Chronic Total Occlusions (CTO): The Final Frontier of Coronary Intervention

Christopher D. Nielsen, M.D.
Director, Adult Cardiac Cath Labs
Medical University of South Carolina

CTO PCI

- What is a CTO and how common is it
- Is there clinical justification for CTO PCI
- What are the success rates for CTO PCI
- What are the predictors of success
- What are the outcomes after successful CTO PCI
- What are the complications of CTO PCI
- How do we perform these procedures
What is a CTO?

- Complete occlusion of a coronary artery of over 3 months duration

CTO Prevalence and Treatment

Patients with Coronary Artery Disease
N = 14,439

CTO 18.4%

Treatment of Patients with CTOs
N = 1,697

Medical Therapy 44%
CABG 26%
Non-CTO PCI 20%

Attempted CTO-PCI 10%

Fefer et al. JACC 2012.
PCI Utilization Disproportionately Low in CTOs

CAD Treatment Strategies

<table>
<thead>
<tr>
<th></th>
<th>PCI</th>
<th>CABG</th>
<th>Med Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTO</td>
<td>12</td>
<td>111</td>
<td>2</td>
</tr>
<tr>
<td>No CTO</td>
<td>132</td>
<td>147</td>
<td>1</td>
</tr>
</tbody>
</table>

BARI Registry Substudy


CABG is Not Always an Option
SYNTAX CTO Substudy

266 CTO patients randomized to receive CABG

- Bypassed: 68%
- Not Bypassed: 32%

Reason not bypassed:
- Not intended to treat (n=12)
- Diseased (n=11)
- Inadequate conduit (n=2)
- Too small (n=19)
- Unable to find (n=1)
- Other (n=36)

ITT, per lesion. 49.6% overall complete revascularization in CTO subset.
Courtesy Patrick Serruys, Syntax CTO substudy, IGT 2008.
What are the clinical indications for CTO PCI?

- Symptom control and quality of life (1,2)
- Improved LV function (3)
- Improved survival and decreased MACE (4)

Ischemia in “Adequately Collateralized” CTOs

No CTOs are Adequately Collateralized

**FFR in 59 pts after successful wire crossing of a CTO**

[Graph showing distribution of FFR values with Werner GS et al. European Heart Journal 2006.]
Improved Symptom Control and Quality of Life

Impact of Successful CTO-PCI: Angina

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>PCI success</th>
<th>PCI failure</th>
<th>Odds Ratio M-H, Random, 95% CI</th>
<th>M-H, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angiolli et al.</td>
<td>10</td>
<td>33</td>
<td>0.34 (0.16, 0.75)</td>
<td></td>
</tr>
<tr>
<td>Aki et al.</td>
<td>12</td>
<td>377</td>
<td>0.012 (0.006, 0.24)</td>
<td></td>
</tr>
<tr>
<td>Drozd et al.</td>
<td>10</td>
<td>233</td>
<td>0.42 (0.16, 1.00)</td>
<td></td>
</tr>
<tr>
<td>Fonti et al.</td>
<td>7</td>
<td>100</td>
<td>0.13 (0.05, 0.31)</td>
<td></td>
</tr>
<tr>
<td>Howie et al.</td>
<td>71</td>
<td>537</td>
<td>0.23 (0.16, 0.32)</td>
<td></td>
</tr>
<tr>
<td>Vanhoutte et al.</td>
<td>41</td>
<td>317</td>
<td>0.26 (0.17, 0.41)</td>
<td></td>
</tr>
<tr>
<td>Manguch et al.</td>
<td>134</td>
<td>260</td>
<td>0.19 (0.06, 0.41)</td>
<td></td>
</tr>
<tr>
<td>Ohmann et al.</td>
<td>7</td>
<td>236</td>
<td>0.14 (0.06, 0.32)</td>
<td></td>
</tr>
<tr>
<td>Valenti et al.</td>
<td>7</td>
<td>314</td>
<td>0.21 (0.06, 0.63)</td>
<td></td>
</tr>
<tr>
<td>Warren et al.</td>
<td>3</td>
<td>26</td>
<td>0.20 (0.04, 0.89)</td>
<td></td>
</tr>
</tbody>
</table>

