MHIF FEATURED STUDY: Rhapsody

DESCRIPTION:
First multinational, phase 3, double-blinded, placebo-controlled, randomized withdrawal, study assessing the efficacy of rilonacept, an interleukin 1 alpha and beta receptor decoy, in the treatment of recurrent pericarditis.

CRITERIA LIST/QUALIFICATIONS:

Inclusion
Diagnosis of recurrent pericarditis

Exclusion
• Pericarditis secondary to specific prohibited etiologies, including tuberculosis (TB); neoplastic, purulent, or radiation etiologies
• Post-thoracic blunt trauma (e.g., motor vehicle accident)
• Myocarditis
• Systemic autoimmune diseases with exception of Still’s disease, pregnancy, hx HIV, prednisone > 60 mg/day, positive Hep B or C, serious infection

MHIF was first in the world to enroll in this trial and has 4 subjects enrolled out of the 9 in the world. Pericarditis patients are experiencing significant benefits and most often have no chest pain after starting this medication.
Update in CTO PCI

Emmanouil S. Brilakis, MD, PhD

Disclosures

- Consulting/speaker honoraria: Abbott Vascular, American Heart Association (associate editor Circulation), Boston Scientific, Cardiovascular Innovations Foundation (Board of Directors), CSI, Elsevier, GE Healthcare, InraRedx, Medtronic
- Research support: Regeneron, Siemens
- Shareholder: MHI Ventures.
- Board of Trustees: Society of Cardiovascular Angiography and Interventions
CTO: occlusion in the coronary artery with TIMI 0 flow of ≥3 months duration

Dallas VAMC: CTO prevalence and revascularization

- Diagnostic caths 1/2011 to 12/2012: 2,193
- Unique patients: 1,699

- No prior CABG; n=1,355 CAD; n=1,015
  - CTO, n=319, 31%
    - PCI n=161 (50%)
    - Medical Rx n=61 (19%)
    - CABG n=97 (30%)

- Prior CABG; n=344
  - CTO, n=305, 89%
    - PCI n=182 (60%)
    - Medical Rx n=121 (40%)
    - CABG n=2 (0.6%)

Case 1
55-year-old diabetic. EF=26% Referred for Circ CTO PCI

Referred for circ CTO PCI
Case 2
Patient testimonial after CTO PCI

When should CTO PCI be done?

Update in the Percutaneous Management of Coronary Chronic Total Occlusions

Peter T. Tal, MD, MB; Nicholas Hauser, MD; Walid Kamel, MD; Bobish Nicolau, MD, PhD; Valentina Furrer, MD; Gerald E. Werner, MD; Lorenz Anderer, MD, PhD, MSC; Vincent Carlon, MD; Walter Russ, MD; Karl-Heinz Reinhardt, MD; Mohamed Aboul-Enein, MD; Rajiv Ramprashad, MD, PhD; William J. Nicholson, MD; Ingo Engle, MD, PhD; Alfred K. Glower, MD; Subhashi Benes, MD, PhD

ABSTRACT

Percutaneous coronary intervention (PCI) for chronic total occlusions (CTO) has been rapidly evolving during recent years, with improvement in equipment and techniques, high success rates can now be achieved at experienced centers, although several success rate remain low. Percutaneous coronary intervention including percutaneous coronary intervention and revascularization for PCI of CTO should be performed where the anticipated benefits exceed the potential risks. New high-quality evidence of the clinical outcomes and techniques of CTO PCI are needed, as the expansion of reports in CTO PCI is expected to achieve excellent clinical outcomes in this challenging patient subset.

In the current issue, the authors present evidence-based publications on PCI for CTO and provide guidance to operators. The evidence-based accounts of the North American Society of Pacing and Electrophysiology (NASPE) and the European Society of Cardiology (ESC) are described, and the current status of the field is discussed.
**EuroCTO**

Primary endpoint: SAQ health status (ITT)

- CMT
- PCI

**Decision CTO**

- CTO-PCI
- Na-CTO-PCI

**EXPLORE trial results**

- REPO CTO = 0.05
- REPO NoCTO = 0.04

**Revasc trial**

Primary endpoint:

