Chronic Total Occlusions
Opening the Way

Reginald Low MD
Chief, Division of Cardiovascular Medicine
University of California, Davis
Disclosures

• Abbott Vascular – Consultant
• Boston Scientific – Consultant
• Direct Flow Medical – Consultant
Chronic Total Occlusion

Clinical Definition

Complete coronary arterial obstruction with TIMI flow 0 for longer than 3 months
Patients with Coronary Artery Disease
N = 14,439

CTO Prevalence
18.4%

Treatment of Patients with CTOs
N = 1,697

- CABG: 26%
- Medical Therapy: 44%
- Non-CTO PCI: 20%
- Attempted CTO-PCI: 10%

Fefer et al. JACC 2012.
Variability in Current Treatment

CTO-PCI attempt rate varied among hospitals from 1% to 16%

CTO treatment strategies in 3 Canadian centers

*p < 0.001; **p = NS; *p < 0.001

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

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.
Benefits of Revascularization

- Quality of Life
- Quantity of Life
Quantity of Life
Ischemia

<table>
<thead>
<tr>
<th>% Ischemic Burden</th>
<th>Cardiac Death Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0.7%</td>
</tr>
<tr>
<td>1-5%</td>
<td>1.0%</td>
</tr>
<tr>
<td>5-10%</td>
<td>2.9%</td>
</tr>
<tr>
<td>11-20%</td>
<td>4.8%</td>
</tr>
<tr>
<td>&gt;20%</td>
<td>6.7%</td>
</tr>
</tbody>
</table>

Quality of Life after PCI

QOL Better

QOL Worse

Asx I II III IV

30 points!

McNulty et al AHA 2012
Rationale for CTO Revascularization

- Improve symptoms
  - Improve coronary blood flow - O$_2$ Supply
- Increase long-term survival
- Improve left ventricular function
- Improve electrical stability of myocardium - reduce predisposition for arrhythmic event
- Increase tolerance of progressive coronary artery disease - provide collaterals
Chronic Total Occlusion

- Percutaneous recanalization of Chronic Total occlusions
  - Most challenging procedure in the Cardiac Cath Lab
  - Technically difficult to treat
    - Time intensive
    - Complex procedure
    - Significant contrast load
    - Complications
  - Historic success rate ~ 50%
  - Success rates now - > 90%
Anatomy and Histopathology

- Thrombotic occlusion, thrombus organization & tissue aging
- Histologically one-half of CTOs are <99% stenotic
- No relationship between severity of histopathic lumen stenosis and plaque composition or lesion age
- Atherosclerotic plaque of CTO
  - Intra and extracellular lipid
  - Smooth muscle cells
  - Extracellular matrix (predominate type I and III) in fibrous stroma
  - Calcium
  - Dense concentration of collagen rich fibrous tissue at proximal and distal ends - columnlike lesion of calcified fibrous tissue

Large - 59% of all CTO
Small - 41% of all CTO
Comparison of CTO Tissues
Differential Elastance of Adventitia and Fibrous Plaque

Adventitia

Plaque

Emery et al. LuMend, Inc.

Stress

Yield
Ultimate

Stiffness

N/mm²

0 2 4 6 8 10 12 14

0 0.4 0.8 1.2 1.6

Adventitia
Plaque
Contralateral Injection
Remodeling

Immediate

6 Months
The CTO Toolbox

- Devices to facilitate
  - Antegrade wire escalation
  - Antegrade dissection/re-entry
  - Retrograde wire escalation
  - Retrograde dissection/re-entry
  - Complication Management
- Guides, balloons, catheters, wires and specialty devices
Specialty CTO Asahi Wires

