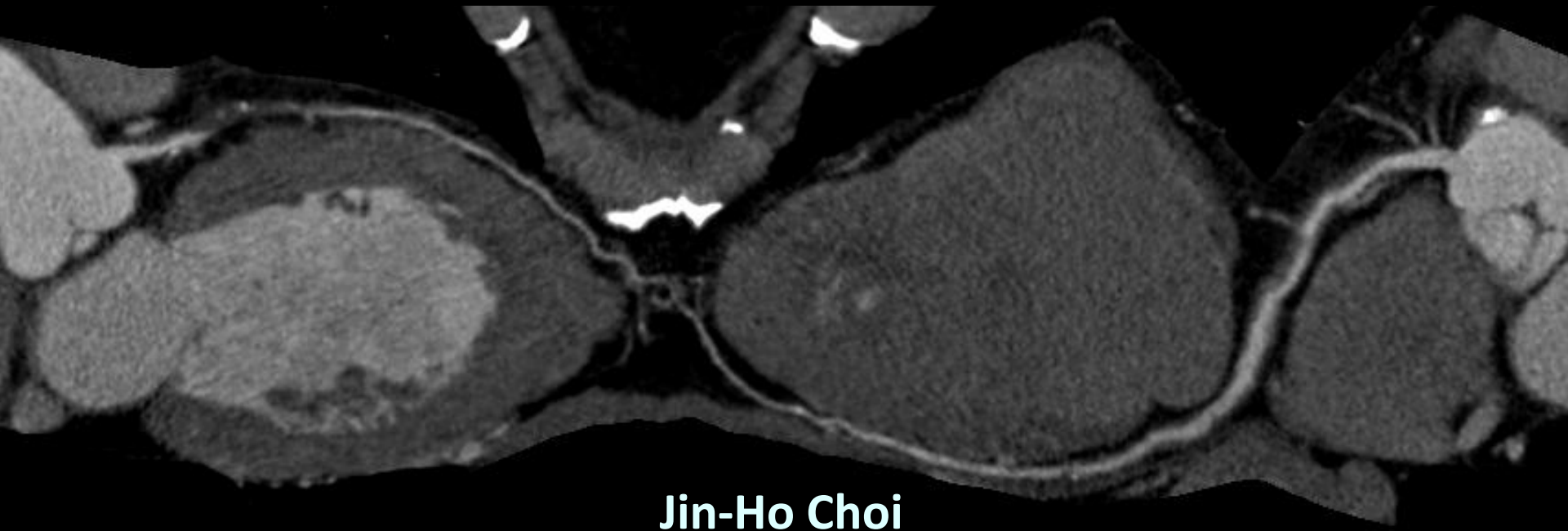
Pathophysiology of CTO

- Based on CT image -



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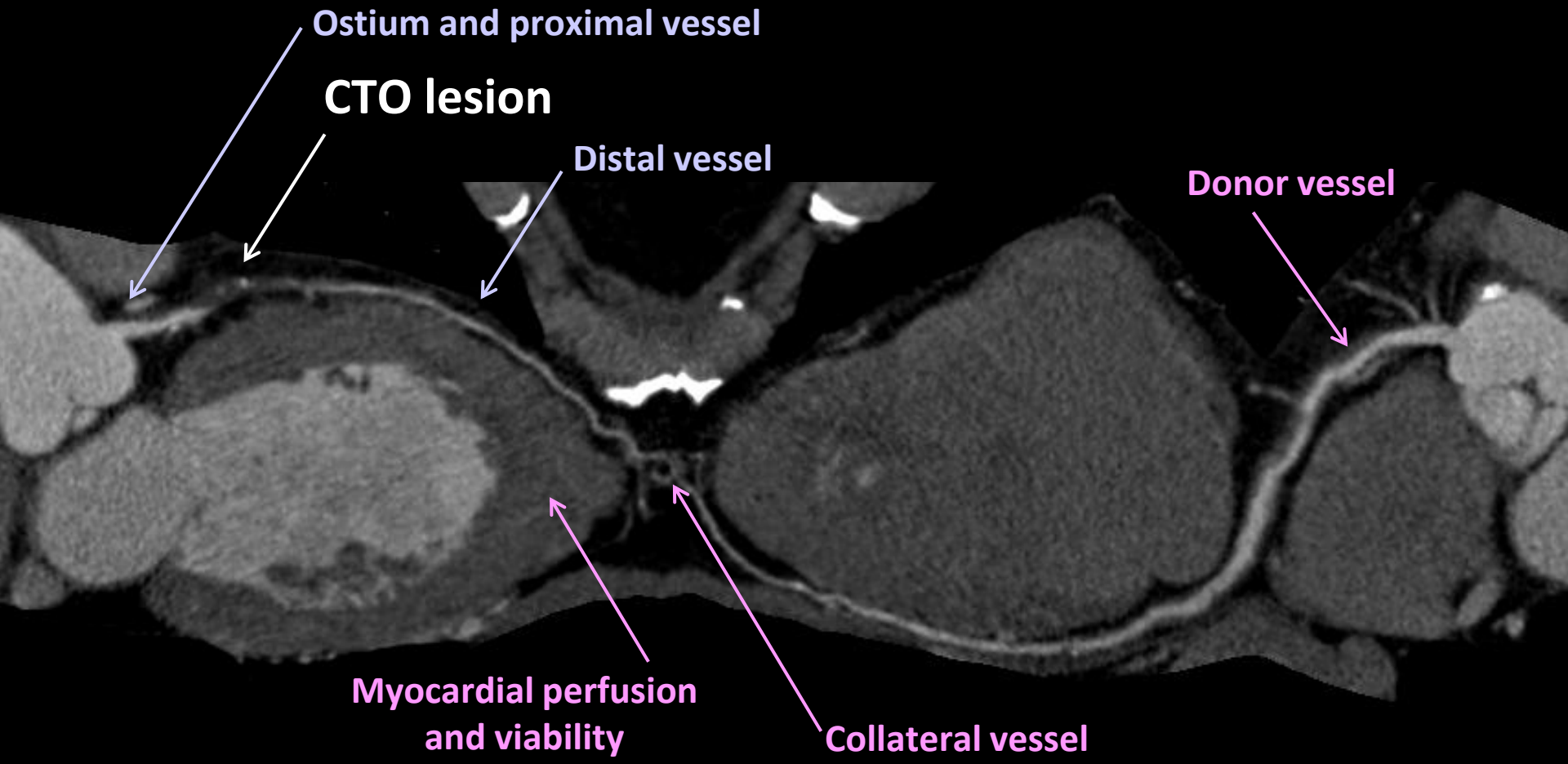
2014-12-13, JCR CCT 2014, Busan, Korea

Why we need CT for CTO PCI

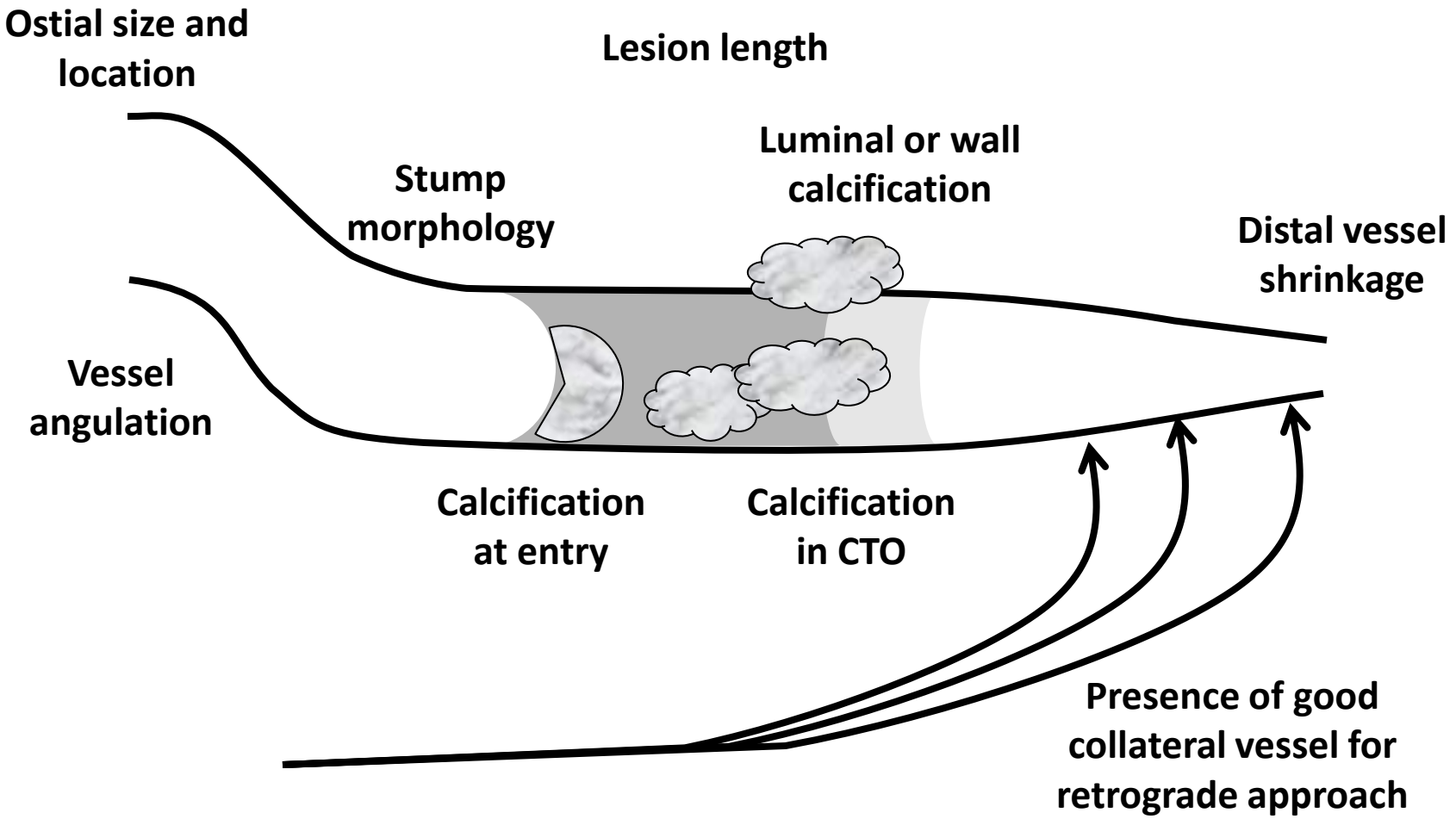
CT can tell **something** better than CAG !


CTO lesion

CT enables systematic evaluation of coronary artery and myocardium

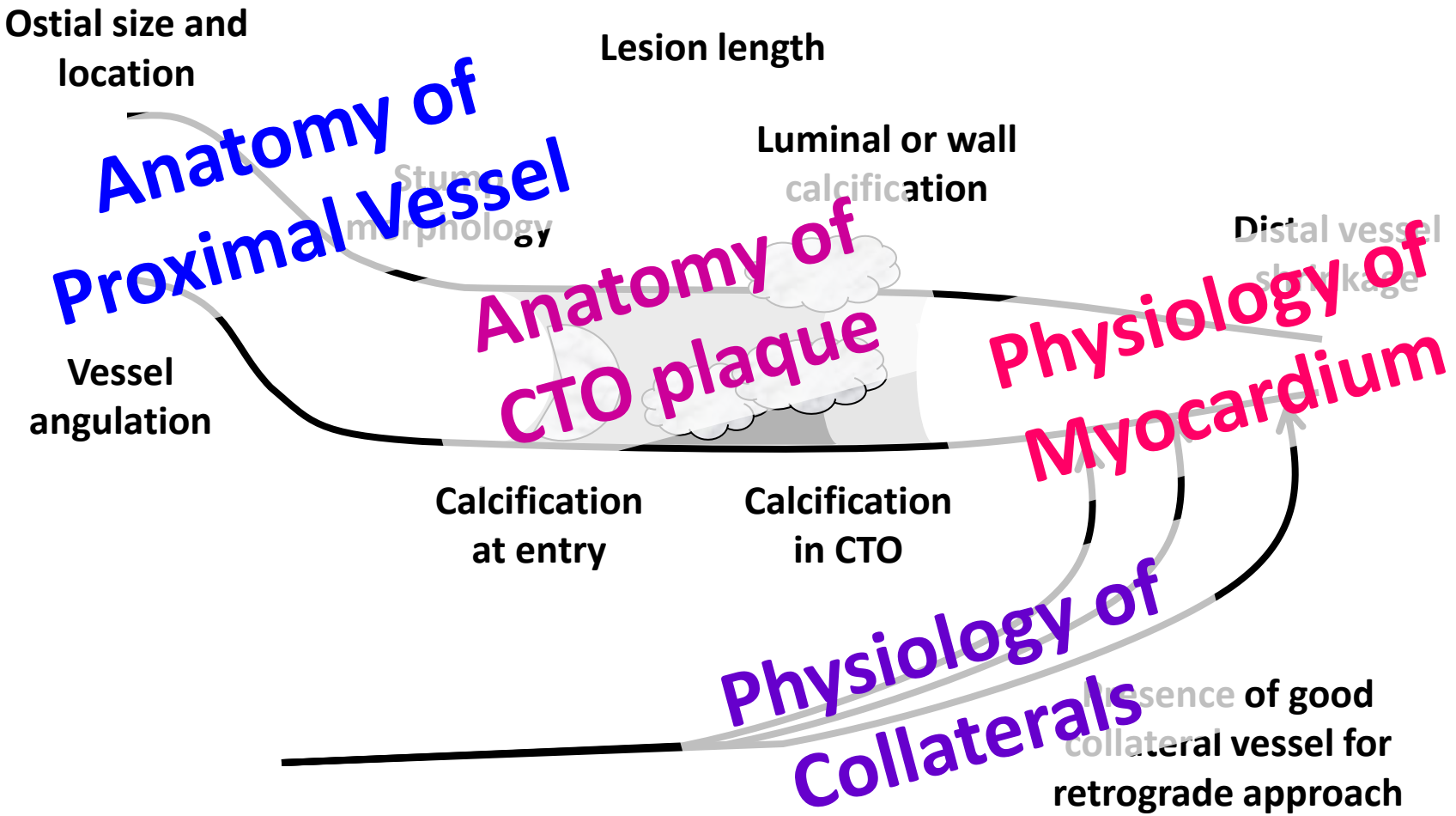


CT evaluates whole vessel anatomy



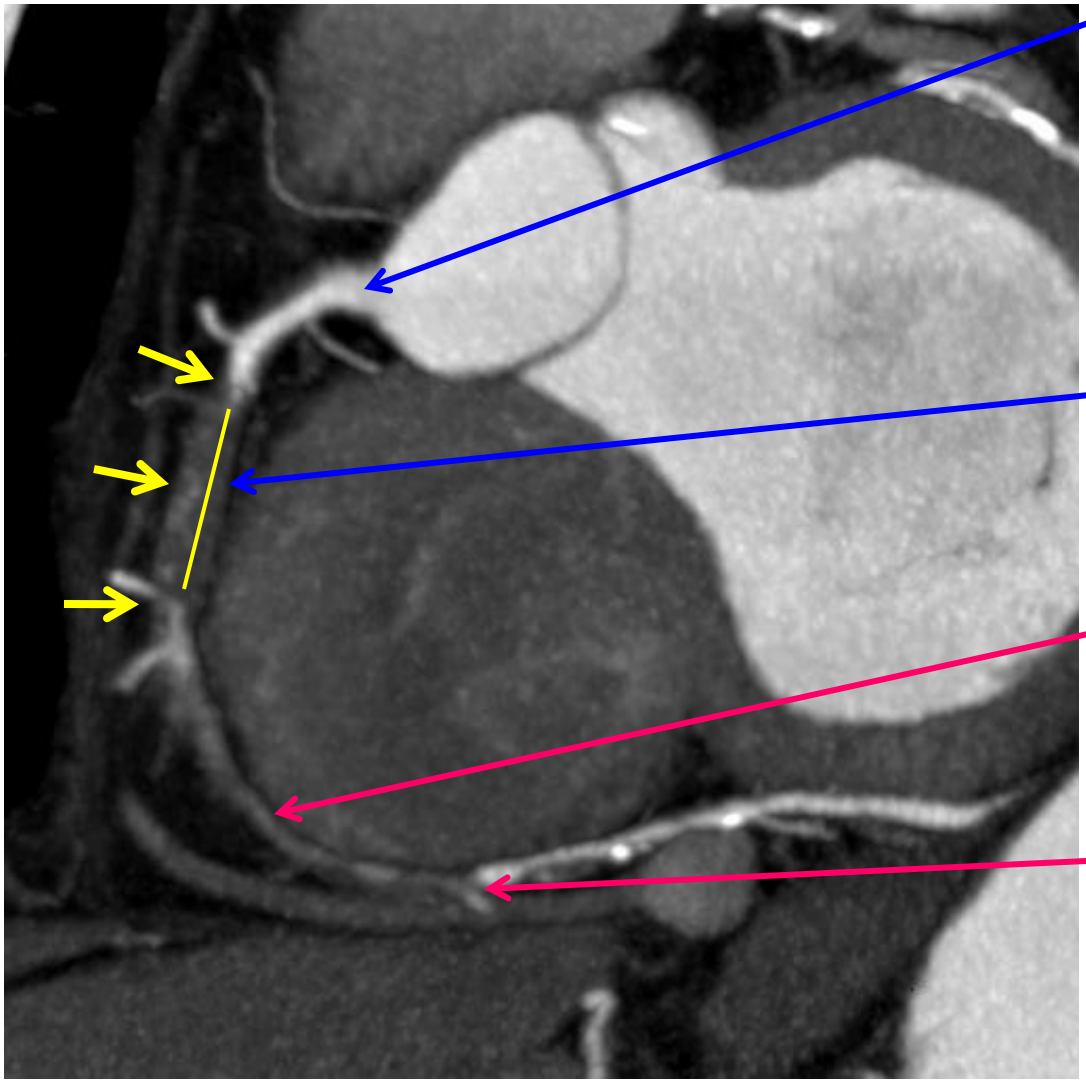
Modified from Feyter, Niemann, EuroPCR 2011

Information available from coronary CT



Modified from Feyter, Niemann, EuroPCR 2011

Ostium and vessel proximal to CTO



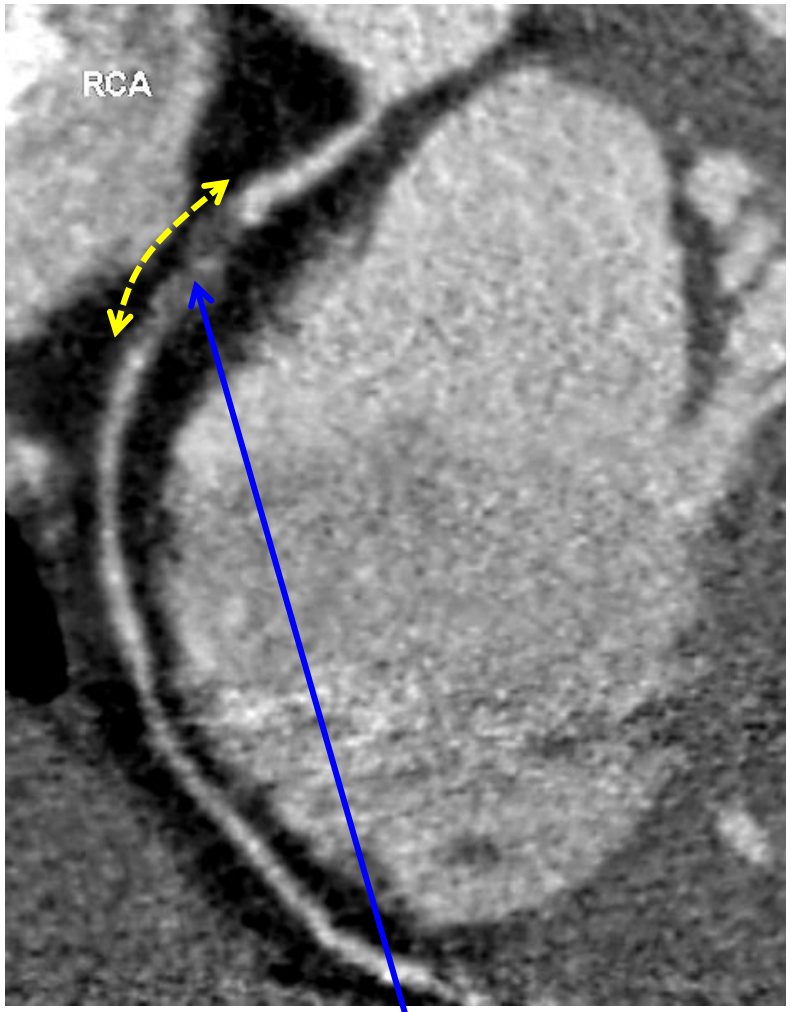
Long and fairly large ostium (7 or 8Fr GC is OK)

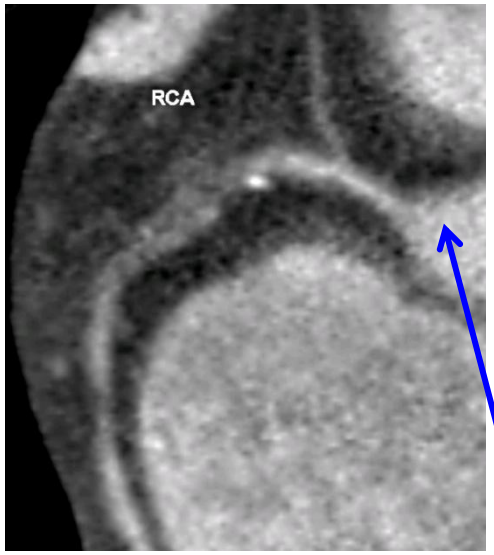
Straight and positively remodeled mid RCA

