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Illuminating the Dark Corners:

Harnessing Intracoronary Imaging for CTO PCI

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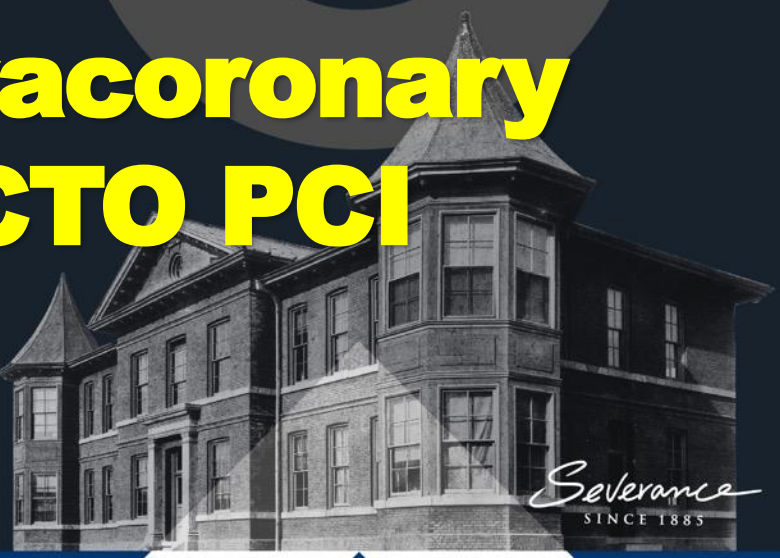

Disclosure Statement of Financial Interest

- Speaker honoraria

  from Hanmi Pharma, Astrazeneca, Biotronik Korea, CKD Pharma, Yuhan Corporation, and Bayer Korea

- Consultation fee

  from Novartis Korea, and Daewoong Pharma

How to use intracoronary imaging for CTO?

- **Pre-procedural imaging tool**
  for the successful CTO recanalization

- Image-guided CTO intervention during CTO procedures

Could **pre-procedural CT scan** improve success rate of the **CTO-PCI**?

JACC: CARDIOVASCULAR IMAGING

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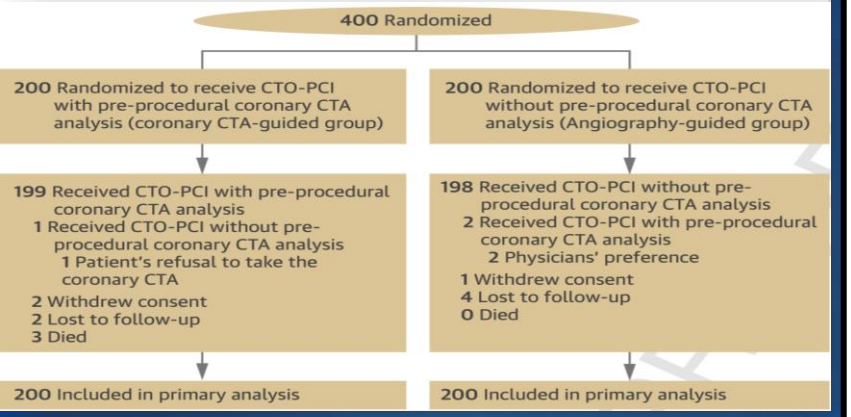
Randomized CT-CTO trial

NEW RESEARCH PAPER

Effect of Coronary CTA on Chronic Total Occlusion Percutaneous Coronary Intervention

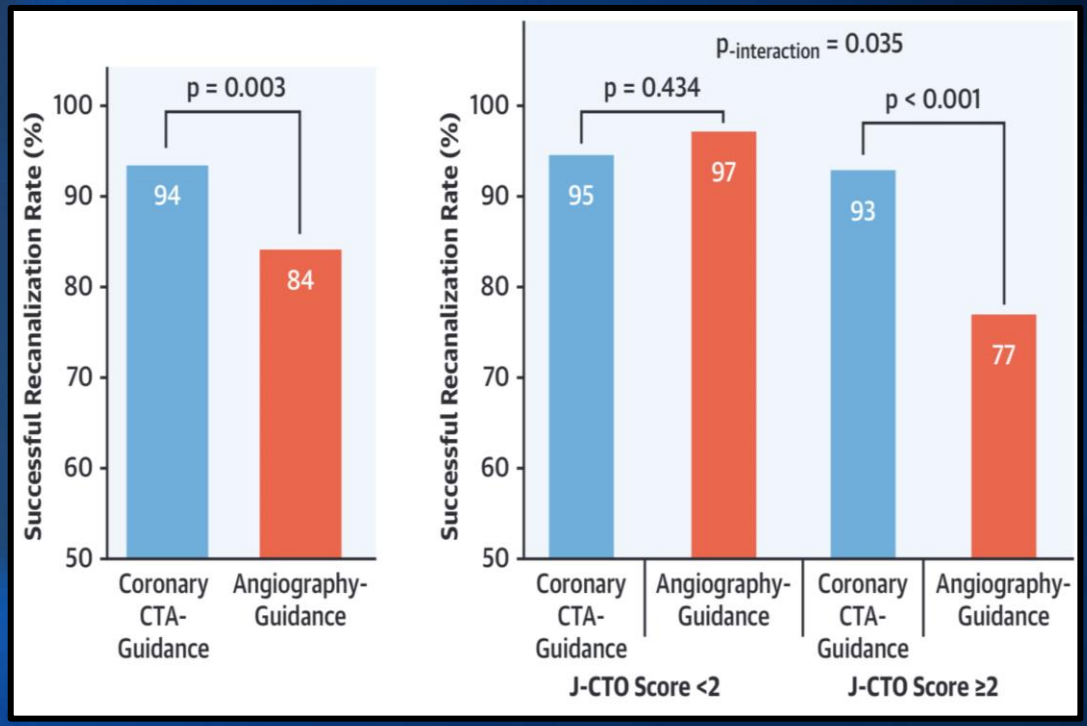
A Randomized Trial

ClinicalTrials.gov Identifier: NCT02037698



- Conducted at 12 centers in South Korea
- Hypothesis; **The success rate of CCTA guidance would be superior to the angiography guidance**

- Primary endpoint: **Rate of the successful recanalization**
  Final TIMI flow grade ≥2 and ≤30% residual stenosis on the final CAG without death or fatal complications during the procedure requiring emergent operation.



CONCLUSIONS Pre-procedural CT-guidance for CTO resulted in higher success rates with numerically fewer immediate complications such as coronary perforations or PPMI than angiography guidance. Higher success rates were more prominently observed in patients with CTO who had a high J-CTO score than those who did not.

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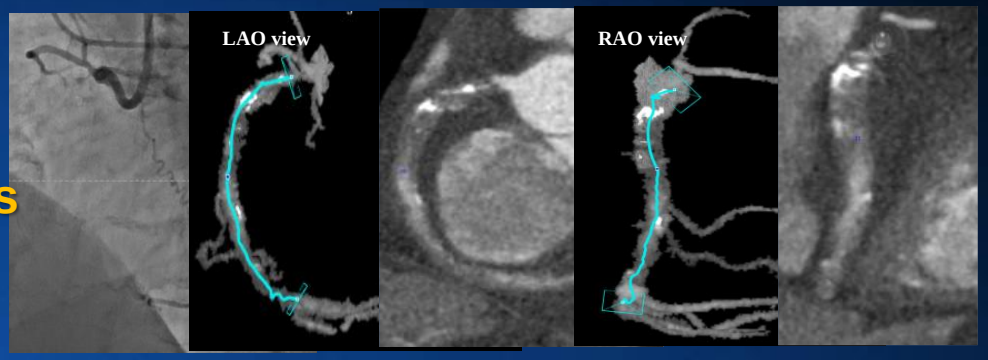
Hong SJ & Kim BK, et al. JACC Cardiovasc Imaging;14:1993-2004

Pre-procedural CT Analyses from CT-CTO trial

1. Making two orthogonal CT images matching with CAG; 3-D volume rendering and MPR images corresponding to 2 orthogonal views

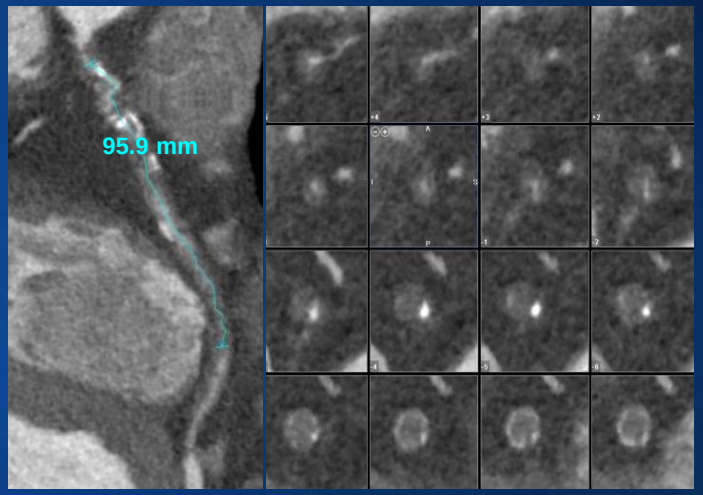
- **CTO courses** (how CTO course goes & what the hidden route is within CTO segment)
- **Anatomical location associated with side branches**



2. Qualitative and quantitative analyses of CTO from MPR images

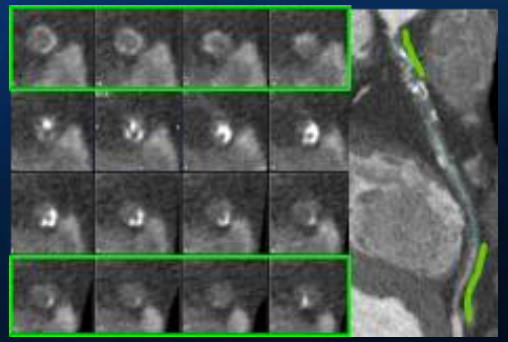
1) **CTO length and the shapes of proximal & distal CTO ends**
2) **Calcification; longitudinal & cross-sectional analyses**
   - Maximal cross-sectional extent; <50% or ≥50%
   - Length of calcification with cross-sectional extent ≥ 50%
   - Calcification shape; semicircular <180°, circular ≥180°, or 360° (full moon)
   - Location of calcium on CTO lesion

   → **"Geographic calcification-mapping"**



3. Analyses of the segments around CTO

- **Check the size of vessel and lumen and the tortuosity in proximal and distal reference segments**



Pre-procedural planning in CTO intervention by coronary CT

- **Blunt stump or long tortuous CTO;**

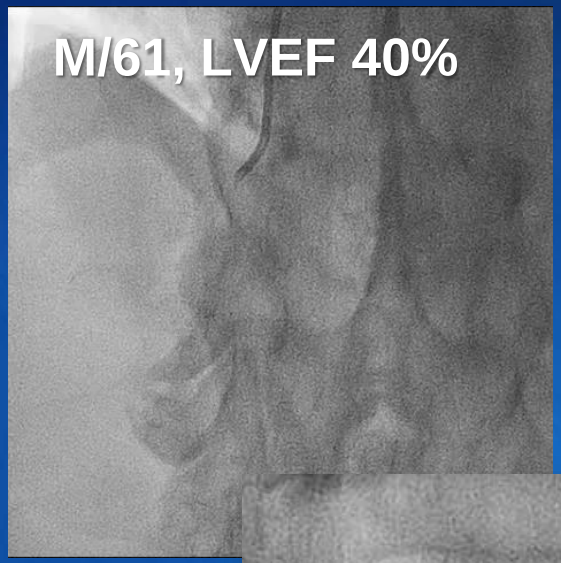
Pre-procedural CCTA could **show the exact anatomical location related with the adjacent SB and the courses from proximal to distal CTO cap.**

