IVUS

- Basics
- Plaque morphology. Interpretation
- Measurements
- Complications
- IVUS as a tool in Cathlab
- Spanish IVUS survey
Basics

- First of all, if you don’t believe that bigger is better, you can leave right now, because any attempt to use IVUS or to learn how to perform procedure from IVUS usage but without IVUS tries to maximize the final result.

- Any attempt to maximize the final result will lead to more vessel trauma. If you think (but only you, not the evidence so far gained!) that vessel wall trauma is more important than final MLD, everything will follow it will be of limited utility.
Instead of learning how to perform procedures without IVUS it may be better to find where IVUS usage is important and advantageous and where of limited value.
Basics - Examples

1. If you plan to use a 4 mm balloon and your friend tells you that a 3.5 mm balloon is more appropriate or vice versa, IVUS may be useful;

2. If you are treating proximal LAD or proximal dominant RCA and you plan to use 2.5 or 3 mm balloon IVUS may be useful;

3. If you are treating long lesions or diffuse disease (requiring stents longer than 30 mm) IVUS may be useful;

4. If you are treating diffuse in-stent restenosis IVUS may be useful;
Basics - Examples

Other less conventional situations in which IVUS may be useful:

1. If your case volume goes down and you want to treat more lesions IVUS may be useful;

2. If you want to find a very good excuse to skip an appointment IVUS may be useful;
Basics
How IVUS image is produced?

High frequency sound waves echo off vessel walls and are sent back to system.

System electronics process the signal.

Sending, receiving, processing sound waves to create a cross-sectional picture of an artery.
Angio limitations

Focal Disease
50% Stenosis

Difuse Disease
50% Stenosis
Angio limitations
Angio limitations

Post Balloon area
Why?
Silent Coronary Disease

Area stenosis in “normal arteries “ is $51 \pm 13\%$

Why?
Remodeling
Angiography Cannot Identify Coronary Remodeling
“Negative” Remodeling

The artery is smaller at the lesion site than it is distally, like a scar that constricts the lumen.

Vessel MLD: 2.5 mm
Vessel CSA: 6.0 mm²

Vessel MLD: 3.0 mm
Vessel CSA: 7.3 mm²

Vessel MLD: 3.1 mm
Vessel CSA: 8.1 mm²
Plaque morphology
Compensatory Dilatation As Atherosclerosis Progresses
Plaque types
Plaque types

Vulnerable

Soft

Fibrous
Plaque types

Calcified

Mixte
IVUS identifies calcium, but not its depth

Methylmethacrylate Stain
Calcium and coronary stents

calcium after PTCA  coronary stent struts
Ulcerated plaque
Measurements
Intravascular Ultrasound Structures and Measurements

- ECHOLUCENT LAYER (MEDIA)
- INNER ECHOGENIC LAYER (INTIMA)
- OUTER ECHOGENIC LAYER (ADVENTITIA)
- Vessel Diameter
- Lumen Diameter
Basic Measurements

- Size
- Length
- Plaque type
Basic Measurements

Diameters
Basic Measurements

Area
Basic Measures

Vessel area
EEM CSA

Stent area

Lumen area
Lumen CSA

Neointimal area
Complications

- PCI.
- Extend of coronary disease
- Lack of experience

Operator Experience

No complications

IVUS as a tool in Cathlab
Intermediate Lesions
Left Main Disease

- Comparing IVUS to LMCA pressure wire (and supported by Murray’s Law*) - most feel that an LMCA lumen area less than 6.0 mm$^2$ (or an MLD <2.9mm) is flow limiting

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

*Mintz, Weisman. IVUS: When and how use it. www.tctcmd.com
Intermediate Lesions

<table>
<thead>
<tr>
<th>Lesion Description</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>

Briguori, et al. AJC 2001;87:136-41
Intermediate Lesions

- Minimal Lumen area < 4mm² in epicardial artery vessels
  - Ischemia (SPECT)
  - Decreased Flow reserve
  - Death, AMI and associated revascularization
POBA PCI
<table>
<thead>
<tr>
<th></th>
<th>POBA Conventional</th>
<th>POBA Guided</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balloon/Artery</td>
<td>1.12 ± 0.15</td>
<td>1.3 ± 0.17</td>
<td>0.0001</td>
</tr>
<tr>
<td>Minimal Lumen Diameter</td>
<td>1.95 ± 0.49</td>
<td>2.21 ± 0.47</td>
<td>0.0001</td>
</tr>
<tr>
<td>% Stenosis</td>
<td>28 ± 15</td>
<td>18 ± 14</td>
<td>0.0001</td>
</tr>
<tr>
<td>Minimal Lumen Area</td>
<td>3.16 ± 1.04</td>
<td>4.52 ± 1.14</td>
<td>0.0001</td>
</tr>
<tr>
<td>Dissections</td>
<td>37%</td>
<td>40%</td>
<td>ns</td>
</tr>
</tbody>
</table>

*Stone. Circulation* 1997; 95:2044
PICTURE: % Restenosis

Peters y col. Circulation 1997; 95:2254
GUIDE II:
Predictive factors of restenosis post POBA.