Negatively remodeled distal RCA

Distal RCA: small size and bifurcation near exit site

Ostium and vessel proximal to CTO





Relatively short CTO

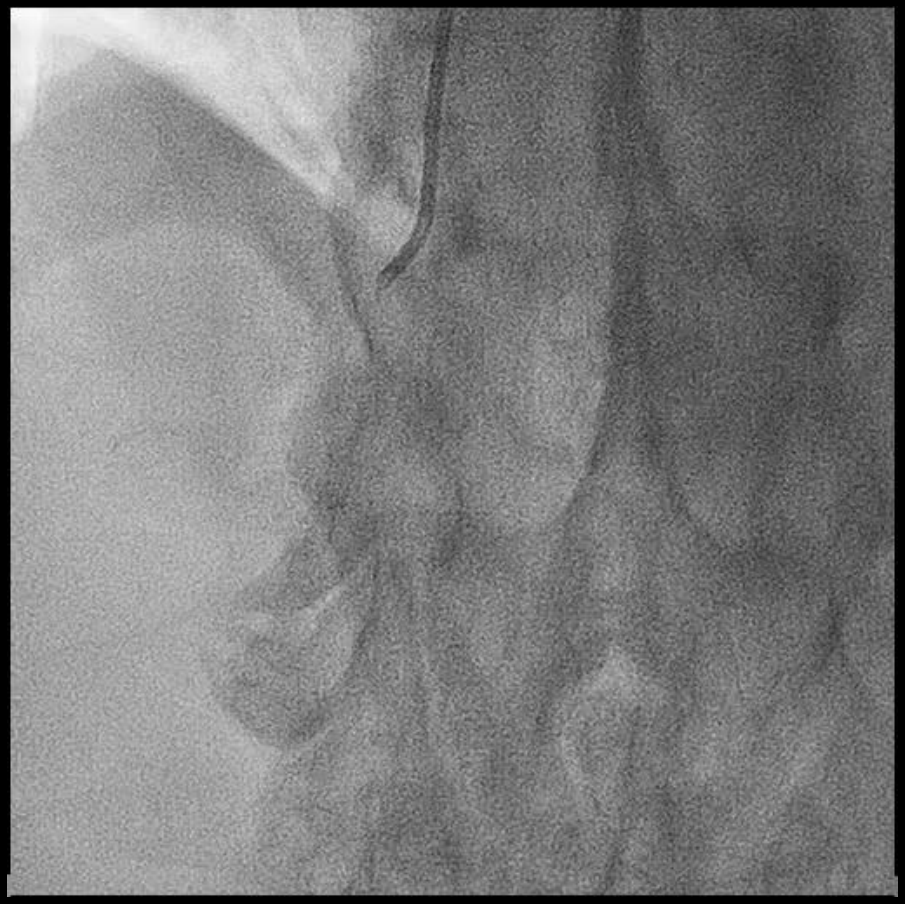
Ostium is relatively small and upward

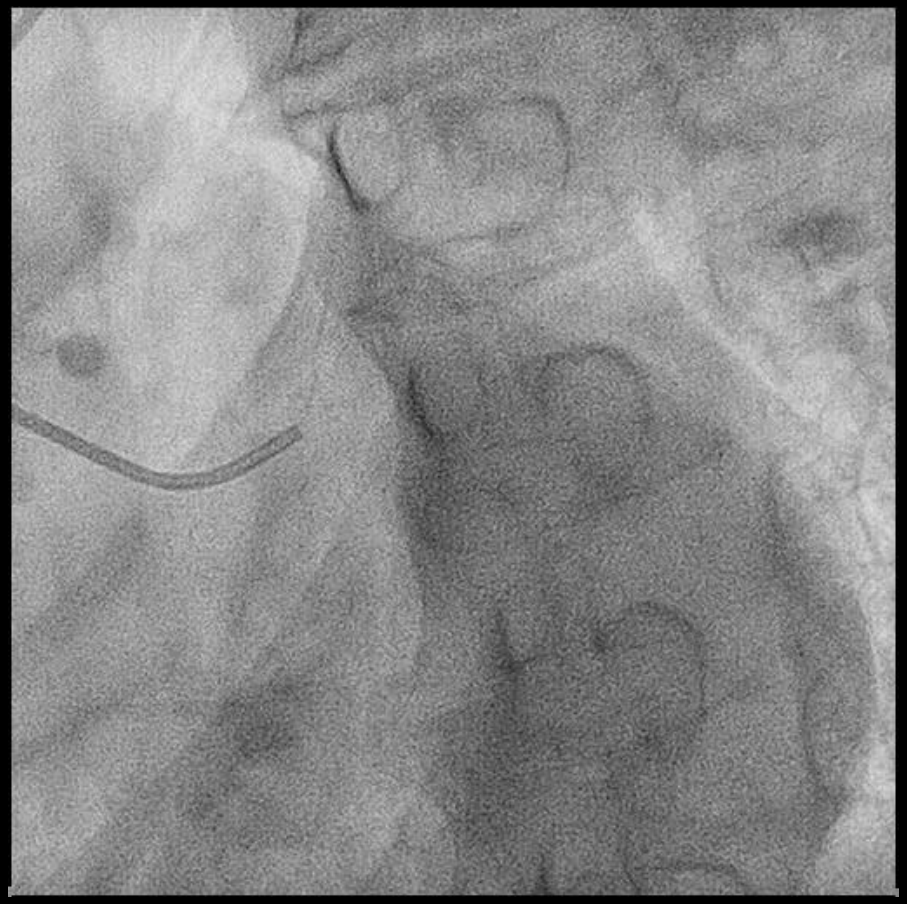
→ use guiding catheter with side hole or small size (5 or 6 Fr)

→ Amplatz or XB-type would be preferred than Judkin Rt

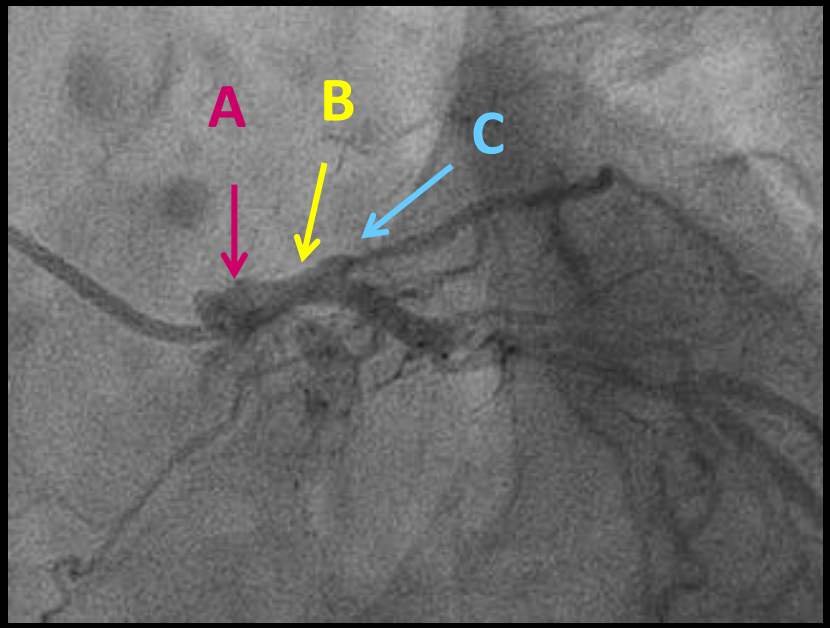
Aorto-ostial CTO - invisible vessel ostium

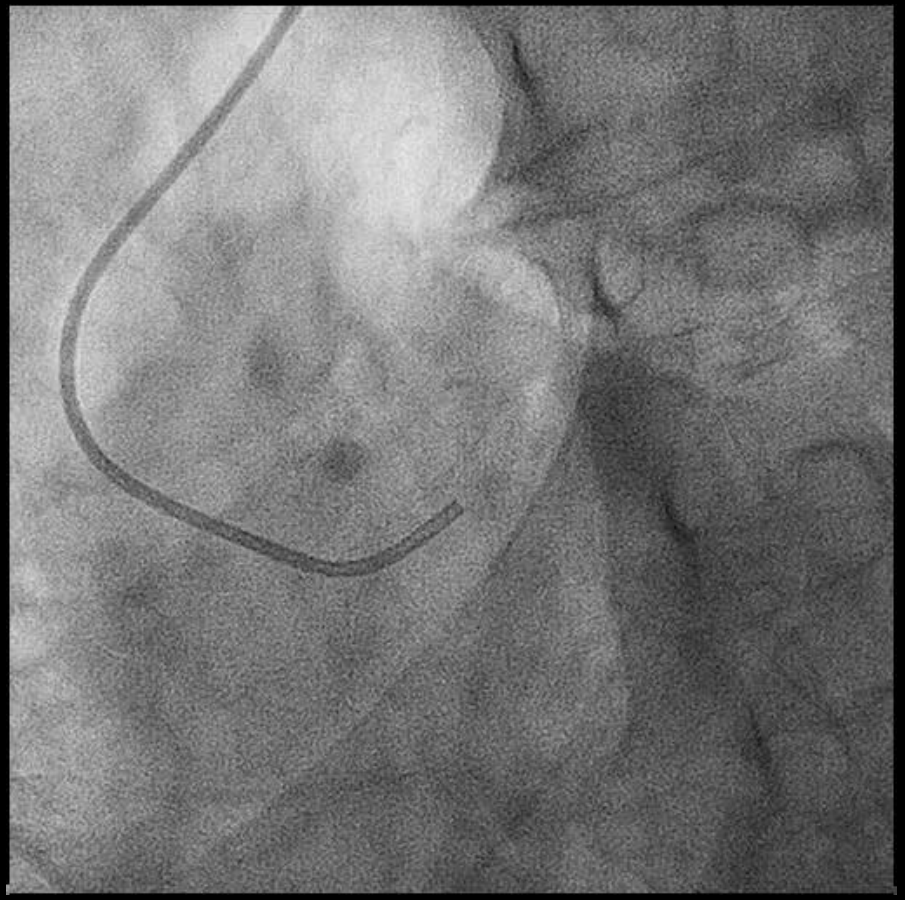
CAG



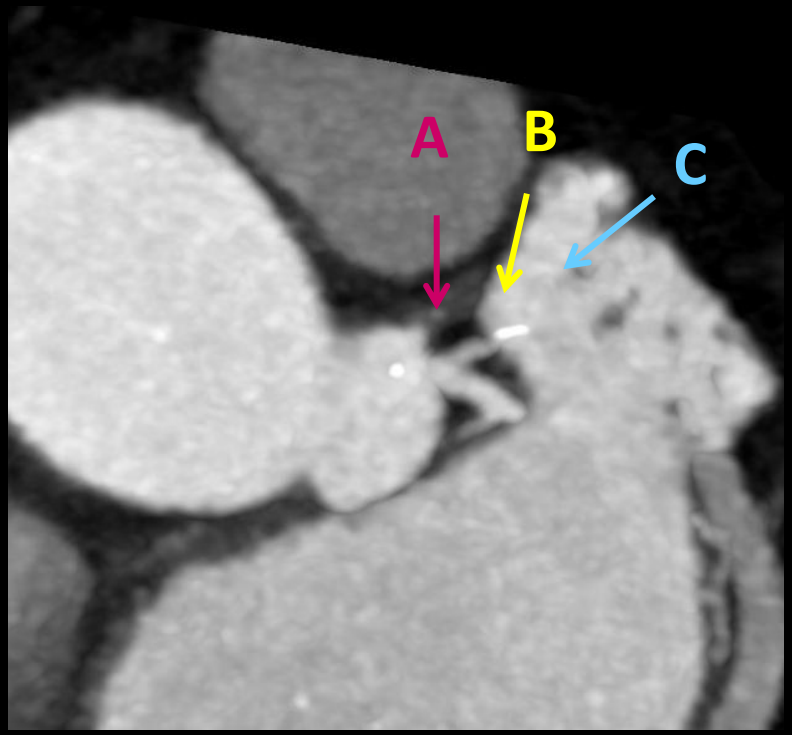


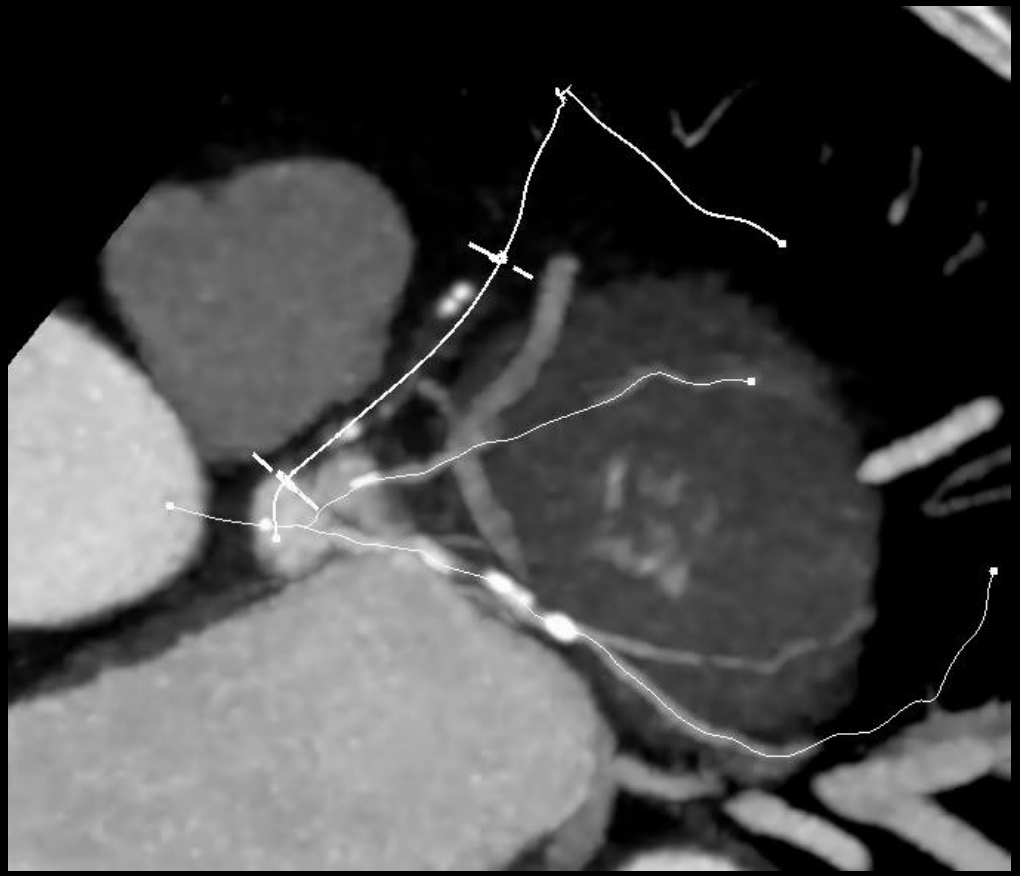
Where is LAD ostium ?



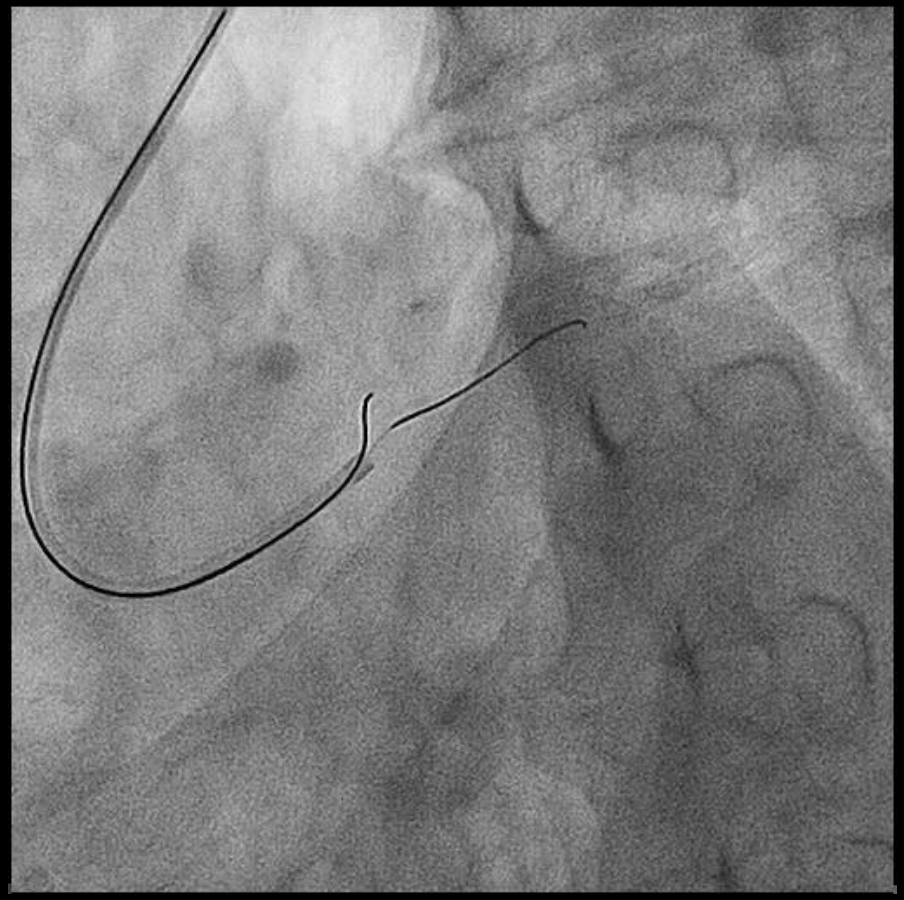


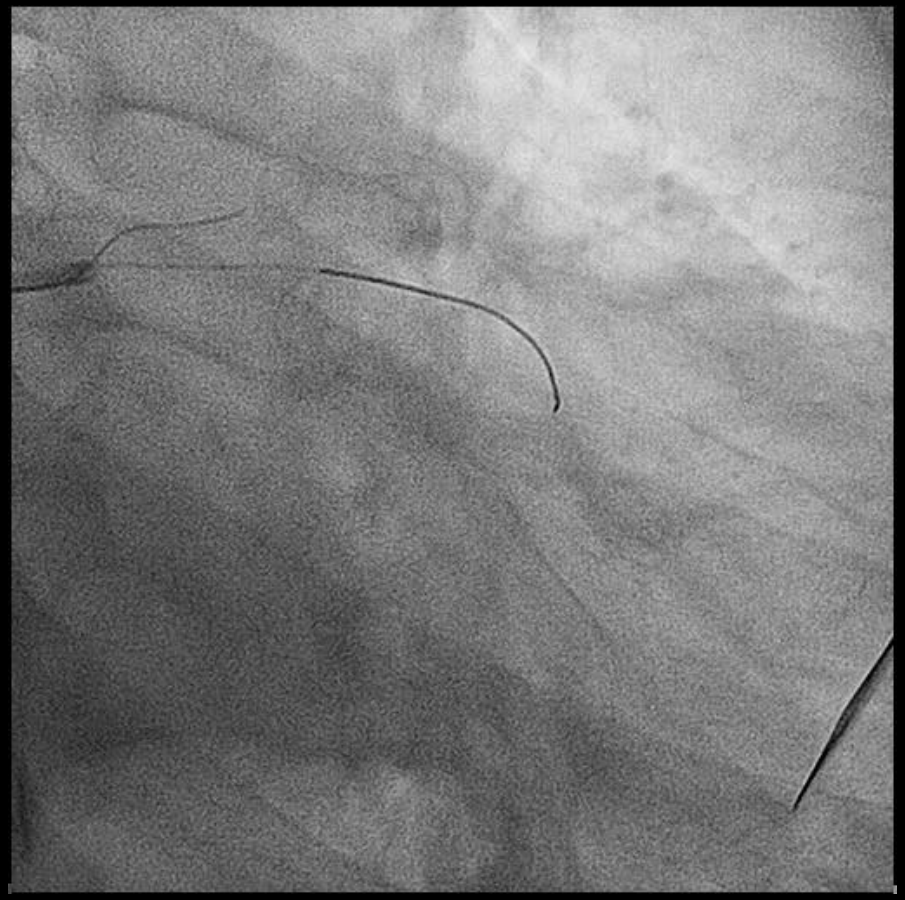
CT revealed nearly hidden separated LAD ostial total occlusion





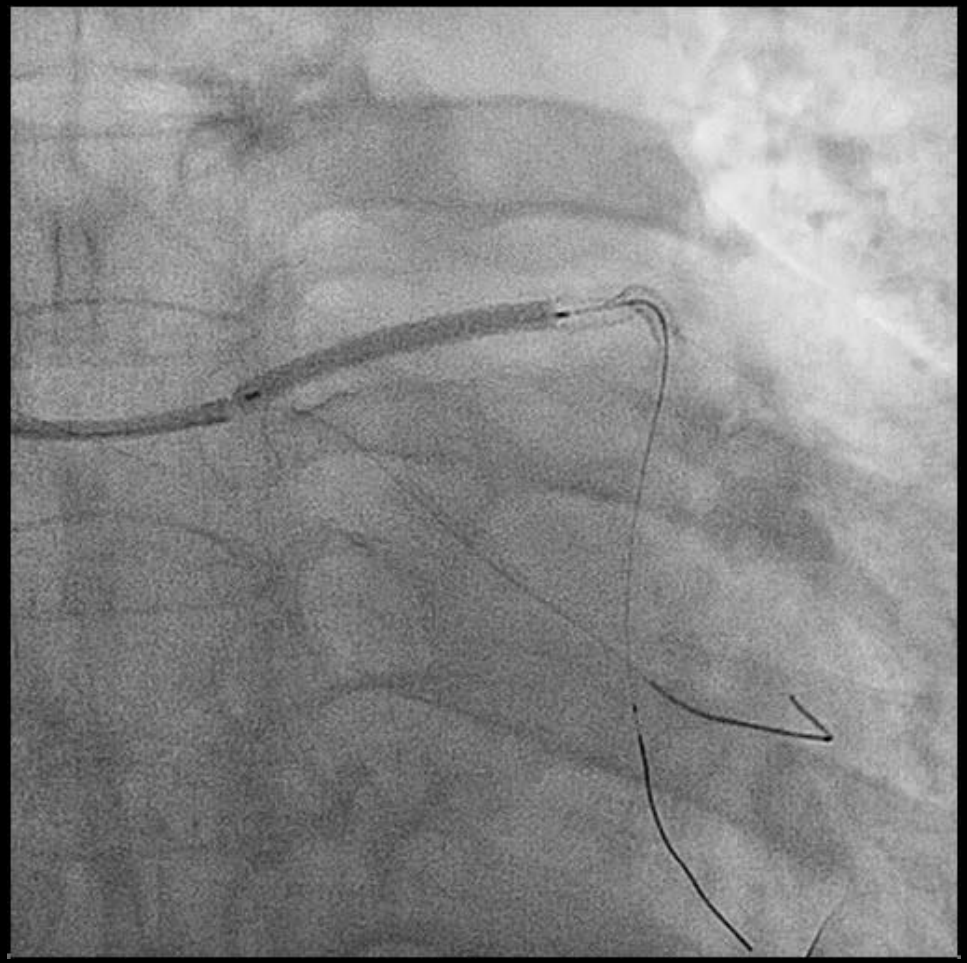
CT-guided intentional puncture of LM ostium CTO (not aortic wall)

