IVUS and DES in Complex PCI

• Alan C. Yeung, MD
• Interventional Cardiology Professor of Medicine
• Stanford University School of Medicine
Intravascular Ultrasound Imaging

…the inside view of DES…

Korea, 2005
Everyone gets a stent
*(mechanical)*

Plaque Residual
CRUISE: Final MSA to Predict TLR

Revolutional Technologies: Drug Eluting Stents

Stent as a Drug-Delivery Platform

- Mechanical Scaffold
- Biological Solution
DES Trial: Case Example

Bare metal stent

Baseline

6M follow-up
DES: Case Example
Bare metal stent

Baseline

6-month follow up (%neointimal volume=50%, late lumen area loss=5.72mm²)
DES: Case Example
Drug-eluting stent

Baseline | 6M follow-up
DES: Case Example
Drug-eluting stent

Baseline

6-month follow up

(%neointimal volume = 0 %,
late lumen area loss = 0 mm²)
Optimal Threshold of MSA for Long-Term Stent Patency Following Sirolimus-Eluting Stent Implantation

**BMS**

- Sensitivity
- Specificity

**SES**

- Sensitivity
- Specificity

JACC, 2004 (Sonoda et al)
Drug-eluting Stent

<table>
<thead>
<tr>
<th>Time</th>
<th>% NIV</th>
<th>MLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>POST</td>
<td>0 %</td>
<td>5.13 mm²</td>
</tr>
<tr>
<td>4 months</td>
<td>1.3 %</td>
<td>5.09 mm²</td>
</tr>
<tr>
<td>1 year</td>
<td>3.5 %</td>
<td>4.83 mm²</td>
</tr>
</tbody>
</table>
Chronological Change of NIH

Changes in % Neointimal Volume

Kuroda, et al.

Sirolimus Studies *

BMS

Kuroda, et al.  Stanford

Stanford Database 2004

* Stanford Database 2004
Clinical Use of IVUS in DES stenting

- Improve precision: length, diameter
- Ostial location, side branch involvement (e.g. left main)
- BMS and DES failure
On-Line IVUS: Length Assessment

- Length = 22.5 mm
- Plaque: fibrofatty
On-Line IVUS: Length Assessment

LM

Diag.

8.1 mm
Longitudinal Reconstruction

Ostial Disease
Case 4M: C.C.

- 88 year old woman with left main disease, referred for CABG
- Recurrent SOB, all SVG has failed.
- H/O anterior (apex HK to AK) infarction, EF 35 to 40% range
9 months
IVUS Issues in DES

Bifurcation stenosis treated with two Cypher™ Stents without IVUS guidance

Seven-Month Follow-Up

DES “failure” 2º chronic LAD stent underexpansion just distal to the diagonal
IVUS Issues in DES

- DES failure 2º intimal hyperplasia

After 3x18 mm Cypher™ Stents

Three Months Later

IVUS

Stent CSA = 7.4 mm²
MLA= 1.8 mm²
IVUS Issues in DES

- DES failure due to stent underexpansion

Pre-Intervention

S/P 3-18 mm Long Cypher™ Stents

Three Months Later

Stent CSA = 4.5 mm²
IVUS Issues in DES

- DES failure due to stent underexpansion in a diabetic

Post 3.0x18 and 3.0x8 Cypher™ Stents

Eight Months Later

Proximal

Distal

Stent CSA = 5.2 mm²
MLA = 3.7 mm²

Stent CSA = 5.2 mm²
MLA = 3.7 mm²
Quantitative IVUS Analysis

- Neointimal Area (mm$^2$)
- Stent Area (mm$^2$)
- Lumen Area (mm$^2$)
- Neointimal Area (mm$^2$)
Cross-Sectional (2-D) Analysis

ENDEAVOR I

IVUS can precisely evaluate:

- **Minimal Luminal Area (MLA)**
- **Maximal Neointimal Area (Max.NIA)**
- **Maximal % Neointimal Area Obstruction (Max.%NIA)**

\[
\text{LA} : \quad \text{NIA} : \quad \%\text{NIA} = \frac{\text{NIA} \times 100}{\text{stent area}}.
\]
Maximal % Neointimal Area Obstruction (Max.%NIA)

Example Trial

Mean ± SD: 23.5 ± 15.1 %
Median (25,75): 19.6 (13.1, 31.6)
Volumetric IVUS Analysis

