Understating Coronary Bifurcation Intervention

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Bifurcation Coronary Disease

- 15~20% of PCI patients
- DES enhanced success rate, but have not resolved completely
- Dependable strategy – not established
  - Rare studies evaluating anatomical intricacies
  - Lack of large randomized trials
  - Many anatomical variants
    → Single technique can’t fit all
Difficulties of Bifurcation PCI

- Risk of periprocedural complication
- Relatively high restenosis
- Not all lesions are the same
  - Size of vessels (Meaningful SB size ≥2.25mm)
  - Variable plaque distribution
  - Extent of SB disease
  - Variable angulation
- Higher risk of stent thrombosis

→ PCI techniques are mainly based on personal experiences from skilled operators
Factors to be considered for PCI strategy

- **Anatomical factors**
  - LMCA bifurcation
  - Location of plaque (Anatomical classification)
  - Plaque or carina shift
  - Angle btw SB and MB
  - Dynamic change in bifurcation anatomy

- **Modalities for objective anatomical evaluation**
  - QCA, IVUS, FFR

- **Selection of devices and strategies**
  - DES vs. BMS
  - Single vs. Double stent techniques
  - Kissing balloon or not
  - Dedicated bifurcation stents
Classification of Bifurcation Lesions

- Plaque Location
- Plaque Extent
- Angle
Safian Classification

**Type I**
*Parent vessel stenosis proximal and distal to bifurcation*

**Type II**
*Parent vessel stenosis proximal to bifurcation*

**Type III**
*Parent vessel stenosis distal to bifurcation*

**Type IV**
*Parent vessel normal, ostial side branch stenosis*
Duke Classification

Type A
Prebranch stenosis not involving the ostium of the side branch

Type B
Postbranch stenosis of the parent vessel not involving the ostium of the side branch

Type C
Stenosis of the parent vessel not involving the ostium of the side branch

Type D
Stenosis involving the parent vessel and the ostium of the side branch

Type E
Stenosis involving the ostium of the side branch only

Type F
Stenosis discretely involving the parent vessel and ostium of the side branch

PCI for Bifurcation Lesions
Lefevre (ICPS) Classification

Type 1
Lesions located in the main branch, proximal and distal, and the ostium of side branch

Type 2
Lesions located only in the main branch, proximal and distal, and not the ostium of side branch

Type 3
Lesions located in the main branch proximal to the bifurcation

Type 4
Only the ostium of each branch of the bifurcation involved with no proximal disease

Type 4a
Lesion located only in the ostium of main branch

Type 4b
Lesion located only in the ostium of side branch

PCI for Bifurcation Lesions
Medina Classification

PCI for Bifurcation Lesions
Limitations of the Medina classification

- Does not take into account
  1. Length of disease in the ostium of the SB
  2. Length of the LMCA before the bifurcation
  3. Trifurcation
  4. Vessel angulation

- The LMCA differs from many other bifurcation lesions due to the importance of the SB (LCx)

More precise classification system?
Plaque Burden at the SB Ostium

Provisional strategy better

Two stent strategy better
Trifurcation

- If, RI size > LCx
  - LM, LAD, RI, LCx

PCI for Bifurcation Lesions
Angulation

**T-shape**
- Prox
- Distal
- SB

- Difficult SB access
- Less plaque shifting
- T-stenting better

**Y-shape**
- Prox
- Distal
- SB

- Easier SB access
- More plaque shifting
- Cullotte or Crush better

PCI for Bifurcation Lesions
Angulation

- Should this be taken into account in the classification?

PCI for Bifurcation Lesions
However ......

• Any classification must be simple to apply and to remember!

• Inclusion of too many variables will make the system too complex to apply in practice
QCA of Bifurcation Lesions
Interpolated Reference

- MLD = 1.3
  - Mean reference: \( (3.5+2.2) / 2 = 2.85 \)
  - DS = \( (2.85-1.3) / 2.85 \times 100 = 54.4\% \)
  - Interpolated reference: 3.2
    - DS = \( (3.2-1.3) / 3.2 \times 100 = 59.4\% \)

- MLD = 0.5
  - Mean reference: \( (3.5+2.2) / 2 = 2.85 \)
  - DS = \( (2.85-0.5) / 2.85 \times 100 = 82.5\% \)
  - Interpolated reference: 2.5
    - DS = \( (2.5-0.5) / 2.5 \times 100 = 80.0\% \)

