

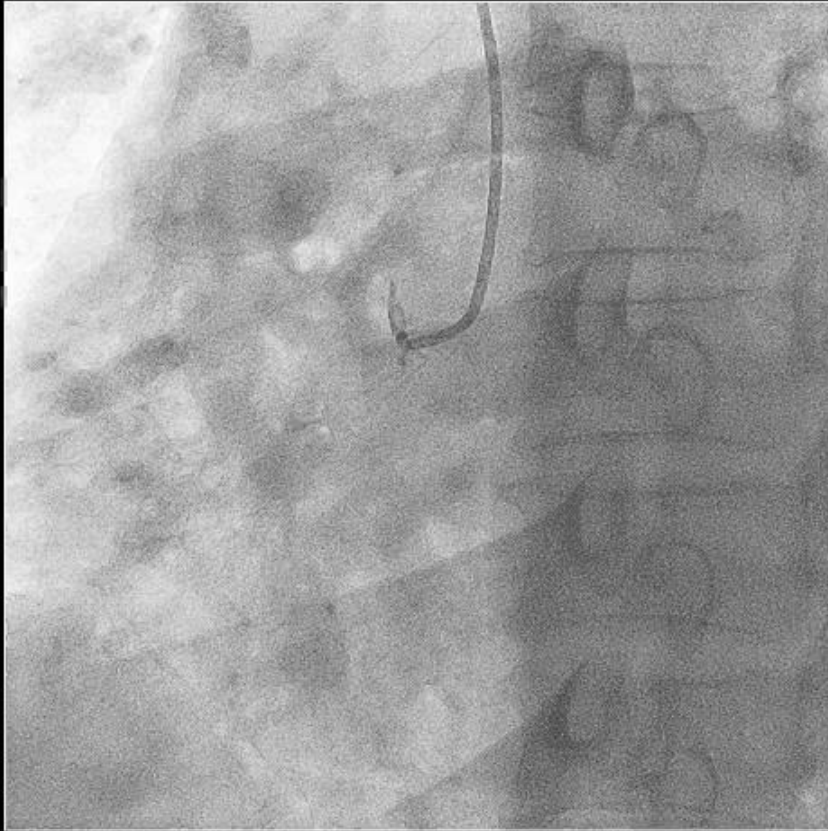
Coronary CT for CTO PCI procedure



Department of Internal Medicine, Emergency Medicine

Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

Why we need CT for CTO PCI

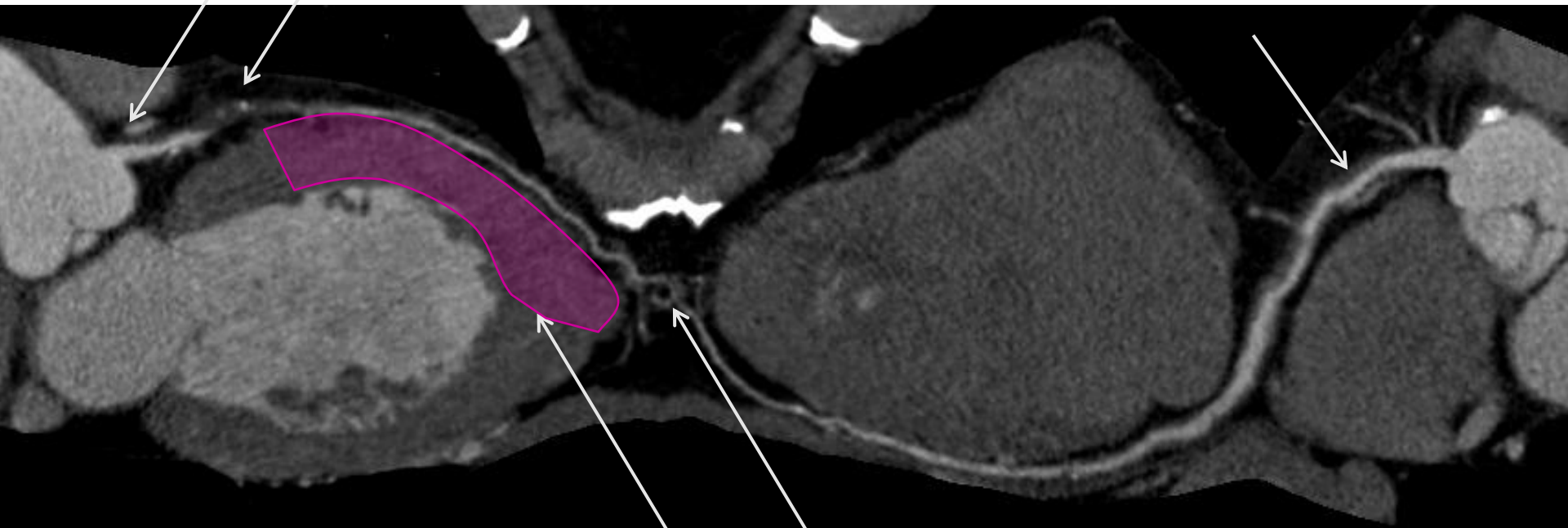


CT can tell something better than CAG !

1. Anatomy of ostium and proximal vessel

2. Anatomy of CTO lesion

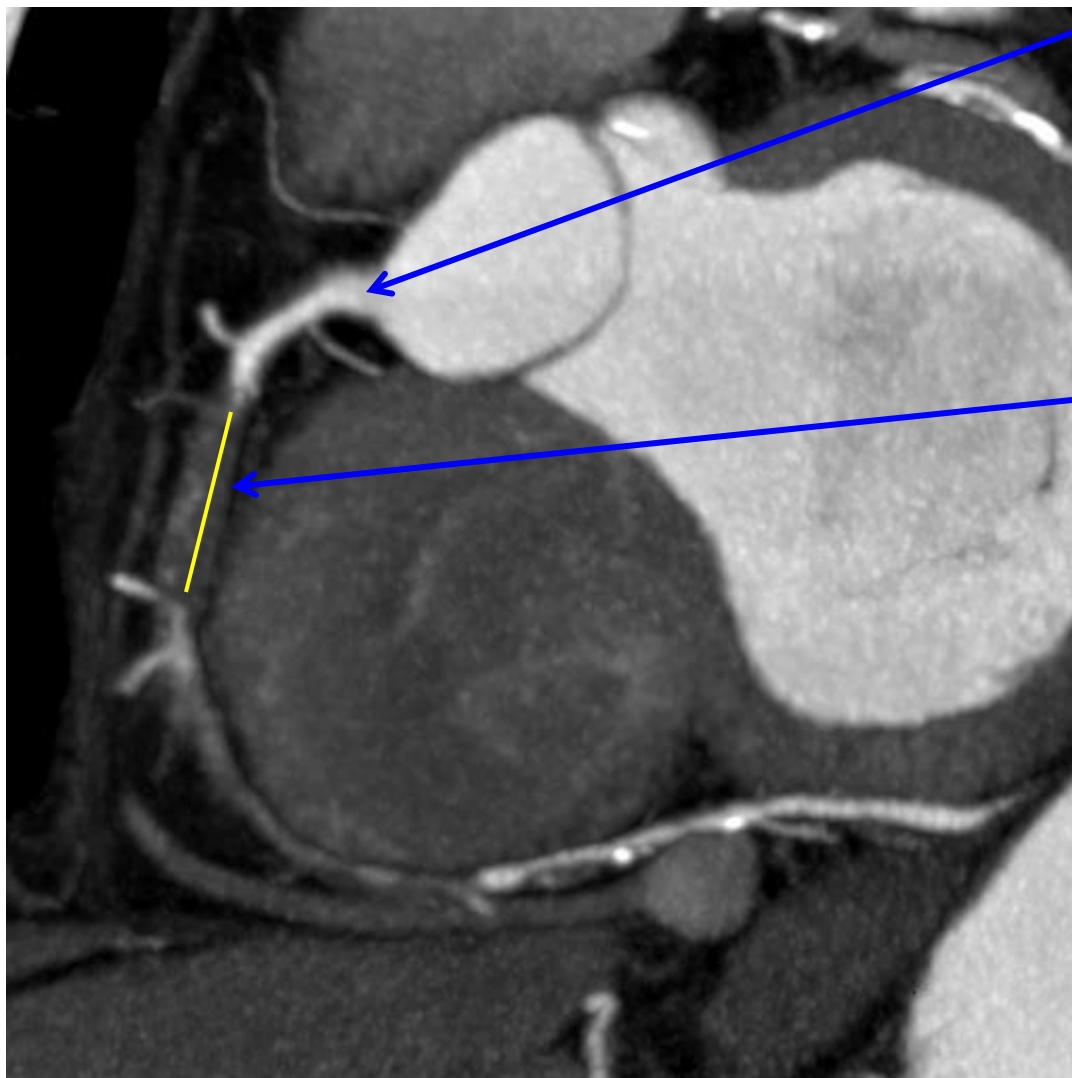
Donor vessel



**3. Physiology of myocardium
(myocardial perfusion, viability)**

4. Physiology of collateral flow

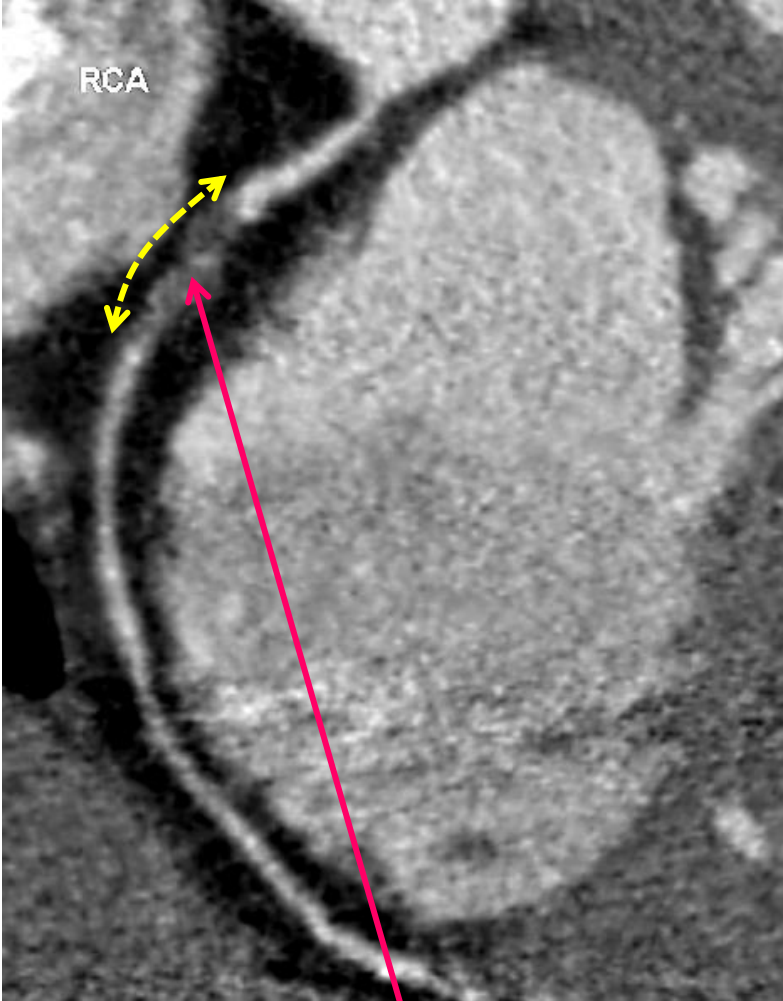
Proximal vessel



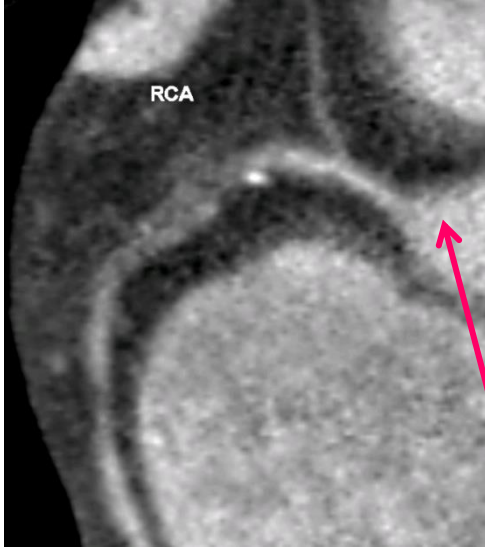
**Long and fairly large
ostium (7 or 8Fr GC is
OK)**

**Straight and positively
remodeled mid RCA**

Proximal vessel



Relatively short CTO



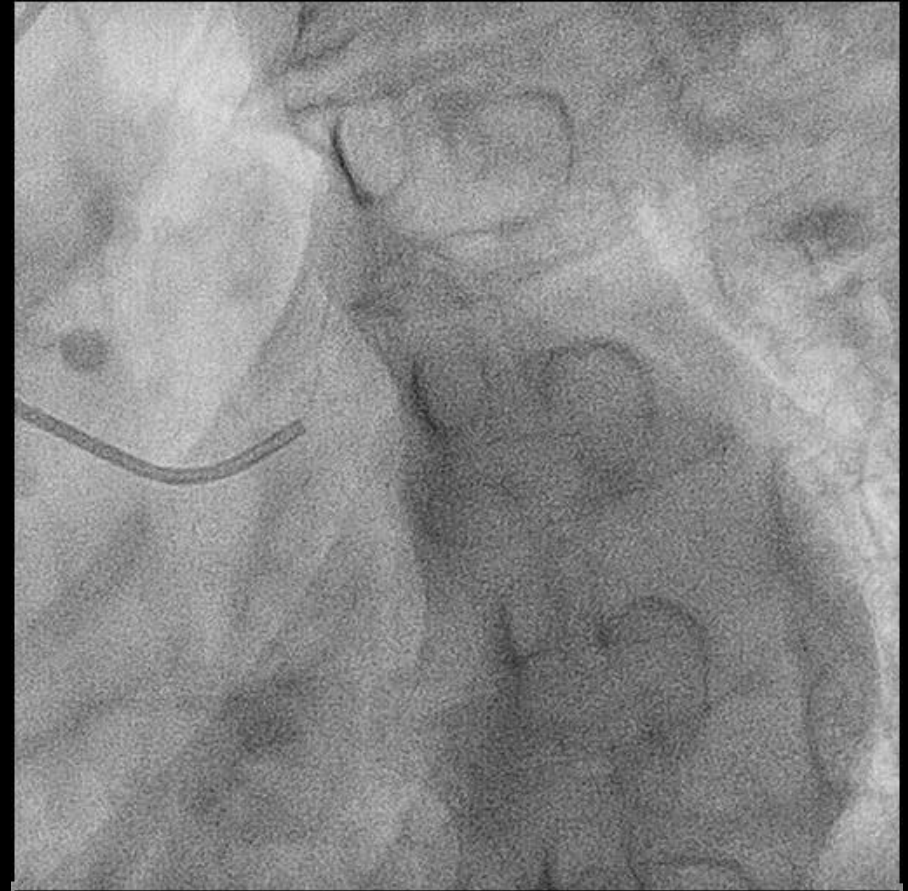
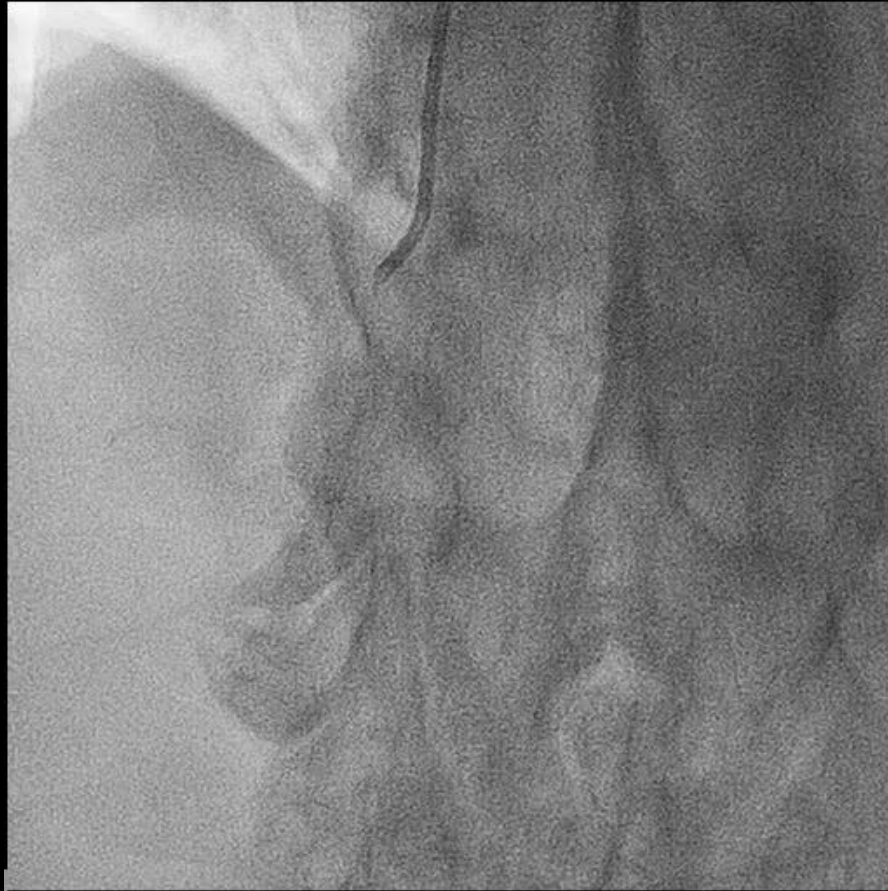
Ostium is relatively small and upward