- **p = 0.07**
- **p = 0.07**

**Impactor CTO**

- Single center
- 94 pts
- 83% CTO PCI success

**A**

- Baseline
- 2 months
- 12 months

- PCI
- CMT

**B**

<table>
<thead>
<tr>
<th></th>
<th>Baseline PCI group (mmHg)</th>
<th>PCI group (mmHg)</th>
<th>p</th>
<th>PCI group (mmHg)</th>
<th>PCI group (mmHg)</th>
<th>p</th>
<th>PCI group (mmHg)</th>
<th>PCI group (mmHg)</th>
<th>p</th>
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<tbody>
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</tr>
<tr>
<td>Physical functioning, median (SF)</td>
<td>40 (22,42)</td>
<td>40 (22,34)</td>
<td>0.40</td>
<td>40 (22,42)</td>
<td>40 (22,34)</td>
<td>0.40</td>
<td>40 (22,42)</td>
<td>40 (22,34)</td>
<td>0.40</td>
</tr>
<tr>
<td>Social/psychological functioning, median (SF)</td>
<td>76 (26,71)</td>
<td>76 (26,71)</td>
<td>0.97</td>
<td>76 (26,71)</td>
<td>76 (26,71)</td>
<td>0.97</td>
<td>76 (26,71)</td>
<td>76 (26,71)</td>
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<tr>
<td>Bodily pain, median (SF)</td>
<td>16 (21,12)</td>
<td>16 (21,12)</td>
<td>0.05</td>
<td>16 (21,12)</td>
<td>16 (21,12)</td>
<td>0.05</td>
<td>16 (21,12)</td>
<td>16 (21,12)</td>
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<tr>
<td>Shortness of breath, median (SF)</td>
<td>59 (23,59)</td>
<td>59 (23,59)</td>
<td>0.07</td>
<td>59 (23,59)</td>
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<td>59 (23,59)</td>
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<td>0.07</td>
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<tr>
<td>Fatigue, median (SF)</td>
<td>30 (20,30)</td>
<td>30 (20,30)</td>
<td>0.03</td>
<td>30 (20,30)</td>
<td>30 (20,30)</td>
<td>0.03</td>
<td>30 (20,30)</td>
<td>30 (20,30)</td>
<td>0.03</td>
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<tr>
<td>Total functioning, median (SF)</td>
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<td>50 (22,50)</td>
<td>0.05</td>
<td>50 (22,50)</td>
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<td>50 (22,50)</td>
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<tr>
<td>Role functional, median (SF)</td>
<td>48 (24,48)</td>
<td>48 (24,48)</td>
<td>0.07</td>
<td>48 (24,48)</td>
<td>48 (24,48)</td>
<td>0.07</td>
<td>48 (24,48)</td>
<td>48 (24,48)</td>
<td>0.07</td>
</tr>
<tr>
<td>Mental health, median (SF)</td>
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<td>0.02</td>
<td>40 (20,40)</td>
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<td>40 (20,40)</td>
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<td>0.02</td>
</tr>
</tbody>
</table>

Anton A. Obedinskiy et al. JCIN 2018;11:1309-1311
7 Global Principles for CTO PCI

1. **Principal indication:** to improve symptoms
2. Dual angiography + careful angiographic review
3. Use of microcatheter for guidewire support
4. 4 CTO crossing strategies: AWE, ADR, RWE, RDR
5. Change increases likelihood of success
6. CTO PCI should be done at experienced-well equipped centers
7. Stent deployment should be optimized

101 operators - 50 countries – Circulation 2019; in press
Effects of CTO PCI on QoL in Depressed and Non-Depressed Patients

- Following CTO PCI, depressed patients experienced ~3x the angina benefit as not depressed patients.
- CTO PCI patients have 3-fold less depression at 1 month.

Bruckel et al, J Invasive Cardiol 2016

Impact of CTO on outcomes post STEMI

The myocardium supplied by a chronic total occlusion is a persistently ischemic zone

Sachdeva et al. CCI 2013

50 CTOs

Proc (Bayl Univ Med Cent) 2015;28(2):196–199
Complete vs. incomplete revascularization

89,883 Patients

12,259 out of 89,883 (13%) died during follow up.

Mortality benefit in patients treated with CABG (RR 0.70; 95% CI: 0.61-0.80, p < 0.001) and PCI (RR 0.72, 95% CI: 0.64-0.81, p < 0.001.

Mortality benefit did not vary with definition of CR.

Case 3
History

- 61-year-old man with NSTEMI
- History of DM, HTN, dyslipidemia, PVD
- 3-vessel disease - turned down for CABG
- s/p LAD and Cx OM PCI (6 years prior)
- ICD implantation for secondary prevention (May, 2016)
- Echocardiography: severely depressed LV systolic function (EF: 24%), hypokinetic anterior septum, akinetic basal posterior, posterolateral and mid inferior segments
EXPLORt E trial design

- **Patients**
  Patients with STEMI treated with pPCI and with a non-infarct related CTO.