- Minimal Lumen Diameter > 1.96
- Plaque Area < 64.2 %

CRUISE: 9 month % TVR

AVID
12 month %TVR

Russo et al. Circulation 1999; 100:234 © 2010 Abbott Vascular. All rights reserved.
TULIP
6 month follow-up


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### IVUS Guided Stent Metanalysis: Restenosis

<table>
<thead>
<tr>
<th>Study</th>
<th>IVUS-guided</th>
<th>Angio-guided</th>
<th>Odds ratios and 95% CI fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIPS, 1996</td>
<td>48/166 (29%)</td>
<td>66/190 (34.7%)</td>
<td>0.76 (0.49–1.20)</td>
</tr>
<tr>
<td>RESIST, 1997</td>
<td>16/71 (22.5%)</td>
<td>21/73 (28.7%)</td>
<td>0.72 (0.34–1.53)</td>
</tr>
<tr>
<td>OPTICUS, 1998</td>
<td>56/229 (24.4%)</td>
<td>52/228 (22.8%)</td>
<td>1.10 (0.71–1.69)</td>
</tr>
<tr>
<td>TULIP, 2001</td>
<td>15/73 (20.5%)</td>
<td>28/77 (36.4%)</td>
<td>0.45 (0.22–0.94)</td>
</tr>
<tr>
<td>Subtotal</td>
<td>135/539 (25%)</td>
<td>167/568 (29%)</td>
<td>0.81 (0.62–1.06)</td>
</tr>
<tr>
<td>Registries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albiero et al., 1995</td>
<td>29/158 (18.3%)</td>
<td>40/154 (26%)</td>
<td>0.64 (0.37–1.10)</td>
</tr>
<tr>
<td>Blasini et al., 1995</td>
<td>22/105 (20.9%)</td>
<td>32/107 (29.9%)</td>
<td>0.62 (0.33–1.16)</td>
</tr>
<tr>
<td>Subtotal</td>
<td>51/263 (19%)</td>
<td>72/261 (27.5%)</td>
<td>0.63 (0.42–0.95)</td>
</tr>
<tr>
<td>Total</td>
<td>186/802 (23%)</td>
<td>239/829 (28.8%)</td>
<td>0.75 (0.60–0.94)</td>
</tr>
</tbody>
</table>

Chi-square heterogeneity: 0.36; 
$P = 0.01$

REVERSAL

% variation plaque volume at 18 month

p = 0.02

Plaque Volume

80 mg Atorvastatin  40 mg Pravastatin

Plaque regression study

Nissen et al. JAMA 2004; 291-1071
Just DES It!
Off-label DES use

54% of DES use was off-label SO
We should implant them in the best way (at least in high risk patients/lesions)

Evanston Hospital 2003-2004
Minimal stent area.

Intimal proliferation.

Stent Size.

Thrombosis.
Minimal Stent Area

- In BMS “bigger is better” was the rule
- In DES, underexpansion is still the most important cause of stent failure.
DES failure

Diabetes: 52%
Unstable angina: 22%
Ostial: 19%
MSA < 5mm²: 67%

Takebayashi Am J Cardiol 2005; 95:498
Neointima Distribution
Bigger is better but also

Longer is better !!!
(full lesion coverage)

CRUISE: 
Àrea mínima intra-stent y Reestenosis
< 5 mm²
> 9 mm²
Hayase J Am Coll Cardiol 1998;31:386
%TVR
MSA (mm²)
45%
9%

> 9 mm²
Bigger is better but also

Longer is better !!!
(full lesion coverage)

