Main vessel to side branch transition zone in human coronaries: Unique geometric insights missed by QCA

Ex Vivo Analysis of Human Coronary Bifurcation Anatomy:

European Bifurcation Club
Mary E. Russell, MD, FACC
Ascent Translational Sciences
Carlisle, Massachusetts, USA

Eitan Konstantino, PhD
Gary Binyamin, PhD
TriReme Medical, Inc
Pleasanton, CA, USA
Technical Challenges with Bifurcations Using Straight, Concentric Tubular Systems

- **Side Branch Access**
  - Distort stent architecture
  - Loss of access

- **Intersection MV & SB**
  - Stent protrusion
  - Dissection
  - Nidus for restenosis
  - Gaps
  - Apposition incomplete
  - Multiple Strut Layers

- **Injury**

- **Scaffolding**
Program Objectives

Define bifurcation anatomy and geometry

• Casts of human coronary tree to evaluate intersection between Main Vessel (MV) & Side Branch (SB)

• Qualitative assessments
  – Shapes at the SB take off

• Quantitative measures
  – Specified Diameters (vessels > 1.6 mm)
  – Various angles
Methods

• Retrograde aortic polymer injection to create casts of the human coronary arteries
• 23 Adult Cadaver Heart Donors:
  – 11 Females, 12 Males
  – Predominantly white
  – Mean age: 66 (range: 56-76)
  – Causes of death: noncardiac in 22 of 23 cases
• 27 vessels with side branches >1.99
• 70 vessels with side branches >1.65 mm
Cast Preparation

1. Aorta perfused retrograde $\geq$ 60 min
2. Polymer injected to fill the aortic sinus and coronary arteries
3. Polymer cured ($\geq$ 60 min)
4. Models immersed in caustic solutions to digest tissue
3 Dimensional Casts of Coronary Tree (Aorta to terminal branches (<1mm))

- Branching
- Curvature
- Tortuosity
- Lesions
- Intersections

LM  RCA  LCX  LAD
Geometric Analysis Performed by Imaging (MV to SB intersection)

- Smartscope MVP100 video-based inspection system
- Gage-X metrology software
- Magnification $\geq 34$ X 
  (novel view between angiographic & microscopic)
- Measurements made with bifurcation perpendicular to the field of view
- Two independent reviewers performed measures 
  if discordant by $>10\%$ then, consensus review
High Power Views of Anatomy & Disease
Multifaceted intersection without discrete angle

- No disease
- Minor stenosis; minimal disease
- Moderate ostial stenosis; diffuse stenosis in SB and proximal MV
- Severe stenosis and disease
Ostial Geometry:
Oval and Asymmetric Rather than Round

Example: Side Branch of RCA

Front view of ostium with SB removed

Side view of ostium with SB removed

Sketches of ostium

- conical taper
- elliptical

Example: Side Branch of RCA
Diameter Measurements

Note: Illustration not to scale
Diameters: Greater proximal to distal
Ostial SB diameter similar to distal MV

<table>
<thead>
<tr>
<th></th>
<th>Proximal vessel diameter</th>
<th>Distal vessel diameter</th>
<th>Ostial Diameter</th>
<th>Side Branch diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Vessel</strong></td>
<td>1.70 - 4.18 mm</td>
<td>2.86</td>
<td>2.39</td>
<td>2.29</td>
</tr>
<tr>
<td><strong>Side Branch</strong></td>
<td>1.59 - 2.59 mm</td>
<td>1.93</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ostial Geometry:
Transition Zone Taper Greater by 3-fold

**Average Taper**

Vessels with SB > 1.99 mm

- (Main Vessel) Proximal to Distal Taper: 0.10 mm
- (Side Branch) Ostium to Side Branch Taper: 0.34 mm

**Main Vessel**
Tapers 0.56 mm over 6.00 mm distance

**Side Branch**
Tapers 0.60 mm over 1.75 mm distance
Three Types of Angle Measurements

Intersection Angles:
intersection of centerline of main vessel and side branch (~measured by angiography)

Transition Zone Angles:
actual main vessel to side branch progression as measured from the main vessel

Note: Illustration not to scale
Intersection Angles*:
Obtuse Proximal $\angle$ vs Acute Distal $\angle$

Proximal angles (77°-178°; mean 134°)

Distal angles (12°-99°; mean 54°)

*Intersection angles = angiographic measurements
Transition Zone Angles*:
Differential smaller between proximal & distal angles

Proximal transition angles (107°-177°; mean 152°)

Distal transition angles (27°-163°; mean 109°)

*Transition zone angles = actual main vessel to side branch progression as measured from the main vessel
Summary

Bifurcation diameters (~ to previous reports)

**MV:** Wide Range (1.7 to 4.2),
- proximal mean = 2.86
- distal mean = 2.39

**SB:** Wide Range (1.6 to 2.6), mean 2.28

**Four types of asymmetric ostial geometry:**
- Multifaceted transition (high magnification detail)
- Oval rather than round ostium
- Taper with SB 3-fold greater than MB
- Side branch take off angles
  - Proximal (obtuse)
  - Distal (acute)
Conclusions

Distort stent or Distort anatomy?

• Complex transition zone from the MV to SB up to 4 asymmetric features

• Anatomic distortion likely with symmetric (cylindrical) designs
  – Strut protrusion/injury
  – Gaps
  – Incomplete wall apposition

• Matching design to asymmetric ostial geometry may minimize implant injury, enhance scaffolding and improve outcomes
Four types of asymmetry
Implications—more questions

Angiography (uniform definitions needed)
• What, where and how angles measured
• Usefulness of measures?

IVUS of SB
• Is SB imaging essential?
• Is the oval shape seen at the SB take off really an artifact due to cathetor angulations on w/drawal?
• How should strut apposition be measured in the MV to SB transition zone

Procedural
• Stent designs to match MV to SB transition zone?
• Post dilation balloons & protocols that maintain elliptical sshpae & differential SB taper?