- **Design**
  Global, multi-center, randomized, prospective two-arm trial with either CTO PCI or no CTO intervention after STEMI. Blinded evaluation of endpoints.

- **Objective**
  To determine whether PCI of the CTO within 7 days after STEMI results in a higher LVEF and a lower LVEDV assessed by MRI at 4 months.


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EXPLORt E trial results

Revasc trial  Primary endpoint:

EF improved to 45% 3 months later
Case 4
81-year-old woman with non-NSTEMI

Occluded SVG-RCA

Stent under-expansion despite high pressure balloon inflations
SVGs have poor long-term outcomes

**Target vessel failure**

- Median FU: 2.7 years

- Log-Rank = 0.79
- p-value = 0.42
- Total Events = 208
- Hazard Ratio of DES Relative to BMS = 1.12
- HR 95% CI = 0.85 - 1.47

* * After 12 months post-randomization, this analysis uses reported TVF events because adjudication was only done for TVF events occurring during the first 12 months post-randomization.

Native coronary PCI better than SVG PCI

**Death or MI or Revascularization**

- Event Free Probability
- Time from PCI (Days)

<table>
<thead>
<tr>
<th></th>
<th>VESSEL</th>
<th>GRAFT</th>
<th>NATIVE</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0.985</td>
<td>0.992</td>
<td>0.985</td>
</tr>
<tr>
<td>1000</td>
<td>0.884</td>
<td>0.893</td>
<td>0.884</td>
</tr>
<tr>
<td>2000</td>
<td>0.784</td>
<td>0.790</td>
<td>0.784</td>
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<tr>
<td>3000</td>
<td>0.684</td>
<td>0.690</td>
<td>0.684</td>
</tr>
<tr>
<td>4000</td>
<td>0.584</td>
<td>0.590</td>
<td>0.584</td>
</tr>
</tbody>
</table>

P < 0.001
2010: The “future”: treat native coronary instead of SVG?

Candidate for redo CABG?

Need for additional revascularization?

LIMA to LAD feasible?

Corresponding native coronary lesion complex?

SVG lesion complex?

Able to treat native lesion?

Consider redo CABG

Native lesion PCI

SVG PCI*

Brilakis et al. JACC 2018
Additional options = Grafts

Grafts
- Arterial
- SVGs
  - patent
  - occluded
  - patent
  - occluded


3 weeks later
CT-angio

Antegrade wire escalation
Unable to cross through prior stent

- Hornet 14
- Pilot 200
- Gaia 2nd
- Gaia 3rd

Pilot 200 subintimal (sub-stent) followed by Corsair
Stingray wire
re-enter distal true lumen
exchanged for Pilot 200
“Stick and swap”

Pilot 200 into true lumen
Conclusions

- Native coronary artery PCI is preferred to SVG PCI (esp after SVG occlusion), if feasible
- Treating ISR CTOs: sub-stent crossing, re-entry, and crushing stents
- Balloon undilatable lesion: subintimal crossing can provide effective treatment

“Staged SVG revascularization”

| Acute SVG failure | Stage 1 SVG PCI | Stage 2 Native coronary PCI |

Xenogiannis I et al. Catheter Cardiovasc Interv 2018
Case 5

History

- 70-year-old man presented to ED with acute substernal pain
- ECG: inferior STEMI
- CAD (PCI 20 years prior), DM type II, HTN, dyslipidemia
- Driven to cath lab for primary PCI
ST elevation
Change to right femoral access

Difficulty to pass external iliac due to aneurysm

Access was lost

Manual pressure over RFA, access through LFA

Hypotension
8x20 mm balloon

Defibrillation
VF
VT
Defibrillation
SR

Cardiac arrest
Lucas Device
IV fluids, noradrenaline, adrenaline and RBC transfusion

Vascular surgeons were notified

Suddenly the patient collapsed => **Cardiac arrest (VF)**

CPR, Lukas device, Defib, intubation, VA-ECMO
• The patient was transferred intubated, in critical condition to the ICU

• Developed AKI and acute hypoxemic encephalopathy

• VA-ECMO was decannulated 2 days later

• Discharged after 17 days and referred to a rehabilitation center
Conclusions

1. Acute vessel closure can be a lethal complication
2. Indented bladder sign: retroperitoneal hematoma
3. VA-ECMO for cardiac arrest
4. ADR for acute vessel closure
5. Collaboration key to success!
Hybrid CTO crossing algorithm

