PCI for Bifurcations: Techniques and Outcomes

Fellows Workshop
June 2014

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Bifurcation PCI

• Account for 15-20% of PCI
• Why an individualized approach?
  – Variations in Anatomy
    ▪ Left main bifurcation disease
    ▪ Plaque burden & location of plaque
    ▪ Angle between MB and SB
  – Dynamic changes in anatomy during treatment
    ▪ Plaque shift
    ▪ Dissection
    **No two bifurcations are identical**
• An appropriate strategy from the outset saves time and minimizes complication
Medina Classification

Medina et al. Rev. Esp. Cardiol 2006; 59(2): 183-4
Classifications of lesions

Duke
Type A
Prebranch stenosis not involving the ostium of the side branch
Type B
Prebranch 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 only
Type E
Stenosis involving the ostium of the side branch only
Type F
Stenosis discretely involving the ostium of the side branch

Sanborn
Type I
True bifurcation lesion
Type II
One-sided asymmetric lesion where only one branch is diseased
Type III
Bifurcation lesion where parent vessel is free of disease and both branches have ostial disease
Type IV
Lesion in the parent vessel either before or after the take off of a side branch that may or may not have additional ostial disease

Safian
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

ICPS-Lefèvre
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
Lesions located only in the ostium of side branch

Movahed

Chen - Gao
Bifurcation Stenting: Diverse Lesion Profile

* Type 1 and 2 most difficult to treat comprise nearly 70% of lesions
* Only Type 3 Requires Single Stent

Type 1
N=15 (18.8%)

Type 2
N=39 (48.8%)

Type 3
N=7 (8.8%)

Type 4
N=10 (12.5%)

Type 4a
N=5 (6.3%)

Type 4b
N=4 (5.0%)
The provisional approach of implanting one stent in the MB should be the default approach in most bifurcations lesions

The approach is dictated by the SB:
- True vs. Non-true
- Size of SB
- Extent and distribution of disease in SB
- How important the side branch is for that patient and for that specific anatomy
- Angle from the main branch
## Randomized Bifurcation Trials

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients (N)</th>
<th>Randomization</th>
<th>Primary End Point</th>
<th>Outcome (Provisional vs Systematic Unless Otherwise Specified)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORDIC</td>
<td>413</td>
<td>Provisional vs systematic (crush, culotte, T)</td>
<td>Death, MI (nonprocedural), TVR, or stent thrombosis at 6 mo</td>
<td>2.9% vs 3.4% (P=NS)</td>
</tr>
<tr>
<td>CACTUS</td>
<td>350</td>
<td>Provisional vs systematic (crush)</td>
<td>Death, MI, TVR at 6 mo</td>
<td>15% vs 15.8% (P=NS)</td>
</tr>
<tr>
<td>BBC ONE</td>
<td>500</td>
<td>Provisional vs systematic (crush, culotte)</td>
<td>Death, MI, TVF at 9 mo</td>
<td>8.0% vs 15.2% (P&lt;0.05)</td>
</tr>
<tr>
<td>Ference et al.</td>
<td>202</td>
<td>Provisional vs systematic (T)</td>
<td>Death, MI, TVF at 9 mo, Angiographic restenosis (side branch) 9 mo</td>
<td>23.0% vs 27.7% (P=NS)</td>
</tr>
<tr>
<td>Colombo et al.</td>
<td>85</td>
<td>Provisional vs systematic (crush, T, culotte)</td>
<td>Angiographic restenosis (either branch) 6 mo</td>
<td>18.7% vs 28.0% (P=NS)</td>
</tr>
<tr>
<td>Pan et al.</td>
<td>91</td>
<td>Provisional vs systematic (T)</td>
<td>Angiographic restenosis (either branch) 6 mo</td>
<td>7% vs 25% (P=NS)</td>
</tr>
<tr>
<td>NORDIC 2</td>
<td>424</td>
<td>Systematic (crush vs culotte)</td>
<td>Death, MI (nonprocedural), TVR, or stent thrombosis at 6 mo</td>
<td>Crush 4.3% vs culotte 3.7% (P=NS)</td>
</tr>
</tbody>
</table>
Meta-Analysis - Bifurcations with DES
One (Provisional) vs Two Stents

Side Branch Restenosis
Angiographic outcome -> No difference

Brar SS et al. Eurointervention 2009;5:475:84
Meta-Analysis - Bifurcations with DES
One (Provisional) vs Two Stents