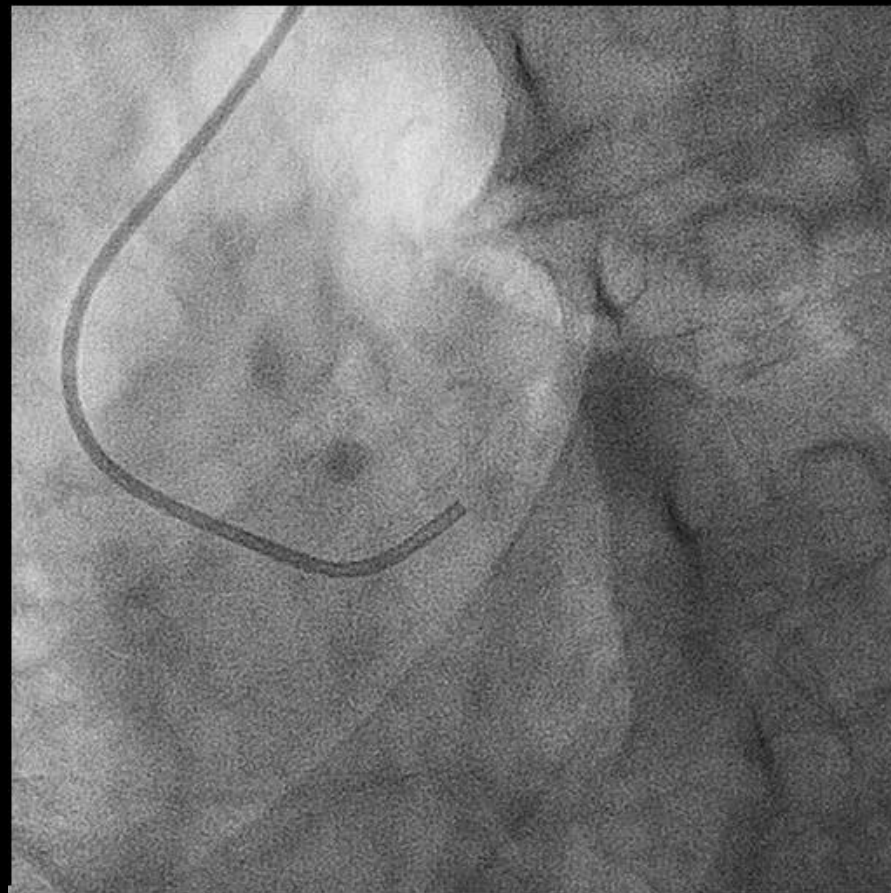
Case: Aorto-ostial CTO

- invisible coronary artery ostium -

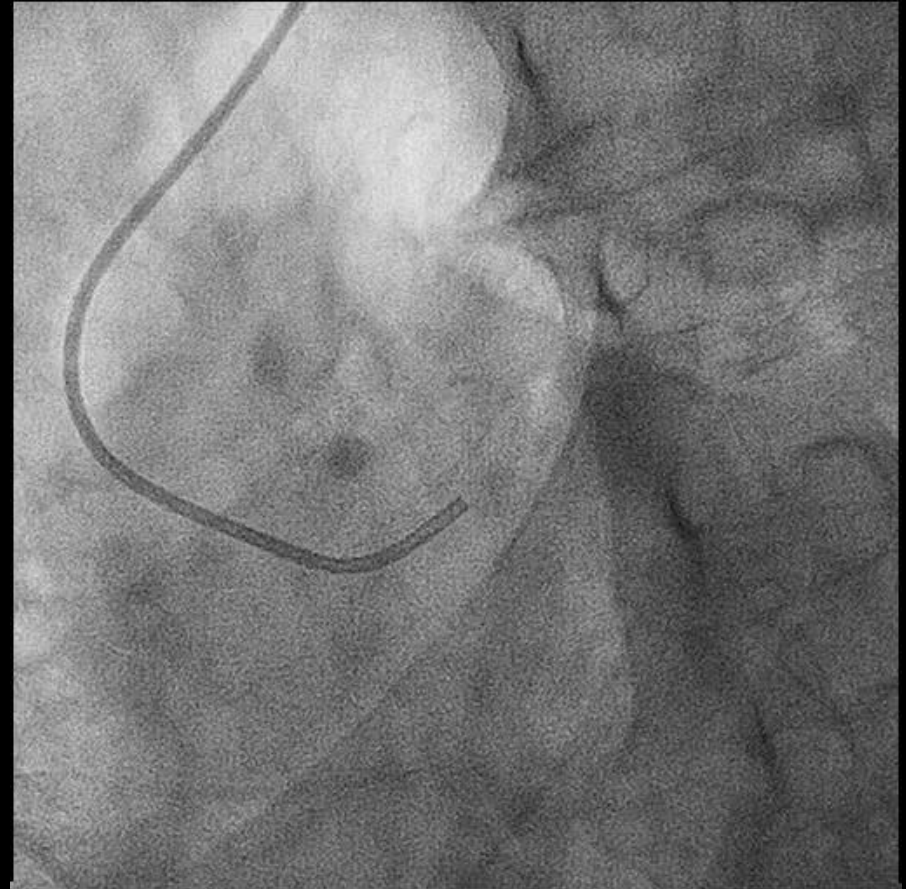
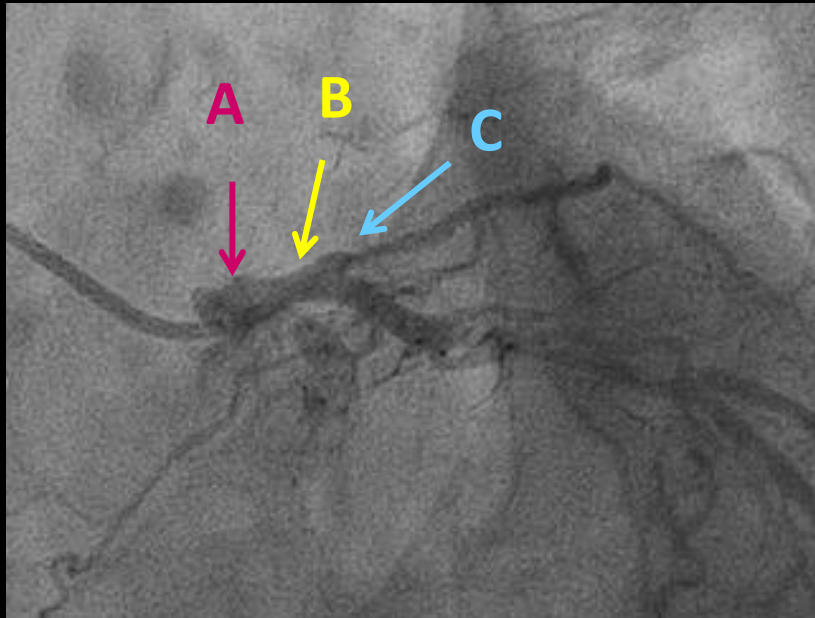
Ischemic CMP (61/M, LVEF 40%). CAG: LAD ostial CTO ??



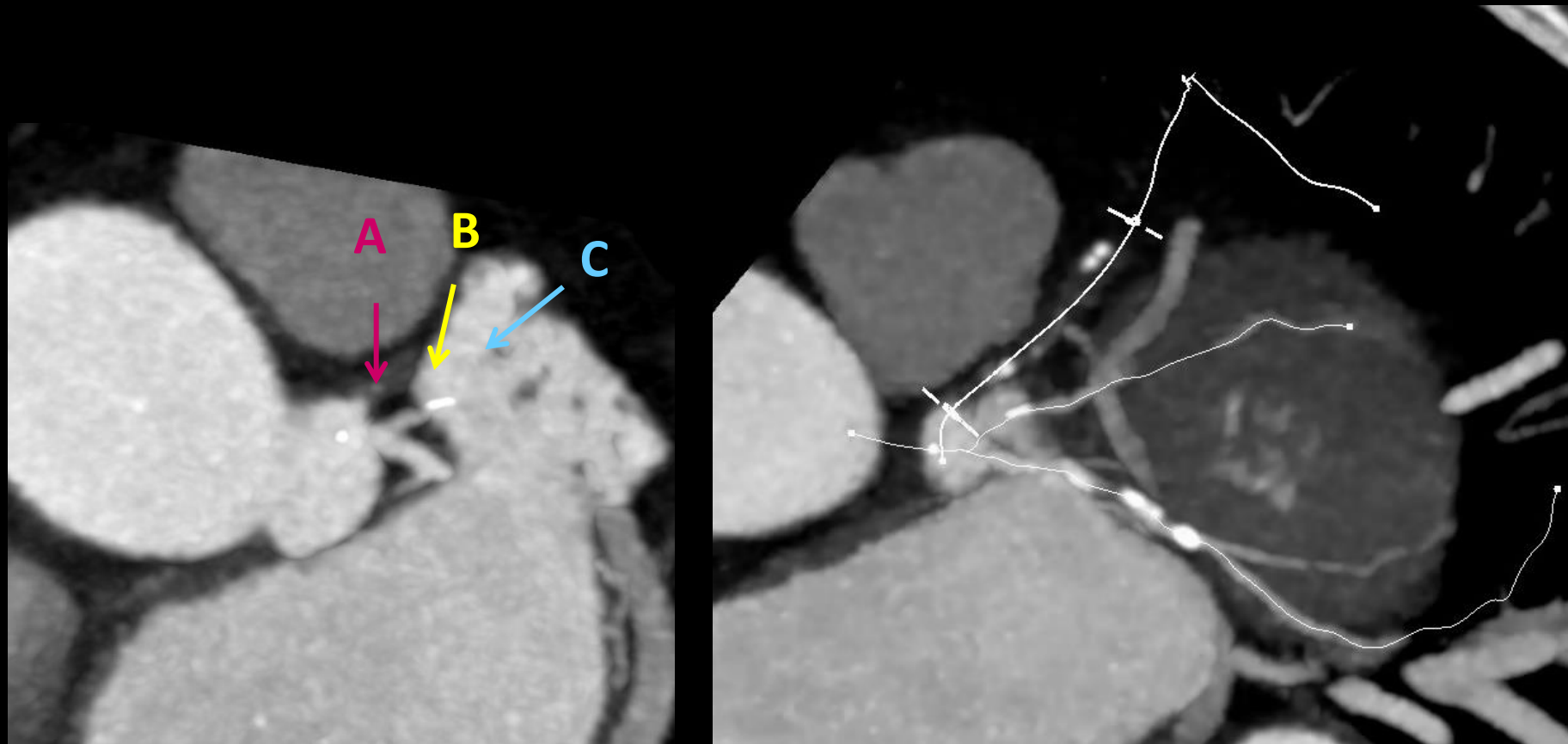
CAG – LAD ostial CTO ??



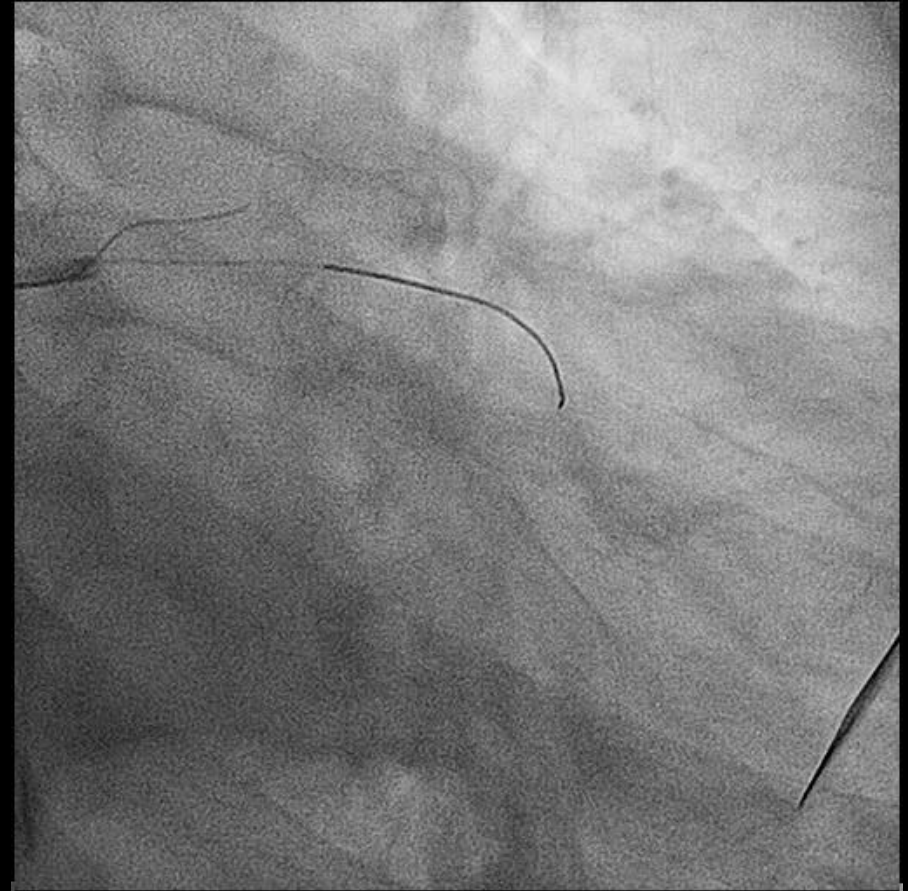
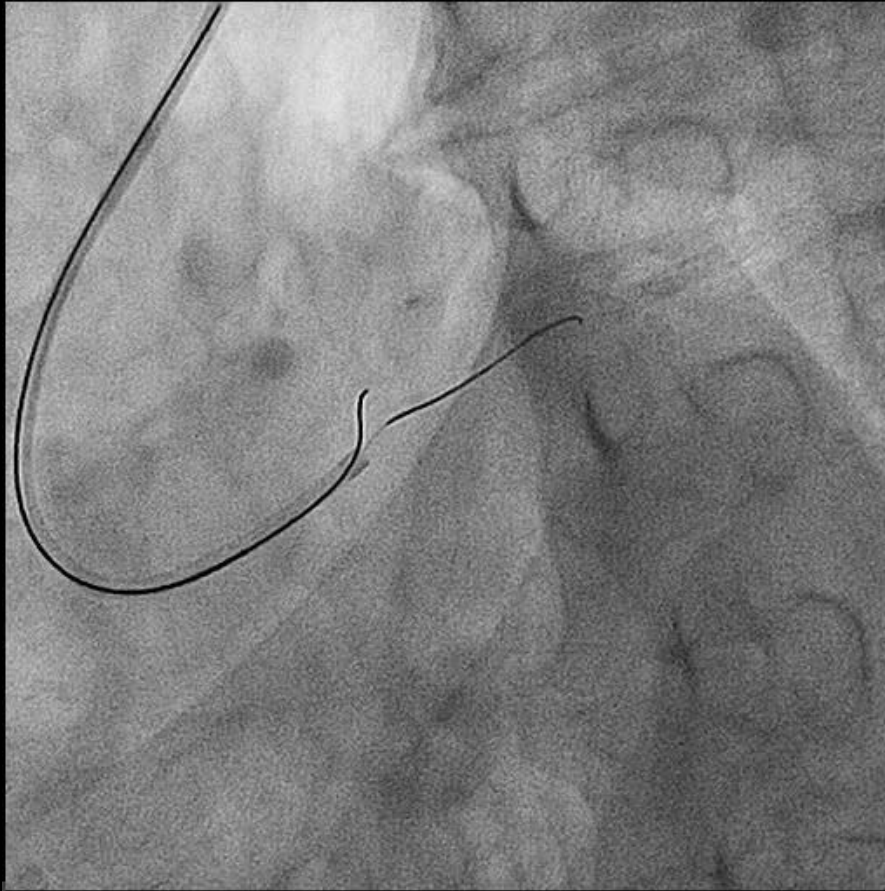
Where is the LAD ostium ?



CT revealed nearly hidden separated LAD ostial total occlusion

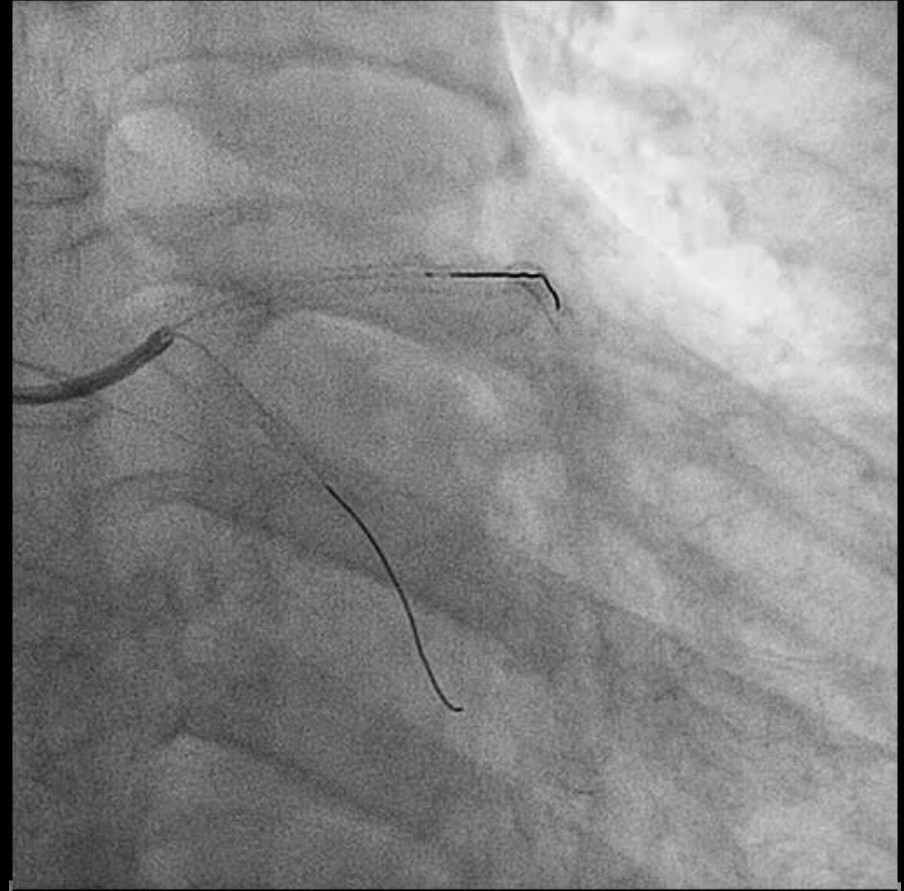
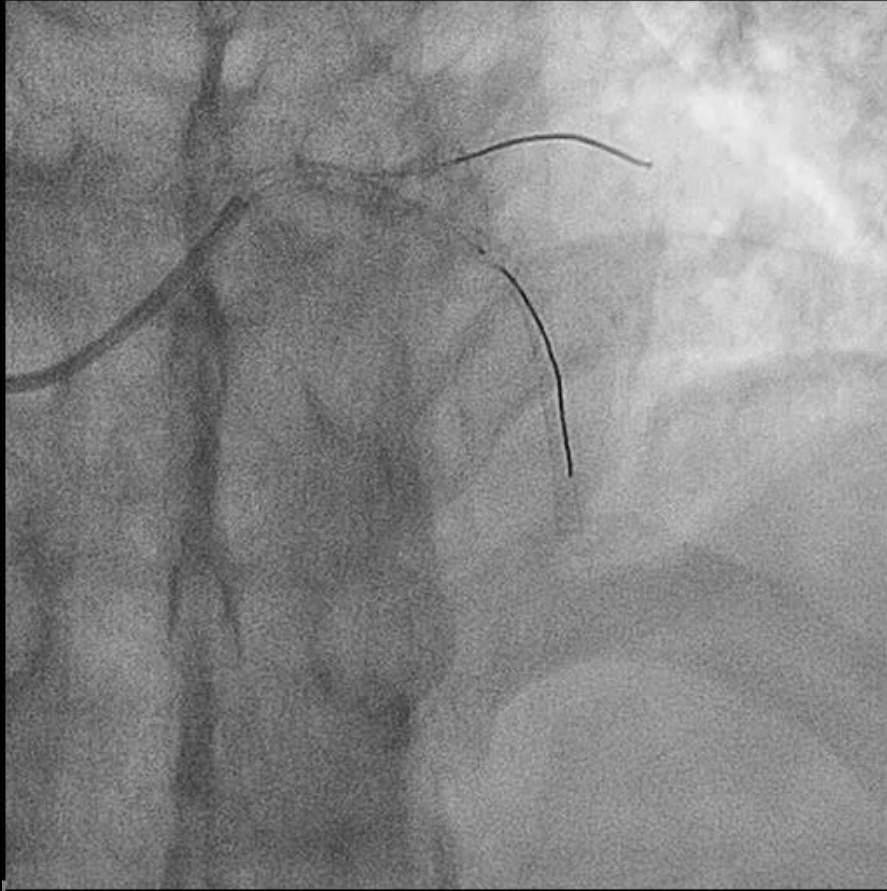