Part I

1. Dual injection

Brilakis, Grantham, Rinfret, Wyman, Burke, Karmpaliotis, Lembo, Pershad, Kandzari, Buller, De Martini, Lombardi, Thompson. JACC Intv 2012
Hybrid CTO crossing algorithm

Part II

Studying the CTO

1. By whom?  Entire cath team
2. How long?  15-30 min
3. How? 4 characteristics

Angiographic review: 4 key components

1. Proximal cap
2. Lesion length/Calcification/Tortuosity
3. Distal vessel
4. Collaterals
Studying the lesion

1. Proximal cap

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

Which proximal vessel would you rather have?

Jang Y. PCI for CTO. Springer 2019
Where is the proximal cap?
Flush RCA CTO?

courtesy Leszek Bryniarski, MD

Flush RCA CTO?

courtesy Leszek Bryniarski, MD
Flush RCA CTO?

courtesy Leszek Bryniarski, MD

Where is the proximal cap?

Choi et al. JACC Interv 2015
Studying the lesion

2. Lesion length – tortuosity - composition

**Calcification**

- Cross-sectional calcium:
  - 0%
  - < 50%
  - > 50%
  - 100% (full moon)

- Shape of cross-sectional calcium:
  - Crescent moon
  - Half-and-half moon
  - Circular

*Jang Y. PCI for CTO. Springer 2019*

---

**Predictors of antegrade failure**

- Length >32 mm
- Ostial or bifurcation lesions
- Negative remodeling

**Remodeling**

* Luo et al. JACC CV Imaging 2015*
3. Distal vessel

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

Studying the lesion

4. Collaterals

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

Studying the lesion
### J-CTO Score

494 native CTO lesions
Crossing within 30 minutes

---

**PROGRESS CTO score**

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>≥3</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>98.2</td>
<td>97.5</td>
<td>91.6</td>
</tr>
</tbody>
</table>

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**POOR CAP VISUALIZATION OR ABSENCE OF CLEARLY TAPERED STUMP**

- Proximal cap ambiguity (1 point)
- Absence of "interventional" collaterals (1 point)
- Moderate/severe tortuosity (1 point)
- Circumflex CTO (1 point)

---

Choose the CTO lesions you attempt wisely...

Early: J-CTO 0-1

Next: J-CTO 2

Later: J-CTO ≥3

Dual injection
CCTA vs angiography J-CTO score

218 CTO PCIs in 205 pts  - 45% equal - 30% higher – 25% lower

Success: 82.6%
30-min wire crossing: 29.4%

Fujino et al. JIMG 2018;11:209-217
CCTA vs angiography J-CTO score

218 CTO PCIs in 205 pts
Success: 82.6%
30-min wire crossing: 29.4%

Fujino et al. JIMG 2018;11:209-217

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,1,2 Stephan Achenbach, MD,1 Annika Schuhbäck, MD,1 Andreas Rolf, MD,1 Helge Möllmann, MD,1 Holger Nef, MD,1 Johannes Rixe, MD,1 Matthias Renker, MD,2 Adam Witkowski, MD,1 Geyartz Kepka, MD,1 Claudia Walther, MD,1 Christian Schlundt, MD,1 Artur Debiski, MD,1 Michal Jakubczyk, MSc,1 Christian W. Hamm, MD,1,2
CT-RECTOR Score Calculator

Predictors Definitions

Multiple Occlusion
Presence of ≥2 complete interruptions of the coronal opacification separated by contrast-enhanced segments of ≥5 mm.

Blunt Stump
Absence of any tendinous stump at the entry or exit site.

Severe Calcification
Presence of any calcium involving ≤50% of the median cross-sectional area at the entry or exit site or within the occlusion route.

Bending 45°
Presence of any bending ≥45° at the entry or exit site or within the occlusion route.

Second Attempt
Previously failed PCI at CTO

Duration of CTO
Duration of CTO ≥12 months or unknown

Difficulty Group
Easy (1)  Difficult (2)
Intermediate (3)  Very Difficult (5)

Total Score

---

Success – Crossing within 2 minutes

---

Failure
Real time CCTA fusion

- Centerlines are displayed. Coloring indicates degree of foreshortening (green=low, red=high)
- Calcification can be toggled on and off
- Individual vessel centerlines can be toggled on or off

Where is the retrograde wire?

