Beyond the CTO
Lessons from Published and AMC data

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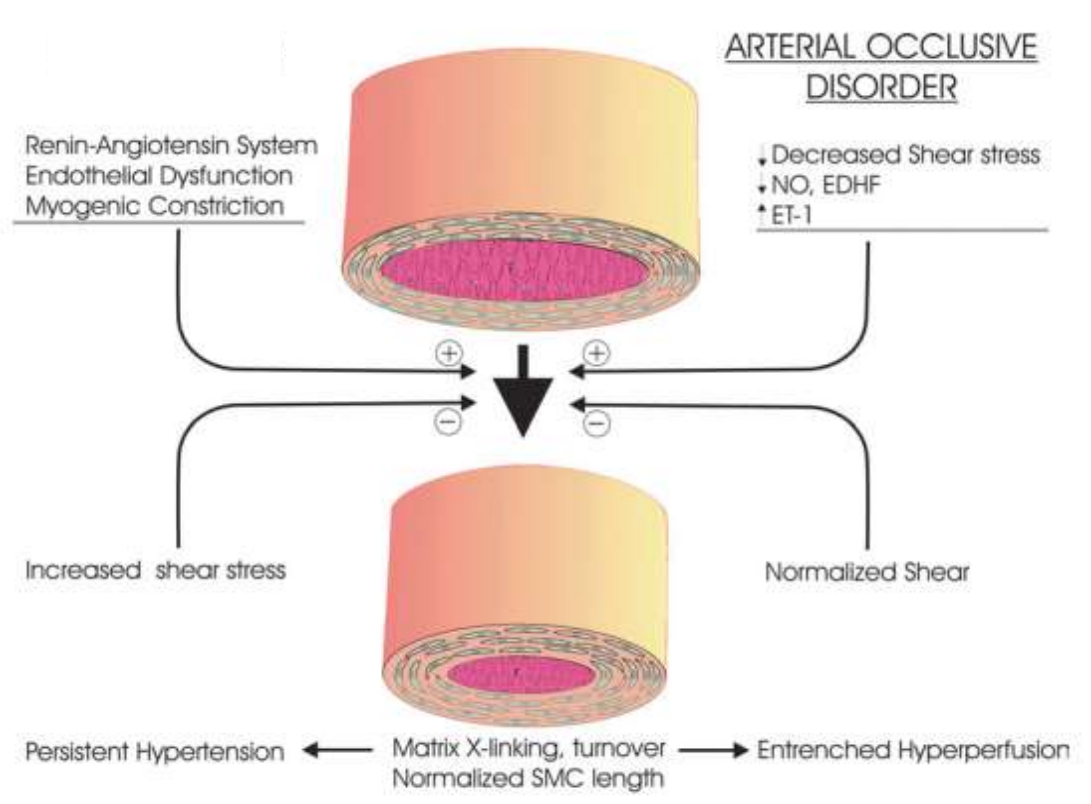
Beyond the CTO
What do we know?

1. Hypoperfusion induced remodeling happens

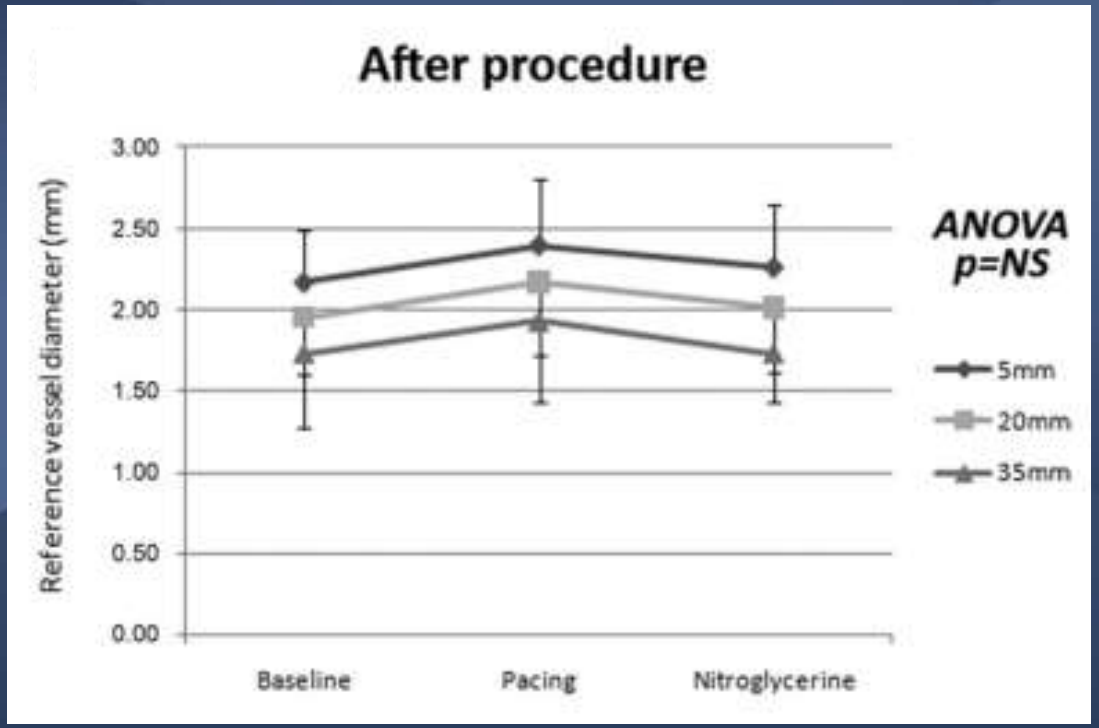


Vasoconstriction → Entrenchment

Clin Sci (Lond). 2007;113:15-23

Beyond the CTO
What do we know?

2. Vasomotion function is impaired immediately after ope ning the vessel.

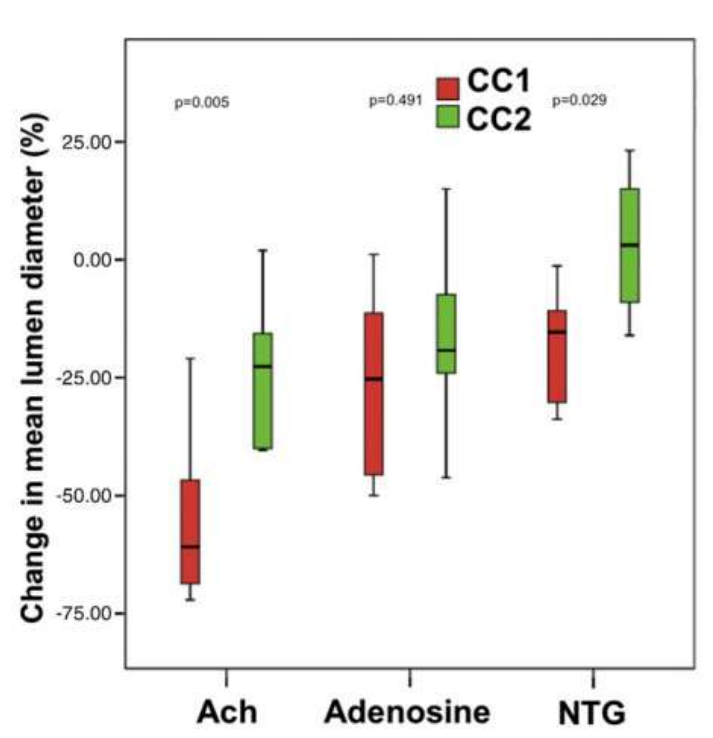


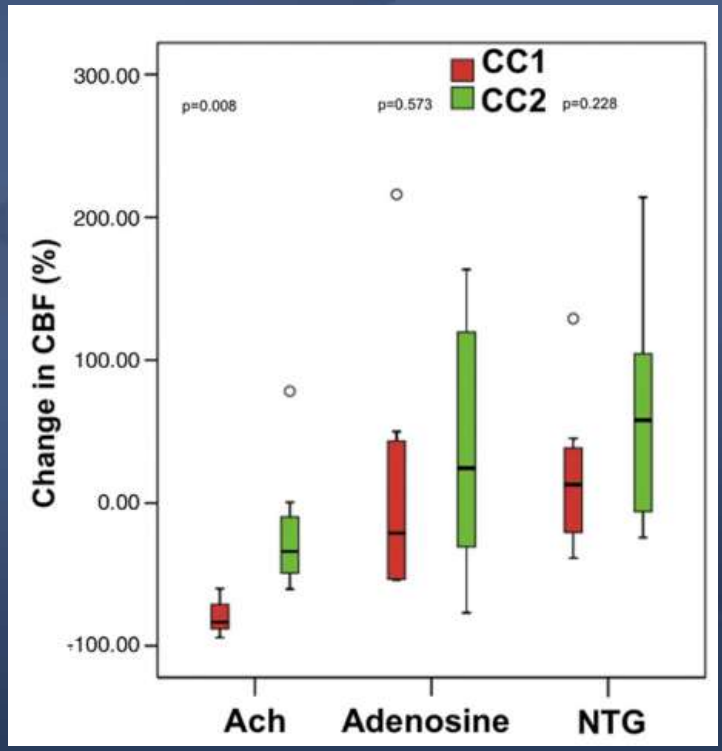
"hibernation of vascular wall"