TLR

Clinical outcome -> No difference

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Events / Total</th>
<th>MH risk ratio and 95% CI</th>
<th>Statistics for each study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisional</td>
<td></td>
<td></td>
<td>MH risk</td>
<td>Lower limit</td>
</tr>
<tr>
<td>Pan et al</td>
<td>2004</td>
<td>1 / 47</td>
<td>0.47</td>
<td>0.04</td>
</tr>
<tr>
<td>Colombo et al</td>
<td>2004</td>
<td>1 / 22</td>
<td>0.48</td>
<td>0.06</td>
</tr>
<tr>
<td>NORDIC</td>
<td>2006</td>
<td>4 / 207</td>
<td>1.99</td>
<td>0.37</td>
</tr>
<tr>
<td>Ferenc et al</td>
<td>2008</td>
<td>11 / 101</td>
<td>1.22</td>
<td>0.53</td>
</tr>
<tr>
<td>BBC ONE</td>
<td>2008</td>
<td>14 / 250</td>
<td>0.78</td>
<td>0.40</td>
</tr>
<tr>
<td>CACTUS</td>
<td>2009</td>
<td>11 / 173</td>
<td>0.87</td>
<td>0.40</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>42 / 800</td>
<td>0.91</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Test for heterogeneity: Q=2.2, df=5, P=0.82 I²=0%
Test for overall effect: Z=-0.49, P=0.63

Fixed Effects Model

Brar SS et al. Eurointervention 2009;5:475:84
Meta-Analysis - Bifurcations with DES
One (Provisional) vs Two Stents

Myocardial Infarction
Provisional -> Significantly lower

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Events / Total</th>
<th>Two Stents</th>
<th>MH risk ratio and 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Provisional</td>
<td>MH risk ratio</td>
</tr>
<tr>
<td>Pan et al</td>
<td>2004</td>
<td>2 / 47</td>
<td>0 / 44</td>
<td>4.69</td>
</tr>
<tr>
<td>Colombo et al</td>
<td>2004</td>
<td>2 / 22</td>
<td>7 / 63</td>
<td>0.82</td>
</tr>
<tr>
<td>NORDIC</td>
<td>2006</td>
<td>0 / 207</td>
<td>1 / 206</td>
<td>0.33</td>
</tr>
<tr>
<td>Ferenc et al</td>
<td>2008</td>
<td>1 / 101</td>
<td>2 / 101</td>
<td>0.50</td>
</tr>
<tr>
<td>BBC ONE</td>
<td>2008</td>
<td>9 / 250</td>
<td>28 / 250</td>
<td>0.32</td>
</tr>
<tr>
<td>CACTUS</td>
<td>2009</td>
<td>15 / 173</td>
<td>19 / 177</td>
<td>0.81</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>29 / 800</td>
<td>57 / 841</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Test for heterogeneity: $Q=5.72$, $df=5$, $P=0.33$ $I^2=13\%$
Test for overall effect: $Z=-2.58$, $P=0.01$

Brar SS et al. Eurointervention 2009;5:475:84
Stent Thrombosis

Provisional $\rightarrow$ "Trend" for lower Stent thrombosis

**Meta-Analysis - Bifurcations with DES One (Provisional) vs Two Stents**

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Events / Total</th>
<th>MH risk ratio and 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Two</strong></td>
</tr>
<tr>
<td>Provisional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan et al</td>
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<td>0 / 47</td>
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<tr>
<td>Colombo et al</td>
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<td>0 / 22</td>
<td>3 / 63</td>
</tr>
<tr>
<td>NORDIC</td>
<td>2006</td>
<td>1 / 207</td>
<td>0 / 206</td>
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<tr>
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<td>2008</td>
<td>2 / 101</td>
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</tr>
<tr>
<td>BBC ONE</td>
<td>2008</td>
<td>1 / 250</td>
<td>5 / 250</td>
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<tr>
<td>CACTUS</td>
<td>2009</td>
<td>2 / 173</td>
<td>3 / 177</td>
</tr>
<tr>
<td>Overall</td>
<td>2009</td>
<td>6 / 800</td>
<td>14 / 841</td>
</tr>
</tbody>
</table>

Test for heterogeneity: $Q=2.2$, df=3, $P=0.52 \, I^2=0\%$
Test for overall effect: $Z=-0.76$, $P=0.45$

**Fixed Effects Model**

Brar SS et al. Eurointervention 2009;5:475:84
Patient-Level Pooled-Analysis of Nordic 1 and BBC