Ghoshhajra, ... Jaffer. European Radiology 2016
Failed re-entry
Why?

Ghoshhajra, ..., Jaffer. European Radiology 2016

Hybrid CTO crossing algorithm

Part III

Brilakis, Grantham, Rinfret, Wyman, Burke, Karmpaliotis, Lembo, Pershad, Kandzari, Buller, De Martini, Lombardi, Thompson. JACC Intv 2012
All crossing strategies have a role

Successful crossing strategy stratified by J-CTO score

PROspective Global REgiStry for the Study of CTO interventions
www.progresscto.org

p<0.0001

Retrograde
ADR
AWE
**PROspective Global REgiStry for the Study of CTO interventions**

www.progresscto.org

**Procedural complications**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>AWE</th>
<th>ADR</th>
<th>Retrograde</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACE overall</td>
<td>1.09%</td>
<td>2.96%</td>
<td>5.61%</td>
</tr>
<tr>
<td>Death</td>
<td>0.36%</td>
<td>0.87%</td>
<td>1.50%</td>
</tr>
<tr>
<td>Acute MI</td>
<td>0.00%</td>
<td>1.22%</td>
<td>2.46%</td>
</tr>
<tr>
<td>Stroke</td>
<td>0.14%</td>
<td>0.35%</td>
<td>0.55%</td>
</tr>
<tr>
<td>Re-PCI</td>
<td>0.14%</td>
<td>0.52%</td>
<td>0.68%</td>
</tr>
<tr>
<td>Emergency CABG</td>
<td>0.14%</td>
<td>0.00%</td>
<td>0.14%</td>
</tr>
<tr>
<td>Pericardial tamponade</td>
<td>0.43%</td>
<td>0.87%</td>
<td>0.96%</td>
</tr>
<tr>
<td>Perforation</td>
<td>1.16%</td>
<td>5.22%</td>
<td>7.52%</td>
</tr>
</tbody>
</table>

**p-values:**
- AWE vs ADR: p<0.0001
- AWE vs Retrograde: p=0.0001
- ADR vs Retrograde: p=0.0171
- Death vs Acute MI: p=0.2629
- Death vs Stroke: p=0.1228
- Death vs Re-PCI: p=0.6637
- Death vs Emergency CABG: p=0.2999
- Death vs Pericardial tamponade: p=0.2629
- Death vs Perforation: p=0.2629

**Hybrid CTO crossing algorithm**

**Part IV:**

**Switch Strategy**

*Brilakis, Grantham, Rinfret, Wyman, Burke, Karpapliotos, Lembo, Pershad, Kandzari, Buller, De Martini, Lombardi, Thompson, JACC Intv 2012*
7 Global Principles for CTO PCI

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7. Stent deployment should be optimized

101 operators - 50 countries – Circulation 2019; in press
Euro CTO algorithm

Consider CTO PCI failure in the following conditions, unless the procedure is well advanced:
- Procedural time > 3 hours
- Contrast load > 4 x eGFR (ml)
- Air Kerma > 5 Gy

Galassi et al. Eurointervention 2018

CTO PCI: the world is converging
7 Global Principles for CTO PCI

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101 operators - 50 countries – Circulation 2019; in press

Expand the stent!

Malapposition

Underexpansion

### Stent patency rates in CTO PCI

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Stent</th>
<th>n</th>
<th>FU angiography time</th>
<th>Prior CABG</th>
<th>Total stent length (mm)</th>
<th>In-stent restenoses (%)</th>
<th>In-segment restenoses (%)</th>
<th>TLR (%)</th>
<th>TVR (%)</th>
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</thead>
<tbody>
<tr>
<td>PRISON II</td>
<td>2006</td>
<td>SES</td>
<td>100</td>
<td>6 months</td>
<td>3</td>
<td>32±15</td>
<td>7</td>
<td>11</td>
<td>4</td>
<td>8</td>
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<tr>
<td>ACROSS-TOSCA 4</td>
<td>2009</td>
<td>SES</td>
<td>200</td>
<td>6 months</td>
<td>8.5</td>
<td>45.9 (30.2, 62.1)</td>
<td>9.5</td>
<td>12.4</td>
<td>9.8</td>
<td>11.4</td>
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<tr>
<td>GISSOC II</td>
<td>2010</td>
<td>SES</td>
<td>78</td>
<td>8 months</td>
<td>6.7</td>
<td>41±18</td>
<td>8.2</td>
<td>9.8</td>
<td>8.1</td>
<td>14.9</td>
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<td>CIBELES</td>
<td>2012</td>
<td>SES</td>
<td>101</td>
<td>9 months</td>
<td>4</td>
<td>47±24</td>
<td>10.5</td>
<td>11.6</td>
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<tr>
<td>ACE-CTO</td>
<td>2012</td>
<td>EES</td>
<td>106</td>
<td>9 months</td>
<td>4.7</td>
<td>50±23</td>
<td>9.1</td>
<td>7.9</td>
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</tr>
</tbody>
</table>

