

Imaging for Complex PCI : Where We Are and Where We Go

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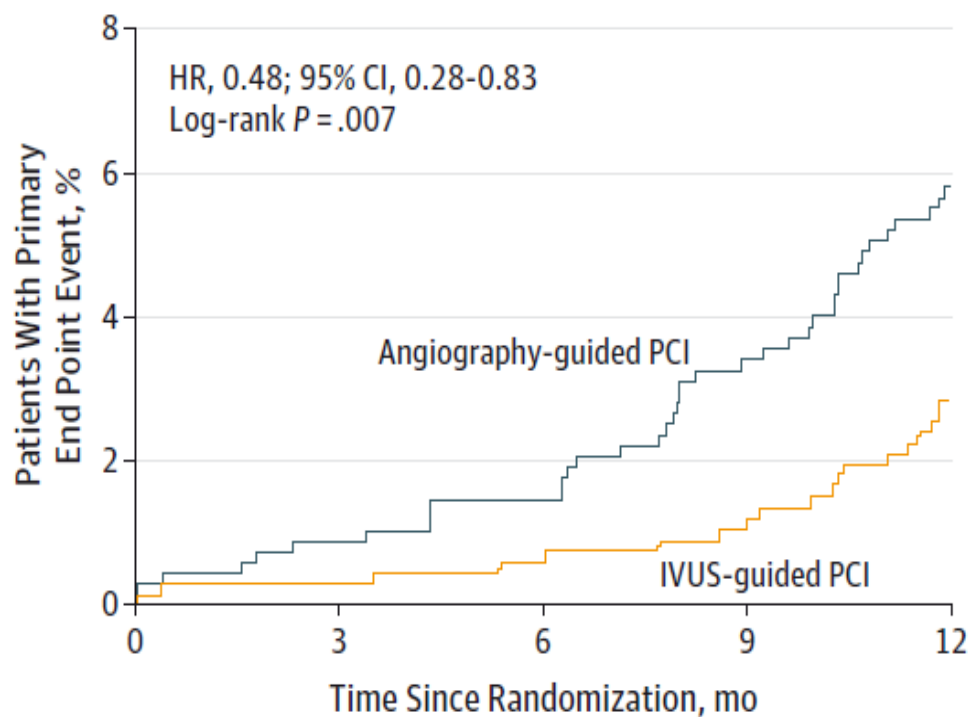
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Why Do We Need IVUS for Complex PCI ?

IVUS Improved Clinical Outcomes in Large RCTs

IVUS-XPL (Long lesions)

MACE (CD+TL-MI+ID-TLR)