J Am Coll Cardiol. 2012: 21;59:711-8

Beyond the CTO
What do we know?

2. Vasomotion function is impaired immediately after ope ning the vessel, but maybe not in all CTO cases



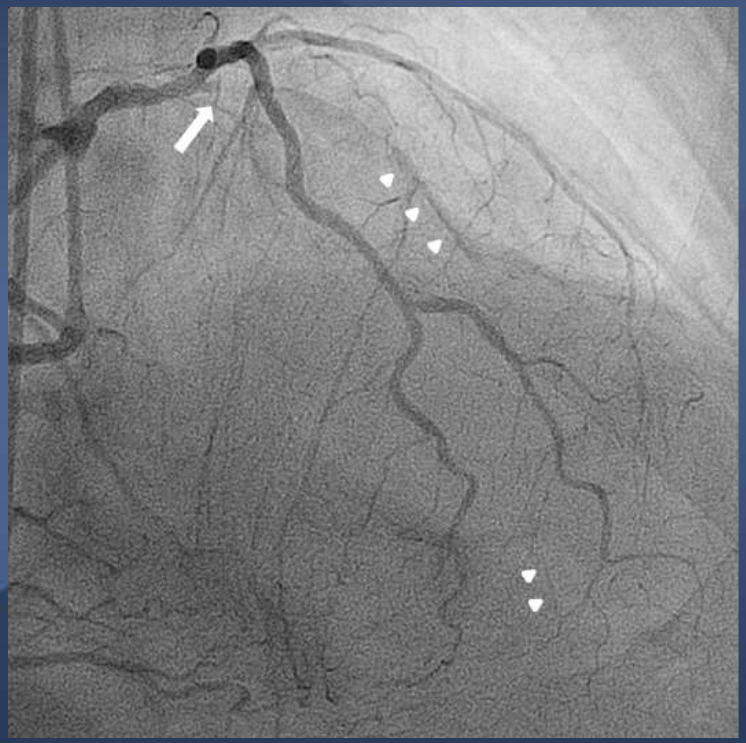


Better vasomotor response to NTG in CC2 collaterals

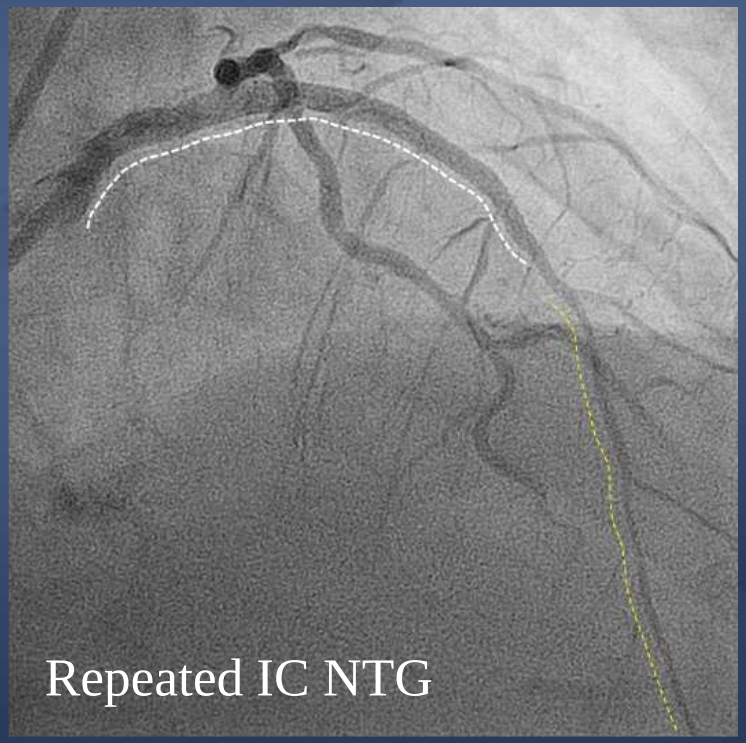
JACC Cardiovasc Interv. 2012;5(2):170-8

Beyond the CTO
What do we know?

3. Remodeling + impairment of vasomotion function mea ns *persistent luminal narrowing beyond the CTO after su ccessful CTO-PCI*



Pre



Post, TIMI 3 flow

Beyond the CTO
What do we know?

3. Remodeling + impairment of vasomotion function mea ns *persistent luminal narrowing beyond the CTO after su ccessful CTO-PCI - not infrequent*

Full Metal Jacket With Drug-Eluting Stents for Coronary Chronic Total Occlusion

Pil Hyung Lee, MD,[a] Seung-Whan Lee, MD, PhD,[b] Sung-Cheol Yun, MS,[b] Jaeseok Bae, MD,[c] Jung-Min Ahn, MD,[a] Duk-Woo Park, MD, PhD,[a] Soo-Jin Kang, MD, PhD,[a] Young-Hak Kim, MD, PhD,[a] Cheol Whan Lee, MD, PhD,[a] Seong-Wook Park, MD, PhD,[a] Seung-Jung Park, MD, PhD[a]

RESULTS Overall, 406 patients (36.7%) underwent the FMJ procedure, increasing in frequency over time (28.5% from 2003 to 2006 and 41.7% after 2011). The mean stent length was 76.8 ± 14.6 mm (range 60 to 122 mm), and the average number of stent overlaps was 2.5 ± 0.6 (range 2 to 4). A total of 127 patients (31.3%) had persistent luminal narrowing at the distal reference segment after stenting. During the median follow-up period of 5.1 years, target lesion failure occurred in 16.0% of patients. There were 17 cases of total reocclusion and 5 cases of stent thrombosis. Multivariate analysis confirmed that the number of implanted stents (hazard ratio: 1.72; 95% confidence interval: 1.16 to 2.54; $p = 0.006$) and persistent distal luminal narrowing (hazard ratio: 2.73; 95% confidence interval: 1.66 to 4.47; $p < 0.001$) were predictors of increased risk for target lesion failure.

