How to select an optimal technique for bifurcation stenting?

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No disclosure
Bifurcation stenting problems

- Real clinical problem: occurrence 15-20%
- Huge variation in anatomy – vessel sizes differences, between vessels angulations, plaques distribution
- Conventional stent is not intended for bifurcations – stent deformation, drug coverage disruption
- High restenosis rates
- Higher rates of stent thrombosis
Bifurcation lesion treatment

Simple approach:
- provisional T stenting (PTS)

Complex approach:
- double stent techniques:
  Crush and Mini-Crush
  Simultaneous Kissing Stent (SKS)
  TAP
  Culotte
Influence of technique on outcome

Whatever technique is used it must be DES!
Guidelines on myocardial revascularization

The Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS)

Developed with the special contribution of the European Association for Percutaneous Cardiovascular Interventions (EAPCI)‡

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Bifurcation stenosis

Coronary stenoses are frequently located at bifurcations and bifurcation lesions still represent a major challenge for PCI, in terms of both procedural technique and clinical outcome. Bifurcation lesions are best described according to the Medina classification. Despite many attempts with a variety of different stenting techniques (T-stenting, Y-stenting, crush, and its modifications, culotte, etc.), the optimal strategy for every anatomical subset has not yet been established. Variables to be considered are plaque distribution, size and downstream territory of each vessel (main and side branch), and the bifurcation angle. Stent implantation in the main vessel only, followed by provisional angioplasty with or without stenting of the side branch, seems preferable compared with routine stenting of both vessels. FFR data from side branches suggest that angiography overestimates the functional severity of side branch stenosis. Final kissing balloon dilatation is recommended when two stents are eventually required. Several stents designed specifically for treatment of bifurcation lesions have undergone extensive evaluation with good angiographic and clinical results, especially with side branch size >2.5 mm. Comparative RCTs vs. provisional stenting are lacking.

The above comments apply to PCI of (unprotected) LM lesions, when indicated (Section 6). For bifurcation and LM lesions, DESs are preferred with special attention to adequate sizing and deployment. For treatment of small vessels (<2.5 mm), DESs with strong antiproliferative properties (late lumen loss <0.2 mm) are preferred to reduce restenosis rates.210
Main vessel stenting only – always optimal strategy?
Myonecrosis (LGE) in the area perfused by side branch

Pre PCI

Post PCI

Myonecrosis (LGE) in the area of septal branch lost during stent placement

Pre PCI

Post PCI

Michalek et al. presented on TCT 2009
Concept of Carina Displacement

Vassilev & Gil, Polish Heart Jour. 2008, April
Vassilev & Gil Jour. Geriatric. Card. 2008 June
Vassilev & Gil Jour. Geriatric Card. 2008 March
Correlation between predicted and observed SB compromise

\[ r = 0.85 \]

\[ \%DS = \cos \alpha; \quad \text{MLD} = ds \left(1 - \cos \alpha\right) \]
Not every SB is compromised significantly!

Physiologic Assessment of Jailed Side Branch Lesions Using Fractional Flow Reserve

38% of lesions > 75% stenosis

Bon-Kwon Koo JACC 2005; 46: 633-7
Difference between MLD (% Diameter Stenosis) and MLA (% Area Stenosis)

$\text{MLA}_{\text{ELLIPSE}} \ggg \text{MLA}_{\text{CIRCLE}}$ !!!
Factors governing SB compromise
(significant, anatomical and functional, stenosis at SB ostium after MV stenting)

- Carina displacement
- Carina length
- Plaque shift
- Ostial spasm
- Ostial dissection
- Local thrombosis
- Stent strut obstruction

FOR SB OSTIAL STENOSIS PARAMETERS:
- IF THERE IS PARTIAL CARINA DISPLACEMENT
  \[ \%DS = \frac{\sin (\alpha - \alpha \, ^\prime)}{\tan (\alpha)} \]
  \[ \text{MLD} = ds (1 - \%DS) \]

Vassilev D, Gil RJ. Polish Heart Journal, 2008
Importance of carina length for extent of SB compromise

Carina length deficit

Carina length excess
The role of the CL on deviation of observed SB compromise from expected according to cosine formula (84 pts, 92 bif’s)
Higher branching angle predicts higher restenosis rates and worse survival

