Chronic Total Occlusions: Why, when and how?

Van Crisco, MD, FACC, FSCAI
First Coast Heart & Vascular Center

drcrisco@firstcoastheart.com
www.firstcoastheart.com
C (678) 313-6695
W(904) 423-0010
RELEVANT DISCLOSURES

- Boston Scientific
  - Speakers Bureau
CHRONIC TOTAL OCCLUSION OF AN EPICARDIAL CORONARY ARTERY (CTO)

- > 3 MONTHS OCCLUDED
- DISTAL COLLATERALIZED ARTERIAL CONTRAST FILLING
- CAUSES A CLINICAL PROBLEM

IT’S A COMPLEX PCI PROCEDURE

- IT’S CLOSED 100%
- NOT ALL IC’S ARE TRAINED OR SHOULD BE
Common misconceptions

- There is no clinical justification
- CTOs are stable and benign
- The procedure is too complex
- Success rates are low
- We don’t have time for long procedures
- Results are not reproducible or teachable
- CTO-PCI is cost-prohibitive

“If you really want to do something, you’ll find a way. If you don’t, you’ll find an excuse.”

-Jim Rohn
Coronary Angiograms
N = 14,439

CTO Prevalence and Treatment
Treatment of CTOs

- Medical Therapy 44%
- CABG 26%
- PCI 30%

Only 10% of PCI involved the CTO, with 70% success rate!

Feer et al. JACC 2012.
CTO Prevalence and Treatment

Translating the results of the Canadian Registry

3.8M PCI Patients

684,000 CTO Patients

2–10% CTO–PCI

≈500,000 clinically eligible patients to receive CTO–PCI

What Does That Mean in Terms of Patient Treatment?

*CTO Prevalence*

18.4% of Patients Referred for Angio w/ at Least 1 CTO

Feer et. al. *JACC* 2012.
Image based on illustration by Dr. J C Spratt / VascularPerspectives, www.ctoilbooks.com
CTO Prevalence
Explaining the Canadian Registry

Total number of patients found with a CTO

Feer et. al. JACC 2012.
Image based on illustration by Dr. J C Spratt / VascularPerspectives, www.ctolbooks.com
CTO Prevalence
Explaining the Canadian Registry

87% CTO Patients Had CCS Class II+ Angina

Feer et. al. JACC 2012.
Image based on illustration by Dr. J C Spratt / VascularPerspectives, www.ctoibooks.com
CTO Prevalence
Explaining the Canadian Registry

10% Attempted CTO–PCI

Feer et. al. JACC 2012.
Image based on illustration by Dr. J C Spratt / VascularPerspectives, www.ctoibooks.com
CTO Prevalence
Explaining the Canadian Registry

70% Successful CTO–PCI

Feer et. al. JACC 2012.
Image based on illustration by Dr. J C Spratt / VascularPerspectives, www.ctoilbooks.com
CTO Prevalence
Explaining the Canadian Registry

Potential CTO–PCI Candidates

Feer et. al. JACC 2012.
Image based on illustration by Dr. J C Spratt / VascularPerspectives, www.ctoibooks.com
CAD Treatment Strategies

CTO–PCI disproportionately low

BARI Registry Substudy

- PCI
- CABG
- Med Rx

CTO
N=1,612

No CTO
N=1,475

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, TCT 2008.
There is No Clinical Justification
Clinical Indications

Why open a chronically occluded coronary artery?

- SYMPTOM CONTROL\(^1\) and INCREASED QUALITY OF LIFE\(^2\)
- IMPROVED LV FUNCTION\(^3\)
- IMPROVED SURVIVAL\(^4\)

---

\(^1\) Grantham JA et al., Circulation: Cardiovascular Quality and Outcomes 2009.
\(^2\) Safley D, Grantham JA, Jones P, and Spertus JA, ACC 2012
\(^3\) Kirschbaum SW et al. American Journal of Cardiology 2008
Impact of Successful CTO-PCI: Angina

*Long-term angina benefit favors CTO-PCI success*

<table>
<thead>
<tr>
<th>Series</th>
<th>Successful PCI (n)</th>
<th>Follow-up (months)</th>
<th>Asymptomatic (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivari 2003</td>
<td>248</td>
<td>12</td>
<td>88.7</td>
</tr>
<tr>
<td>Berger 1996</td>
<td>139</td>
<td>6</td>
<td>87</td>
</tr>
<tr>
<td>Stewart 1993</td>
<td>45</td>
<td>12</td>
<td>68</td>
</tr>
<tr>
<td>Ivanhoe 1992</td>
<td>264</td>
<td>36</td>
<td>69</td>
</tr>
<tr>
<td>Ruocco 1992</td>
<td>160</td>
<td>24</td>
<td>69</td>
</tr>
<tr>
<td>Bell 1991</td>
<td>234</td>
<td>32</td>
<td>76</td>
</tr>
</tbody>
</table>
Impact of Successful CTO-PCI: Angina