### IVUS-CTO: Primary endpoint (Cardiac death, MI, TVR)

- **Angiography-guided group**
- **IVUS-guided group**

**Cumulative incidence (%)**

- **12-month**
- **Follow-up duration (months)**

**Number at risk**
- Angiography-guided: 201, 198, 198, 179, 186
- IVUS-guided: 201, 198, 198, 179, 186

**HR=0.35, 95% CI = 0.13 – 0.97, p = 0.035**

Kim et al. Circ Cardiovasc Interv. 2015;8:e002592
**Funding:** Abbott Northwestern Hospital Foundation

**International sites:**
- Meshalkin Novosibirsk Research Institute, Russian Republic
  - O. Krestyaninov, D. Khelimskii
- Kogialeneio-Benakeio Hellenic Red Cross, Greece
  - M. Koutouzis, Y. Tsiafoutis
- Henry Dunant Heart Hospital, Greece
  - V. Tzifos, A. Kolyviras, D. Damaskos
- St. Boniface General Hospital, Canada
  - B. Elbarouni, M. Love
- St. George Hospital University Medical Center, Lebanon
  - A. Maalouf, F. A. Jaoudeh, N.A. Rafeh

**41 Sites – Study PI: E. S. Brilakis – National Coordinator: B.V. Rangan – Database Manager: I. Xenogiannis**

**PROspective Global REgiStry for the Study of CTO interventions**

**www.progresscto.org**

**5/2012 to 11/2018**

**25 centers, 4,410 lesions**

**Technical success: 86%**

**Major complications: 2.3%**

(composite of 0.44% mortality, 0.84% MI, 0.81% pericardiocentesis, 0.23% stroke, 0.12% CABG, 0.28% re-PCI)

---

![Diagram showing Applied techniques: AWE 84%, ADR 28%, Retrograde 35%](image-url)
**CTO PCI: success and complications**

<table>
<thead>
<tr>
<th>First Author</th>
<th>Study Period</th>
<th>Centers</th>
<th>Cases</th>
<th>Technical Success</th>
<th>Procedural Success</th>
<th>Overall MACE</th>
<th>Death</th>
<th>Acute MI</th>
<th>Stroke</th>
<th>TVR</th>
<th>Tamponade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Konstantinidis</td>
<td>EURO-CTO registry 2008–2015</td>
<td>53</td>
<td>17,626</td>
<td>85%</td>
<td>—</td>
<td>0.6%</td>
<td>0.2%</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.4%</td>
</tr>
<tr>
<td>Habara</td>
<td>Japanese Retrograde Summit Registry 2012–2013</td>
<td>56</td>
<td>3,229</td>
<td>—</td>
<td>88%</td>
<td>0.5%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>—</td>
<td>0.3%</td>
</tr>
<tr>
<td>Tajti</td>
<td>PROGRESS-CTO 2012–2017</td>
<td>20</td>
<td>3,055</td>
<td>87%</td>
<td>85%</td>
<td>3.0%</td>
<td>0.3%</td>
<td>0.7%</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Wilson</td>
<td>UK Hybrid 2012–2014</td>
<td>7</td>
<td>1,156</td>
<td>90%</td>
<td>—</td>
<td>1.6%</td>
<td>0.0%</td>
<td>0.8%</td>
<td>0.4%</td>
<td>0.0%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Maeremans</td>
<td>RECHARGE 2014–2015</td>
<td>17</td>
<td>1,253</td>
<td>89%</td>
<td>86%</td>
<td>2.6%</td>
<td>0.2%</td>
<td>0.2%</td>
<td>2.2%</td>
<td>0.1%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Sapontis</td>
<td>OPEN CTO 2013–2017</td>
<td>12</td>
<td>1,000</td>
<td>86%</td>
<td>85%</td>
<td>7.0%</td>
<td>0.9%</td>
<td>2.6%</td>
<td>0.0%</td>
<td>0.1%</td>
<td>—</td>
</tr>
</tbody>
</table>