- **Reasons for recanalization failure in CT-CTO trial**

Reasons for failure	CCTA-guidance N=13	Angiography-guidance N=32	*P*
No. of failed antegrade-only approach	10	17	
Wiring to false lumen and fail to enter to true lumen	7 (70)	8 (47)	0.247
Failure to advance the cap or the CTO segment	1 (10)	2 (12)	0.260
Failure to enter the cap due to anatomical ambiguity	0	6 (35)	0.033
Failure to achieve TIMI grade flow ≥2 after stenting	2 (20)	1 (6)	0.888

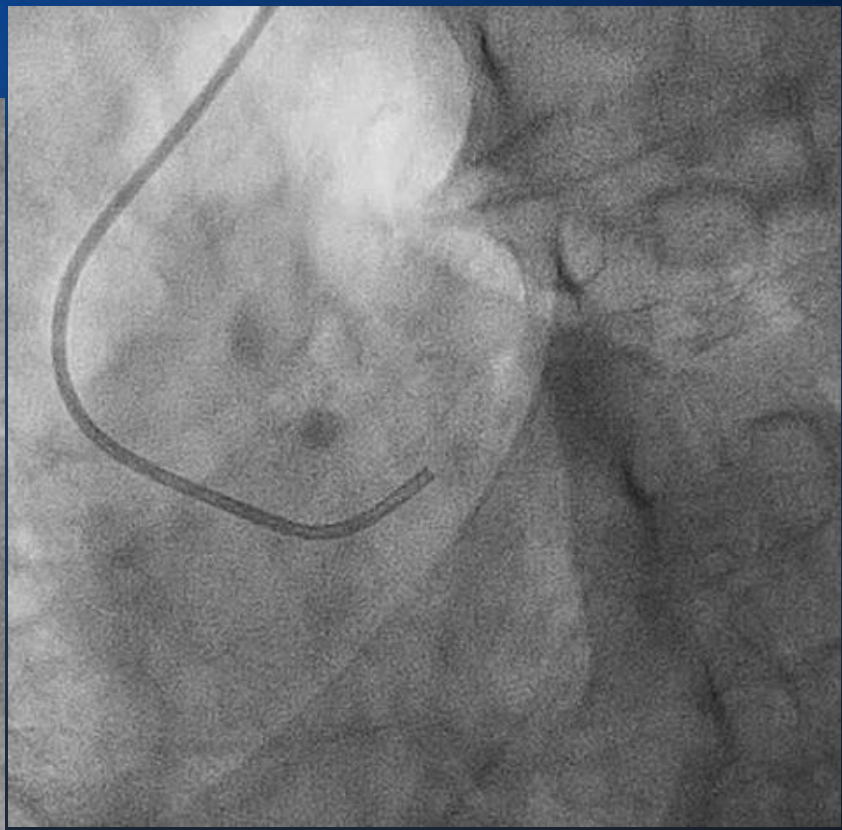
JACC Cardiovasc Imaging;14:1993-2004

Case 1: Aorto-ostial CTO, invisible coronary artery ostium from CAG



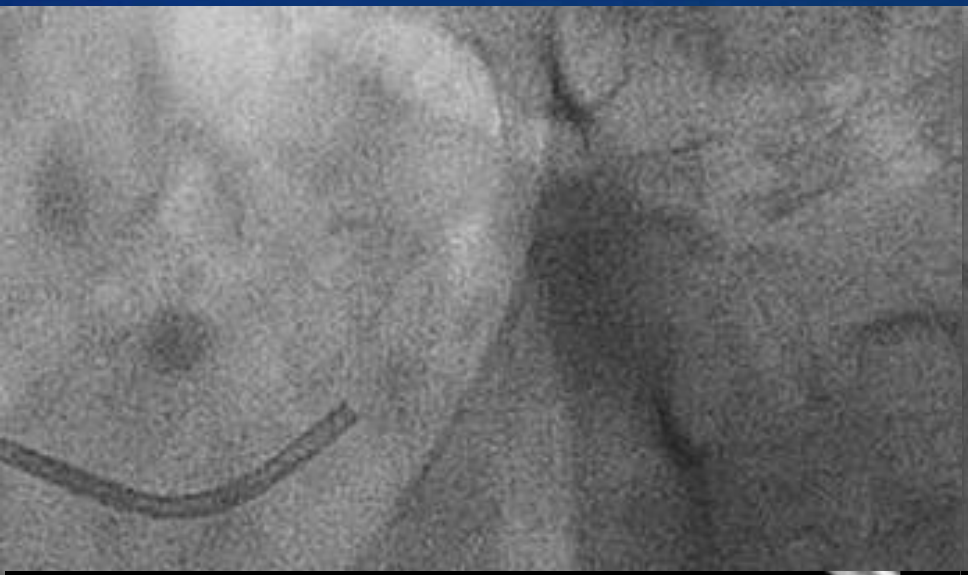
Where is LAD ostium?

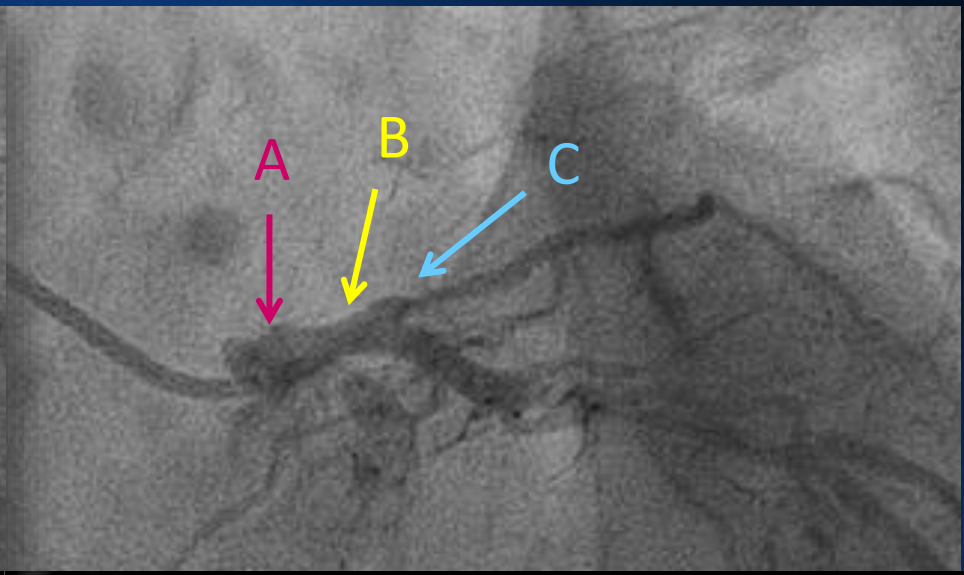
Ambiguous CTO anatomy



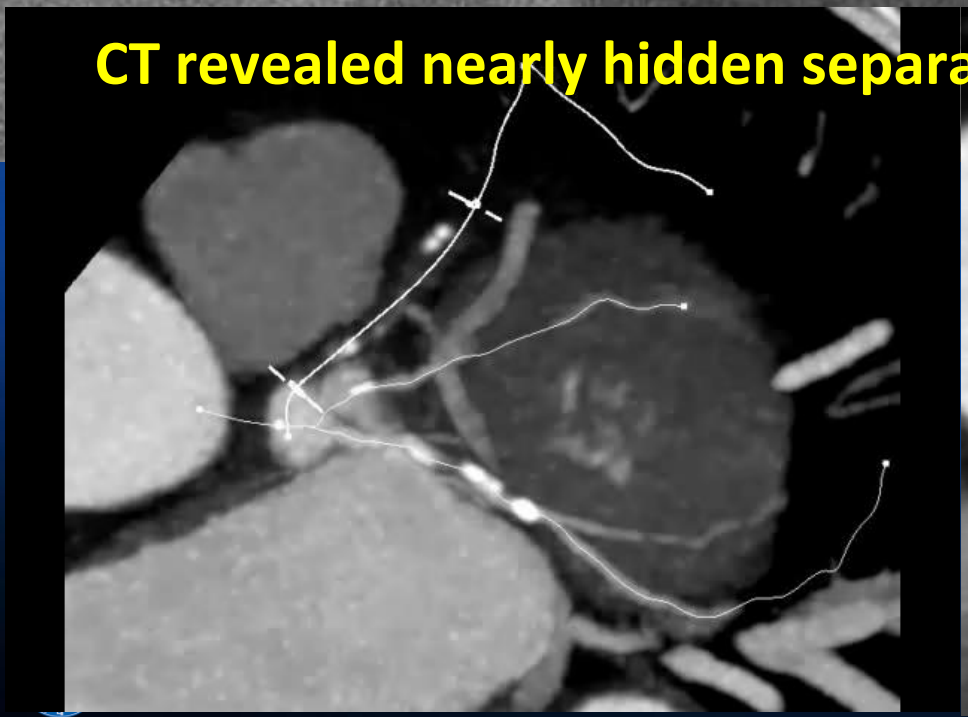
Courtesy of Dr Jinho Choi

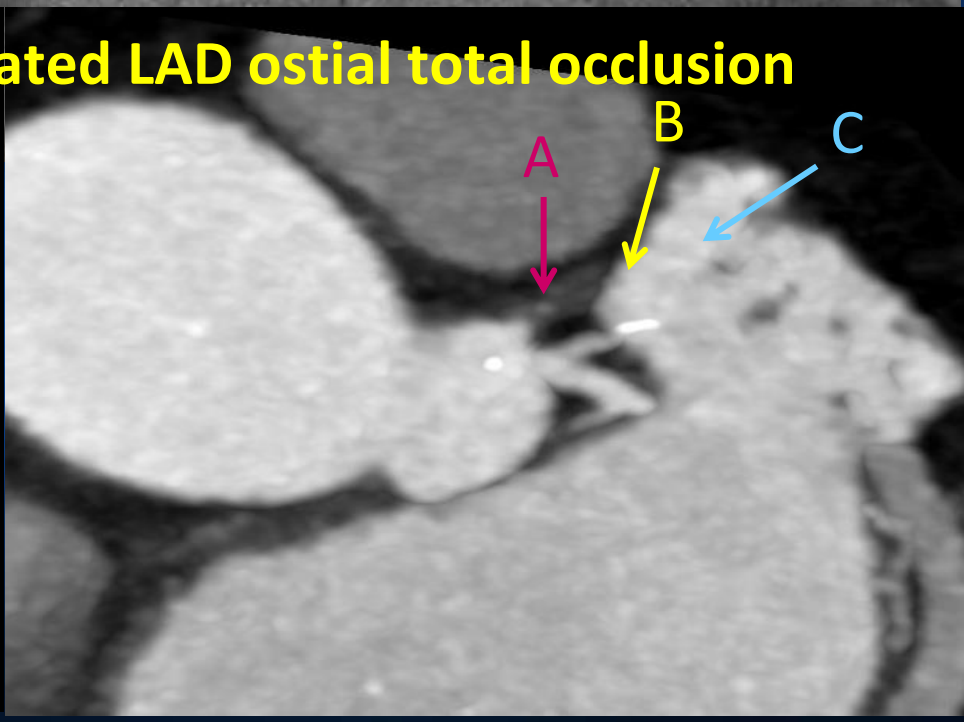
Where is the LAD ostium ?