Total (95% CI) 2624 1325 100.0% 0.22 (0.17, 0.27)

Chi-square: 0.01, df = 1 (P = 0.99); (P = 0.9%)

Favors Success
Improvement of LV function with CTO-PCI

Ejection Fraction (EF)

Segmental Wall Thickening (SWT)

MRI assessment at baseline and at 6 months shows an improvement in EF and SWT in patients who had successful CTO-PCI

Long Term LV Function Improvement with CTO-PCI
Most Significant Improvement with <25% Infarction

- Improvements in LV volume maintained at 3 years
- Degree of transmurality of scar by MRI

Kirschbaum SW et al. American journal of Cardiology 2008
Medical Therapy May Not be Enough
Higher Ischemic Burden Correlated to Mortality

Shaw et al., Circulation 2008;117

p=0.063
p=0.023
p=0.002

Death or MI Rate

Ischemic Burden

0% (n=23)
1%-4.9% (n=141)
5%-9.9% (n=88)
≥10% (n=62)

Long term survival after successful CTO PCI

BCIS: British Cardiovascular Intervention Society
George, et al. Long-term Follow-up of Elective Chronic Total-Coronary Occlusion Angioplasty. JACC 2014;63(5).
- Late (3 Years) Follow-Up of Successful Versus Unsuccessful Revascularization in Chronic Total Coronary Occlusions Treated by Drug Eluting Stent

- 317 total patients, 196 successful

Am J Cardiol 2012;110:948–953

Survival free of MACE

Log-rank p=0.003
Survival free of MACE

Am J Cardiol 2012;110:948–953

Euro Heart J 2011
CTO Impact on Non-CTO Vessel AMI Mortality
Higher 1-year Mortality Rate w/ CTO

CTO is an independent predictor of mortality

CTO and Cardiogenic Shock
CTO Is An Independent Predictor Of Mortality

30 Day Mortality in Patients with Cardiogenic Shock

When is CTO-PCI Appropriate?
Based on Patient Risk, Angina, and Medical Management

Maximum Medical Therapy

<table>
<thead>
<tr>
<th>Risk</th>
<th>Class 0</th>
<th>Class I/II</th>
<th>Class III/IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Risk No Rx</td>
<td>U</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Int Risk No Rx</td>
<td>I</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>Low Risk No Rx</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
</tbody>
</table>

No Maximum Medical Therapy

<table>
<thead>
<tr>
<th>Risk</th>
<th>Class 0</th>
<th>Class I/II</th>
<th>Class III/IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Risk Max Rx</td>
<td>U</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Int Risk Max Rx</td>
<td>U</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Low Risk Max Rx</td>
<td>I</td>
<td>U</td>
<td>U</td>
</tr>
</tbody>
</table>

Single vessel CTO
Modified from Patel et al / Am Coll Cardiol 2009:53:530-553

2011 ACC CTO-PCI Guidelines

Chronic Total Occlusions

PCI of a CTO in patients with appropriate clinical indications and suitable anatomy is reasonable when performed by operators with appropriate expertise.

©2011 by the American College of Cardiology Foundation and the American Heart Association, Inc. All rights reserved.
Success rates

- Success rates vary by operator and experience
Factors associated with Cto PCI success

J Am Coll Cardiol Intv 2015;

J Am Coll Cardiol Intv 2015;
Complications
Factors associated with Cto PCI complications

AGE-10yrs
Female
Race-White
BMI
No Insurance
GINA 1ounits
Smoker
HTN
Diabetes
Family Hx CAD
Prior MI
Prior HF
PVC-PCI
Valve Surgery
Prior CABG
Current Dialysis
Prior CVD
Prior PAD
CLD
EM
Prior 2 wks HF
Prior Cardiogenic Shock
Prior CABMI
Prior Stent MI
CCTA-LAD
CCTA-LOC
Avg. CTO-yr-1 proc.
Avg. Selective Proc-10 proc.

RR
0.22
0.5
1
2
4
8
0.01
0.04
0.2
0.4
1

Table 1. Incidence of periprocedural complications in patients undergoing chronic total occlusion percutaneous coronary interventions.