Primary outcome (death, MI, TVR) for individual subgroups

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Odds ratio and 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>True bifurcations (657)</td>
<td>1.90 (1.22-2.94)</td>
</tr>
<tr>
<td>Angle&lt;60-70° (217)</td>
<td>1.67 (0.78-3.62)</td>
</tr>
<tr>
<td>SB diameter≥2.75mm (281)</td>
<td>2.42 (1.22-4.80)</td>
</tr>
<tr>
<td>SB lesion&gt;5mm (464)</td>
<td>1.71 (1.05-2.77)</td>
</tr>
<tr>
<td>SB diameter≥2.75mm/lesion&gt;5mm (137)</td>
<td>1.84 (0.68-4.97)</td>
</tr>
<tr>
<td>Equivalence (108)</td>
<td>1.35 (0.48-3.70)</td>
</tr>
<tr>
<td>Total (913)</td>
<td>1.84 (1.28-2.66)</td>
</tr>
</tbody>
</table>

Favours Simple  Favours Complex

5 Year Follow-Up Nordic Bifurcation Study
Simple vs Complex Stenting Strategy in Non-LM PCI

- MACE event were low and did not differ significantly in patients treated with a simple versus a complex bifurcation stenting technique.

- Stent thrombosis rate was not increased in patients treated with 2-stents.
Meta-Analysis: NORDIC I & BBC I (Non LM Bifurcations)
Probability of MACE (Death/MI/TVR)

In the Nordic-BBC meta analysis the average SB stenosis was 59% and 65% for the simple & complex strategy respectively.

In many of these trials, up to 25% of patients have no SB disease.
In non-LM bifurcation PCI multiple studies have demonstrated the superiority of IVUS guidance over angiographic guidance. More durable long term outcomes.

- Kim et al. Am Heart J 2011;161:180-7
  - Bifurcation lesions, propensity score matching (n=487 in each group)
- Kim et al. Am J Cardiol 2010;106:612-8
  - Bifurcation lesions, propensity score matching (n=303 / n=111)
- Patel et al. Am J Cardiol,
  - Bifurcation lesions, propensity score matching (n=247 / n=202)
An Important Principle of IVUS Imaging
Direct Imaging of Both Parent & Daughter Vessel

Indirect LAD imaging

Direct LAD imaging

Tangential Imaging

LAD

Diagonal branch appears disease free

Direct Imaging

Diagonal
IVUS Guidance Saves Lives in UPLM PCI

A finding yet to be convincingly demonstrated in Non-LM bifurcation PCI

DK Crush Technique
Double Kiss and Crush

Figure 4. Double kissing (DK) crush technique. Two wires are inserted into two vessels (a). One stent and balloon are advanced into side branch and main vessel simultaneously (b). Inflated side stent firstly (c), then the balloon in the main artery is inflated after removal of stent balloon and wire from side branch (d). First kissing balloon inflation is performed after successful rewiring to side branch (e). Stenting main vessel is underwent (f), with final kissing inflation as the final step (g). The orifice of side branch is relatively largely expanded, compared to classical crush (g).
1 Year Outcomes DK Crush Versus Provisional Stenting

- **↓TLR and ↓TVR favoring DK Crush**
- **↓ in MB and SB angiographic restenosis favoring DK Crush**
- **Trend toward reduced MACE**

### Table 1. One-Year Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Double Kissing Crush</th>
<th>Provisional Stenting</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MACE</strong></td>
<td>10.3%</td>
<td>17.3%</td>
<td>0.070</td>
</tr>
<tr>
<td><strong>Cardiac Death</strong></td>
<td>1.1%</td>
<td>1.1%</td>
<td>1.000</td>
</tr>
<tr>
<td><strong>MI</strong></td>
<td>3.2%</td>
<td>2.2%</td>
<td>0.751</td>
</tr>
<tr>
<td><strong>TVR</strong></td>
<td>6.5%</td>
<td>14.6%</td>
<td>0.017</td>
</tr>
<tr>
<td><strong>TLR</strong></td>
<td>4.3%</td>
<td>13.0%</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>Definite Stent Thrombosis</strong></td>
<td>2.2%</td>
<td>0.5%</td>
<td>0.372</td>
</tr>
</tbody>
</table>

DK Crush in non-LM Bifurcation
DK CRUSH vs Cuolotte in UPLM

<table>
<thead>
<tr>
<th></th>
<th>DK Crush (n = 176)</th>
<th>Culotte (n = 174)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-stent Restenosis</td>
<td>6.8%</td>
<td>12.6%</td>
<td>0.037</td>
</tr>
<tr>
<td>Diameter Stenosis</td>
<td>16.39 ± 7.45%</td>
<td>25.50 ± 7.36%</td>
<td>0.001</td>
</tr>
<tr>
<td>In-stent Late Loss, mm</td>
<td>0.20 ± 0.30</td>
<td>0.39 ± 0.36</td>
<td>0.001</td>
</tr>
</tbody>
</table>

At 1 year, the primary endpoint of MACE (cardiac death, MI, and TVR) was more than halved in the DK crush group, driven mainly by a reduction in TVR. TLR was also decreased in the DK crush group (table 2).