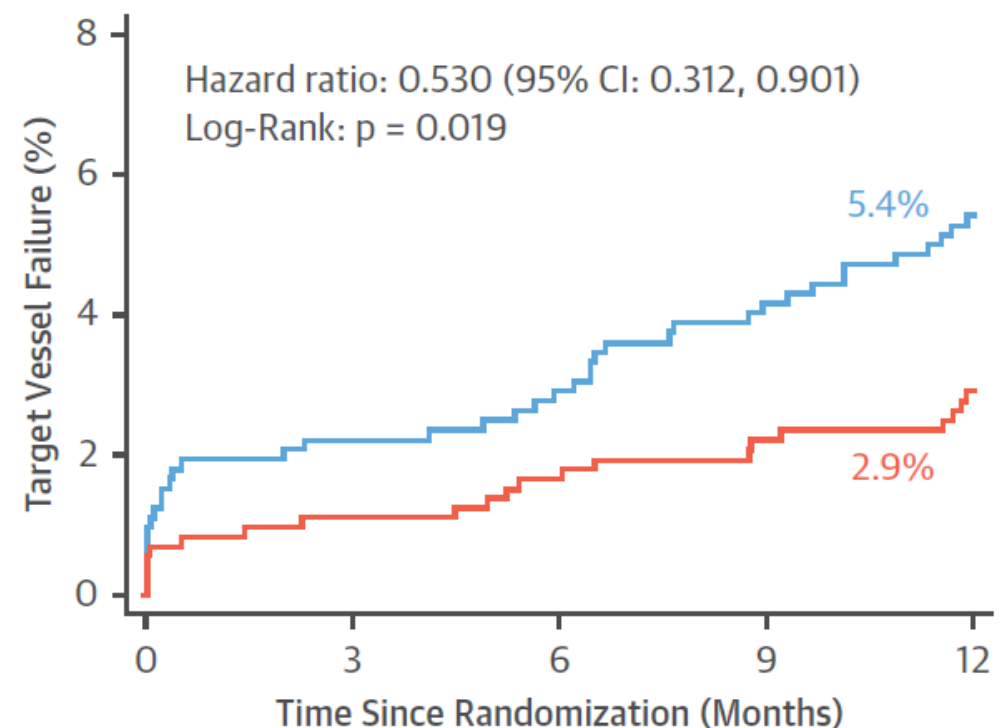


Angiography-guided	700	673	660	643	624
IVUS-guided	700	671	665	654	641

Hong SJ, Hong MK et al. JAMA 2015;314:2155-63.

ULTIMATE (All-comer)

TVF (CD+TV-MI+CD-TVR)



Number at risk					
Angiography	724	706	698	685	676
IVUS	724	715	710	704	696

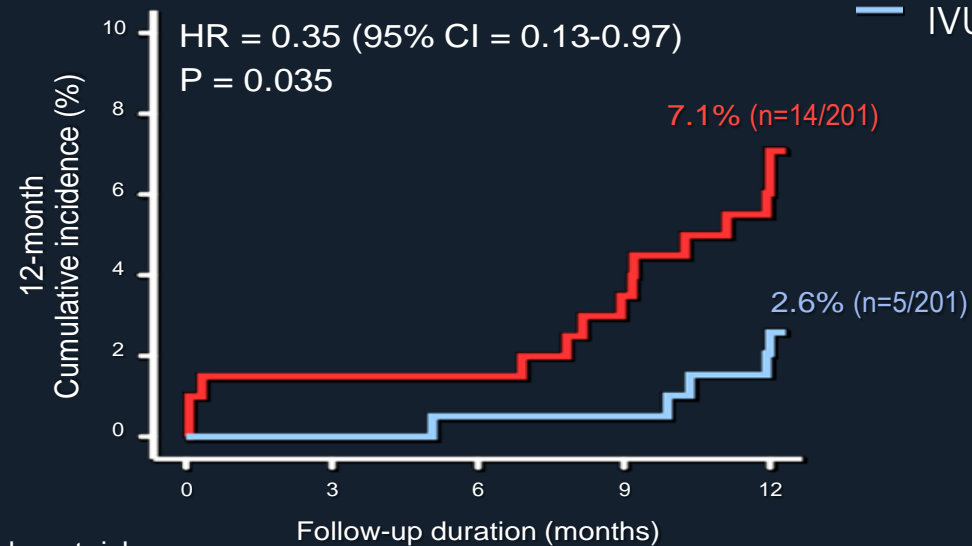
Zhang J et al. J Am Coll Cardiol 2018;72:3126-27.

