Pitfalls and Limitations of QCA in the Analysis of Bifurcation Lesions

Alexandra Lansky, MD
Associate Professor, Clinical Medicine
Columbia University Medical Center

Cardiovascular Research Foundation
Columbia University Medical Center
The realities of bifurcation lesions are the greatest challenges of QCA

- Lesion location is variable in bifurcation disease (ostial side branch, within the carina)
- One bifurcation lesion but 3 vessel segments (4 for trifurcations)
- How to quantify extent of lesion length?
- Bifurcation stenoses rarely seen in one single view—require multiple views for analysis
Lesson #1: The Basics
Bifurcations need work to uncover pathology
Lesson #2 Beware and understand the limitations of QCA bifurcation results!

Method to determine the proper reference diameter for each individual segment.

The “Step down” phenomenon is a major limitation of Standard QCA when applied to bifurcation analyses.
Left Main Trifurcation with extreme proximal:distal vessel miss-match
Limitations of Standard Analysis

Problem: Mismatch between prox vessel and distal vessel

Results in: Overestimated Reference
Overestimated %DS
Better for lesion length

Solutions: Use Distal Reference or Limit analysis to distal PV
Greatest Limitation: Reference Diameter

• **Problems:** Vessel contour track into MLD
  Cannot assess lesion length

• **Results in:** Underestimates reference
  Underestimates %DS

• **Solution:** Use Distal Reference
Constant RVD relation between PV and SB in the normal coronary tree

N= 47 pts (173 bifurcations)

<table>
<thead>
<tr>
<th>variable</th>
<th>For all</th>
</tr>
</thead>
<tbody>
<tr>
<td># of bifurcation</td>
<td>173</td>
</tr>
<tr>
<td>$D_m$ (mean±DS)</td>
<td>3.339±0.948</td>
</tr>
<tr>
<td>$D_{d\text{-larger}}$ (mean±DS)</td>
<td>2.708±0.774</td>
</tr>
<tr>
<td>$D_{d\text{-smaller}}$ (mean±DS)</td>
<td>2.236±0.689</td>
</tr>
<tr>
<td>Reduction in mm (mean±DS)</td>
<td>0.631±0.365</td>
</tr>
<tr>
<td>% reduction</td>
<td>18.9</td>
</tr>
<tr>
<td>Mean ratio</td>
<td>0.678</td>
</tr>
</tbody>
</table>

Variables are presented as mean ± SD

- $D_m$: Diameter of the mother vessel (mm)
- $D_{d\text{-larger}}$: Diameter of the larger daughter vessel (mm)
- $D_{d\text{-smaller}}$: Diameter of the smaller daughter vessel (mm)
- Reduction: difference between the diameter of the mother vessel and the diameter of the larger daughter vessel
- Ratio: $D_m / (D_{d\text{-larger}} + D_{d\text{-smaller}})$
**Constant RVD relation between PV and SB in the normal coronary tree**

\( N = 47 \text{ pts (173 bifurcations)} \)

Finet et Gilard

<table>
<thead>
<tr>
<th>Experimental approach</th>
<th>Murray’s law</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D_p = 0.66 \cdot (D_{v1} + D_{v2}) )</td>
<td>( D_p^3 = D_{v1}^3 + D_{v2}^3 )</td>
</tr>
</tbody>
</table>

\( D_p \): parent vessel diameter  

\( D_{v1} \): daughter 1 vessel diameter  

\( D_{v2} \): daughter 2 vessel diameter
Three sections model for the bifurcation analysis (MEDIS)
Arterial contour: 4 segments

Concept is to exclude the carina from consideration in the assessment of the reference measures (avoids overestimation of reference for the distal vessels)

The problem is that the carina is left “in limbo”
To measure diameters in the central fragment of a distal section, an artificial contour in the central fragment is generated automatically.
Dedicated Bifurcation Software
But... Different Results for Same Lesion