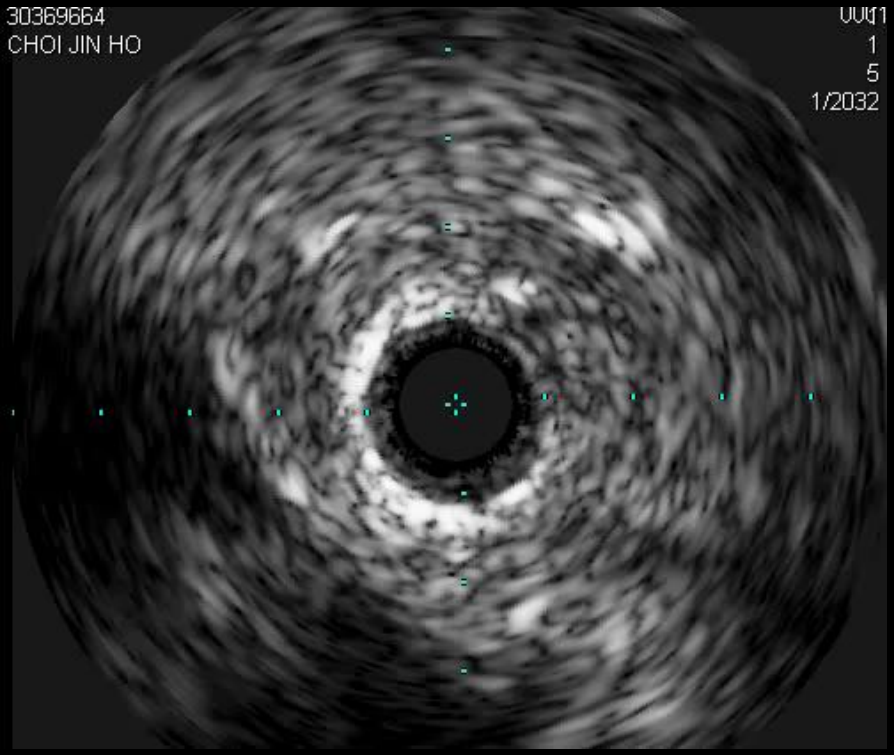




LCX: Sion, LAD: Ultimate 3 → Fielder XT → Miracle 6

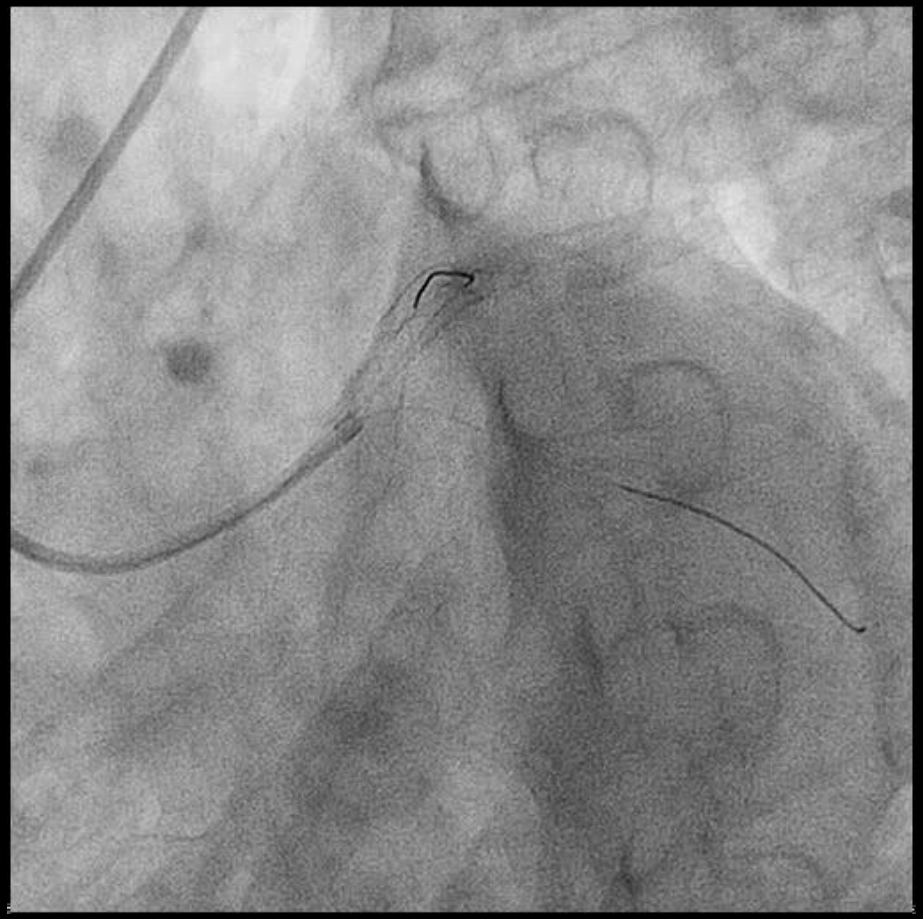
One-stage PCI

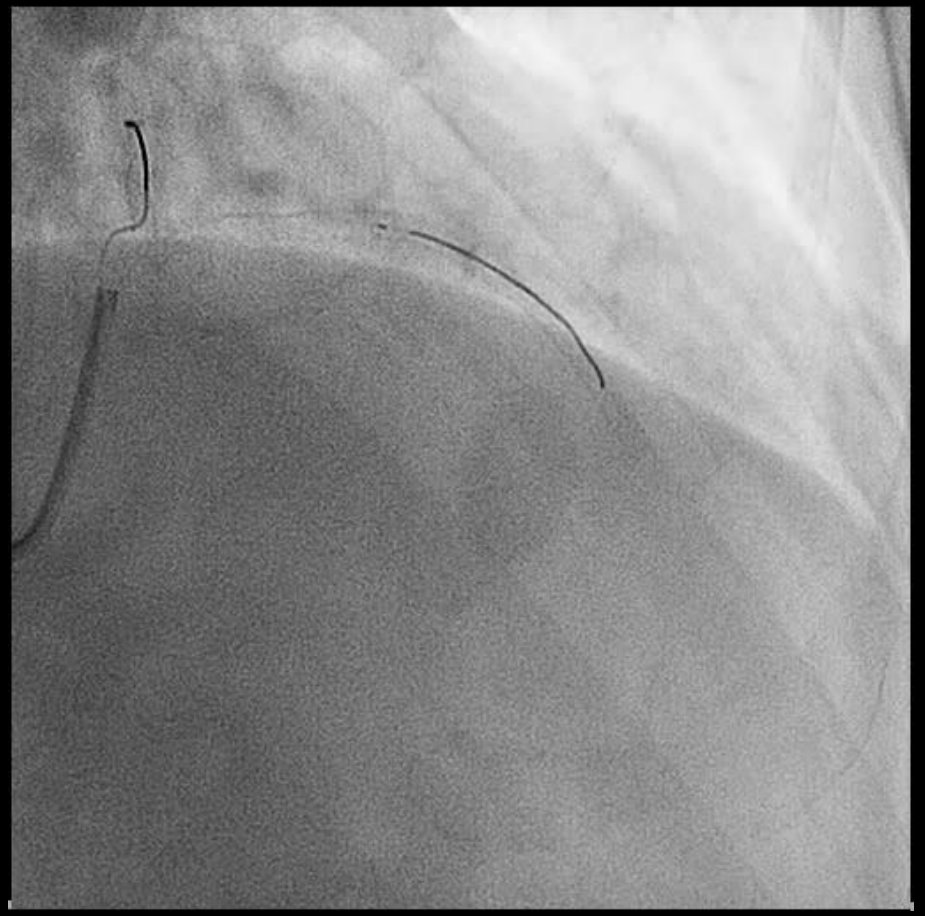




2.75x33mm Xience Prime, post VH-IVUS (x2 speed, 60 FPS)

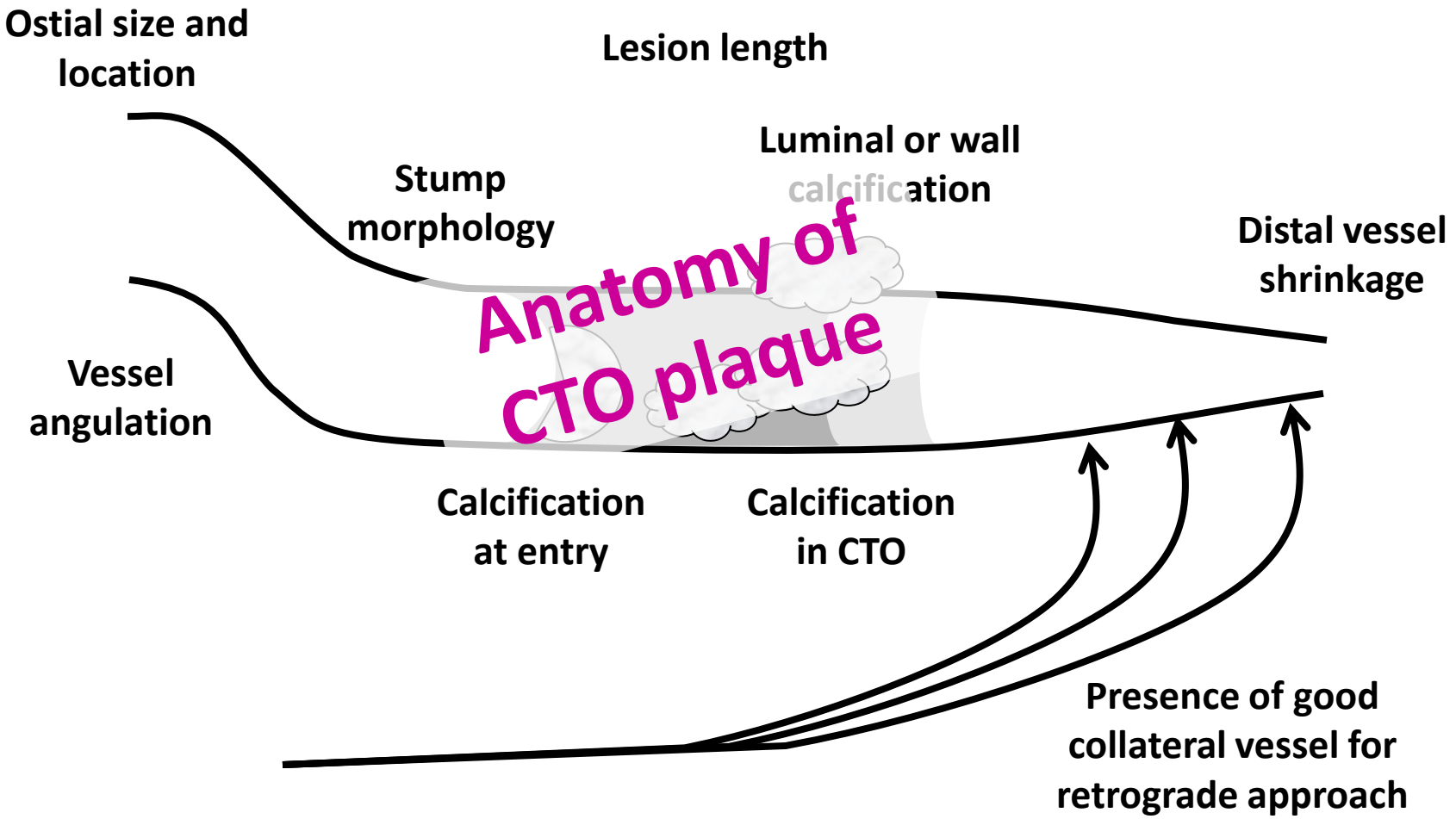
One-stage PCI





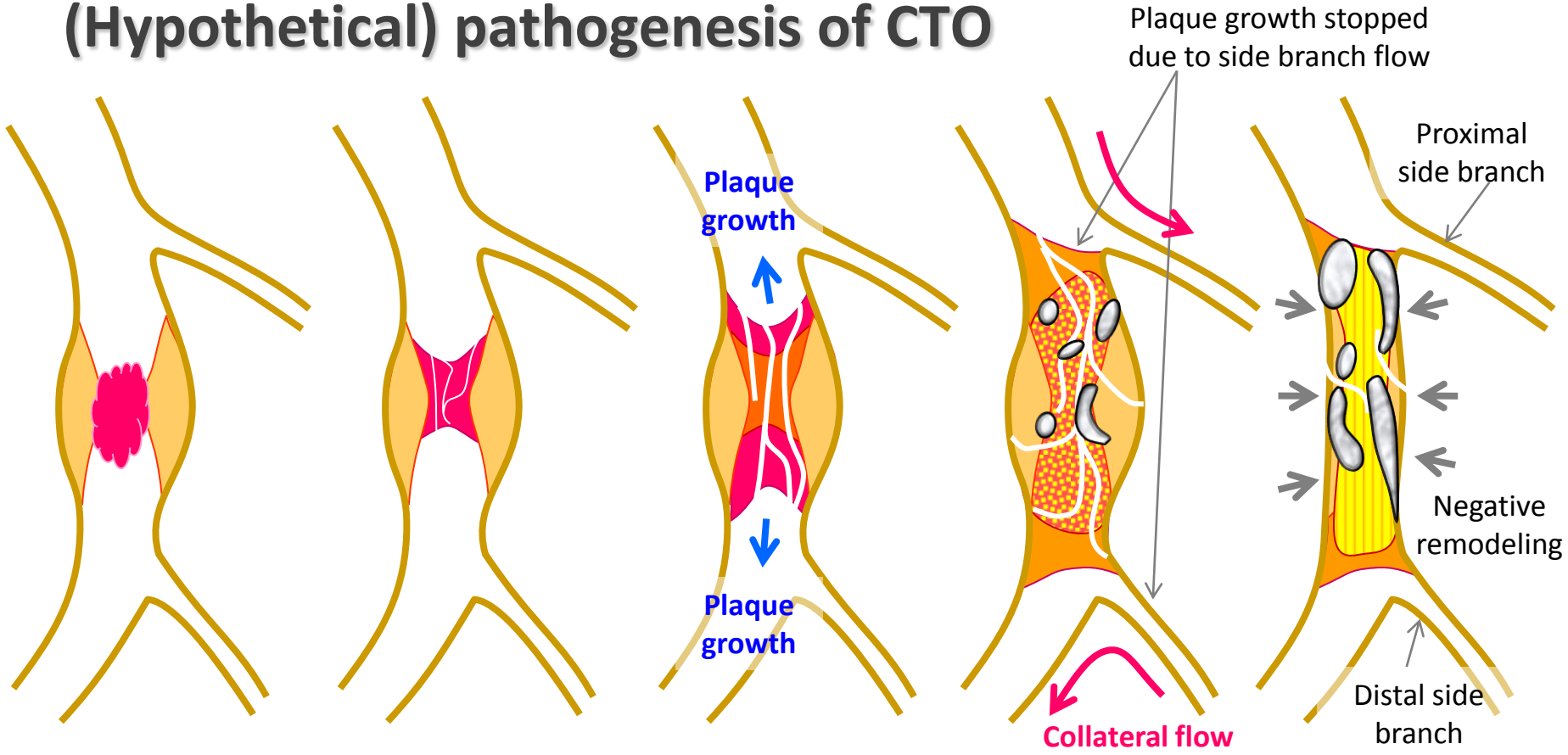
Final

Information available from coronary CT



Modified from Feyter, Niemann, EuroPCR 2011

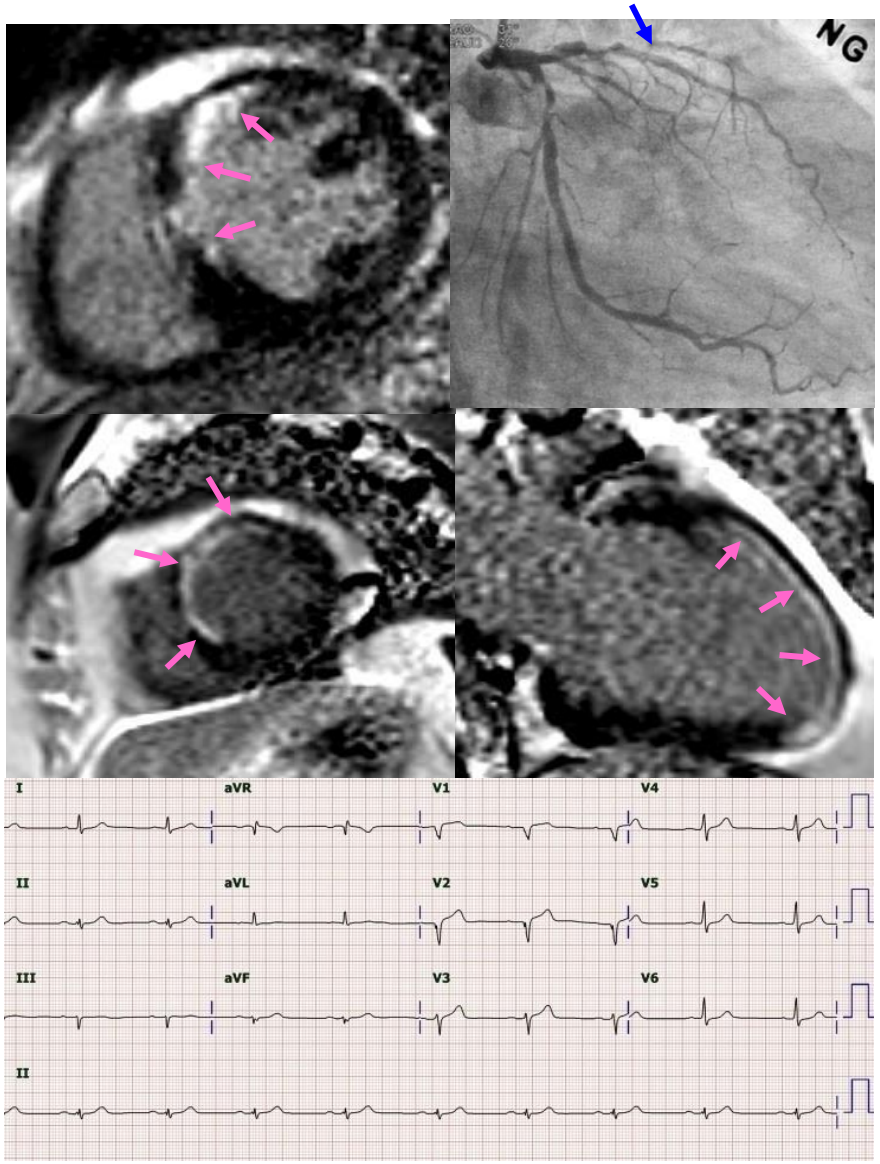
(Hypothetical) pathogenesis of CTO



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

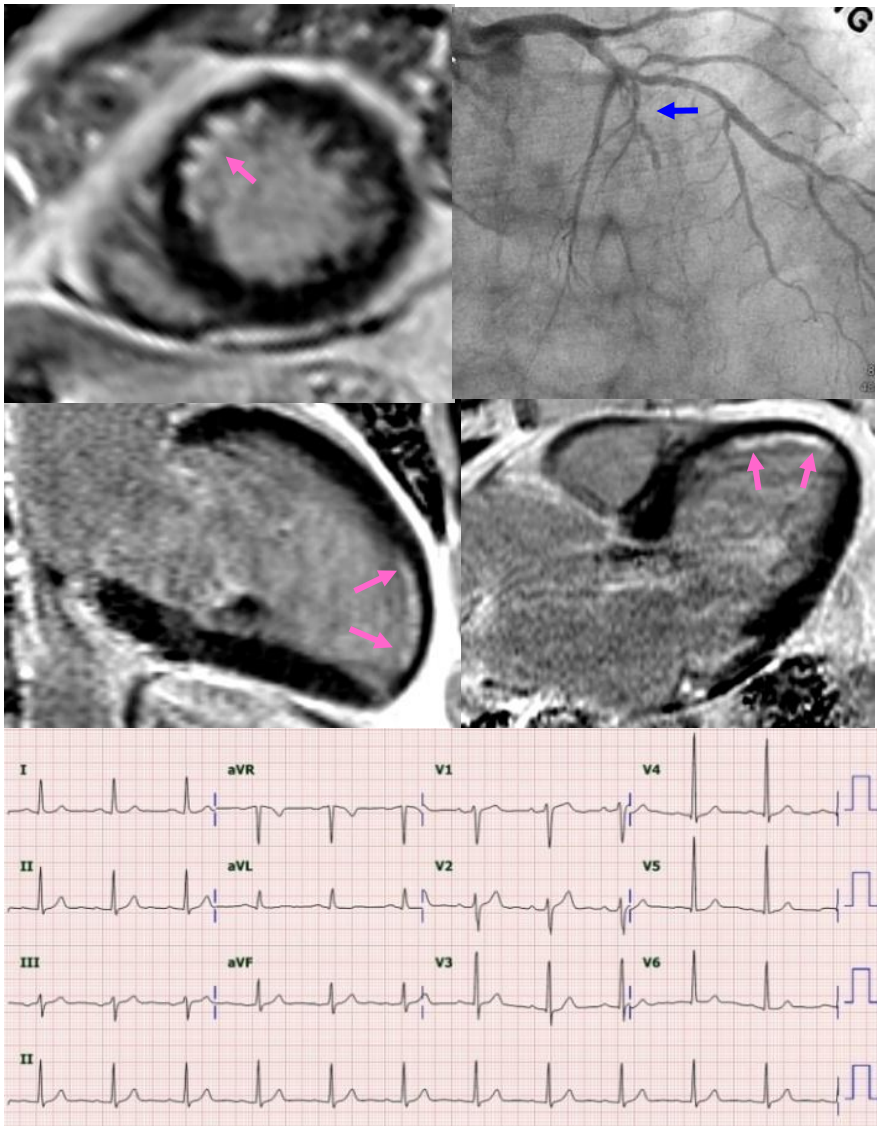
Modified from Feyter, Niemann, EuroPCR 2011; Sumitsuji, JACC Interv 2012

Representative case (4): Q wave (+), RWMA (+), and DHE (+)