IVUS Improved Clinical Outcomes in CTO PCI

CTO-IVUS (N=402), Primary endpoint : Cardiac death, MI, and TVR

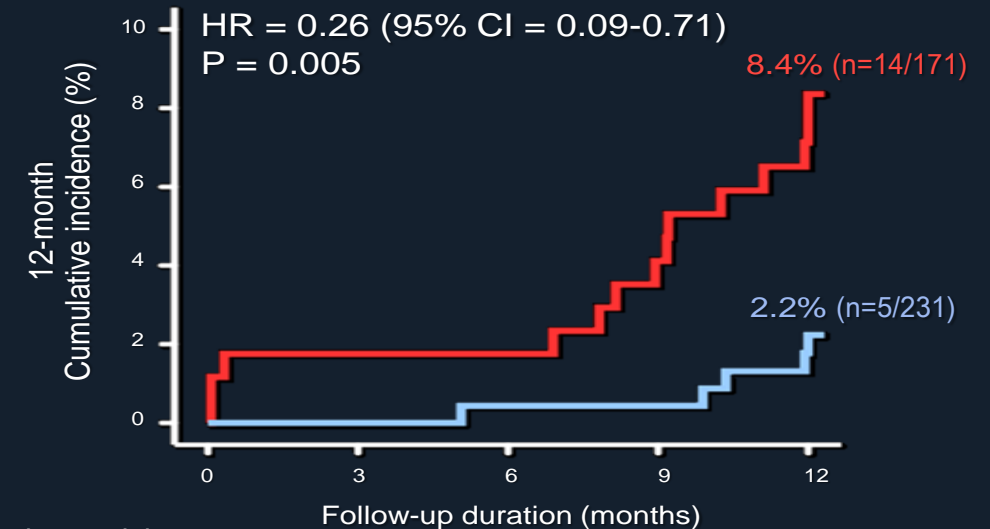
Intention-to-Treat

— Angiography-guided group
— IVUS-guided group



	IVUS	Angio	P-value
Cardiac death/MI	0%	2%	0.045
TVR	2.6%	5.2%	0.186

Per Protocol

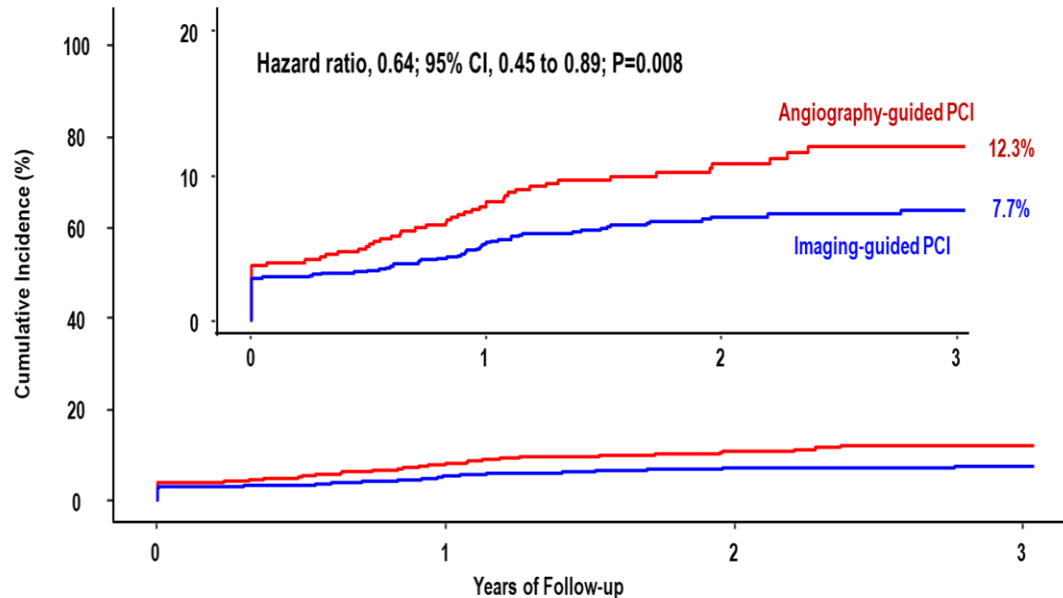


	IVUS	Angio	P-value
Cardiac death/MI	0%	2.3%	0.019
TVR	2.2%	6.1%	0.049

IVUS Improved Clinical Outcomes in Large RCTs

RENOVATE-COMPLEX-PCI (Bifurcation, CTO, LM, Long, MV, ISR, Calcification)