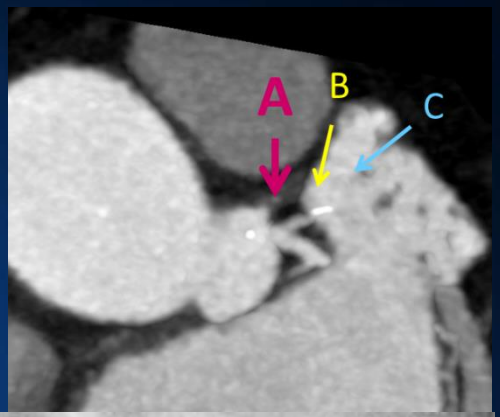


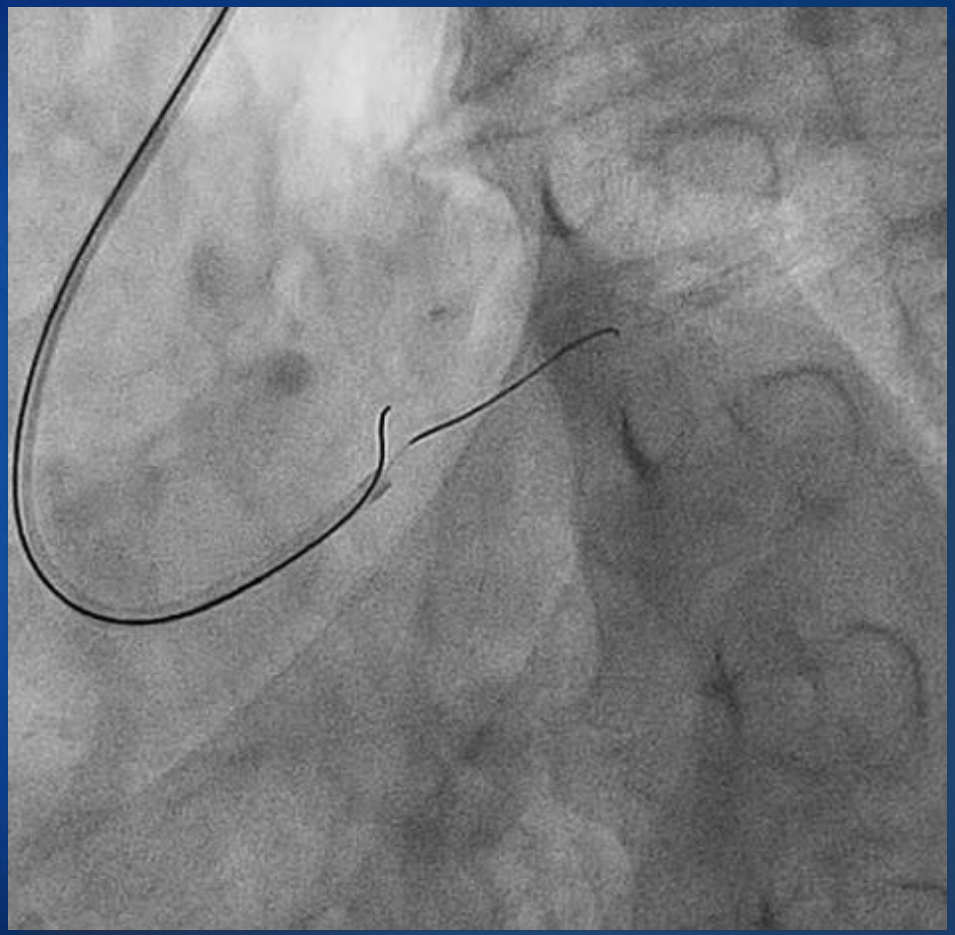
CT revealed nearly hidden separated LAD ostial total occlusion

