

# CTO PCI. Presente y Futuro

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# CTO: The problem

- CTO is the occlusion of a coronary artery (TIMI 0 flow) with an estimated duration of at least 3 months.
- CTOs are present in 18-25% of coronary angiography performed on patients with coronary artery disease.
- Despite the collaterals, less than 10% of these patients have normal flow.



# CTO: The problem

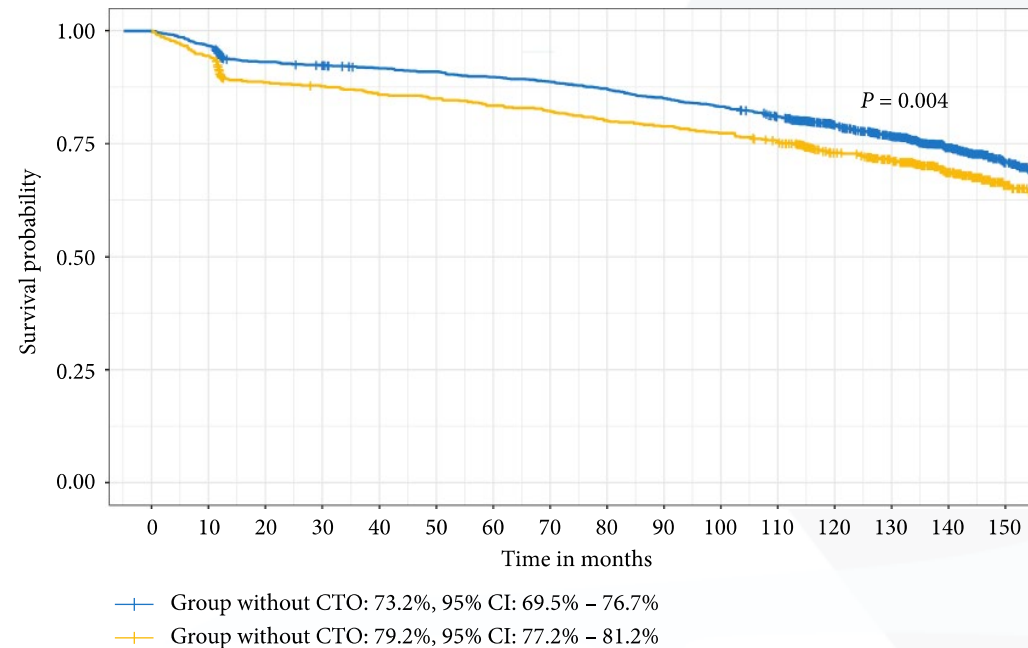


## ***VA CART Program***

***El 65% de los ptes con  
CTO son excluidos para  
ATC en la práctica  
habitual***

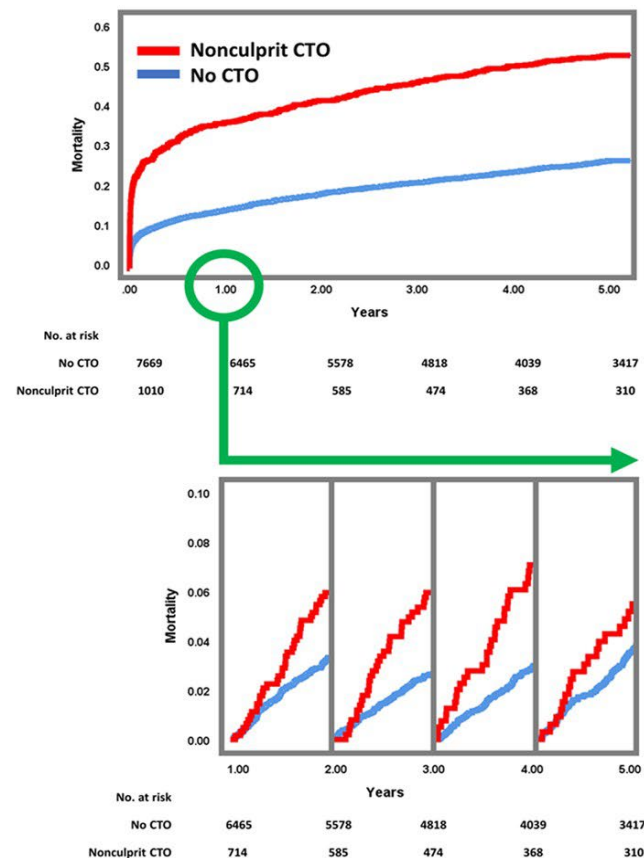
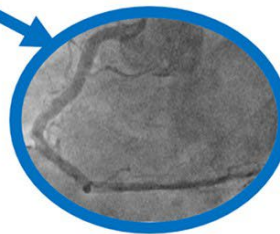
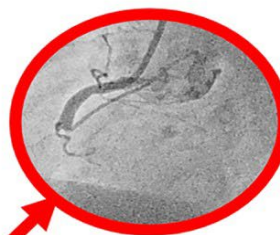
# CTO: Impact

MACCE	CTO group (N = 629)	No-CTO group (N = 1653)	Total (N = 2282)	P value
Death from cardiovascular causes	43 (6.8%)	82 (5.0%)	125 (5.5%)	0.0778
Recurrent AMI	45 (7.2%)	112 (6.8%)	157 (6.9%)	0.7461
Stroke	18 (2.9%)	30 (1.8%)	48 (2.1%)	0.1188
TLR	127 (20.2%)	270 (16.3%)	397 (17.4%)	0.0292
<b>Total MACCE</b>	<b>191 (30.4%)</b>	<b>402 (24.3%)</b>	<b>593 (26.0%)</b>	<b>0.003468</b>



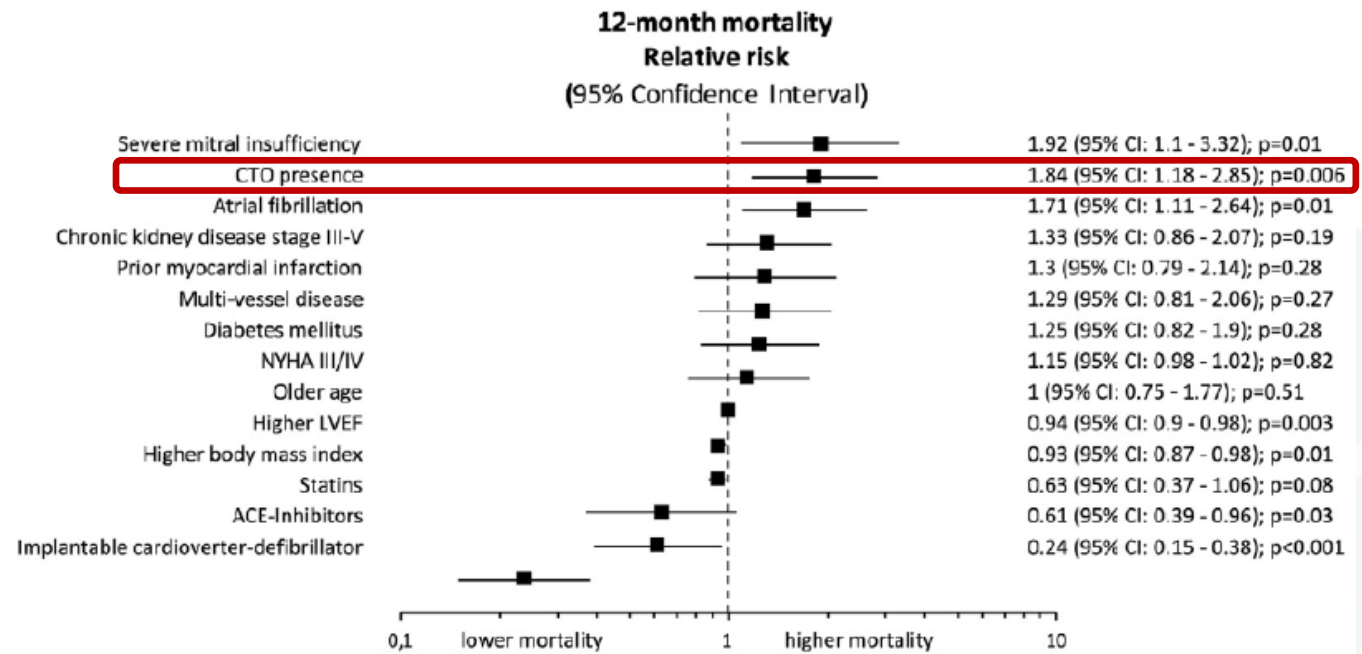
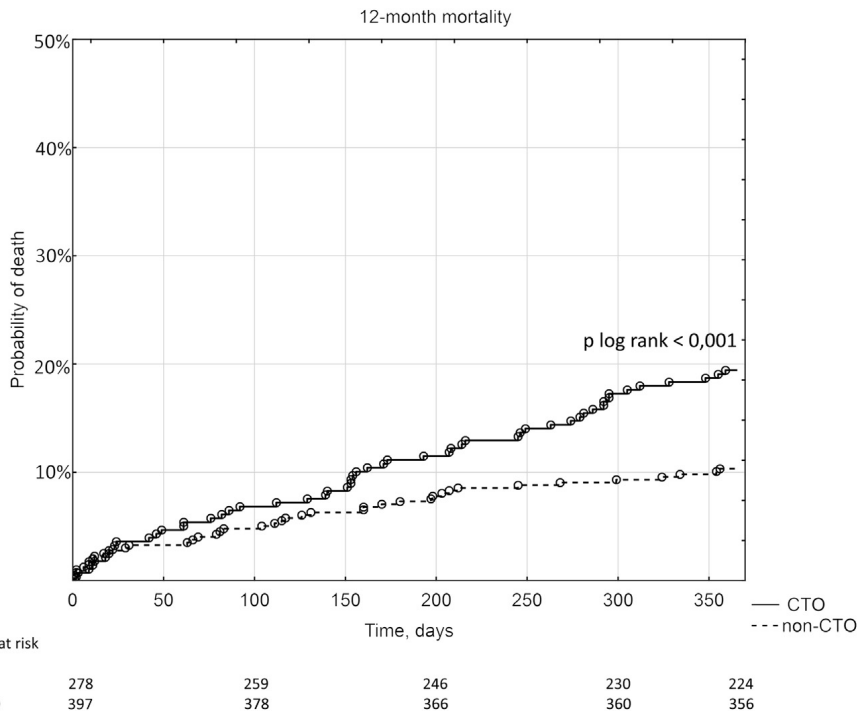
# CTO: Impact