Dzavik et al.  
Am Heart J 2006;152:76229

T. Adriaenssens et al.  

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age increase by 10 years</td>
<td>2.38 (1.21–4.98)</td>
<td>0.01</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3.43 (0.71–16.60)</td>
<td>0.13</td>
</tr>
<tr>
<td>Male sex</td>
<td>0.62 (0.15–2.53)</td>
<td>0.51</td>
</tr>
<tr>
<td>Medina classification</td>
<td>0.42 (0.13–1.32)</td>
<td>0.14</td>
</tr>
<tr>
<td>Restenotic lesion</td>
<td>0.52 (0.12–2.24)</td>
<td>0.38</td>
</tr>
<tr>
<td>Bifurcation angle increase by 10°</td>
<td>1.53 (1.04–2.23)</td>
<td>0.03</td>
</tr>
<tr>
<td>Calcified lesion</td>
<td>0.53 (0.12–2.24)</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Proximal main vessel
- Reference vessel diameter decrease by 1 mm: 4.55 (0.17–123.36) 0.37
- Baseline stenosis increase by 10%: 0.91 (0.67–1.23) 0.54

Distal main vessel
- Reference vessel diameter decrease by 1 mm: 0.10 (0.00–3.17) 0.19
- Baseline stenosis increase by 10%: 1.47 (1.03–2.09) 0.03

Side branch vessel
- Reference vessel diameter decrease by 1 mm: 31.83 (1.71–592.77) 0.02
- Baseline stenosis increase by 10%: 0.97 (0.82–1.15) 0.75
- Kissing balloon post-dilatation: 0.37 (0.13–1.10) 0.07

Predictors of binary restenosis. CI, confidence interval.
Bifurcation lesion treatment

Simple approach:
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Complex approach:
- double stent techniques:
  Crush and Mini-Crush
  Simultaneous Kissing Stent (SKS)
  TAP
  Culotte
Eight Months Angiographic Follow-up in Patients Randomized to Crush or Culotte Stenting of Coronary Artery Bifurcation Lesions

**Primary endpoint**
Cardiac death, myocardial infarction, TVR and stent thrombosis after 6 months

![Graph showing primary endpoint comparison between Crush and Culotte stenting.](image)

- Crush: 4.3%
- Culotte: 3.7%

P = 0.8
Clinical Outcomes in Trials Comparing One-DES (1S) vs. Two-DES (2S) Strategy in Treating Coronary Bifurcations

MACE

TLR

Colombo et al.
SES stents (n=85)

Hildick et al.
BBC ONE (n=500)

Ferenc et al.
T-stenting (n=202)

Steigen et al.
NORDIC Trial (n=413)

Colombo et al.
CACTUS trial (n=85)

Pan et al.
SES stents (n=91)

Sharma et al.
PRECISE-SKS (n=100)

%
Clinical Outcomes in Trials Comparing One-DES (1S) vs. Two-DES (2S) Strategy in Treating Coronary Bifurcations

Stent Thrombosis

<table>
<thead>
<tr>
<th>Study</th>
<th>1S Group (%)</th>
<th>2S Group (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombo et al. SES stents</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Hildick et al. BBC ONE</td>
<td>2.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Ferenc et al. T-stenting</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Steigen et al. NORDIC Trial</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Colombo et al. CACTUS trial</td>
<td>1.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Pan et al. SES stents</td>
<td>0</td>
<td>2.0</td>
</tr>
<tr>
<td>Sharma et al. PRECISE-SKS</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: The numbers represent the percentage of stent thrombosis in each group for the respective studies.
# NORDIC I + BBC I composed metaanalysis

<table>
<thead>
<tr>
<th>Event</th>
<th>Simple (n=457)</th>
<th>Complex (n=456)</th>
<th>HR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause death, myocardial infarction (periprocedural and subsequent) or target vessel revascularization at 9 months</td>
<td>46 (10.1%)</td>
<td>79 (17.3%)</td>
<td>1.84 (1.28–2.66)</td>
<td>0.001</td>
</tr>
<tr>
<td>All-cause death, myocardial infarction (subsequent alone) or target vessel revascularization at 9 months</td>
<td>32 (7.0%)</td>
<td>41 (9.0%)</td>
<td>1.38 (0.87–2.20)</td>
<td>0.168</td>
</tr>
<tr>
<td>All-cause death</td>
<td>5 (1.0%)</td>
<td>5 (1.0%)</td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>Periprocedural</td>
<td>2 (0.4%)</td>
<td>3 (0.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsequent</td>
<td>3 (0.6%)</td>
<td>2 (0.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>22 (4.8%)</td>
<td>56 (12.3%)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Periprocedural</td>
<td>16 (3.5%)</td>
<td>45 (9.9%)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Subsequent</td>
<td>6 (1.3%)</td>
<td>11 (2.4%)</td>
<td></td>
<td>0.22</td>
</tr>
<tr>
<td>Target vessel revascularization</td>
<td>26 (5.7%)</td>
<td>33 (7.2%)</td>
<td></td>
<td>0.34</td>
</tr>
<tr>
<td>PCI</td>
<td>24 (5.3%)</td>
<td>20 (4.4%)</td>
<td></td>
<td>0.54</td>
</tr>
<tr>
<td>CABG</td>
<td>2 (0.4%)</td>
<td>13 (2.9%)</td>
<td></td>
<td>0.004</td>
</tr>
<tr>
<td>Stent thrombosis (ARC definite)</td>
<td>3 (0.7%)</td>
<td>6 (1.3%)</td>
<td></td>
<td>0.31</td>
</tr>
<tr>
<td>In-hospital</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>2 (0.4%)</td>
<td>3 (0.6%)</td>
<td></td>
<td>0.65</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>17 (3.7%)</td>
<td>45 (9.9%)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CABG</td>
<td>0 (0.0%)</td>
<td>4 (0.8%)</td>
<td></td>
<td>0.04</td>
</tr>
</tbody>
</table>