Pre

Post, TIMI 3 flow

JACC Cardiovasc Interv. 2017;24;10:1405-1412

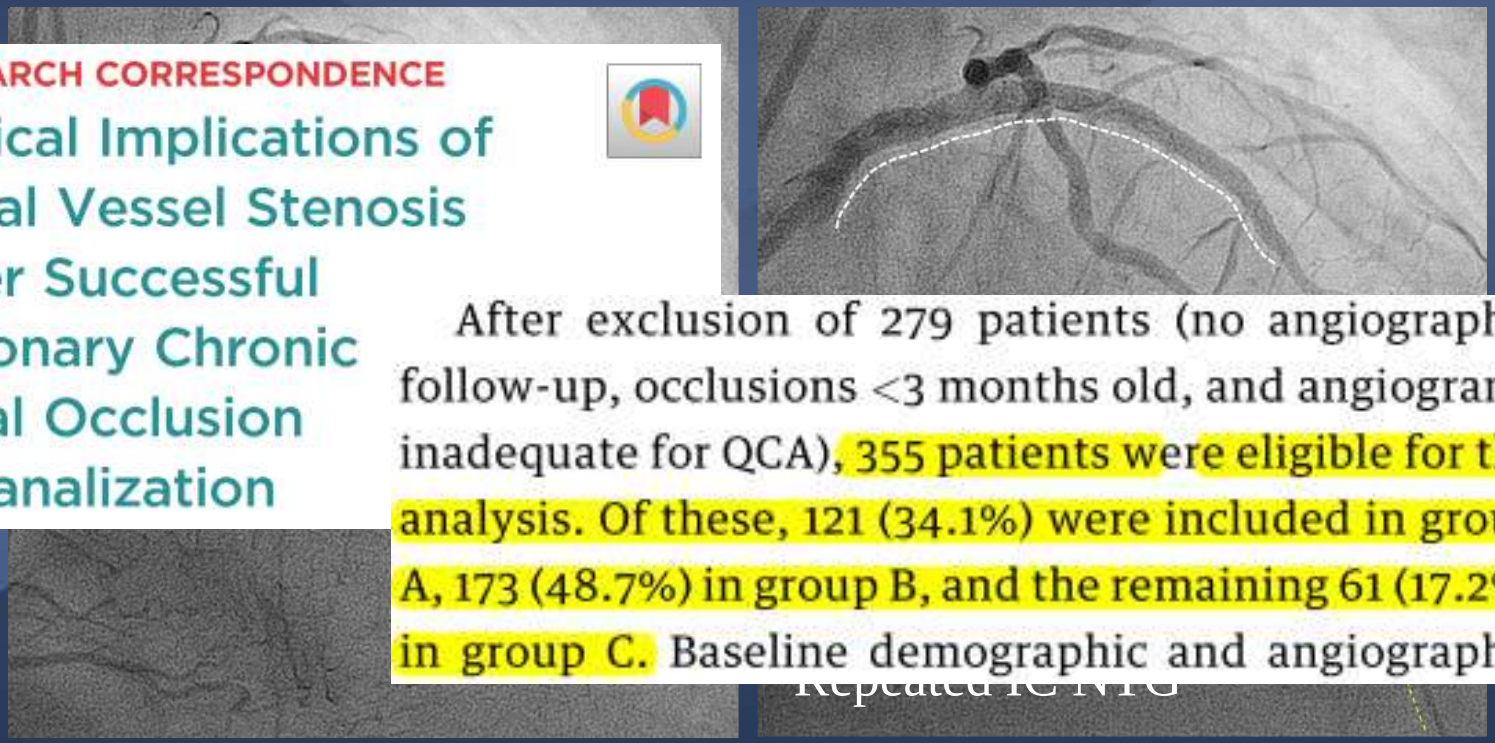
Beyond the CTO
What do we know?

3. Remodeling + impairment of vasomotion function mea ns *persistent luminal narrowing beyond the CTO after su ccessful CTO-PCI - not infrequent*

RESEARCH CORRESPONDENCE

Clinical Implications of Distal Vessel Stenosis After Successful Coronary Chronic Total Occlusion Recanalization

After exclusion of 279 patients (no angiographic follow-up, occlusions <3 months old, and angiograms inadequate for QCA), 355 patients were eligible for the analysis. Of these, 121 (34.1%) were included in group A, 173 (48.7%) in group B, and the remaining 61 (17.2%) in group C. Baseline demographic and angiographic



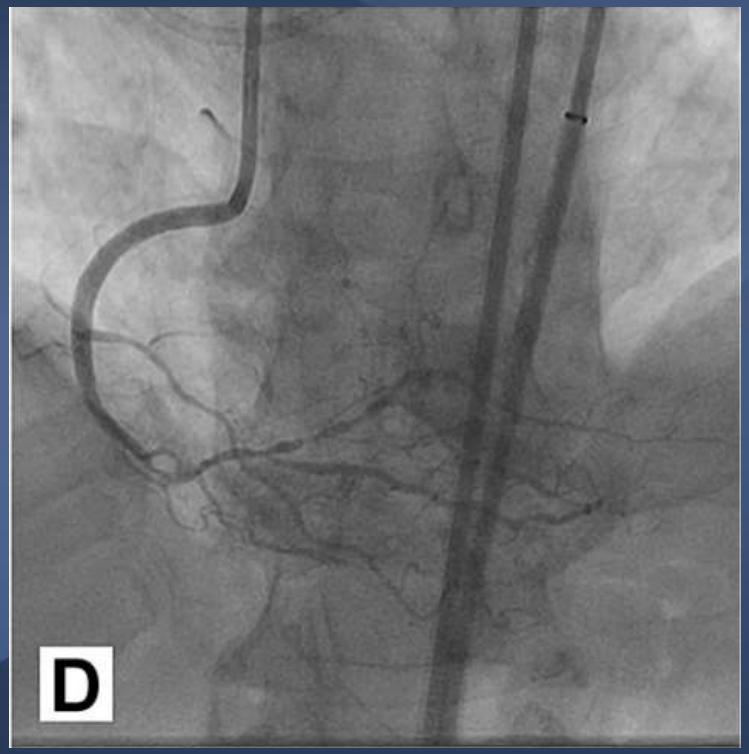
Pre

Post, TIMI 3 flow

JACC Cardiovasc Interv. 2018;26;11:2343-2345

Beyond the CTO
What do we know?

4. Vasomotion function beyond the CTO *recover over ti me* after flow restoration



Post

6-month FU

JACC Cardiovasc Interv. 2014;7(4):e31-3.

Beyond the CTO
What do we know?

4. Vasomotion function beyond the CTO *recover over ti me* after flow restoration – reverse the remodeling

The Recanalization of Chronic Total Occlusion
se in
ı Selected Patients

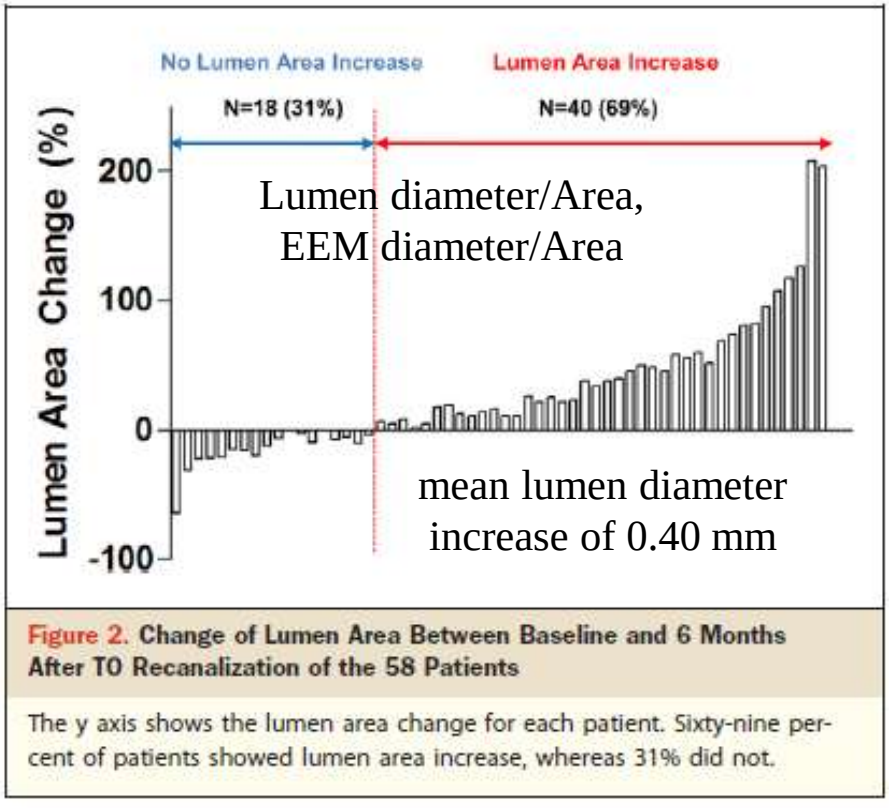


Figure 2. Change of Lumen Area Between Baseline and 6 Months After TO Recanalization of the 58 Patients

The y axis shows the lumen area change for each patient. Sixty-nine percent of patients showed lumen area increase, whereas 31% did not.

