Percutaneous Coronary Interventions (PCI) in Chronic Total Occlusions (CTOs)
The Last Frontier
Ramon L. Lloret, MD, FACC, FSCAI

Educational Objectives
At the end of this talk, attendees will:
• Understand the rationale for the treatment of Chronic Total Occlusions
• Understand the potential patient benefits of a successful CTO PCI
• Understand the current objections of performing CTO PCI and whether the clinical data and literature supports the objections
• Understand the criteria for appropriate patient selection for CTO PCI
• Be able to apply the concepts learned to case studies

Conflict of Interest Disclosure
Consultant and Speaker
• Astra Zeneca
• Novartis
• Aralez

Definition of a Chronic Total Occlusion
A CTO is defined as:
• Occlusions in the coronary arteries with TIMI 0 flow
• Functional occlusions with TIMI 1 flow of at least three months duration

TIMI Flow Classification

TIMI = Thrombolysis in Myocardial Infarction

<table>
<thead>
<tr>
<th>TIMI Flow</th>
<th>Grade 0</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMI 0 Flow</td>
<td>No Perfusion</td>
<td>Partial Perfusion</td>
<td>Complete Perfusion</td>
<td></td>
</tr>
</tbody>
</table>

TIMI Flow Classification

Chronic Total Occlusion (CTO) Morphology

The Complexity of a CTO
What’s in the lumen?
Histopathology of CTOs

Thrombosis → Thrombus Organization → Tissue Aging

Neovascularization

“Microchannels”

Fibrocalcification

“Calcified Areas”


CTO ANTEGRADE LAD
Patient Benefits of Successful CTO PCI

Benefits of CTO PCI

- Relief of Angina
- Improved Exercise Tolerance
- Improve Survival
- Improved LV Function
- Improved Tolerance of a Future ACS
- Reduce the need for CABG
- Reduce Ischemic Burden
- Reduce Arrhythmias

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Relief of Angina

Angina is one of the major symptoms and chief complaints of patients with a CTO.

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Relief of Angina / Improved Exercise Tolerance

- 302 CTO PCI attempts
- 70% success
- 22% failed
- 70% follow up at 1 year

A 5 point difference in AQL is considered clinically relevant.

Successful CTO PCI procedures significantly improved AQL scores when compared to a failed attempt.
Improved Survival / Mortality

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Improved LV Function
- In 39% of patients with LV dysfunction, significant myocardial recovery was observed at follow-up.

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- Reduce Ischemic Burden
- Reduce Arrhythmias
Patients with 10-15% ischemia of the LV Mass will most likely see a 5% reduction in ischemia with successful CTO PCI.
Reduce Arrhythmias

Kaplan-Meier survival curves for freedom from first appropriate device therapy in CTO and non-CTO populations.

CTO is an independent predictor for ventricular arrhythmias and has an adverse impact on long-term mortality.

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The Naysayers

- “There is no evidence for CTO-PCI in asymptomatic patients”
- “Outside of ACS, PCI has never been shown to be life prolonging”
- “Vessel has been occluded a long time.”
- “The vessel has good collaterals”

Collaterals in CTO

Collaterals are usually not sufficient to substantially reduce ischemia in CTO.


Patient Criteria for CTO-PCI

Symptomatic Patients
- Angina refractory to Optimal Medical Therapy
- Poor Exercise Tolerance - Fatigue
Ischemic Burden in the CTO Territory
Viable Myocardium
Asymptomatic Patients without documented ischemia and viable myocardium not on OMT will not benefit from CTO PCI

Conclusions

- There is evidence that recanalization of CTOs is beneficial to patients
- It is appropriate to continue to attempt recanalization of CTOs as long as it is done by knowledgeable and skilled operators, and patient selection is appropriate
ANTEGRADE WITH AMBIGUOUS ORIGIN OF LAD
**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

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**The Hybrid Algorithm**

Antegrade

- Clear Proximal Cap
- Good Distal Target
  - YES
  - NO

Retrograde

- Wire Escalation
  - YES
  - NO
- Dissection Re-Entry
  - YES
  - NO
- Dissection Re-Entry (Reverse CART)
  - FAIL

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**Antegrade Wire Escalation**

- Soft-tipped polymer-jacketed
  - Excellent Steerability
  - Poor Penetration
- Moderate stiff-tipped polymer-jacketed
  - Good Steerability
  - Moderate Penetration
- Heavy tipped non-polymer-jacketed
  - Heavy tipped
  - Non-polymer-jacketed

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**Coronary CTO Crossing and Re-entry System**