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**Mean**

Interpolated

PCI for Bifurcation Lesions

Courtesy of YH Kim
Interpolated Reference of Bifurcation
Not easy…

LM LAD

Diameter main

Reference diameter

Luminal diameter

Courtesy of YH Kim
Interpolated Reference

LM
LAD
LCX

Diameter main

Reference diameter
Luminal diameter

PCI for Bifurcation Lesions

Courtesy of YH Kim
Interpolated Reference

LM  LAD  LCX

Diameter main

Reference diameter

Luminal diameter

Courtesy of YH Kim

PCI for Bifurcation Lesions
Limitation of Current QCA Software

Different Results for Same Lesion

Artificial “interpolation” of RVD across carina
Carinal segment reported 3 times with differing results
Confusion
The spot is LM, LAD, or LCX?
Murray’s Law

\[ D_{\text{mother}} = 0.67 \times (D_{\text{daughter 1}} + D_{\text{daughter 2}}) \]

Ref. = 0.67 \times (MB + SB)

Relative deviation between the expected diameter of the mother vessel calculated with this formula and the measured diameter:

-1.27% ± 9.85%

QCA Methods for Bifurcation Lesions

QCA Methods and Reporting

1 – Proximal Edge
2 – Proximal Stent
3 – Distal PV Stent*
4 – Ostium of distal PV (5mm)
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
11 – distal edge PV Stent

*if additional stent(s) placed

A. Lansky, JACC Intervention 2008, In press
Polygon of Confluence by CASS-QCA
: Innovative Method of Bifurcation QCA

Courtesy of YH Kim
Description of Bifurcation QCA

1. Proximal edge (5mm)  6. Distal edge side (5 mm)
2. Proximal main stent  7. Polygon of confluence
3. Distal main stent    8. Ostium of side branch (5mm)
4. Distal edge main (5mm)  9. Main vessel stent + edges
5. Side branch stent    10. Side branch stent + distal edge

Presenting results in segmental model

Courtesy of YH Kim
Description of Bifurcation QCA

Other important parameters

- Bifurcation angle
- TIMI flow in both branches
- Degree of calcifications
- Uneven or ulcerated segments
- Concentric or eccentric locations of MV lesions
- Contra- or ipsi-lateral MV plaque location
- Length of SB stenosis
PCI for Bifurcation Lesion
Side Branch Loss

Main Mechanism of Adverse Outcomes

- Pretreatment
  - Shifting or Snowplow
  - Ostial spasm
  - SB Ostial dissection
  - Main vessel dissection

- After stenting
Plaque Shift

INSIGHT – IVUS

Pre → Post

SB ostium

Lumen  Vessel  Plaque

p=0.14  p=0.25  p=0.54

Costa MA, TCT 2007

PCI for Bifurcation Lesions
IVUS Predictors of SB Occlusion

SB occlusion A vs B+C: 8.2 vs 35.0 %; p=0.003

Furukawa. Cir J 2005;69:325
SB Jailed Wire

- Helps to keep the SB open
- Useful in case of SB closure
- Change the angle btw proximal MB & SB
- Difficult? → more after MB stenting!
SB Predilation

● Cons
  - Unnecessary trauma or dissection

● Pros
  - To assess how the lesion will behave
  - To optimise subsequent stent expansion, esp. calcified SB
  - To better evaluate the most appropriate stenting strategy
  - To facilitate subsequent re-wiring if >90% baseline stenosis
  - To reduce the potential for ischemia during the procedure
Is All Jailed SB Important?

QCA vs. FFR

Jailed side branch lesions (n=94)

27% of SB lesions
>75% stenosis
FFR <0.75

Koo BK, JACC 2005;46: 633
Simple vs. Complex Technology

- **Simple stenting technique**
  DES implantation only at the main vessel with optional balloon angioplasty or stenting at the side branch

- **Complex stenting technique**
  DES implantation at the main vessel and the side branch
DES in Bifurcation; Restenosis

NORDIC Bifurcation

- Entire lesion DS >50%
  - Single stent: 22.5%
  - MV + SB: 16.0%
p = 0.15

- MV DS >50%
  - Single stent: 16.0%
  - MV + SB: 4.6%
p = 0.84

- SB DS >50%
  - Single stent: 19.2%
  - MV + SB: 5.2%
p = 0.062

Only 1 patient (single stent group) had a SB occlusion at FU

Steigen et al Circulation 2006;114:1955-61

PCI for Bifurcation Lesions
DES in Bifurcation; Safety

% Stent Thrombosis

2 stents
1 stent + PTS

PCI for Bifurcation Lesions
# Ongoing Randomized Trials

<table>
<thead>
<tr>
<th>Trial</th>
<th>N</th>
<th>Strategy</th>
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<tr>
<td>PRECISE</td>
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<td>SKS vs. provisional</td>
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<td>NORDIC II</td>
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<td>Crush vs. Cullotte</td>
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<tr>
<td>NORDIC III</td>
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<td>KB or not in Provisional strategy</td>
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<tr>
<td>CACTUS</td>
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<td>Crush vs. Provisional T</td>
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<tr>
<td>PERFECT</td>
<td>500</td>
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<tr>
<td>CROSS</td>
<td>180</td>
<td>KB or not in Provisional strategy</td>
</tr>
</tbody>
</table>
Coronary bifurcation lesions