Table 4. Independent Predictors of Lumen Area Increase

	p Value	Odds Ratio	95% CI Lower	95% CI Upper
Poor collateral flow (vs. normal flow)	0.032	14.8	1.28	172.8
CTO	0.008	12.0	1.92	74.2
Statin use	0.047	7.4	1.03	53.6

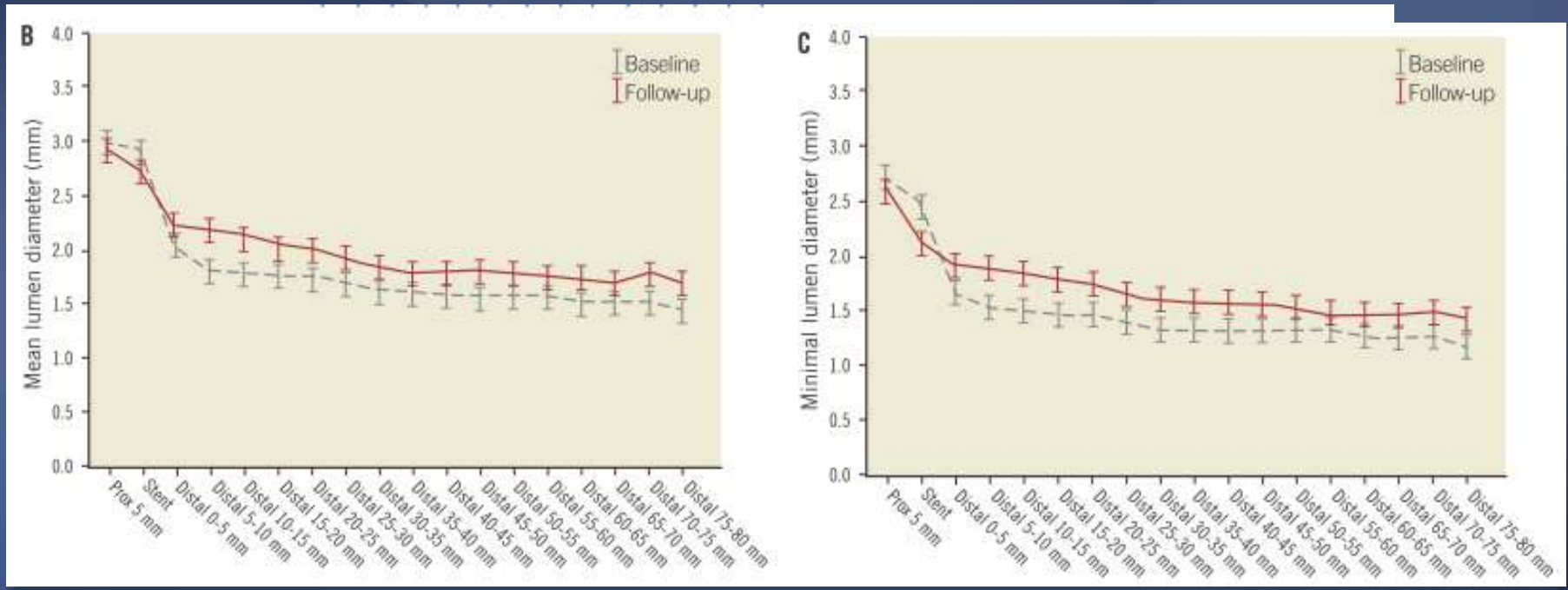
CTO, collateral flow grade, CAD extent, TO location, statin use, age, sex, diabetes mellitus, hypertension, and smoking status were entered into multivariate analysis. CTO was defined as TO with a total occlusion duration longer than 3 months.

CI = confidence interval; other abbreviations as in Table 1.

JACC Cardiovasc Interv. 2012;5:827-36.

Beyond the CTO
What do we know?

4. Vasomotion function beyond the CTO *recover over ti me* after flow restoration – reverse the remodeling



QCA; MinLD 23.9%, MeanLD 16.4%

IVUS (N=31); Lumen volume 26.9%, Plaque volume -3.9%

EuroIntervention 2014;9:1181-1188

AMC-CTO registry

May 2003 to August 2015
1,650 lesions in 1570 patients

1,320 successful CTO stenting

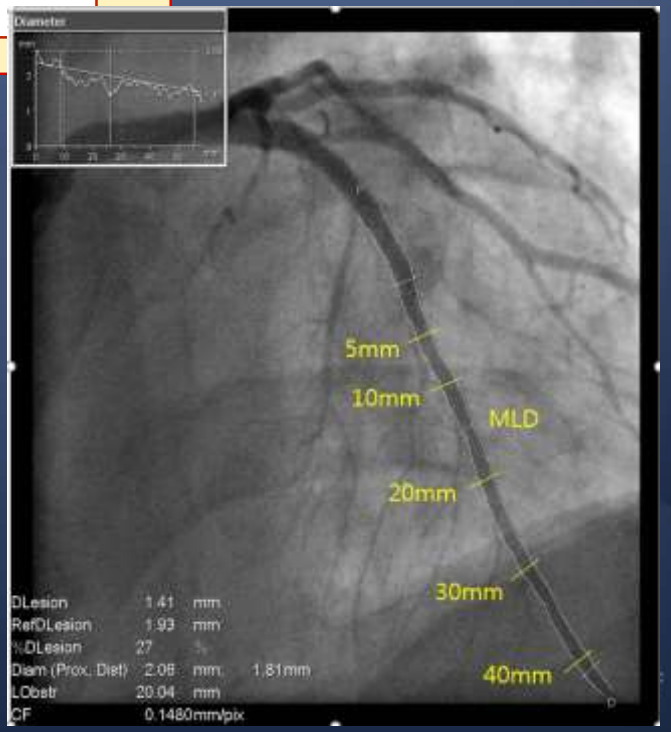
548 cases with follow-up angiography

507 cases

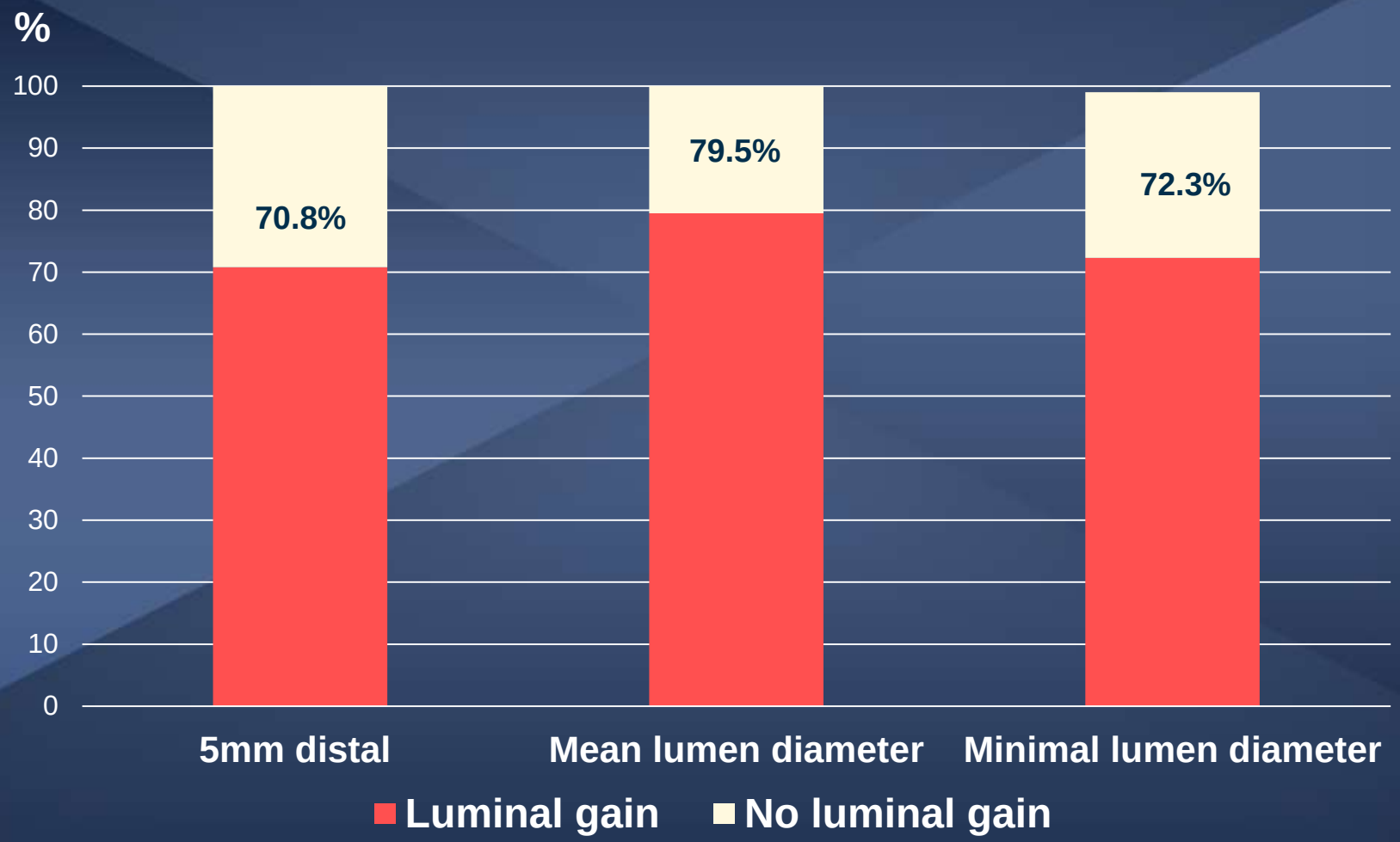
Excluded
18 total in-stent occlusion
23 not amenable for QCA analysis