Torque response, drilling, anti-trap

**Straight Tip**

ASAHI MIRACLEBROS™ 3
- TIP LOAD: 3.0G
- Radiopacity length: 11cm
- Joint-less

ASAHI MIRACLEBROS™ 4.5
- TIP LOAD: 4.5G
- Radiopacity length: 11cm
- Joint-less

ASAHI MIRACLEBROS™ 6
- TIP LOAD: 6.0G
- Radiopacity length: 11cm
- Joint-less

ASAHI MIRACLEBROS™ 12
- TIP LOAD: 12.0G
- Radiopacity length: 11cm
- Joint-less

Increasing Support

Interrogate lesion - transmits lesion information

**Tapered Tip**

ASAHI CONFIANZA™ 9
- TIP LOAD: 9.0G
- Radiopacity length: 20cm
- Outside diameter: 0.014inch
- Tip outside diameter: 0.009inch
- Joint-less

ASAHI CONFIANZA PRO™ 9
- TIP LOAD: 9.0G
- Radiopacity length: 20cm
- Outside diameter: 0.014inch
- Tip outside diameter: 0.009inch
- Joint-less

The working length has a hydrophilic coating to ease navigation while the distal 1mm tip is hydrophobic for increased control and tactile feedback in chronic occlusions.

ASAHI CONFIANZA PRO™ 12
- TIP LOAD: 12.0G
- Radiopacity length: 20cm
- Outside diameter: 0.014inch
- Tip outside diameter: 0.009inch
- Joint-less

The working length has a hydrophilic coating to ease navigation while the distal 1mm tip is hydrophobic for increased control and tactile feedback in chronic occlusions.
Newer Specialty CTO Asahi Wires

**Fielder XT**
- 16cm Radio-opaque spring coil
- Stainless Steel Core
- PTFE Coating

**Fielder FC**
- 11cm Spring Coil
- 3cm Radio-opaque Coil
- Stainless Steel Core
- PTFE Coating

**ASAHI® SION**
- 20cm Polymer Sleeve & SLIP COAT®
- SLIP COAT® coating
- 28cm
Corsair Catheter
Collateral Crossing and Support Catheter

Flexible tapered tip of ASAHI Corsair contributes excellent channel tracking and also effectively works for super-selective tip injection
Antegrade Toolbox

WIRES

• Soft, tapered, jacketed
  • Initial probing-crossing wire

• Stiff, non-tapered, jacketed
  • Complex lesion crossing wire

• Stiff, tapered, non-jacketed
  • Stiff Penetrating wire

SUPPORT

• Microcatheter
  – Stiffen wire and facilitate quick wire exchange

• Guide Extension and Support
Retrograde and Ancillary Toolbox

RETROGRADE
- Same wires as antegrade
- Externalization guidewires
- Snares

ANCILLARY
- Doddering device
- Specialty balloons (small, long)
- 8 Fr 23-45cm femoral sheaths
- 90 cm guides (retrograde)
- Hemostasis valves

PERFORATION KIT
- Pericardiocentesis tray
- Covered stent
- Occlusion coils, coil pusher, delivery catheter
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
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

Clear Proximal Cap
Good Distal Target

Antegrade

YES

Dissection Re-Entry
(CrossBoss™– Stingray™)

FAIL

Dissection Re-Entry
(Reverse CART)

NO

Length < 20mm

Retrograde

YES

Dissection Re-Entry
(Reverse CART)

FAIL

Dissection Re-Entry
(CrossBoss™– Stingray™)

NO

Wire Escalation

FAIL

DISSECTION RE-ENTRY (CROSSBOSSTM– STINGRAY™)
Hybrid CTO Registry Results
Most Successful Strategy for Complex Lesions

Success Hybrid
N=194 CTO lesions

Success Japanese CTO
N=528 lesions

Success Royal Brompton
N=269 lesions

% Cases

J-CTO 0-1
J-CTO 2
J-CTO 3

More Complex Lesions

Daniels D, TCT2013
Procedural Efficiency
Lowest procedure time and contrast used in Hybrid Registry

