PCI for Chronic Total Occlusions
Chronic Total Occlusions

20-40% of patients with CAD

Why should we open?
Rationale for CTO Revascularization

• Relief of symptomatic ischemia and angina
• Increase long-term survival
• Improve left ventricular function
• Reduced predisposition to arrhythmic events
• Improved tolerance of contralateral coronary occlusion
12-Month Clinical Outcome of PCI in CTO

TOAST-GISE

N=390, Success 73.3%

Olivari Z, et al. JACC 2003; 41:1672-1678
## Long-term Survival
### Success vs. Failure

<table>
<thead>
<tr>
<th>Trial</th>
<th>Number of Patients(n)</th>
<th>Success (n)</th>
<th>Duration of follow-up(y)</th>
<th>Mortality(%)</th>
<th>Mortality(%)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Columbia Cardiac Registry¹</td>
<td>1458</td>
<td>1118(74.4%)</td>
<td>1</td>
<td>10.0</td>
<td>19.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Suero et al.²</td>
<td>2007</td>
<td>1491(76.7%)</td>
<td>10</td>
<td>26.6</td>
<td>35.0</td>
<td>0.001</td>
</tr>
<tr>
<td>TOAST-GISE³</td>
<td>369</td>
<td>286(77.5%)</td>
<td>6</td>
<td>1.1</td>
<td>3.6</td>
<td>0.13</td>
</tr>
</tbody>
</table>

¹ Kandzari, et al. TCT 2003  
² Suero, et al. JACC 2001;38:409-414  
³ Olivari Z, et al. JACC 2003; 41:1672-1678
Reopening of CTO
20 Years Experience

Percent surviving

CTO-Success
CTO-Failure

P = 0.005

Suero, et al. JACC 2001;38:409-414
Effect on LV function
PCI in CTO improves LV function

Van Belle E, et al. AJC 1997;80:1150-1154

LV EDVI
Pre: 89
6 Mo Post: 82

ESVI
Pre: 46
6 Mo Post: 35

EF
Pre: 49
6 Mo Post: 57

PCWP
Pre: 19
6 Mo Post: 14

*P < 0.05
Issues in CTO Intervention

- Very dangerous
- Low procedural success
- High restenosis rate
Issues in CTO Intervention

- Very dangerous
- Low procedural success
- High restenosis rate
Possibility of High Complication

- Impairment of collateral flow
  - spasm, shearing off side-branches and collateral by dissection, distal embolization
- Retrograde dissection with branch occlusion Perforation
  - intra-wall balloon expansion, side-branch dilatation, damage of neochannels connecting vasa vasorum
- Guidewire entrapment
- Subacute vessel reocclusion
  - 8% of total occlusion within 24hr Vs. 1.8% of non total occlusion
- Extensive contrast use and fluorescence time
In-Hospital Major Complication

Not dangerous!

CTO (n=2007) vs. Non-CTO (n=2007)

All \( p = NS \)

Issues in CTO Intervention

- Very dangerous
- Low procedural success
- High restenosis rate
Reasons for PCI failure in CTO

- Passage failure of guidewire 63%
- Long intimal dissection 24%
- Dye extravasation 11%
- Balloon did not cross or dilate 2%
- Thrombus 1.2%

Predictors of Procedural Success

- Duration of occlusion
- Length of occluded lesion
- Presence of a non-tapered stump
- Origin of a side branch at occlusion site
- Vessel and lesion tortuosity and calcification
- Absence of antegrade flow
- Ostial occlusion
- Bridging collateral
# Predictors of Procedural Success