Mean follow-up interval: 13.5 months

- **Institutional core laboratory**
- **Two experienced analysts (ICC=0.97)**
- **QCA software : CAAS, version 5.7 (Pie Medical BV, Maastricht, The Netherlands)**



Lumen gain of any degree



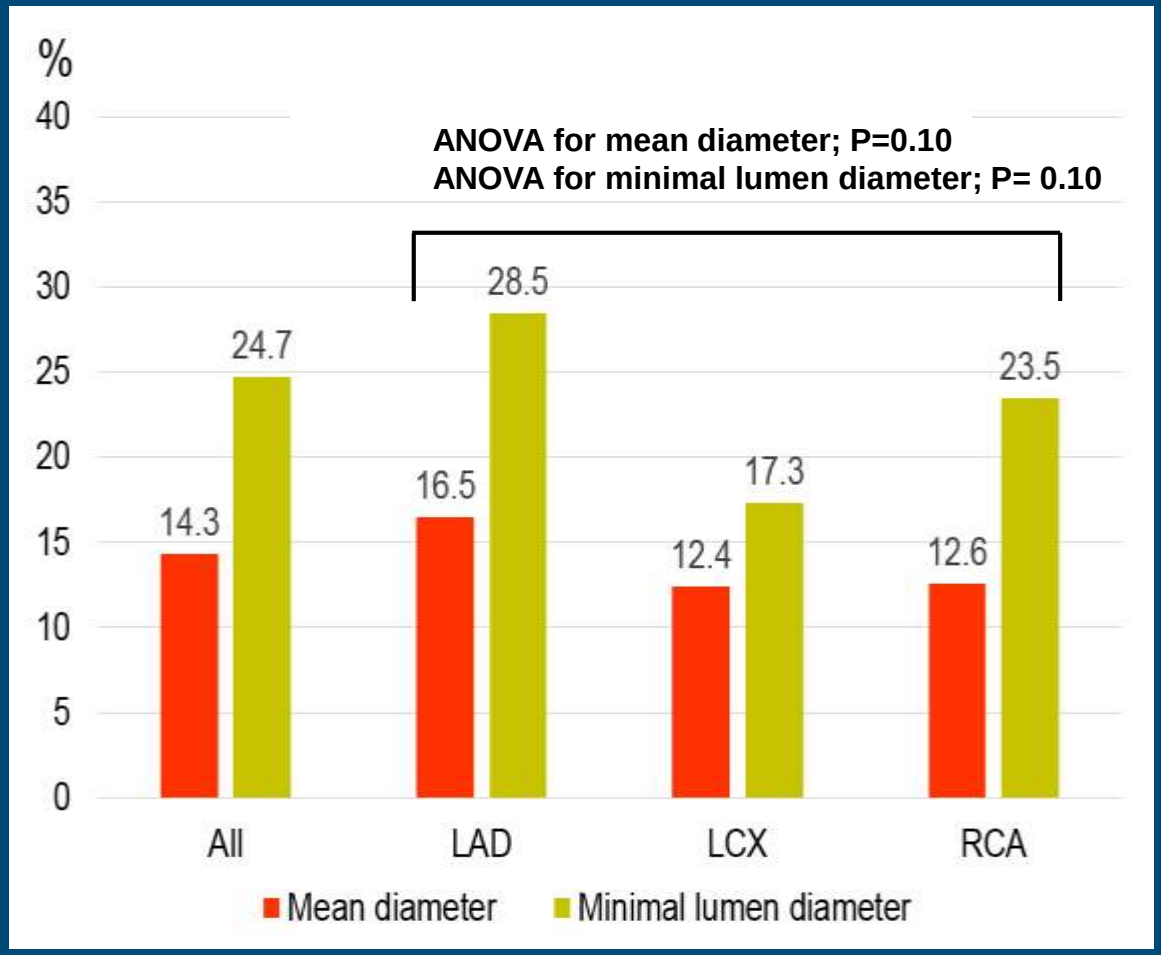
Lumen diameter changes at proximal or distal segment

Location from the stent segment	Immediately post (mm)	Follow-up (mm)	Change (follow-up – baseline) (mm)	Percent diameter changes (%)	P
5mm proximal	3.04 ± 0.64	2.98 ± 0.68	- 0.06 ± 0.45	-0.7 ± 17.2	<0.02
5mm distal	2.03 ± 0.61	2.30 ± 0.57	0.26 ± 0.47	18.2 ± 32.2	<0.001
10mm distal	1.97 ± 0.61	2.23 ± 0.55	0.26 ± 0.45	19.6 ± 34.7	<0.001
20mm distal	1.93 ± 0.59	2.18 ± 0.56	0.25 ± 0.46	17.6 ± 32.4	<0.001
30mm distal	2.01 ± 0.71	2.26 ± 0.62	0.25 ± 0.53	18.7 ± 38.4	<0.001
40mm distal	2.09 ± 0.77	2.23 ± 0.68	0.29 ± 0.52	17.9 ± 31.8	<0.001*
Mean lumen diameter	1.99 ± 0.51	2.22 ± 0.47	0.23 ± 0.35	14.3 ± 20.7	<0.001
Minimal lumen diameter	1.59 ± 0.87	1.85 ± 0.98	0.22 ± 0.80	24.7 ± 42.3	<0.001