**PERFECT**

- Side branch stenosis <50%
  - Provisional
  - Randomization
  - Leave alone

- If, Poststenting SB stenosis ≥50%
  - Randomization
  - Leave alone

**CROSS**

- Side branch stenosis ≥50%
  - Randomization
  - Provisional
  - Crushing
  - Kissing balloon inflation
    - If, SB – DS ≥70%, TIMI≤2, or Dissection ≥C
    - TAP

*PCI for Bifurcation Lesions*
Simple Stenting Technique

*Single stent with provisional strategy*

*Stent placement in the main branch only*

and / or

1) Optional kissing balloon inflation
2) Provisional T stenting (TAP)
3) Provisional reverse crush technique
4) Provisional cullotte technique
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

Normal or diminutive side branch ostium

A B C D

Side branch

Main vessel

PCI for Bifurcation Lesions
Stent Distortion may

- Predispose to SAT
- Predispose to restenosis
- Limit subsequent access

Before KB

After KB

Ormiston CCI 1999;47:258
Proximal Optimization Technique

Before POT

After POT

Cypher 3.5×23 mm

Murray’s Law

\[(3.5 + 3.0) \times 0.67 = 4.35 \text{ mm}\]

Darremont, EBC 2007

PCI for Bifurcation Lesions
Provisional T Stenting

In cases with significant narrowing of side branch after main branch stenting

A
Jailed SB after MB stenting

B
SB stenting with minimal protrusion

C
Final kissing is necessary

D
Slightly protruded stent strut to MB
Tips of TAP Technique

SB stent should not be too distal leaving gaps

SB stent should not be too proximal potentially Obstructing main vessel
Tips of TAP Technique

High pressure sequential balloon dilatation followed by final KB dilatation

PCI for Bifurcation Lesions
“Internal” or “Reverse” Crush
allows provisional SB stenting without strut protrusion

A
Jailed SB after MB stenting

B
Balloon back-up in MB

C
Crushed second stent implanted in SB

D

PCI for Bifurcation Lesions
“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

E: Re-advancement of wire into the side branch
F: Opening of the side branch ostium
G: Final kissing balloon inflation
H:
Y (Culotte) Stenting

A  B  C  D

• Complete lesion coverage
• Too much stent overlap at the proximal segment

PCI for Bifurcation Lesions
Complex Stenting Techniques

Planned two stenting technology

1. Modified T stenting
2. Crush
3. Mini-crushing
4. V stenting
5. Simultaneous kissing stenting
Modified T-Stenting

A  B  C  D

Side branch

Main vessel + final kissing is recommended
Limitation of Modified T Stenting

Restenosis site of T stenting in SIRIUS bifurcation

Potential gap without enough drug diffusion

To prevent potential gap at the ostial side branch, the first stent should cover the entire surface of the side branch.
Modified T-Stenting
For Proper Ostial positioning

A
SB stent draw back

MB balloon 4-6 atm

B
MB balloon 4-6 atm
SB stent 16 atm

C
SB balloon Pull back 18-20 atm

D
MB balloon 12-16 atm
Minimal crush

E
MB stenting
Final kissing recommended

PCI for Bifurcation Lesions
Crush Technique

Proximal location of the stent in the main vessel

A

Side branch

Main vessel

B

C

D

PCI for Bifurcation Lesions
One More Step of Crush Technique

Final Kissing Balloon Dilatation
for side branch re-opening and stent optimization

- **E**: Re-advancement of wire into the side branch
- **F**: Opening of the side branch ostium
- **G**: Final kissing balloon inflation
- **H**: PCI for Bifurcation Lesions
Crush Technique

- Safe, quick, limited ischemic time
- Reliably treats the SB
- Always under control
- “Kissing” balloon post-dilation
  - the most difficult, but the most important

Before KB

After KB
Crush Technique

Limit the length of the 3 layers of overlap

Endothelization with a single layer of DES was better than with overlap.

Finn ACC 05
Crush Technique

Solution for recrossing

Difficulty wiring crushed sidebranch stent:
- Redilate main branch stent at high pressure
- Hydrophilic – PT2 or Whisper wires

Difficulty crossing:
- 1.25 or 1.5 balloon very helpful if difficulty getting back through struts
- ACE balloon if 1.25 or 1.5 fails
- Anchor balloon technique at distal main stent
- If that fails put two wires into side branch
- Pass another SB strut
SB Stent Underexpansion After Crush

Final optimal angiographic result

$\text{SB stent ostium}$

$\text{MV}$

$\text{SB distal stent}$

$r = 0.532$

$p < 0.006$

PCI for Bifurcation Lesions

Costa R. JACC 2006;46:599
Incomplete “Crush” Apposition

| Complete crush (apposition) of the SB stent – arrows indicate the 3 layers of stent struts | Incomplete crushing – incomplete apposition of the SB or PV stent struts against the MV wall proximal to the carina, found in >60% of non-LM lesions |

Costa R. JACC 2006;46:599
Malapposition at Bifurcation

OCT Evaluation;
100% stents have at least one strut malapposited

IVUS (40MHz) OCT

Strut?