CT-guided **intentional puncture** of LM ostium CTO (**not aortic wall**)



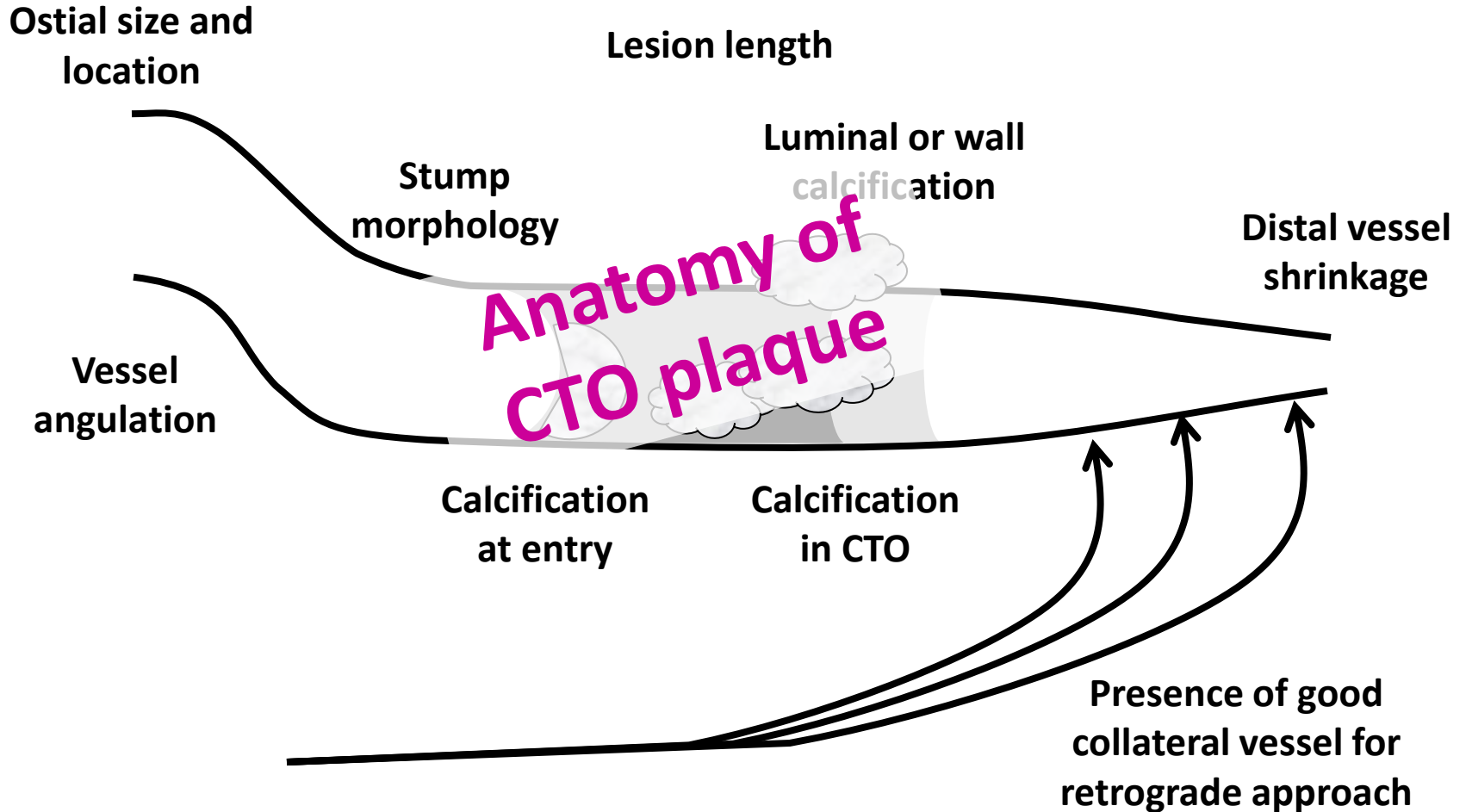
LCX: Sion, LAD: Ultimate 3 → Fielder XT → Miracle 6

One-stage PCI

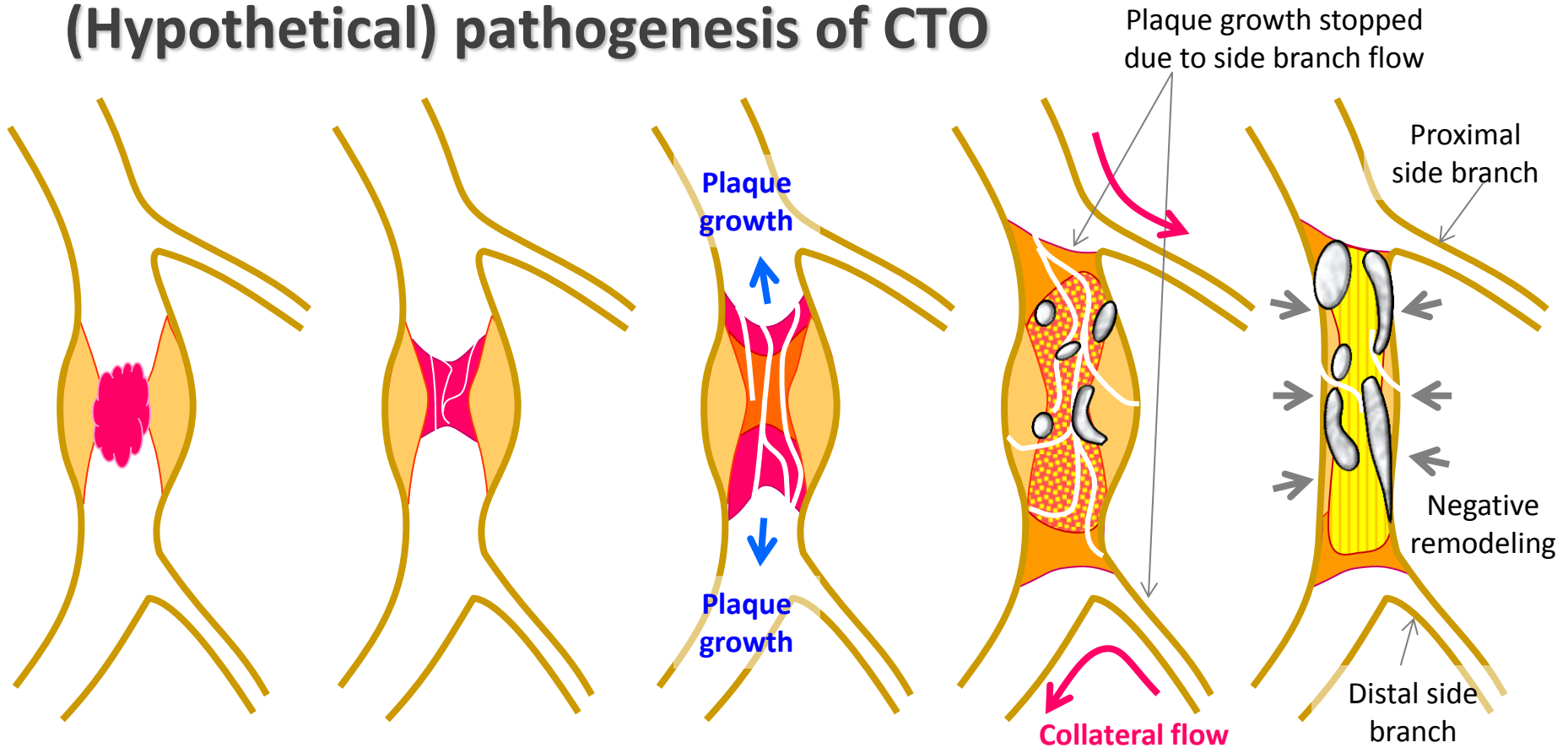


Final

Information available from coronary CT

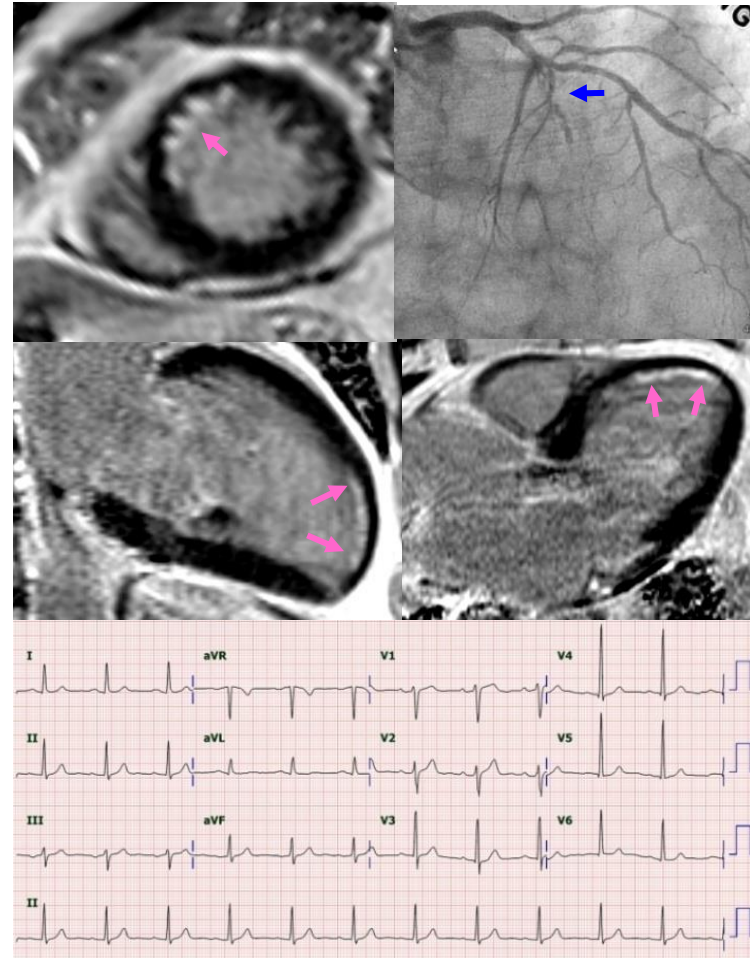
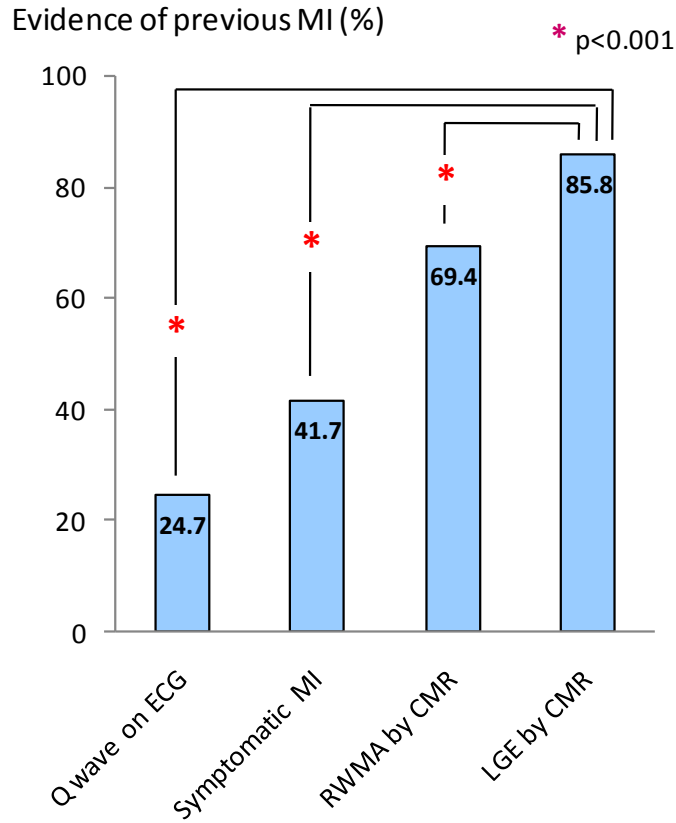


(Hypothetical) pathogenesis of CTO



1. Subclinical thrombotic occlusion and progression of occlusive lesion (until branches)
2. Organized thrombi and proteoglycan/fibrin → Type I collagen and calcification
3. Negative remodeling of CTO body
4. Microchannel formation – intraplaque, or connected to vasa vasorum

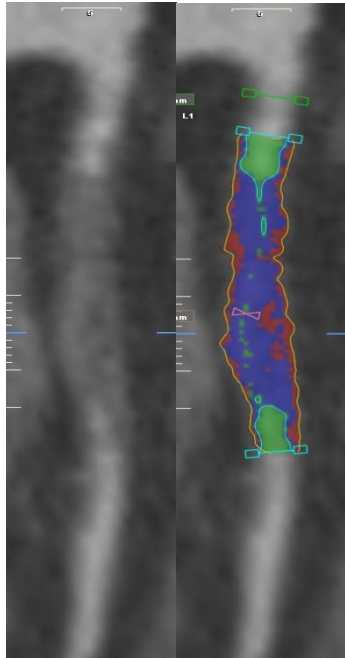
Cardiac MRI study: infarct scar is found in most CTO territory, even with normal EKG, echo, no prior history of chest pain