Diameter changes in 401 patients with the lumen gain

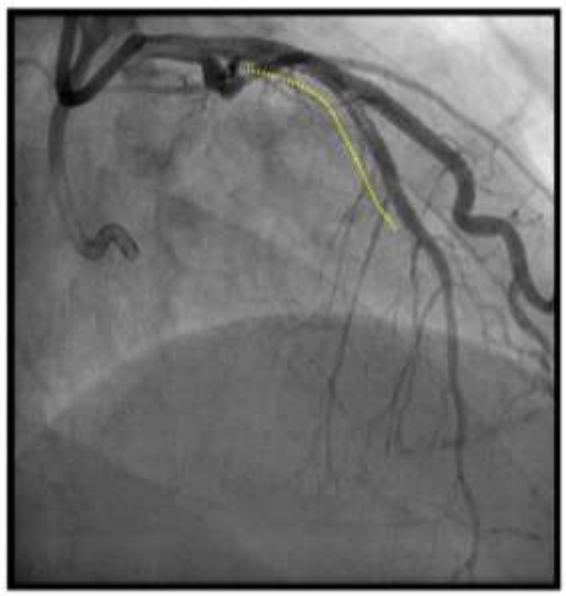
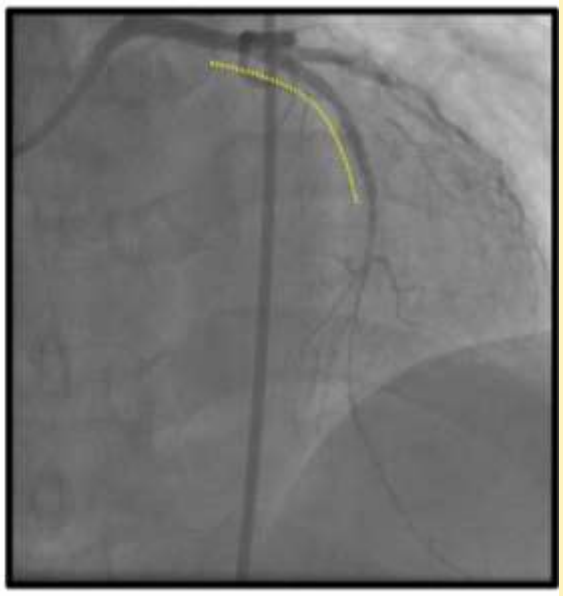
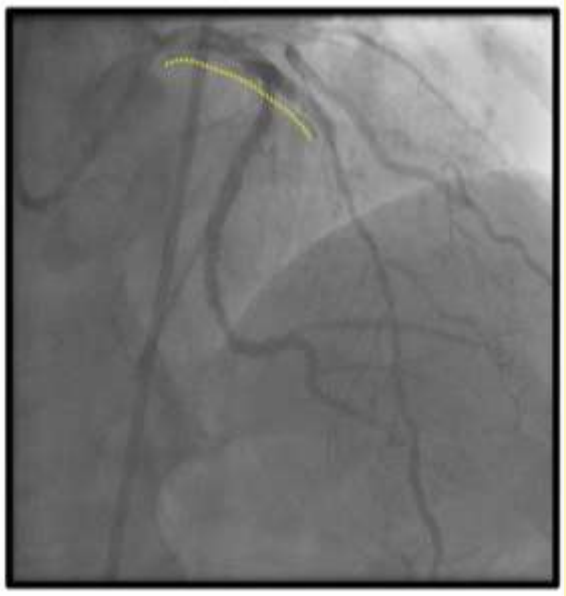
Location from the stent segment	Immediately post (mm)	Follow-up (mm)	Change (follow-up – baseline) (mm)	Percent diameter changes (%)	P
5mm proximal	3.02 ± 0.63	3.03 ± 0.68	0.01 ± 0.44	1.34 ± 17.2	0.70
5mm distal	1.97 ± 0.57	2.35 ± 0.55	0.37 ± 0.41	24.1 ± 30.4	<0.001
10mm distal	1.90 ± 0.58	2.26 ± 0.55	0.36 ± 0.41	25.0 ± 34.7	<0.001
20mm distal	1.87 ± 0.56	2.20 ± 0.56	0.34 ± 0.43	22.5 ± 31.6	<0.001
30mm distal	1.89 ± 0.68	2.23 ± 0.64	0.35 ± 0.50	25.2 ± 40.5	<0.001
40mm distal	1.95 ± 0.74	2.33 ± 0.68	0.39 ± 0.51	22.9 ± 33.1	<0.001*
Mean lumen diameter	1.91 ± 0.47	2.26 ± 0.46	0.35 ± 0.25	20.8 ± 17.8	<0.001
Minimal lumen diameter	1.51 ± 0.93	1.88 ± 1.06	0.32 ± 0.85	33.0 ± 42.6	<0.001

Percent change of Diameter
according to the type of epicardial vessel



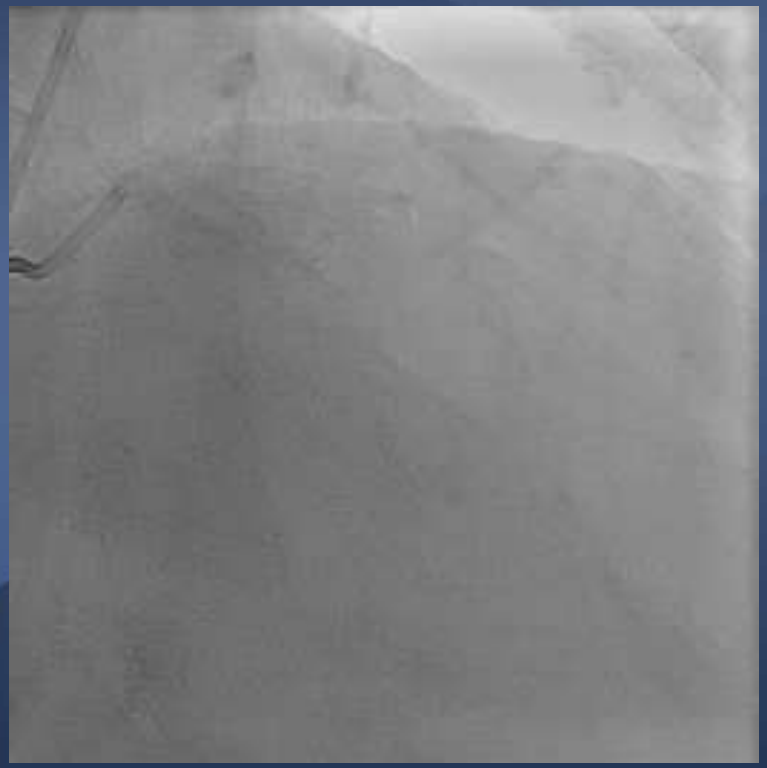
Beyond the CTO
What we don't know

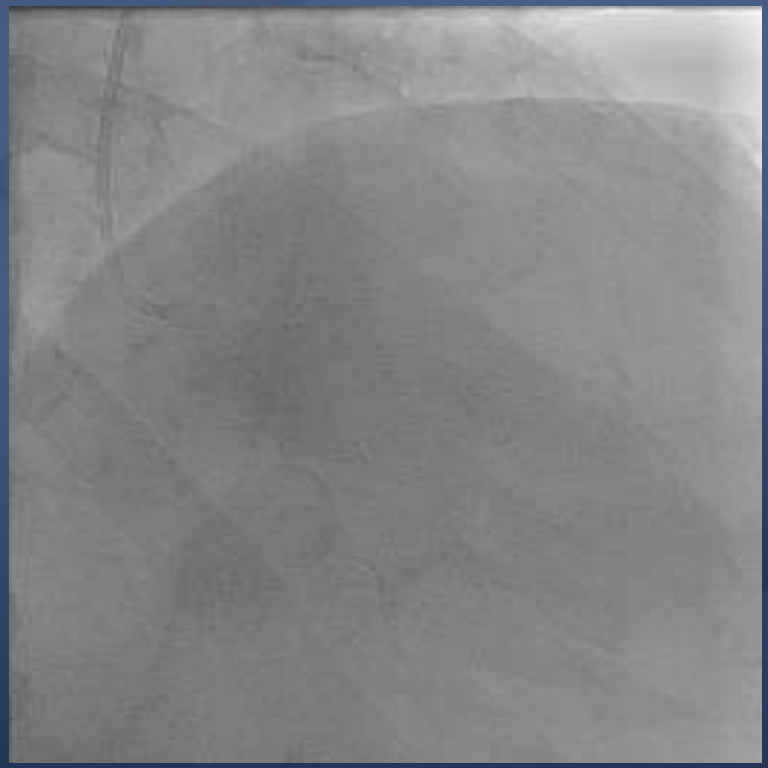
1. How to differentiate the vessel shrinkage vs. plaque b urden contribution to luminal narrowing

Normal	Shrunken?	Stenoses?
		