Carlo Di Mario, TCT 2007
Crush Technique

High pressure sequential balloon dilatation followed by final KB dilatation

Crush 1  Crush 2  Crush 3  Crush 4  Crush 5  Crush 6  Crush 7

16-20 atm by KB with
Noncompliant B

Crush 8  Crush 9  Crush 10  Crush 11  Crush 12  Crush 13  Crush 14

Small balloon

HP

PCI for Bifurcation Lesions
Mini-Crush with balloon
Performed with 6~7Fr guiding catheter

A
Side branch
SB stenting and/or MB balloon back-up

B
Crush SB stent

C
MB stenting

D
V Stenting

- Bifurcation without stenosis proximal to the bifurcation
- Short LM
- Less angle
Simultaneous Kissing Stenting

- Large proximal reference
- Bifurcation with stenosis proximal to the bifurcation
<table>
<thead>
<tr>
<th>M</th>
<th>Main prox first</th>
<th>A</th>
<th>Main across side first</th>
<th>D</th>
<th>Distal first</th>
<th>S</th>
<th>Side branch first</th>
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<td>1st stent</td>
<td>1 PM stenting</td>
<td>6 MB stenting across SB</td>
<td>13 DM stenting</td>
<td>19 SB ostial stenting</td>
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<td>After Balloon</td>
<td>2 Skirt</td>
<td>7 MB stenting + SB balloon</td>
<td>14 Provisional SKS</td>
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6F Transradial incompatible
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<tr>
<td>After Balloon</td>
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<td>Inv. provisional SKS</td>
<td>Inv. DM ostial stenting</td>
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<td>DM minicrush</td>
<td>DM crush</td>
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<td>Inv. TAP culotte</td>
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**PCI for Bifurcation Lesions**
Choice of Two Stenting Technology

Based on Angulation

**T-shape:** ~ 25%

- >70°
  - Minimize crushed strut
    - T-stenting

**Y-shape:** ~ 75%

- <70°
  - Don’t miss SB ostium
    - Crush or Cullotte

Mini-Crush Can Work All Angulations
Dedicated Bifurcations Stents

**Dedicated Stent Platform**
- Extra-perimeter to best scaffold the side branch ostium
- Extra-perimeter to best withstand extra-deformation

**Cordis DBS**

**AST - Petal Stent**
- Dedicated Stent Platform + SDS
- Concave Iliac design
- 6 F Guiding Catheter compatible
- Special spheric SB balloon
  - Supposed to provide full (360°) ostium coverage

**Guidant - Frontier**

**DES Coated Petal**
- No webbing in narrow strut regions
- Coating comparable to commercialized TAXUS stent

**Phytis - Diamond Side Branch Stent**
- Special Stent Platform + Standard SDS
- DLC Coating (Diamond Like Carbon)
- 2 lengths available 13 mm and 17 mm
- Larser Cells to facilitate GW entry to the SB (1)
  - Very poor scaffolding of HV around the carina
  - Lack of SB ostium scaffolding

**PCI for Bifurcation Lesions**
Guidelines for Bifurcation PCI

• Assess the patient
  - Clinical presentation, LV EF, Age, Viability …

• Assess the lesion
  - Distribution of plaque
  - Angulation
  - Importance of SB

• Plan your strategy
  - Think several moves ahead
  - Have a backup
Selection of Stenting Strategy

Bifurcation lesion

1 wire

Minimal SB disease
Small SB size

2 wires

Less severe / Short SB stenosis

Difficult SB access / Long SB lesions

Provisional strategy

SB balloon ?

MB stent

Two stent technique
(Minicrush, Mod T, SKS, V)

SB DS<70%

Sequential HP balloon

SB DS≥70%

Kissing

No Kissing

Stent SB ? (T,TAP,RevCr,Cullotte)

Final KB mandatory

Final kissing mandatory

End of procedure

PCI for Bifurcation Lesions
PCI for Bifurcation Lesions

- DES implantation has dramatically improved long-term outcome of the main vessel in the bifurcation lesions.

- There is no perfect solution for bifurcation stenting with DES.

- Until now, no statement can be made regarding the most appropriate technique with DES for bifurcation lesions.

- Therefore, treatment decision should depend on each patient and each lesion.
Thanks for your time