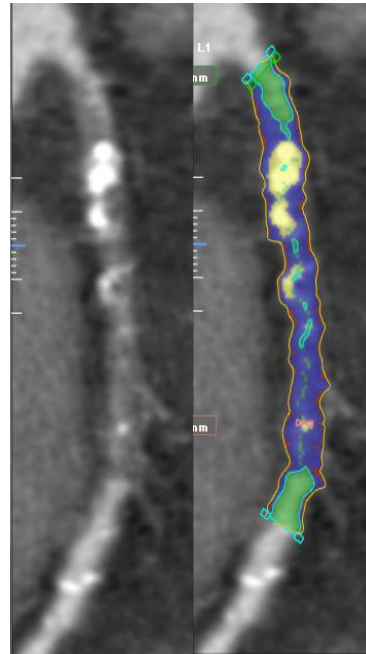
Remodeling pattern of CTO plaque

CTO lesion:
N = 186

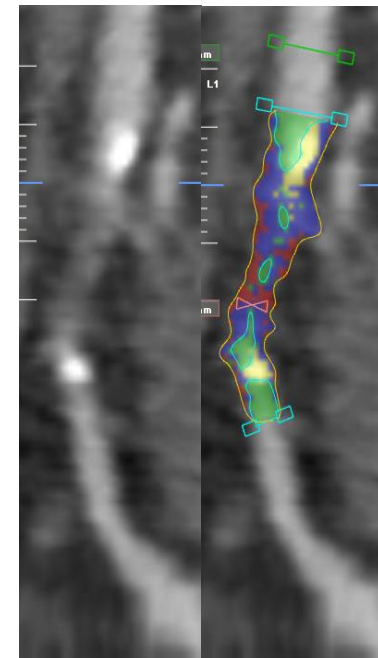
**Positive
remodeling**



Neutral



**Negative
remodeling**



CTO \leq 1 yr

35.4%

7.6%

57.0%

CTO $>$ 1 yr

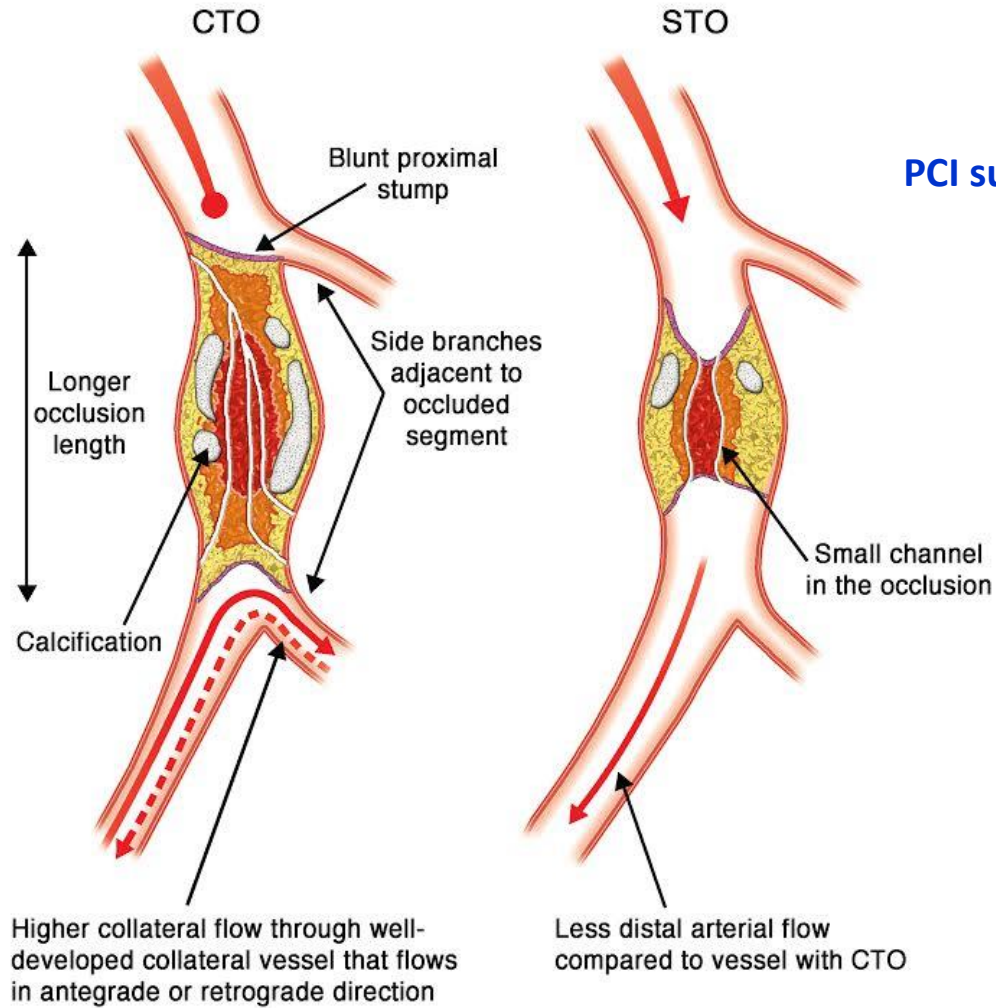
16.5%

5.0%

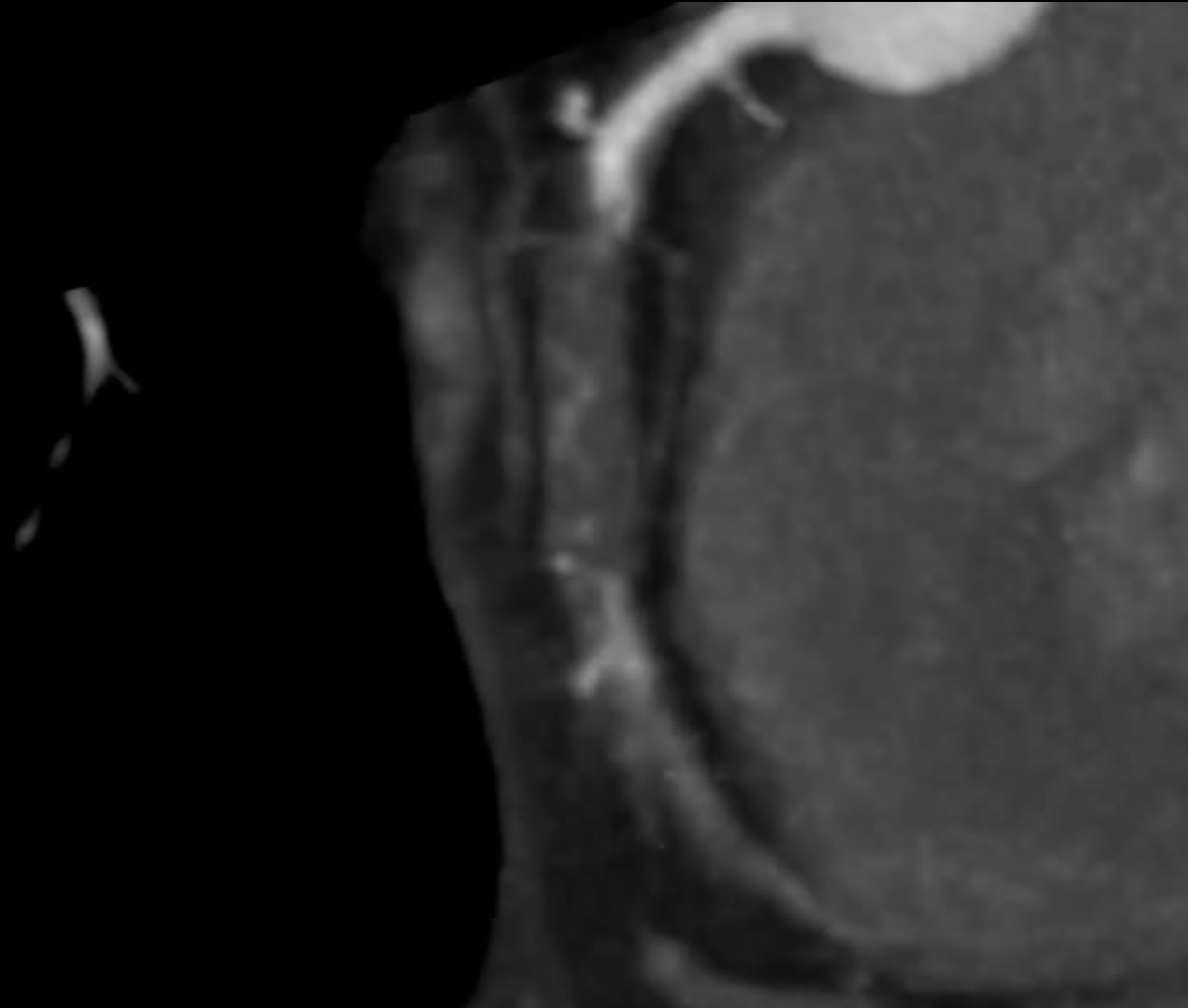
78.5%

Development of CTO plaque: lesson from CT findings

PCI success 75%



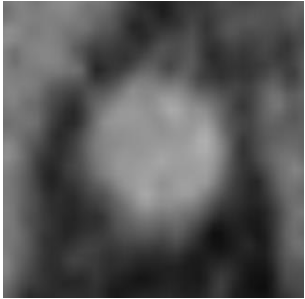
CTO grows as “**Inter-Bifurcation**” disease



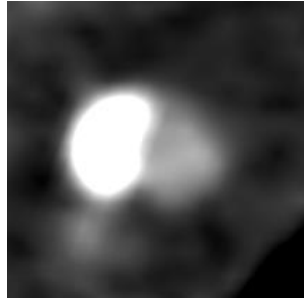
Calcification: is really a big obstacle for CTO PCI ?

Cross-sectional calcium

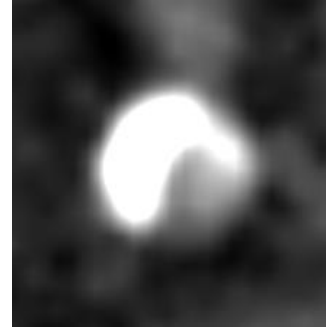
0%



< 50%



> 50%

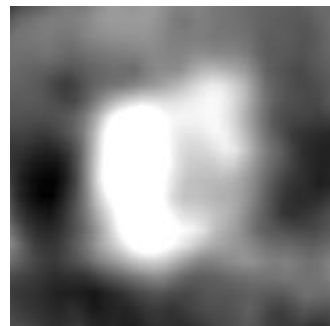


100% (full moon)

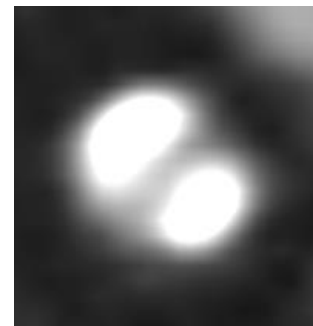


Shape of cross-sectional calcium

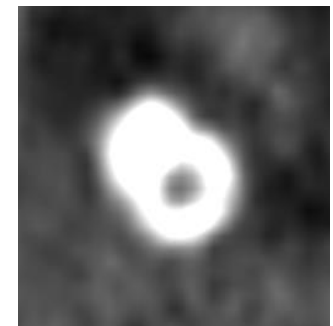
Crescent moon



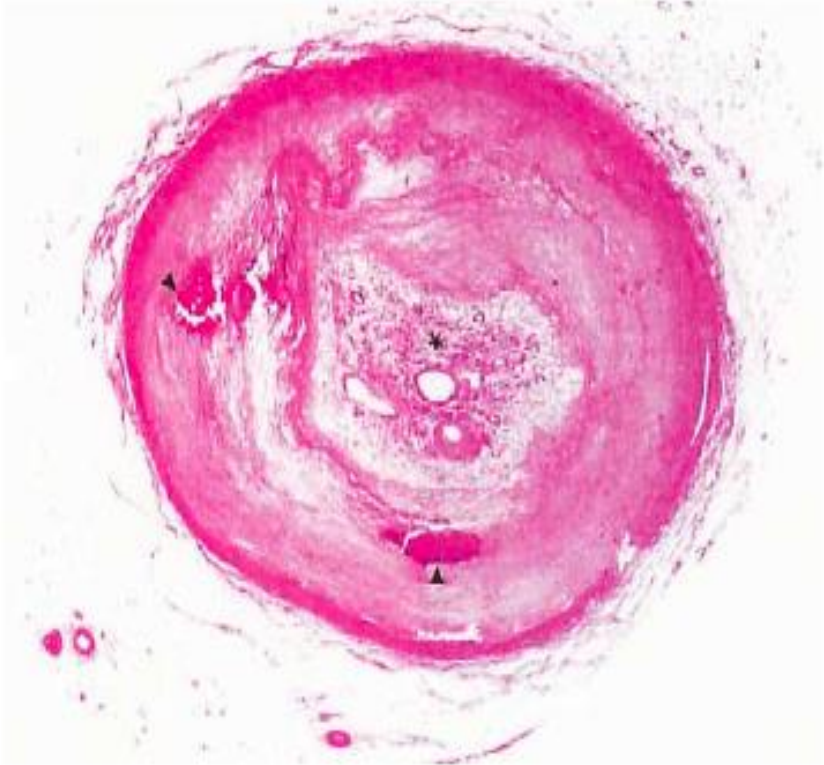
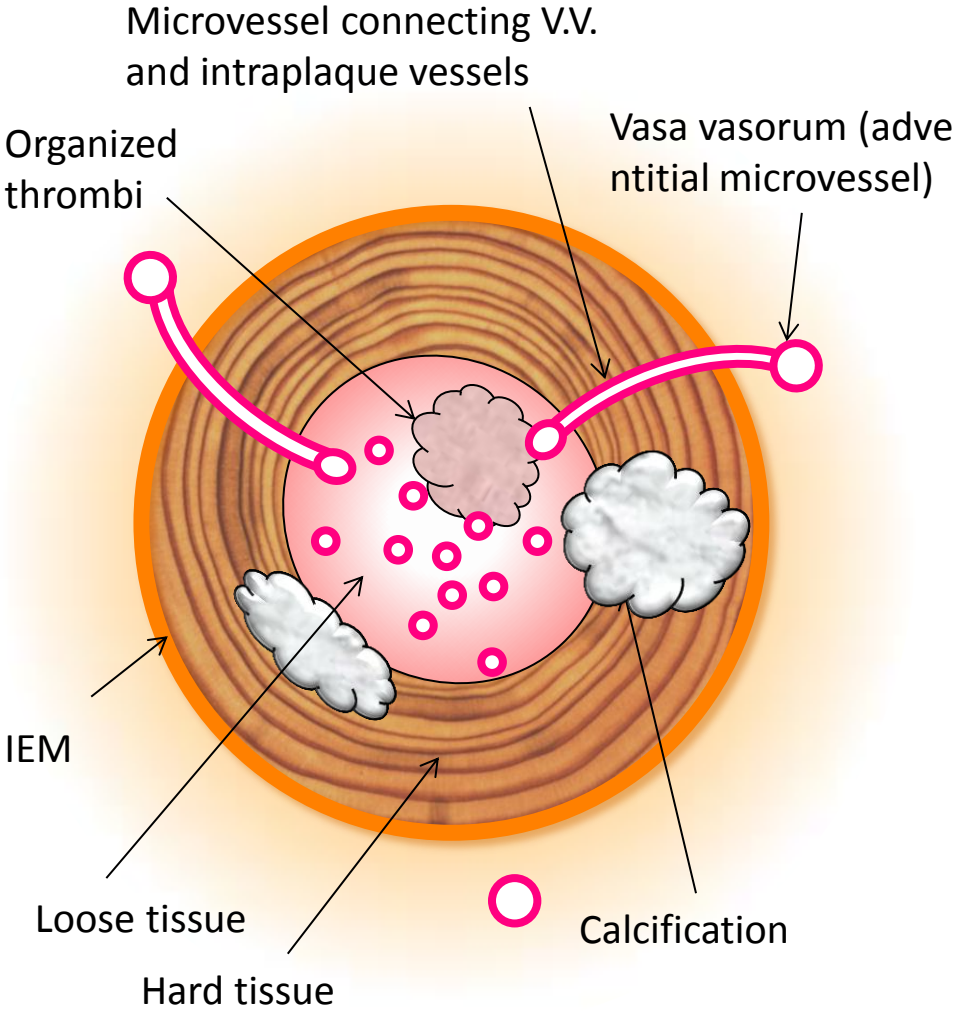
Half- and Half-moon