Coronary stenosis <20% with no luminal irregularities or loss of concentric vessel profiles	Coronary stenosis ≥20% without luminal irregularities or loss of concentric vessel profiles	Stenosis ≥20% accompanying luminal irregularities or loss of concentric vessel profiles

Beyond the CTO
What we don't know

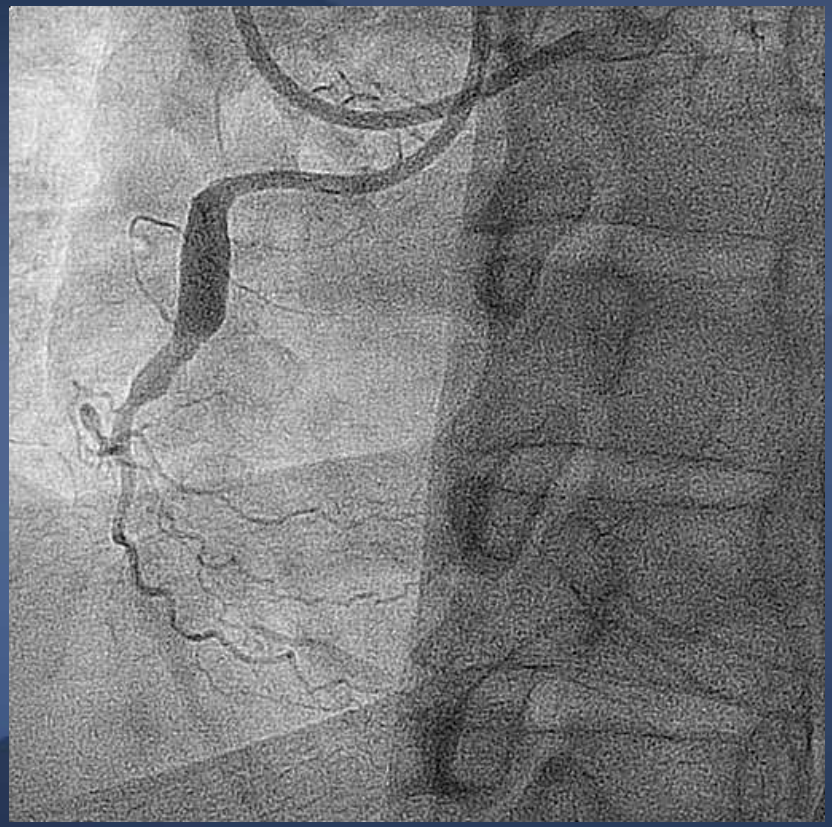
1. How to differentiate the vessel shrinkage vs. plaque burden contribution to luminal narrowing; Any angiographic or imaging surrogates? Biomarkers?

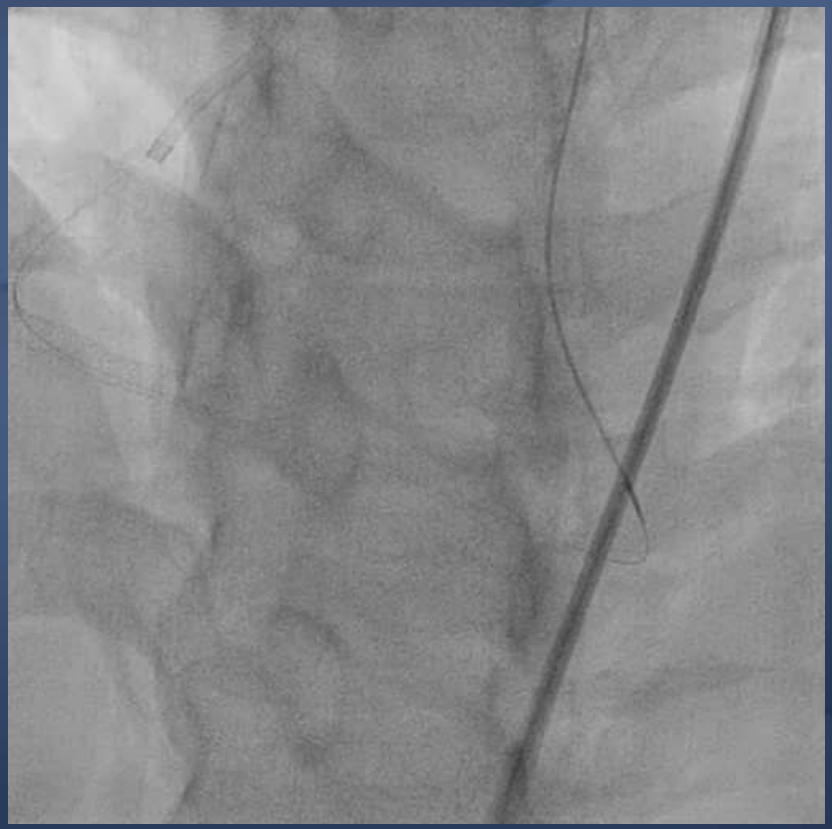




Beyond the CTO
What we don't know

2. How to predict the original vessel size





Resolute 4.0 x 22+3.5 x 38

Korean Circ J. 2019;49:366-368

Beyond the CTO
What we don't know

2. How to predict the original vessel size

Resolute 3.5 x 33

Korean Circ J. 2019;49:366-368

Beyond the CTO
What we don't know

2. How to predict the original vessel size

The Recanalization of Chronic Total Occlusion Leads to Lumen Area Increase in Distal Reference Segments in Selec

An Intravascular Ultrasound Study

Jin Joo Park, MD,* In-Ho Chae, MD,† Young-Seok Cho, MD,†
Han-Mo Yang, MD,* Jae-Bin Seo, MD,‡ Song-Yi Kim, MD,§ Il-
Chang-Hwan Yoon, MD,† Jung-Won Suh, MD,† Kyung-Woo Pa
Woo-Young Chung, MD,‡ Tae-Jin Youn, MD,† Dong-Ju Choi,

Seongnam, Seoul, and Jeju, South Korea

Objectives This study sought to investigate the extent of and factors r
area change in coronary arteries after total occlusion (TO) recanalizatior

Background TO of a coronary artery promotes negative remodeling in
Recanalization can restore blood flow, potentially leading to positive va

Methods From March 2005 to June 2008, 58 consecutive patients with
least 1-month duration were enrolled. We performed intravascular ultra
taneous coronary intervention and at the 6-month follow-up, and we q
tal reference segments.

Results At the 6-month follow-up, there was a significant increase in t
(+0.21 mm, p = 0.001), the mean external elastic membrane diameter
lumen area (+0.87 mm^2, p < 0.001), and the external elastic membran
p = 0.001) in the distal reference segments and an increase in the left
(+2.77%, p = 0.010). Overall, 40 of 58 patients (69%) showed lumen ar
had increase in lumen diameter by 0.40 ± 0.34 mm (p < 0.001) and in
apposition rate (p = 0.006). A TO duration of longer than 3 months (oc
fidence interval [CI]: 1.28 to 172.8, p = 0.032), a poor collateral flow (OR
p = 0.008), and statin use (OR: 7.4; 95% CI: 1.03 to 53.6, p = 0.047) we
lumen area increase.

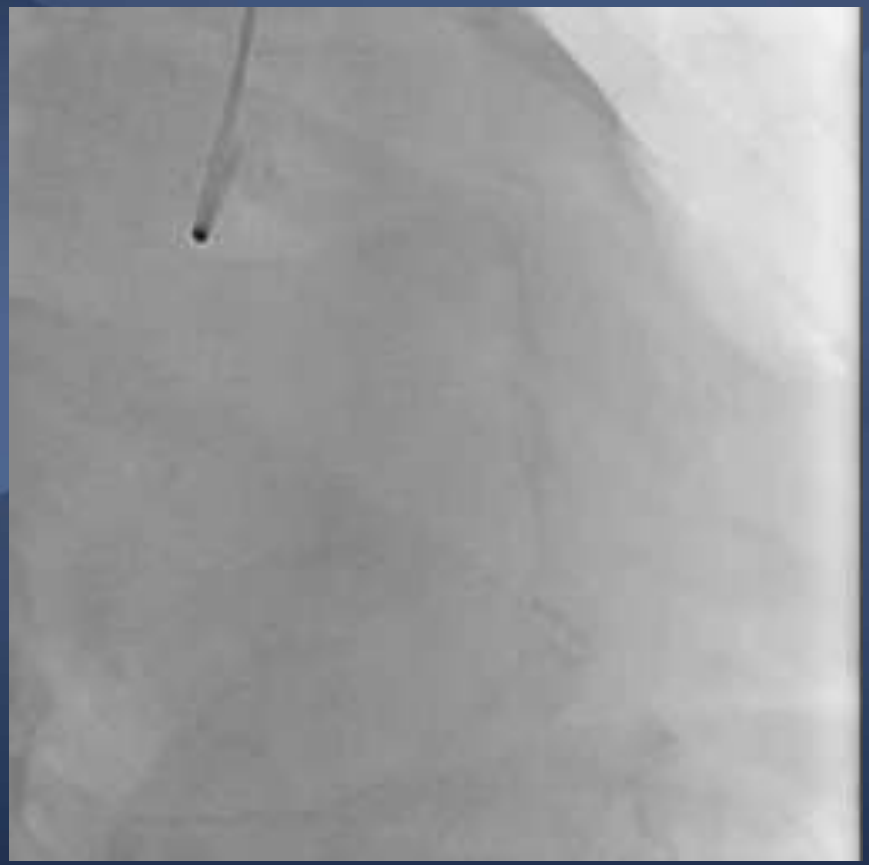
Serial Intravascular Ultrasound Findings After Treatment of Chronic Total Occlusions Using Drug-Eluting Stents