<table>
<thead>
<tr>
<th>Complications</th>
<th>n = 336</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major*</td>
<td>13 (3.9%)</td>
</tr>
<tr>
<td>Deaths</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>Emergent coronary artery bypass graft surgery</td>
<td>2 (0.6%)</td>
</tr>
<tr>
<td>Stroke/transient ischemic attack</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>Clinical myocardial infarction</td>
<td>3 (0.9%)</td>
</tr>
<tr>
<td>Vascular complications</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>2 (0.6%)</td>
</tr>
<tr>
<td>Major bleeding or major vascular events</td>
<td>3 (0.9%)</td>
</tr>
<tr>
<td>Minor*</td>
<td>35 (10.4%)</td>
</tr>
<tr>
<td>Perforation</td>
<td>8 (2.4%)</td>
</tr>
<tr>
<td>Coronary-induced trauma/tamponade</td>
<td>6 (1.8%)</td>
</tr>
<tr>
<td>Minor bleeding or minor vascular events</td>
<td>16 (4.8%)</td>
</tr>
<tr>
<td>Transient hypertension</td>
<td>2 (0.6%)</td>
</tr>
<tr>
<td>Device lmx</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>Vascular reaction</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>Bacteremia</td>
<td>1 (0.3%)</td>
</tr>
</tbody>
</table>

*These patients had both a major and minor complication.
Data given as number (percentage).
Table 5. Major complications in retrograde versus non-retrograde procedures.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Retrograde (n = 87)</th>
<th>Antegrade (n = 249)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>1 (1.1%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Emergent coronary artery bypass graft surgery</td>
<td>1 (1.1%)</td>
<td>1 (0.4%)</td>
</tr>
<tr>
<td>Stroke/transient ischemic attack</td>
<td>1 (1.1%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Tamponade</td>
<td>1 (1.1%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Donor vessel injury</td>
<td>2 (2.3%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Major bleeding or major vascular events</td>
<td>1 (1.1%)</td>
<td>2 (0.8%)</td>
</tr>
<tr>
<td>Clinical myocardial infarction</td>
<td>1 (1.1%)</td>
<td>1 (0.4%)</td>
</tr>
</tbody>
</table>

Table 4. Procedural characteristics for patients with and without complications.

<table>
<thead>
<tr>
<th>Procedural Characteristics</th>
<th>No Complications (n = 291)</th>
<th>Major Complications (n = 13)</th>
<th>P-Value No Complications vs Major Complications</th>
<th>Minor Complications (n = 32)</th>
<th>P-Value No Complications vs Minor Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral access</td>
<td>57.8%</td>
<td>92.3%</td>
<td>.05</td>
<td>53.3%</td>
<td>.64</td>
</tr>
<tr>
<td>Retrograde approach</td>
<td>24.2%</td>
<td>61.3%</td>
<td>.01</td>
<td>26.1%</td>
<td>.63</td>
</tr>
<tr>
<td>Lesions treated (no)</td>
<td>1.2 ± 0.5</td>
<td>1.3 ± 0.9</td>
<td>.47</td>
<td>1.1 ± 0.3</td>
<td>.23</td>
</tr>
<tr>
<td>Procedure time (minutes)</td>
<td>135.8 ± 68.3</td>
<td>212.1 ± 96.6</td>
<td>&lt;.001</td>
<td>143.5 ± 78.9</td>
<td>.60</td>
</tr>
<tr>
<td>Contrast volume (mL)</td>
<td>351.7 ± 138.1</td>
<td>501.7 ± 137.7</td>
<td>&lt;.001</td>
<td>347.6 ± 100.7</td>
<td>.97</td>
</tr>
<tr>
<td>Fluoroscopy time (minutes)</td>
<td>382 ± 114</td>
<td>552 ± 26.1</td>
<td>&lt;.001</td>
<td>372 ± 17.0</td>
<td>.80</td>
</tr>
<tr>
<td>Radiation DAP (mGy-cm²)</td>
<td>327453 ± 185598</td>
<td>554233 ± 198169</td>
<td>.01</td>
<td>346722 ± 174691</td>
<td>.59</td>
</tr>
<tr>
<td>Technical success</td>
<td>78.6%</td>
<td>69.2%</td>
<td>.42</td>
<td>68.8%</td>
<td>.21</td>
</tr>
<tr>
<td>Stents implanted (no)</td>
<td>2.2 ± 1.7</td>
<td>2.3 ± 2.3</td>
<td>.80</td>
<td>1.8 ± 1.7</td>
<td>.18</td>
</tr>
</tbody>
</table>