- Cap-Fracturing Catheter
  - Designed to quickly and safely deliver a guidewire via true lumen or subintimal pathways
- Re-Entry Balloon and Wire System
  - Designed to accurately target and re-enter the true lumen from a subintimal position

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**Antegrade Dissection Re-Entry**

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

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**2/21/2017**

**Designed to quickly and safely deliver a guidewire via true lumen or subintimal pathways.**
Dual injection

Utility of Bilateral Coronary Injections During Complex Coronary Angioplasty

Maaskeep Singh, MD, Malcolm R. Bell, MB, BS, Peter B. Berger, MD, David R. Holmes Jr., MD

ABSTRACT: We describe a technique useful in complex coronary intervention wherein simultaneous bilateral coronary injection may be used in both coronary arteries. This technique is useful in chronic total occlusions in which the distal coronary vessel is not visualized except by collateral filling via the contralateral artery. This technique was applied in 8 patients. Of 10 with native coronary ostium and one in which the target site was distal to the contrast injection into a true graft supplying a more distal site, an additional patent native vessel. While this technique, the distal coronary artery segment can be better visualized, which helps to aim and track the guide wire across the occluded segment.

J INV AS CARD IOS, 1999;2:78-79

Keywords: bilateral injection, percutaneous coronary angioplasty, technique

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Dual injection

1. Low magnification (10 inch)
2. Inject donor vessel first
3. Wait 1-2 sec before injecting CTO vessel
4. No panning
5. Cine until contrast clears

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Hybrid CTO crossing algorithm

ANTEGRADE RCA

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AN giography

1. Ambiguous proximal cap
2. Poor distal target
3. Appropriate “Interventional” collaterals

Antegrade

Retrograde

Antegrade dissection and reentry

Retrograde true lumen puncture

Retrograde dissection and reentry

CONTROLLED (antegrade)

WIRE BASED (Latex)

AN giography


ANTEGRADE RCA
Studying the CTO

1. By whom?  Entire cath team
2. How long?  15-30 min
3. How?
   1. Proximal cap ambiguity
   2. Lesion length
   3. Quality of distal vessel
   4. Collaterals

Strategic Plan

1. Proximal cap
   1. Proximal vessel tortuosity - caliber
   2. Ambiguous or clear?
   3. Tapered or blunt?
   4. Side branches?
   5. Calcification

3. Distal vessel
   1. Caliber and quality of distal vessel
   2. Bifurcation
   3. Prior bypass graft insertion sites
4. Collaterals

1. Type (septal, bypass grafts, epicardial)
2. Size (Werner classification)
3. Tortuosity
4. Dominance
5. Angle and location of entry

Conclusions

1. Dual injection critical for success of CTO PCI
2. Careful pre-procedure angiographic review
3. Focus on 4 elements

ACCF/AHA/SCAI Guideline for PCI

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.
What is Really Happening?

Current State of Care of Patients with CTO

- Revascularization is offered less often and with surgery
- Revascularization with PCI is variable
  - Depends on operator experience and institutional treatment biases
- Revascularization with PCI dictated by angiogram not patient needs

Procedural Success vs. Complication Rate of CTO PCI

Angiographic core lab, Events adjudication, NCDR auditing
Interpretation of Angiography

Four Characteristics Outlined by Treatment Algorithm
- Proximal Cap Location and Morphology
- Lesion Length
- Target Coronary Vessel at the Distal Cap
- Size and Suitability of Collateral Circulation for Retrograde Technique

Proximal Cap Location and Morphology

First Step of the Hybrid Algorithm
"Can we easily define the proximal cap or is it ambiguous?"
- Ability to identify the proximal cap location unambiguously via angiography or intravascular ultrasound
- Ability to properly engage lesion
  - Presence of side branches at the proximal cap
  - Presence of bridging or other collateral

Lesion Length

Critical Measure = 20 mm in Length
- <20 mm: 20 mm success rates with antegrade wire escalation are high
- ≥20 mm: Substantially decreased success rates with standard antegrade wire escalation techniques
  - Consider:
    - Primary Dissection and Reentry
    - Primary Retrograde

Target Coronary Vessel at Distal Cap

Assessing the Quality of the Distal Target Vessel for Re-Entry
- Size of the Lumen
- Presence of Side Branches or Bifurcations
- Presence or absence of disease at the re-entry zone
- Ability to adequately visualize this segment