Table 2. One-year Outcomes

<table>
<thead>
<tr>
<th></th>
<th>DK Crush (n = 210)</th>
<th>Culotte (n = 209)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACE</td>
<td>6.2%</td>
<td>16.3%</td>
<td>0.001</td>
</tr>
<tr>
<td>Cardiac Death</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.0</td>
</tr>
<tr>
<td>MI</td>
<td>3.3%</td>
<td>5.3%</td>
<td>0.377</td>
</tr>
</tbody>
</table>

ACC 2013
# The DKCRUSH studies: An Overview

<table>
<thead>
<tr>
<th></th>
<th>DKCRUSH-1</th>
<th>DKCRUSH-II</th>
<th>DKCRUSH-III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesion types</td>
<td>111/011/101</td>
<td>111/011</td>
<td>111/011</td>
</tr>
<tr>
<td>Techniques</td>
<td>DK/crush</td>
<td>DK/provisional</td>
<td>DK/culotte</td>
</tr>
<tr>
<td>DES</td>
<td>PES</td>
<td>SES</td>
<td>SES</td>
</tr>
<tr>
<td>Locations</td>
<td>all</td>
<td>all</td>
<td>LM</td>
</tr>
<tr>
<td>SB diameter</td>
<td>2.0 mm</td>
<td>&gt;2.5 mm</td>
<td>LCX</td>
</tr>
<tr>
<td>lesion length</td>
<td>10.2 mm</td>
<td>11.3 mm</td>
<td>16.9 mm</td>
</tr>
<tr>
<td>MI (not acute)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CTO</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>No. patients</td>
<td>312</td>
<td>370</td>
<td>420</td>
</tr>
<tr>
<td>Endpoint</td>
<td>MACE 8-m</td>
<td>MACE 12-m</td>
<td>MACE 12-m</td>
</tr>
</tbody>
</table>

C/o S. Chen, from EJCI, JACC, JACC
<table>
<thead>
<tr>
<th>DKCRUSH studies: Angiographic/Procedural Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>DKCRUSH-1 Crush vs DK</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>RVD-MV, mm</td>
</tr>
<tr>
<td>RVD-SB, mm</td>
</tr>
<tr>
<td>DS-SB, %</td>
</tr>
<tr>
<td>No. stent in SB</td>
</tr>
<tr>
<td>FKBI, %</td>
</tr>
<tr>
<td>Proc. Time (min)</td>
</tr>
</tbody>
</table>

c/o S. Chen, from EJCI, JACC, JACC
How Often We Need 2nd Stent after MV Stent?

Crossover from 1 Stent to 2 Stents

Nordic-Baltic Bifurcation Study III

(Re)stenosis at 8-months QCA: Entire bifurcation lesion

Binary Restenosis: ≥50% diameter stenosis at follow-up
True bifurcation subgroup MACE and TLR at 6 month clinical FU

- MACE
  - FKBD (n=121): 2.5%
  - No-FKBD (n=118): 0.8%
  - P=0.62

- TLR
  - FKBD (n=121): 1.7%
  - No-FKBD (n=118): 1.7%
  - P=0.68
What is a “Complex Bifurcation”? 

SB stenosis severity 

SB Size

Diameter & Length 

SB stenosis length 

SB takeoff angle, Ca++, etc
Provisional Stenting Technique
Why wire both branches in Provisional Stenting

- Protects SB from closure due to plaque shift and/or stent struts during MB stenting

- Jailed SB wire facilitates re-wiring of the SB:
  - Widening the angle between the MB and SB
  - By acting as a marker for the SB ostium if SB occludes
  - Changing the angle of SB take-off

- In the Tulipe multicenter study, absence of this jailed wire was associated with a higher rate of re-interventions (OR: 4.26; 1.27–14.35) during follow-up

- CAUTION WHEN REMOVING JAILED WIRES!
Why Protect SB’s from Closure?

- Occlusion of SB’s >1mm associated with 14% incidence of myocardial infarction

- SB closure associated with large periprocedural MI
Murray’s law

3.68 = 0.67 \times (3.0 + 2.5)

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

D_{1} = 0.678 (D_{2} + D_{3})

D_{1}^3 = D_{2}^3 + D_{3}^3

(Murray’s law)

Insights from the 2nd meeting of the EBC. EuroIntervention 2007;3:44
The 3 Diameter Rule

Recommendations:
- In single stent techniques, the primary stent should be sized according to the distal main vessel diameter.
- Postdilatation (POT), or kissing balloon inflations (FKB), are required to optimise the proximal main vessel stent diameter.