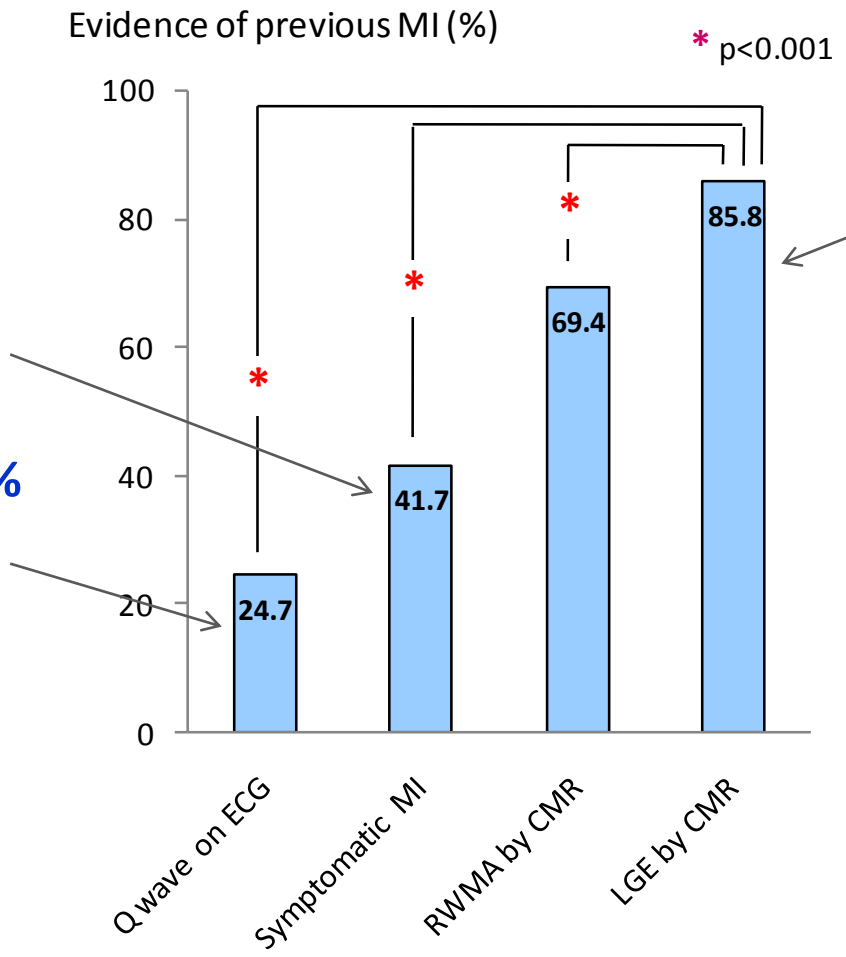
Choi, Circulation 2013

Representative case (2): no Q wave, no RWMA, but DHE (+)



Choi, Circulation 2013

Evidence of prior MI in CTO: discrepancy among diagnostic modalities



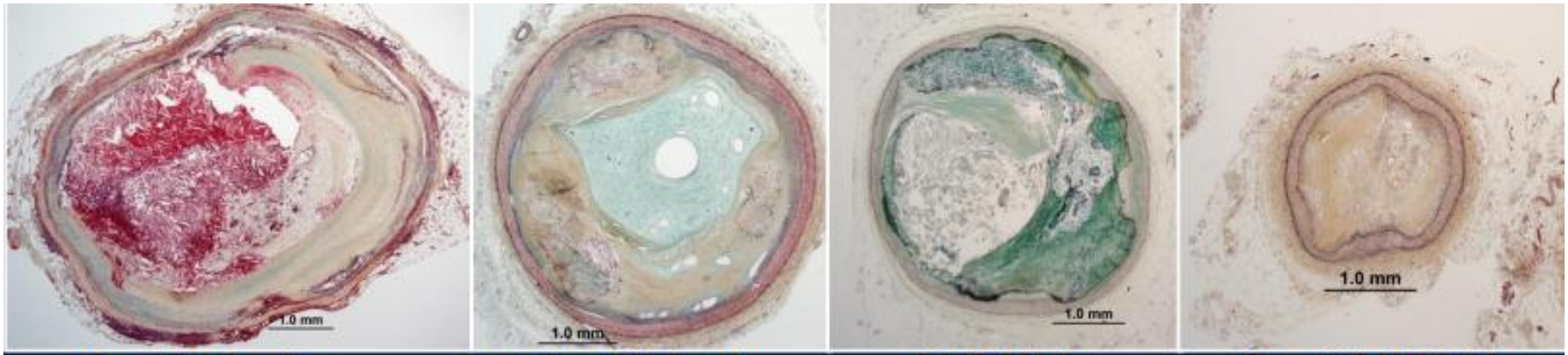
History of prior MI in 42%

EKG Q wave in 25%

Old MI scar in 86%

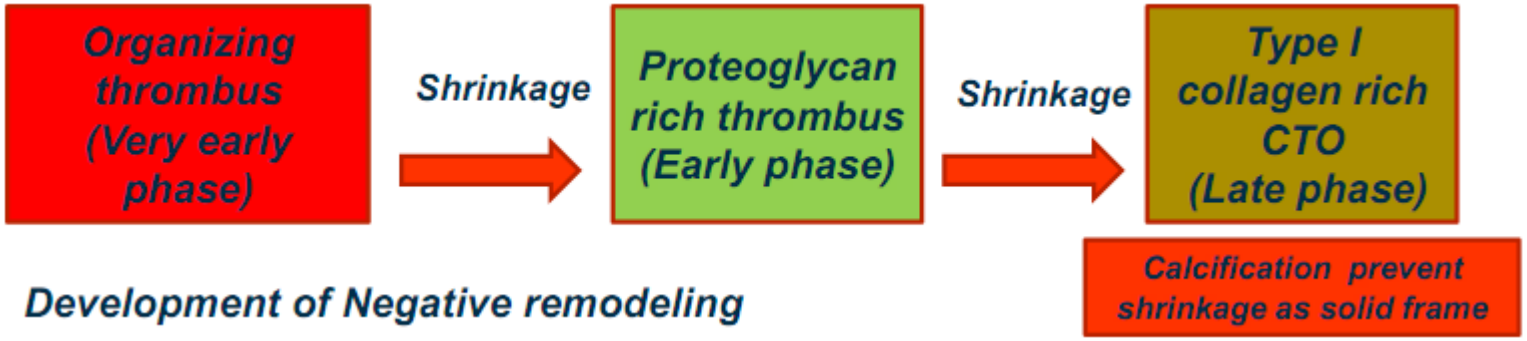
Choi, Circulation 2013

CTO age-dependent change of CTO plaque



Organizing thrombus	*Proteoglycan rich thrombus*	*Calcified CTO*	*Non-calcified CTO rich in type I collagen*

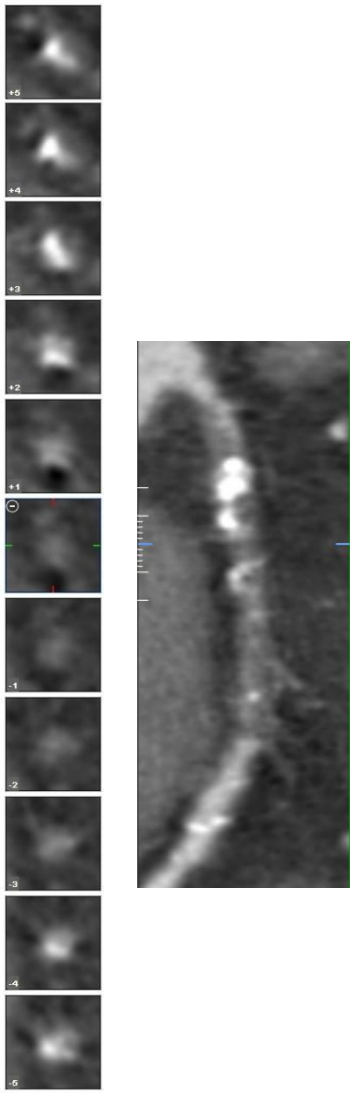
Lesion analysis	Organizing thrombus n=46	Proteoglycan rich thrombus n=82	Calcified CTO (≥10% calcification area) n=186	Non-calcified CTO rich in collagen (<10% calcification area) n=232	P value
Remodeling index	0.99 (0.75-1.35) †	0.77 (0.61-1.03) ‡	0.79 (0.56-1.15) §	0.63 (0.47-0.86)	<0.001



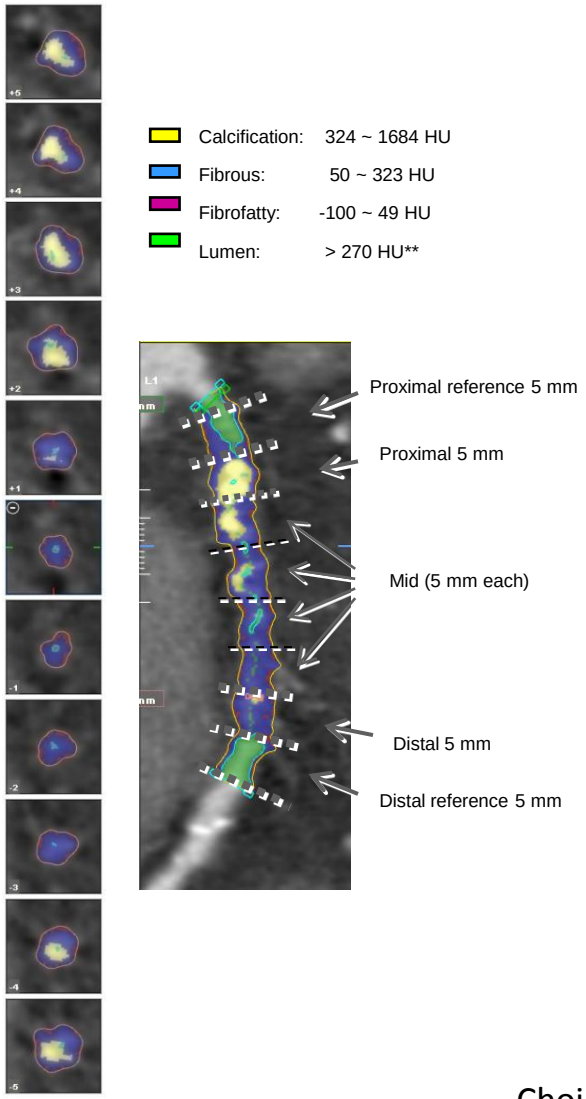
Sakakura, Eur Heart J 2013, Srivatsa, JACC 1997

CTO plaque analysis based on CT HU values

Curveplanar reconstructed (CPR)



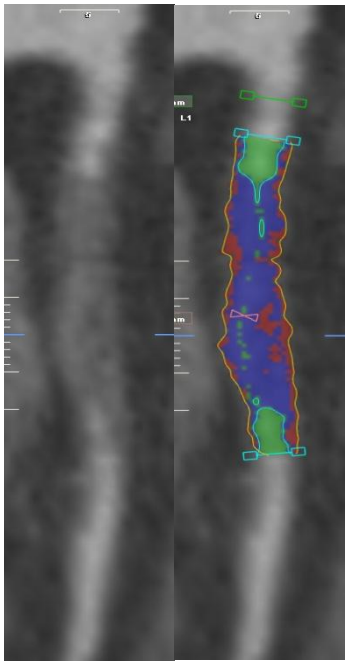
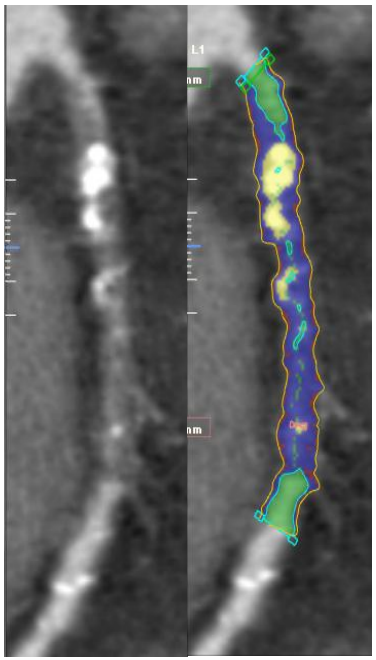
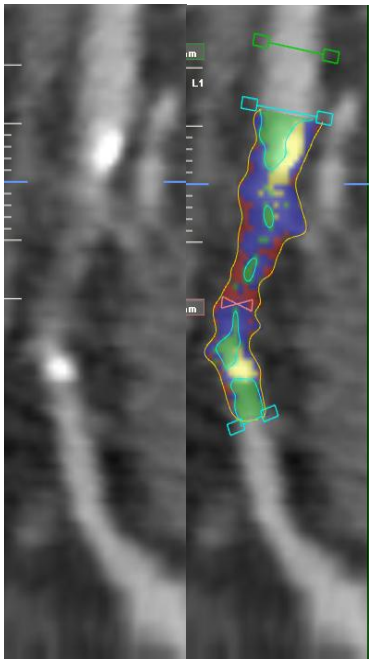
3D-volumetric analysis by Sureplaque™



Choi, Circ J 2011

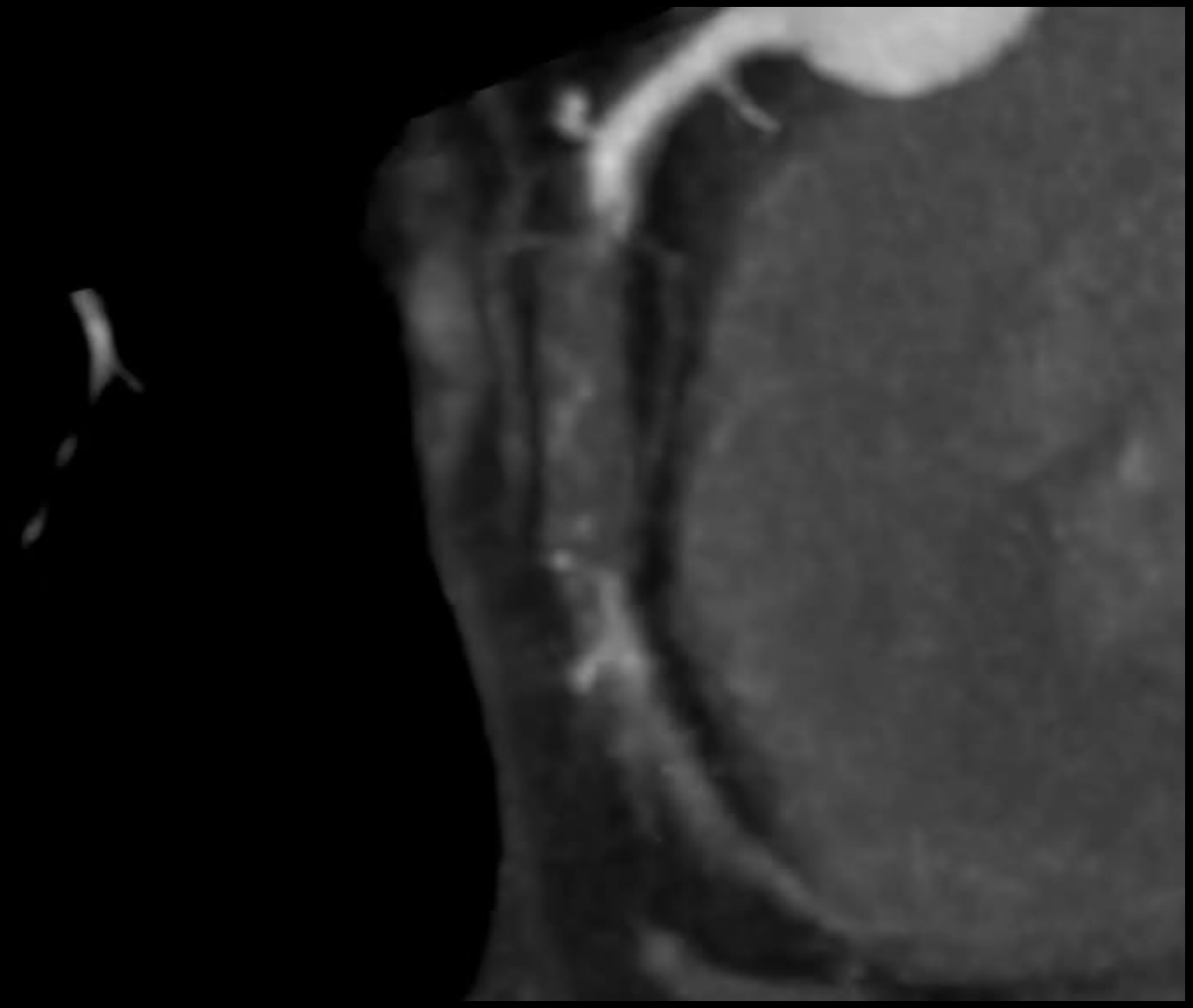
Remodeling pattern of CTO plaque

CTO lesion:
N = 186

	Positive remodeling	Neutral	Negative remodeling
			
CTO ≤ 1 yr	**35.4%**	7.6%	57.0%
CTO > 1 yr	16.5%	5.0%	**78.5%**

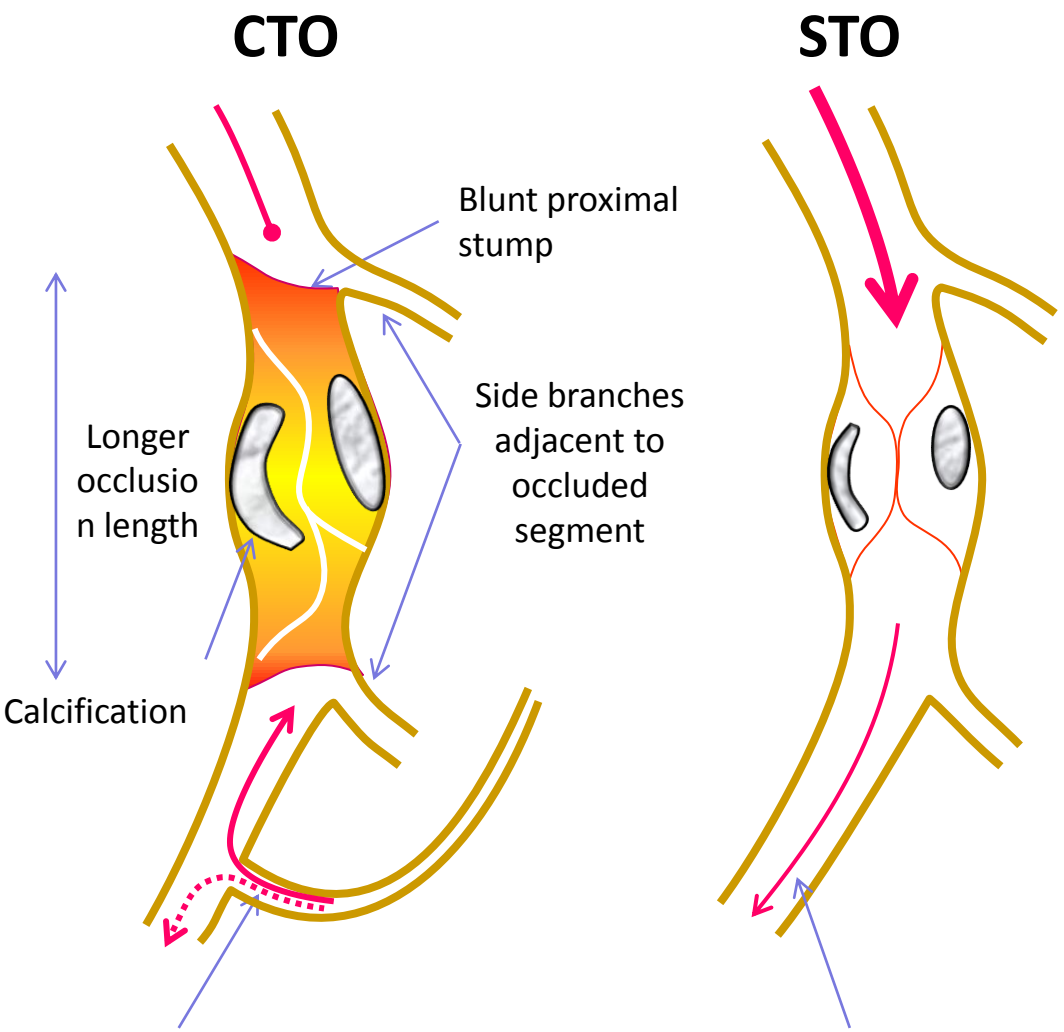
Choi, Circ J 2011

CTO is "Inter-Bifurcation" disease



SMC CTO registry, unpublished

Non-invasive discrimination of true CTO and pseudo CTO (or subtotal)

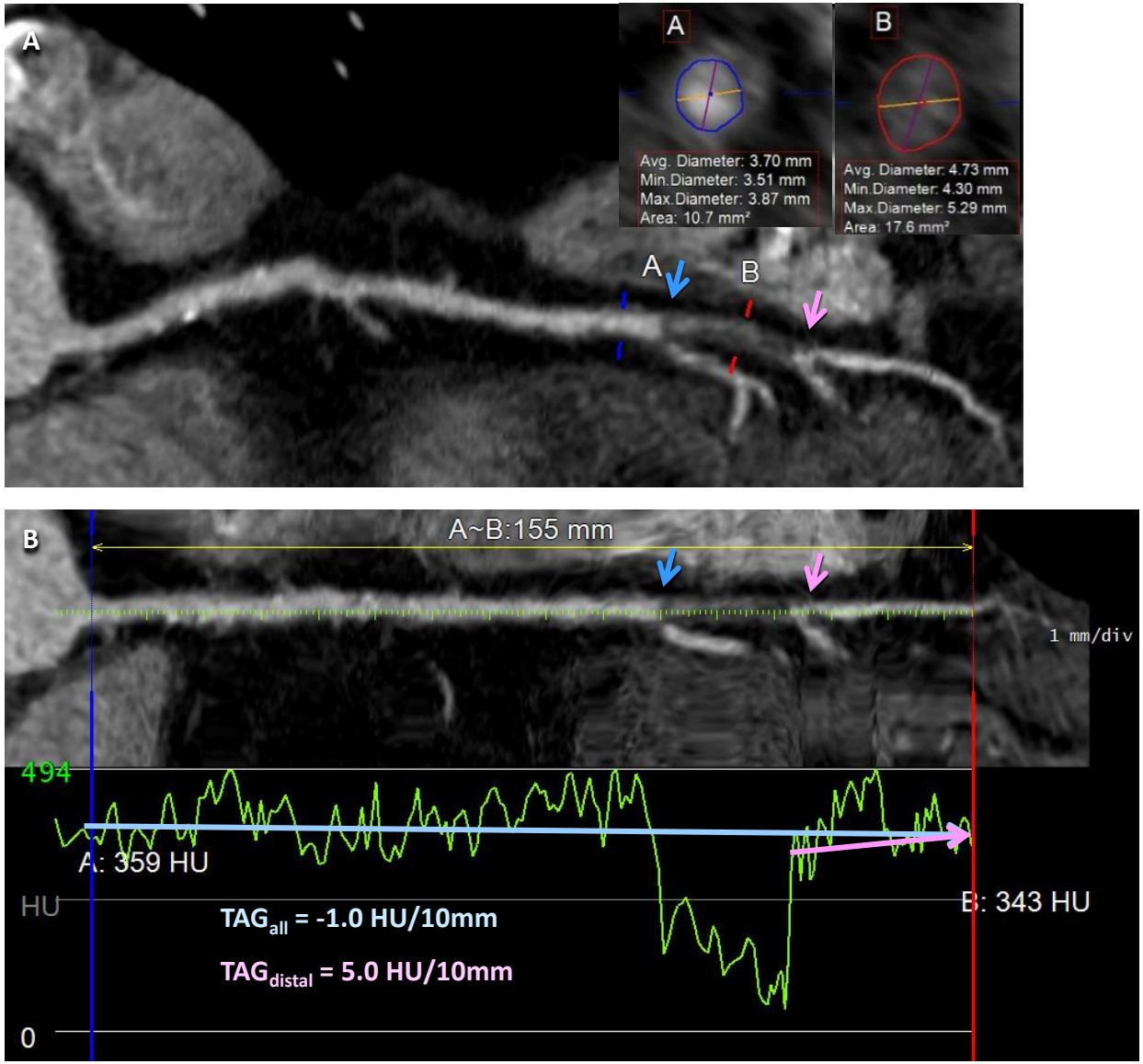


Higher collateral flow through well-developed collateral vessel that flows in antegrade or retrograde direction