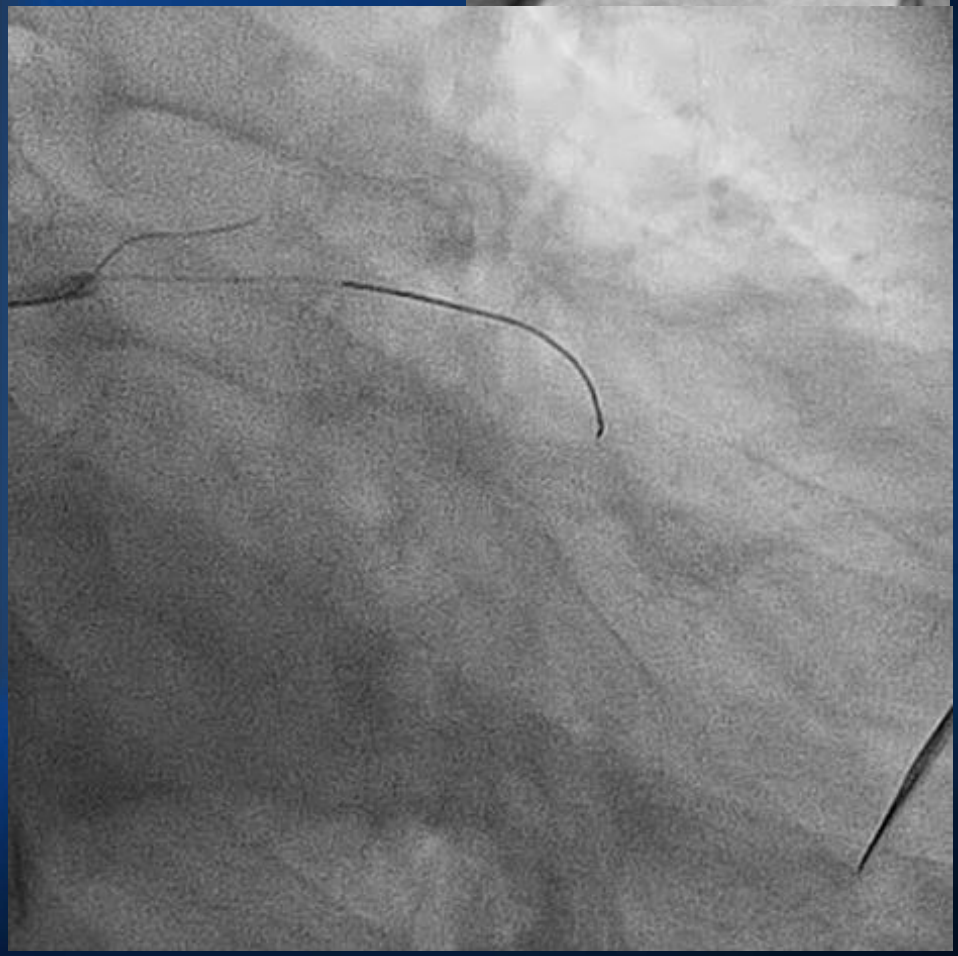




CT-guided wire-puncture of LAD-Os CTO



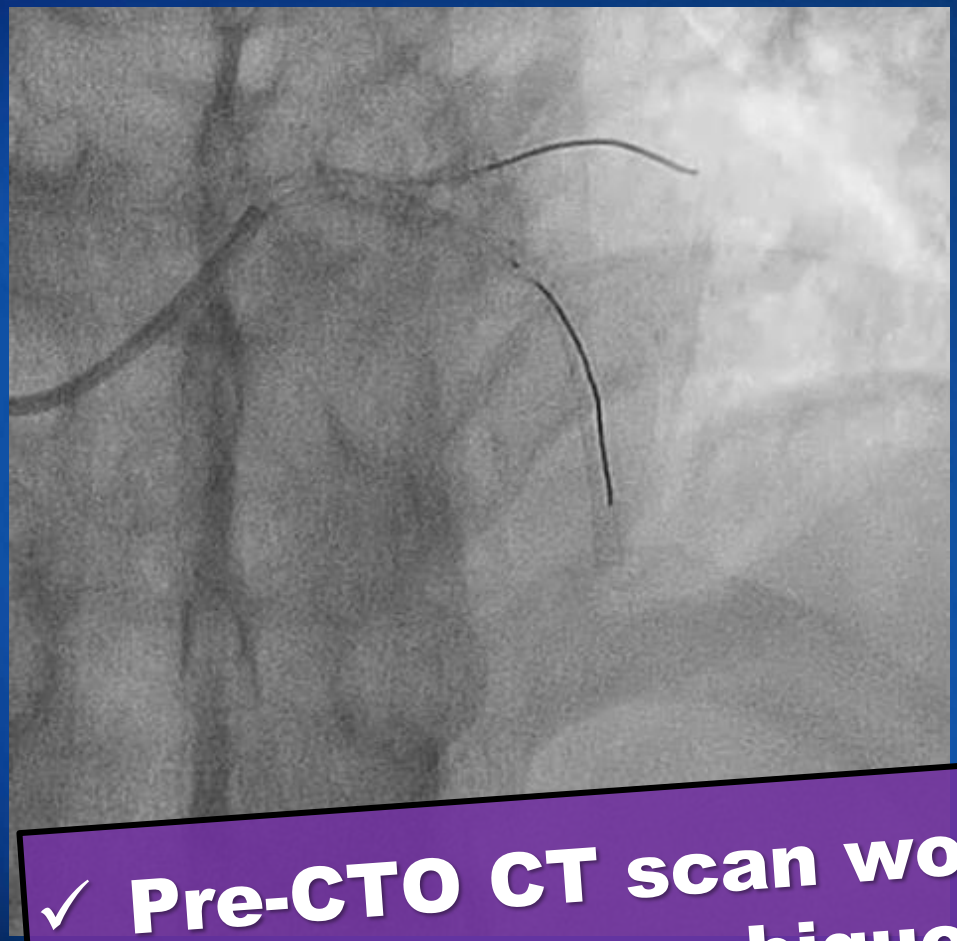


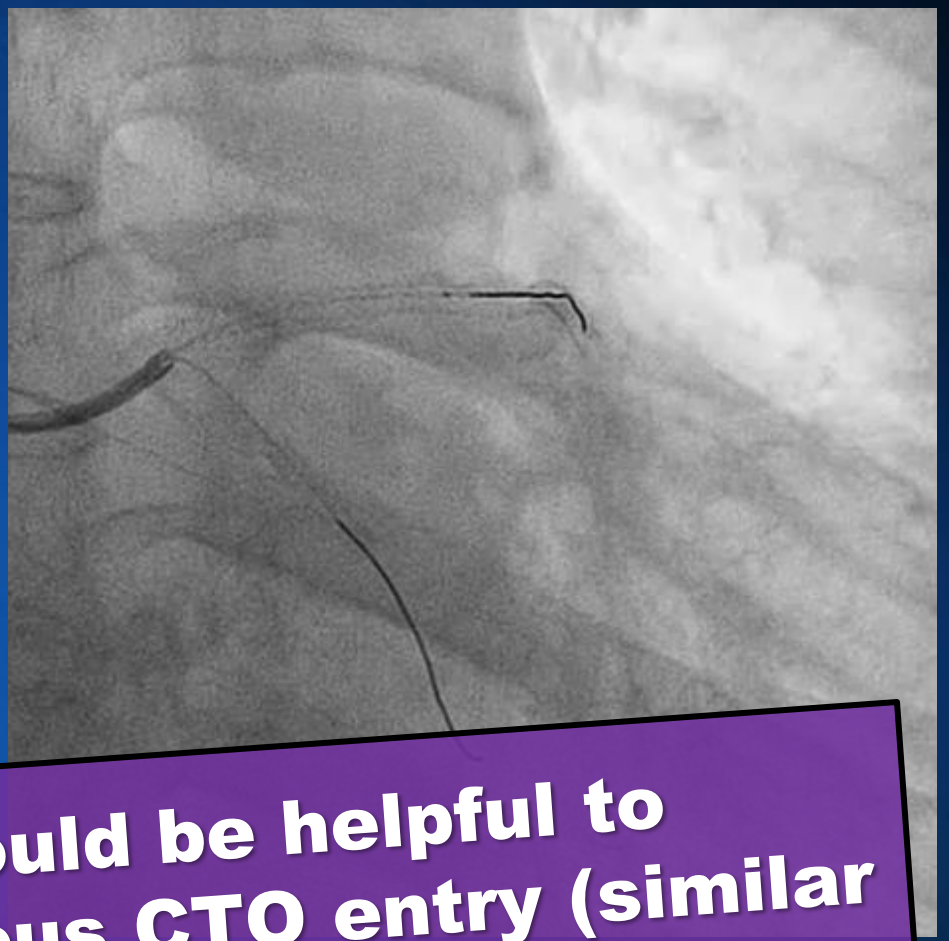


- LAD: Ultimate 3 → Fielder XT → Miracle 6
- LCX: Sion

Courtesy of Dr Jinho Choi

Final CAG after stenting





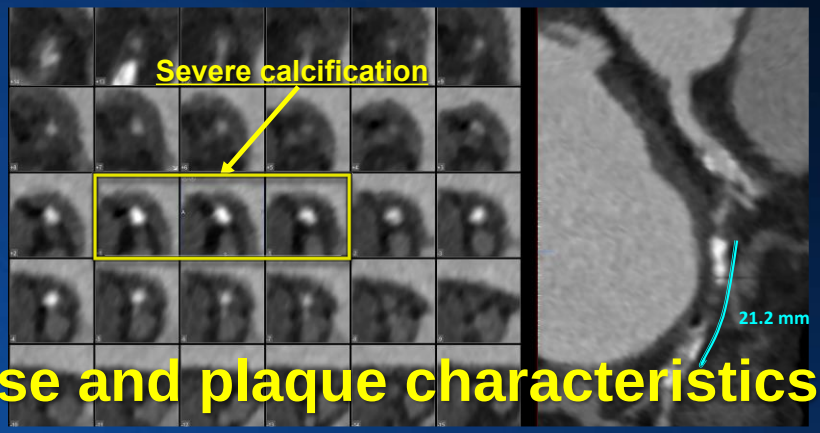
✓ **Pre-CTO CT scan would be helpful to identify the ambiguous CTO entry (similar role like wiring under IVUS).**

Courtesy of Dr Jinho Choi

Pre-procedural planning in CTO intervention by coronary CT

- **CTO with severe calcification;**

Calcification arc 180-360° & CSA ≥50%



- **CCTA → visualizing CTO course and plaque characteristics** (calcification geometry)
  Be helpful **for navigating & selecting the proper wires and devices**

Reasons for recanalization failure in CT-CTO trial	CCTA-guidance N=13	Angiography-guidance N=32	*P*
No. of failed hybrid approach (antegrade & retrograde)	3	15	
Failure to cross collaterals with retrograde wire	3 (100)	7 (47)	0.090
Failure to enter distal cap with retrograde wire	0	2 (13)	0.502
Failure to deliver the supporting device	0	1 (7)	0.645
Failure to meet both wires on the same plane	0	4 (27)	0.310
Failure to achieve TIMI grade flow ≥2 after stenting	0	1 (7)	0.645

JACC Cardiovasc Imaging;14:1993-2004

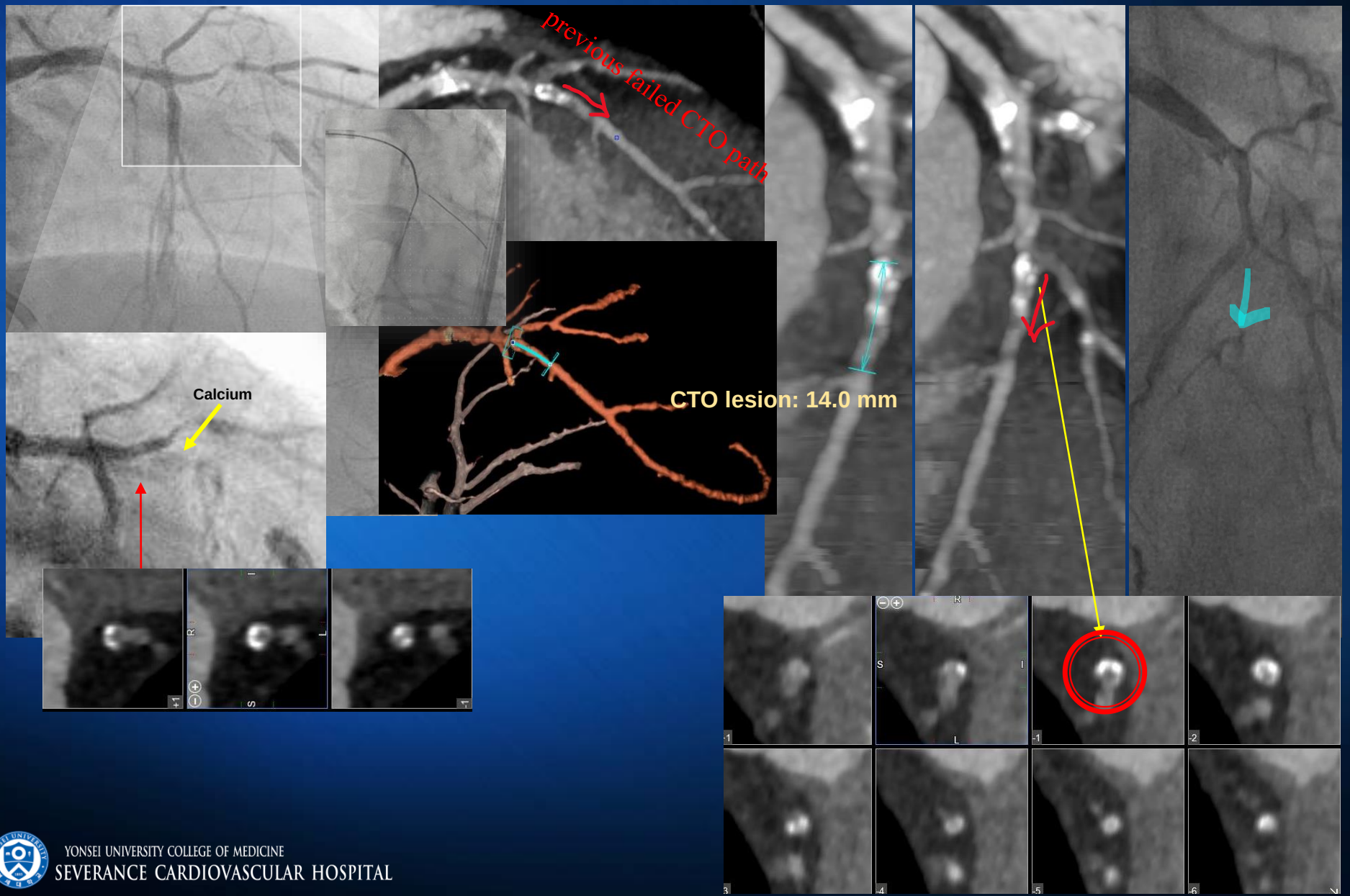
Procedural characteristics & outcomes in CT-CTO trial

	CCTA-guidance (N=200)	Angio-guidance (N=200)	p Value
Total procedure time, min	80 (55-120)	80 (60-110)	0.981
Total crossing time, min	45 (24-81)	52 (30-85)	0.147
Antegrade-only crossing time, min	44 (20-72)	47 (28-80)	0.042
Fluoroscopic time, min	35 (22-62)	36 (26-56)	0.909
Successful recanalization	187 (94%)	168 (84%)	0.003
Successful retrograde CTO-PCI	45/48 (94%)	34/49 (69%)	0.002
Coronary perforation ≥type II	2 (1%)	8 (4%)	0.055
Post-procedural peak CK-MB, ng/ml	4.6 $ 7.2	6.8 $ 31	0.342
Post-procedural CK-MB elevation ≥ 10 x UNL	0 (0%)	4 (2%)	0.123

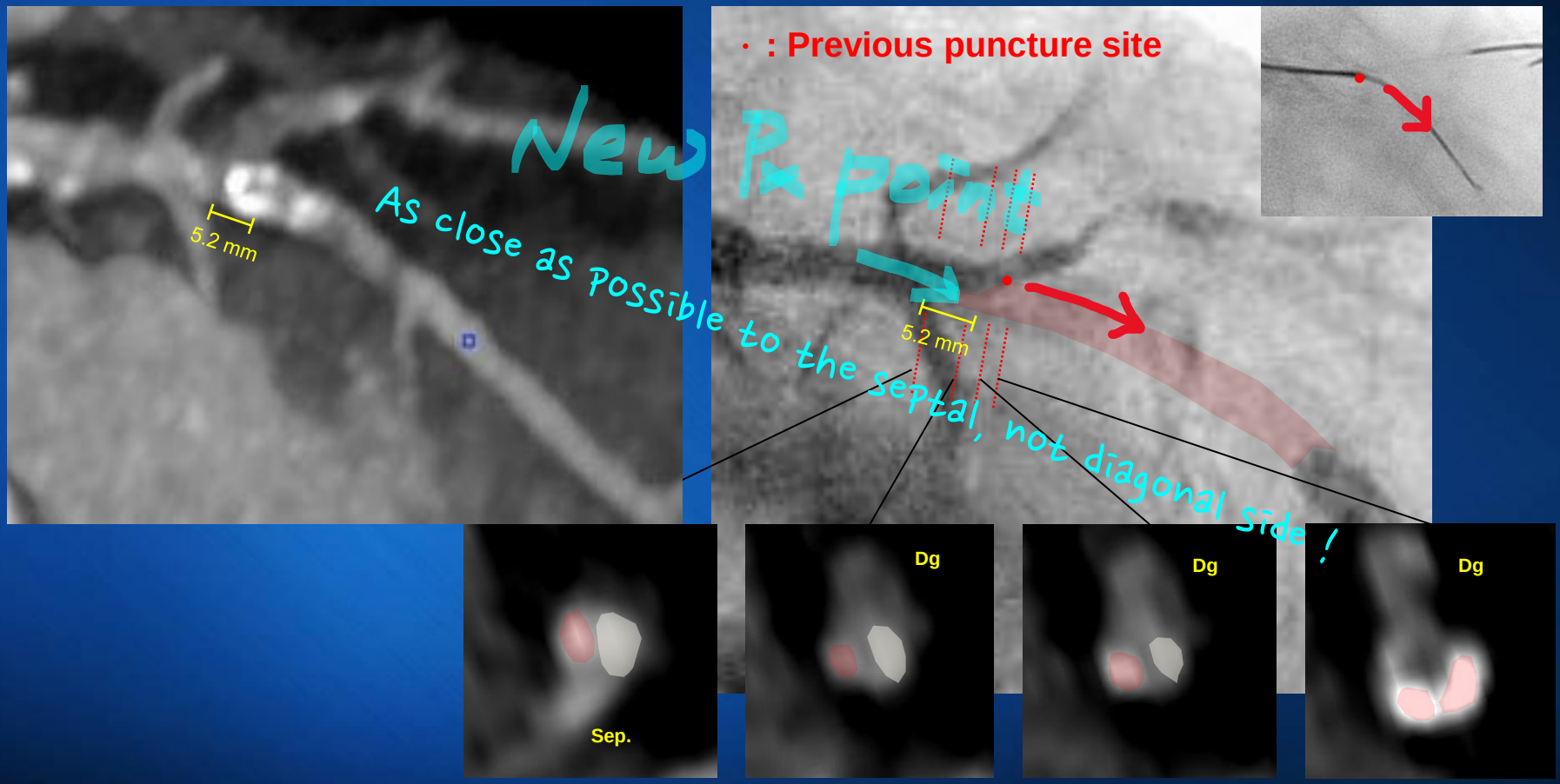
Hong SJ & Kim BK, et al. JACC Cardiovasc Imaging;14:1993-2004