D1 = 0.67 * (D2 + D3)

Insights from the 4\textsuperscript{nd} meeting of the EBC. EuroIntervention 2009;5:39-49
Consensus from 5\textsuperscript{th} EBC meeting. EuroIntervention 2010;6(1):34-8
Proximal Optimisation Technique (POT)

D1 = 0.67 * (D2 + D3)

- Expansion of the stent at the carina, using a short oversized balloon
- Produces curved expansion of the stent into the bifurcation point and facilitates recrossing, distal recrossing, kissing inflations and ostial stent coverage of the side branch

**First Recommendation:** the POT technique should be used in any case of difficulty recrossing into a side branch

Consensus from 5th EBC meeting. EuroIntervention 2010;6(1):34-8
Second Recommendation:
• When using a single stent technique (in the absence of kissing balloon inflations) the proximal main vessel stent should be postdilated (POT) to an appropriate diameter.
Stent diameter = DM diameter

$D_1 = \frac{(D_2 + D_3)}{2/3}$

Stent diameter = PM diameter
After MV stenting, cross into the SB through the distal strut

In the provisional technique, wire cross following MV stenting should be done through the distal strut, because it creates better SB scaffolding than a proximal crossing.

Insights from the 4\textsuperscript{th} meeting of the EBC. EuroIntervention 2009;5:39-49
Stent diameter = PM diameter

D1 = \frac{(D2 + D3)}{2/3}

Stent diameter = DM diameter

Wire should cross the MV into the SB through the distal strut

- **Recommendation**: When rewiring a side branch, efforts should be made to cross the main vessel stent **distally**, thereby ensuring stent coverage of the ostium of the side branch

Consensus from 5th EBC meeting. EuroIntervention 2010;6(1):34-8
MV Stent Distortion after FKBD

Distal cross → Good SB scaffolding after kissing

Proximal cross → Poor SB scaffolding after kissing

Albiero Remo, MD from 4th EBC meeting
Side-Branch Stenosis Functional Significance – FFR

Correlation between FFR and % Stenosis

97 patients with sidebranch jailed by stent
No lesion with angiographic stenosis <75% by QCA had FFR <0.75
Only 20/73 lesions with angiographic stenosis >75% were functionally significant

Almost All Side Branch Lesions <70% DS Are Not Functionally Significant

Koo et al, JACC 2005;46:633-7
How often do we need a second stent when using the Provisional approach?


>50% DS
TIMI<3
TIMI=0 after balloon dilatation

<table>
<thead>
<tr>
<th>% Of Bifurcations</th>
<th>Colombo</th>
<th>Pan</th>
<th>Steigen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossover to 2S</td>
<td>14.2</td>
<td>4.5</td>
<td>19.2</td>
</tr>
<tr>
<td>SB restenosis in 1S group</td>
<td>4.5</td>
<td>2.1</td>
<td>4.3</td>
</tr>
<tr>
<td>TLR</td>
<td>4.9</td>
<td>2.1</td>
<td>1.9</td>
</tr>
</tbody>
</table>
NORDIC 3
RCT on FKB vs no FKB in All Bifurcations

Only 50 % of the cases had a True Bifurcation Lesion!!

Primary end point
MACE at 6 months

Niemela et al Circulation 2011 (123): 79-86
NORDIC III
RCT on FKB or No FKB on all Bifurcations
Only 50% of the cases had a True Bifurcation Lesion

Randomization

Bifurcation patients with successful MV stenting
n = 477

No Kissing balloon
n = 239

Kissing balloon
n = 238

Clinical follow-up after 1 and 6 months
n = 477 (100%)

Primary end point
MACE (cardiac death, index lesion MI, TLR, stent thrombosis) after 6 months

• Conclusion: Routine use of Final Kissing Balloon (FKB) did not improve clinical outcome, but there was not a penalty for undertaking FKB

Secondary end point
Side Branch (SB) Binary (Re)stenosis after 8 months

• Conclusion: FKBD reduced angiographic side branch (re)stenosis, especially in patients with true bifurcation lesions

In the MV was 2.5% vs 3.1% (P=0.68)

Provisional Approach - requiring a 2nd stent in the SB

TAP
- Easy to perform
- No recrossing
- Struts protruding into MB

Reverse Crush
- Complete coverage of ostium
- Any anatomy
- Recrossing into SB
- 3 layers of struts

Culotte
- Complete coverage of ostium
- More labourious
- Rewiring both branches
- Double stent layer

Courtesy Dr. Chieffo
The Guidelines
Provisional versus Elective SB stenting

Provisional side-branch stenting should be the initial approach in patients with bifurcation lesions when the side branch is not large and has only mild or moderate foal disease at the ostium.