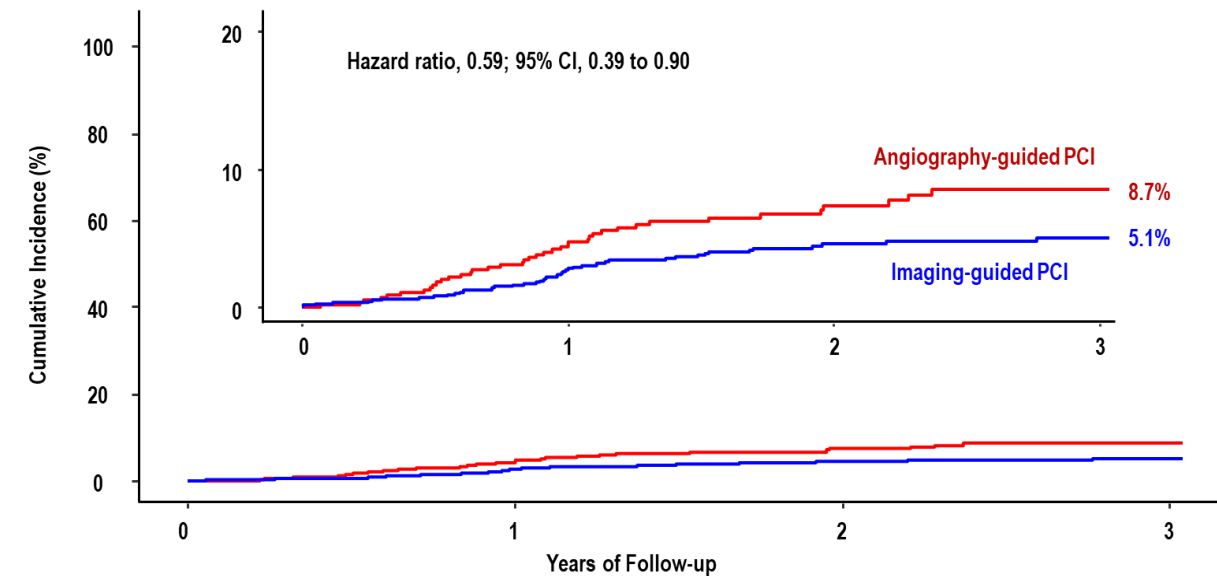
Target Vessel Failure



Number at risk

Angiography-guided PCI	547	496	280	120
Imaging-guided PCI	1092	1023	591	255

TVF excluding PMI



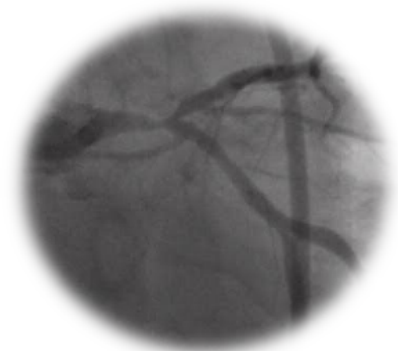
Number at risk

Angiography-guided PCI	547	516	284	121
Imaging-guided PCI	1092	1051	596	256

IVUS Improved 10-yr Clinical Outcomes in LM Registry

MAIN-COMPARE Registry

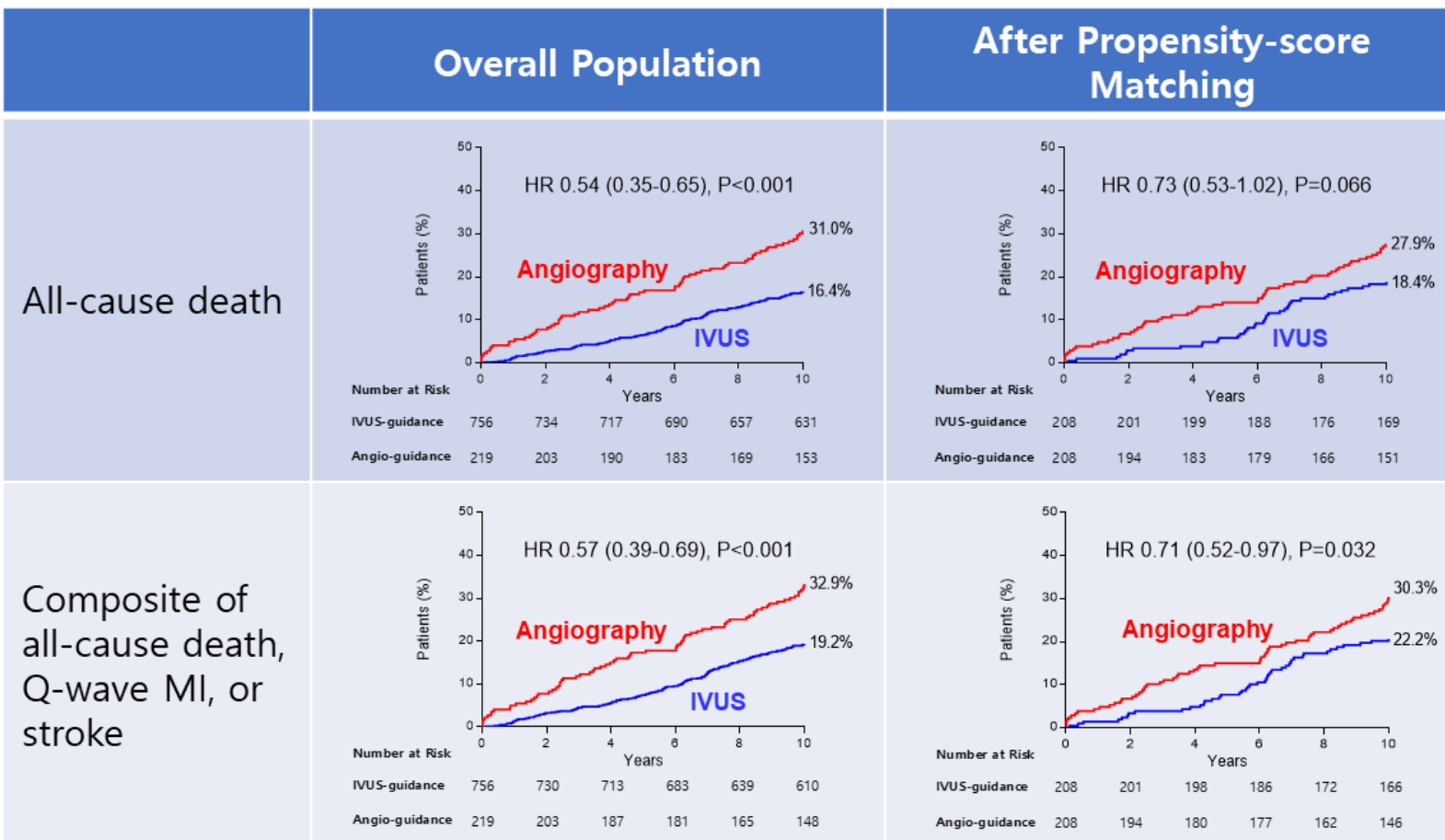
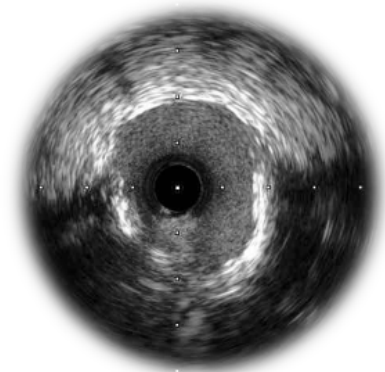
Left Main Disease



10-Year
Follow-up



IVUS-guided PCI



IVUS vs. Angio-guided LM PCI : Ongoing RCTs

OPTIMAL (NCT04111770)

IVUS vs. QCA in 800 patients

Any unprotected LM disease

PoCE : Death, stroke, MI, RR at 2 yr

Europe

PI : Dr. Adrian Banning

INFINITE (NCT04072003)

IVUS vs. Angio in 616 patients

True LM bifurcation (1,1,1 or 0,1,1)