Prognostic impact of nonculprit CTO over time in patients with STEMI treated with primary PCI

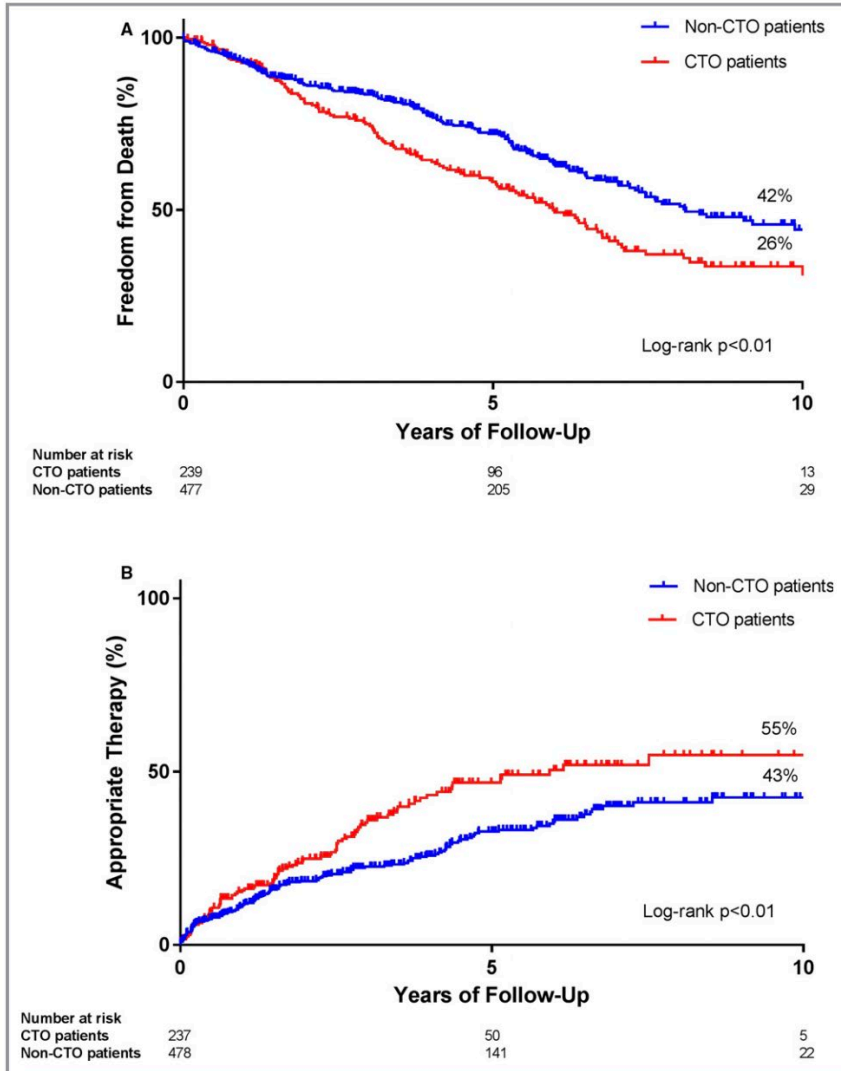


STEMI → Culprit artery reperfusion → **Nonculprit CTO** → **Long-term mortality**

# CTO: Impact in patients with low EF



# CTO: Impact in ventricular arrhythmia



	Appropriate Device Therapy			All-Cause Mortality		
	CTO (n=240)	No-CTO (n=482)	P Value	CTO (n=240)	No-CTO (n=482)	P Value
1-y follow-up	15.8%	11.2%	0.103	7.4%	7.3%	0.982
3-y follow-up	36.0%	22.6%	0.003	25.1%	16.5%	0.020
5-y follow-up	46.8%	32.8%	0.002	41.9%	27.8%	0.001

# CTO revascularization: Any benefit?

**Table 1 Chronic total occlusion study results and clinical outcomes according to hierarchical levels of evidence-based medicine: Registries, meta-analyses, and randomized clinical trials**

Studies	Patients (n)	CTO-PCI success	Follow-up	PCI success vs PCI failure		
				MACE	Death	
Registries	OPEN-CTO 2020 (12) (Hybrid approach)	1000	90%	1 yr	3.4% vs 3.7%	0.9% vs 0%
	EXPERT-CTO 2019 (2) (New generation DES)	250	96.4%	1 yr	18.5% vs 24.4%	NR
	Valenti <i>et al</i> 2019 (3) (Elderly ≥ 75 yr)	460	72%	5 yr	9.6% vs 17%	84% ± 3% vs 72% ± 6%
	Sudhakar <i>et al</i> 2014 (4)	13443	70.6%	2.65 yr	NR	HR 0.72, 95%CI: 0.62-0.83
Metanalyses	Christakopoulos <i>et al</i> 2015 (5)	28486	71%	3.11 yr	29.1%	6.4% vs 9.5%
	Hoebbers <i>et al</i> 2015 (6)	15459	71.7%	1-10 yr	NR	10.4% vs 14.9%
	Chenmin <i>et al</i> 2021 (7) (Elderly ≥ 75 yr)	4693	70.4%-78.36%	20 mo-5 yr	16.8% vs 28.9%	HR: 0.51, 95%CI: 0.34-0.77
RCTs	DECISION CTO 2019 (8)	834	90.6%	4 yr	22.3% vs 22.4%	3.6% vs 5.3%
	EURO CTO 2018 (9)	396	86.6%	1 yr	5.2% vs 6.7%	0.8% vs 0%

RCT: Randomised controlled trial; CTO: Chronic total occlusion; PCI: Percutaneous coronary intervention; MACE: Major adverse cardiovascular events; DES: Drug-eluting stents; NR: Not reported.



# CTO revascularization: Symptomatic benefit?

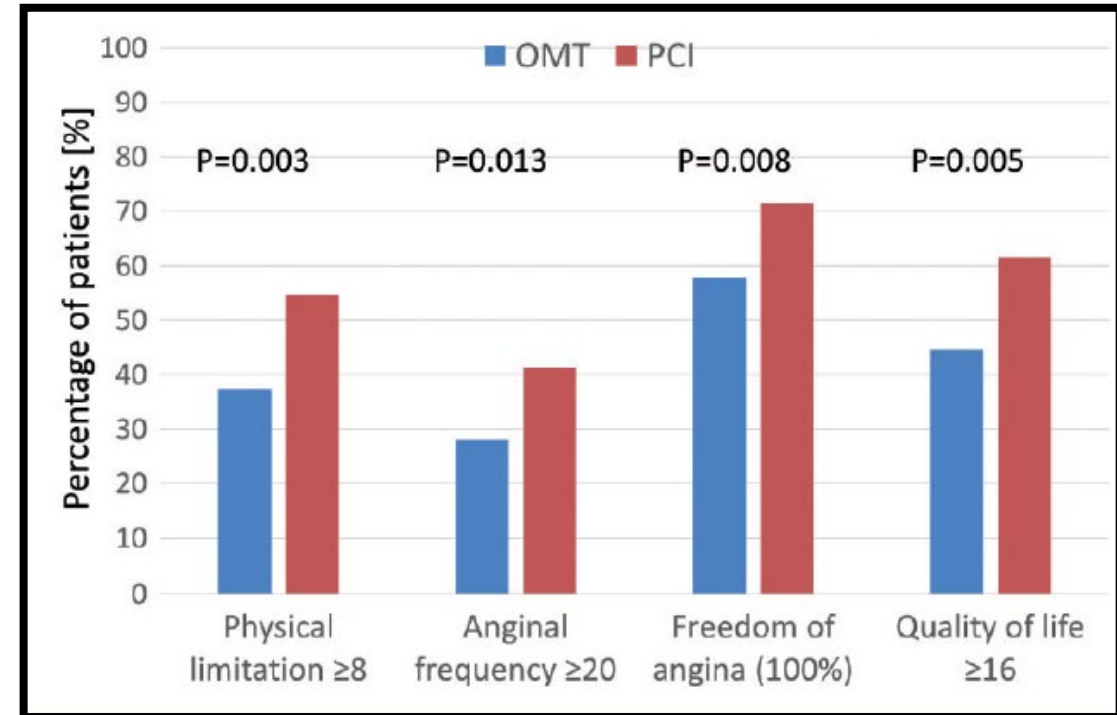
**ESC** European Heart Journal (2018) 0, 1–10  
European Society of Cardiology doi:10.1093/eurheartj/ehy220

**CLINICAL RESEARCH**  
Interventional cardiology

## A randomized multicentre trial to compare revascularization with optimal medical therapy for the treatment of chronic total coronary occlusions