Pre-procedural CTO-CT analysis for retry of LAD-CTO

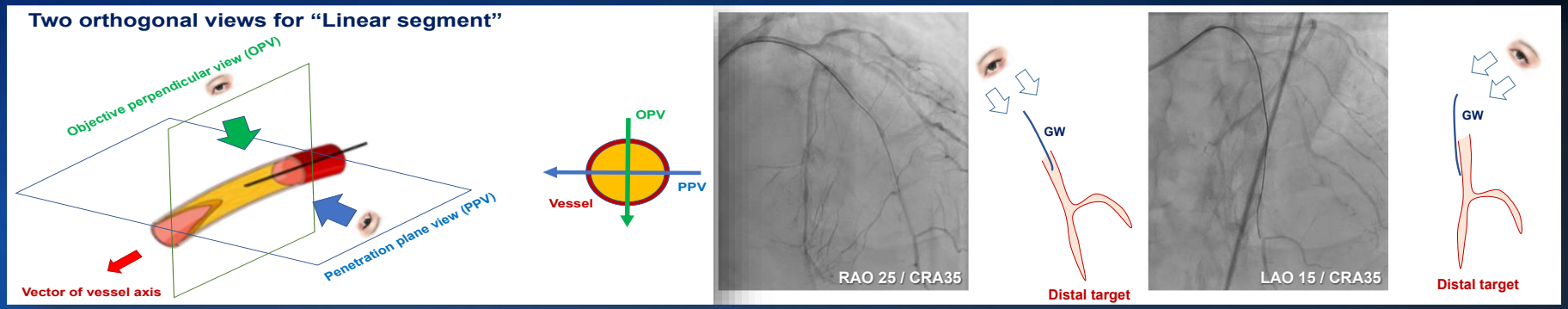
Tracing & matching of previous failed CTO path



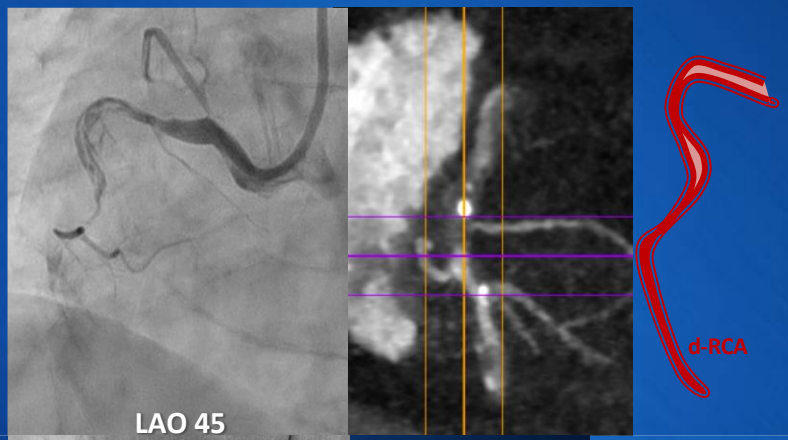
Pre-procedural CTO-CT analysis for retry of antegrade LAD-CTO
→ For planning &deciding the new puncture point of blunt stump



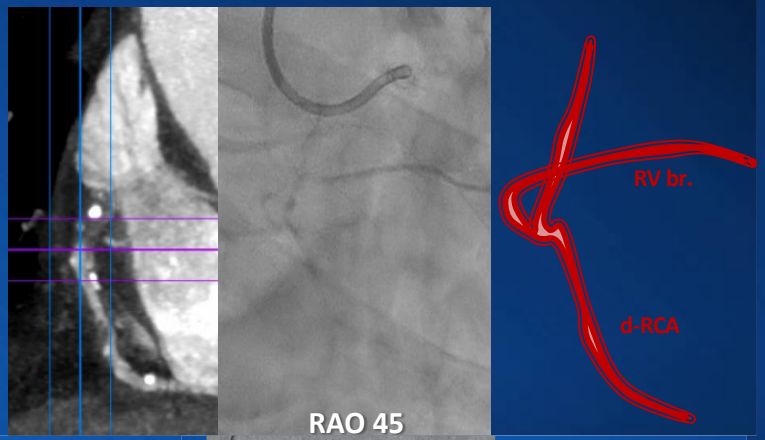
Application of Penetration Plane Method using Pre-procedure CT

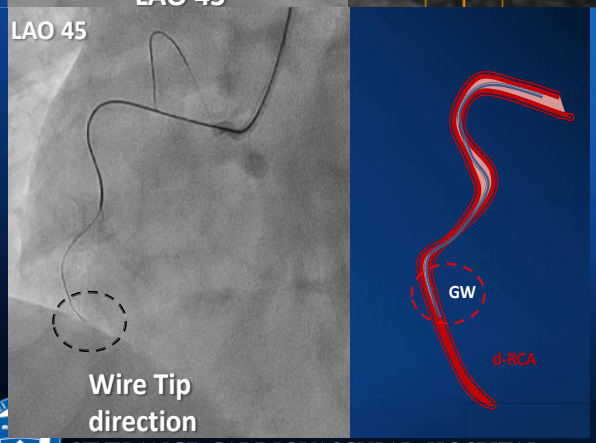


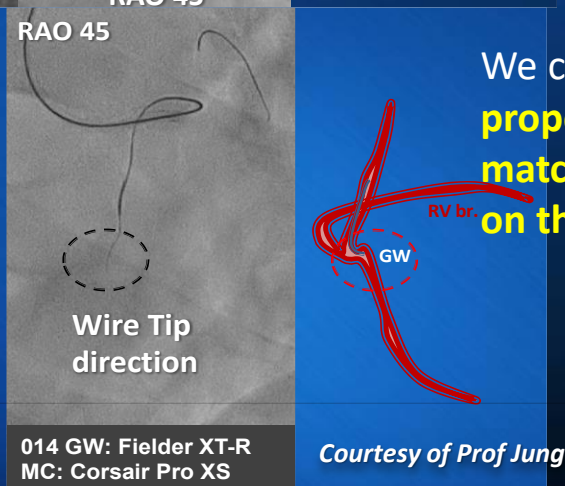
Penetration plane view (PPV)



Objective perpendicular view (OPV)







We can decide the **proper angiographic matching angle based on the CT findings !!!**

Courtesy of Prof Jung-Hee Lee & Sanghoon Shin

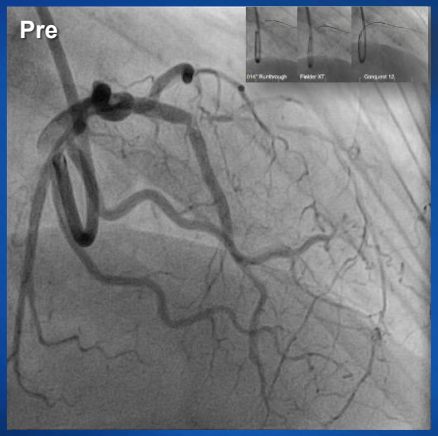
How to use a coronary imaging for CTO?

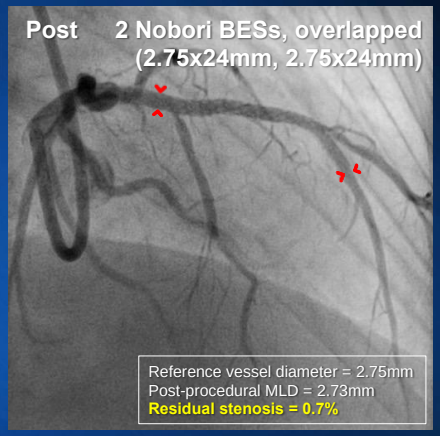
- Pre-procedural imaging tool for the successful CTO recanalization

- **Image-guided (IVUS guidance) CTO intervention during CTO procedures**

Patient 1. LAD-CTO

F/66; Heart failure (EF=35~45%), HiBP

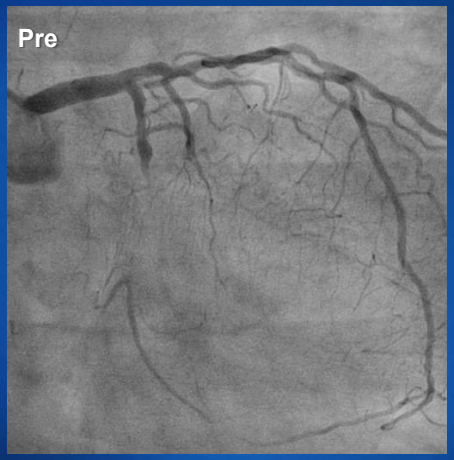


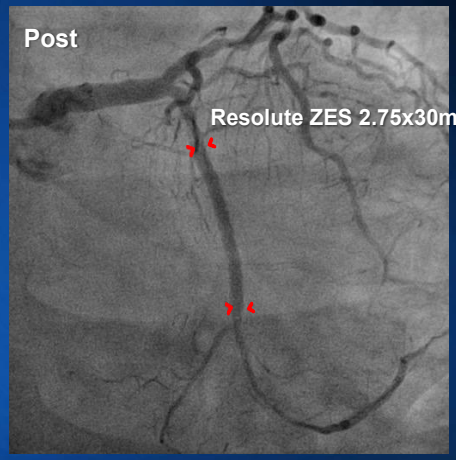


- Antegrade approach → wire-escalation → successful

Patient 2. LCx-CTO

F/55; DM

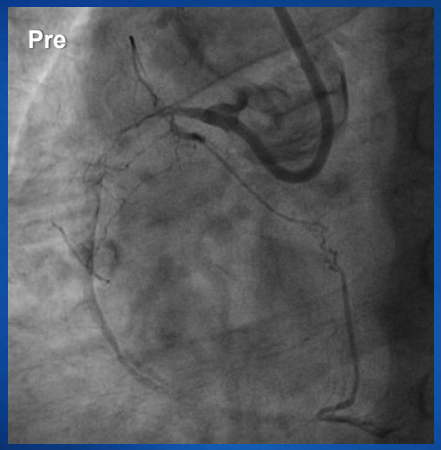


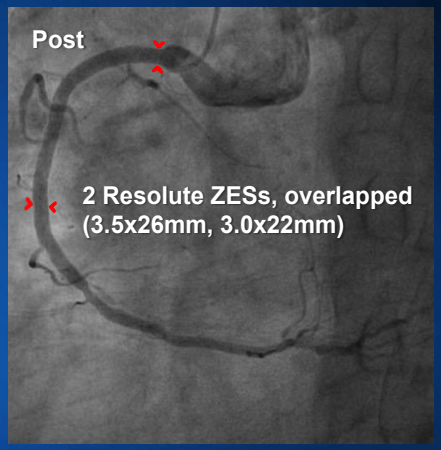


- Ipsilateral collateral channel → finally succeed (procedure time; 4hrs)