It is reasonable to use elective double stenting in patients with complex bifurcation morphology involving a large side branch where the risk of side-branch occlusion is high and the likelihood of successful side branch re-access is low.
Can you treat all of these bifurcations in the same way?
Two Stent Bifurcation Techniques
True Bifurcation  
(significant stenosis on the main and side branches)

**No**  
Provisional SB stenting  
Stent on MB “Keep It Open” for SB

**Yes**  
Is SB suitable for stenting?  
SB disease is diffuse &/or not localized to within 5 mm from the ostium?  
Elective implantation of two stents (MB and SB)

**No**  
Provisional SB stenting

**Yes**  
Elective implantation of two stents (MB and SB)
Bifurcation Stenting Techniques with Workhorse Stents

- T Stenting
- V Stenting
- Y Stenting
- Culotte
- Crush

Kissing Stent
## Workhorse Stents, a Suboptimal Solution

<table>
<thead>
<tr>
<th></th>
<th>Coverage</th>
<th>Amount of metal</th>
<th>Branch jailing</th>
<th>Number of stents</th>
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<tbody>
<tr>
<td><strong>T stent</strong>ing</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td><strong>V stent</strong>ing</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td><strong>Y stent</strong>ing</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>Culotte <strong>stent</strong>ing</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>Crush <strong>stent</strong>ing</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>Kissing <strong>Stent</strong></td>
<td>A</td>
<td>C</td>
<td>A</td>
<td>B</td>
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</tbody>
</table>
### Bifurcation PCI
Provisional and Dedicated 2-Stent Techniques

<table>
<thead>
<tr>
<th>Performed with 6 Fr Guide</th>
<th>Performed with a 7F Guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisional Single Stent</td>
<td>Crush and Mini-Crush</td>
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<tr>
<td>T- and modified T</td>
<td>V-stent</td>
</tr>
<tr>
<td>T and Protrusion (TAP)</td>
<td>Simultaneous Kissing Stents (SKS)</td>
</tr>
<tr>
<td>Step and Double Kiss Crush</td>
<td></td>
</tr>
<tr>
<td>Culotte</td>
<td></td>
</tr>
<tr>
<td>Reverse Crush</td>
<td></td>
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</tbody>
</table>
Double Stenting Techniques for Bifurcations

Step-by-Step Handbook
Crush, Culotte, SKS: What Do They Have in Common?

In Theory, Full Coverage of the Entire Bifurcation

<table>
<thead>
<tr>
<th></th>
<th>Crush</th>
<th>Culotte</th>
<th>SKS</th>
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</thead>
<tbody>
<tr>
<td>Guiding</td>
<td>7</td>
<td>6</td>
<td>7</td>
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<tr>
<td>MV Access</td>
<td>+++</td>
<td>-</td>
<td>+++</td>
</tr>
<tr>
<td>SB Access</td>
<td>-</td>
<td>-</td>
<td>+++</td>
</tr>
<tr>
<td>Complexity</td>
<td>++</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>SB Cover</td>
<td>Mandatory</td>
<td>Provisional</td>
<td>Mandatory</td>
</tr>
</tbody>
</table>
Rates of in-segment restenosis in crush vs culotte-treated bifurcation lesions.

Copyright © American Heart Association, Inc. All rights reserved.
Results

Comparison of three stent strategies in complex bifurcation lesions

Freedom from Target Lesion Revascularisation (TLR)

Time/Months

log rank $p = 0.033$
DK Crush Technique
Double Kiss and Crush

Figure 4. Double kissing (DK) crush technique. Two wires are inserted into two vessels (a). One stent and balloon are advanced into side branch and main vessel simultaneously (b). Inflated side stent firstly (c), then the balloon in the main artery is inflated after removal of stent balloon and wire from side branch (d). First kissing balloon inflation is performed after successful rewiring to side branch (e). Stenting main vessel is underwent (f), with final kissing inflation as the final step (g). The orifice of side branch is relatively largely expanded, compared to classical crush (g).
DKCRUSH studies

Completed

- DKCRUSH-I
- DKCRUSH-II
- DKCRUSH-III

ongoing

- DKCRUSH-IV: dynamic change of FFR after DK/PT
- DKCRUSH-V: DK/PT for LMCA
- DKCRUSH-VI: FFR-/Angio-SB
- DKCRUSH-VII: registry, Post-DES FFR predicts MACE