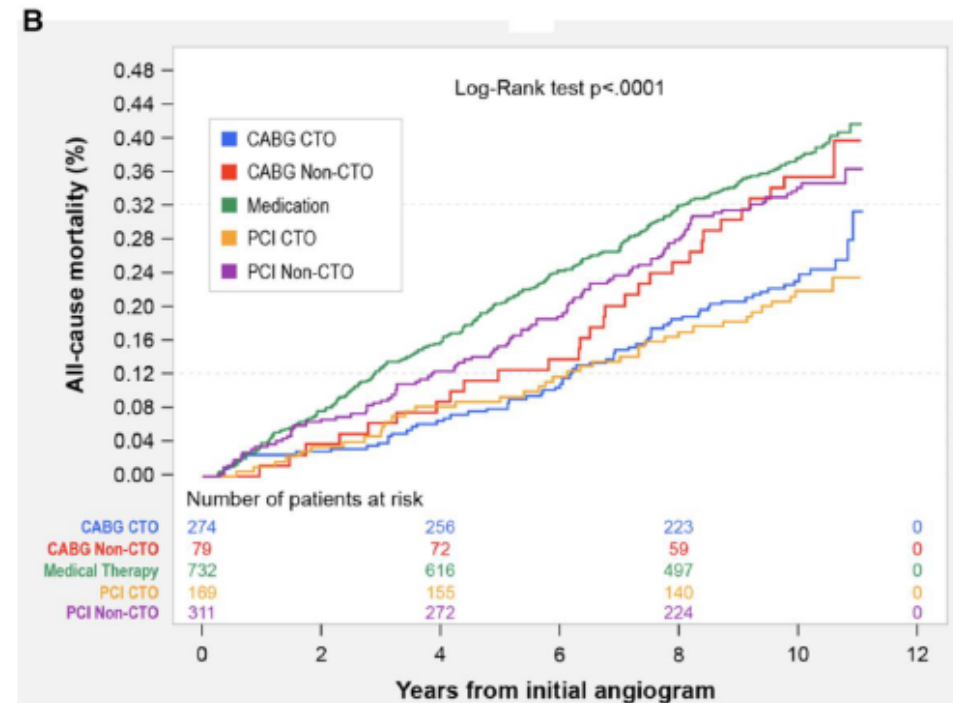
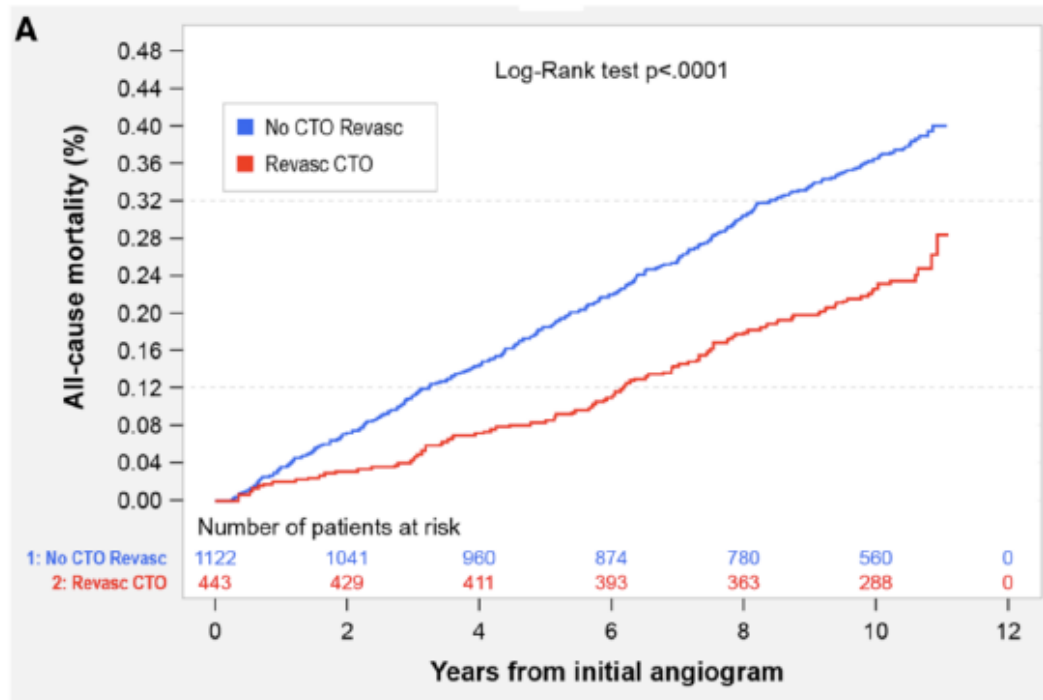
Gerald S. Werner<sup>1\*</sup>, Victoria Martin-Yuste<sup>2</sup>, David Hildick-Smith<sup>3</sup>, Nicolas Boudou<sup>4</sup>, Georgios Sianos<sup>5</sup>, Valery Gelev<sup>6</sup>, Jose Ramon Rumoroso<sup>7</sup>, Andrejs Erglis<sup>8</sup>, Evald Høj Christiansen<sup>9</sup>, Javier Escaned<sup>10</sup>, Carlo di Mario<sup>11</sup>, Thomas Hovasse<sup>12</sup>, Luis Teruel<sup>13</sup>, Alexander Bufe<sup>14</sup>, Bernward Lauer<sup>15</sup>, Kris Bogaerts<sup>16</sup>, Javier Goicolea<sup>17</sup>, James C. Spratt<sup>18</sup>, Anthony H. Gershlick<sup>19</sup>, Alfredo R. Galassi<sup>20</sup>, and Yves Louvard<sup>12</sup>; for the EUROCTO trial investigators<sup>†</sup>

**396 patients**  
**CTO + OMT vs OMT**



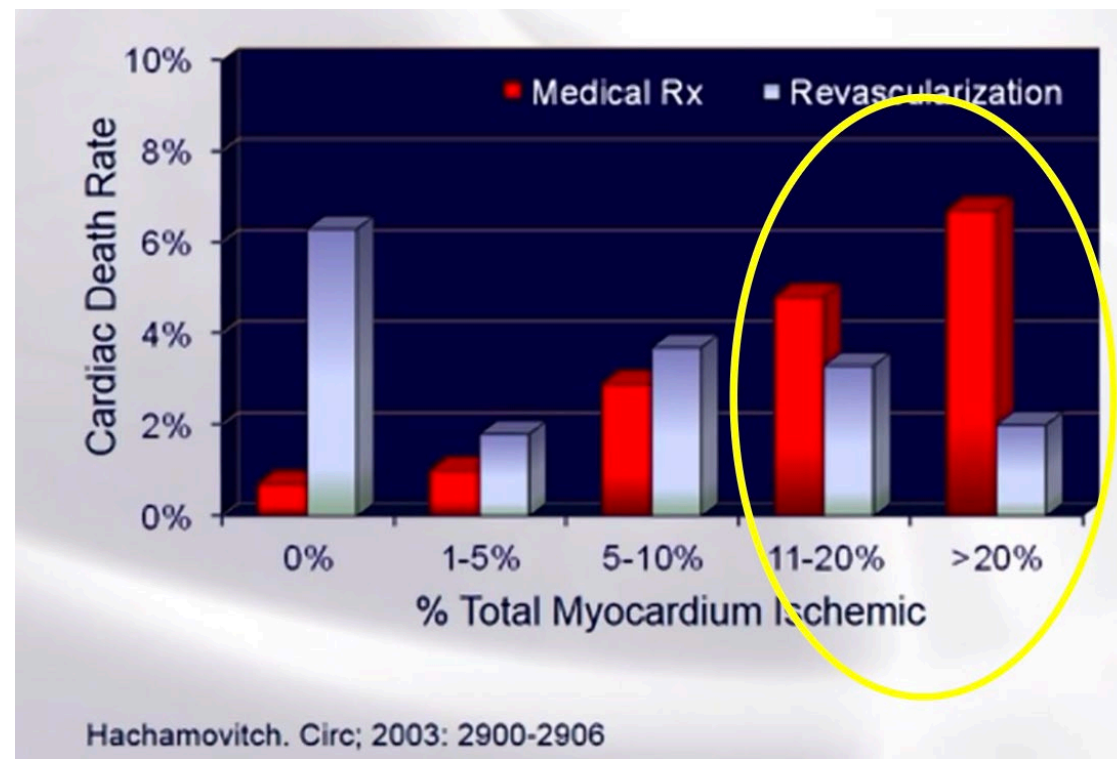
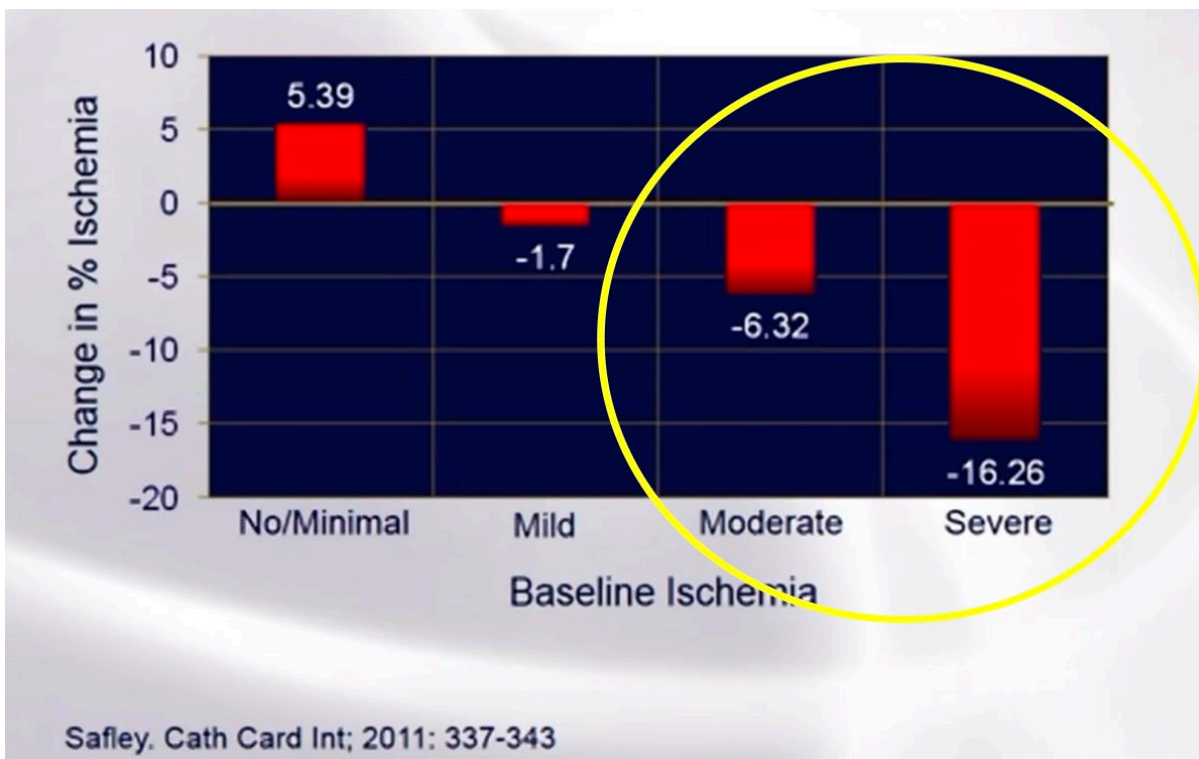
# CTO revascularization: Any benefit?

## Canadian Multi-center CTO Registry: 10 years FU



Strauss BH, Wijeyesundera HC, et al. *Circ Cardiovasc Interv.* 2021;14(12):e010546.