Multivariate analysis from TOAST-GISE

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hazard Ratio</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length $\geq$ 15 Vs. &lt;8 mm</td>
<td>3.9</td>
<td>0.028</td>
</tr>
<tr>
<td>Length not measurable Vs. &lt;8 mm</td>
<td>3.8</td>
<td>0.019</td>
</tr>
<tr>
<td>Moderate to severe calcification</td>
<td>3.5</td>
<td>0.023</td>
</tr>
<tr>
<td>Duration $\geq$ 180 days</td>
<td>3.1</td>
<td>0.013</td>
</tr>
<tr>
<td>Multivessel disease</td>
<td>2.3</td>
<td>0.009</td>
</tr>
<tr>
<td>Stump morphology not discernable</td>
<td>2.2</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Olivari Z, et al. JACC 2003;41:1672-1678
Procedural Success

**Favorable**
- Tapered stump
- Functional occlusion
- Pre or post occlusion
- Bridging collateral (-)

**Unfavorable**
- Stump absent
- Total occlusion
- Side branch (+)
- Bridging collateral (+)
How to improve procedural success?

- Better guiding support
- Smart guidewire
- New device
- Technical advancement
Improved Success Rate
We can improve!

- No tapered tip: 64.6%
- Stepwise guidewire technique: 67.9%
- New guidewire: Conquest etc: 81.0%
- Double wire technique: 87.7%

1039 lesions, 934 patients

P<0.001
P=0.029

1995-1996: 64.6%
1998: 67.9%
2001: 81.0%
2004: 87.7%

Hiroyuki Tanaka, et al. ACC 2005
How to improve procedural success?

- Better guiding support
- Smart guidewire
- New device
- Technical advancement
Guiding Catheter for RCA
Two Guiding Catheter for RCA
Guiding Catheter for LCA
Position of Support Catheter

RAO

LAO Caud
How to improve procedural success?

- Better guiding support
- Smart guidewire
- New device
- Technical advancement
New Technologies for CTO

- **Dedicated guidewires**
  - Hydrophilic guidewire
  - Tapered-tip guidewire: Cross-IT, Conquest, Miracle
  - Guidewire manipulation by microchannel guidance
  - Re-entry technique

- **New devices**
  - FrontRunner™ Catheter
  - OCR SafeSteer™ System
  - Flow Cardia Crosser™ System

- **Biological approach**
  - Prolonged urokinase/tPA infusion
  - Collagenase plaque digestion
## Ability to Cross CTO

### Hydrophilic-coated Guidewire

<table>
<thead>
<tr>
<th></th>
<th>Conventional (n=46)</th>
<th>Crosswire (n=42)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; GW success(%)</td>
<td>35</td>
<td>74</td>
<td>0.001</td>
</tr>
<tr>
<td>Crossover(%)</td>
<td>59</td>
<td>26</td>
<td>0.009</td>
</tr>
<tr>
<td>GW success after crossover(%)</td>
<td>37</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total GW No.</td>
<td>1.7 ± 0.6</td>
<td>1.3 ± 0.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Procedure(min)</td>
<td>84 ± 33</td>
<td>42 ± 20</td>
<td>0.013</td>
</tr>
</tbody>
</table>

*Lefevre et al, Am J Cardiol 2000;85:1144-7*
Ability to Cross CTO

Tapered guidewire

- Technical success: 76%
- Success rate in visible microchannel
  - incomplete micro-channel: 81%
  - micro-channels with distal filling: 100%

Buettner HJ, et al. JACC 2002;39:30A
**New CTO Wires for CTO Lesions**

- **Miracle 12g** is more controllable
  - to penetrate proximal cap,
  - to advance in the tight CTO with bending,
  - to puncture from pseudo to true lumen.

- **Conquest** should be used
  - only when the appropriate direction can be seen
  - to penetrate distal cap,
  - to puncture from pseudo to true lumen.