Less distal arterial flow compared to vessel with CTO

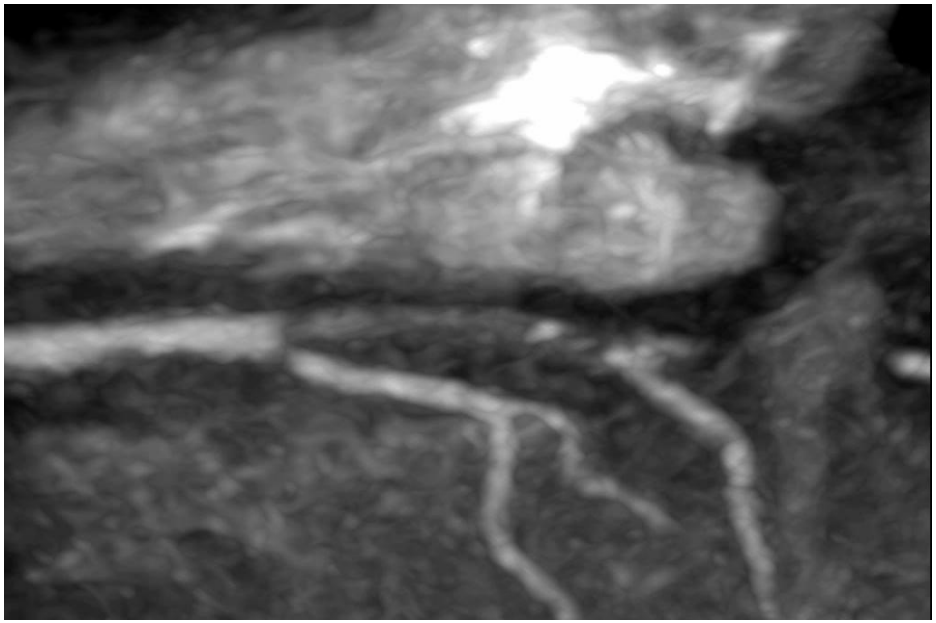
Kim EK, Choi JH et al., In revision

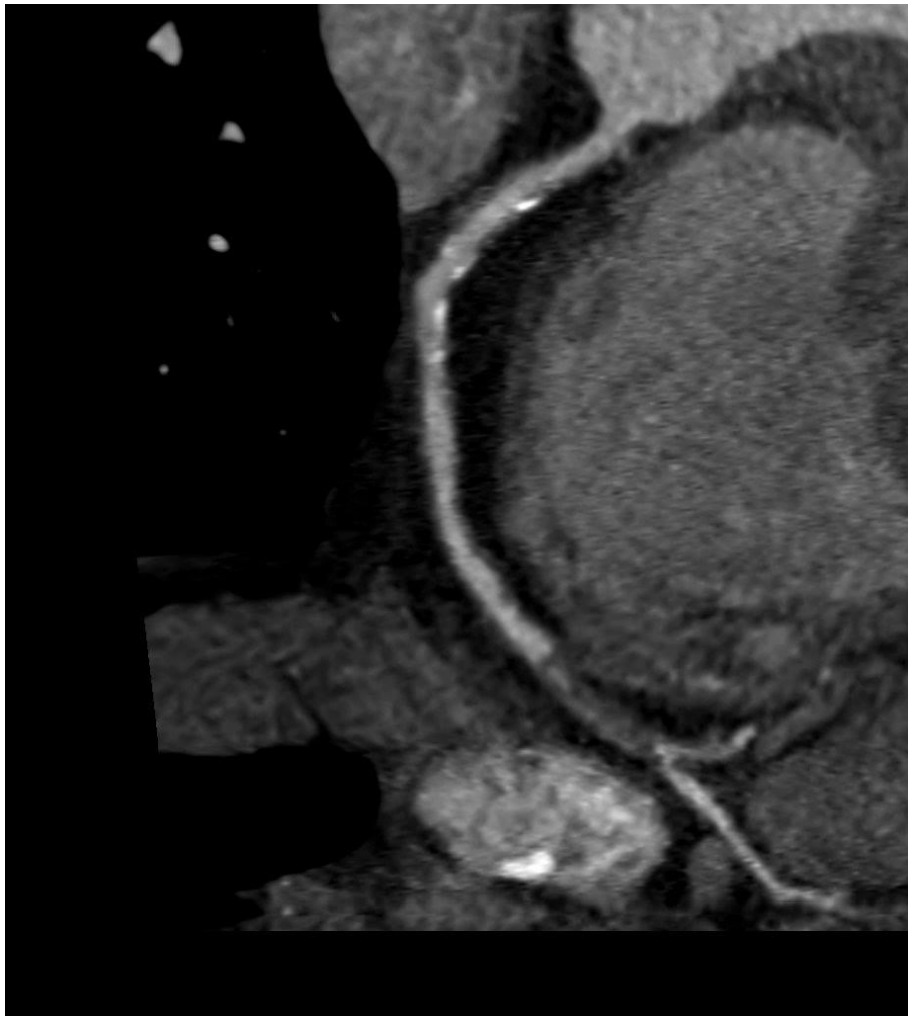
True CTO



SMC educational file

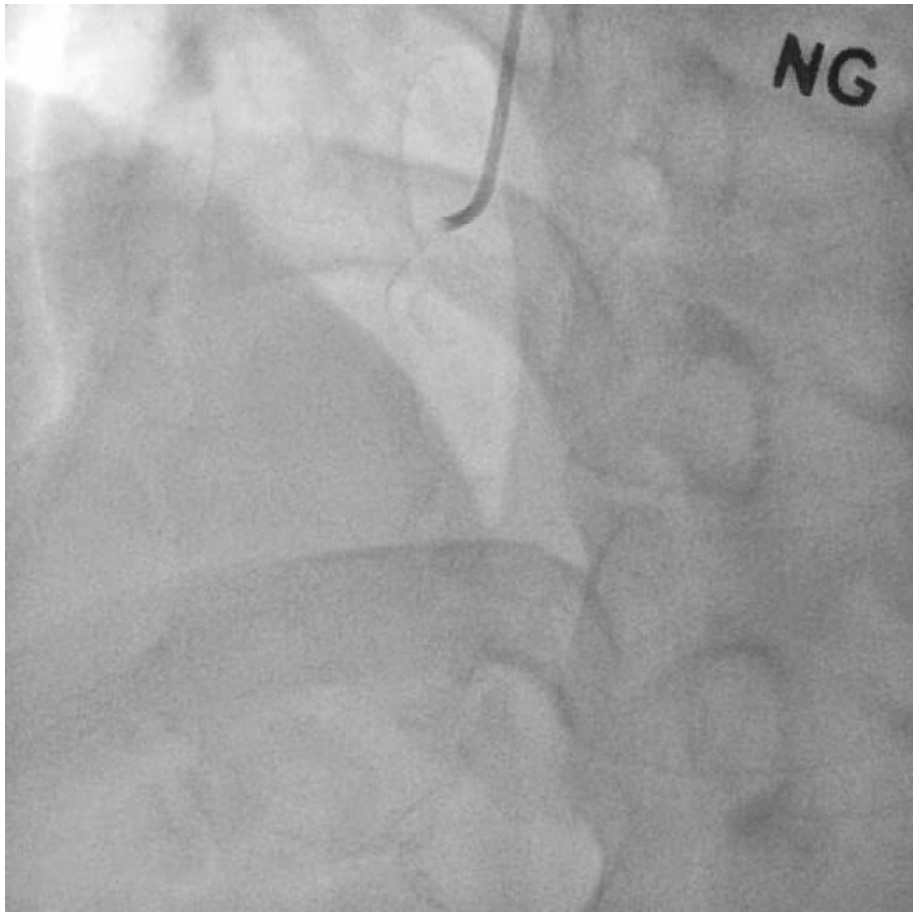
True CTO

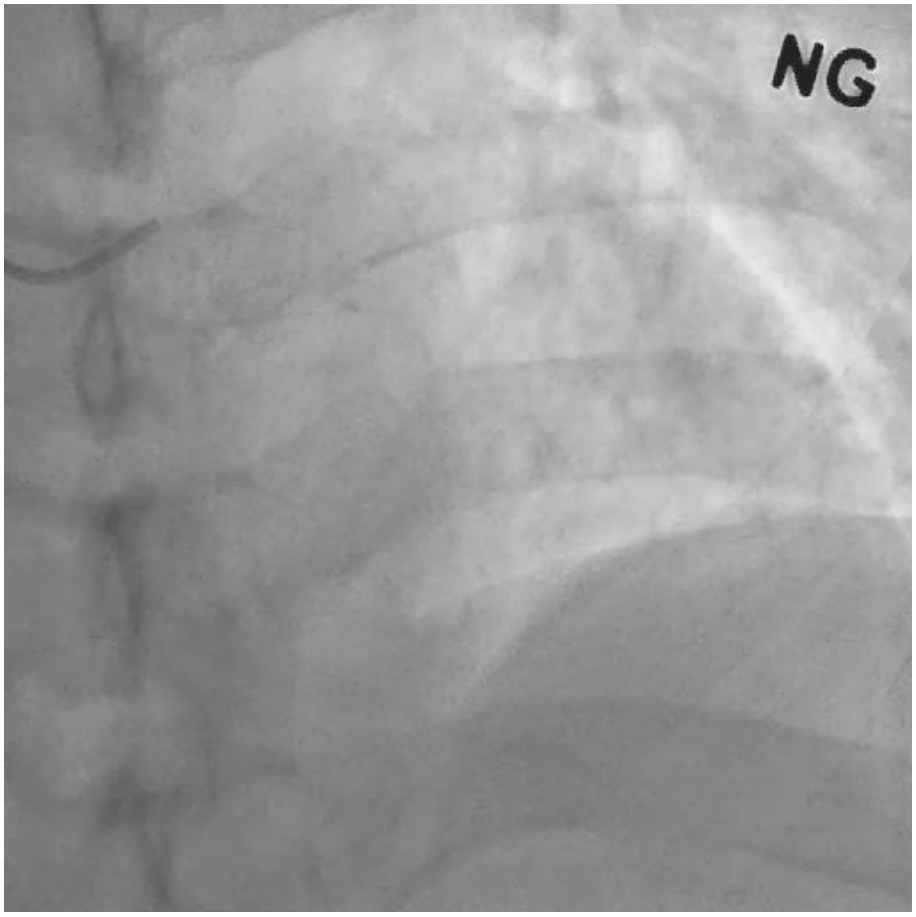




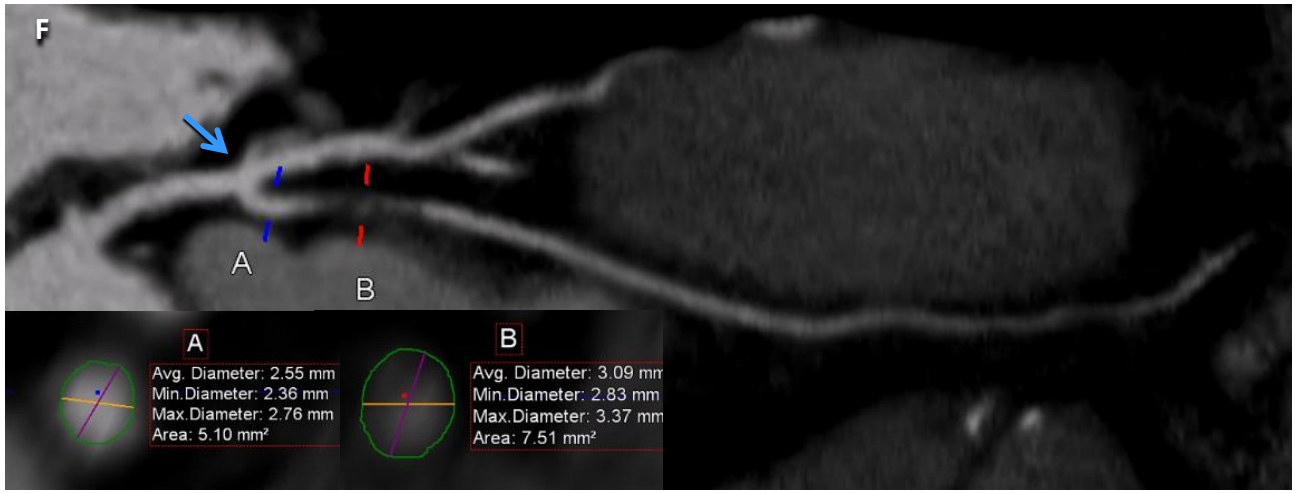
SMC educational file

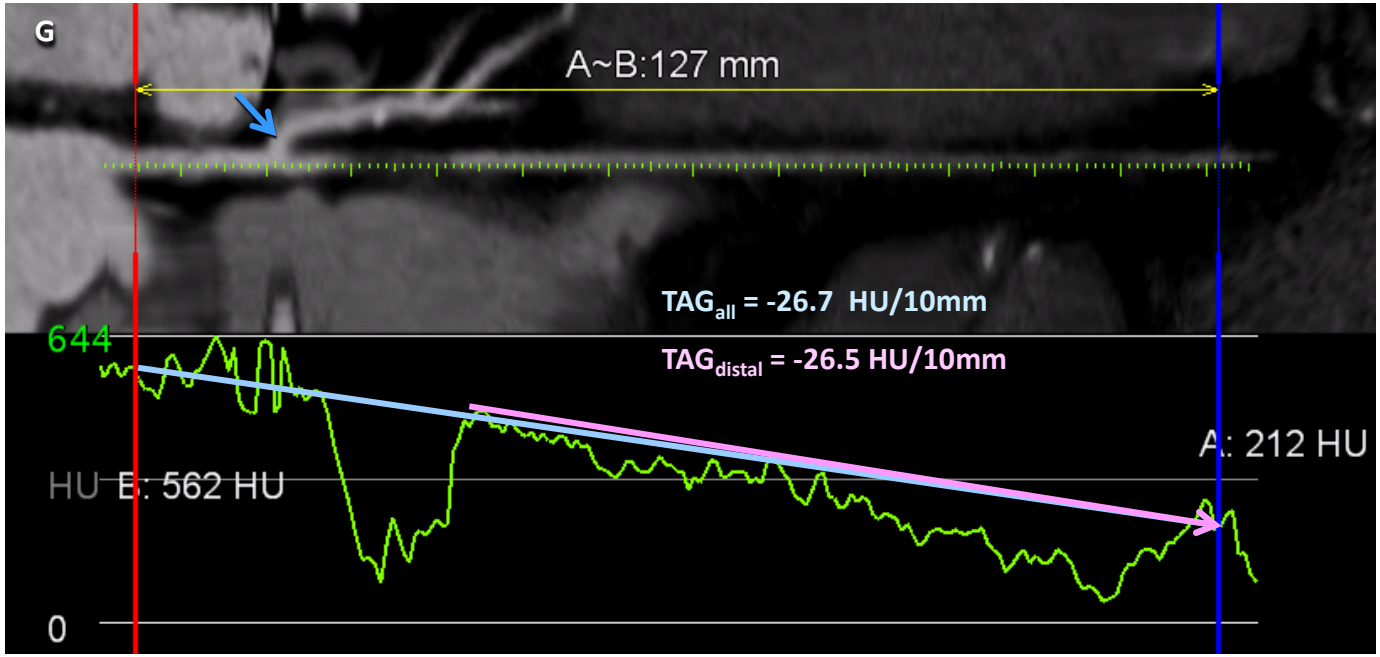
True CTO



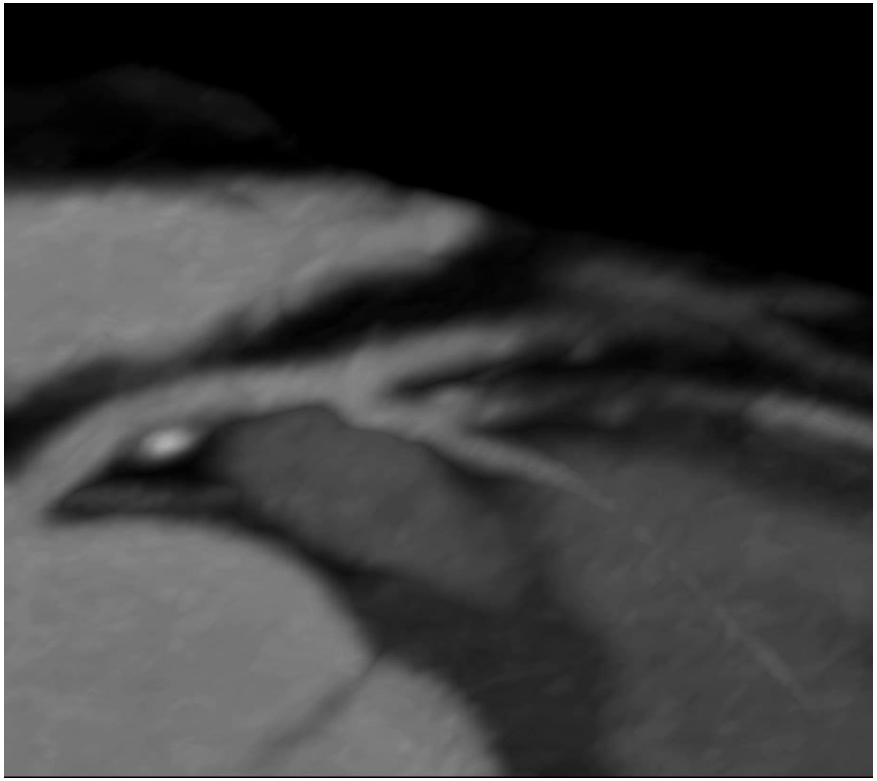


Subtotal occlusion

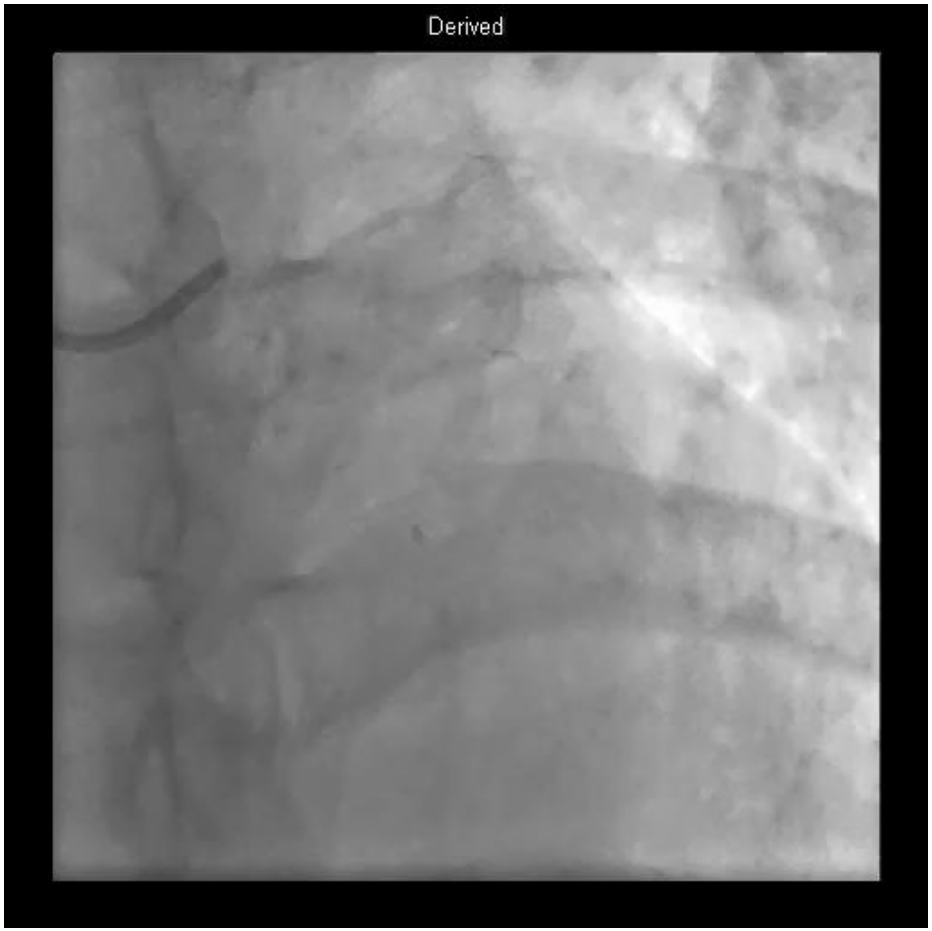


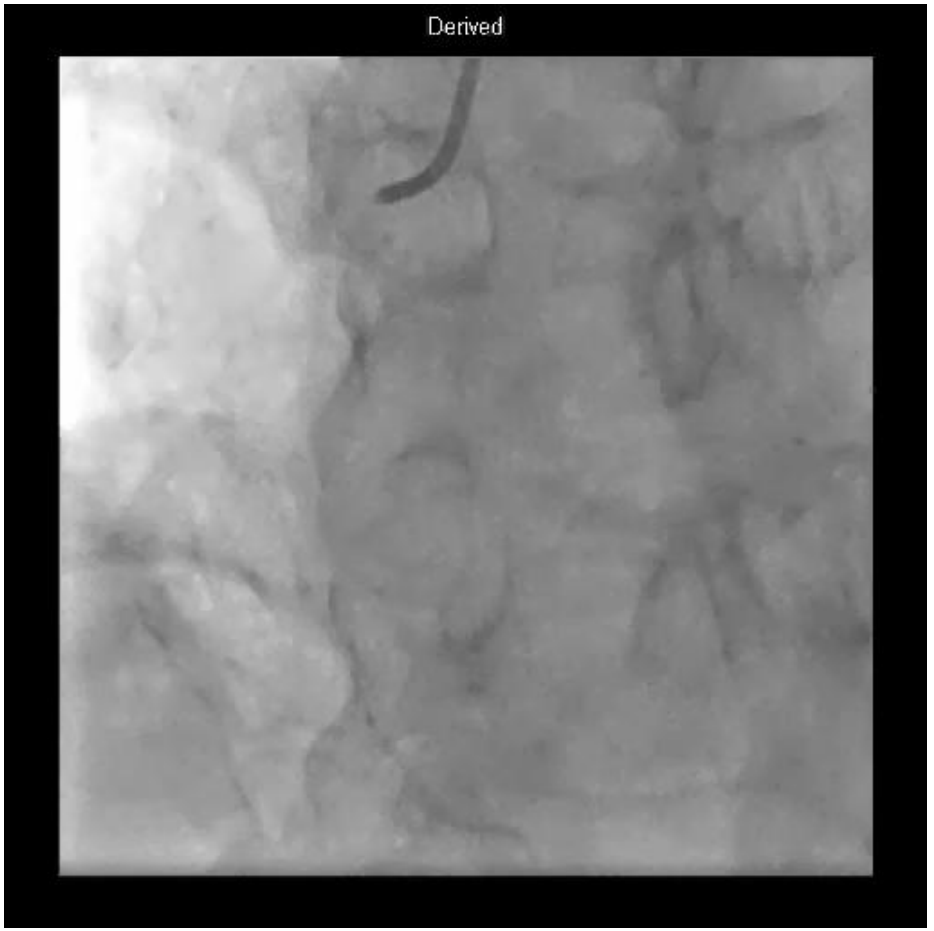


Subtotal occlusion

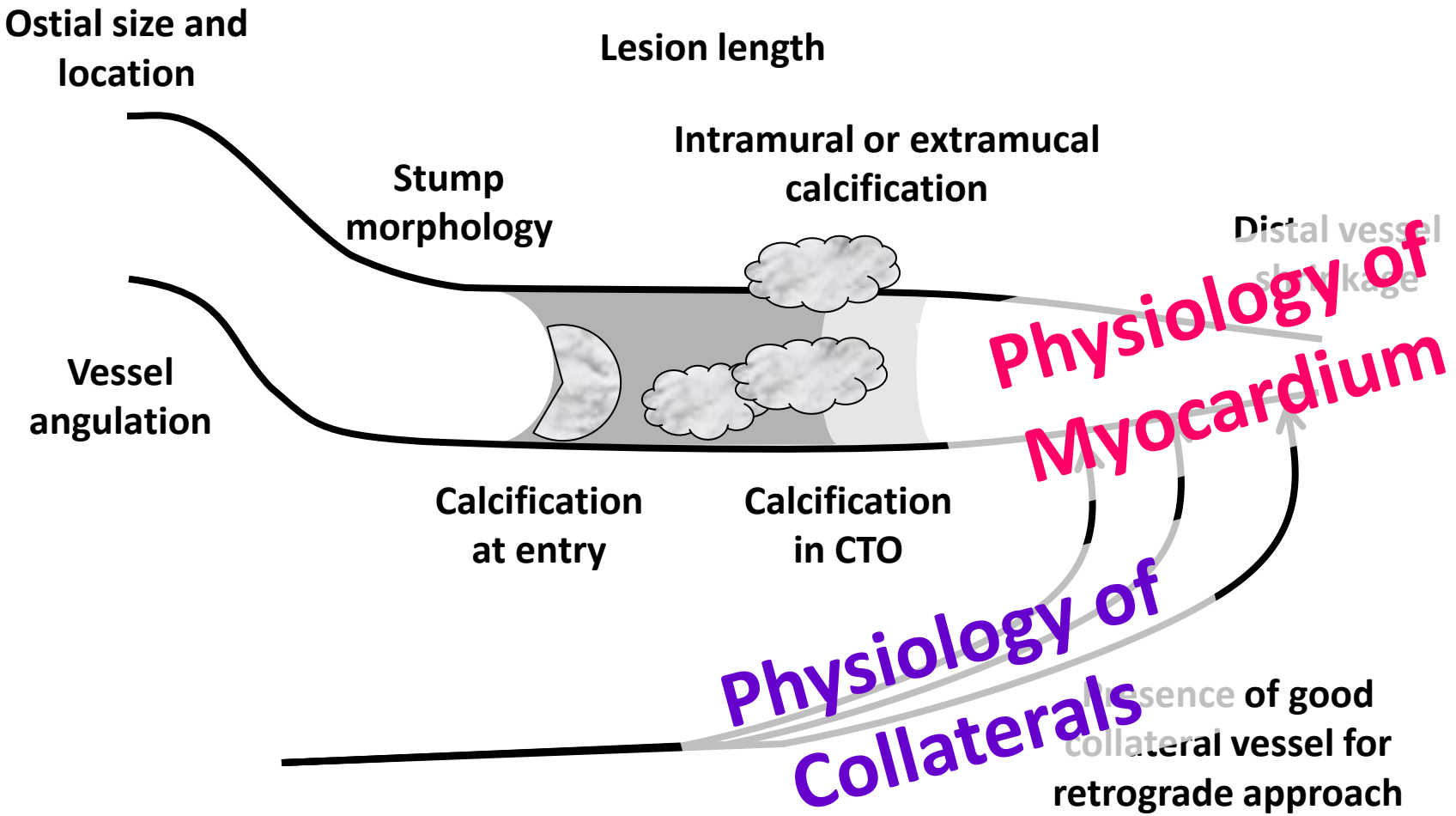


Subtotal occlusion





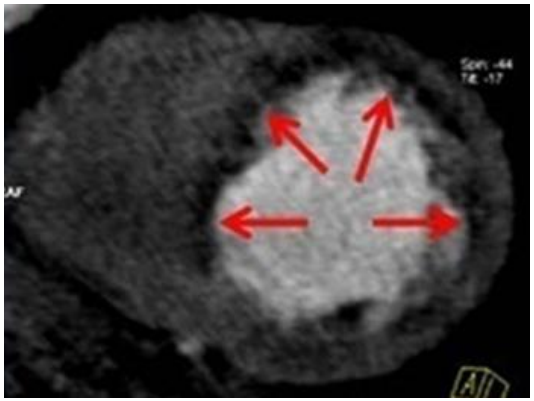
Information available from coronary CT



Modified from Feyter, Niemann, EuroPCR 2011

Beyond anatomical stenosis - Evaluation of myocardial ischemia by CT

Myocardial stress perfusion



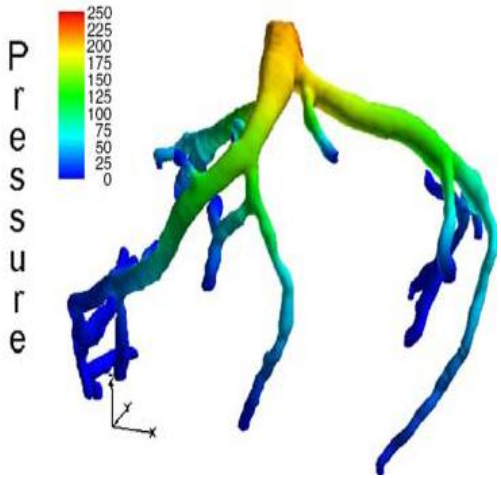
Feuchtner , Circ Img 2011

Ho, JACC Img 2010

Ko, Eur Heart J 2011

… so many papers

Computational fluid dynamics

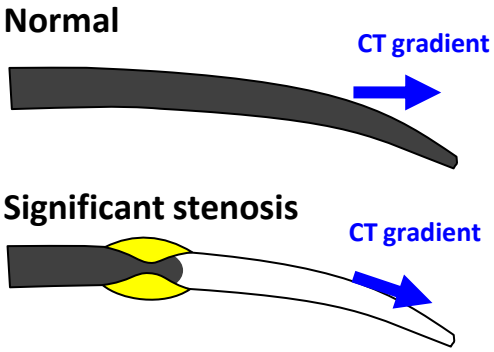


Yoon, Choi, Koo, JACC Img 2012

DeFACTO, Min, JAMA 2012

DISCOVER-FLOW, Koo, JACC 2011

Transluminal attenuation gradient



Wong, JACC 2013