Shigeo Saito, MD[a,b,c], Akiko Maehara, MD[b,c,*], Tadayuki Yakushiji, MD[a], Tomotaka Dohi, MD, PhD[b,c,d], Nobuaki Kobayashi, MD, PhD[b,c,e], Lei Song, MD[b,c,f], Gary S. Mintz, MD[b], and Masahiko Ochiai, MD, PhD[a]

Morphologic changes after chronic total occlusion (CTO) treatment with drug-eluting stents (DESs) have not been assessed in detail. Our aim was to use both baseline and follow-up intravascular ultrasound studies to evaluate the morphologic changes and, especially, the changes in distal vessel size and the effect of subintimal stenting after treatment of CTOs with DES. We analyzed serial follow-up intravascular ultrasound (baseline and follow-up at 9 ± 2 months) after DES implantation into 40 CTOs. Overall, 33 CTOs were treated by the anterograde approach; and 7 were treated by the retrograde approach. Minimum lumen cross-sectional area (CSA) trended toward a decrease from baseline to follow-up (4.8 ± 1.7 vs 4.5 ± 1.7 mm^2, p = 0.10), although the minimum stent CSA (4.8 ± 1.7 vs 4.9 ± 1.7 mm^2, p = 0.26) did not change. The distal reference, but not the proximal reference lumen CSA, increased significantly at follow-up (3.8 ± 2.0 to 5.1 ± 2.3 mm^2, p = 0.0004). Late-acquired stent malapposition was seen in 17 patients (42.5%). In 8 CTOs (20%), a part of the stent was implanted into a subintimal space; in these 8 patients, maximum percent neointimal hyperplasia and minimum lumen area was similar in the subintimal segment compared with the adjacent intraplaque segment. The frequency of late-acquired stent malapposition was similar. In conclusion, after CTO treatment with DES, distal vessel enlargement was detected. Subintimal stenting after recanalization of CTO was not inferior compared with stenting within the plaque in terms of long-term morphologic impact. (Am J Cardiol 2016;117:727–734)

Beyond the CTO
What we don't know

3. How to ensure that it's ok for the distal narrowing *; TIMI 3 flow enough? Hemodynamic parameter?*



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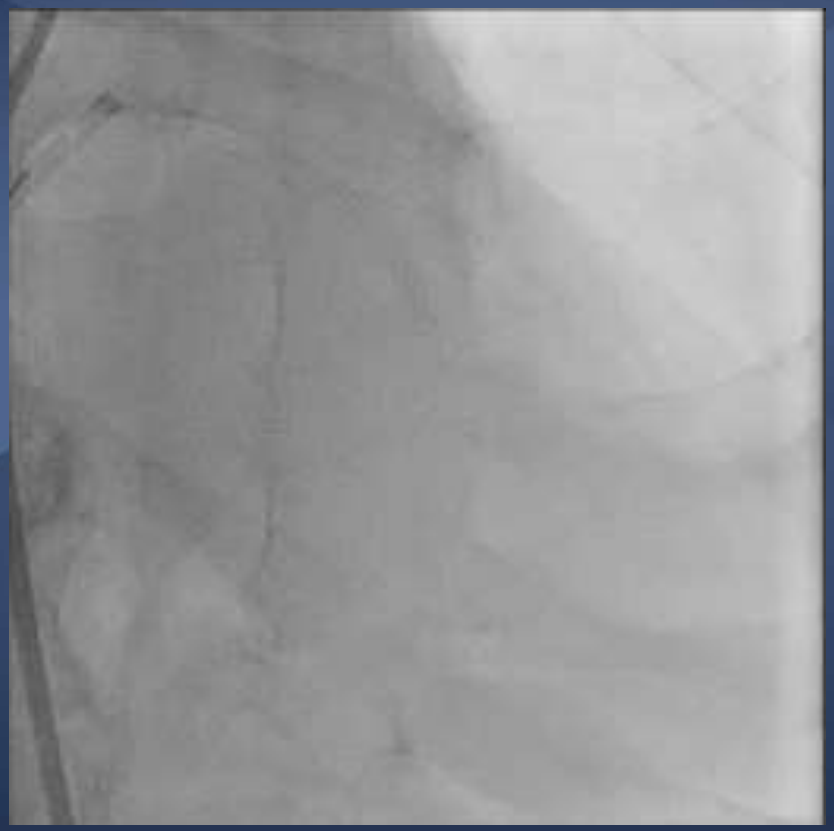

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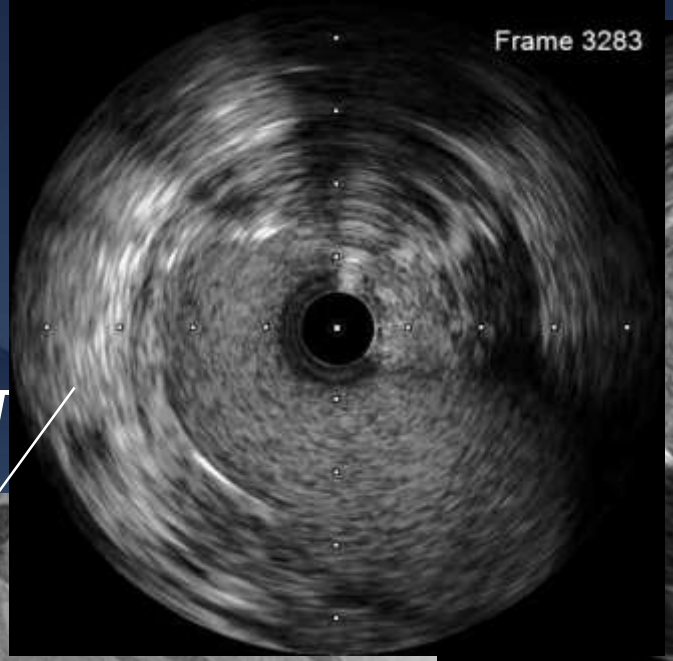

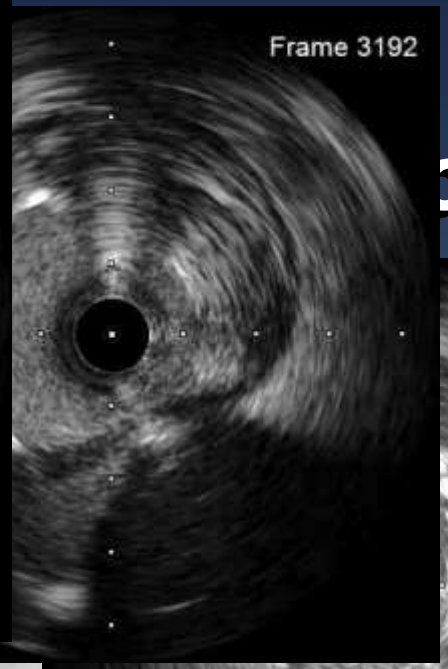

Beyond the CTO
What we don't know

3. How to ensure that it's ok for the distal narrowing *; TIMI 3 flow enough? Hemodynamic parameter?*

5 days later, AMI, ST

Beyond the CTO

Lot's of things to find out