**LCA Main**
- LAD Proximal
- LCX Proximal

**Obstruction diam.**
- 1.72 mm

**Reference diam.**
- 2.92 mm

**Diameter stenosis**
- 41.15%

**Obstruction length**
- 3.98 mm

---

**LCA Main**
- LAD Proximal
- LCX Proximal

**Obstruction diam.**
- 1.10 mm

**Reference diam.**
- 3.18 mm

**Diameter stenosis**
- 65.50%

**Obstruction length**
- 6.58 mm

---

**LCA Main**
- LAD Proximal
- LCX Proximal

**Obstruction diam.**
- 1.71 mm

**Reference diam.**
- 3.70 mm

**Diameter stenosis**
- 53.74%

**Obstruction length**
- 7.35 mm
<table>
<thead>
<tr>
<th>Cardiovascular Research Foundation</th>
<th>Angiographic Core Laboratory of New York</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type A</strong></td>
<td></td>
</tr>
<tr>
<td>Prebranch stenosis not involving the ostium of the side branch</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>PV</td>
</tr>
<tr>
<td>SB</td>
<td>SB</td>
</tr>
<tr>
<td><strong>Type B</strong></td>
<td></td>
</tr>
<tr>
<td>Postbranch stenosis of the parent vessel not involving the origin of the side branch</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>PV</td>
</tr>
<tr>
<td>SB</td>
<td>SB</td>
</tr>
<tr>
<td><strong>Type C</strong></td>
<td></td>
</tr>
<tr>
<td>Parent vessel only stenosis encompassing the side branch but not involving the ostium</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>PV</td>
</tr>
<tr>
<td>SB</td>
<td>SB</td>
</tr>
<tr>
<td><strong>Type D</strong></td>
<td></td>
</tr>
<tr>
<td>Bifurcation stenosis involving the parent vessel and ostium of the side branch</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>PV</td>
</tr>
<tr>
<td>SB</td>
<td>SB</td>
</tr>
<tr>
<td>60%</td>
<td></td>
</tr>
<tr>
<td><strong>Type E</strong></td>
<td></td>
</tr>
<tr>
<td>Ostial stenosis involving the ostium of the side branch only</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>PV</td>
</tr>
<tr>
<td>SB</td>
<td>SB</td>
</tr>
<tr>
<td>18%</td>
<td></td>
</tr>
<tr>
<td><strong>Type F</strong></td>
<td></td>
</tr>
<tr>
<td>Prebranch and Ostial Stenosis discretely involving the parent vessel and ostium of the side branch</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>PV</td>
</tr>
<tr>
<td>SB</td>
<td>SB</td>
</tr>
</tbody>
</table>

Reference: Schematic Classification system for types of bifurcation stenosis-Duke classification
Novel bifurcation software solves some but not all problems

- **Benefits:**
  - Single analysis of the 3 vessels, fast, easy, more reproducible
  - More accurate reference vessel diameter (outside carina)
  - More accurate %DS (outside carina)

- **Limitations:**
  - Reference in carina is interpolated for the segment analyzed (LAD vs LCx vs LM)
  - Single lesion in Carina is reported 3 times (with different reference, MLD, %DS depending on vessel analyzed)
  - Cannot always acquire in a single best view
The challenge is to determine (inter-(extra)-polate) the true diameter of the carina simulating the undiseaseased state?

This would result in a constant reference, MLD and %DS in the carina.
GE: Bifurcation Quantification Prototype

Proximal Reference: 2.85 +/- 0.21 mm
Distal Reference: 3.24 +/- 0.24 mm
Minimum Lumen Diameter: 1.90 +/- 0.14 mm
Proximal Stenosis Ratio: 33.20%
Distal Stenosis Ratio: 41.28%
Lesion Length: 19.48 +/- 1.39 mm
Lesson # 3: Question

In assessing the long-term angiographic outcomes of a bifurcation lesion, which is correct...