Choi, EHJ Img 2012

Choi, JACC Img 2011

Chow, JACC 2010

Steigner, Circ Img 2009

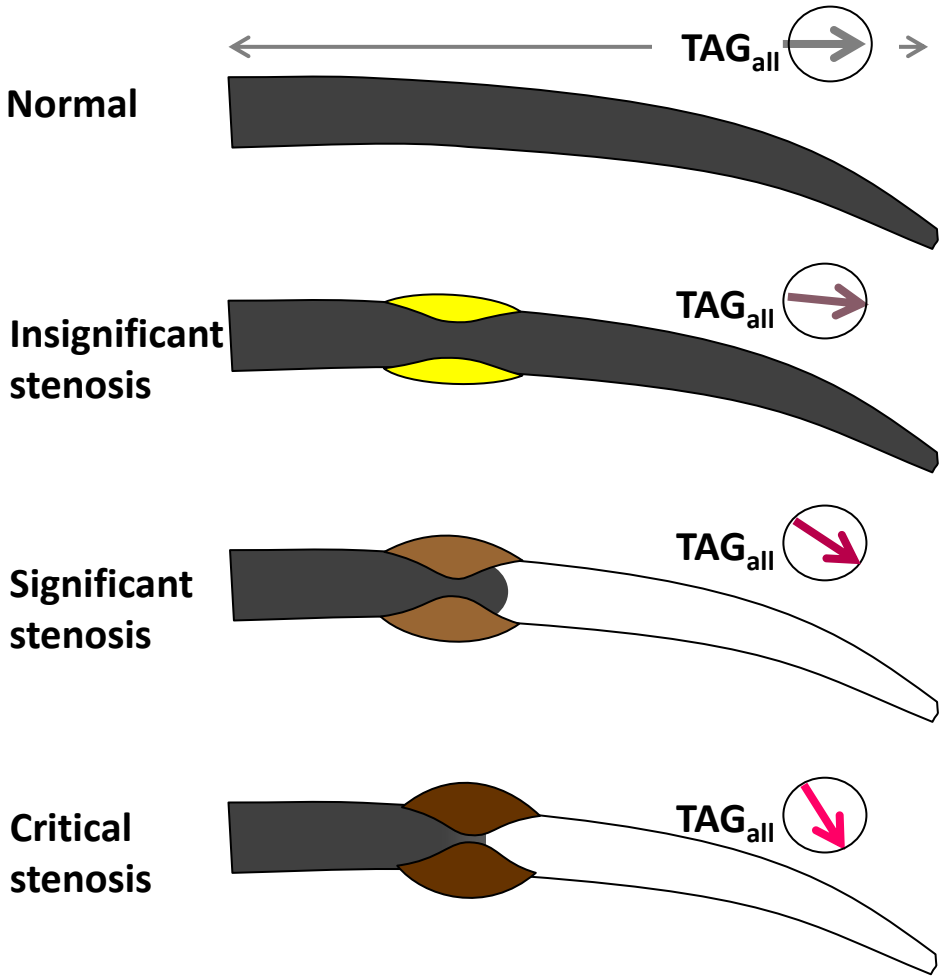
Lachner, ROFO 2010

Transluminal Attenuation Gradient (TAG)

Gradient of radiological density (HU) along vessel axis

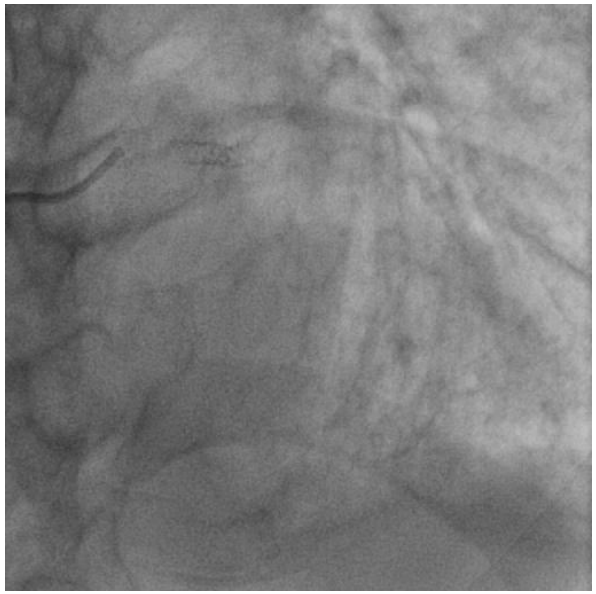
TAG reflects kinetics of contrast media in coronary artery

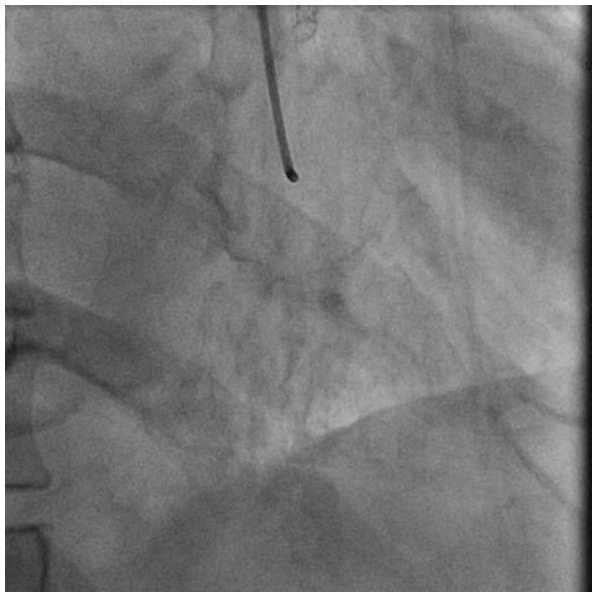
A simple method for evaluation of coronary stenosis

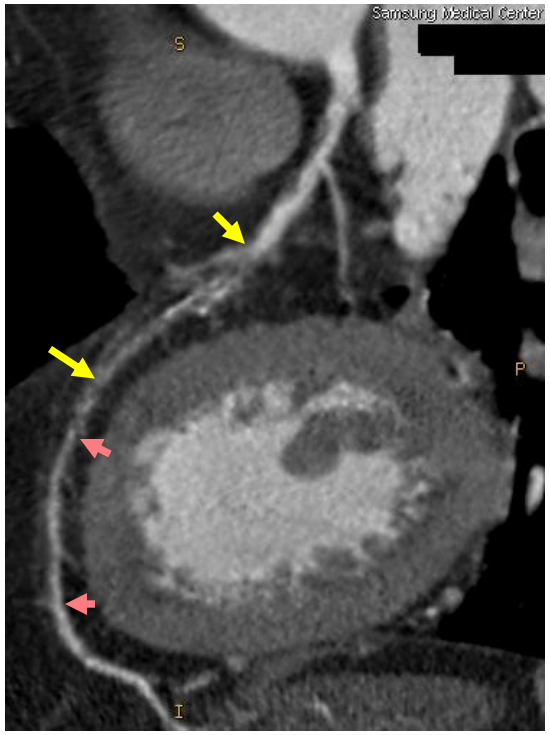


Publication	Result
Krug, ROFO 2009	Pre-clinical study
Rybicki, Int J Cardiovasc Img 2009	TAG vs presence of CAD
Steigner, Circ Img 2009	TAG vs presence of CAD
Chow, JACC 2010	CCO vs presence of CAD
Choi, JACC Img 2011	Validation of TAG with semiquantitative QCA
Yoon & Choi, JACC Img 2012	Validation of TAG with FFR, compared with CT-FFR
Choi, EHJ Img 2012	Validation of TAG with FFR, compared with CCO
Wong, JACC 2013	Validation of TAG with FFR, 320-slice CT

Representative case: Retrograde Rentrop 2 flow

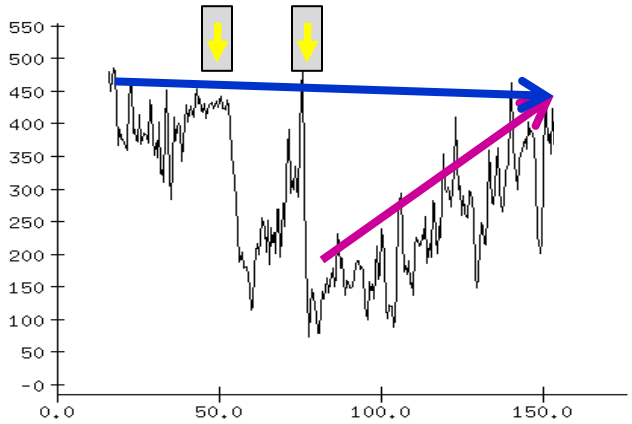


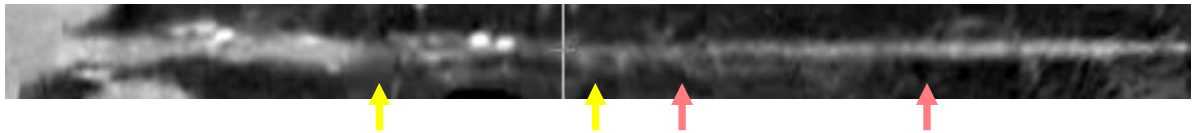




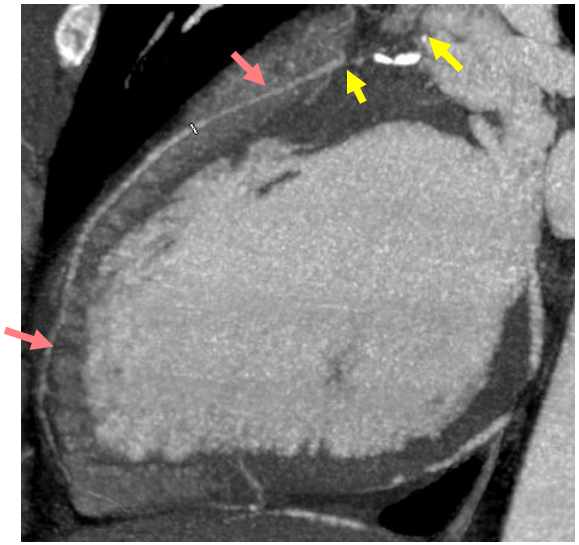
TAG_{all} = -3.1 (HU/10mm)

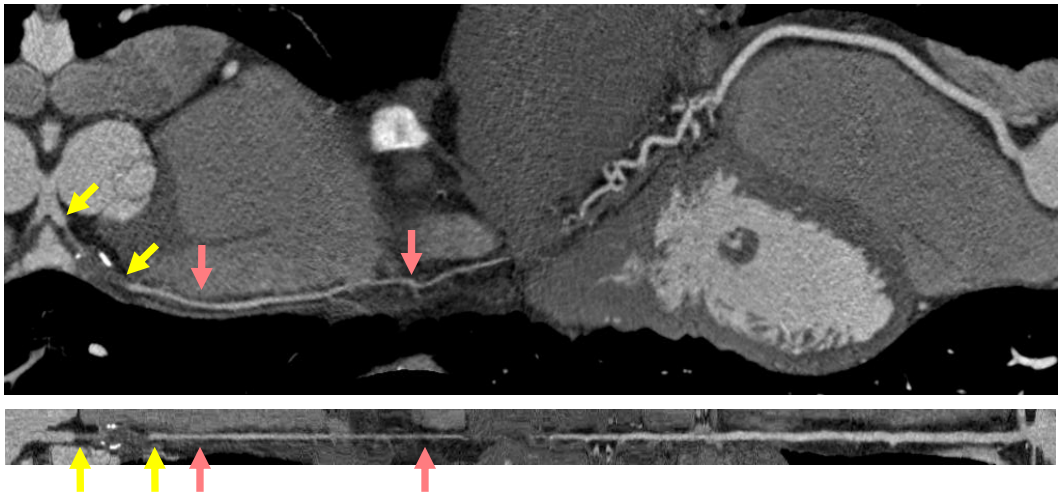
TAG_{distal} = 35.8 (HU/10mm)

