LM stenting: diameters, prevention of SB occlusion, and stent choice

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No conflict of interest to declare
Benoit Mandelbrot (1924-2010): fractals
**Structure-function scaling laws of vascular trees**

- **Finet’s law**
  \[ D_1 = 0.67(D_2 + D_3) \]

- **Murray’s law**
  \[ D_1^3 = D_2^3 + D_3^3 \]
Flow Patterns and Spatial Distribution of Atherosclerotic Lesions in Human Coronary Arteries

Low wall shear stress and atheroma in bifurcation
Pathological Findings at Bifurcation Lesions: Impact of Flow Distribution on Atherosclerosis and Arterial Healing After Stent Implantation

<table>
<thead>
<tr>
<th></th>
<th>DES (12 Lesions, 17 Stents)</th>
<th>BMS (14 Lesions, 18 Stents)</th>
<th>p Value for DES vs. BMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neointimal thickness (mm)</td>
<td>0.07 (0.03-0.15)</td>
<td>0.17 (0.09-0.23)</td>
<td>0.001</td>
</tr>
<tr>
<td>Fibrin deposition (% struts)</td>
<td>60 (21-67)</td>
<td>17 (0-55)</td>
<td>0.01</td>
</tr>
<tr>
<td>Uncovered struts (% struts)</td>
<td>40 (16-76)</td>
<td>0 (0-15)</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Local flow conditions in jailed SB lesions using computational fluid dynamics

Area of low WSS (<4 Pa) in 8-computational bifurcation models (post treatment ?)

- A: 1.8%
- B: 26.6%
- C: 24.8%
- D: 27.8%
- E: 23.2%
- F: 8.6%
- G: 12.4%
- H: 20.5%

SH. Na, BK. Koo, Korean Circ J 2011;41:91-96
Distal LM stenosis is a bifurcation stenosis

- Same branching laws
- Same distribution of plaques (opposite to the carena)

**But:**
- Big bifurcation
- Take off from the aorta
- Larger B angle
- Bigger myocardial mass at risk (MMAR)

- Technically more difficult ?: No ! But not forgiving mistakes
LM IVUS: A Large Vessel Underestimated by Angio and Poorly Predicted by Patient Physical Parameters

IVUS and Angiographic blinded evaluation of the LMCA in 82 consecutive pts (age, 62 ± 7; 59 men)

<table>
<thead>
<tr>
<th></th>
<th>Angiography</th>
<th>IVUS</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM size (mm)</td>
<td>4.01 ± 0.52</td>
<td>4.90 ± 0.51</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

BSA, Age, gender (4.93 ± 0.6 vs 4.88 ± 0.49), height, weight, or ideal body weight did not predict LM size

D.C. Metzger, TCT 2003
Diffuse atherosclerotic left main coronary artery disease unmasked by fractal geometric law applied to quantitative coronary angiography: an angiographic and intravascular ultrasound study.


Abstract
AIMS: Angiographic analysis of left main coronary artery (LMCA) stenosis can be hindered by the lack of any reference segment when the LMCA is short or there is diffuse atheroma. Fractal geometric law (FGL) enables the theoretic diameter of one bifurcated vessel to be calculated from those of the other two (Dmother=0.678(Ddaughter1+Ddaughter2). Applied to the LMCA, the FGL can help the quantification of stenoses.

METHODS AND RESULTS: Fifty-two patients with angiographically mild focal LMCA disease (n=14) or normal to nearly normal LMCA (n=38) who had undergone intravascular ultrasound (IVUS) were included. IVUS analysis confirmed all 14 focal stenoses (group C); of the 38 angiographically normal patients, however, 10 were found to present diffuse LMCA disease (group B), the remaining 28 showing a truly healthy LMCA (group A). LMCA stenosis in groups A, B and C was respectively 3%, 4% and 42% on usual quantitative coronary angiography (QCA) and 5%, 31% and 43% on QCAfractal applying the FGL. In cases of diffuse atheroma, the FGL corrected the underestimation of LMCA diameter, which averaged 1.2 mm. Conclusions: Angiographic underestimation of LMCA stenosis can be corrected by applying the FGL to obtain a theoretic LMCA diameter, thereby unmasking any diffuse atherosclerotic LMCA disease, or to quantify focal stenosis more precisely where the adjacent segments are also pathological.
Measurement of Coronary Artery Bifurcation Angles by Multidetector Computed Tomography

[Chart showing bar graphs for LAD / LCX, LAD / Diag1, PDA / Rpld, and LCX / OM1 with statistical symbols (*, #, $) for significance.]
High risk
High risk? = No
Risk assessment

3 VD?
Occluded RCA (dominant?)
Dominant LCA?
Collaterals? LCA to RCA / RCA to LCA
LVEF?
Lesion complexity (handling time)?
Syntax score II, Euroscore ....