Patient 3. RCA-CTO

F/80; HiBP, Smoker

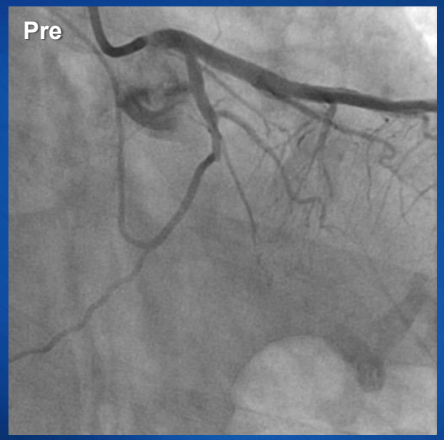


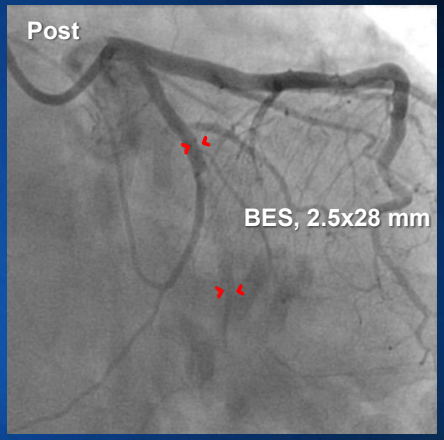


- Start anterograde → Change into retrograde approach
  → finally succeed ! (total No. of wires used; 9)

Patient 4. LCx-CTO

M/70; Heart failure (EF=34%), Smoker





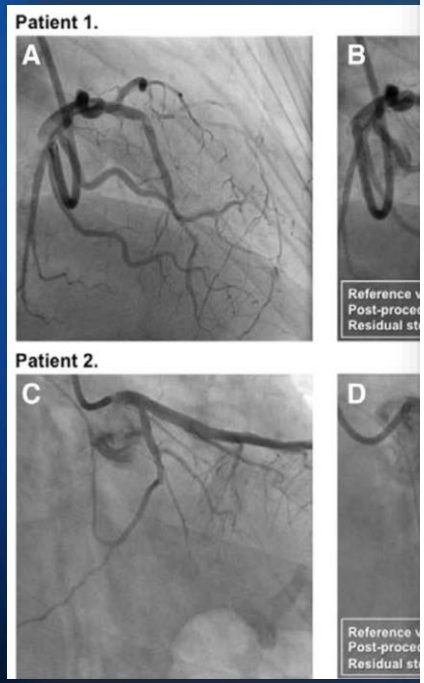
- Successful antegrade wiring within 10 mins
  → 1 DES implanted
  → However, procedure ended without obtaining TIMI III

Cases with "Cardiac death or MI" during follow-up in CTO-IVUS trial

Clinical Impact of Intravascular Ultrasound–Guided Chronic Total Occlusion Intervention With Zotarolimus-Eluting Versus Biolimus-Eluting Stent Implantation

Randomized Study

Byeong-Keuk Kim, MD; Dong-Ho Shin, MD; Myeong-Ki Hong, MD; Hun Sik Park, MD; Seung-Woon Rha, MD; Gary S. M
Seung-Jin Lee, MD; Hee-Yeol Kim,
Jin-Ho Choi, MD; Yangsoo Jang



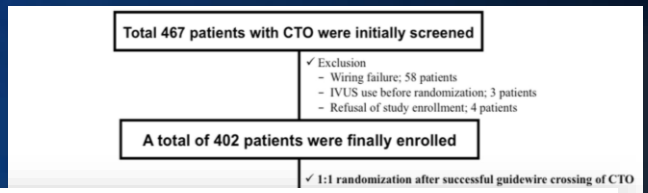
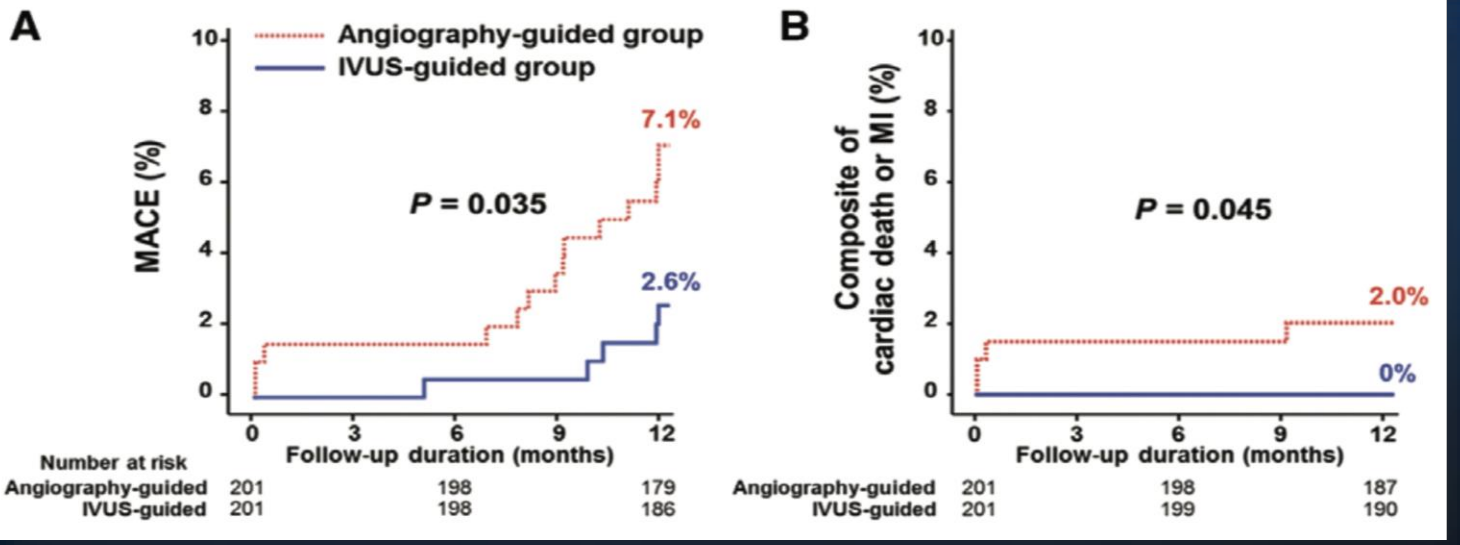


Table 3. Comparison of the Clinical Outcomes Between the IVUS-Guided Group and the Angiography-Guided Group

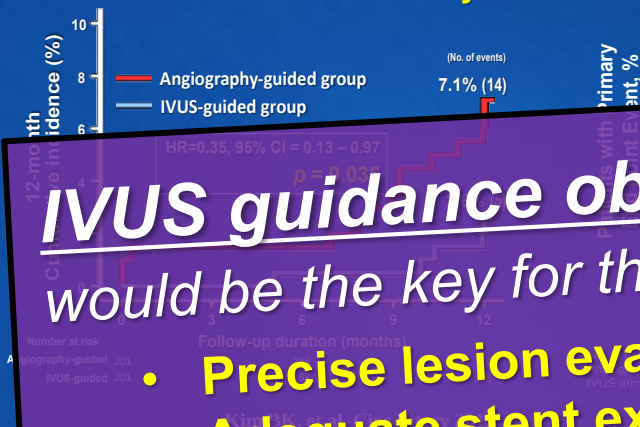
	IVUS-Guided Group (n=201)	Angiography-Guided Group (n=201)	*P* Value	Hazard Ratio (95% CI)
Composite events				
MACE	5 (2.6)	14 (7.1)	0.035	0.35 (0.13–0.97)
Cardiac death or MI	0 (0.0)	4 (2.0)	0.045	*



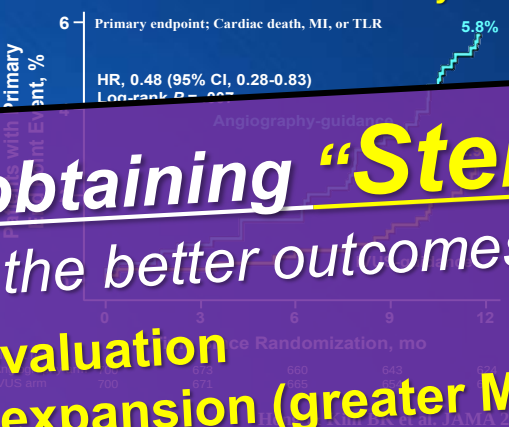
Kim BK, et al. Circ Interv 2015

How to improve clinical outcomes in complex lesions?

Randomized CTO-IVUS study



Randomized IVUS-XPL study



QCA outcomes from CTO-IVUS & IVUS-XPL trials

Randomized CTO-IVUS study	IVUS-guided (n=201)	Angiography-guided (n=201)	p value
Total number of stents, n	1.7 ± 0.8	1.6 ± 0.7	0.198
Total stented length, mm	43.6 ± 18.7	41.5 ± 17.6	0.245
High-pressure inflation	[illegible]	[illegible]	0.045
Maximal inflation pressure, atm	[illegible]	[illegible]	0.040
Post-procedural MLD, mm	2.64 ± 0.35	2.56 ± 0.41	0.025

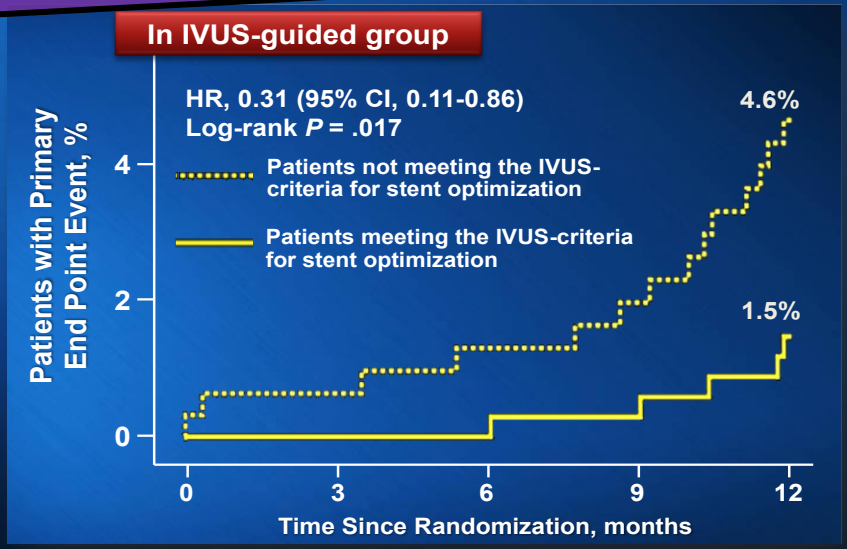
IVUS-XPL Randomized Clinical Trial	IVUS-guidance (n=700)	Angiography-guidance (n=700)	P value
No. of stents per lesions	1.3 (0.5)	1.3 (0.5)	.48
Adjunct post-dilatation	534 (76)	402 (57)	<.001
Final balloon size, mm	3.14 ± 0.43	3.04 ± 0.42	<.001
Maximal inflation pressure, atm	16.5 ± 4.1	15.9 ± 4.1	.052
Post-procedural MLD, mm	2.64 ± 0.42	2.56 ± 0.39	<.001

IVUS guidance obtaining "Stent optimization"

would be the key for the better outcomes;

- **Precise lesion evaluation**
- **Adequate stent expansion (greater MLD)**
- **Detection of complications**