For every 10 mm stent, restenosis only increase 1.6% !!!
But

If we decide to implant longer stents, we must be sure that they are well implanted.
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Drug</th>
<th>Stent</th>
<th>N</th>
<th>FU</th>
<th>Thromb</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIM</td>
<td>Observ.</td>
<td>Sirolimus</td>
<td>BX Velocity</td>
<td>30</td>
<td>2 y</td>
<td>0.0%</td>
</tr>
<tr>
<td>RAVEL</td>
<td>Random.</td>
<td>Sirolimus</td>
<td>BX Velocity</td>
<td>120</td>
<td>12 m</td>
<td>0.0%</td>
</tr>
<tr>
<td>SIRIUS</td>
<td>Random.</td>
<td>Sirolimus</td>
<td>BX Velocity</td>
<td>533</td>
<td>12 m</td>
<td>0.4%</td>
</tr>
<tr>
<td>E-SIRIUS</td>
<td>Random.</td>
<td>Sirolimus</td>
<td>BX Velocity</td>
<td>175</td>
<td>9 m</td>
<td>1.1%</td>
</tr>
<tr>
<td>C-SIRIUS</td>
<td>Random.</td>
<td>Sirolimus</td>
<td>BX Velocity</td>
<td>50</td>
<td>12 m</td>
<td>2.0%</td>
</tr>
<tr>
<td>ASPECT</td>
<td>Random.</td>
<td>Paclitaxel</td>
<td>Supra-G</td>
<td>90</td>
<td>6 m</td>
<td>0.0%</td>
</tr>
<tr>
<td>ELUTES</td>
<td>Random.</td>
<td>Paclitaxel</td>
<td>V-Flex Plus</td>
<td>153</td>
<td>12 m</td>
<td>0.7%</td>
</tr>
<tr>
<td>TAXUS I</td>
<td>Random.</td>
<td>Paclitaxel</td>
<td>NIR</td>
<td>31</td>
<td>12 m</td>
<td>0.0%</td>
</tr>
<tr>
<td>TAXUS II</td>
<td>Random.</td>
<td>Paclitaxel</td>
<td>NIR</td>
<td>266</td>
<td>12 m</td>
<td>1.1%</td>
</tr>
<tr>
<td>TAXUS IV</td>
<td>Random.</td>
<td>Paclitaxel</td>
<td>Express</td>
<td>662</td>
<td>9 m</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

Patients receiving DES ➔ 2602 ➔ 0.61%
Subacute thrombosis: IVUS Cause identification

In 83% we identified lack of stent expansion

Who was thrombogenic: the stent or the doctor?

Serruys. Circulation
1995; 91: 1676
IVUS Predictors of Very Late (>12 months) DES Thrombosis

- Stent length
- Stent overlap

**MSA (mm²)**
- Very Late DES Thrombosis (n=13): 6.6
- Controls (n=175): 6.6
- **P=0.04**

**Expansion (%)**
- Very Late DES Thrombosis (n=13): 68
- Controls (n=175): 81
- **P<0.001**

**Stent malapposition @ time of VLST (%)**
- Very Late DES Thrombosis (n=13): 12
- Controls (n=175): 77
- **P<0.001**

*(Cook et al. Circulation 2007;115:2426-34) © 2010 Abbott Vascular. All rights reserved.*
Quantification of LSM in Patients with Very Late DES ST

- Maximum LSM (mm²)
  - 10 Very Late ST with LSM: 8.3
  - 21 Controls with LSM: 4
  - P = 0.03

- Maximum LSM length (mm)
  - 10 Very Late ST with LSM: 6.3
  - 21 Controls with LSM: 1.5
  - P < 0.001

- Maximum LSM depth (mm)
  - 10 Very Late ST with LSM: 1.8
  - 21 Controls with LSM: 0.8
  - P = 0.03

(Cook et al. Circulation 2007;115:2426-34)
IVUS Cases (1)
Spanish IVUS survey

Intracoronary Diagnostic Techniques

<table>
<thead>
<tr>
<th>Year</th>
<th>IVUS</th>
<th>Other</th>
<th>Pressure</th>
<th>Doppler</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>1312</td>
<td>110</td>
<td>35</td>
<td></td>
<td>2557</td>
</tr>
<tr>
<td>2005</td>
<td>1138</td>
<td></td>
<td></td>
<td></td>
<td>2871</td>
</tr>
<tr>
<td>2004</td>
<td>1350</td>
<td></td>
<td></td>
<td></td>
<td>2906</td>
</tr>
<tr>
<td>2003</td>
<td>1128</td>
<td></td>
<td></td>
<td></td>
<td>2143</td>
</tr>
</tbody>
</table>

Centros=63
Centros=65

REGISTRO 2.006
- **Before Intervention:**

  - Vesel Size.
  - Stenosis grade.
  - Plaque evaluation.
  - Ambiguous images
    - Dissection.
    - Thrombus.
    - Aneurism.
    - Perforation

- **After Intervention:**

  - Balloon
  - Stent
  - Atherectomy
  - Brachitherapy

60% (n=812)
• Is not only an investigational tool

• It is a useful tool in PCI
Cases Review
1. QCA underestimates true vessel size compared to IVUS;

2. Discrepancy higher in:
   a) Small vessels;
   b) Diabetics;
   c) Proximal segments.
When do we gain with IVUS?

VA = 15.1 mm²
VD = 4.2x4.2mm
BMS 4.0 x 12 mm

VA = 17.8 mm²
VD = 4.5x4.7mm

VA = 11.5 mm²
VD = 4.0x4.0mm
BMS 4.0 x 19 mm

VA = 11.4 mm²
VD = 3.7x3.9mm
When do we gain with IVUS?