- **Conquest should not be used**
  - to seek the true lumen or advance for long distance.
Special Device for CTO recanalization

- Failed special device
  - Magum/Magnarail system
  - Kensey Catheter
  - ROTACS Low Speed Rotational Atherectomy Catheter
  - Excimer Laser Wire

- CTO device in current use
  - OCR SafeSteer™ System
    (Optical Coherence Reflectometry)
  - FrontRunner™ Catheter
  - Flow Cardia Crosser System
OCR SafeSteer System

- *Forward looking guidance system*, using OCR to determine tissue types (*plaque vs arterial wall*).
- Designed to navigate through total occlusion.
OCR SafeSteer System

OCR Waveform Displays
GREAT Registry

116 Lesions 21 centers with CTO “failure to cross”
median occlusion duration: 22 months
Median lesion length: 25mm (>30mm long in 25%)

- Device Success 63 (54.3%)
- Complication
  MACE 8 (6.9%)
  - Non-Q MI 5 (5.2%)
  Clinical perforation 3 (2.6%)
  - Device related 1 (0.9%)

Baim DS et al. Am J Cardiol 2004;94:853-858
FrontRunner Catheter

**Controlled Blunt Micro-Dissection**

- Blunt controlled passage through occlusion
- Uses elastic properties of adventitia vs. inelastic fibrocalcific plaque
FrontRunner Catheter

**Advantages**
- Torqueable
- Guide support
- Directable/Steerable
- Hydrophilic coating
- Blunt tip to avoid perforation
- Avoids side branches

**Disadvantages**
- Difficult anatomy: tortuosity, small vessel, heavy calcium
- Expensive
- 8 Fr guiding for curved jaw
- Failure Modes
Clinical Outcomes of FrontRunner Catheter

- N = 909
  - Pre-approval phase: 119 (using the largest device),
  - Post-approval phase: 197 (using a smaller, more flexible catheter),
  - Current design: 593 (using X-39 Frontrunner)
- Lesion length: >30mm in 21%
- Success rate
  - Pre-approval phase: 56%
  - Post-approval phase: 59%
  - Current design: 61%
- Perforation: 0.9%

FrontRunner Catheter

Milan Experiences

50 pts with 50 CTO, Refractory to guidewire
Mean occlusion length \(38.3 \pm 22\) mm

- Overall Device Success \(50\%\) (25)
- Coronary perforation \(17.3\%\) (9)
- Adverse events \(\oplus \) 30 days \(15.7\%\) (8)
  7 non-Q wave MI, 1 sudden death

Relatively high risk of perforation!

A Colombo et al, ACC 2004
The Crosser™ System

- **Generator** converts line power into high frequency current
- **Transducer** converts electric current into mechanical vibration
- **The Crosser catheter**
54 pts with 56 CTO, Refractory to guidewire
Mean occlusion length 27 mm (8~46 mm)

- Average time spent 2:43 min
- MACE (2 NQMI) 3.6% (2/56)
- Clinical perforation 0%

High frequency mechanical recanalization is a promising technology.

G. Sutsch et al, JIM 2004
How to improve procedural success?

- Better guiding support
- Smart guidewire
- New device
- Technical advancement
Technical Advancement

Conventional Technique

- Bilateral angiography
- Over-the-wire catheter
- Collateral angiography
- Biplane angiographic equipment
- Stepwise guidewire exchange
Technical Advancement

New Technique

- Parallel wire technique
- Side branch technique
- Sub-intimal re-entry technique
- IVUS-guided recanalization technique
- Seesaw wiring technique
- etc
CONQUEST trial

Stepwise guidewire change

- Prospective Multicenter Registry in Japan
- Method: stepwise guidewire change
  - First step: intermediate GW
  - Second step: Conquest GW series
  - Third step: additional Conquest GW, Seesaw wire technique

T. Muramatsu, et al. TCT 2004
CONQUEST trial

110 patients, 116 CTO lesions

Success rate (%)

90.5%

T. Muramatsu, et al. TCT 2004
Side Branch Technique
Parallel Wire Technique
IVUS Guided Technique

- False lumen
- Guide wire
- True lumen
Stop When...