# CTO revascularization: Ischemia



# CTO revascularization: Impact in LV function?

Study or Subgroup	After CTO PCI			Before CTO PCI			Weight	Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Bucciarelli et al 2016	67	12	50	62	13	50	2.1%	5.00 [0.10, 9.90]
cardona et 2016	37.7	8	29	31.3	7.4	29	2.8%	6.40 [2.43, 10.37]
Chadid et al 2015	51.5	10.8	43	49.1	10.4	43	2.4%	2.40 [-2.08, 6.88]
chen et al 2009	54	8	132	45	11	132	4.8%	9.00 [6.68, 11.32]
choi et al 2017	51.6	12.5	305	47.8	12.3	305	5.3%	3.80 [1.83, 5.77]
Chung et al 2003	57.44	17.93	75	53.28	16.004	75	1.8%	4.16 [-1.28, 9.60]
Danchin et al 1996	60.14	13.18	55	54.38	13.6	55	2.0%	5.76 [0.75, 10.77]
Daniłowicz-Szymanowicz et al 2014	55.48	8.42	23	50.05	7.95	23	2.2%	5.43 [0.70, 10.16]
Dzavik et al 2001	62.5	11.6	139	62	11.5	139	4.2%	0.50 [-2.22, 3.22]
El shafey et al 2015	54.4	5.52	37	52.75	5.56	37	4.5%	1.65 [-0.87, 4.17]
Engelstein et al 1994	62.57	10.75	49	56.9	6.9	49	3.2%	5.67 [2.09, 9.25]
Erdogan et al 2013	58.32	10.2	118	56.31	9.81	118	4.4%	2.01 [-0.54, 4.56]
Ermis et al 2005	52.8	10.2	19	44.7	10.9	19	1.3%	8.10 [1.39, 14.81]
Fang et al 2005	58.77	15.76	129	56.2	16.19	129	2.8%	2.57 [-1.33, 6.47]
Fiocchi et al 2009	54.15	16.84	14	49.68	16.13	14	0.4%	4.47 [-7.74, 16.68]
Ivanhoe et al 1992	56	10	175	55	10	242	5.4%	1.00 [-0.94, 2.94]
Jin et al 2001	39.65	6.7	64	34.24	6.1	64	4.9%	5.41 [3.19, 7.63]
Kirschbaum et al 2008	63	11	21	60	9	21	1.5%	3.00 [-3.08, 9.08]
Kirschbaum et al 2012	54	12	43	50	11	43	2.1%	4.00 [-0.87, 8.87]
Melchior et al 1987	63	9	20	59	11	20	1.4%	4.00 [-2.23, 10.23]
Mori et al 1996	44.8	10.9	96	40.47	9.41	96	4.0%	4.33 [1.45, 7.21]
Nakashi et al 2017	56.1	10.6	59	54.2	12.1	59	2.7%	1.90 [-2.20, 6.00]
Omura et al 2013	56	13	168	55	13	168	4.1%	1.00 [-1.78, 3.78]
park et al 2012	60.1	8.3	58	57.3	9.9	58	3.4%	2.80 [-0.52, 6.12]
Pavlovic et al 2009	47.86	15.355	20	45.66	14.45	20	0.7%	2.20 [-7.04, 11.44]
Piscione et al 2005	48.7	8.11	35	41.7	8.11	35	2.9%	7.00 [3.20, 10.80]
Pujadas et al 2013	65	11.5	33	62	12.2	33	1.6%	3.00 [-2.72, 8.72]
Roifman et al 2013	54.3	10.7	19	50.3	12.6	19	1.1%	4.00 [-3.43, 11.43]
Sirnes et al 1998	67	11	95	62	13	95	3.3%	5.00 [1.58, 8.42]
sotomi et al 2017	59.2	15	35	57.7	15.9	37	1.1%	1.50 [-5.64, 8.64]
Stuijtzand et al 2017	47.5	11.4	69	46.4	11	69	3.0%	1.10 [-2.84, 4.84]
Sun et al 2012	51.2	7.838	99	46.8	9.34	99	4.7%	4.40 [2.02, 6.78]
Valentini et al 2008	46.5	11.3	290	42.2	12.1	290	5.4%	4.30 [2.39, 6.21]
Werner et al 2005	67	16	119	60	19	119	2.4%	7.00 [2.54, 11.46]
<b>Total (95% CI)</b>			<b>2735</b>			<b>2804</b>	<b>100.0%</b>	<b>3.84 [3.01, 4.67]</b>

Heterogeneity: Tau<sup>2</sup> = 2.34; Chi<sup>2</sup> = 59.50, df = 33 (P = 0.003); I<sup>2</sup> = 45%  
Test for overall effect: Z = 9.09 (P < 0.00001)

Forrest plot of studies evaluating the impact of successful CTO PCI on LVESV.

Study or Subgroup	After CTO PCI			Before CTO PCI			Weight	Mean Difference IV, Fixed, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Bucciarelli et al 2016	56	38	50	65	38	50	1.8%	-9.00 [-23.90, 5.90]
cardona et 2016	143	58	29	160	54	29	0.5%	-17.00 [-45.84, 11.84]
Chadid et al 2015	81	47	43	89	41	43	1.1%	-8.00 [-26.64, 10.64]
El shafey et al 2015	48.14	8.96	37	51.59	10.86	37	18.9%	-3.45 [-7.99, 1.09]
Erdogan et al 2013	31.63	16.22	118	34.54	16.49	118	22.4%	-2.91 [-7.08, 1.26]
Fiocchi et al 2009	85.53	52.35	14	91.6	50.05	14	0.3%	-6.07 [-44.01, 31.87]
Nakashi et al 2017	52.4	11.6	59	52.1	13.4	59	19.1%	0.30 [-4.22, 4.82]
Pavlovic et al 2009	127.53	75.45	20	130.03	70.96	20	0.2%	-2.50 [-47.89, 42.89]
Pujadas et al 2013	56	38.6	33	60	34.9	33	1.2%	-4.00 [-21.75, 13.75]
Sun et al 2012	58.25	11.43	99	65.32	12.64	99	34.6%	-7.07 [-10.43, -3.71]
<b>Total (95% CI)</b>			<b>502</b>			<b>502</b>	<b>100.0%</b>	<b>-4.09 [-6.06, -2.12]</b>

Heterogeneity: Chi<sup>2</sup> = 8.40, df = 9 (P = 0.49); I<sup>2</sup> = 0%  
Test for overall effect: Z = 4.06 (P < 0.0001)

Forrest plot of studies evaluating the impact of successful CTO revascularization on LVEDV

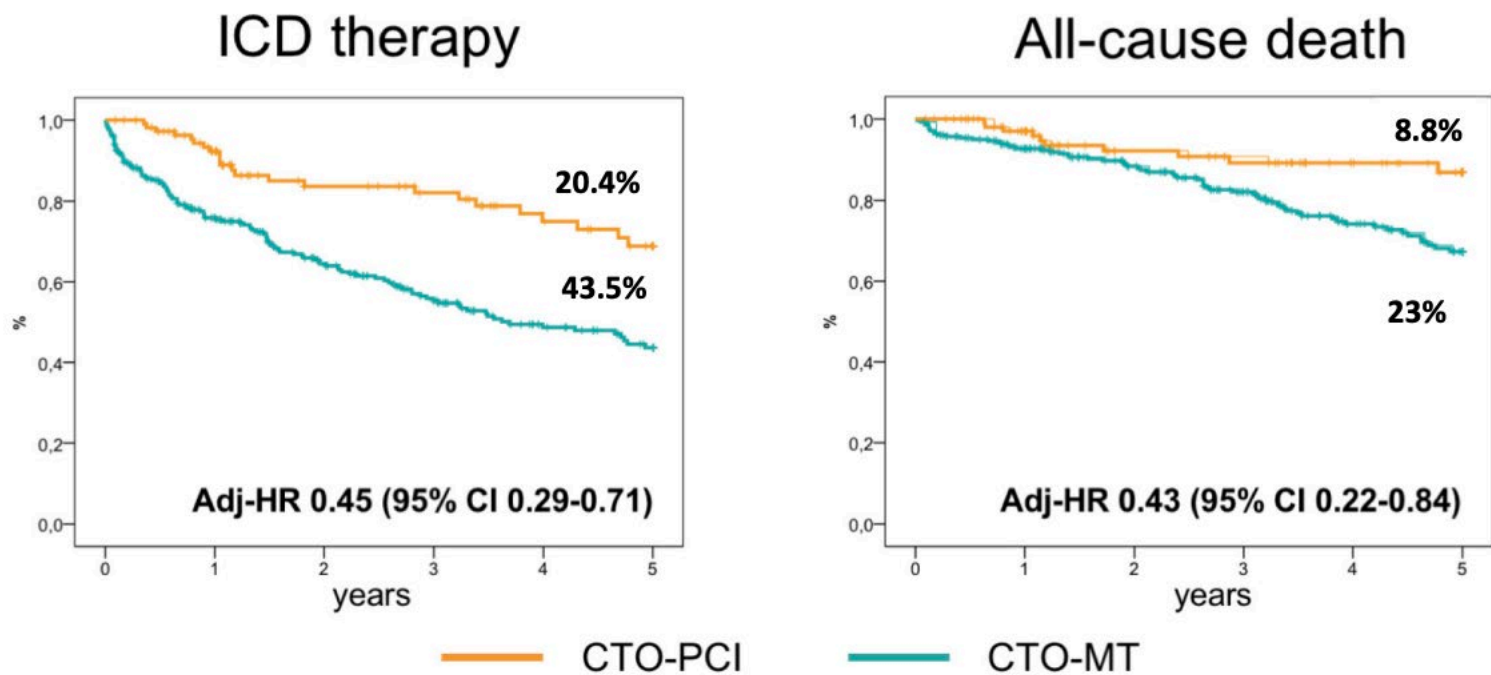
Study or Subgroup	After CTO PCI			Before CTO PCI			Weight	Mean Difference IV, Fixed, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Bucciarelli et al 2016	161	42	50	166	42	50	4.4%	-5.00 [-21.46, 11.46]
cardona et 2016	221	58	29	230	64	29	1.2%	-9.00 [-40.44, 22.44]
Chadid et al 2015	160	56	43	169	49	43	2.4%	-9.00 [-31.24, 13.24]
El shafey et al 2015	114.36	14.16	37	115.24	14.96	37	26.8%	-0.88 [-7.52, 5.76]
Erdogan et al 2013	71.98	22.64	118	76.22	22.55	118	35.5%	-4.24 [-10.01, 1.53]
Fiocchi et al 2009	163.78	10.7	14	162.31	9.62	14	20.8%	1.47 [-6.07, 9.01]
Nakashi et al 2017	99.1	38.8	59	102	40.1	59	5.8%	-2.90 [-17.14, 11.34]
Pavlovic et al 2009	210.86	84.81	20	218.33	83.69	20	0.4%	-7.47 [-59.69, 44.75]
Pujadas et al 2013	149	46.8	33	153	38.9	33	2.7%	-4.00 [-24.76, 16.76]
<b>Total (95% CI)</b>			<b>403</b>			<b>403</b>	<b>100.0%</b>	<b>-2.29 [-5.72, 1.15]</b>