1. A single measure of LLL for the bifurcation lesion is the best measure to compare 2 treatment groups because it is a surrogate of intimal hyperplasia

2. In a bifurcation lesion, LLL is only meaningful if applied to a specific vessel segment that has minimal vessel taper

3. Binary restenosis is the only angiographic parameter at follow-up that can be applied to the entire bifurcation lesion (PV and SB)
LLL is only meaningful if the segment analyzed is specified

1 – Proximal Edge of the Prox PV Stent
2 – Prox PV Stent
3 – Distal PV Stent*
4 – Distal Edge of the PV Stent
5 – SB Stent*
6 – Distal Edge of the SB Stent*
7 – Carina
8 – Ostium of the SB (5mm)
9 – PV In-Lesion
10 – SB In-Lesion

*if additional stent(s) placed
Lesson #4: Diagnostic Considerations
Ostial SB Lesion Severity at Baseline

Measurements on Current Frame

<table>
<thead>
<tr>
<th></th>
<th>Area (mm²)</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumen</td>
<td>3.83</td>
<td>2.33</td>
</tr>
<tr>
<td>Vessel</td>
<td>6.31</td>
<td>2.35</td>
</tr>
<tr>
<td>Stent Plaque</td>
<td>2.46 (39.2% of Vessel)</td>
<td>2.35</td>
</tr>
</tbody>
</table>

Comparative Lumen Area
Lesson #5: Diagnostic Considerations
Ostial SB Lesion Severity after SB Jailing

Angiography vs FFR: To treat or Not?

Fractional Flow Reserve (FFR < 0.75 = ischemia)

- SB FFR measured in 94 pts after side branch jailing
- FFR reflects both degree of stenosis and myocardial territory

Bon-Kwon Koo, MD
QCA vs. FFR in Jailed side branch lesions (n=94)

Functionally significant stenosis

$r = -0.464$
$p < 0.001$
FFR (< 0.75) vs. QCA (% stenosis)

Bon-Kwon Koo, MD

- All Lesions (n=94) -

<table>
<thead>
<tr>
<th>% stenosis</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>75%</td>
<td>1.0</td>
<td>0.39</td>
</tr>
<tr>
<td>85%</td>
<td>0.8</td>
<td>0.77</td>
</tr>
</tbody>
</table>

AUC: 0.85 (95% CI: 0.76 - 0.94)

Best Cut-off Value
Are significant side branch lesions really significant?

The angiographic %DS cut-off value for (jailed) side branches is 75% DS

- **DS<75%**: high NPV
- **Generalizability to non-jailed SB (initial evaluation)?**
- **Reason:**
  - radiographic artifact, limitations of QCA
  - small branches, small myocardial mass, low flow
  - Initial edema after stenting

*More strict angiographic evaluation criteria and less aggressive SB intervention strategy should be applied*

Bon-Kwon Koo, MD
After Bifurcation PCI... A preponderance of Restenosis occurs in the SB Ostium

Preprocedure  Final  6 Months Follow-Up
Lesson #6: Diagnostic Considerations
SB Ostium Stent Under Expansion
Lesson #6: Diagnostic Considerations

SB Ostium Stent Under Expansion

LA : 2.23mm²
SA : 2.23mm²
Crush Technique: IVUS Insights

40 pts post bifurcation crush: Minimum stent CSA (MSA) was assessed at 5 distinct locations: Restenosis 17% (6/35); all 6 in SB ostium and 1 extending to PV

Bifurcation Lesions Treated with Crush Stenting with Final IVUS in Both Branches
Suggested Improvements in Analysis Algorithms

- Methodology and algorithm for contour detection
  - Ostial Sidebranch flaring
  - Interpolation across carina is artificial (should not be done)
  - Carina reference should reflect un-diseased diameter (this would result in a constant reference and %DS)

- Reporting should allow one single MLD and DS for the entire bifurcation lesion

- Allow multiple segment of interest analysis (DES bifurcation software) to avoid having to do multiple segment analyses
QCA Methods and Reporting

1 – Proximal Edge
2 – Proximal Stent
3 – Distal PV Stent*
4 – Distal Edge of the PV Stent
5 – SB Stent*

6 – Distal Edge of the SB Stent*
7 – Carina
8 – Ostium of the SB (5mm)
9 – PV In-Lesion
10 – SB In-Lesion

*if additional stent(s) placed