- **Volumes**: Stent, Lumen, Neointima (mm$^3$)
- **Volume Index** = Volume / length (mm$^3$/mm)
- **% Neointimal Volume** = Neointima / Stent (%)
**Statistical Distributions of NIH**

**Bare Metal Stents**

\[ \text{Mean} \pm \text{SD} = 2.55 \pm 1.35 \]

\[ \text{Mean} \pm \text{SD} = 32 \pm 16 \]

\( n = 1421 \)
**Volumetric Analysis Vs. Cross-sectional Analysis**

**SIRIUS Trial BMS Arm**

**% NIV at 8M-FU**

- Mean ± SD: 33.1 ± 14.0%
- Median (25,75): 30.8 (21.9, 44.5)%

**Max.%NIA at 8M-FU**

- Mean ± SD: 55.6 ± 14.5%
- Median (25,75): 57.0 (43.2, 66.2)%

(N of patients)
Volumetric Analysis Vs. Cross-sectional Analysis

SIRIUS Trial Cypher® Arm

% NIV at 8M-FU

Max.%NIA at 8M-FU

(n=51)

Mean ± SD: 2.8 ± 4.9 %
Median (25,75): 1.0 (0.1, 3.9) %

Mean ± SD: 19.3 ± 17.0 %
Median (25,75): 18.0 (3.8, 24.9) %
Impact of Biological Modification

Drug-Eluting Stents

Sirolimus

ABT-578
(PC-only)

Paclitaxel
(Non-Polymer)

% Neointimal Volume (%)
3-D Intravascular Ultrasound Drug-Eluting Stents: Neointimal Volume

Frequency Distributions:

- Sirolimus
- Drug A
- Drug B
- Control

DES Trials

Neointimal Volume (%)

Neointimal Volume (%)
Stent Trials: Frequency Distributions of NIH

Randomized Trials

DES + BMS

Neointimal Volume (%)
Neointimal Volume Obstruction

**DELIVER** (N=70)

- % NIV = 29.42
- Median (%) = 26.98

1:1 Randomization

(%) of cases

% Neointimal Volume Obstruction

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Neointimal Volume Obstruction

DELIVER (N=70)

% NIV = 29.42
Median (%) = 26.98

(% of cases)

% Neointimal Volume Obstruction

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**%Neointimal Volume**

LLL = 0.72 ± 0.41
Median(25, 75) = 0.63(0.43, 0.93)

(N=165)

%NIH = 24.1±14.9
Median (%) = 22.0

1:1 Randomization

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STEALTH 1 IVUS Results

~ Distribution of %Neointimal Volume ~

(Neointimal Volume / Stent Volume)

%NIV = 10.0 ± 13.5
Median: 3.2
25% Quartile: 1.0
75% Quartile: 12.6

*overall results

2:1 Randomization

*out of 81 patients with follow-up 3D analysis
Relationship between Volume and Area Obstruction

Max. %NIA (%) vs. %NIV (%)

Focal

Diffuse

(n=87)
Relationship between Volume and Area Obstruction

Max. %NIA (%)

%NIV: 13.7%

Max%NIA: 19.6%
Relationship between Volume and Area Obstruction

Max. %NIA (%) = 54.2%
%NIV = 12.6%

(n=87)
Relationship between Volume and Area Obstruction

Max. %NIA (%) = 55.1%

%NIV: 45.8 %

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Relationship between Volume and Area Obstruction

Focal

Diffuse

Max. %NIA (%)

0 10 20 30 40 50 60 70 80

%NIV (%) (n=87)

A

B

C

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Intravascular Ultrasound: The view from within ...

* Magnitude of IH
* Statistical Distribution
* Distribution of IH in stent
* Safety issues
The changing landscape by DES...

...the edges are important

...incomplete apposition
Follow-up Incomplete (± remodeling)

Baseline

Follow-up IA (no remodeling)

Follow-up IA (remodeling)
**Late Incomplete Apposition**

*Drug-eluting stent group*

Baseline

Follow-up
Rapa-eluting stent: IH distribution

Mid-stent location of late IA … asymmetric IH distribution

8.9 %
Drug-eluting stent: IH distribution

(more even distribution...fills in gaps)

Ptx / Express II

Incidence of LIA = 1.2 %

.. drug and platform
Intravascular Ultrasound: The view from within ...

* Clinical Subset adjunct
* Clinical efficacy and safety
* New Applications