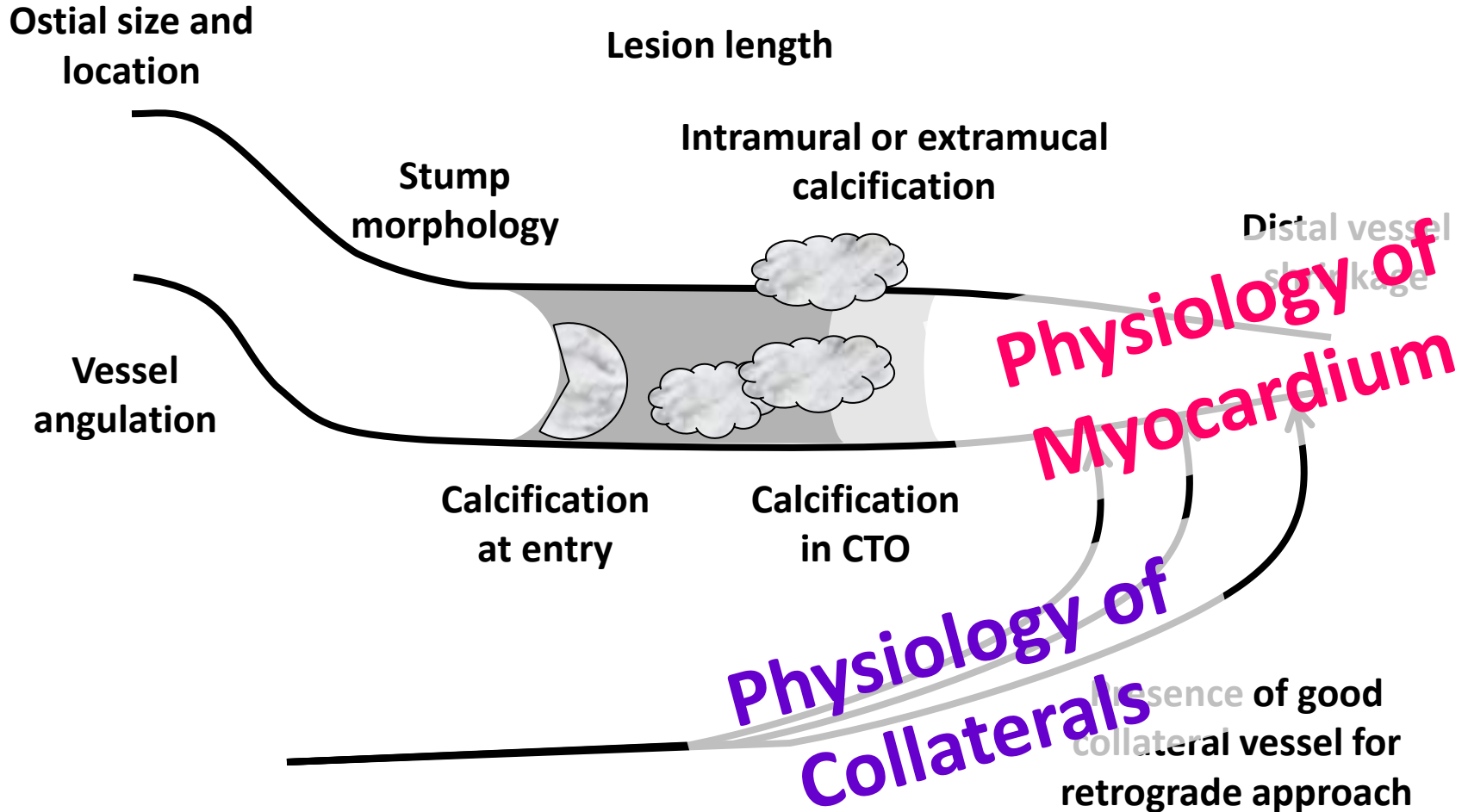
Circular



Histology of CTO: schematic concept



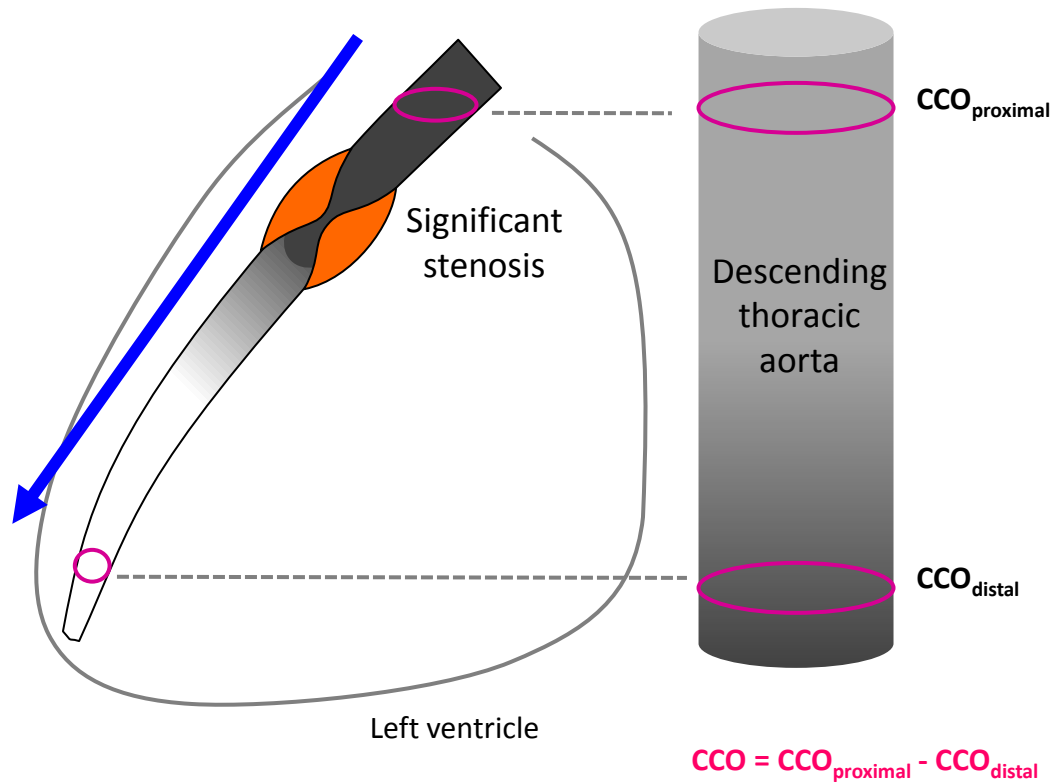
Information available from coronary CT



Gradient analysis of intracoronary contrast agent

– A simple method for coronary stenosis evaluation -

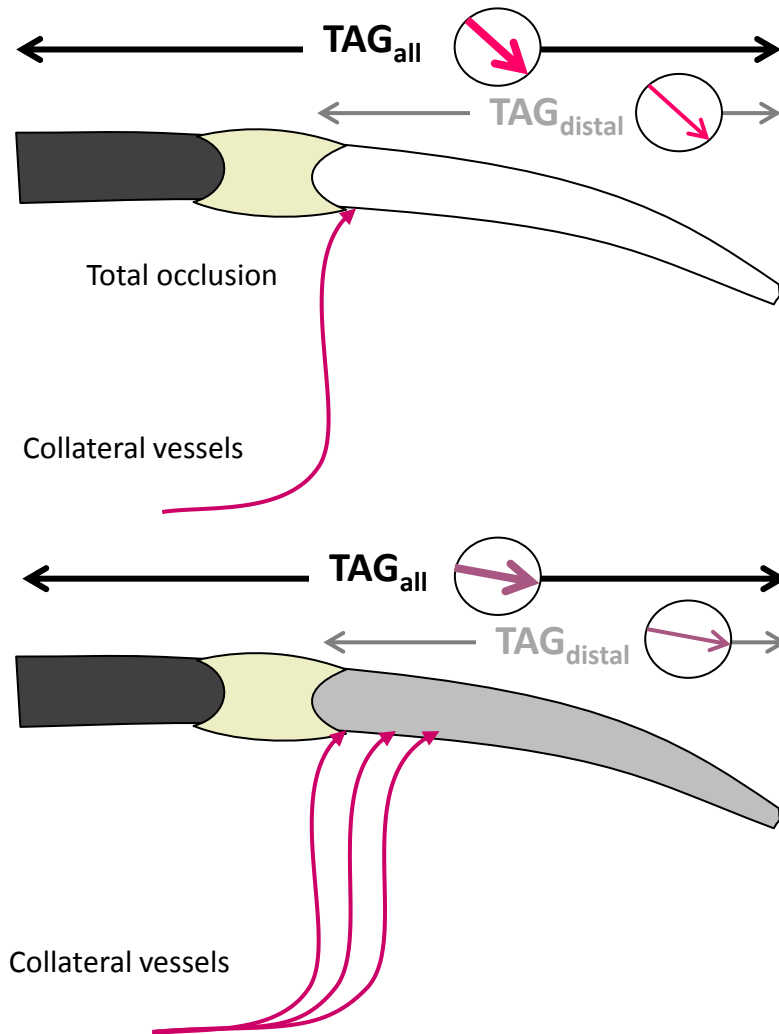
$$\text{TAG} = (\text{HU}_{\text{proximal}} - \text{HU}_{\text{distal}}) / \text{length}$$



Lachner, ROFO 2011; Steigner, Circ Img 2009; Chow, JACC 2010; Wong, JACC 2013

Choi, JACC Img 2011; Yoon and Choi, JACC Img 2012; Choi, EHJ Img 2012; Choi, Circ Img 2014; Zheng, Eur Radiol 2014; Chatzizisis, IJCI 2014

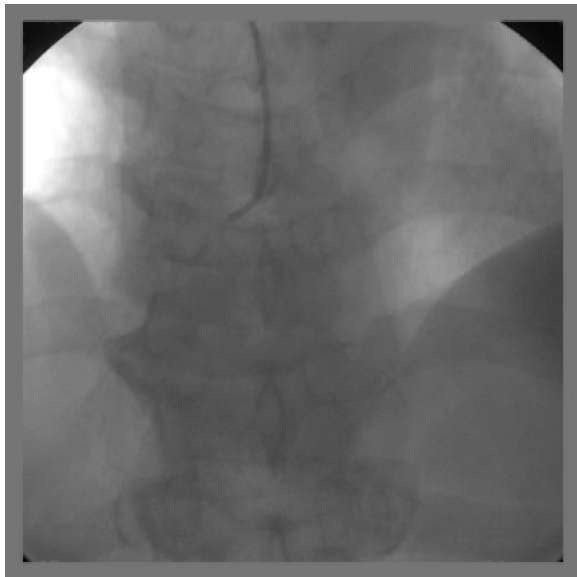
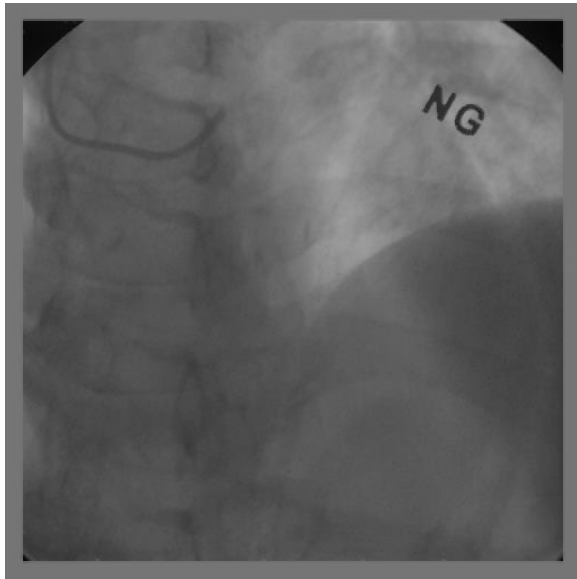
Assessment of the **functional extent** of collateral flow using TAG_{all}



Poorly developed collateral

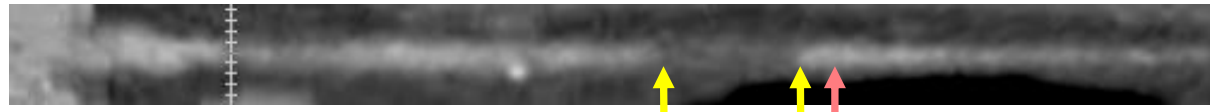
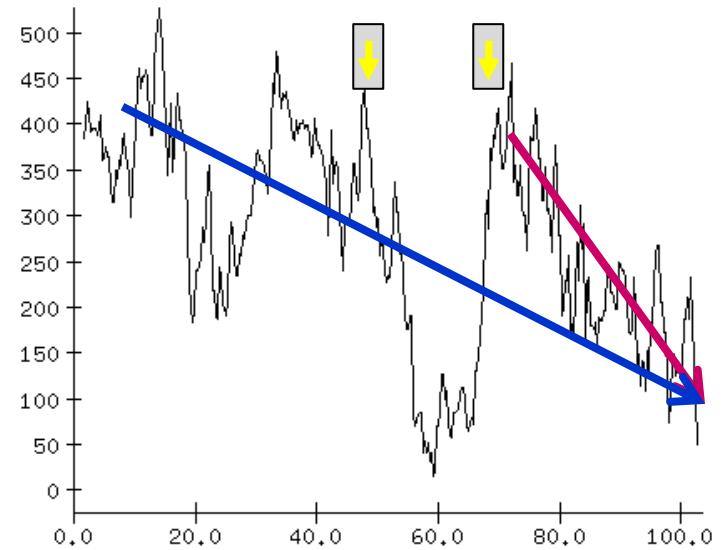
Well-developed collateral

Representative case: Antegrade Rentrop 1 flow

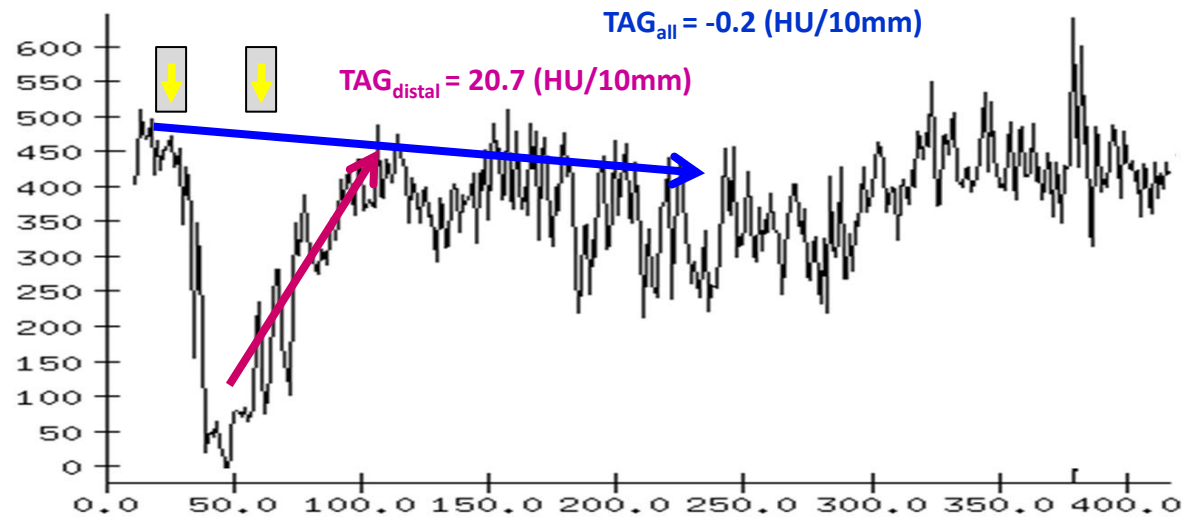
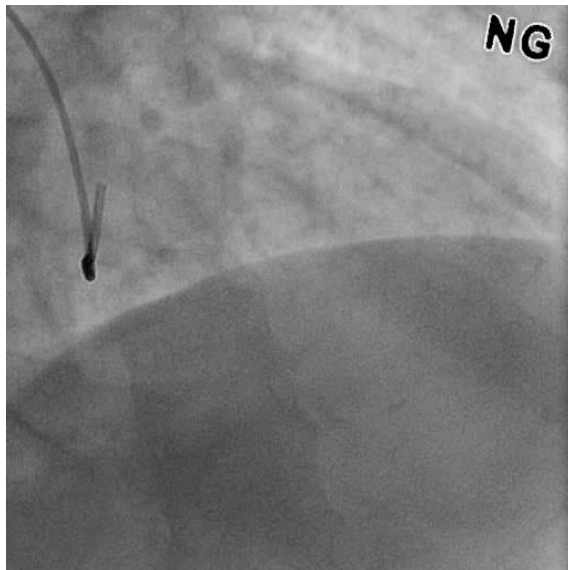
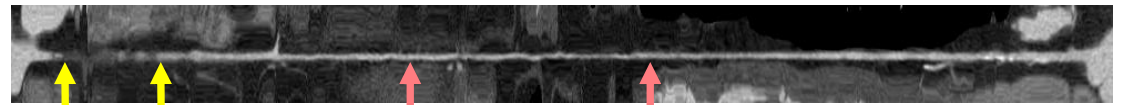
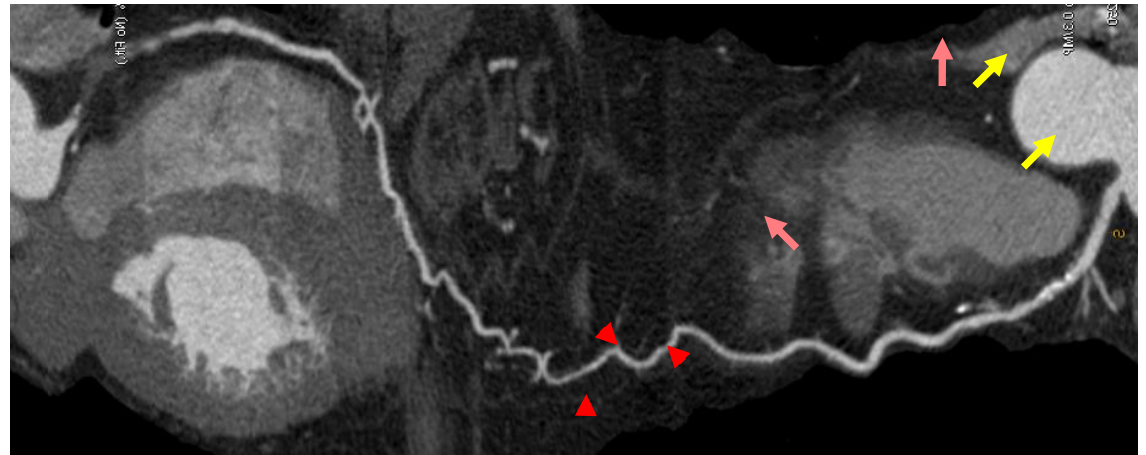
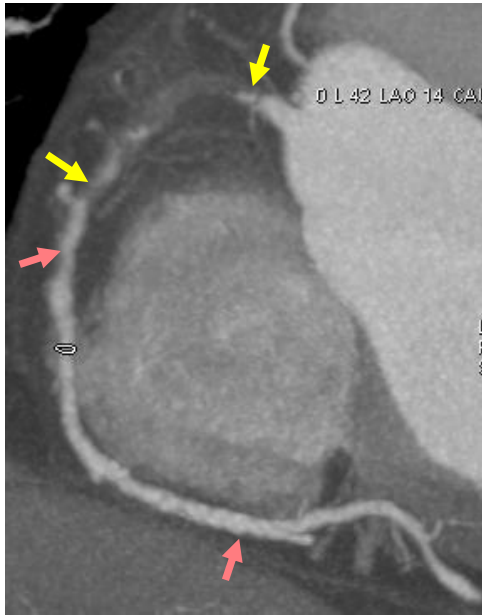


$TAG_{all} = -21.2$ (HU/10mm)

$TAG_{distal} = -56.3$ (HU/10mm)

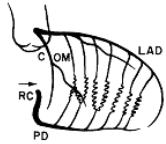


Representative case: Retrograde Rentrop 3 flow

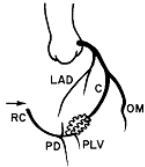


Localization of coronary collateral vessels: visual-based

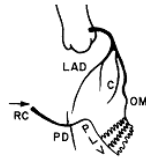
RCA



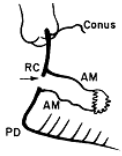
A. RAO-LC Injection (28)



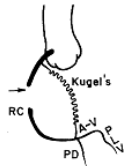
B. LAO-LC Injection (24)



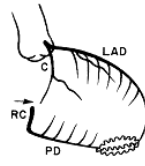
C. LAO-LC Injection (17)



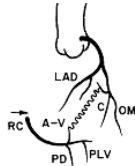
D. RAO-RC Injection (9)



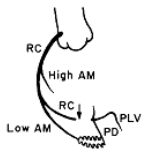
E. LAO-RC Injection (9)



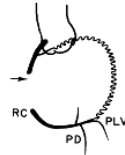
F. RAO-LC Injection (9)



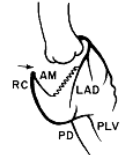
G. LAO-LC Injection (6)



H. LAO-RC Injection (6)

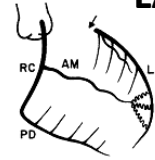


I. LAO-RC Injection (2)



J. LAO-LC Injection (2)

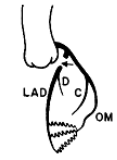
LAD



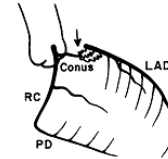
A. RAO-RC Injection (28)



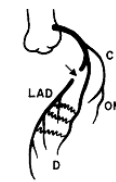
B. RAO-LC Injection (27)



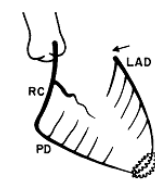
C. LAO-LC Injection (17)



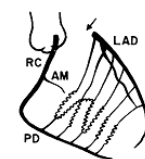
D. RAO-RC Injection (15)



E. LAO-LC Injection (6)

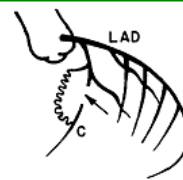


F. RAO-RC Injection (3)

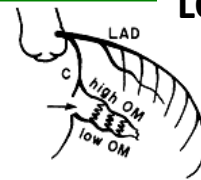


G. RAO-RC Injection (3)

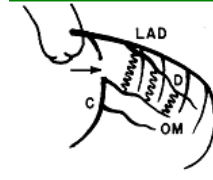
LCX



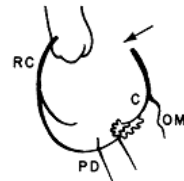
A. RAO-LC Injection (7)



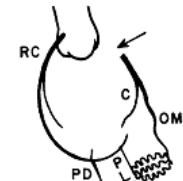
B. RAO-LC Injection (6)