PCI indicates percutaneous coronary intervention; CABG, coronary artery bypass graft; ARC, academic research consortium.
A Randomized Clinical Study Comparing Double Kissing Crush With Provisional Stenting for Treatment of Coronary Bifurcation Lesions: DK Crush II Study

Chen S et al, JACC 2011;57:914
# NORDIC I + BBC I composed metaanalysis (simple vs complex)

**Table 5. Trial End Points for Different Subgroups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Total (n=913)</th>
<th>True Bifurcation (n=657)</th>
<th>SB ≥2.75 mm (n=281)</th>
<th>Bilirucation Angle &gt;60–70° (n=217)</th>
<th>SB Lesion Length &gt;5 mm (n=464)</th>
<th>SB Diameter ≥2.75 mm + Lesion Length &gt;5 mm (n=137)</th>
<th>Equivalence (n=108)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite</td>
<td>10.1% vs 17.3%*</td>
<td>9.2% vs 17.3%†</td>
<td>10.4% vs 20.7%†</td>
<td>9.6% vs 15.7%</td>
<td>12.1% vs 19.1%†</td>
<td>11.6% vs 19.15%</td>
<td>12.0% vs 15.5%</td>
</tr>
<tr>
<td>Death</td>
<td>1.0% vs 1.0%</td>
<td>0.6% vs 0.9%</td>
<td>0.8% vs 1.9%</td>
<td>0.9% vs 1.0%</td>
<td>1.4% vs 2.0%</td>
<td>0% vs 3.2%</td>
<td>0% vs 1.7%</td>
</tr>
<tr>
<td>MI (total)</td>
<td>4.8% vs 12.3%*</td>
<td>4.6% vs 12.6%*</td>
<td>6.1% vs 13.2%</td>
<td>6.1% vs 11.8%</td>
<td>4.8% vs 14%*</td>
<td>6.96% vs 14.89%</td>
<td>8.0% vs 12.1%</td>
</tr>
<tr>
<td>TVR</td>
<td>5.7% vs 7.2%</td>
<td>5.5% vs 7.3%</td>
<td>4.3% vs 8.2%</td>
<td>4.3% vs 2.9%</td>
<td>7.2% vs 7.4%</td>
<td>4.65% vs 4.26%</td>
<td>6.0% vs 6.9%</td>
</tr>
<tr>
<td>ST</td>
<td>0.7% vs 1.3%</td>
<td>0.6% vs 1.1%</td>
<td>0.0% vs 1.9%</td>
<td>0% vs 0%</td>
<td>1.0% vs 1.2%</td>
<td>0% vs 1.3%</td>
<td>0% vs 5.0%</td>
</tr>
</tbody>
</table>

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**No benefits from complex**

Choice of stenting strategy in true coronary artery bifurcation lesions.
Lin QF et al.: *Coron Artery Dis* 2010, Sep; 21 (6): 345-51

108 pts with true BL treated with SES+PES;

Population:    Group 1 – routine 2 vessels stenting  
                Group 2 – provisional T stenting

Follow-up – 8 months; MACE (MI, cardiac death, stent thrombosis, TVR)

**Conclusion:**

Routine stenting significantly improved the MACE outcome of PCI in true coronary bifurcation and bifurcation angle of 60 or less as compared with provisional stenting.
New classification of bifurcation lesions – based on risk of side branch occlusion and restenosis occurrence in *main vessel*

<table>
<thead>
<tr>
<th>SB Classification</th>
<th>Alpha &lt; 40°</th>
<th>Alpha &gt; 40°</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. SB &lt; 2 mm</td>
<td>IA</td>
<td>IB</td>
</tr>
<tr>
<td>II. SB &gt; 2 mm</td>
<td>IIA</td>
<td>IIB</td>
</tr>
</tbody>
</table>

Log-rank \( p = .007 \)

Vassilev, Gil et al. Polish Heart J. 2008

Algorithm for Bifurcation Lesions

**DES for Bifurcation lesion**

### Side-branch size

- **>2.75 mm**
- **2.00 – 2.75 mm**
- **<2.00 mm**

### Bifurcation stenting

- “SKS” technique
- “T” stent technique
- “Cullote” technique
- “Mini-Crush” technique
- “DKCRUSH” technique