- **Imaging guidance, guarantee the successful outcomes?**



IVUS criteria for stent optimization

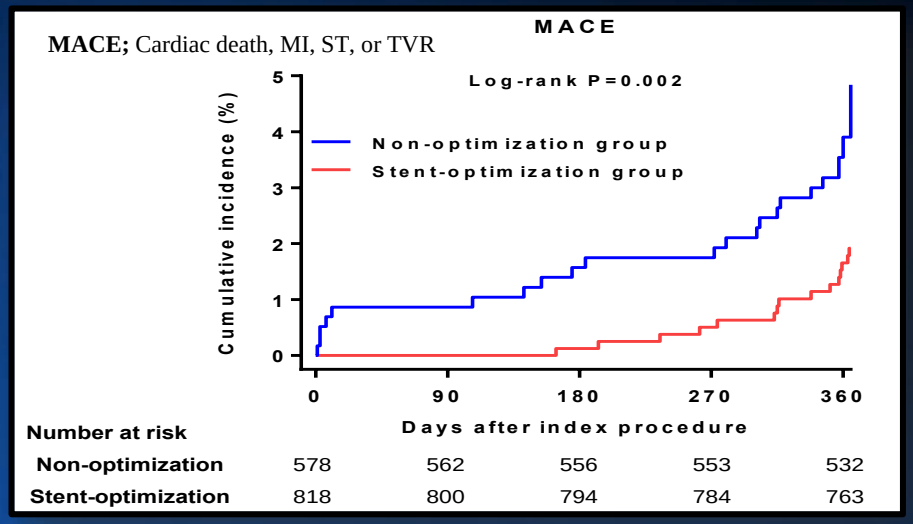
Minimal lumen CSA > lumen CSA at distal reference segments

Hong & Kim BK et al. JAMA 2015

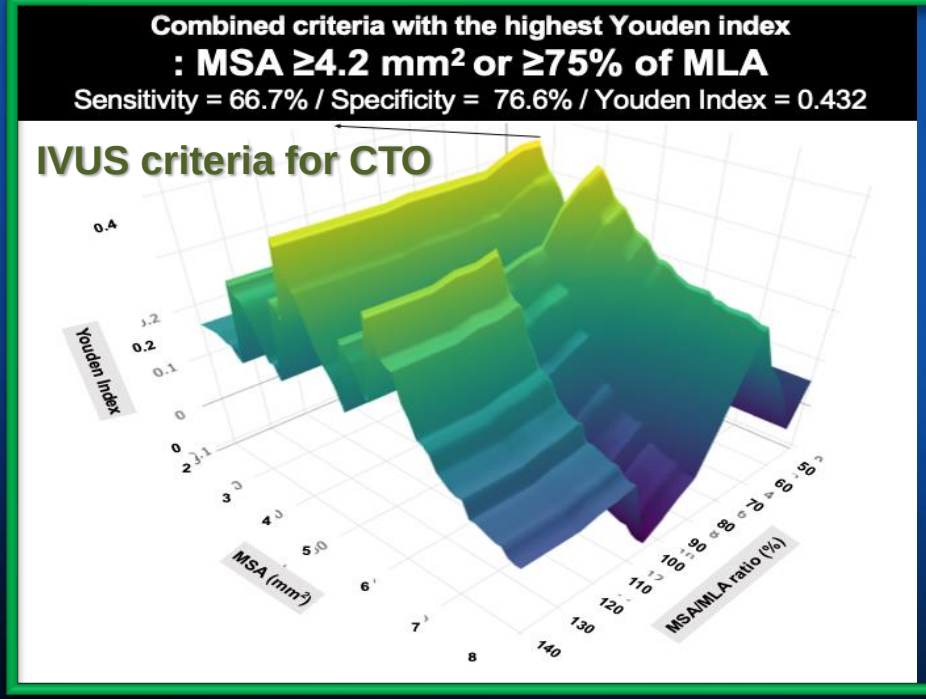
Outcome of Stent optimization IVUS criteria for CTO ?

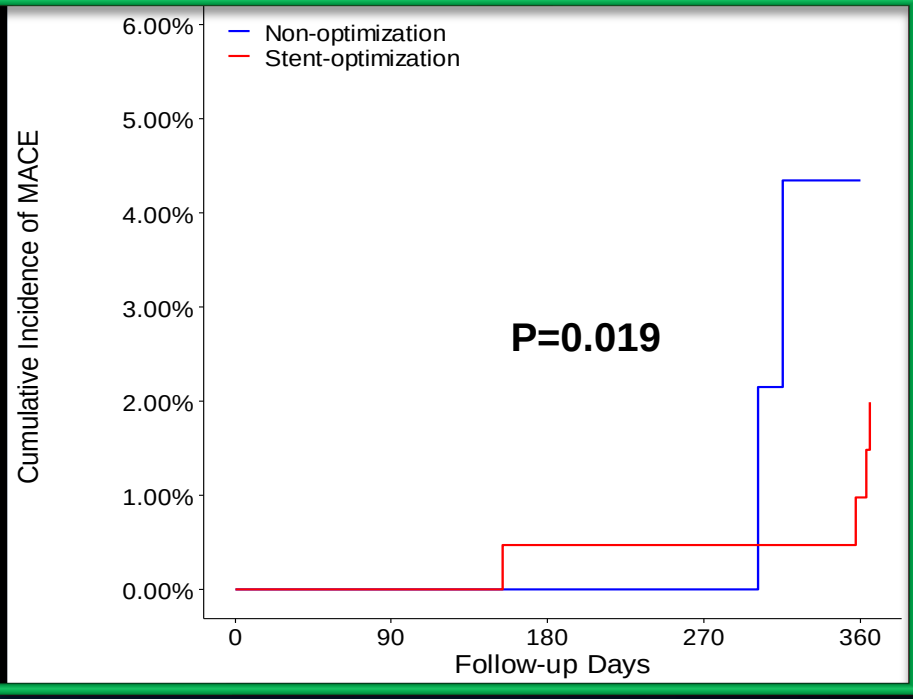
IVUS-guided PCI in diffuse long or CTO lesions
From RESET, CTO-IVUS, IVUS-XPL, ULTRA-ZET trials
(N = 1,396)

- **Stent-optimization group** (N = 818)
- **Non-optimization group** (N = 578)



Stent optimization criteria; MSA ≥5.5 mm² or 80% of mean reference lumen area



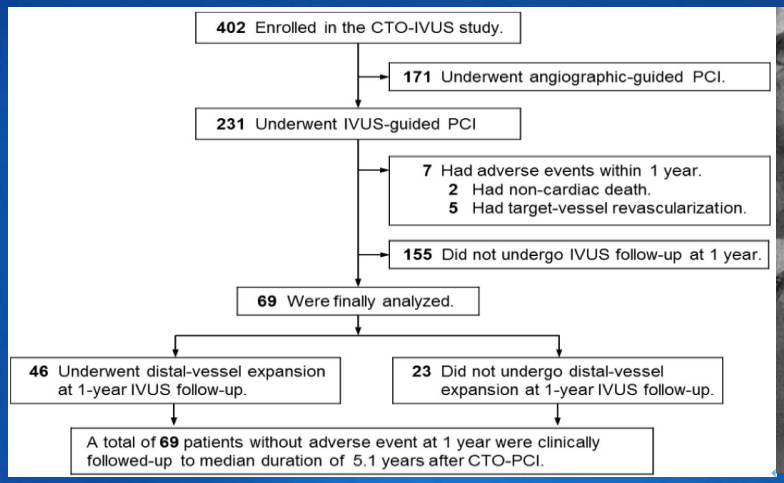


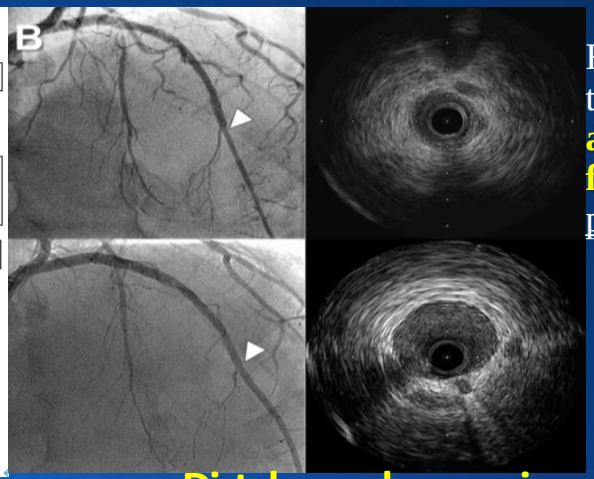
Kim D & Kim BK, et al. Eurointervention 2020

Question 2.

Angiographic outcomes of stent-optimization by IVUS guidance

Stent Optimization & Distal-vessel expansion after successful CTO intervention?

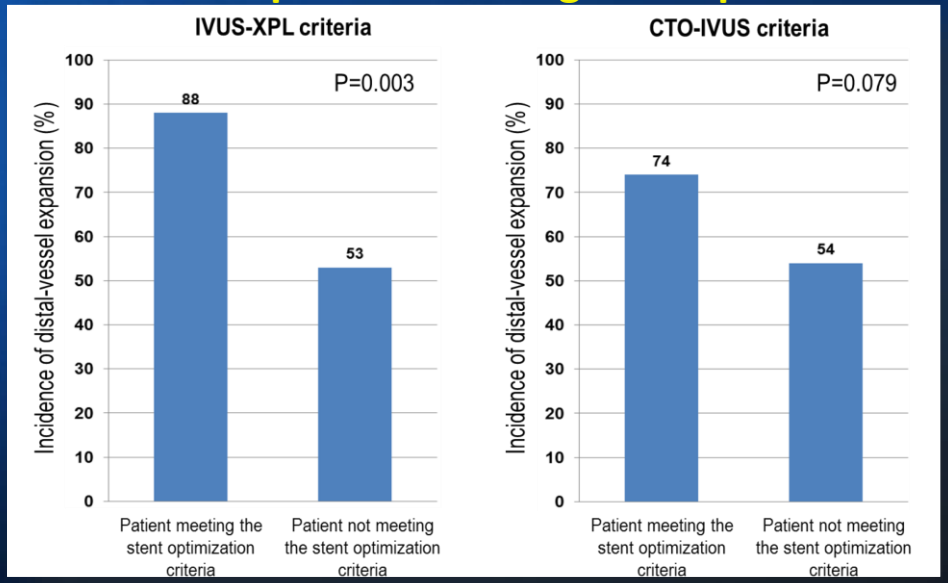




From the CTO-IVUS randomized trial, **serial matching IVUS analyses between index & 1-year follow-up** were performed in 69 patients with new-generation DESs.