C. RAO-LC Injection (5)

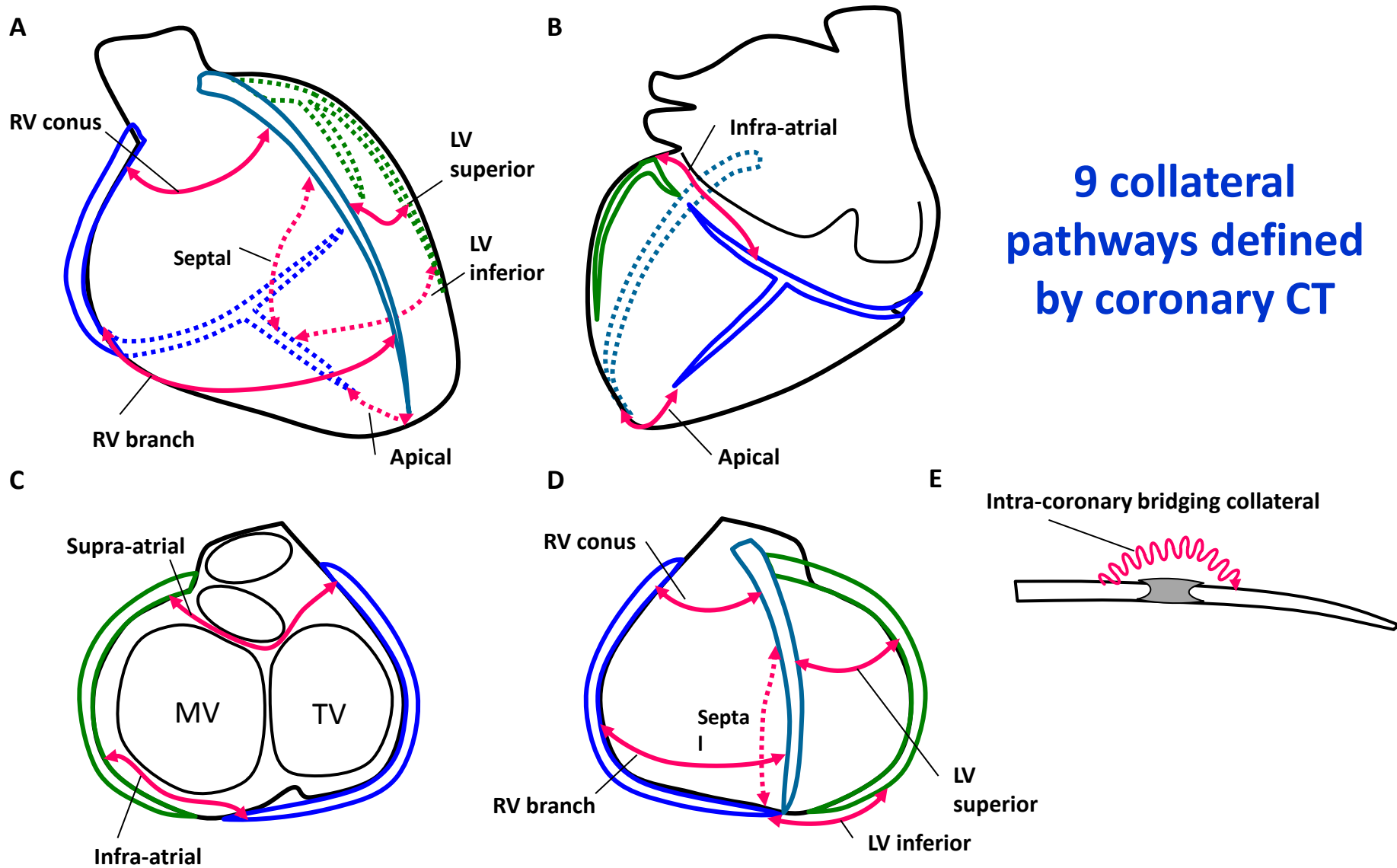


D. LAO-RC Injection (2)

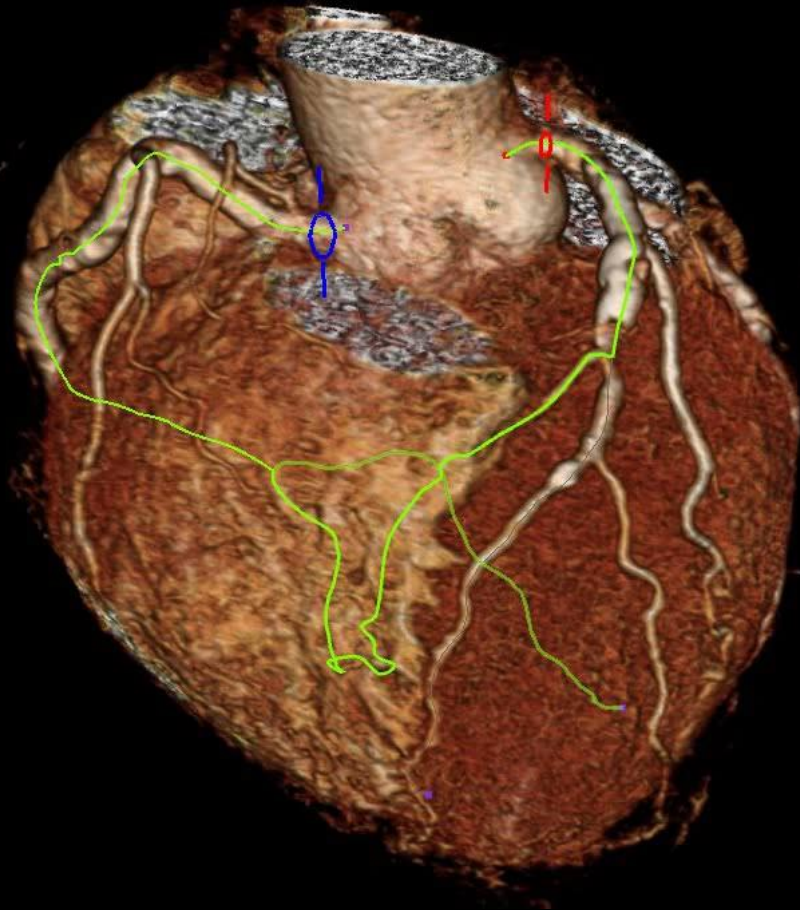


E. LAO-RC Injection (2)

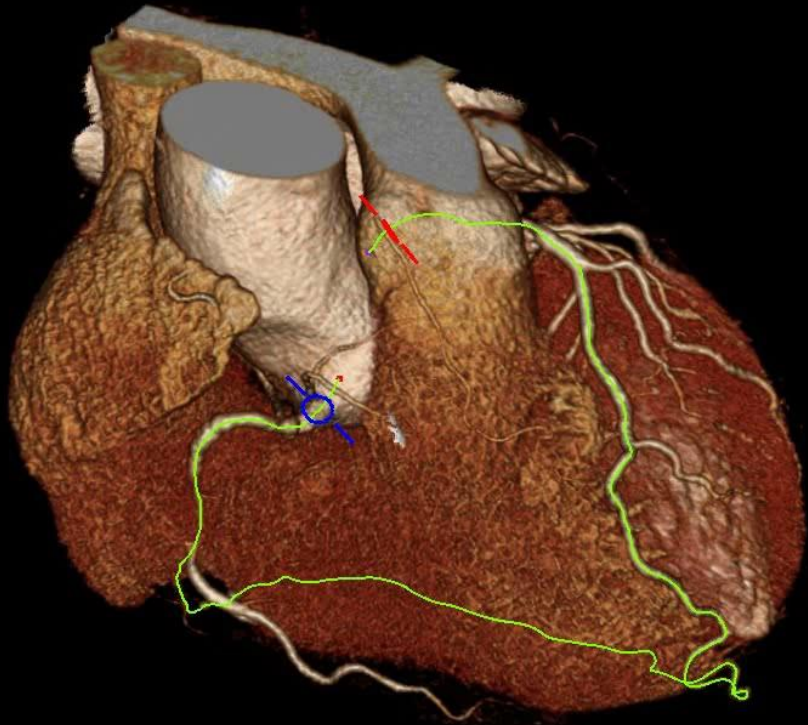
Localization of coronary collateral vessels: Based on knowledge from CT



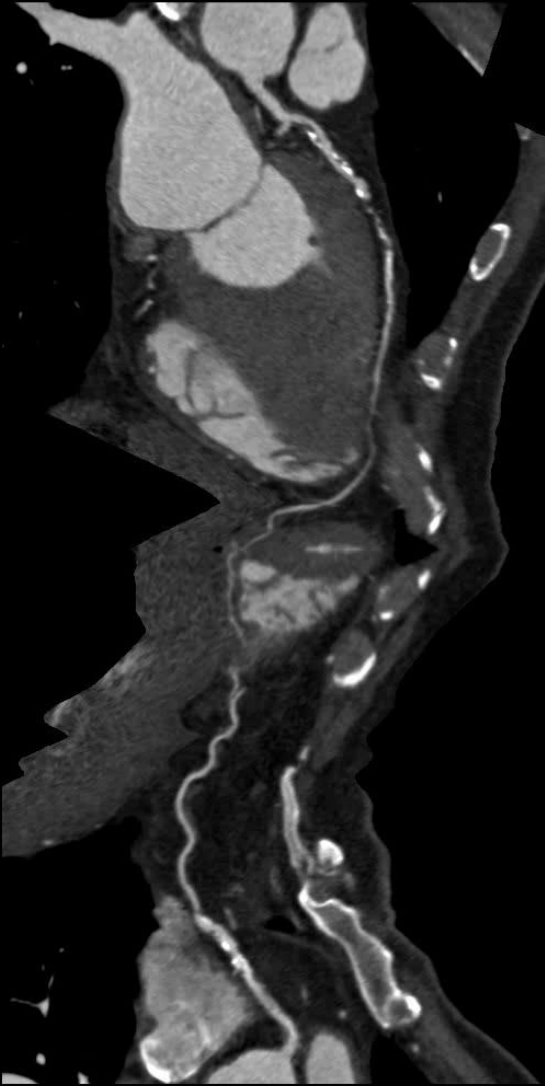
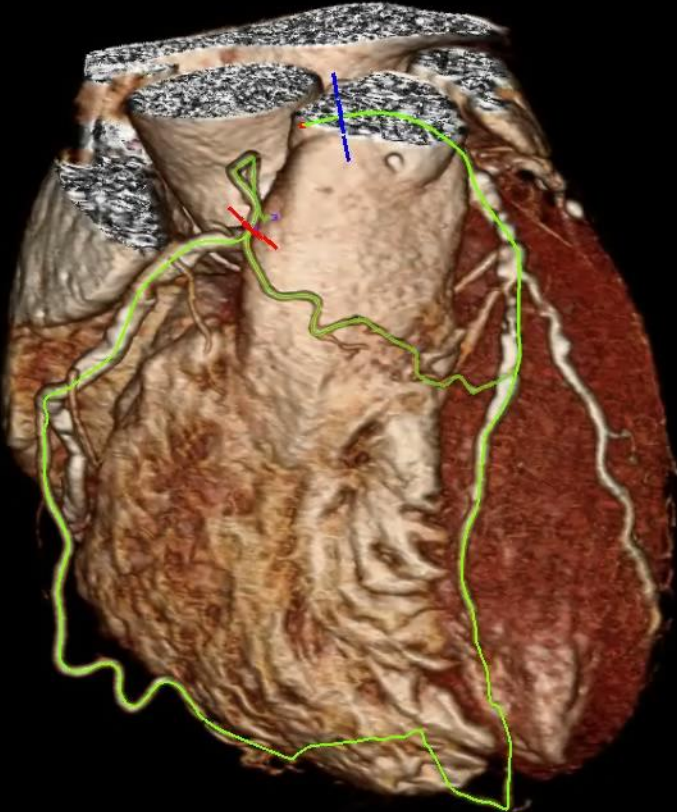
Septal collaterals



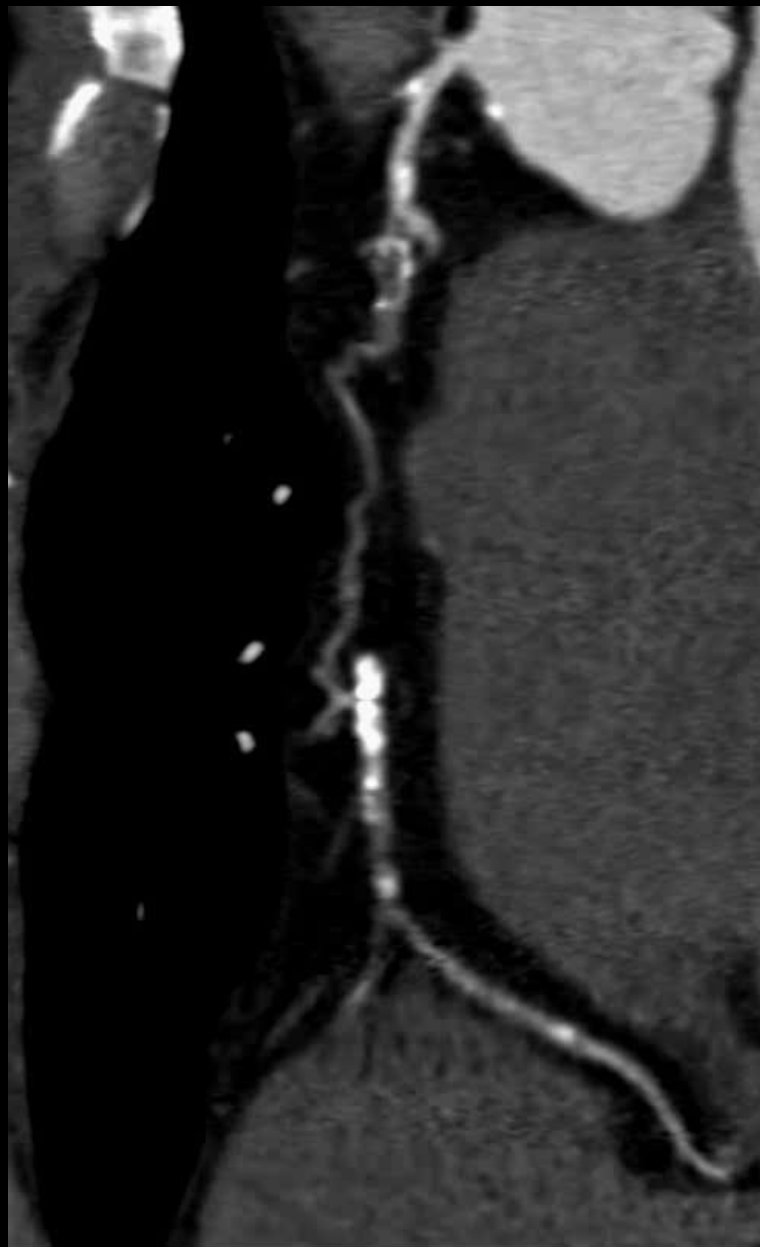
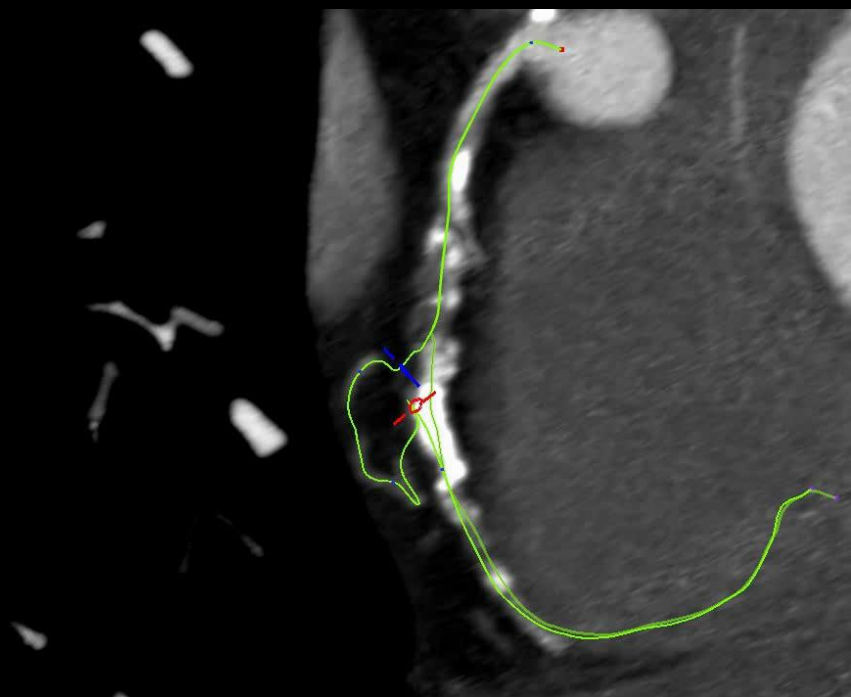
Collaterals running on LV apical wall