*Long-term angina benefit favors CTO-PCI success*

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>PCI success</th>
<th>PCI failure</th>
<th>Odds Ratio</th>
<th>M-H, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events</td>
<td>Total</td>
<td>Events</td>
<td>Total</td>
<td>Weight</td>
</tr>
<tr>
<td>Angioli et al.</td>
<td>10</td>
<td>93</td>
<td>28</td>
<td>108</td>
</tr>
<tr>
<td>Aziz et al.</td>
<td>12</td>
<td>377</td>
<td>36</td>
<td>166</td>
</tr>
<tr>
<td>Drozd et al.</td>
<td>10</td>
<td>280</td>
<td>12</td>
<td>149</td>
</tr>
<tr>
<td>Fincl et al.</td>
<td>7</td>
<td>100</td>
<td>37</td>
<td>100</td>
</tr>
<tr>
<td>Hoye et al.</td>
<td>71</td>
<td>567</td>
<td>117</td>
<td>304</td>
</tr>
<tr>
<td>Ivannhoe et al.</td>
<td>41</td>
<td>317</td>
<td>59</td>
<td>163</td>
</tr>
<tr>
<td>Noguchi et al.</td>
<td>9</td>
<td>134</td>
<td>26</td>
<td>92</td>
</tr>
<tr>
<td>Olivari et al.</td>
<td>7</td>
<td>286</td>
<td>13</td>
<td>83</td>
</tr>
<tr>
<td>Valenti et al.</td>
<td>7</td>
<td>344</td>
<td>13</td>
<td>142</td>
</tr>
<tr>
<td>Warren et al.</td>
<td>3</td>
<td>26</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>2524</strong></td>
<td><strong>1325</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>0.22 [0.17, 0.27]</strong></td>
</tr>
<tr>
<td>Total events</td>
<td>177</td>
<td>348</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.01; Chi² = 9.90, df = 9 (P = .36); I² = 9%
Test for overall effect: Z = 13.41 (P < .00001)

Clinical Indications

Why open a chronically occluded coronary artery?

- SYMPTOM CONTROL¹ and INCREASED QUALITY OF LIFE²
- IMPROVED LV FUNCTION³
- IMPROVED SURVIVAL⁴

---

¹ Grantham JA et al., Circulation: Cardiovascular Quality and Outcomes 2009.
²-³ Safley D, Grantham JA, Jones P, and Spertus JA, ACC 2012
³ Kirschbaum SW et al. American Journal of Cardiology 2008
⁴ Hachamovitch et al Circulation. 2003; 107:2900-2907
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

$<25\%$ infarcted has most significant improvement

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

Kirschbaum SW et al. *American Journal of Cardiology* 2008
Higher ischemic burden correlated to mortality

Death or MI Rate

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

- p=0.063
- p=0.023
- p=0.002

Shaw et al, Circulation 2008;117
Clinical Indications

*Why open a chronically occluded coronary artery?*

- SYMPTOM CONTROL\(^1\) and INCREASED QUALITY OF LIFE\(^2\)
- IMPROVED LV FUNCTION\(^3\)
- IMPROVED SURVIVAL\(^4\)

---

\(^1\) Grantham JA et al., Circulation: Cardiovascular Quality and Outcomes 2009.
\(^2\) 1-2 Safley D, Grantham JA, Jones P, and Spertus JA, ACC 2012
\(^3\) Kirschbaum SW et al. American Journal of Cardiology 2008
Impact of Successful CTO-PCI: Mortality and Clinical Events for Coronary Bypass Grafts