DKCRUSH-I: c/o S. Chen
<table>
<thead>
<tr>
<th></th>
<th>DKCRUSH-1 Crush vs DK</th>
<th>DKCRUSH-II PT vs DK</th>
<th>DKCRUSH-III Culotte vs DK</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACE,%</td>
<td>24.4 vs 11.4</td>
<td>17.3 vs 10.3</td>
<td>16.3 vs 6.2</td>
</tr>
<tr>
<td>TLR,%</td>
<td>18.9 vs 9.0</td>
<td>13.0 vs 4.3</td>
<td>6.7 vs 2.4</td>
</tr>
<tr>
<td>TVR,%</td>
<td>26.5 vs 10.3</td>
<td>14.6 vs 6.5</td>
<td>11.0 vs 4.3</td>
</tr>
<tr>
<td>CD,%</td>
<td>1.7 vs 0.6</td>
<td>1.1 vs 1.1</td>
<td>1.0 vs 1.0</td>
</tr>
<tr>
<td>QMI,%</td>
<td>3.5 vs 1.2</td>
<td>2.2 vs 3.2</td>
<td>5.3 vs 3.3</td>
</tr>
<tr>
<td>ST*, %</td>
<td>3.0 vs 1.1</td>
<td>0.6 vs 2.2</td>
<td>1.0 vs 0.5</td>
</tr>
</tbody>
</table>

c/o S. Chen, from EJCI, JACC, JACC
1 or 2 stents?

A) If the side branch is significantly diseased at its ostium or nearby or if it is sufficiently large to be stented or safety and duration of the PCI are an issue: use 2 stents

B) In all other conditions 1 stents and then evaluate

If you are not certain:

In many conditions such as A), you will get an optimal result following 1 stent in the main branch a wire in the side branch will guarantee safety and then you can make your final decision
Suboptimal coverage & Drug delivery

- As bifurcation angle changes from 90°, unstented vessel area increases rapidly with “workhorse stents” unless stents overlap or workhorse struts engage the ostium of side branch.

Unstented Vessel area versus Bifurcation angle
Bifurcation Techniques

A. Stent-and-Retrieve

1. Stent deployment in parent vessel
2. Retrieve sidebranch if needed
3. Double guidewire and sequential PTCA; remove branch wire
4. Stent parent vessel and post-dilate; remove wire
5. Recross sidebranch through stent struts; rehydrate sidebranch
6. Final result
7. Recross parent vessel; adjunctive kissing balloons
8. Position and deploy stent in branch; leave guidewire in place

B. T-stent

1. Double wire and sequential PTCA
2. Position branch stent in ostium and parent stent distal to branch
3. Deploy branch stent in ostium and dilate (a); retract parent vessel stent into position (b)
4. Remove guidewire from branch and deploy parent vessel stent
5. Adjunctive PTCA with high pressure kissing balloon

D. Kissing Stents

1. Bifurcation lesion
2. Kissing balloon for predilation
3. Kissing stents
4. Adjunctive PTCA
1-2 mm of SB stent positioned in MV (proximal SB stent marker on MB wire or SB just covers proximal edge of ostim)

The SB stent is deployed & stent balloon withdrawn slightly with high RBP inflation (flares proximal stent) – then angiogram to make sure no distal dissection

The SB is crushed by a MV balloon then rewire and kiss (extra kiss)

c/o J. Hermiller, adapted from Ormiston JACC Intv 2008
• Deploy Main Branch Stent
• Rewire SB (for 2nd kiss)
• SB – high pressure dilatation NC balloon (1st step of kissing balloon inflation)
• Final kissing balloon inflation

c/o J. Hermiller, adapted from Ormiston JACC Intv 2008
Example of Double Kiss Crush

Example of Culotte
Example of Culotte and Provisional stenting
Example of Culotte with Tryton
Example of Provisional Stenting
A Second Kiss: Two Step

No Kiss  One-step Kiss  Two-step Kiss

Slide courtesy of John Ormiston
Technical Factors that May be Important in Reducing Restenosis & TLR when 2 Stents Implanted in Bifurcations

- High pressure side branch inflation
- 2-step Kiss: Pre-FKI side branch dilatation
- Use of low-compliant balloons
- Less protrusion of SB stent into MB (mini-crush)
- IVUS-guided stenting
Optimal Performance of 2 Stent Techniques Important in Reducing Event Rates

Impact of learning curve in Technique; TCT 2006
Result with Crush stenting according to performance of final kiss: restenosis and late loss are significantly reduced for the side branch.