Collaterals from RV branches and RV conus arteries



Intracoronary bridging collateral



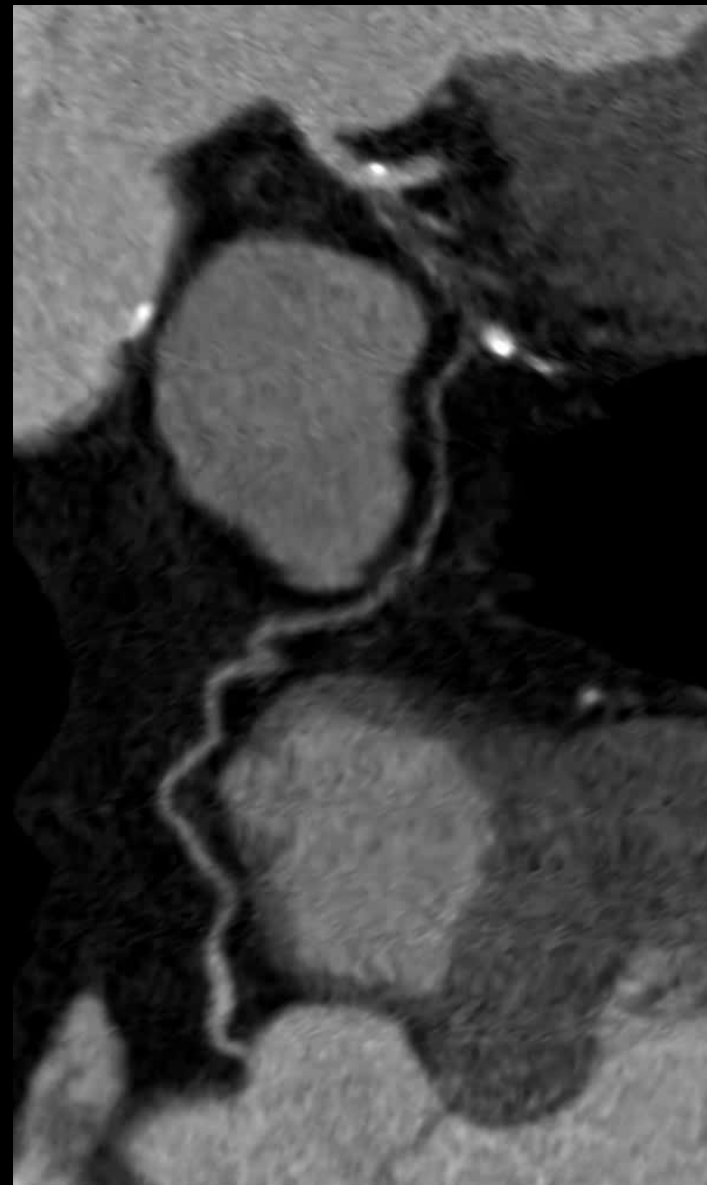
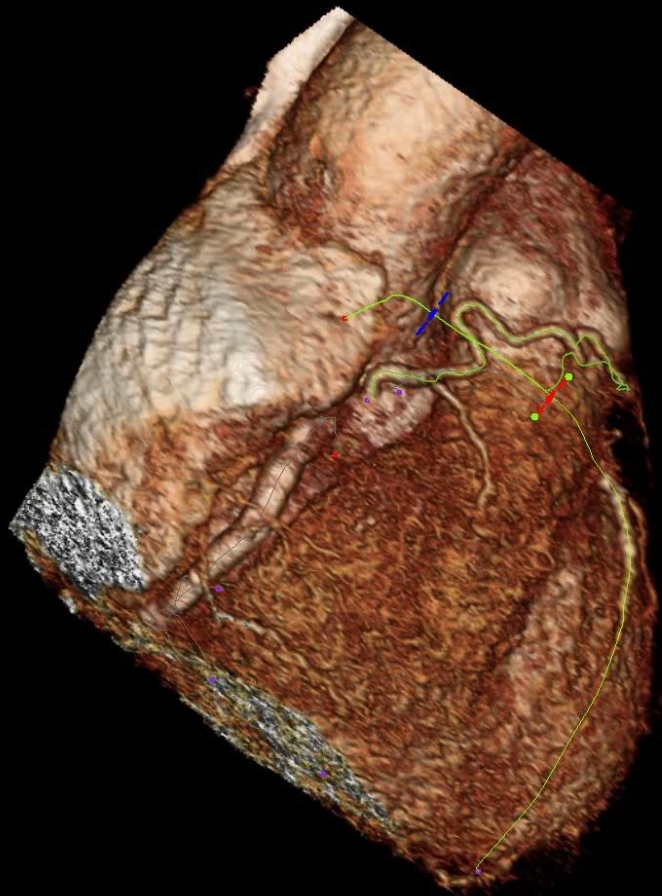
Case: Unexpected source of collateral flow

- Importance of another source of collateral vessel -

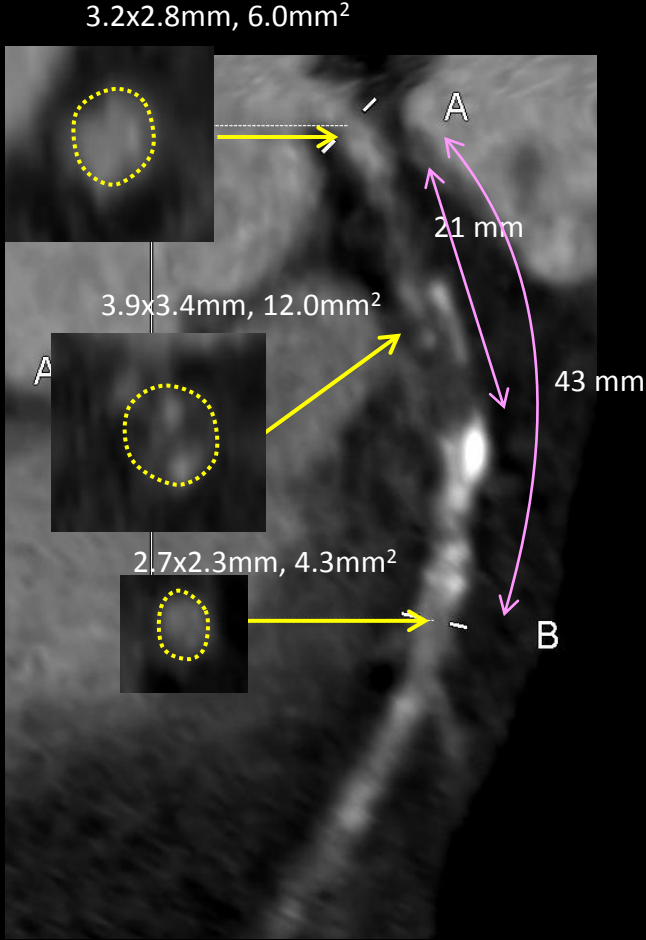
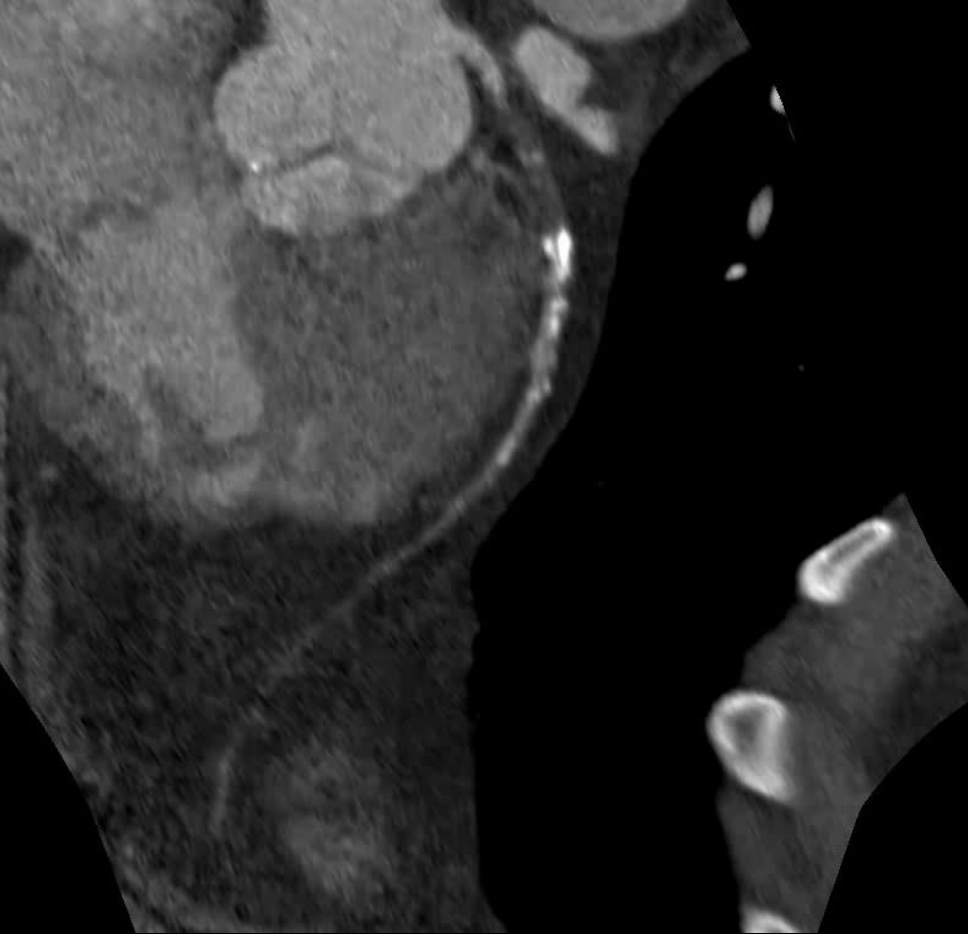
Stable angina, 70/M. Outside CAG: very poor LAD flow ?



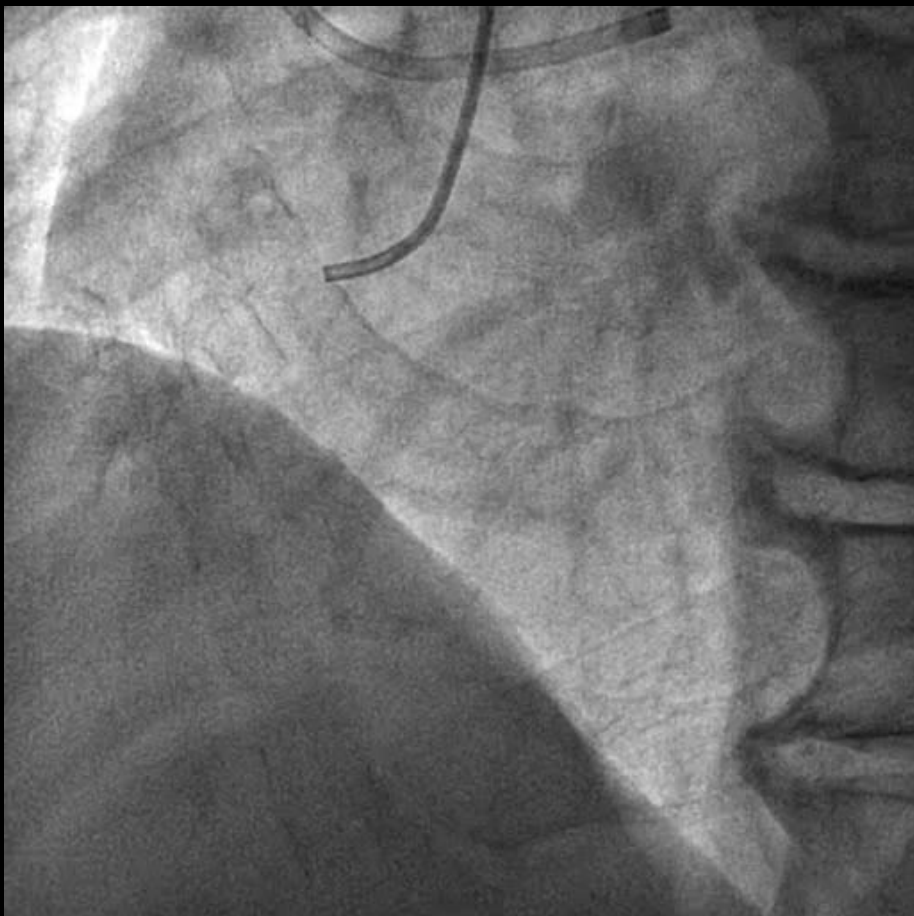
Collateral flow from separated RV conus branch supplying occluded LAD



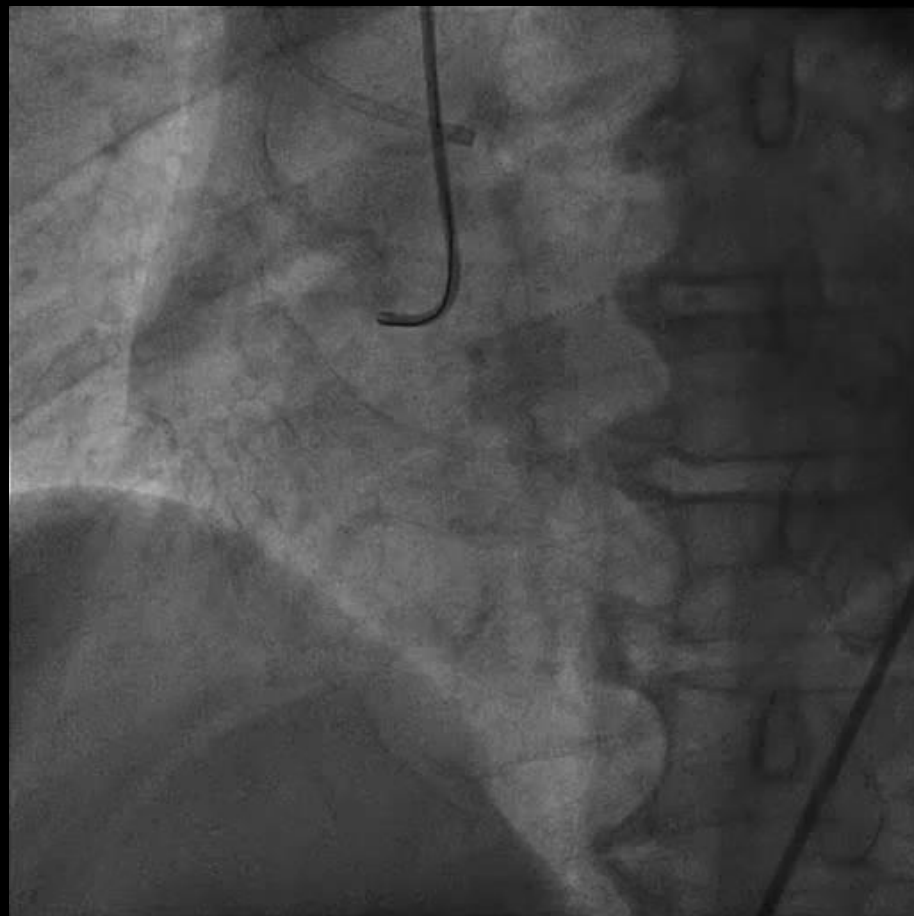
CT: CTO of proximal LAD



One-stage PCI

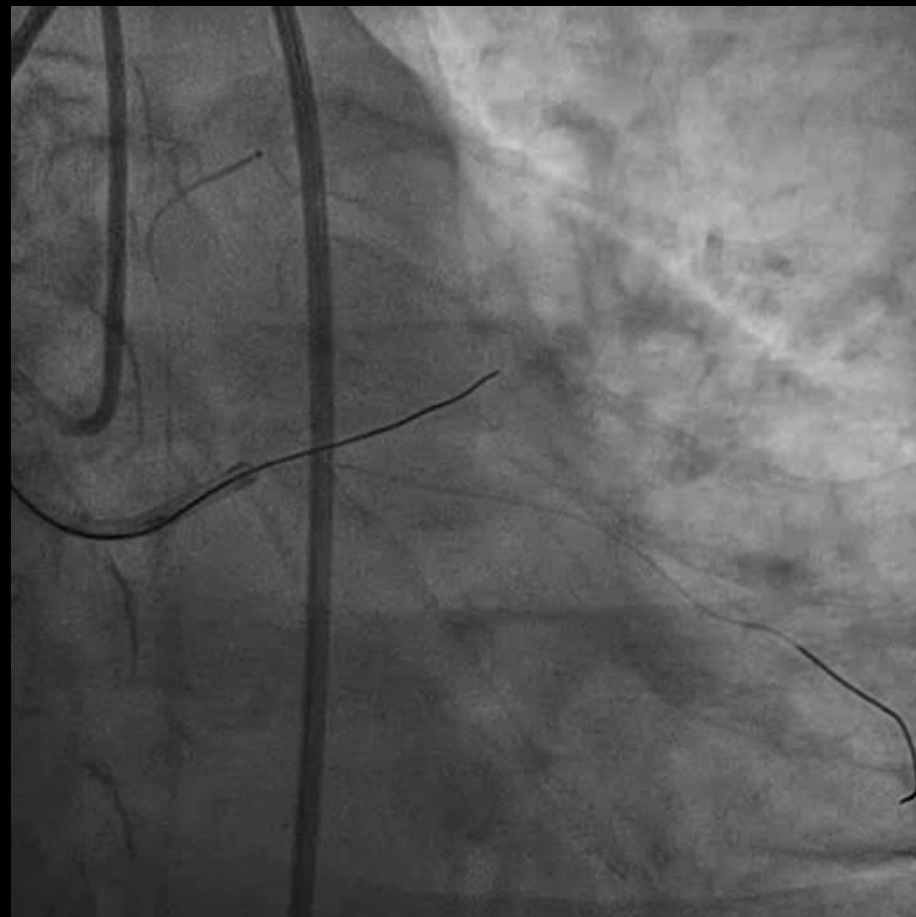
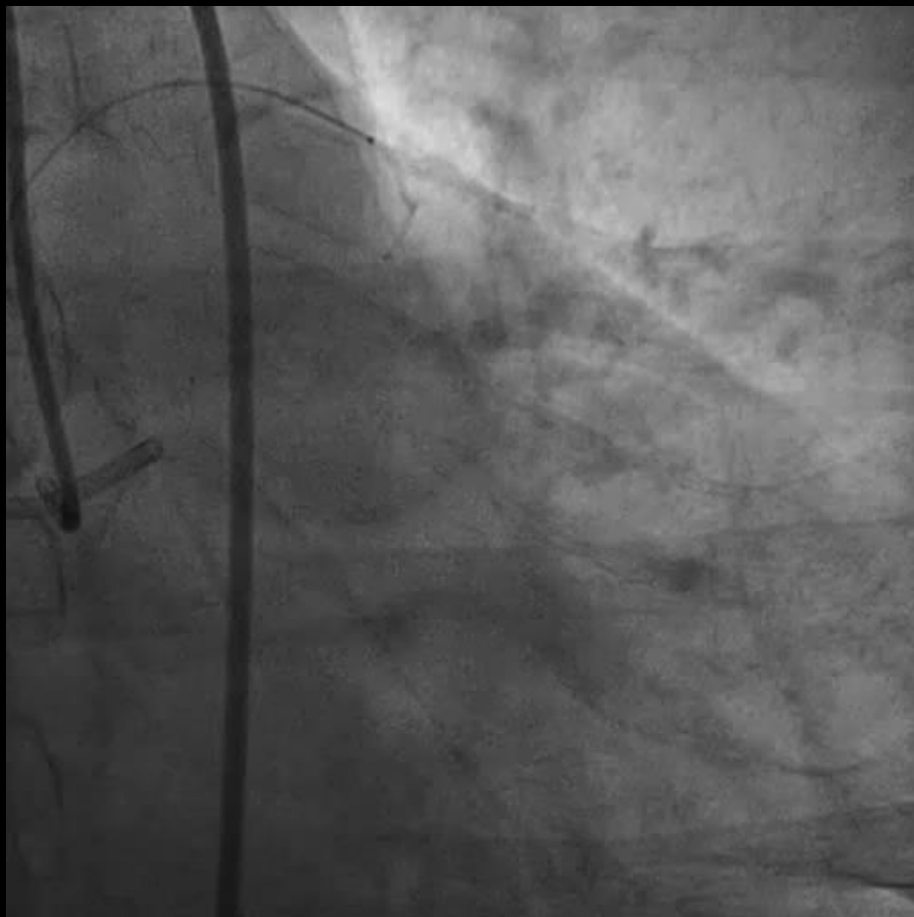