Heterogeneity: Chi<sup>2</sup> = 2.27, df = 8 (P = 0.97); I<sup>2</sup> = 0%  
Test for overall effect: Z = 1.30 (P = 0.19)

**Significant increase in EF & reduction in systolic and diastolic diameters**

# CTO revascularization: Arrhythmia?

Impact of Successful Chronic Coronary Total Occlusion Recanalization on Recurrence of Ventricular Arrhythmias in Implantable Cardioverter-Defibrillator Recipients for Ischemic Cardiomyopathy (VACTO PCI Study)



# Guidelines

## CLINICAL PRACTICE GUIDELINE: FULL TEXT

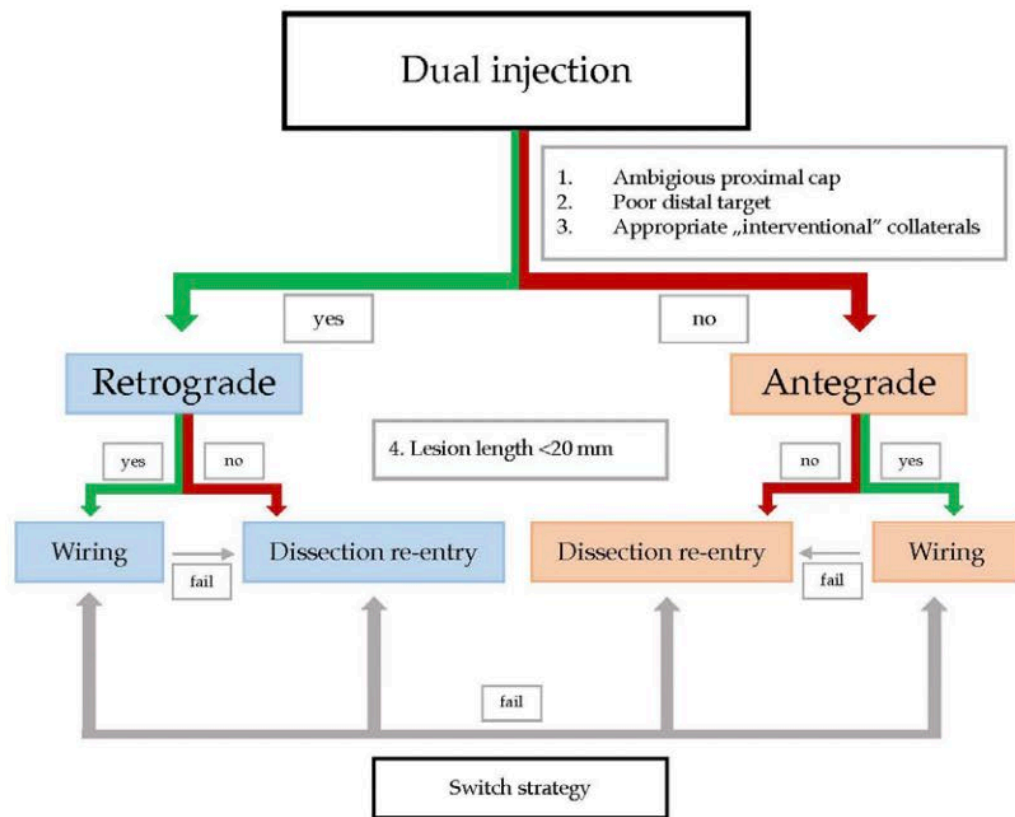
# 2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization

A Report of the American College of Cardiology/American Heart Association  
Joint Committee on Clinical Practice Guidelines

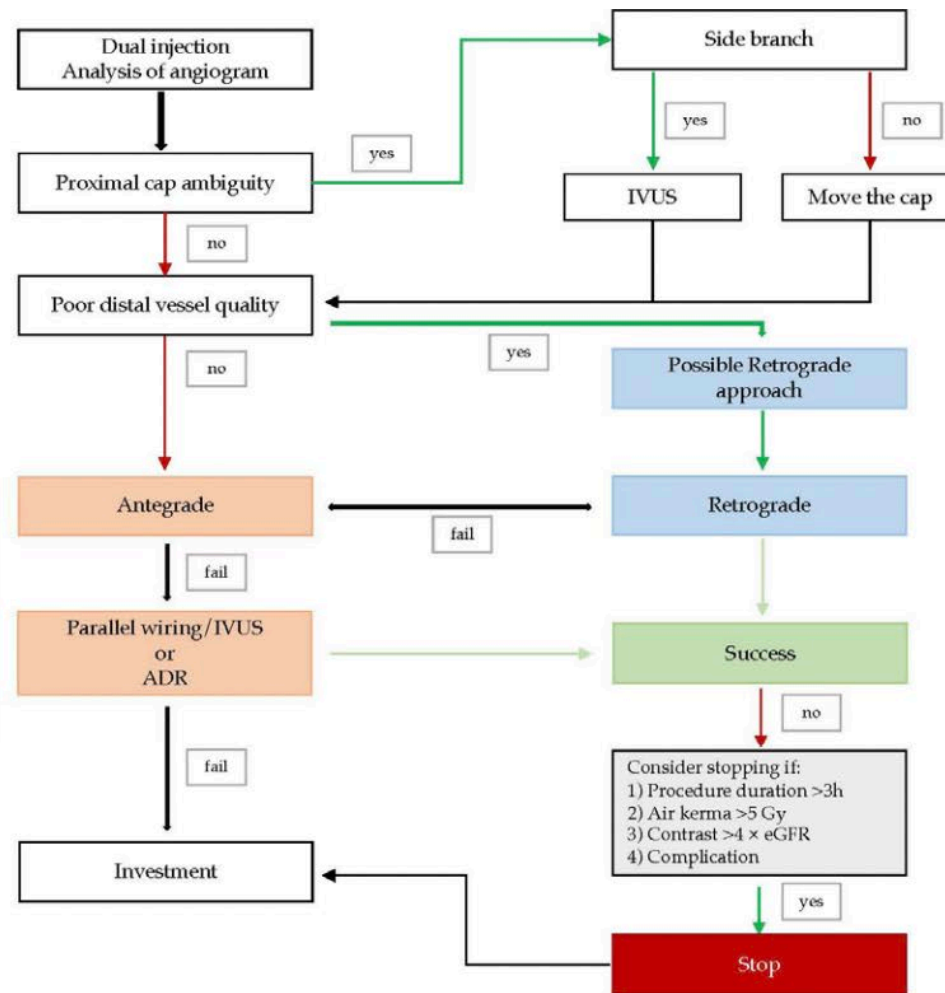
COR	LOE	RECOMMENDATION
2b	B-R	1. In patients with suitable anatomy who have refractory angina on medical therapy, after treatment of non-CTO lesions, the benefit of PCI of a CTO to improve symptoms is uncertain (1-4).

Lawton JS, et al. *J Am Coll Cardiol.* 2022;79(2):e21-e129.