- Creation of a large false lumen, especially if adventitial staining is present
- Shearing off collateral resulting in loss of visualization of the distal flow
- Excessive patient or operator fatigue
- Excessive radiation exposure (e.g., 60 min of fluoroscopy time)
- Excessive dye consumption

→ Second try at 6-8 weeks later
PCI with DES for Chronic Total Occlusions
6 Month Restenosis Rate

<table>
<thead>
<tr>
<th>Registry</th>
<th>(n)</th>
<th>Restenosis Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOSCA</td>
<td>179</td>
<td>55</td>
</tr>
<tr>
<td>STOP</td>
<td>48</td>
<td>42</td>
</tr>
<tr>
<td>GISSOC</td>
<td>56</td>
<td>32</td>
</tr>
<tr>
<td>SICCO</td>
<td>57</td>
<td>32</td>
</tr>
<tr>
<td>RESEARCH</td>
<td>33</td>
<td>9</td>
</tr>
</tbody>
</table>

Serruys et al, JACC 2004;43:1594-8
## Asian Registry with Cypher

<table>
<thead>
<tr>
<th></th>
<th>SES  (n=60)</th>
<th>BMS  (n=120)</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late loss (mm)</td>
<td>0.08 ± 0.10</td>
<td>1.36 ± 0.88</td>
<td>0.001</td>
</tr>
<tr>
<td>Restenosis (%)</td>
<td>2</td>
<td>32</td>
<td>0.001</td>
</tr>
<tr>
<td>Reocclusion (%)</td>
<td>0</td>
<td>6</td>
<td>0.001</td>
</tr>
<tr>
<td>1 yr MACE, n(%)</td>
<td>2 (3)</td>
<td>50 (42)</td>
<td>0.001</td>
</tr>
<tr>
<td>Death (%)</td>
<td>0</td>
<td>0</td>
<td>NS</td>
</tr>
<tr>
<td>MI (%)</td>
<td>0</td>
<td>3 (3)</td>
<td>NS</td>
</tr>
<tr>
<td>Re-PCI (%)</td>
<td>2 (3)</td>
<td>44 (37)</td>
<td>0.001</td>
</tr>
<tr>
<td>CABG (%)</td>
<td>0</td>
<td>7 (6)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Nakamura et al. AJC 2005;95:161-166
## German Study with Taxus

<table>
<thead>
<tr>
<th></th>
<th>Taxus (n=48)</th>
<th>BMS (n=48)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late loss (mm)</td>
<td>0.19 ± 0.62</td>
<td>1.21 ± 0.70</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Restenosis (%)</td>
<td>8.3</td>
<td>51.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Reocclusion (%)</td>
<td>2.1</td>
<td>23.4</td>
<td>0.003</td>
</tr>
</tbody>
</table>

### 1 yr MACE, n(%)  

<table>
<thead>
<tr>
<th></th>
<th>Taxus</th>
<th>BMS</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death (%)</td>
<td>2.1</td>
<td>4.2</td>
<td>NS</td>
</tr>
<tr>
<td>MI (%)</td>
<td>4.2</td>
<td>2.1</td>
<td>NS</td>
</tr>
<tr>
<td>Re-PCI (%)</td>
<td>6.3</td>
<td>31.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CABG (%)</td>
<td>0</td>
<td>12.8</td>
<td>NS</td>
</tr>
</tbody>
</table>