Colombo Circulation 2004;109:1244-9
Need for high pressure side branch inflation and kissing

J. Ormiston (Crush)
Treatment of Bifurcational lesions

After Crush

After Kissing
2-Step Kiss

No Kiss

One-step Kiss

Two-step Kiss

Slide courtesy of John Ormiston
Independent risk factors for major adverse cardiac event and target lesion revascularization (1691 non LM bifurcations)

<table>
<thead>
<tr>
<th></th>
<th>Hazard ratio</th>
<th>(95% confidence interval)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MACE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final kissing ballooning</td>
<td>2.01</td>
<td>(1.29-3.13)</td>
<td>0.002</td>
</tr>
<tr>
<td>Use of paclitaxel-eluting stent</td>
<td>1.98</td>
<td>(1.34-2.92)</td>
<td>0.001</td>
</tr>
<tr>
<td>Stent length in the main vessel</td>
<td>1.02</td>
<td>(1.001-1.03)</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>TLR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final kissing ballooning</td>
<td>3.09</td>
<td>(1.84-5.16)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Use of paclitaxel-eluting stent</td>
<td>2.28</td>
<td>(1.45-3.59)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Stent length in the main vessel</td>
<td>1.02</td>
<td>(1.01-1.04)</td>
<td>0.01</td>
</tr>
<tr>
<td>Stent diameter in the main vessel</td>
<td>0.42</td>
<td>(0.20-0.89)</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Dedicated Bifurcation Devices

- Dedicated bifurcation stent systems remain limited (EBC)
- Comparative RCTs vs. provisional stenting are lacking (ESC)

1. MB stenting with provisional SB stenting
   - Twin-Rail
   - NILE
   - Petal
   - Abbott’s SB Access DES
   - Antares®
   - SideKick
   - Stentys

2. Side branch stents
   - Capella Sideguard
   - Tryton

3. Proximal
   - Axxess

4. Bifurcated stent
   - Medtronic Y stent

Consensus from 5th EBC meeting. EuroIntervention 2010;6(1):34-8
Conventional photos and Cell Size after SB Dilatation with a 4mm Balloon

CoStar

Bx Velocity

Select

Liberte

Driver

Vision
Randomized Trials using DES and Bifurcations

1. Compared to historical studies utilizing bare-metal stents, a remarkable improvement has been achieved in the treatment of bifurcation lesions when 1 (MB) or 2 stents (MB and SB) are implanted.

2. The side branch seems to be the weak link in the chain in terms of a higher risk of angiographic restenosis (~20%) and a slightly higher risk of thrombosis when 2 stents are implanted (~3.6% at 9 month f/u).

3. When possible, the placement of a single stent on the MB gives a result similar to that obtained with placement of 2 stents.

Iakavou JAMA 2005:293:2126-30
Ge AJC 2005;95:757-760
Pan M AHJ 2004;148:857-864
When to Favor a Planned 2 Stent Technique (and Which One)?

Summary

- The goal of PCI in bifurcation lesions is to attain optimal results in the MV and maintain physiologic patency of the SB. Planning of the strategy up front is critical and knowledge of all possible bailout techniques must be kept in mind.

- 4 out of 5 RCTs comparing provisional to 2-stent technique included low-risk bifurcation lesions

- While provisional SB stenting should be the default technique for “low-risk” bifurcations a 2-stent technique may be preferable for “high-risk” or true bifurcations

- Although evidence is lacking as to the superiority of one 2-stent technique versus others its unlikely that any single 2-stent technique would be superior in all bifurcation morphologies. The DK crush technique seems to be most favorable but TAP and Culotte techniques are also excellent options.

- The decision as to which 2-stent technique to use should be driven by bifurcation morphology, operator experience and randomized controlled trials.
Bifurcational Lesion Treatment: BSC Development

Step-by-Step Guide to Crushing, SKS, and More

- Stent Redesign
  Platinum enriched radiopaque stainless steel
  Thinner struts – 0.0032”
  Reduce strut spacing in mid-portion

- Translute™ coating with paclitaxel

Courtesy of Boston Scientific Corporation
Tryton Sidebranch Stent

19 mm Stent

- Side Branch Region
  - Standard stent

- Transition Zone
  - Coverage
  - Hoop strength

- Main Vessel Region
  - 3 fronds
    - Minimal coverage
  - Wedding band

Courtesy of Dr. Aaron Kaplan from Columbia Univ, NY
Dedicated Self-Expanding Stent for Optimal SB Coverage

(Courtesy of Dr. A. Colombo)
Conclusions

Treatment of bifurcation lesions using DES is feasible with very low immediate angiographic complications. One stent should be the first strategy. When 2 stents are needed, the crush stent or ‘Y’ stent technique with kissing balloon inflation/deflations or V/SKS stenting should be considered depending on location, size and bifurcation classification. Based on early data the “Y” stent technique seems to be a bit safer with lower TLR in the sidebranch but clearly technically it is more challenging.

In complex bifurcations 2 stents should be used as intention to treat.

Low rates of target vessel revascularization have been observed in the main branch. Thrombosis rates are low but not insignificant (larger number of patients needed to make a statement)

Problem of restenosis at the side branch is improved but not fully resolved