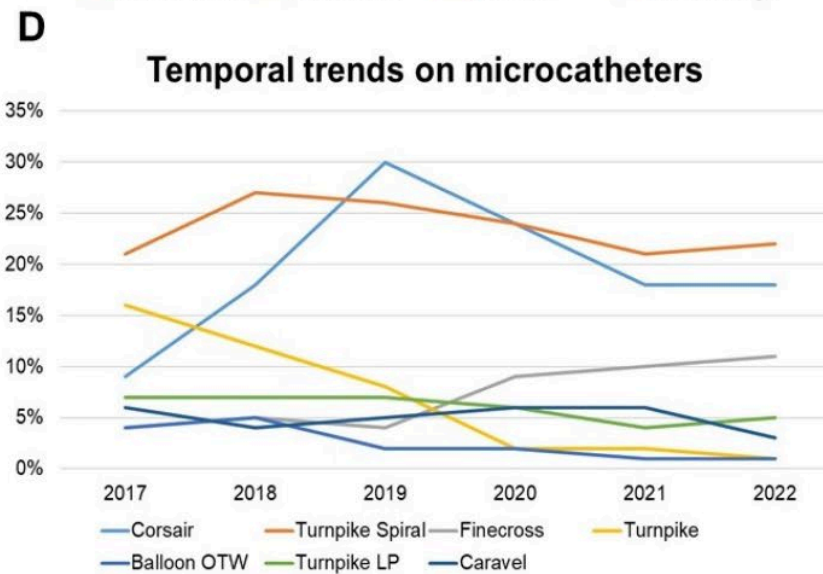
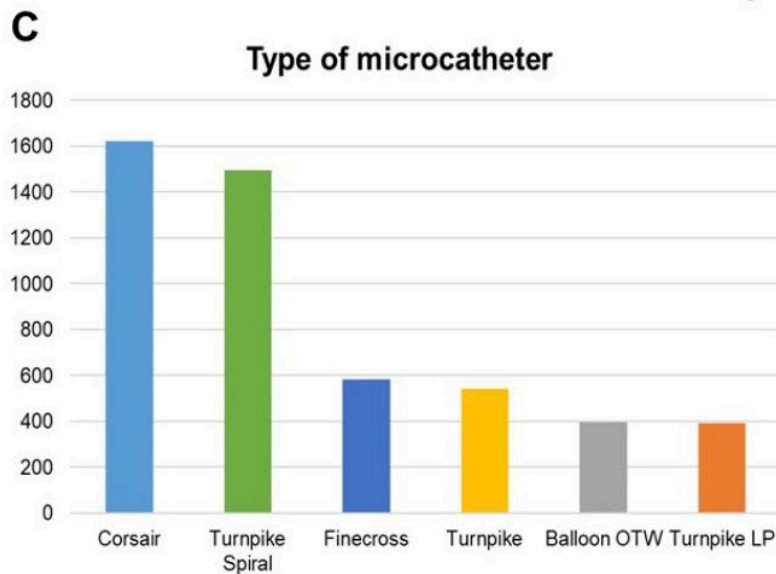
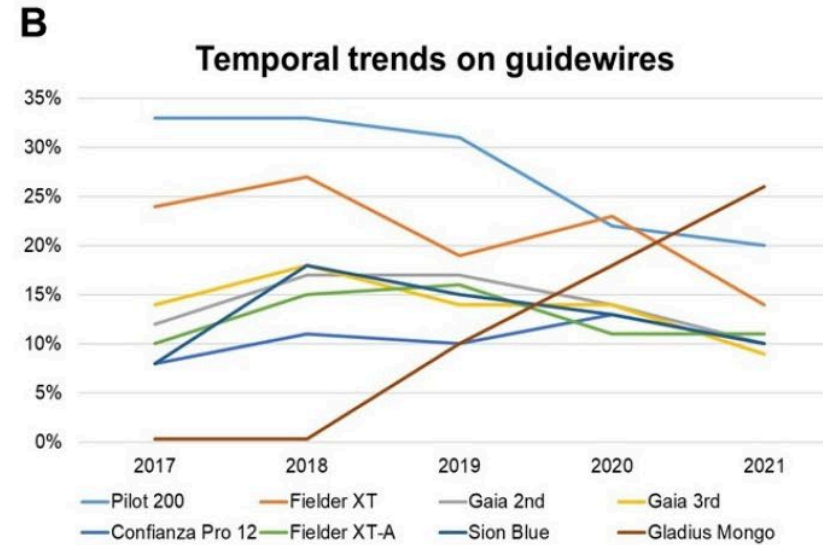
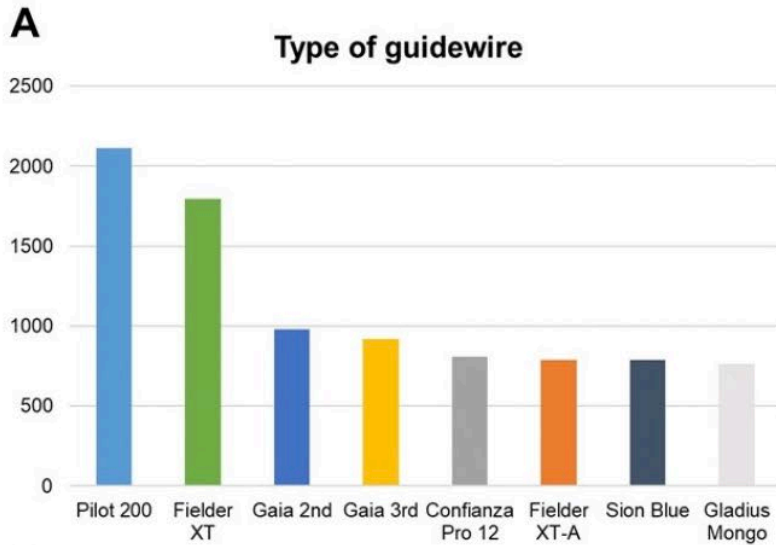
# Hybrid Approach



# Global Approach



# Equipment – wires - Microcatheters





# Characteristics by approach

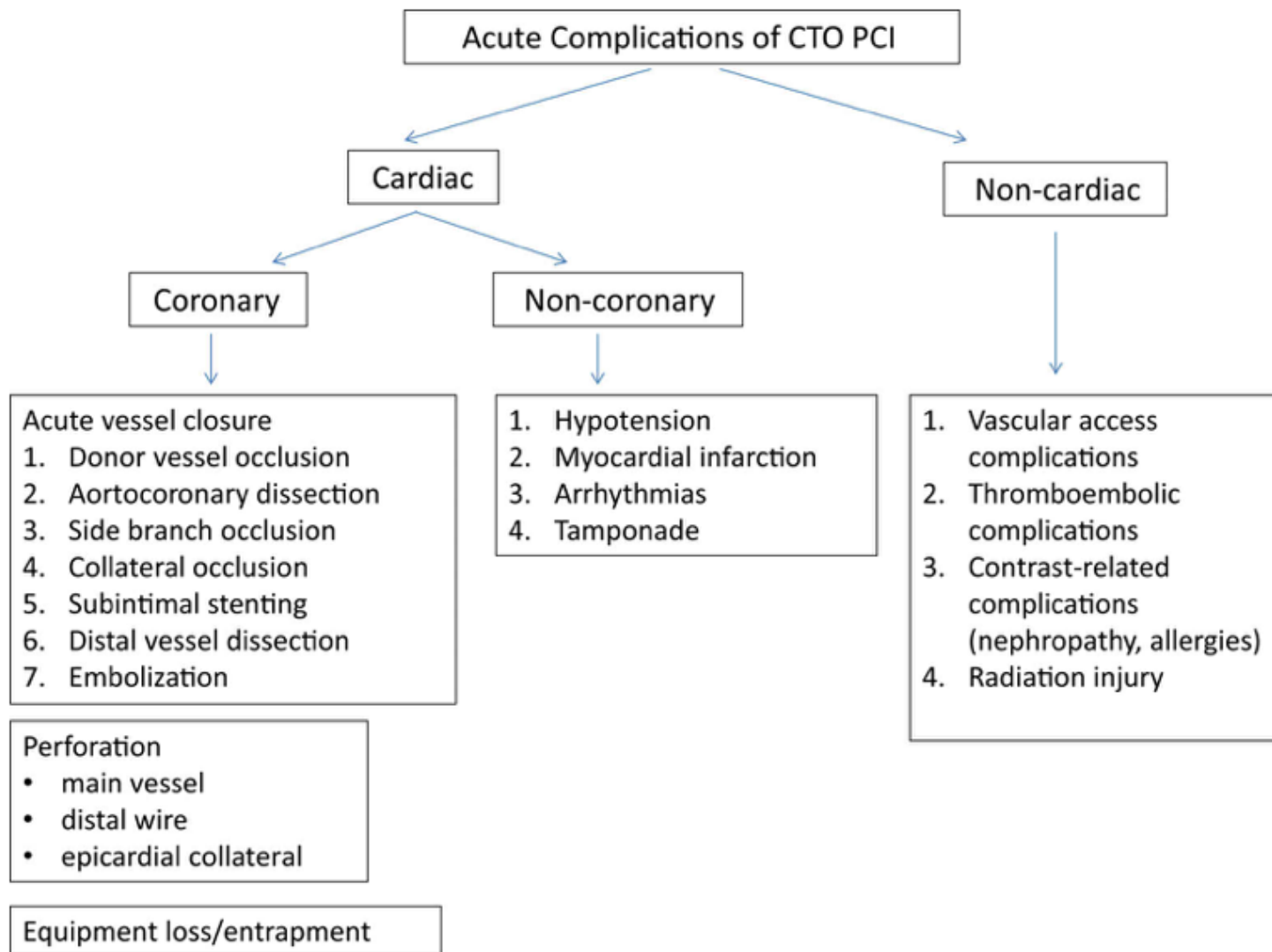
Clinical Characteristics	Overall (n = 11,002)	Antegrade Approach (n = 7,638, 69%)	Retrograde Approach (n = 3,364, 31%)	P-Value
Age (years)	64 ± 10	64 ± 10	65 ± 10	.02
Men	81%	80%	84%	<.001
Body mass index (kg/m <sup>2</sup> )	30 ± 6	30 ± 6	31 ± 6	<.001
Diabetes mellitus	43%	43%	44%	.34
Hypertension	89%	89%	91%	<.001
Dyslipidemia	86%	85%	90%	<.001
Left ventricular ejection fraction (%)	50 ± 13	50 ± 13	50 ± 13	.14
Family history of coronary artery disease	32%	32%	34%	.01
Congestive heart failure	29%	28%	30%	.12
Prior myocardial infarction	45%	43%	49%	<.001
Prior percutaneous coronary intervention	62%	59%	70%	<.001
Prior coronary artery bypass graft surgery	29%	23%	44%	<.001
Cerebrovascular disease	10%	10%	12%	<.001
Peripheral arterial disease	14%	12%	18%	<.001
Prior attempt to open CTO	19%	17%	23%	<.001
<b>Angiographic characteristics</b>				
CTO target vessel				
Right coronary	53%	46%	67%	<.001
Left anterior descending	26%	31%	16%	
Left circumflex	19%	21%	15%	
Other	2%	2%	2%	
CTO length (mm)	25 (15-40)	20 (15-30)	30 (22-50)	<.001
Side branch at the proximal cap	55%	51%	63%	<.001
Blunt/no stump	48%	40%	65%	<.001
Moderate/severe calcium	46%	40%	60%	<.001
Moderate/severe proximal tortuosity	29%	24%	40%	<.001
Distal cap at bifurcation	33%	27%	46%	<.001
In-stent restenosis	16%	18%	13%	<.001
J-CTO score	2.4 ± 1.3	2.0 ± 1.2	3.1 ± 1.1	<.001
PROGRESS-CTO score	1.3 ± 1.0	1.2 ± 1.1	1.3 ± 1.0	<.001
PROGRESS-CTO MACE score	2.4 ± 1.6	1.7 ± 1.3	3.9 ± 1.2	<.001
Intravascular ultrasound use	49%	44%	60%	<.001

# Results

Clinical Characteristics	Overall (n = 11,202)	Antegrade Approach (n = 7628; 68%)	Retrograde Approach (n = 3574; 32%)	P-Value
<b>Procedural outcomes</b>				
Technical success	86%	90%	79%	<.001
Procedural success	85%	89%	77%	<.001
In-hospital MACE	2.0%	1.3%	3.5%	<.001
Procedure time (min)	113 (74-167)	92 (64-130)	173 (133-226)	<.001
Fluoroscopy time (min)	43 (26-68)	33 (21-48)	75 (55-97)	<.001
Air kerma radiation dose (Gray)	2.2 (1.2-3.7)	1.8 (1.0-3.1)	3.0 (1.8-4.8)	<.001
Contrast volume (mL)	210 (150-300)	200 (145-280)	250 (175-350)	<.001

Data presented as median (25th-75th percentile) or percentage.  
MACE = major adverse cardiac events.