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>PCI success</th>
<th>PCI failure</th>
<th>Weight</th>
<th>Odds Ratio</th>
<th>M-H, Random, 95% Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angioli et al.</td>
<td>3</td>
<td>9</td>
<td>93</td>
<td>3.4%</td>
<td>0.37 [0.10, 1.40]</td>
</tr>
<tr>
<td>Aziz et al.</td>
<td>9</td>
<td>12</td>
<td>377</td>
<td>6.7%</td>
<td>0.31 [0.13, 0.76]</td>
</tr>
<tr>
<td>Drozd et al.</td>
<td>7</td>
<td>5</td>
<td>280</td>
<td>4.3%</td>
<td>0.74 [0.23, 2.37]</td>
</tr>
<tr>
<td>Finci et al.</td>
<td>5</td>
<td>3</td>
<td>100</td>
<td>2.9%</td>
<td>1.70 [0.40, 7.32]</td>
</tr>
<tr>
<td>Hoye et al.</td>
<td>37</td>
<td>36</td>
<td>567</td>
<td>14.4%</td>
<td>0.52 [0.32, 0.84]</td>
</tr>
<tr>
<td>Ivanhoe et al.</td>
<td>3</td>
<td>7</td>
<td>317</td>
<td>3.2%</td>
<td>0.21 [0.05, 0.83]</td>
</tr>
<tr>
<td>Labriolle et al.</td>
<td>7</td>
<td>2</td>
<td>127</td>
<td>2.4%</td>
<td>1.25 [0.25, 6.27]</td>
</tr>
<tr>
<td>Noguchi et al.</td>
<td>7</td>
<td>15</td>
<td>134</td>
<td>6.1%</td>
<td>0.28 [0.11, 0.72]</td>
</tr>
<tr>
<td>Olivari et al.</td>
<td>2</td>
<td>3</td>
<td>286</td>
<td>1.9%</td>
<td>0.19 [0.03, 1.14]</td>
</tr>
<tr>
<td>Prasad et al.</td>
<td>229</td>
<td>101</td>
<td>914</td>
<td>21.6%</td>
<td>0.82 [0.62, 1.08]</td>
</tr>
<tr>
<td>Suero et al.</td>
<td>395</td>
<td>180</td>
<td>1491</td>
<td>23.8%</td>
<td>0.67 [0.54, 0.83]</td>
</tr>
<tr>
<td>Valente et al.</td>
<td>17</td>
<td>17</td>
<td>344</td>
<td>9.3%</td>
<td>0.38 [0.19, 0.77]</td>
</tr>
<tr>
<td>Warren et al.</td>
<td>0</td>
<td>0</td>
<td>26</td>
<td>Not estimable</td>
<td></td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>5056</td>
<td>2232</td>
<td>100.0%</td>
<td>0.56 [0.43, 0.72]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.06; Chi² = 18.74, df = 11 (P = 0.07); I² = 41%
Test for overall effect: Z = 4.39 (P < .0001)

Favors Success

Favors Failure

Impact of Successful CTO–PCI on All Cause Mortality

CTOs are Stable and Benign
Ischemia in “Adequately Collateralized” CTOs
No CTOs are adequately collateralized

FFR in 59 pts after successful wire crossing of a CTO

Werner GS et al, European Heart Journal 2006.
CTO Impact on Non-CTO Vessel AMI Mortality

Higher 1-year mortality rate w/ CTO

“Double Jeopardy” Concept

CTO is an independent predictor of mortality

Survival Post STEMI With Concomitant CTO
Claessen et al. JACC: CI 2:11; Nov 2009, 1128–1134

**Figure 1. Landmark Survival Analysis**

Cumulative risk of death during the first 30 days after primary percutaneous coronary intervention (PCI) and thereafter for patients with single-vessel disease (SVD), multivessel disease (MVD), and a chronic total occlusion (CTO).
# Long Term Survival With CTO PCI

## Success vs. Failure

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Era</th>
<th>Mean Follow-up (years)</th>
<th>Survival % (CTO Success)</th>
<th>Survival % (CTO Failure)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suero</td>
<td>2007</td>
<td>1980-1999</td>
<td>Cumulative 10 yr</td>
<td>73.5</td>
<td>65.1</td>
<td>0.001</td>
</tr>
<tr>
<td>Hoye</td>
<td>874</td>
<td>1999-2002</td>
<td>4.47 +/- 2.69</td>
<td>93.5</td>
<td>88.0</td>
<td>0.02</td>
</tr>
<tr>
<td>Aziz</td>
<td>199</td>
<td>2000-2004</td>
<td>Cumulative 2 year</td>
<td>98.0</td>
<td>94.2</td>
<td>0.045</td>
</tr>
<tr>
<td>Olivari</td>
<td>390</td>
<td>2003</td>
<td>1 Year</td>
<td>98.1</td>
<td>92.8</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Prasad</td>
<td>1,262</td>
<td>1979-2005</td>
<td>Cumulative 10 years</td>
<td>~78</td>
<td>~72</td>
<td>0.025*</td>
</tr>
<tr>
<td>De Labriolle</td>
<td>172</td>
<td>2003-2005</td>
<td>2 years</td>
<td>95.1</td>
<td>94.7</td>
<td>0.30</td>
</tr>
<tr>
<td>Valenti</td>
<td>486</td>
<td>2003-2006</td>
<td>Cumulative 4 year</td>
<td>91.6</td>
<td>87.4</td>
<td>0.025</td>
</tr>
<tr>
<td>*New York-Milan CTO registry</td>
<td>1362</td>
<td>2000-2007</td>
<td>3 years</td>
<td>96.4</td>
<td>91.3</td>
<td>0.012</td>
</tr>
<tr>
<td>*Dartmouth</td>
<td>487</td>
<td>1996-2008</td>
<td>Cumulative 7 years</td>
<td>87.0</td>
<td>74.0</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Modified from Werner GS et al, European Heart Journal 2006, courtesy Werner GS
CTO and Cardiogenic Shock