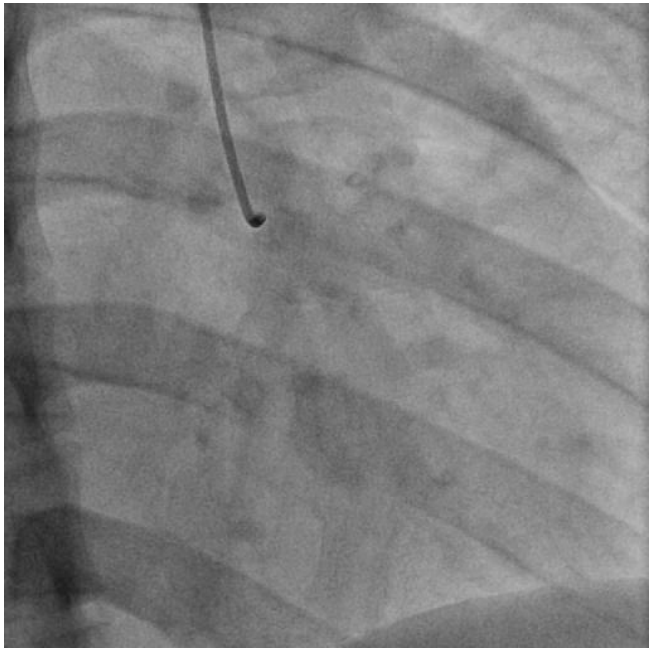




Representative case: Antegrade Rentrop 3 flow

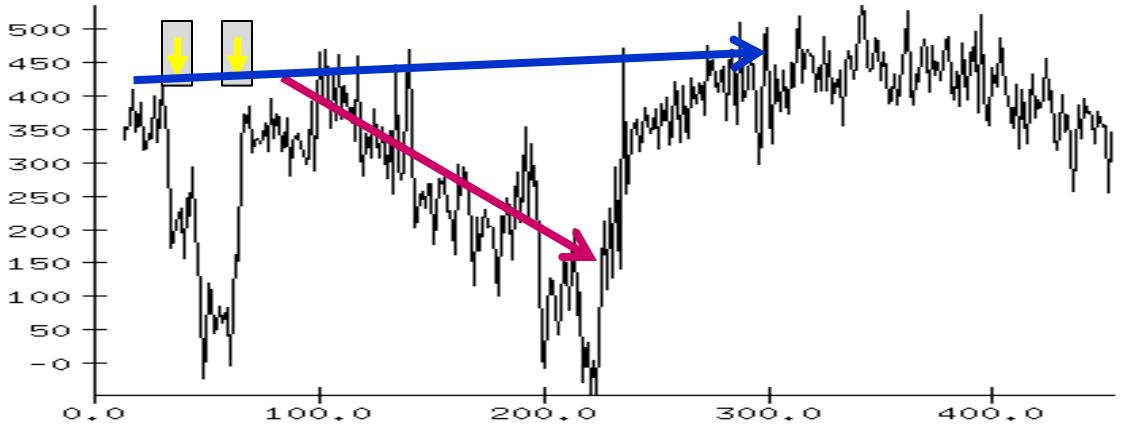




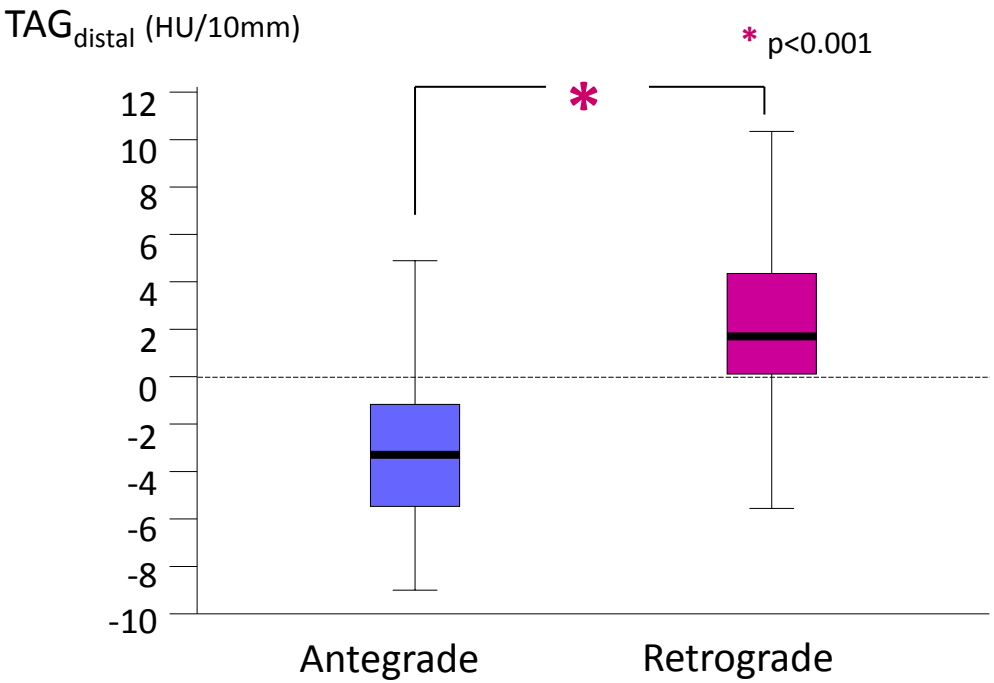


TAG_{all} = 0.2 (HU/10mm)

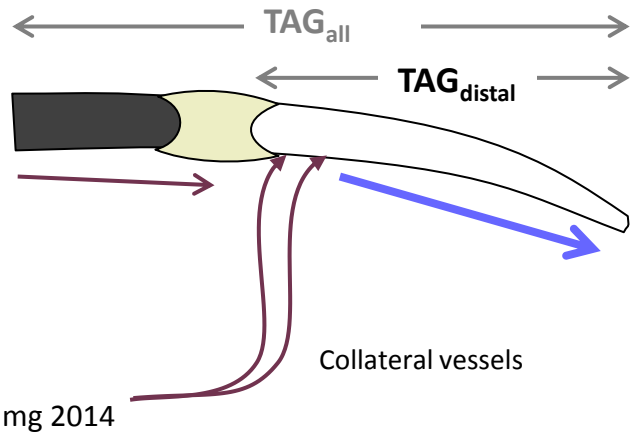
TAG_{distal} = -13.7 (HU/10mm)

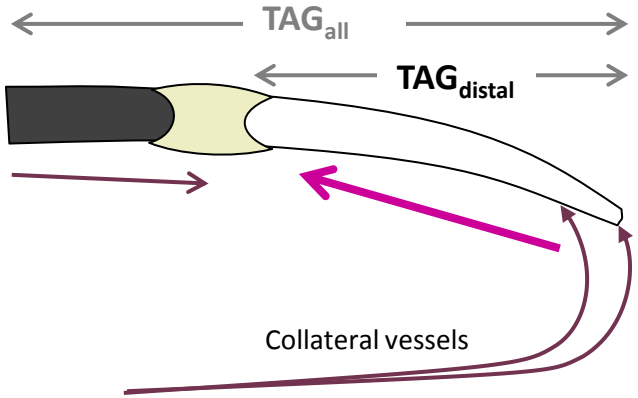


Assessment of flow direction in distal vessel



Per-vessel analysis

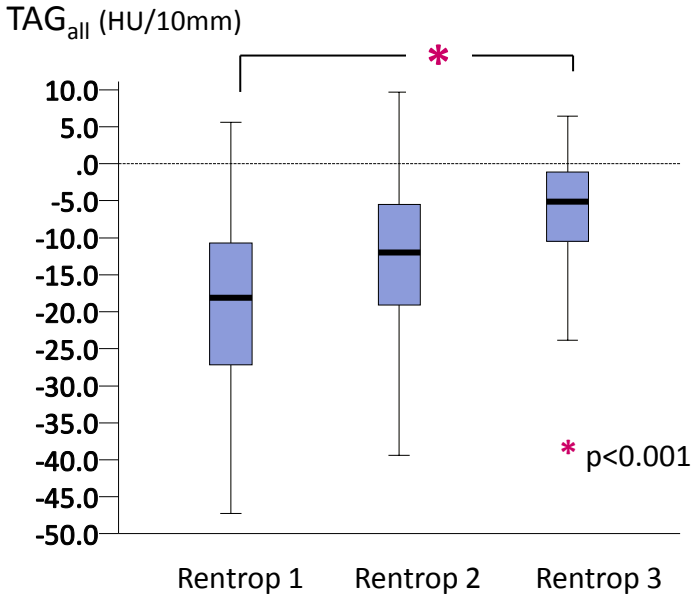


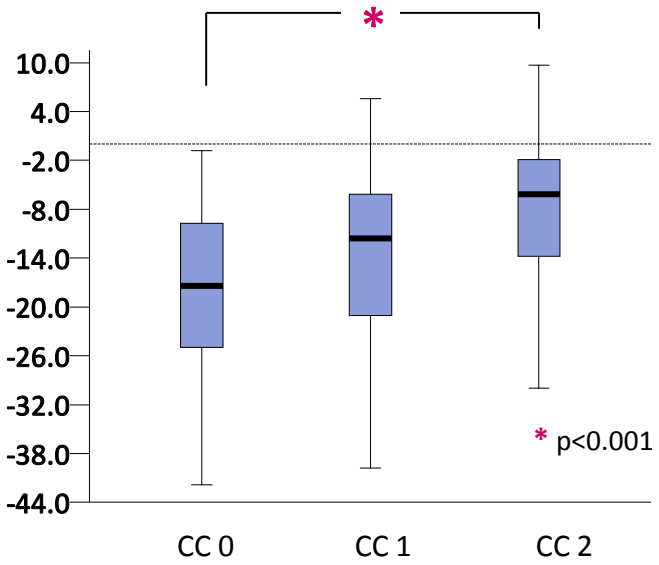


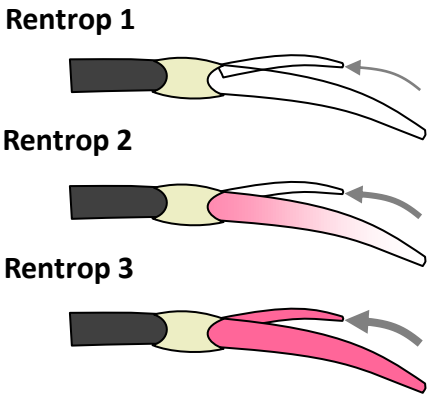
Choi, Circ Img 2014

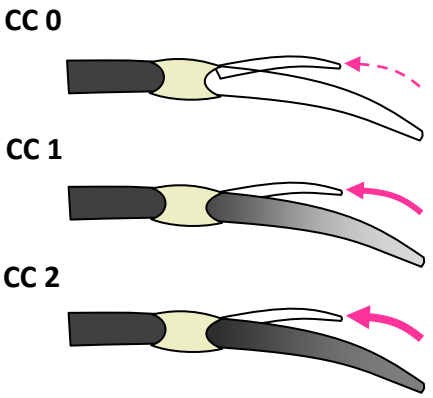
Assessment of functional extent of collateral flow

Per-vessel analysis





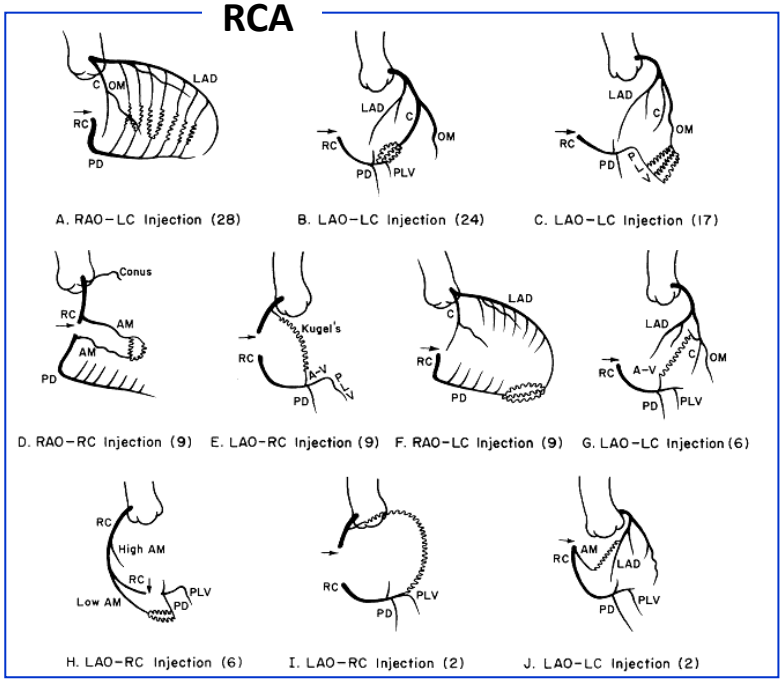




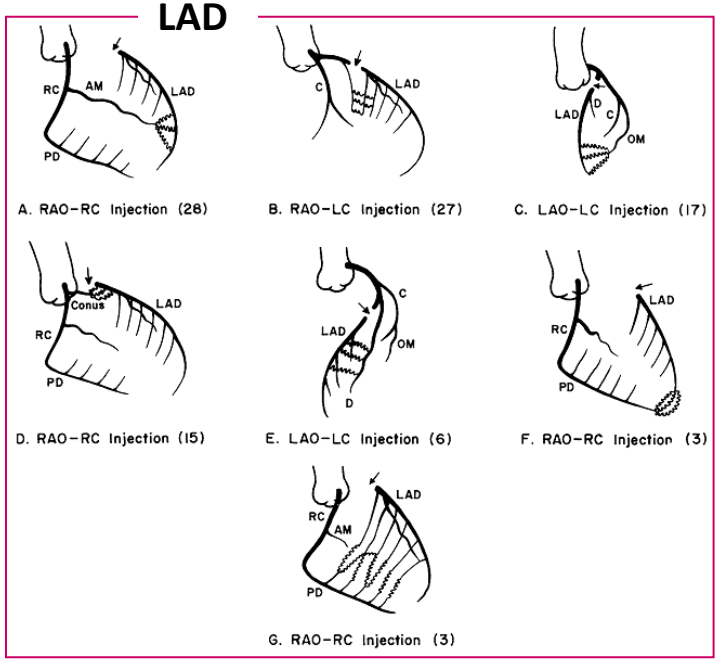
Choi, Circ Img 2014

Localization of coronary collateral vessels: visual-based

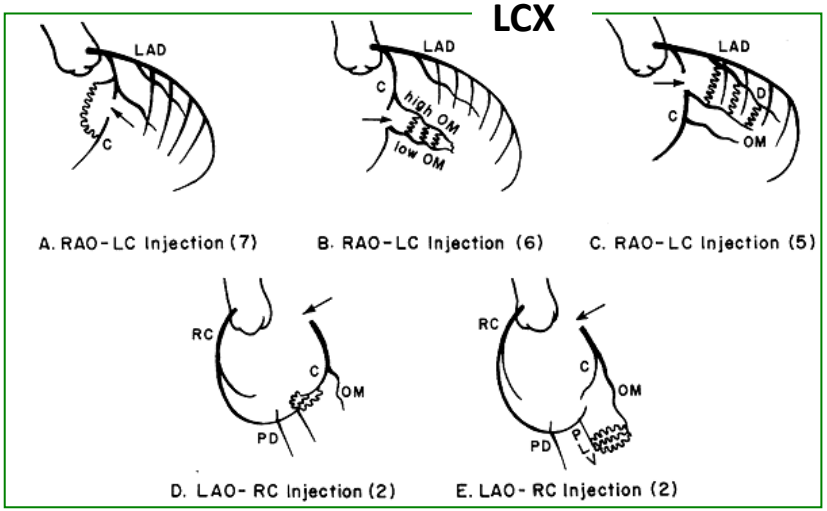
RCA



LAD

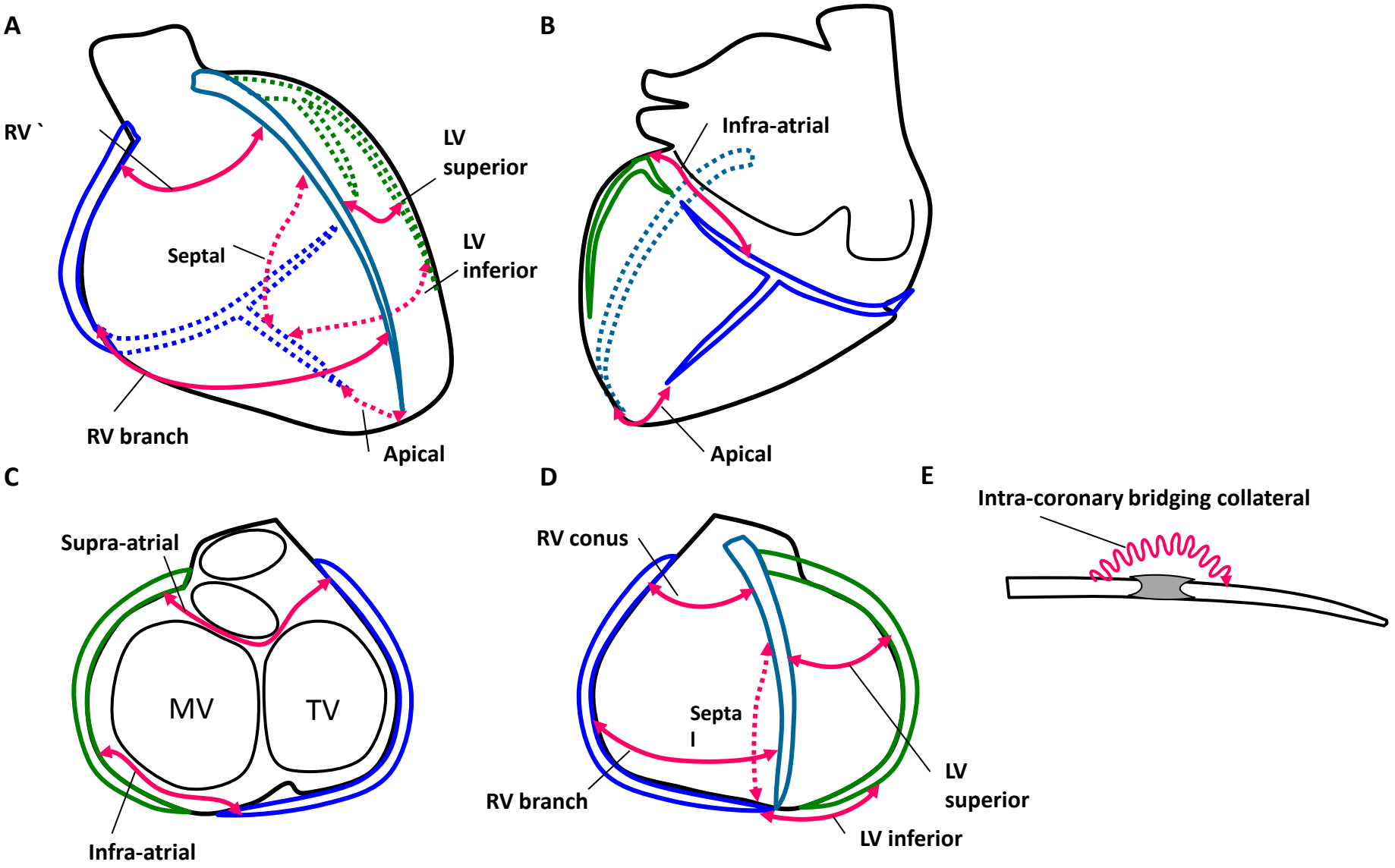


LCX



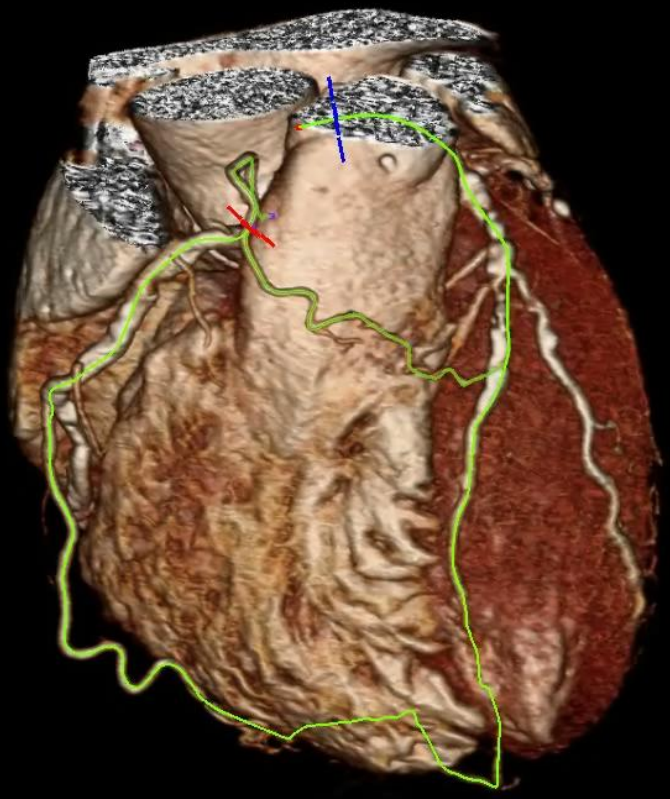
Levin, Circulation 1974

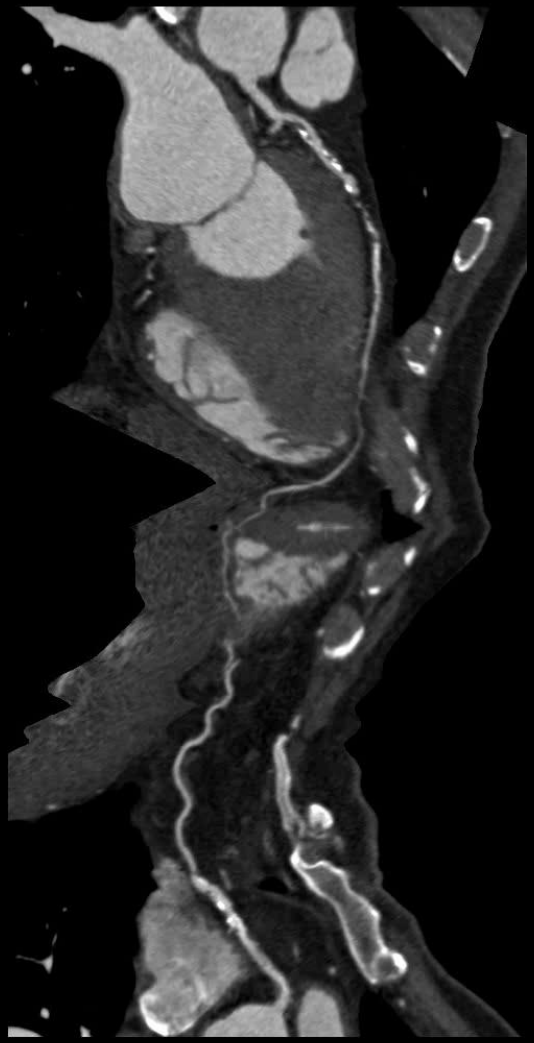
Localization of coronary collateral vessels: Based on knowledge from CT