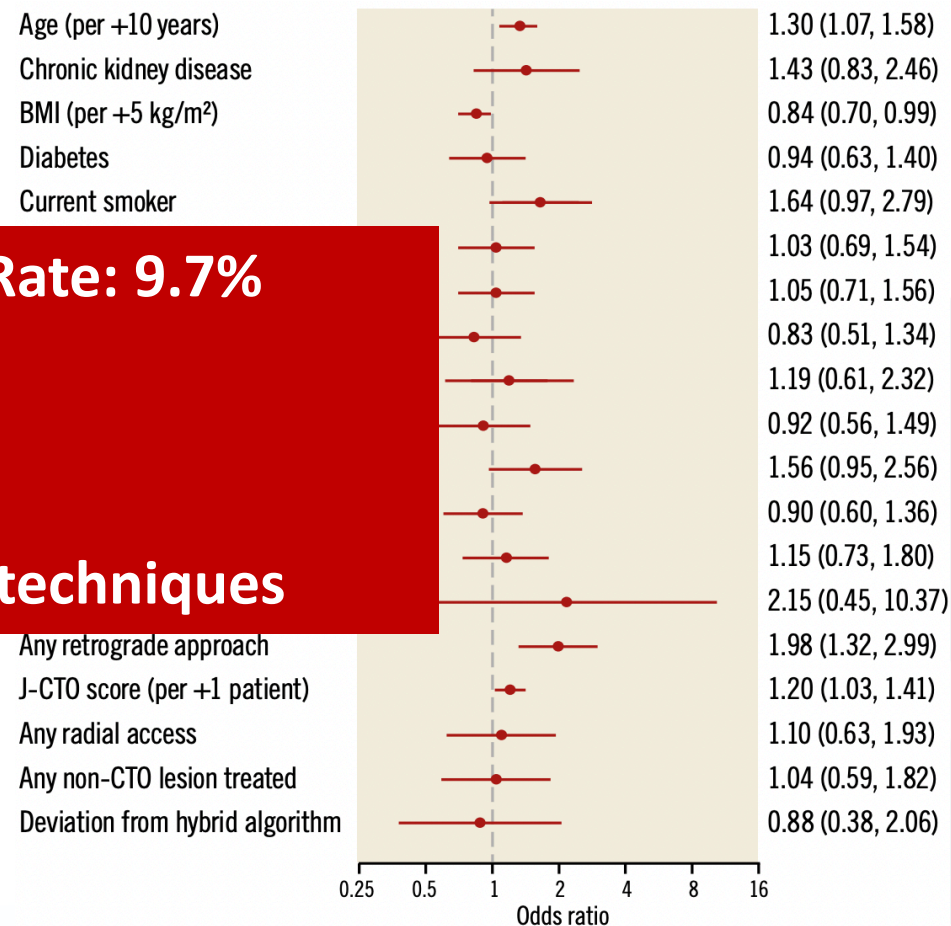
# Complications



# Complications

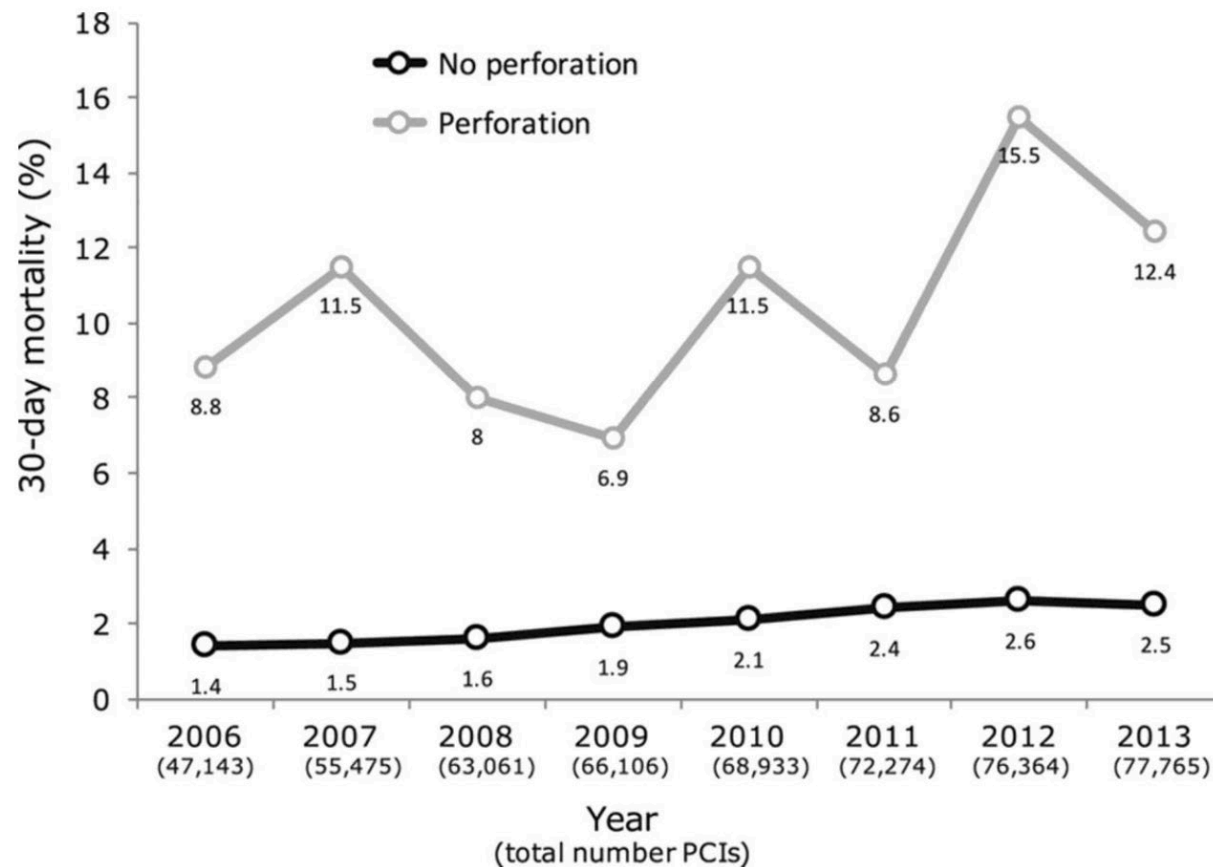
Complication	n=1,000
Any complication	97 (9.7%)
All-cause death	9 (0.9%)
Post-PCI myocardial infarction	26 (2.6%)
Need for emergency surgery	
Stroke	
Major bleeding	
Contrast-induced nephropathy	
Cardiogenic shock	
Donor vessel thrombosis	
Arrhythmia requiring treatment	
Coronary perforation (core lab)	88 (8.8%)
Ellis grade I	11 (12.5%)
Ellis grade II	44 (50%)
Ellis grade III	28 (31.8%)
Ellis grade III (cavity spilling)	5 (5.7%)

- **Overall Complication Rate: 9.7%**
- **Predictors include:**
  - **Advanced age**
  - **J-CTO Score**
  - **Use of retrograde techniques**



# Impact of CTO complications

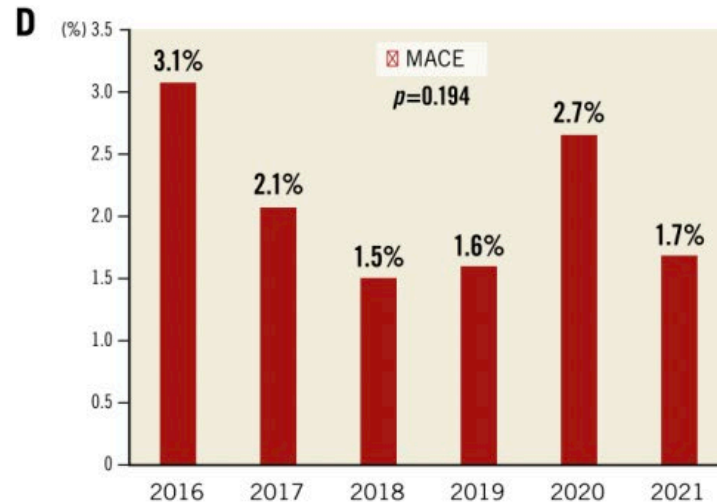
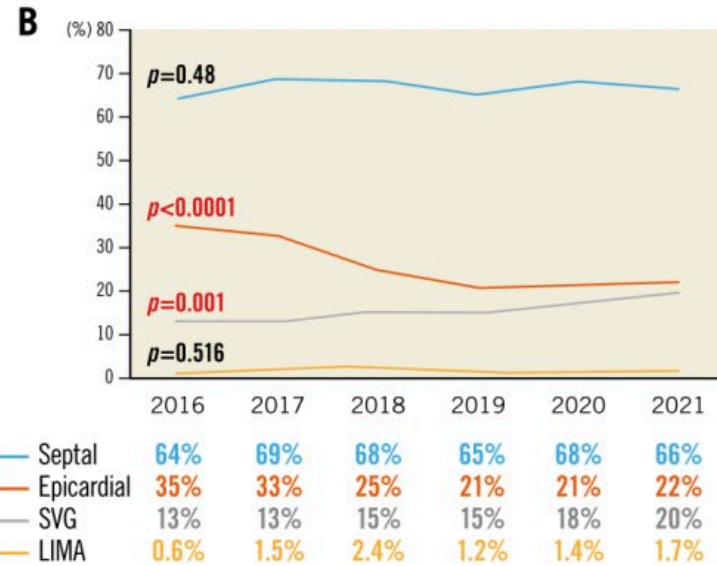
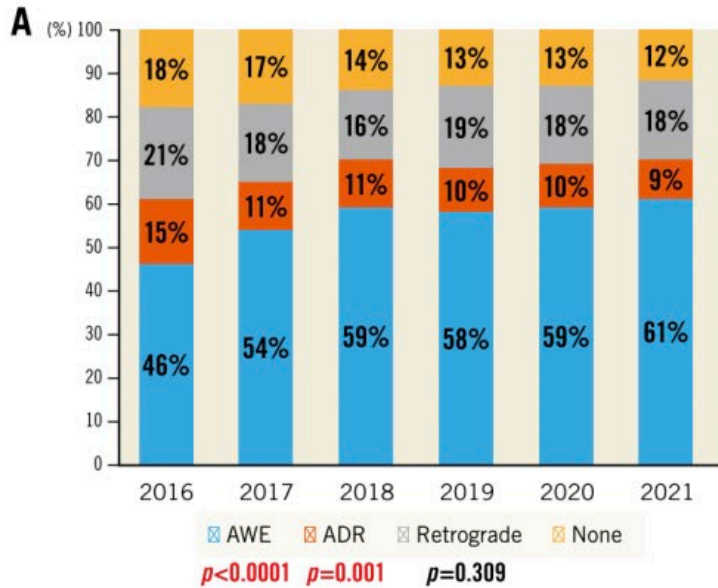
Months	All-cause mortality		p-value
	Complication	No complication	
0	4.1±2.0%	0.0±0.0%	<0.001
1	11.3±3.2%	0.2±0.2%	
6	11.3±3.2%	2.0±0.5%	
12	12.4±3.3%	3.1±0.6%	
Reported as percentages±standard error.			