*Data given as percentage or mean ± standard deviation.*
Table 1. In-Hospital Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Failed CTO PCI</th>
<th>Successful CTO PCI</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACE</td>
<td>8.98%</td>
<td>3.75%</td>
<td>2.25 (1.59-2.96)</td>
</tr>
<tr>
<td>Mortality</td>
<td>1.44%</td>
<td>0.50%</td>
<td>2.88 (1.98-4.24)</td>
</tr>
<tr>
<td>MI</td>
<td>3.17%</td>
<td>2.40%</td>
<td>1.35 (1.03-1.78)</td>
</tr>
<tr>
<td>Urgent CABG</td>
<td>4.00%</td>
<td>0.50%</td>
<td>6.67 (4.26-10.43)</td>
</tr>
</tbody>
</table>

Figure Legend:

Pooled complication rates of chronic total occlusion percutaneous coronary interventions. CABG = coronary artery bypass graft; CN = contrast nephropathy; MACE = major adverse cardiac events; MI = myocardial infarction; QWMI = Q-wave myocardial infarction.
The technique for CTO intervention

New Approach to Treat CTOs
The Hybrid Strategy

FOUR ANGIOGRAPHIC CHARACTERISTICS DICTATE STRATEGY
• Proximal cap ambiguity
• Lesion length
• Quality of distal target
• Suitability of "interventional" collaterals

HYBRID STRATEGY PRINCIPLES
• Consistent evaluation approach
• Emphasizes procedural safety, success, and efficiency
• Minimizes radiation and contrast
• Quick transition to alternate plans when failure mode occurs
The Hybrid Algorithm

Antegrade Wire Escalation
Antegrad e Dissection Re-Entry

CTO crossing through the subintimal space, advancing across the occlusion, re-entering into the distal true lumen

Coronary CTO Crossing and Re-entry System

CrossBoss™ Catheter
Designed to quickly and safely deliver a guidewire via true lumen or subintimal pathways

Stingray™ Catheter
Designed to accurately target and re-enter the true lumen from a subintimal position
1. Microcatheters
2. Wires

Essential tools for retrograde collateral wiring

Illustration by Dr. J C Spett / VascularPerspectives, www.clinicalbooks.com

Retrograde Techniques

Once septal collaterals allow access to distal cap...

the distal cap should then be tackled like proximal cap.

Follow the Hybrid approach.

Images provided by Boston Scientific. Results from case studies are not predictive of results in other cases. Results in other cases may vary.
Retrograde Techniques
Dissection Re-Entry Techniques: Reverse CART

Illustration by Dr. J C Spratt / Vascular Perspectives, www.ctoibooks.com
Procedural Success Rates Over Time
Operators with Retrograde Skills >90% Success

Dartmouth - North Cascade Multicenter CTO Registry, Thompson CA, Lombardi WL

Predictors of success
J Am Coll Cardiol Intv. 2011

Int J Cardiovasc Imaging (2013)
Coronary Computed Tomographic Prediction Rule for Time-Efficient Guidewire Crossing Through Chronic Total Occlusion

Insights From the CT-RECTOR Multicenter Registry (Computed Tomography Registry of Chronic Total Occlusion Revascularization)

Maksymilian P. Opolski, MD,* y Stephan Achenbach, MD, z Annika Schuhbäck, MD, z Andreas Rolf, MD,* Helge Möllmann, MD,* Holger Nef, MD, x Johannes Rixe, MD, x Matthias Renker, MD, x Adam Witkowski, MD, y Cezary Kepka, MD, k Claudia Walther, MD,* Christian Schlundt, MD, z Artur Debski, MD, y Michal Jakubczyk, MSC, ( Christian W. Hamm, MD, x
JACC Interventions Feb 2015
Chronic Total Occlusions (CTO): The Final Frontier of Coronary Intervention

Christopher D. Nielsen, M.D.
Director, Adult Cardiac Cath Labs
Medical University of South Carolina