LAD is NOT visualized by collateral from RCA



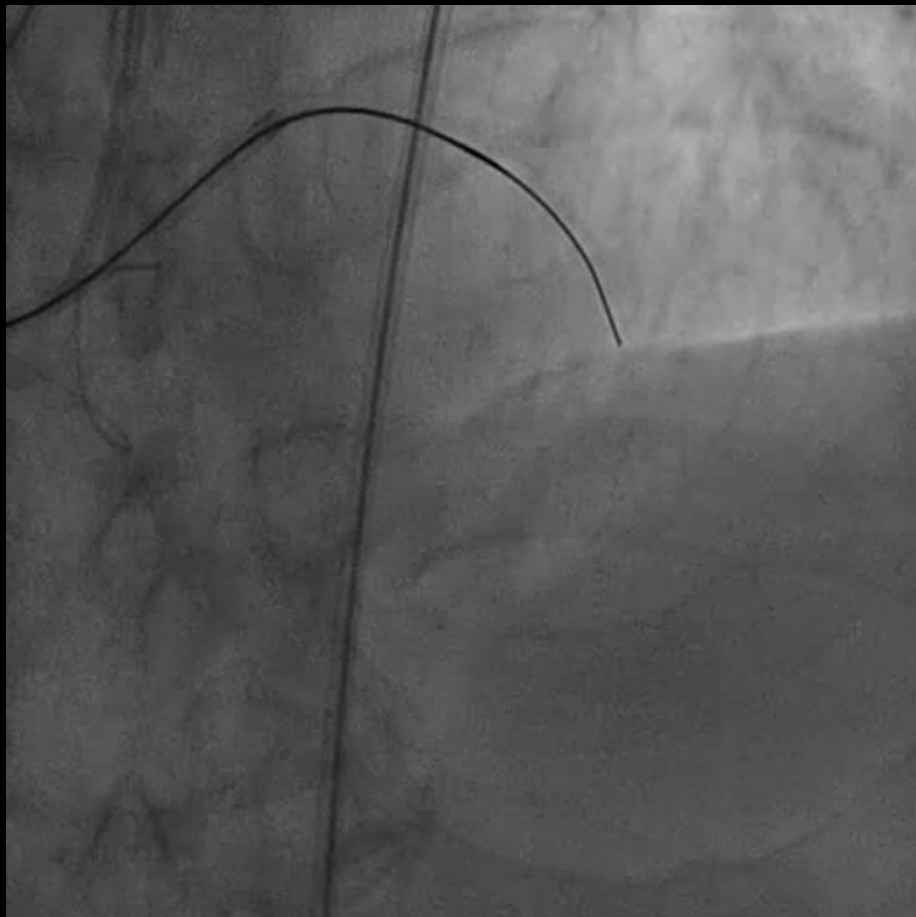
LAD is visualized by collateral from separated RV conus branch

One-stage PCI (retrograde visualization by RV conus collateral)

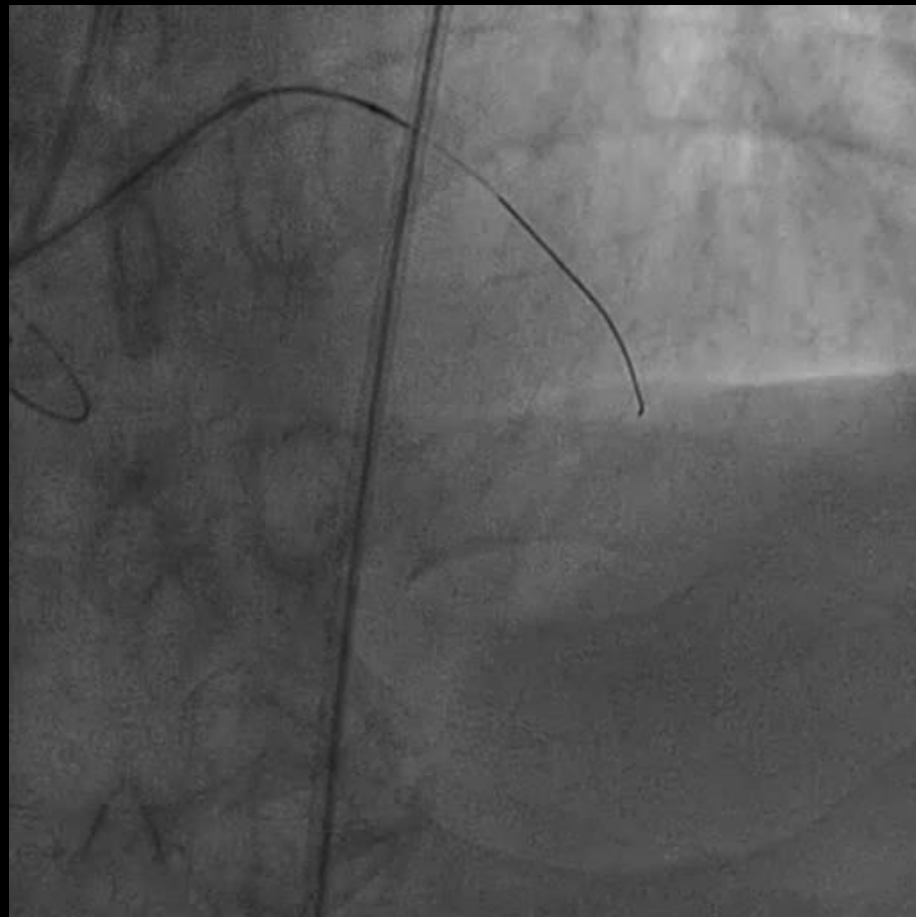


Tip injection from microcatheter enables controlled advancement of guidewire

One-stage PCI

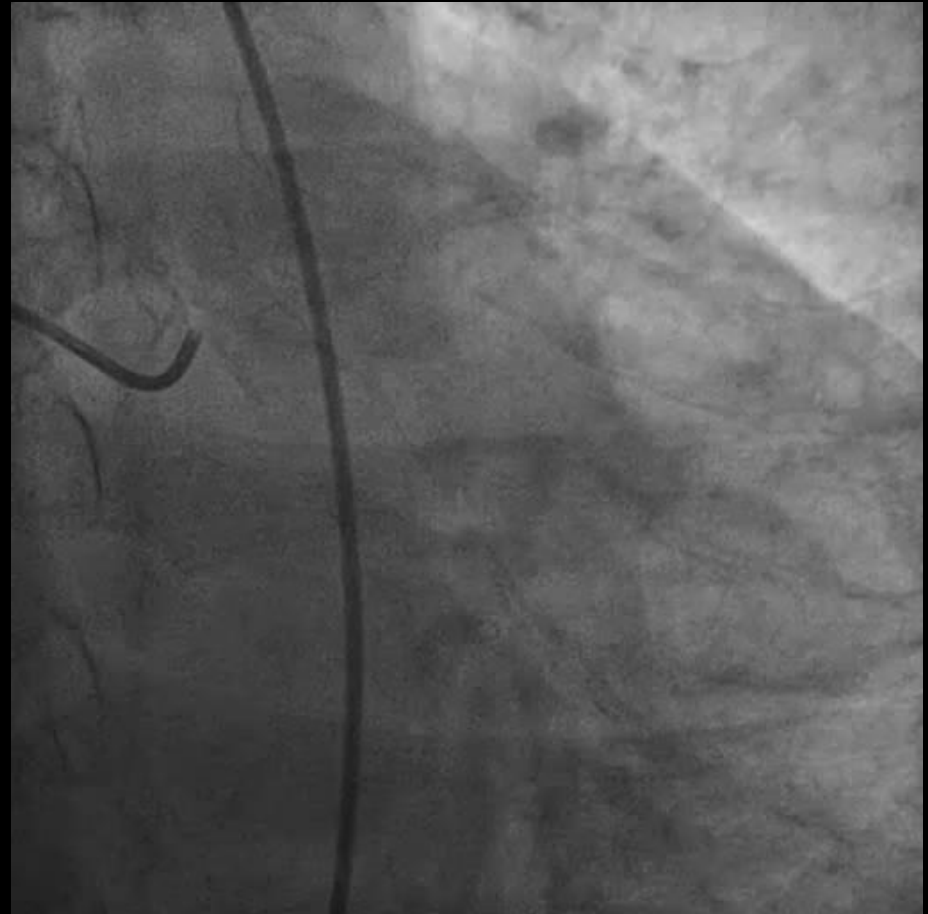
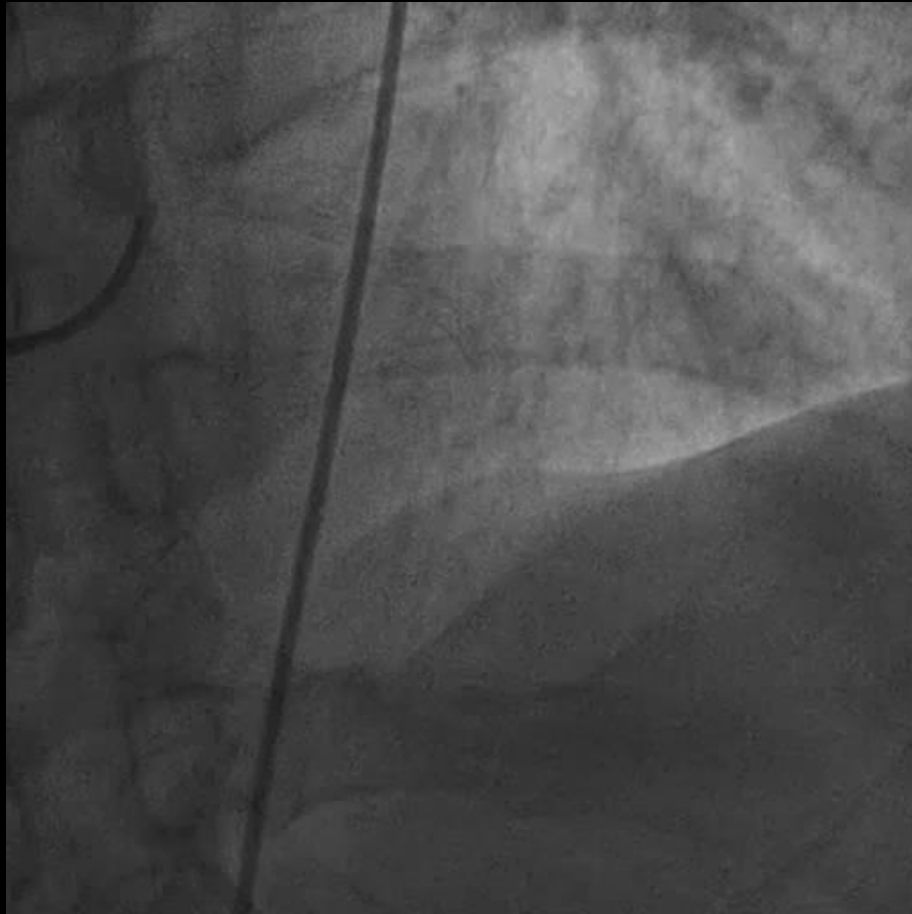


False lumen



True lumen

One-stage PCI



Orsiro stent 2EA (total stent length 45mm; 2.5x15mm, 2.25x30 mm)

Prediction of CTO PCI success by pre-procedural CT



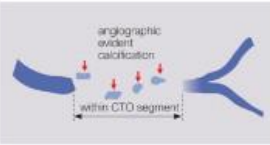
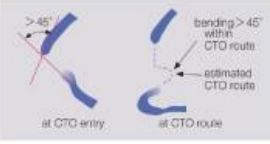
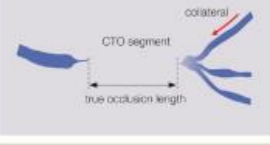
	N of CTO	Success (%)	CT predictors	Independent predictors
Mollet, Am J Cardiol 2005	45	53%	Calcification > 15 mm Blunt stump	Calcification > 15 mm Blunt stump
Soon, J Interv Cardiol 2007	43	56%	Transluminal calcification > 50% Blunt stump (by CAG)	
Otsuka, Int J Cardiovasc Imaging 2008	26	100%	None (100% success)	
Cho, Int J Cardiol 2009	72	76%	Length Regional calcium scores % Ca area/CSA	% Ca area/CSA
Garcia, Eurointervention 2009 (CTTO registry)	139	63%	CSA > 50% Angulation Calcium at entry > 15 mm	CSA > 50%
Ehara, J Inv Cardiol 2009	110	85%	Bending, Shrinkage, Calcium	
Choi, Circ J 2010	186	77%	Length > 18 mm Density > 139 HU	CTO > 1 year
Araki, EuroPCR 2011	114	82%	Intramural calc	Intramural calc
Jen, Int J Cardiol 2010	82	81%	Calcium length ration > 0.5 Calcium at proximal and distal stump	

Most accepted predictors: severity of calcification and lesion length

Predictor of CTO PCI (wire crossing ≤ 30 min)

J-CTO score



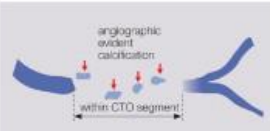

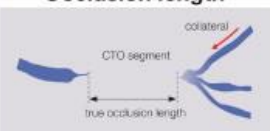
1.0

Variables and definitions			
<p>Tapered</p> 	<p>Blunt</p>  <p>Entry with any tapered tip or dimple indicating direction of true lumen is categorized as "tapered".</p>	<p>Entry shape</p> <input type="checkbox"/> Tapered (0) <input type="checkbox"/> Blunt (1)	
<p>Calcification</p>  <p>Regardless of severity, 1 point is assigned if any evident calcification is detected within the CTO segment.</p>		<p>Calcification</p> <input type="checkbox"/> Absence (0) <input type="checkbox"/> Presence (1)	
<p>Bending > 45degrees</p>  <p>One point is assigned if bending > 45 degrees is detected within the CTO segment. Any tortuosity separated from the CTO segment is excluded from this assessment.</p>	<p>Bending > 45°</p> <input type="checkbox"/> Absence (0) <input type="checkbox"/> Presence (1)	<p>point</p>	
<p>Occlusion length</p>  <p>Using good collateral images, try to measure "true" distance of occlusion, which tends to be shorter than the first impression.</p>	<p>Occl.Length</p> <input type="checkbox"/> <20mm (0) <input type="checkbox"/> ≥ 20 mm (1)	<p>point</p>	
<p>Re-try lesion</p> <p>Is this Re-try (2nd attempt) lesion ? (previously attempted but failed)</p>		<p>Re-try lesion</p> <input type="checkbox"/> No (0) <input type="checkbox"/> Yes (1)	<p>point</p>
<p>Category of difficulty (total point)</p> <input type="checkbox"/> easy (0) <input type="checkbox"/> Intermediate (1) <input type="checkbox"/> difficult (2) <input type="checkbox"/> very difficult (≥ 3)		<p>Total</p> <div style="background-color: #808080; width: 20px; height: 20px; display: inline-block; margin-right: 5px;"></div> <p>points</p>	

Predictor of CTO PCI (wire crossing ≤30 min)

J-CTO score

1.0

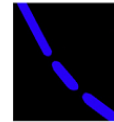
Variables and definitions		N=520
<p>Tapered</p> 	<p>Blunt</p> 	<p>Entry with any tapered tip or dimple indicating direction of true lumen is categorized as "tapered".</p>
		<p>Entry shape</p> <input type="checkbox"/> Tapered (0) <input type="checkbox"/> Blunt (1)
		point
<p>Calcification</p> 		<p>Regardless of severity, 1 point is assigned if any evident calcification is detected within the CTO segment.</p>
		<p>Calcification</p> <input type="checkbox"/> Absence (0) <input type="checkbox"/> Presence (1)
		point
<p>Bending >45degrees</p> 		<p>One point is assigned if bending > 45 degrees is detected within the CTO segment. Any tortuosity separated from the CTO segment is excluded from this assessment.</p>
		<p>Bending >45°</p> <input type="checkbox"/> Absence (0) <input type="checkbox"/> Presence (1)
		point
<p>Occlusion length</p> 		<p>Using good collateral images, try to measure "true" distance of occlusion, which tends to be shorter than the first impression.</p>
		<p>Occl.Length</p> <input type="checkbox"/> <20mm (0) <input type="checkbox"/> ≥20mm (1)
		point
<p>Re-try lesion</p> <p>Is this Re-try (2nd attempt) lesion ? (previously attempted but failed)</p>		<p>Re-try lesion</p> <input type="checkbox"/> No (0) <input type="checkbox"/> Yes (1)
		point
<p>Category of difficulty (total point)</p> <input type="checkbox"/> easy (0) <input type="checkbox"/> Intermediate (1) <input type="checkbox"/> difficult (2) <input type="checkbox"/> very difficult (≥3)		<p>Total</p> <div style="background-color: #ccc; width: 20px; height: 20px; display: inline-block;"></div> points

CT-RECTOR score

N=240

Predictors Definitions

Multiple Occlusion



Presence of ≥2 complete interruptions of the contrast opacification separated by contrast-enhanced segment of ≥5 mm.

Multiple Occlusion

- Presence (1)
- Absence (0)

Blunt Stump

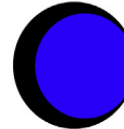


Absence of any tapered stump at the entry or exit site.

Blunt Stump

- Presence (1)
- Absence (0)

Severe Calcification

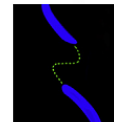


Presence of any calcium involving ≥50% of the vessel cross-sectional area at the entry or exit site or within the occlusion route.

Severe Calcification

- Presence (1)
- Absence (0)

Bending ≥45°



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

Bending ≥45°

- Presence (1)
- Absence (0)

Second Attempt

Previously failed PCI at CTO

Second Attempt

- Yes (1)
- No (0)

Duration of CTO

Duration of CTO ≥12 months or unknown

Duration of CTO

- Yes (1)
- No (0)

Difficulty Group

- Easy (0)
- Intermediate (1)
- Difficult (2)
- Very Difficult (≥3)

Total Score



Korean CTO CT multicenter registry

- N ~ 500
- Comprehensive analysis of CT, CAG, and the result of PCI

Take home message

1. Coronary CT may reveal important findings which can be missed by plain CAG (coronary CT = **non-invasive CAG + IVUS**).
2. CT helps you to **understand the whole coronary artery tree**, and may help your **CTO PCI procedure**.
3. Review **coronary CT as well as CAG** before CTO PCI. It may be helpful for planning of wire advancement and complex PCI procedure.