Werner et al. JACC 2004;44:2301-6
# RECIPI study

## Cypher vs. Taxus

<table>
<thead>
<tr>
<th></th>
<th>Cypher</th>
<th>Taxus</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients number</td>
<td>142</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Stent number</td>
<td>1.4 ± 0.7</td>
<td>1.4 ± 0.8</td>
<td>NS</td>
</tr>
<tr>
<td>Stent length (mm)</td>
<td>41 ± 19</td>
<td>38 ± 25</td>
<td>NS</td>
</tr>
<tr>
<td>In hospital Re-PCI, n(%)</td>
<td>1 (0.7)</td>
<td>1 (1.2)</td>
<td>NS</td>
</tr>
<tr>
<td>MACCE at 1 month, n(%)</td>
<td>5 (3.5)</td>
<td>1 (1.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Death</td>
<td>1 (0.7)</td>
<td>0</td>
<td>NS</td>
</tr>
<tr>
<td>Non-Q MI</td>
<td>1 (0.7)</td>
<td>0</td>
<td>NS</td>
</tr>
<tr>
<td>TVR</td>
<td>3 (1.1)</td>
<td>1 (1.2)</td>
<td>NS</td>
</tr>
<tr>
<td>CABG</td>
<td>0</td>
<td>1(1.2)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Giuesppe Sangiorgi et al. ACC 2005
CTO in AMC

179 patients, 185 CTO

March 2003-July 2004

February 2002-February 2003

DES
104 patients (106 lesions)

BMS
75 patients (79 lesions)
# More Complex Lesion

<table>
<thead>
<tr>
<th></th>
<th>DES (N=106)</th>
<th>BMS (N=79)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-stenting, mm</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal RD</td>
<td>2.93 ± 0.50</td>
<td>3.11 ± 0.58</td>
<td>0.052</td>
</tr>
<tr>
<td>Lesion length</td>
<td>35.9 ± 19.5</td>
<td>25.8 ± 11.9</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Post-stenting, mm</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal RD</td>
<td>3.07 ± 0.49</td>
<td>3.29 ± 0.60</td>
<td>0.070</td>
</tr>
<tr>
<td>MLD</td>
<td>2.69 ± 0.45</td>
<td>2.89 ± 0.60</td>
<td>0.020</td>
</tr>
<tr>
<td>DS (%)</td>
<td>13.5 ± 13.4</td>
<td>12.5 ± 16.1</td>
<td>0.759</td>
</tr>
<tr>
<td>Acute gain</td>
<td>2.66 ± 0.45</td>
<td>2.82 ± 0.58</td>
<td>0.066</td>
</tr>
</tbody>
</table>
### Follow-up Results

<table>
<thead>
<tr>
<th>Metric</th>
<th>DES (N=46)</th>
<th>BMS (N=54)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference, mm</td>
<td>2.85 ± 0.57</td>
<td>3.12 ± 0.47</td>
<td>0.053</td>
</tr>
<tr>
<td>MLD, mm</td>
<td>2.37 ± 0.76</td>
<td>1.69 ± 0.88</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>DS, %</td>
<td>11.8 ± 19.3</td>
<td>34.7 ± 22.7</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>Late loss, mm</td>
<td>0.44 ± 0.64</td>
<td>1.13 ± 0.74</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>Loss index</td>
<td>16.06 ± 23.66</td>
<td>40.29 ± 28.88</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>Restenosis</td>
<td>4 (8.7)</td>
<td>16 (29.6)</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Restenosis Rate: 8.7%
Historical Comparison
6 Month Restenosis Rate

<table>
<thead>
<tr>
<th>Study</th>
<th>Restenosis Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOSCA</td>
<td>55%</td>
</tr>
<tr>
<td>STOP</td>
<td>42%</td>
</tr>
<tr>
<td>GISSOC</td>
<td>32%</td>
</tr>
<tr>
<td>SICCO</td>
<td>32%</td>
</tr>
<tr>
<td>RESEARCH</td>
<td>9%</td>
</tr>
<tr>
<td>AMC</td>
<td>9%</td>
</tr>
</tbody>
</table>

Serruys et al, ACC 2004
DES for CTO

- DES implantation is much more effective in reducing intimal growth and repeat intervention rate than BMS implantation for CTO lesions.
- However, the technical difficulties in re-crossing the occlusion keep the CTO lesion a challenging field in interventional cardiology.
Issues in CTO Intervention

• Very dangerous: Not as expected

• Low procedural success Improved with new devices and techniques

• High restenosis rate No more in DES era