lumen area</td>
<td>0.75 /1mm²</td>
<td>0.0002</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1.6</td>
<td>0.1</td>
</tr>
</tbody>
</table>

*(Maehara et al. Am J Cardiol 2003;91:1335-8)*
Association of positive remodeling and ACS

Schoenhagen et al. Circulation 2000;101:598-603

Of all the coronary segments, the LMCA has the greatest angiographic assessment variability.

Poor interobserver agreement in the CASS study - I

Comparison between percent stenosis assessment from the quality control lab vs the clinical site

*area of the square is proportional to the number of cases with the given reading

(Fisher et al. CCD 1982;8:565-575)
Poor interobserver agreement in the angiographic assessment of LMCA stenosis in the CASS study - II

Five grades of LM severity
1: 0-24% DS
2: 25-49% DS
3: 50-74% DS
4: 75-89% DS
5: 90-100% DS

# of grades of difference in assessment of LM severity
0: no difference
+1 or -1: 1 grade difference
+2 or -2: 2 grades of difference
+3 or -3: 3 grades of difference
+4 or -4: 4 grades of difference

(Cameron et al. Circulation 1983;68:484-489)
IVUS determinants of LMCA FFR <0.75

(Jasti et al. Circulation 2004;110:2831-6)
Follow-up of 122 pts with moderate LM disease

Independent predictors of MACE @11.7 months: DM (P=0.004), an untreated lesion >50% (p=0.037), and IVUS MLD (P=0.005).

(Abizaid AS et al. JACC 1999;34:707-15)
IVUS Criteria for a ‘Significant’ LMCA Stenosis

• Most IVUS LMCA studies show either insignificant disease or critical disease, only a minority require careful quantification

• Based on studies comparing IVUS to LMCA pressure wire and based on Murray’s Law* - most feel that an LMCA lumen area less than 6.0 mm² (or an MLD <2.9mm) is flow limiting

*Murray’s Law: \((r_{\text{parent vessel}})^3 = \sum (r_{\text{daughter vessel}})^3\)
Unusual Lesions

- Aneurysms
- Filling Defects
- Acute Coronary Syndromes
- Spontaneous Dissections
- Hazy Lesions
IVUS Classification of Angiographic Aneurysms

Of 77 angiographic aneurysms
- 21 (27%) true aneurysm
- 3 (4%) pseudoaneurysm
- 12 (16%) complex plaques or unhealed dissections
- 41 (53%) normal segment adjacent to one or more stenoses

(Maehara et al Am J Cardiol 2001;88:365-70)
Three Vessel IVUS Imaging in 24 Pts with ACS and Positive Tn

- 50 ruptured plaques
  - 9 culprit lesion
  - 41 nonculprit lesion
- 19 pts had at least 1 nonculprit plaque rupture (79%)
  - 17 pts had 1 plaque rupture in a second artery
  - 3 pts had plaque ruptures in all 3 arteries

(Rioufol et al Circulation 2002;106:804-808)
Ruptured plaques in patients with MI and stable angina

% of patients

- In MI, the only independent predictor of plaque rupture was elevated CRP (p=0.035, OR=2.139).
- In stable angina, the only independent predictor was diabetes mellitus (p=0.034, OR=2.553).

Number of ruptured plaques per patient

(Hong et al Circulation 2004;110:928-33)
IVUS vs QCA measurements of reference lumen dimensions (3311 nonostial lesions)
In 884 native coronary arteries, plaque burden in angiographically “normal” reference segments was 51 ± 13%.

(Mintz et al. J Am Coll Cardiol 1995;25:1479-1485)
IVUS vs QCA measurement of lesion length

IVUS length (mm)

QCA length (mm)

IVUS-QCA length = 0.6 ± 7.2 mm

r = 0.583
Stent sizing using IVUS

Proximal

Lesion

Distal

Max LD = 3.5 mm

Max LD = 3.3 mm

6mm

5.5mm
Fate of intermediate in-stent restenosis lesions

- 142 patients with 150 intermediate ISR lesions (angiographic diameter stenosis of 40-75%)
  - 34% of lesions had a diameter stenosis >50%
  - 17% of patients had a positive exercise thallium
- Repeat intervention was deferred if the IVUS minimum lumen area measured >3.5mm² regardless of symptoms, noninvasive testing, or angiographic findings
- At follow-up that averaged 32 months
  - 10% of patients had events
  - 2-year event-free survival was 96.5%.

(Nishioka et al AHA 2002)
The intimal hyperplasia characteristic of early in-stent restenosis often appears as tissue with very low echogenicity, at times less echogenic than the blood speckle in the lumen. The intimal hyperplasia of late in-stent restenosis may appear more echogenic. Appropriate system settings are critical to avoid suppressing this relative non-echogenic material.
Unexpanded stent in vein graft