- **Incidences distal-vessel expansion** (defined as any increase of lumen area at distal reference (LA_{distal}) on 1-year IVUS follow-up) ; **67%** (identified in 46 pts)

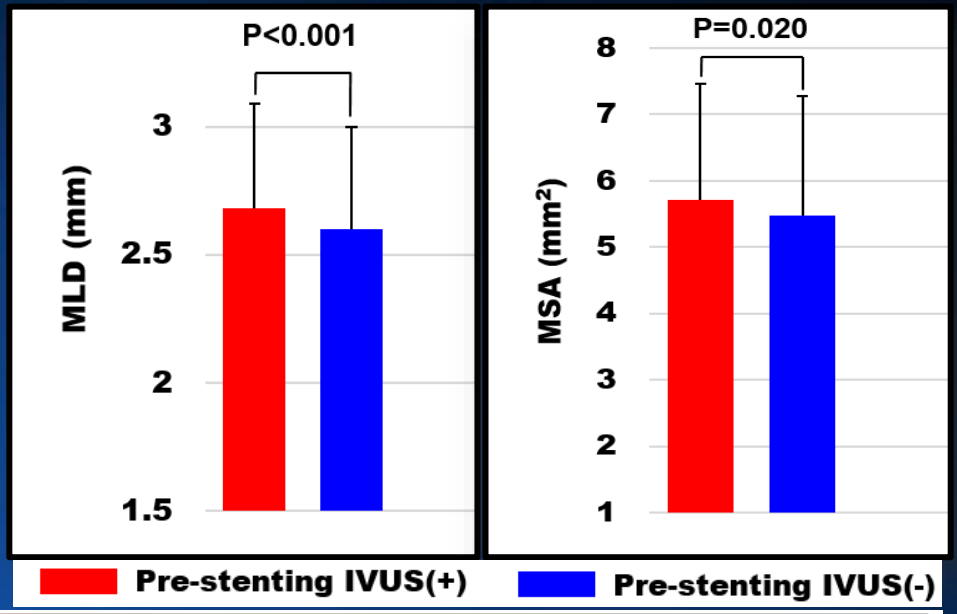
Distal-vessel expansion according to the optimization



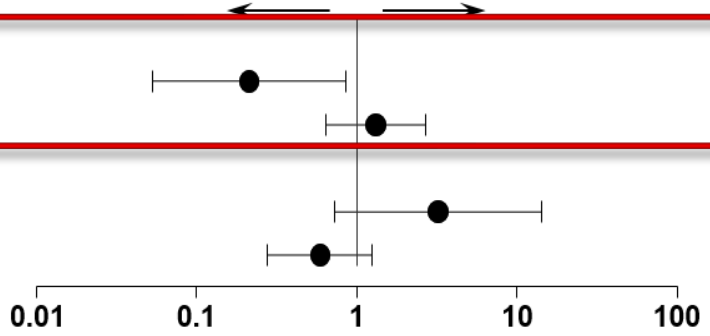
Hong & Kim BK, et al. Catheter Cardiovasc Interv. 2020;95:154-164.

Question.

Way to obtain a "better optimization/expansion" during CTO-PCI?



	Pre-stenting IVUS(+) n/N (event rate)	Pre-stenting IVUS(–) n/N (event rate)	P-value	P-interaction
Chronic occlusions				
Yes	4/214 (2.0%)	4/45 (8.9%)	0.028	0.022
No	23/691 (3.4%)	11/446 (2.6%)	0.467	
Lesion length				
<30 mm	13/353 (3.8%)	2/176 (1.2%)	0.125	0.047
≥30 mm	14/552 (2.6%)	13/315 (4.3%)	0.170	



- In the CTO subset, pre- stenting IVUS(+) compared to pre-stenting IVUS(-) showed a better composite outcome.
- In case of CTO-PCI, the determination of stent sizing and length is difficult due to the long-term reduced flow and negative vessel remodeling. → **Pre-stenting IVUS evaluation in CTO would be helpful for the better angiographic and clinical outcomes.**

Hong SJ & Kim BK, et al. Eurointervention 2020

RESEARCH SUMMARY

Intravascular Imaging–Guided or Angiography-Guided Complex PCI

Lee JM et al. DOI: 10.1056/NEJMoa2216607

CLINICAL PROBLEM

During percutaneous coronary intervention (PCI), guidance with intravascular imaging, with the use of intravascular ultrasonography or optical coherence tomography (OCT), can optimize stent implantation. However, for patients with complex coronary-artery lesions, data regarding clinical outcomes after intravascular imaging–guided PCI as compared with outcomes after angiography-guided PCI are limited.

CLINICAL TRIAL

Design: A prospective, multicenter, open-label, randomized trial in South Korea evaluated whether intravascular imaging–guided PCI would result in better clinical outcomes than angiography-guided PCI in adults with complex coronary-artery lesions.

Intervention: 1639 patients were assigned in a 2:1 ratio to undergo either intravascular imaging–guided PCI, with the use of ultrasonography or OCT, or angiography-guided PCI. The primary end point was target-vessel failure, which was defined as a composite of death from cardiac causes, target-vessel–related myocardial infarction, or clinically driven target-vessel revascularization.

RESULTS

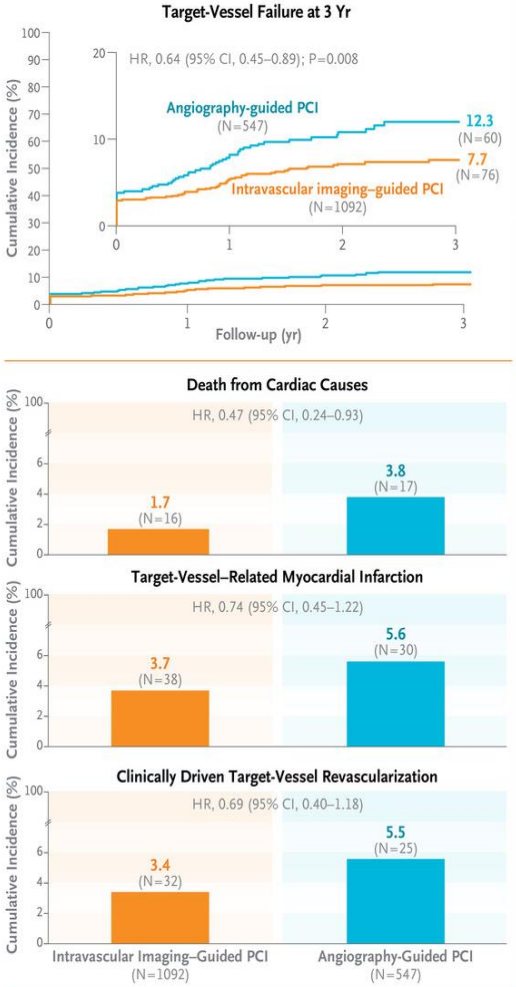
Efficacy: At a median follow-up of 2.1 years, the incidence of target-vessel failure was lower in the intravascular imaging group than in the angiography group.

Safety: The incidence of procedure-related complications during the index hospitalization appeared to be similar in the two groups.

LIMITATIONS AND REMAINING QUESTIONS

- The trial was unblinded, and the operator could not be unaware of the patient's assigned group.
- Stent optimization as defined on the basis of intravascular imaging occurred in less than half the patients.
- All the patients were East Asian, and more than half the patients were enrolled at one trial center, which potentially limits the generalizability of the findings.

Links: Full Article | NEJM Quick Take | Editorial



CONCLUSIONS

Among patients with complex coronary-artery lesions, intravascular imaging–guided PCI led to a lower incidence of a composite of death from cardiac causes, target-vessel–related myocardial infarction, or clinically driven target-vessel revascularization than angiography-guided PCI.

Study Design

RENOVATE-COMPLEX-PCI Trial (NCT03381872)

1,620 Patients with Complex Coronary Artery Lesions Undergoing PCI

* Definition of Complex Coronary Artery Lesions
① True bifurcation (Median 1,1,1/1,0,1/0,1,1) with side branch ≥2.5mm
② Chronic total occlusion (≥3 months) as target lesion
③ PCI for unprotected left main disease
④ Implanted stent length ≥38mm
⑤ Multivessel PCI (≥2 vessels treated at one PCI session)
⑥ Multiple stent needed (≥3 more stent per patient)
⑦ In-stent restenosis lesion as target lesion
⑧ Severely calcified lesion (encircling calcium in angiography)
⑨ Ostial lesion in LAD, LCX, and RCA

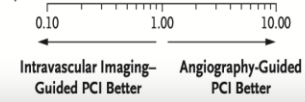
Randomization (2:1) for Treatment Strategy of Target Lesions
(Stratified by acute coronary syndrome and participating centers)

Imaging-Guided Strategy
N = 1,080

Angiography-Guided Strategy
N = 540

All patients were followed until 1 year after last patient enrollment.

Subgroup	Intravascular Imaging–Guided PCI	Angiography-Guided PCI	Hazard Ratio (95% CI)
	no. of events/total no. of patients (cumulative incidence, %)		
Overall	76/1092 (7.7)	60/547 (12.3)	0.64 (0.45–0.89)
Type of imaging devices			
Intravascular ultrasonography	59/800 (8.0)	60/547 (12.3)	0.66 (0.46–0.95)
Optical coherence tomography	15/278 (5.8)	60/547 (12.3)	0.47 (0.27–0.83)
Type of complex coronary lesions			
True bifurcation	23/233 (10.3)	13/126 (11.8)	0.97 (0.49–1.93)
● Chronic total occlusion	9/220 (5.0)	13/99 (14)	0.30 (0.13–0.71)
● Unprotected left main coronary artery disease	9/138 (6.8)	11/54 (25)	0.31 (0.13–0.76)
● Diffuse long coronary-artery lesion	36/617 (6.5)	31/281 (11.9)	0.52 (0.32–0.83)
Multivessel PCI involving ≥2 major coronary arteries	36/409 (9.5)	22/213 (11.7)	0.84 (0.50–1.44)
Lesion necessitating use of ≥3 stents	16/208 (8.1)	6/97 (6)	1.24 (0.49–3.18)
Lesion with in-stent restenosis	22/158 (15.6)	12/78 (17)	0.90 (0.45–1.82)
Severely calcified lesion	11/157 (7.3)	11/74 (17)	0.46 (0.20–1.06)
● Ostial lesions of major coronary artery	8/182 (4.4)	9/69 (16)	0.33 (0.13–0.85)
Initial presentation			
Stable ischemic heart disease	25/532 (5.0)	27/275 (10.4)	0.46 (0.27–0.80)
Acute coronary syndrome	51/560 (10.4)	33/272 (14.6)	0.74 (0.48–1.15)
Age			
<65 yr	36/517 (7.8)	23/238 (10.6)	0.72 (0.42–1.21)
≥65 yr	40/575 (7.4)	37/309 (13.6)	0.57 (0.36–0.88)
Sex			
Male	66/869 (8.3)	46/431 (11.7)	0.70 (0.48–1.02)
Female	10/223 (5.2)	14/116 (14.5)	0.35 (0.16–0.80)
Diabetes mellitus			
Yes	45/394 (12.9)	26/223 (12.3)	0.97 (0.60–1.57)
No	31/698 (4.7)	34/324 (12.2)	0.41 (0.25–0.67)
Chronic kidney disease			
Yes	22/203 (13.3)	19/93 (23)	0.51 (0.27–0.93)
No	54/889 (6.4)	41/454 (9.9)	0.66 (0.44–0.99)
Left ventricular ejection fraction			
<50%	22/210 (12.0)	12/84 (15)	0.72 (0.35–1.45)
≥50%	54/882 (6.7)	48/463 (11.8)	0.58 (0.39–0.85)



Take-home message

Harnessing Intracoronary Imaging for CTO PCI

- **Pre-procedural imaging by coronary CT scan**
  … helpful and significantly associated with a **higher CTO success with a lower trend of complications** (esp. coronary perforation, PPMI) and a **high efficiency** (less time in antegrade CTO) in the difficult/complex CTO-PCI, confirmed in the randomized CT-CTO trial.

- **Intra-procedural imaging guidance by IVUS during CTO-PCI**
  - significantly related with the **better clinical outcomes short- and long-term clinical outcomes**.
  - However, because IVUS-guidance did not guarantee the improved outcomes, the **attainment of stent optimization** would be essential, especially in the complex lesions including CTO.