Success: 12 of 12
Complications: none
**CTO PCI in NCDR**

- **594,510 procedures**
- **22,365 CTO PCI**
- **2009-2013**

![Graph showing procedural success and MACE for CTO PCI in NCDR](image1)


**CTO PCI in England/Wales**

- **66 of 80**

![Graph showing procedural success percentage for CTO PCI in England/Wales](image2)

*Kinnaird et al. Circulation Intervention 2018*
1. Training

The Four Stages of Learning CTO PCI

<table>
<thead>
<tr>
<th>STAGE 1</th>
<th>STAGE 2</th>
<th>STAGE 3</th>
<th>STAGE 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques</td>
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<td>Techniques</td>
</tr>
<tr>
<td>Antegrade wire escalation</td>
<td>Antegrade dissection/re-entry</td>
<td>Antegrade wire escalation</td>
<td>Retrograde via epicardial collaterals</td>
</tr>
<tr>
<td>Antegrade only</td>
<td>Antegrade and Retrograde</td>
<td>Antegrade dissection/re-entry</td>
<td>Retrograde via septal collaterals and bypass grafts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antegrade dissection/re-entry</td>
<td>Retrograde via septal collaterals and bypass grafts</td>
</tr>
</tbody>
</table>

Catheterization and Cardiovascular Interventions 89:656-657 (2017)
Naive practice

Purposeful practice
1. Goals
2. Challenge
3. Focused
4. Monitor progress
5. Motivated

Deliberate practice
Purposeful +
1. Well established field
2. Teacher

Mental representations

Approach to “balloon uncrossable” CTO

“Balloon Uncrossable” CTO

• Inflate 1.20-1.5 mm balloon, Threader, Glider
• Rupture balloon in vessel (grenadoplaspy)

1st line

• Tornus, Corsair, Finecross
• Wire “cutting”

2nd line

• Guide catheter extensions
• Anchor balloon strategies

3rd line

• Laser
• Rotational atherectomy

4th line

• Subintimal: external “crush” - retrograde
• Subintimal: distal anchor
How to learn CTO PCI

1. Books
2. Journals
3. Online
4. Courses
5. Proctoring
6. Doing
7. Community
8. Participating in studies
9. Keep track of outcomes
10. Publish
Global cardiovascular education
CCAD YouTube channel

Brilakis, Banerjee, Karmpaliotis, Lombardi, Tsai, Shunk, Kennedy, Sportus, Holmes, Grantham.
J Am Coll Cardiol Intv 2015;8:245–53

only 8 operators performed 50 or more CTO PCI per year.
2. Technology

1. Sheaths
2. Guides
3. Microcatheters
4. Guidewires
5. Dissection/re-entry
6. Snares
7. “Balloon Uncrossable” equipment
8. Intravascular Imaging - physiology
9. Complication management
10. Radiation protection
11. Balloons and Stents

A. “Big”
   - Mamba
   - Teleport Control
   - M-Cath

B. “Small”
   - Mamba Flex
   - Teleport

C. Angulated
   - Sasuke
   - NHancer Rx
   - ReCross

D. Dual lumen
   - FineDuo
   - Crusade
   - Twin-Pass Torque & Twin-Pass

E. Plaque modification
   - Tornus
   - Turnpike Gold

Microcatheter classification

Guidewires

1. Workhorse
   1. Composite core
      • Sion
      • Sion blue
      • Suoh 03
   2. Dual coil
      • Samurai RC
   3. Other
      • Runthrough
      • BMW
      • ??????

2. Polymer jacketed
   1. Fielder FC, XT, XT-A, XT-R
   2. Fighter
   3. Sion black
   4. Whisper
   5. Pilot 50
   6. Pilot 200
   7. PT2
   8. Gladius, Mongo
   9. Bandit, Raider

3. Stiff
   1. Gaia
   2. Confianza Pro 12
   3. Hornet
   4. Whisper
   5. Pilot 50
   6. Pilot 200
   7. PT2
   8. Gladius, Mongo
   9. Bandit, Raider

4. Support
   1. Grand Slam
   2. Ironman
   3. Mailman

5. Other
   1. Wiggle
   2. Suoh 03
   3. Externalization wires
   4. Rotafloppy - Viper

Upcoming techniques/devices

Penetration

Soundbite system
E-CART (ElectroCautery-Assisted Re-enTry) of an Aorto-Ostial Right Coronary Artery Chronic Total Occlusion

First-in-Man

William Nicholson, MD,1,2,4 James Harvey, MD, MSc,1,2,4 Rajiv Dhawan, MD,5

Distal crossing tip of the guidewire was energized in cutting mode at 50 W for a 1-s burst, with immediate unimpeded crossing into the lumen of the aorta.