PCI/CABG?, hemodynamic support?
LM longitudinal stent distorsion: guiding / stent proximity
LM longitudinal stent distorsion: guiding / stent proximity
LM longitudinal stent distorsion: guiding / stent proximity

- Stent Viz (General Electrics) evidenced a shortening of the stent with a disrupted portion in its proximal edge.
LM longitudinal stent distorsion: guiding / stent proximity
Avoid SB occlusion
## Predictors and outcomes of SB occlusion after main vessel stenting in coronary bifurcation lesions

### Clinical Outcomes at 12-Month Follow-Up

<table>
<thead>
<tr>
<th>Outcome</th>
<th>SB Occlusion (n = 187)</th>
<th>No SB Occlusion (n = 2,040)</th>
<th>Unadjusted HR (95% CI)</th>
<th>p Value</th>
<th>Adjusted HR* (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>10 (5.3)</td>
<td>74 (3.6)</td>
<td>1.55 (0.80-2.99)</td>
<td>0.20</td>
<td>1.50 (0.76-2.97)</td>
<td>0.24</td>
</tr>
<tr>
<td>Cardiac death</td>
<td>7 (3.7)</td>
<td>20 (1.0)</td>
<td>3.95 (1.67-9.35)</td>
<td>0.002</td>
<td>4.19 (1.66-10.59)</td>
<td>0.002</td>
</tr>
<tr>
<td>MI</td>
<td>4 (2.1)</td>
<td>32 (1.6)</td>
<td>1.44 (0.59-4.07)</td>
<td>0.49</td>
<td>1.50 (0.51-4.41)</td>
<td>0.46</td>
</tr>
<tr>
<td>Cardiac death or MI</td>
<td>10 (5.3)</td>
<td>50 (2.5)</td>
<td>2.29 (1.16-4.52)</td>
<td>0.02</td>
<td>2.34 (1.15-4.77)</td>
<td>0.02</td>
</tr>
<tr>
<td>Stent thrombosis†</td>
<td>6 (3.2)</td>
<td>9 (0.4)</td>
<td>7.68 (2.73-21.59)</td>
<td>&lt;0.001</td>
<td>6.19 (2.00-19.13)</td>
<td>0.002</td>
</tr>
<tr>
<td>TLR</td>
<td>14 (7.5)</td>
<td>129 (6.3)</td>
<td>1.26 (0.73-2.19)</td>
<td>0.41</td>
<td>1.31 (0.74-2.30)</td>
<td>0.36</td>
</tr>
<tr>
<td>MACE</td>
<td>23 (12.3)</td>
<td>164 (8.0)</td>
<td>1.63 (1.06-2.53)</td>
<td>0.03</td>
<td>1.64 (1.05-2.58)</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Predictors and Outcomes of SB Occlusion After Main Vessel Stenting in Coronary Bifurcation Lesions Results From the COBIS II Registry

Lesion and Procedural Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SB Occlusion (n = 187)</th>
<th>No SB Occlusion (n = 2,040)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bifurcation location</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left main bifurcation</td>
<td>14 (7.5)</td>
<td>566 (27.3)</td>
<td></td>
</tr>
<tr>
<td>LAD/diagonal</td>
<td>124 (66.3)</td>
<td>1,124 (55.1)</td>
<td></td>
</tr>
<tr>
<td>LCX/OM</td>
<td>32 (17.1)</td>
<td>272 (13.3)</td>
<td></td>
</tr>
<tr>
<td>RCA bifurcation</td>
<td>17 (9.1)</td>
<td>88 (4.3)</td>
<td></td>
</tr>
<tr>
<td>Medina classification</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1.1.1</td>
<td>97 (51.9)</td>
<td>567 (27.8)</td>
<td></td>
</tr>
</tbody>
</table>

Patients with recovery of the occluded SB had jailed wire in the SB more frequently than those without recovery of the occluded SB (74.8% vs. 57.8%, p < 0.02)

SB occlusion
wo JW = 7%
w  JW = 9%
Independant predictors of SB occlusion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio (95% CI) (range)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-procedural %DS of the SB ≥50%</td>
<td>2.34 (1.59-3.43)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pre-procedural %DS of the proximal MV ≥50%</td>
<td>2.34 (1.57-3.50)</td>
<td>0.03</td>
</tr>
<tr>
<td>SB lesion length</td>
<td>1.03 (1.003-1.06)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Acute coronary syndrome</td>
<td>1.53 (1.06-2.19)</td>
<td>0.02</td>
</tr>
<tr>
<td>Left main lesions (vs. non-left main lesions)</td>
<td>0.34 (0.16-0.72)</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Hahn, J Am Coll Cardiol 2013;62:1654–9
IVUS findings of Carina shift vs. Plaque shift