<table>
<thead>
<tr>
<th>Procedure Time (minutes)</th>
<th>Hybrid CTO N=194 lesions</th>
<th>European CTO N=1983 lesions</th>
<th>Japanese CTO N=528 lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure Time (minutes)</td>
<td>83</td>
<td>105</td>
<td>272</td>
</tr>
<tr>
<td>Procedure Time (minutes)</td>
<td>p&lt;0.0001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contrast (cc)</th>
<th>Hybrid CTO N=194 lesions</th>
<th>European CTO N=1983 lesions</th>
<th>Japanese CTO N=528 lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast (cc)</td>
<td>272</td>
<td>313</td>
<td>293</td>
</tr>
<tr>
<td>Contrast (cc)</td>
<td>p&lt;0.0025</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data on procedure time from J-CTO was not published. Presented by Daniels, D at TCT 2013. Gallasi et al. Eurointervention 2011;7:472-49.
Hybrid CTO Registry Results
Complex Lesions Crossed Quickly in More Cases

JCTO ≥ 2 Lesions Crossed in Less Than 30 Minutes

Hybrid Registry: 50%
Japanese CTO Registry: 29%

Daniels D, CTO/LM Summit 2013
Antegrade Wire Escalation

- Soft-tipped polymer-jacketed
  - Excellent Penetration
  - Easier Perforation
  - Excellent Steerability
  - Poor Penetration

- Moderate stiff-tipped polymer-jacketed
  - Good Steerability
  - Moderate Penetration

- Heavy tipped non-polymer-jacketed
  - Excellent Penetration
  - Easier Perforation
Ostial LAD CTO
Antegrade 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
CTO of the RCA

Contralateral injection of the L ➔ R collaterals
CrossBoss Catheter
Angioplasty and Stenting
Final Angiography
Re-re-reattempt at RCA CTO
Simultaneous RCA & LCA Injections
CrossBoss Catheter - Subintimal
Wire redirection and advancement of CrossBoss
Wire redirection and advancement of CrossBoss
Stingray Positioning for Reentry

Incorrect Position

Correct Position
Stingray wiring into true lumen
Stingray wiring into true lumen
Exchange for Corsair and workhorse wire
PTCA of lesion
Stenting of lesion with DES
Final Angiography
Retrograde Techniques

Retrograde collateral wiring

Essential tools for retrograde
1. Microcatheters
2. Wires

Illustration by Dr. J C Spratt / VascularPerspectives, www.ctoibooks.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 / VascularPerspectives, www.ctoibooks.com
CTO of the RCA – Retrograde Approach
Identify an appropriate septal collateral
Septal channel wiring – In real time
CTO of the RCA - Retrograde
CTO of the RCA - Retrograde
Successive Balloon Angioplasty
Multiple drug-eluting stents placed
Initial and Final Angiography
Patient

- 56 yo male
- Hypertension, hyperlipidemia
- MI 2006
- MI 2014
- Exertional angina and shortness of breath
- Anterior wall ischemia with viability
- LVEF 45%
- ASA, clopidogrel, metoprolol, isorsorbide dinitrate, atorvastatin, losartan
- CTO attempted with LAD dissection
- Referred for CABG
Initial Angiograms demonstrating mid LAD CTO
Initial Angiograms demonstrating mid LAD CTO
Evidence of septal perforator collateral to the distal LAD
Corsair into the septal with distal tip injections and successful wiring into distal LAD
Advancing Corsair and preparing antegrade system
Attempting to cross occlusion to proximal true lumen with retrograde system
Advancing antegrade and retrograde wires and confirming position in orthogonal views
Advancing Corsair in preparation for Reverse CART procedure
Performing Reverse CART technique
Retrograde advancement of the Corsair and wiring of guide catheter
Retrograde Corsair into guide catheter to externalize wire
Sequential Predilation
Multiple DES deployed
High pressure post dilation
Final angiograms
Conclusions

• Pt is doing well in follow up with complete relief of symptoms
• Discontinued his long acting nitrates
• Increasing his exercise tolerance
• Quit smoking!
## Complications