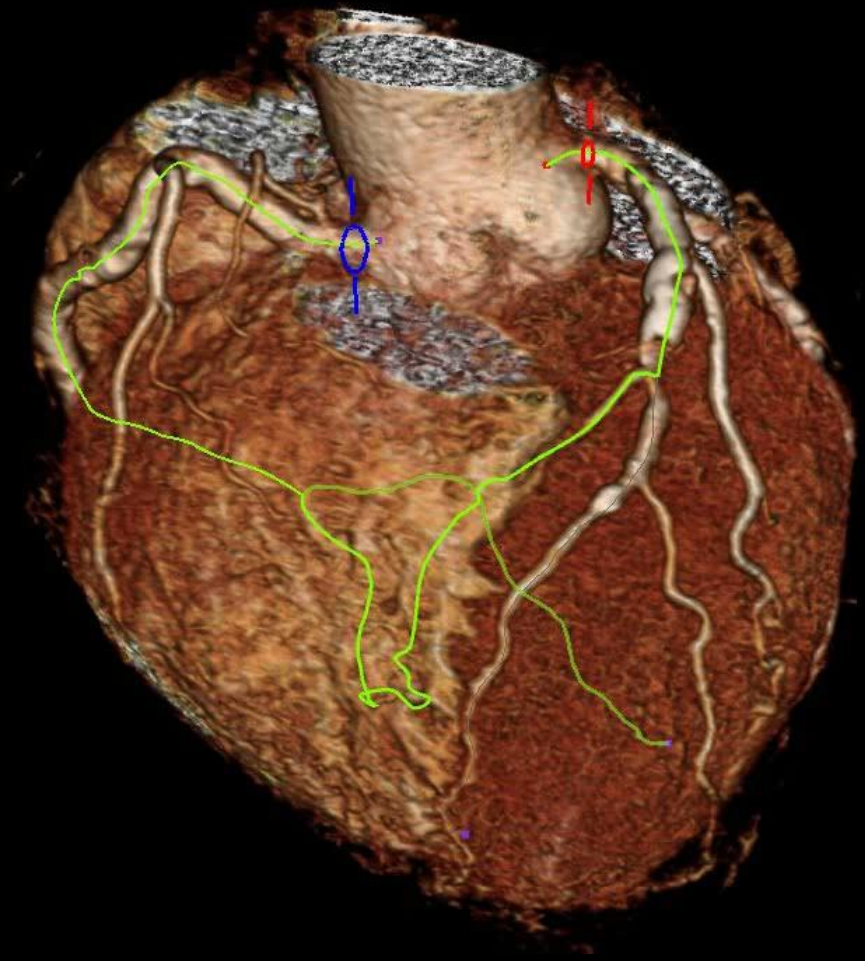
Choi JH, unpublished data

Collaterals from RV branches and RV conus arteries



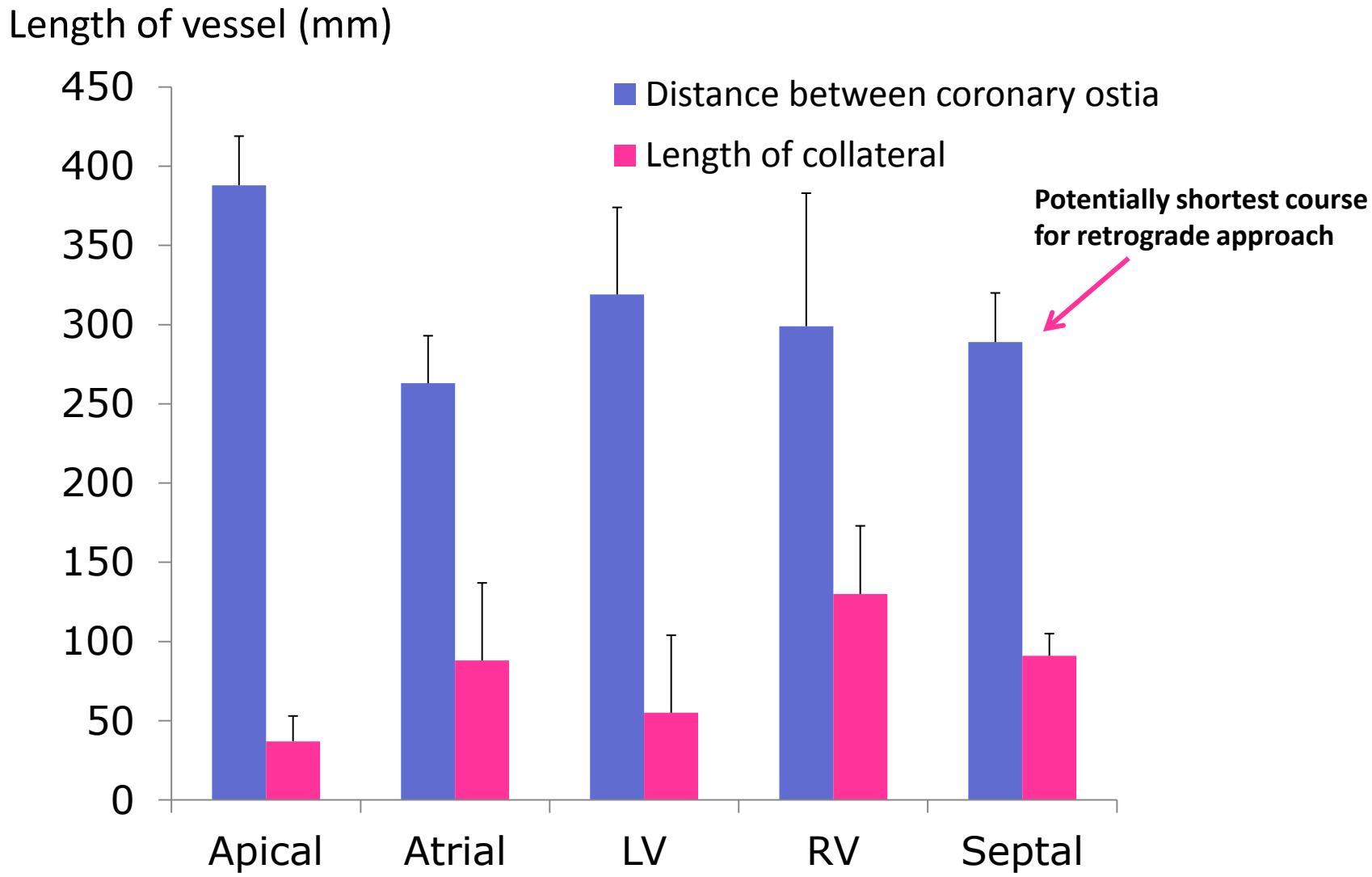


Septal collaterals



Collaterals running on atrial wall inferiorly

Length of vessel course and collaterals



SMC unpublished data

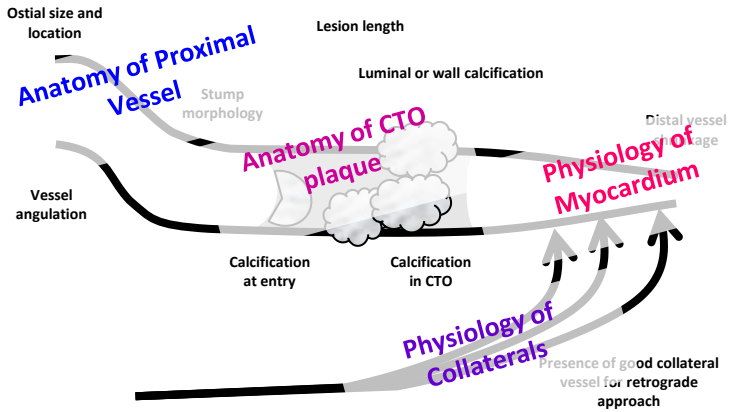
CTO: lessons from CT and MR

1. **Understand coronary ostium and proximal vessel**

2. **Understand CTO plaque**

3. **Understand distal vessel flow and myocardial perfusion**

4. **Pre-planning procedure and device size before real intervention**

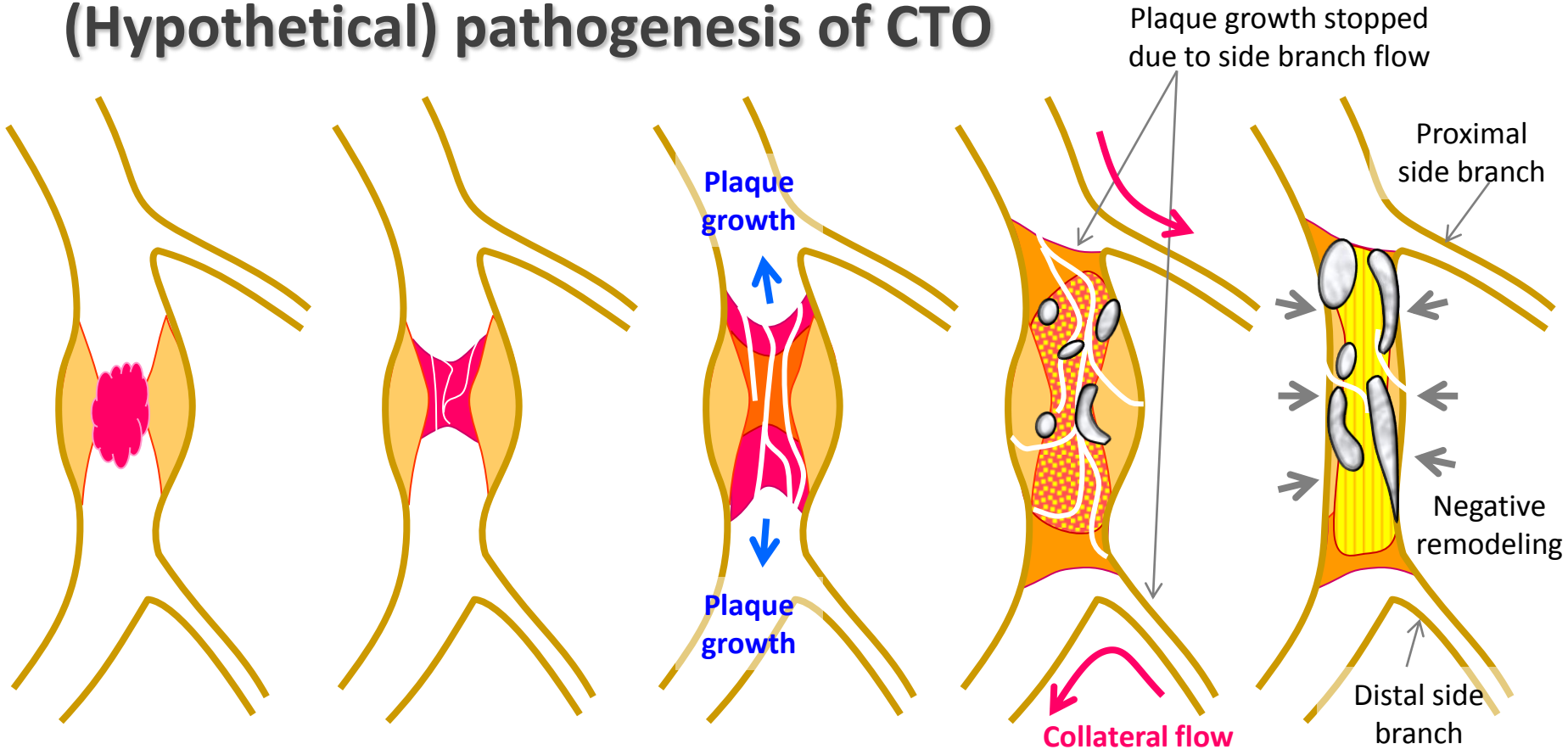


What is the origin of CTO ?

Subclinical silent MI ?

Progressive narrowing ?

(Hypothetical) pathogenesis of CTO



1. Subclinical thrombotic occlusion and progression of occlusive lesion (until branches)

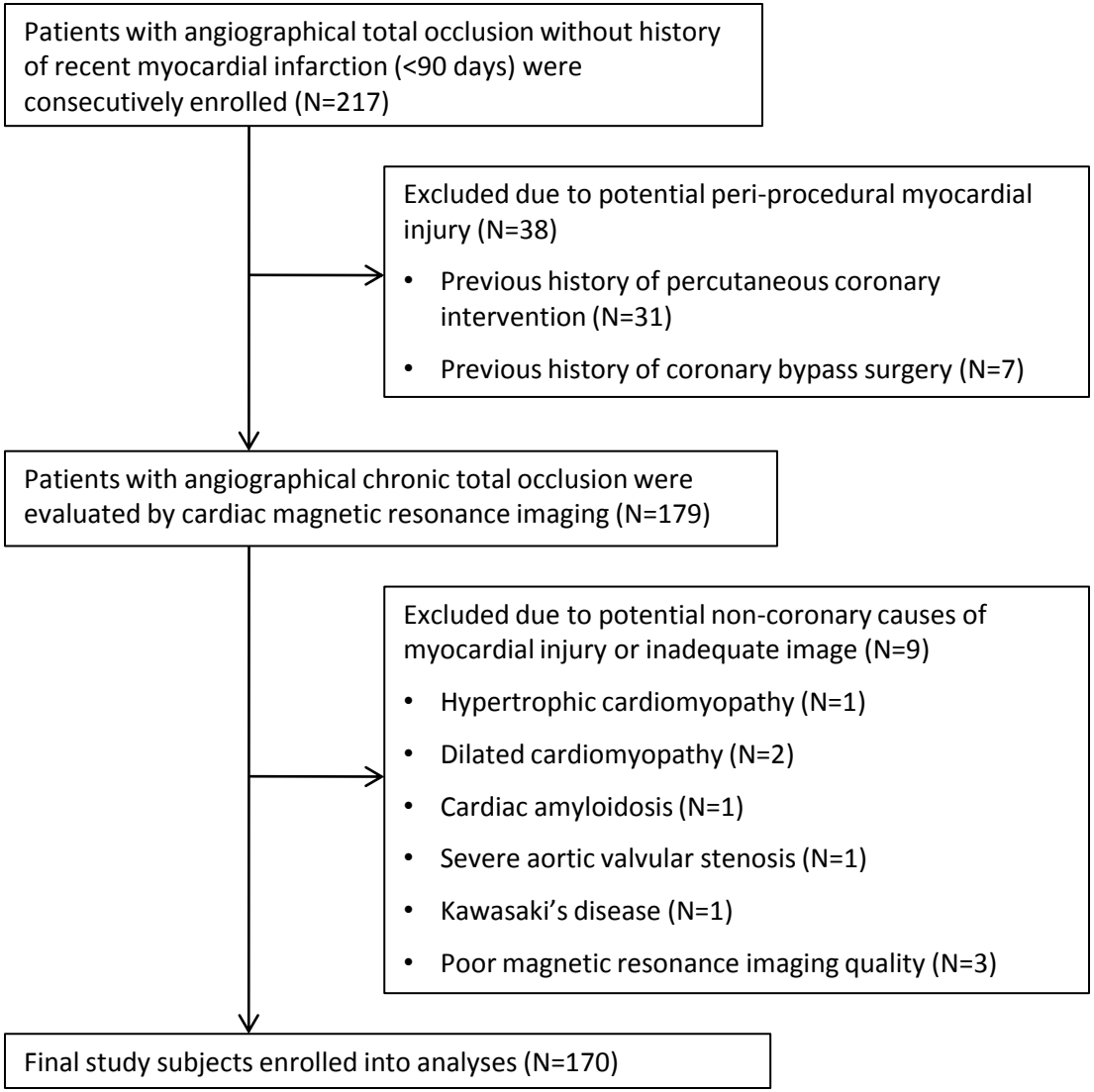
2. Organized thrombi and proteoglycan/fibrin → Type I collagen and calcification

3. Negative remodeling of CTO body

4. Microchannel formation – intraplaque, or connected to vasa vasorum

Modified from Feyter, Niemann, EuroPCR 2011; Sumitsuji, JACC Interv 2012

SMC CTO MRI registry



Choi, Circulation 2013

Does CT help the CTO PCI in real clinical practice ?

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 Cariovasc 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

J-CTO SCORE SHEET

Version 1.0

Variables and definitions

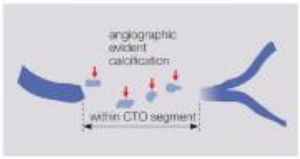
Tapered / Blunt

Entry with any tapered tip or dimple indicating direction of true lumen is categorized as "tapered".

Entry shape
☐ Tapered (0)
☐ Blunt (1)

point

Calcification

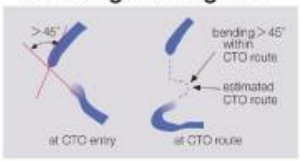


Regardless of severity, 1 point is assigned if any evident calcification is detected within the CTO segment.

Calcification
☐ Absence (0)
☐ Presence (1)

point

Bending > 45degrees

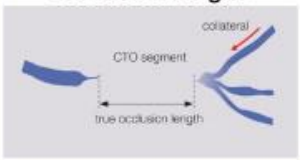


One point is assigned if bending > 45 degrees is detected within the CTO segment. Any tortuosity separated from the CTO segment is excluded from this assessment.

Bending > 45°
☐ Absence (0)
☐ Presence (1)

point

Occlusion length



Using good collateral images, try to measure "true" distance of occulusion, which tends to be shorter than the first impression.

Occl.Length
☐ <20mm (0)
☐ ≥20mm (1)

point

Re-try lesion

Is this Re-try (2nd attempt) lesion ? (previously attempted but failed)

Re-try lesion
☐ No (0)
☐ Yes (1)

point

Category of difficulty (total point)
☐ easy (0) ☐ Intermediate (1)
☐ difficult (2) ☐ very difficult (≥3)

Total ____ points

CTO success rate

CT:

length

calc

CAG:

length

calc

tapered/blunt (most CTO is bifurcation disease)

bending > 45

MRA:

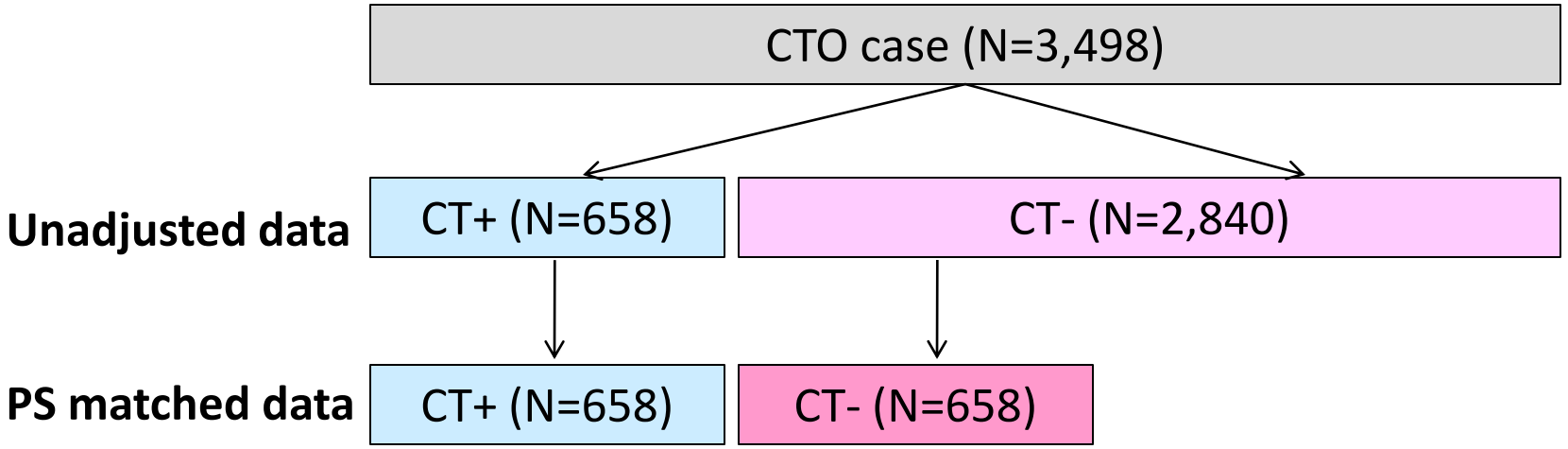
(length)

signal intensity (bright vs dark)

(myocardium)

CT+ vs CT- : Result from K-CTO registry

- Retrospective study using K-CTO data (http://www.e-cto.org), a Korean multicenter registry comprising 26 centers.
- Analysis of clinical, angiographical, and procedural results of 3,498 consecutive CTO PCI cases between Jul 2003 and Sep 2011.
- Comparison of unadjusted data and propensity score matched pairs



CT+ vs CT- : Result from K-CTO registry

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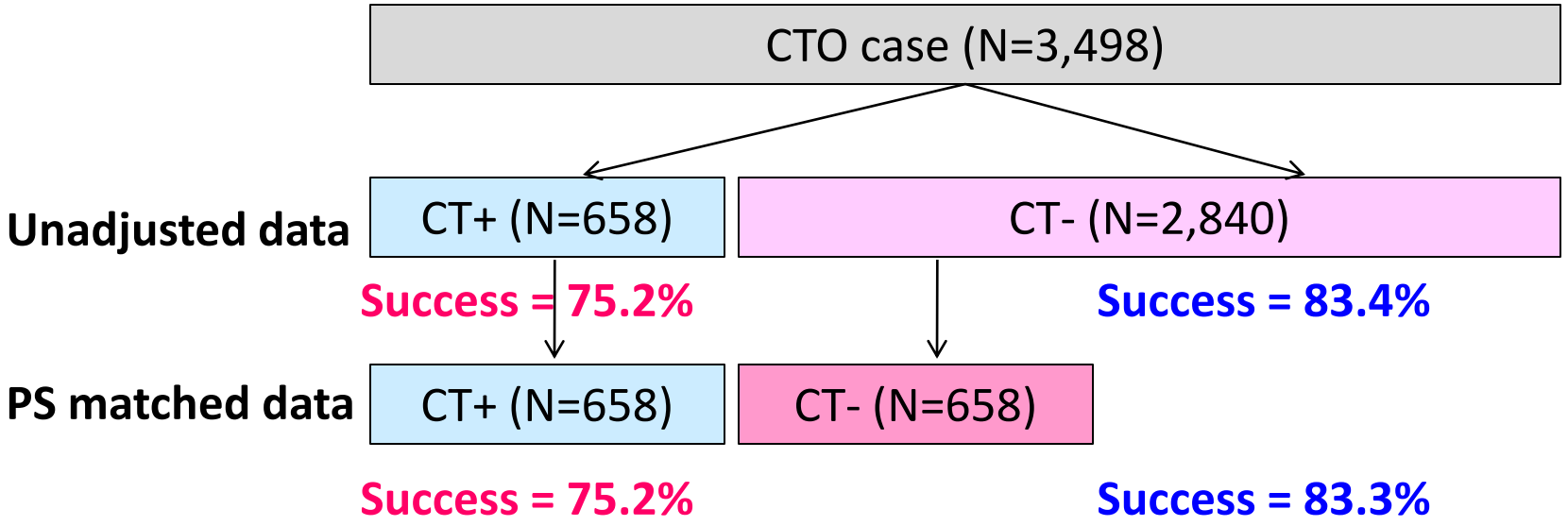

Choi and K-CTO investigators

Take home message

1. Coronary CT = **non-invasive CAG + IVUS**

2. **Review CT / MR** before revascularization of CTO or complex lesion, as like as CAG review.

3. CT/MR helps you to **understand and have better result** for treatment of CTO and complex coronary lesions.