# Complications Cart

- **Pericardiocentesis Kit**
- **Covered Stents**
- **Embolization tools**
  - § Coils
  - § Fat
  - § Micro Spheres
  - § Thrombin
- **Equipment Retrieval**
  - § Snares
- **Hemodynamic Support Devices**
  - § IABP
  - § ECMO
  - § Impella CP
- **Vascular Access Management**

# The Present



- Anatomic complexity & crossing strategies remained ~ same
- Less bifemoral, more rad-fem
- Retrograde: less epicardial, more SVGs
- Success rates are increasing
- MACE are stable

# The Future





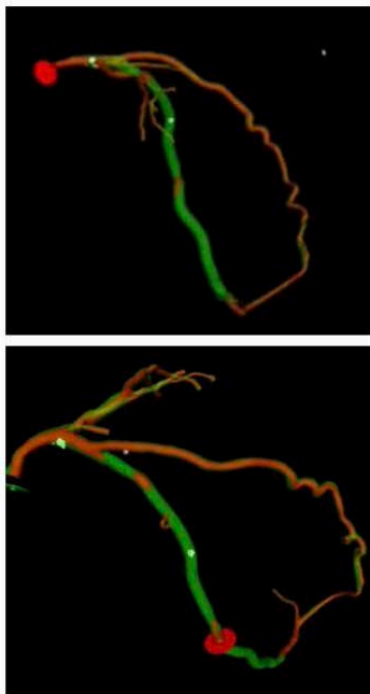
# Physiology

## IMPACT-CTO 2 trial

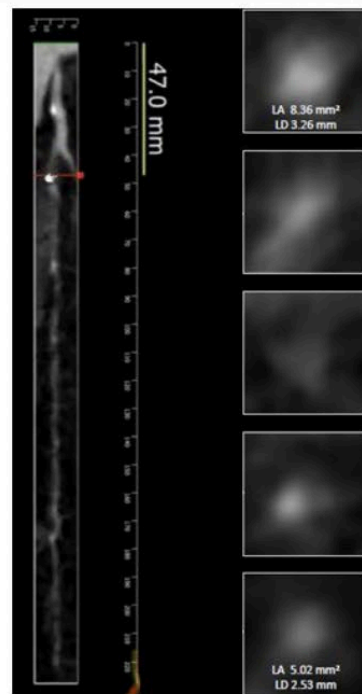
- The aim of the study is to document changes in CTO vessels physiology post PCI and at 3 months follow up.
- Correlations between anatomical features identified with intravascular imaging and physiological parameters, how these develop at follow up and how they relate to the revascularization technique.

# Images by CT

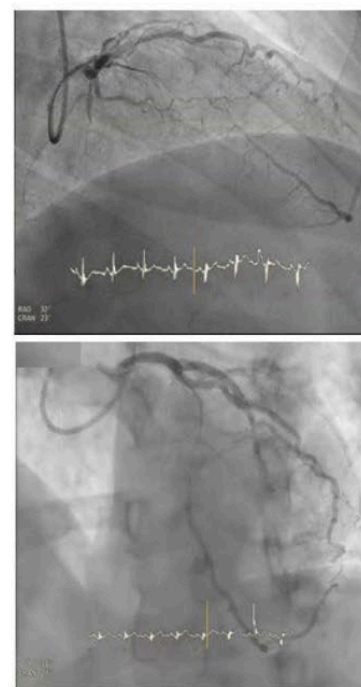
Extensive  
anatomical  
characterisation



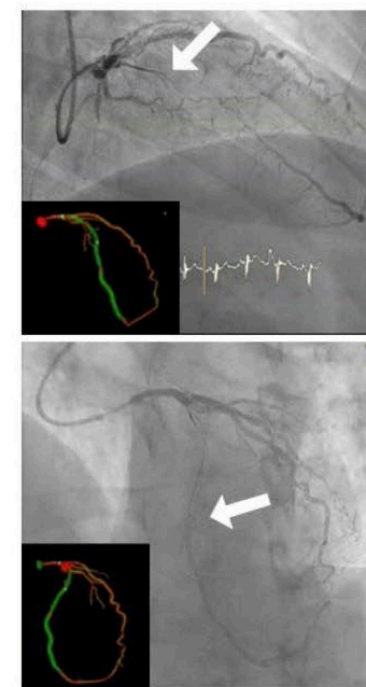
Lesion length and  
plaque composition  
analysis



Selection of the  
best angiographic  
projections



Roadmap for  
coronary wire  
progression in the  
occluded segment



# Fewer layers of metal?

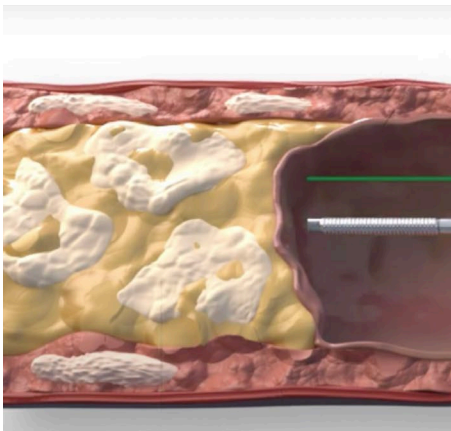
## The Co-CTO trial

### DEB vs DES in CTO

# Crossing Techniques

## PlasmaWire System

### SoundBite XS Crossing System

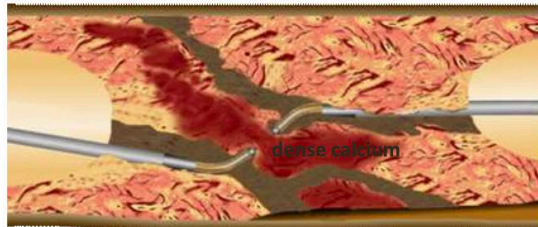
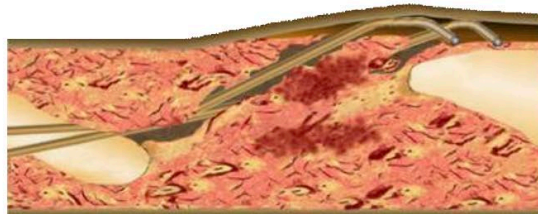
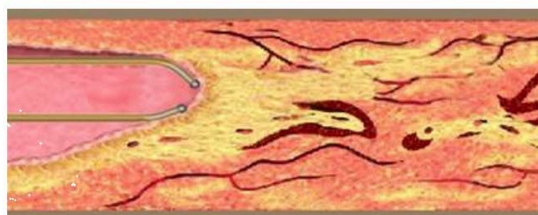


Ablation of proximal fibrous cap

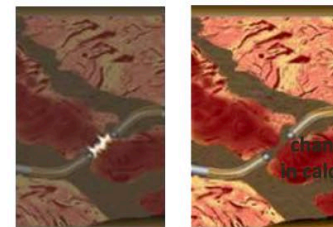
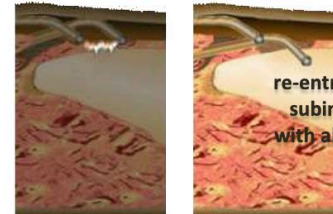
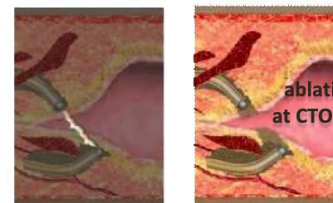
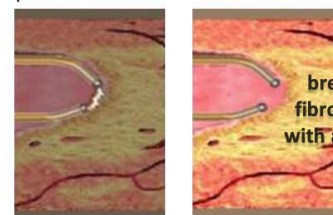
Recanalization with CTO exit

Antegrade re-entry

Retrograde re-entry with or w/o calcium ablation



### NovoCross microcatheter



break of fibrous cap with ablation

ablation at CTO exit

re-entry from subintima with ablation

channel in calcium

**Loop**  
THE LIMITS



# On-going Trials

<b>CTO TRIALS</b>	<b>Hypothesis</b>	<b>Design</b>	<b>Primary Endpoint</b>	<b>Target number/ recruitment</b>	<b>Investigator</b>
<b>CTO Arrythmia</b>	Successful CTO PCI reduces clinically significant arrythmias	Randomized PCI+OMT vs OMT	Incidence of clinically significant arrythmias, MACCE	200 (80)	Aalborg, Denmark Kirk Jensen Leif Thuesen
<b>REVISE CTO</b>	With ischemia >12.5% CTO PCI reduces ischemic burden, improves LV function and functional outcomes	Randomized trial. OMT or OMT+CTO PCI in pts with ischemic threshold >12.5% (SPECT C)	Reduction of ischemia assessed by exercise myocardial perfusion SPECT-CT from baseline to 6-month	80	Netherland
<b>CT prior to CTO PC</b>	CCTA prior to CTO PCI leads to improved success rates	1:1 Randomisation to CTCA or no CTCA prior to CTO PCI	Procedural success		UK
<b>CRUISE CTO</b>	IVUS-guided DES Implantation leads to better Clinical Outcomes Compared to Angiography guided CTO PCI				China
<b>ORBITA CTO (Pilot study)</b>	Does PCI improve Angina compared to a sham procedure in patients with CTOs	Randomised placebo-controlled, double-blind, study of CTO PCI vs placebo	Pilot study: Establish the feasibility of placebo-controlled study in a CTO population		UK

# Take Home Messages

- PCI to CTO is a complex intervention in constant growth and development.
- The success of the intervention continues improving as new techniques and approaches continue being developed.
- New trials are underway and may help to improve indications and results of the intervention.



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# Thanks!

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