*CTO is an independent predictor of mortality*

30 Day Mortality in Patients with Cardiogenic Shock

<table>
<thead>
<tr>
<th>No CTO</th>
<th>1 CTO</th>
<th>&gt;1 CTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% n=102</td>
<td>66% n=32</td>
<td>100% n=7</td>
</tr>
</tbody>
</table>

P < 0.0001*

The Procedure is Too Complex
Evolution of CTO-PCI

*Increasing success rates related to technique evolution*

- **2004**
  - Antegrade Wires and IVUS

- **2007**
  - Rudimentary Retrograde

- **2010**
  - Early Antegrade Dissection Re-Entry

- **2012**
  - Hybrid
The Hybrid Strategy
New Approach to Treat CTOs

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
True to True: Wire escalation

Antegrade Wiring
Antergrade Dissection Re-Entry
Antegrade Dissection Re-Entry

CTO crossing through the subintimal space, advancing across the occlusion, re-entering into the distal true lumen
Cross Boss
Sting Ray re-entry
Bi-directional rotation of torque device designed to aid advancement
Antegrade Dissection Re-Entry: StingRay Catheter
Procedure Sequence Two

The Stingray® Catheter is advanced and inflated up to 4 ATM within the subintimal space.
Failed Antegrade Retrograde Conversion
Retrograde Techniques
Retrograde Techniques

*Retrograde collateral wiring*

Essential tools for retrograde

1. Microcatheters
2. Wires

Illustration by Dr. J C Spratt / VascularPerspectives, www.ctoilbooks.com
Retrograde Techniques

Dissection Re-Entry Techniques: Reverse CART

Illustration by Dr. J C Spratt / VascularPerspectives, www.ctoibooks.com
Success Rates are Low
Procedural Success Rates Over Time

Operators with retrograde skills >90% success

Dartmouth –North Cascade Multicenter CTO Registry, Thompson CA, Lombardi WL
Hybrid CTO Registry Results

Most successful strategy for complex lesions

Success by J-CTO score

- Success Hybrid
- Success J-CTO
- Success Royal Brompton

More Complex Lesions

Daniels D, CTO/LM Summit 2013
The procedure is cost-prohibitive.
CTO Health Economics & Reimbursement

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Physician Payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic PTCA/Stenting Procedure</td>
<td>$604</td>
</tr>
<tr>
<td>CTO</td>
<td>$677</td>
</tr>
<tr>
<td>AMI</td>
<td>$677</td>
</tr>
<tr>
<td>SVG</td>
<td>$604</td>
</tr>
<tr>
<td>Atherectomy</td>
<td>$676</td>
</tr>
</tbody>
</table>

The Piedmont Study on Economic Outcomes of CTOs showed that both charges and payments were higher in the CTO group, and overall hospital contribution margins were similar.\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>CTO</th>
<th>Non CTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reimbursement</td>
<td>$16,013</td>
<td>$13,166</td>
</tr>
<tr>
<td>Procedure Cost</td>
<td>$4,640</td>
<td>$4,376</td>
</tr>
<tr>
<td>(non device related)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device Cost</td>
<td>$6,230</td>
<td>$3,060</td>
</tr>
<tr>
<td>Contribution Margin</td>
<td>$5,173</td>
<td>$5,730</td>
</tr>
</tbody>
</table>

\(^1\) Piedmont Study: CTO, n=154; non CTO, n=1847
CTO Revascularization: Economic Outcomes

$10,870 \quad P<0.001 \\
$7,436 \quad P<0.001 \\
$6,230 \quad P=0.58 \\
$3,060 \quad P=0.58 \\
$5,173 \\
$5,730 \\

Total Direct Costs

Procedural Costs

Contribution Margin

CTO, N=154

Non-CTO, N=1,847
4 Rules of CTO’s

• If it ain’t fun it ain’t fun
  – You have to believe it’s the right thing to do
• If you do not attempt to conquer you never will
  – Nothing is impossible
• Chance Favors the prepared mind
  – Wires, guides, technique and technology
• Always show your superior judgment so that you don’t have to show your superior skill
  – Know when to quit or come back another day