Coronary calcification
Before OAS  
Crown will only sand the hard components of plaque  
Soft components (plaque/tissue) flex away from crown  

After OAS  

**Centrifugal Force:**  
- 360° crown contact designed to create a smooth, concentric lumen  
- Allows constant blood flow and particulate flushing during orbit  
- Increasing speed increases orbital diameter  
- Ability to treat multiple vessel diameters with one crown  
- Treat large vessels through 6 French

**Differential Sanding:**  
- 30 micron diamond coating  
- Bi-directional sanding, eccentric mounted crown  
- Healthy elastic tissue flexes away minimizing damage to the vessel

---

**Primary Endpoints**  
**Imaging** - In-stent minimal cross-sectional area as assessed at the conclusion of the procedure in the imaging cohort.  
**Clinical** - 1-year TVF (defined as the composite of cardiac death, target vessel related myocardial infarction, or clinically driven target vessel revascularization).

**ECLIPSE trial**  
**Evaluation of Treatment Strategies for Severe Calcific Coronary Arteries: Orbital Atherectomy vs. Conventional Angioplasty Prior to Implantation of Drug Eluting Stents**  
- ~2000 pts with severely calcified lesions; ~60 US sites  
- Randomize 1:1  
- Orbital Atherectomy Strategy  
  - 2nd generation DES implantation and optimization  
  - 1st endpoints: 1) Post-PCI in-stent MSA by OCT (N~400 in imaging study)  
  - 2-year TVF (all patients)  
- Conventional Angioplasty Strategy  
  - 2nd generation DES implantation and optimization  
- Sponsor: Cardiovascular Systems, Inc.
Coronary Lithoplasty: A Novel Treatment for CAC

- Based on 30 years of Lithotripsy technology
- Constant, ultra-low pressure
- Sonic pressure waves emitted
  - Circumferential, unfocused
  - 1 pulse/second
  - Pulse exceeds 50 atm

- Sonic pressure waves crack calcium

How can you reduce radiation dose?

1. INTENSITY
2. TIME
3. DISTANCE
4. SHIELDING
Impact of X-ray machine

Anthropomorphic phantom

Martinez-Parachini R et al. ACC 2017

ControlRad System

- 75% dose reduction to medical staff
- No impact to workflow or image quality

Med. Phys. 43 (3), March 2016
ControlRad Eye-Tracker moves Region-of-Interest (ROI) in Real-Time

ControlRad is an integrated system that optimizes the X-ray beam to deliver the highest image quality inside the ROI while maintaining appropriate resolution in the periphery.

1. X-ray Tube
2. Flat Panel Detector
3. Proprietary Image Processing

Certified Tablet Interface
Dynamic Filters

MHIF CV Grand Rounds – April 15, 2019
Many unanswered questions....

<table>
<thead>
<tr>
<th>Patient questions</th>
<th>MD questions</th>
<th>Payor/hospital questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How will I feel afterwards?</td>
<td>1. What strategy is most likely to be successful?</td>
<td>1. What is the cost-effectiveness of CTO PCI?</td>
</tr>
<tr>
<td>2. Will I live longer?</td>
<td>2. Which strategy should be avoided?</td>
<td>2. Which centers should be performing CTO PCI?</td>
</tr>
<tr>
<td>3. What is the likelihood of success?</td>
<td>3. How long should I try a strategy before switching?</td>
<td>3. Have CTO PCI outcomes been improving over time?</td>
</tr>
<tr>
<td>4. What is the likelihood of complications?</td>
<td>4. When should I stop?</td>
<td></td>
</tr>
<tr>
<td>5. Will I die during the procedure?</td>
<td>5. Which is the best way to learn CTO PCI?</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions

CTO PCI

- CTO PCI: revascularization tool
- RCTs: important limitations
- Good results at experienced centers
- Poor results overall
- Key indication: Symptom Improvement
- Risk/benefit ratio key for pursuing CTO PCI
- Global consensus reached
- Need for more specialized experts and dedicated operators

www.progresscto.org
www.ctomanual.org