<table>
<thead>
<tr>
<th>Event</th>
<th>CTO Angioplasty (n=2007)</th>
<th>Non-CTO Angioplasty (n=2007)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>1.3%</td>
<td>0.8%</td>
<td>0.13</td>
</tr>
<tr>
<td>Q-wave myocardial infarction</td>
<td>0.5%</td>
<td>0.6%</td>
<td>0.67</td>
</tr>
<tr>
<td>Non-Q wave myocardial infarction</td>
<td>1.9%</td>
<td>2.4%</td>
<td>0.27</td>
</tr>
<tr>
<td>Urgent bypass graft surgery</td>
<td>0.7%</td>
<td>1.1%</td>
<td>0.25</td>
</tr>
<tr>
<td>Urgent repeat PCI</td>
<td>1.5%</td>
<td>2.0%</td>
<td>0.23</td>
</tr>
<tr>
<td>Major adverse cardiac events</td>
<td>3.8%</td>
<td>3.7%</td>
<td>0.39</td>
</tr>
<tr>
<td>Stroke</td>
<td>0.01%</td>
<td>0.1%</td>
<td>0.63</td>
</tr>
<tr>
<td>Vascular complication</td>
<td>1.7%</td>
<td>2.5%</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Suero JA JACC 2001;38:409
Complications

- Death and MI
  - Shearing off collateral circulation
  - Injure proximal vessel or side branch
  - Perforation
  - Air embolism
  - Thrombus
  - Arrhythmia
- Emergency CABG
  - Proximal vessel injury or side branch
  - Guidewire fracture or entrapment
  - Perforation
  - Subacute vessel closure
- Contrast nephropathy
- Radiation skin injury
Complications

- **Major Complications**
  - Death 0.8%
  - Emergency CABG 0.3%
  - Q wave MI 0.2%

- **Minor Complications**
  - Tamponade 1.1%
  - Aortic Dissection 0.4%
  - Acute Occlusion 0.8%
  - Subacute Occlusion 0.4%
  - Side branch compromise 2.6%
  - Coronary perforation
    - Type I 9.0%
    - Type II 1.1%
Procedural Success Rates Over Time
Operators with Retrograde Skills >90% Success

<table>
<thead>
<tr>
<th>Year</th>
<th>Procedural Success (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early 05</td>
<td>50</td>
</tr>
<tr>
<td>Late 05</td>
<td>60</td>
</tr>
<tr>
<td>Early 06</td>
<td>70</td>
</tr>
<tr>
<td>Late 06</td>
<td>60</td>
</tr>
<tr>
<td>Early 07</td>
<td>50</td>
</tr>
<tr>
<td>Late 07 / Early 08</td>
<td>80</td>
</tr>
<tr>
<td>2009-2010</td>
<td>100</td>
</tr>
</tbody>
</table>

Operators with Retrograde Skills >90% Success

Dartmouth – North Cascade Multicenter CTO Registry, Thompson CA, Lombardi WL
Is CTO-PCI for you?

**YOU**
- PCI aggressive
- Technically accomplished
- Do complex angioplasty (rotablator IVUS, cutting balloon)
- Willing to change old habits
- Comfortable being uncomfortable
- Okay with failure
- CTO-committed work strategy

**YOUR INSTITUTION**
- Two reliable PCI labs with good imaging
- Demonstrable excellent PCI outcomes
- A team that is comfortable with complex PCI
- Enthusiastic core of nurse/technicians
- Efficient, flexible, patient-centered flow
- CTO partner and supportive practice
Summary

• Successful PCI of Chronic Total Occlusion may
  • Relieve symptoms
  • Improve LV function
  • Improve survival
  • Improve electrical stability
  • Enhance tolerance for progressive CAD
• Assess Risk / Benefit for each patient
  • Consider clinical, angiographic and technical factors
• Essentials of a CTO program
  • Knowledge of histopathology
  • Equipment knowledge and selection
  • Techniques - Guidewire, parallel wire, side branch, retrograde, etc.
  • Specialty devices - Tornus, Cross Boss, Stingray Balloon, Corsair, etc
  • High resolution imaging, contra-lateral injection, orthogonal views
  • Operator, patient, staff, scheduling commitment to CTO program
Thank You

University of California Davis Medical Center