Before MB stent

After MB stent

Both plaque shift and carina shift ➔ Aggravation of SB luminal narrowing after MB stent implantation

Koo, Circ Cardiovasc Interv 2010;3;113-119
Stent diameter

Optimal
Provisional SB
Stenting
Stent diameter

Optimal Provisional SB Stenting

POT
Left Main Stenting Acute Result, 6 Month CTCA
One stent, two diameters … but which ones?
Early plaque accumulation in human coronary arteries is associated with compensatory enlargement of vessel size (positive remodeling). Therefore, luminal size is initially not affected by plaque growth. These complex changes of lumen, plaque and external elastic membrane (EEM) may also affect plaque regression.

Positive remodeling and vessel diameter

adapted from Schoenhagen, JACC 2001;38:297–306
Positive remodeling and vessel diameter

adapted from Schoenhagen, JACC 2001;38:297–306
Positive remodeling and vessel diameter

adapted from Schoenhagen, JACC 2001;38:297–306
OCT compared with IVUS in a coronary lesion assessment
The OPUS-CLASS study

MLA in Phantom Models: FD-OCT / IVUS

MLD in patients: FD-OCT, IVUS, and QCA

Kubo, J Am Coll Cardiol Img 2013;6:1095–104
Usefulness of the Finet law to guide stent size selection in ostial LM stenting: Comparison with standard angiographic estimation

A

80% stenosis

QCA

3.6 mm

Finet

D1 = 4.4 mm

D2 = 3.2 mm

D3 = 3.4 mm

<table>
<thead>
<tr>
<th>Balloon Max Size</th>
<th>Synergy</th>
<th>Xpedition</th>
<th>Res. Onyx</th>
<th>Ultimaster</th>
<th>BioMatrix A</th>
<th>Orsiro</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small vessel (8 crowns, 2-4 connectors)</td>
<td>Small vessel (6 crowns, 3 connectors)</td>
<td>Small vessel workhorse (6.5 crowns, 2 connectors)</td>
<td>Small vessel (8 crowns, 2 connectors)</td>
<td>Small vessel (6 crowns, 3 connectors)</td>
<td>Small vessel (6 crowns, 3 connectors)</td>
</tr>
<tr>
<td>4.0</td>
<td>Expansion: 3.6mm</td>
<td>Expansion: 4.1mm</td>
<td>Expansion: 3.3mm</td>
<td>Expansion: 4.3mm</td>
<td>Expansion: 4.1mm</td>
<td>Expansion: 4.0mm</td>
</tr>
<tr>
<td>2.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.75</td>
<td>Workhorse (8 crowns, 2-4 connectors)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.00</td>
<td>Expansion: 4.2mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.50</td>
<td>Large vessel (9 crowns, 3 connectors)</td>
<td>Large vessel (9.5 crowns, 2.5 connectors)</td>
<td>Large vessel (8 crowns, 2 connectors)</td>
<td>Large vessel (9 crowns, 3 connectors)</td>
<td>Large vessel (6 crowns, 3 connectors)</td>
<td></td>
</tr>
<tr>
<td>4.00</td>
<td>Expansion: 5.6mm</td>
<td>Expansion: 5.6mm</td>
<td>Expansion: 5.8mm</td>
<td>Expansion: 5.9mm</td>
<td>Expansion: 5.3mm</td>
<td></td>
</tr>
<tr>
<td>4.50</td>
<td>Extra-Large vessel (10.5 crowns, 2.5 connectors)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>Expansion: 6.0mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- Expansion: inner stent MLD excluding struts
- Max balloon size: Maverick 6.0mm at 14 ATM

Foin, Ng, 2016
A « SB » occlusion...
Female patient, 70 yo

Live in Euro-PCR
Runthrough ns X 2, Trek 2.5X20
Cx occlusion
POT 3.5X10
Cx wire failure: Fielder FC, Asahi medium,
Finecross + Fielder XT-A
Result
3.0-3.5
Conclusions (1)

• Coronary trees have « pseudo » fractal anatomy

• This anatomy has a distributive fonction in epicardic arteries

• In pathologic conditions it explain development of plaques opposite to the carena

• But this anatomy remains the most effective and has to be respected by treatment

• Particularly important in LM stenting regarding the lethal risk
Conclusions (2)

- Respect the anatomy but how to choose the stent diameters?
- IVUS is oversizing and QCA undersizing the luminal diameter
- Media to media diameter choice is a provider of SB occlusion?
- After diameter choice, stent choice using independant maximal expansion measurements is important
- We need bench evaluation of stents in severe curves