### Plaque modification of the side-branch

- Atherotomy, Rota
  - Leave the wire in the SB
  - GP IIb/IIIa inhibitors

### Stent only the main vessel

- Stent only the main vessel
- For side-branch...
  - Even if goes down: Ignore & increase Beta-blockers

### Lesion preparation: Rota, CB

- Save the 2nd stent for restenosis
Bifurcations - Anatomic considerations

- Main Vessel: 1.70 - 4.18 mm
- Side Branch: 1.59 - 2.59 mm

Arterial taper: SB taper greater by 2.5-fold

- Proximal vessel diameter
- Distal vessel diameter
- Ostial Diameter
- Side Branch diameter

- Main Vessel Proximal to Distal Taper (Main Vessel): 0.08
- Side Branch Ostium to Side Branch Taper (Side Branch): 0.20

M. Russel TCT 2009
Stent cell size requirements (with ideal positioning against SB/MB opening)

\[ SBOD = \frac{SB \ RVD}{\sin \alpha} \]
\[ MBOD = \frac{MB \ RVD}{\sin \alpha} \]

SBOD is important for Crush stenting

MBOD is important for Culotte stenting
SBOD is important for Crush stenting

MBOD is important for Culotte stenting

Dependence of distance A from bifurcation angle

Distance A in mm at different sizes of side branches

bifurcation angle (degrees)

<table>
<thead>
<tr>
<th>Angle (degrees)</th>
<th>SB-2.0</th>
<th>SB-2.5</th>
<th>SB-3.0</th>
<th>SB-3.5</th>
<th>MB-2.5</th>
<th>MB-3.0</th>
<th>MB-3.5</th>
<th>MB-4.0</th>
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</thead>
<tbody>
<tr>
<td>20</td>
<td>5.84</td>
<td>7.30</td>
<td>8.77</td>
<td>10.23</td>
<td>7.30</td>
<td>8.77</td>
<td>10.23</td>
<td>11.69</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>40</td>
<td>3.11</td>
<td>3.88</td>
<td>4.66</td>
<td>5.44</td>
<td>3.88</td>
<td>4.66</td>
<td>5.44</td>
<td>6.22</td>
</tr>
<tr>
<td>50</td>
<td>2.61</td>
<td>3.26</td>
<td>3.91</td>
<td>4.66</td>
<td>3.26</td>
<td>3.91</td>
<td>4.66</td>
<td>5.22</td>
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<td>60</td>
<td>2.30</td>
<td>2.88</td>
<td>3.46</td>
<td>4.04</td>
<td>2.88</td>
<td>3.46</td>
<td>4.04</td>
<td>4.61</td>
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<tr>
<td>70</td>
<td>2.12</td>
<td>2.66</td>
<td>3.19</td>
<td>3.72</td>
<td>2.66</td>
<td>3.19</td>
<td>3.72</td>
<td>4.25</td>
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<tr>
<td>80</td>
<td>2.03</td>
<td>2.53</td>
<td>3.04</td>
<td>3.55</td>
<td>2.53</td>
<td>3.04</td>
<td>3.55</td>
<td>4.06</td>
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<tr>
<td>90</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
</tr>
</tbody>
</table>

SBOD          MBOD
# Stent`s design and geometrical implications

<table>
<thead>
<tr>
<th>3.5 mm stents</th>
<th>Maximum cell diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioDyvisio (Abbott)</td>
<td>2.9</td>
</tr>
<tr>
<td>Bx Velocity (Cordis)</td>
<td>3.0</td>
</tr>
<tr>
<td>Carbostent (Sorin)</td>
<td>3.0</td>
</tr>
<tr>
<td>Express (Boston)</td>
<td>3.7</td>
</tr>
<tr>
<td>Liberte</td>
<td>4.5</td>
</tr>
<tr>
<td>Flexstent (Jomed)</td>
<td>2.9–3.6</td>
</tr>
<tr>
<td>Penta (Abbott)</td>
<td>4.0</td>
</tr>
<tr>
<td>Driver</td>
<td>6.5</td>
</tr>
<tr>
<td>R stent (Orbus)</td>
<td>4.5</td>
</tr>
<tr>
<td>Chopin2 (Balton)</td>
<td>3.97</td>
</tr>
</tbody>
</table>

Modified from Louvard et al. Heart 2004
What is best solution?

Provisional T-stenting with dedicated bifurcation stent
„Ideal” bifurcation stent

1. Stent which restore anatomical MV – MB sizes without need of additional dilatation
2. Stent which keeps good access to SB allowing for second stent implantation
3. Drug eluting stent with biodegradable carrier
4. Stent easy for handling with very high procedural success
Thank you!