Post stenting

LA = 11.6 mm²
LD = 3.9x3.9mm

LA = 10.0 mm²
LD = 3.5x3.9mm
When do we gain with IVUS?

CRUISE Study (Can Routine Ultrasound Influence Stent Expansion)
- 525 patients, 545 lesions
- Prospective multicenter study
- Clinical outcomes at 9 months

**When do we gain with IVUS?**

**TULIP Study**

Thrombocyte activity evaluation in a study to determine the effect of Ultrasound guidance of Long Intracoronary stent Placement

- 150 patients, 150 lesions
- Randomized single-center study
- Lesion length >20mm

<table>
<thead>
<tr>
<th></th>
<th>IVUS n=73</th>
<th>No IVUS n=77</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference diameter, mm</td>
<td>3.0</td>
<td>2.9</td>
<td>NS</td>
</tr>
<tr>
<td>Lesion length, mm</td>
<td>29±10</td>
<td>27±9</td>
<td>NS</td>
</tr>
<tr>
<td>MLD post procedure, mm</td>
<td>3.0</td>
<td>2.8</td>
<td>0.02</td>
</tr>
<tr>
<td>MLD at 6month, mm</td>
<td>1.8</td>
<td>1.5</td>
<td>0.04</td>
</tr>
<tr>
<td>Restenosis rate, %</td>
<td>20</td>
<td>36</td>
<td>0.05</td>
</tr>
<tr>
<td>TLR (6M), %</td>
<td>6</td>
<td>16</td>
<td>0.045</td>
</tr>
<tr>
<td>Total MACE (6M), %</td>
<td>12</td>
<td>23</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Oemrawsingh PV, et al. ACC 2001

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Identification of a Vulnerable Plaque

Baseline Angiogram

Baseline IVUS
Slow Flow After Stent Implantation
Coronary Artery Thrombus Not Visualized by Angiography

1 week post AMI treated with Streptokinase
Slow flow  versus  thrombus
Coronary Wall Hematoma a Complication of Overdilation

Baseline

BMS

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Focal Stain in Proximal RCA Post Stent

Post Stent Insertion

“Punch Out” Dilation
Angio and IVUS Post Balloon Expansion

Lumen Compromise

Proximal RCA
IVUS of Proximal RCA After Punch Out Dilation

- LUMEN
- PLAQUE
- INT. ELASTIC MEMBRANE
- HEMATOMA
- CONTRAST
- CONTRAST
Quick Self Assessment …

IVUS
The basic IVUS measurement-vessel CSA is:

a) Intima to intima
b) Media to media
c) Adventitia to adventitia
d) Lumen to lumen
The basic IVUS measurement-vessel CSA is:

a) Intima to intima
b) Media to media
c) Adventitia to adventitia
d) Lumen to lumen
Which wire is suitable to deliver IVUS catheter to the coronary artery:

a) 0.014” guidewire
b) 0.020” exchange wire
c) 0.035” exchange wire
d) All three wires
Which wire is suitable to deliver IVUS catheter to the coronary artery:

a) 0.014” guidewire
b) 0.020” exchange wire
c) 0.035” exchange wire
d) All three wires
The lumen CSA can be calculated from:

a) Lumen radius
b) Lumen diameter intima to intima
c) Length of the lesion
d) Amount of plaque burden
The lumen CSA can be calculated from:

a) Lumen radius
b) Lumen diameter intima to intima
c) Length of the lesion
d) Amount of plaque burden
IVUS is particularly important in following situations (all true EXCEPT):

a) Long lesions
b) Bifurcations
c) Evaluation of intermediate lesions
d) Operator’s curiosity
IVUS is particularly important in following situations (all true EXCEPT):

a) Long lesions
b) Bifurcations
c) Evaluation of intermediate lesions
d) Operator’s curiosity
Which value of LMN lumen CSA is flow limiting (supported by Murray’s law):

a)  $< 9.0 \text{ mm}^2$

b)  $< 8.0 \text{ mm}^2$

c)  $< 7.0 \text{ mm}^2$

d)  $< 6.0 \text{ mm}^2$
Which value of LMN lumen CSA is flow limiting (supported by Murray’s law):

a) \(< 9.0 \text{ mm}^2\)

b) \(< 8.0 \text{ mm}^2\)

c) \(< 7.0 \text{ mm}^2\)

d) \(< 6.0 \text{ mm}^2 \text{ (or MLD } < 2.9 \text{ mm)}\)