Size and Suitability of Collateral Circulation for Retrograde

“Are there interventional collaterals present?”
1. Healthy or repaired donor vessel
2. Easily accessed with microcatheters
3. Minimal tortuosity
4. Not the ONLY source of Flow to the CTO segment
5. Enter the CTO vessel well beyond the distal cap
6. Septal Collaterals are the preferred
7. Epicardial Collaterals carry a higher risk of perforation and associated tamponade

CART and Reverse CART

Controlled Antegrade and Retrograde subintimal Tracking
- CART
  - Connecting Proximal → Distal
- Reverse CART
  - Connecting Distal → Proximal

Utilized to connect the proximal true lumen to the distal true lumen via the subintimal space
Utilized to connect the distal true lumen to the proximal true lumen via the subintimal space
Summary

- Starting a CTO PCI procedure with dual injection provides key information in determining how the operator will proceed with the case.
- By answering the questions in Step 2 of the algorithm (ambiguous proximal cap?, poor distal target?, presence of interventional collaterals?), the operator can determine the best lesion access technique, with which to begin the procedure.
- The key to successful utilization of the algorithm is to not get "stuck" in any section for a long period of time. This will cause you to reach your limits of radiation and contrast doses to your patient.
- The cadence of fluoro time and radiation dose should be evenly distributed at each stage of the procedure to avoid any one stage reaching critical dose levels.
Equipment and Procedural Differences Between CTO-PCI and PCI


Guide Wires

Table 1

<table>
<thead>
<tr>
<th>Equipment and procedural differences between CTO PCI and non-CTO PCI</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Arterial access sheaths</td>
</tr>
<tr>
<td>Guide catheters</td>
</tr>
<tr>
<td>Coronary angiography</td>
</tr>
<tr>
<td>Coronary guide wire</td>
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<tr>
<td>Guide wire support</td>
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</tbody>
</table>

Abbreviations: CIA, common iliac artery; RA, radial artery

Microchannel probing and Crossing

- Wire with a tapered tip (0.09), soft tip (<3.4 g) and non-polymer jacketed wire with hydrophilic coating.

Collateral Crossing for Retrograde

- Hydrophilic coated, non-tapered wire with the lowest tip load (<1.5 g).
- Composite wire with extra soft tip load of less than 1.5 g.

Proximal or Distal Cap Penetration

- Non-polymer juxtaluminal wire with hydrophilic coating and <8.5 g tip load.

Knuckle Dissection

Polymer jacketed, hydrophilic wires that easily “knuckle”.

Re-Entry

- Sharp tip (0.03), non-polymer juxtaluminal wire with hydrophilic coating and <8.5 g tip load.
- 28° Angled tip wire that tapers from 0.014 to 0.007 to 0.003 distally.
- Non-tapered, full polymer jacketed wire with hydrophilic coating and >8.5 g tip load.

Externalization

- Wires that are <300 cm in length.
Shaping Guide Wires for CTO PCI

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Shape</th>
</tr>
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<tbody>
<tr>
<td>Wire shape to penetrate the occlusion cap or to find a microchannel.</td>
<td></td>
</tr>
<tr>
<td>Wire shape to reenter into the true lumen from the subintimal space.</td>
<td></td>
</tr>
<tr>
<td>Wire shape for controlled subintimal dissection.</td>
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</tbody>
</table>

Microcatheters

- Multiple brands available
- OTW Balloon

Cap-Fracturing Catheter

- Multi-wire coiled shaft
- Tracks via FAST Spin Technique
  - Highly torqueable coiled-wire shaft
  - FAST Spin reduces push required to cross CTO
- Atraumatic distal tip advanced across a CTO ahead of the guide wire
- OTW 0.014” guide wire compatible

Re-Entry Balloon and Wire System

Goal: re-enter the true lumen from a subintimal position

Tools for Complication Management

- Coils and Injectable Material
- Covered Stents
- Pericardiocentesis Equipment

Sample CTO PCI Inventory

<table>
<thead>
<tr>
<th>Tool</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>Urgent catheter</td>
<td>1</td>
</tr>
<tr>
<td>6F and 8F Guide Catheters</td>
<td>5 of each configuration</td>
</tr>
<tr>
<td>Specialty Wires</td>
<td>2 of each</td>
</tr>
<tr>
<td>Specialty Microcatheters</td>
<td>1</td>
</tr>
<tr>
<td>Special System for Controlled Dissection and Re-entry</td>
<td>5 complete systems</td>
</tr>
<tr>
<td>Coils and delivery system</td>
<td>2 of each of the following</td>
</tr>
<tr>
<td>Pericardiocentesis set</td>
<td>1</td>
</tr>
</tbody>
</table>