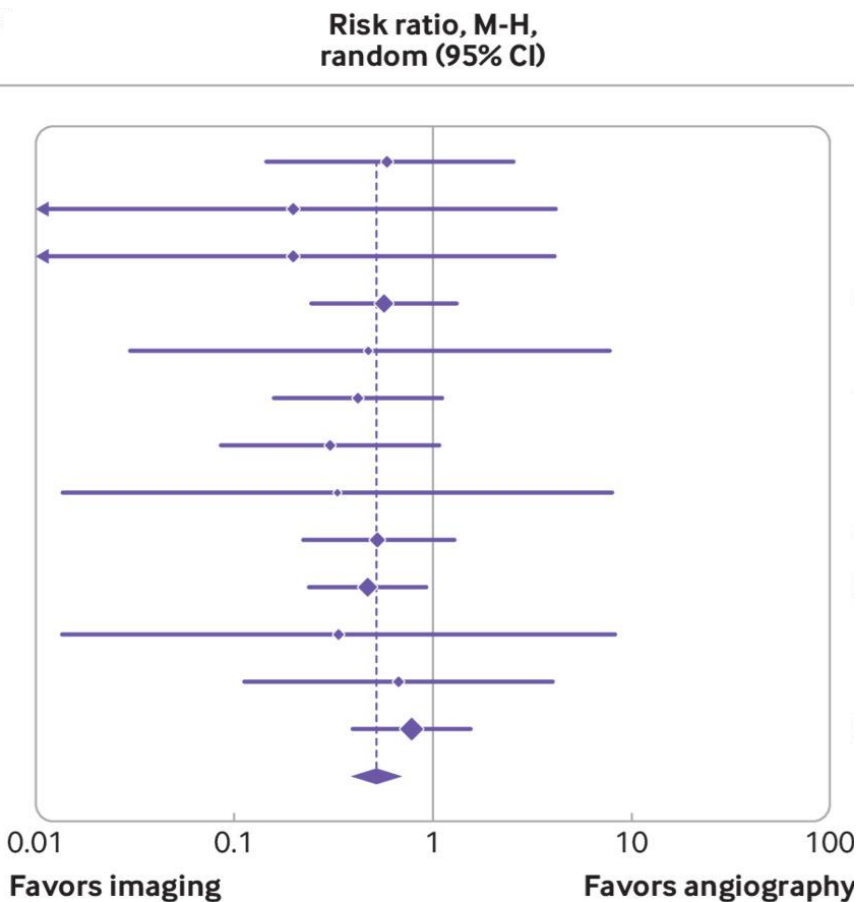
TVF : CD, TVMI, TVR at 12 month

China

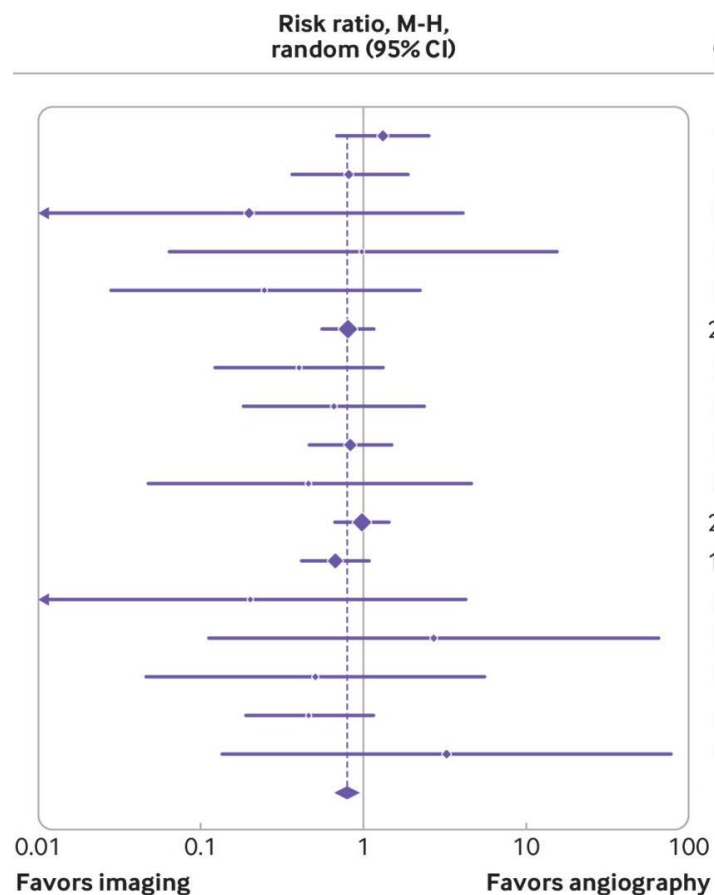
PI : Dr. Junbe Ge

Imaging vs. Angio-guided PCI : Meta-analysis of 20 RCTs

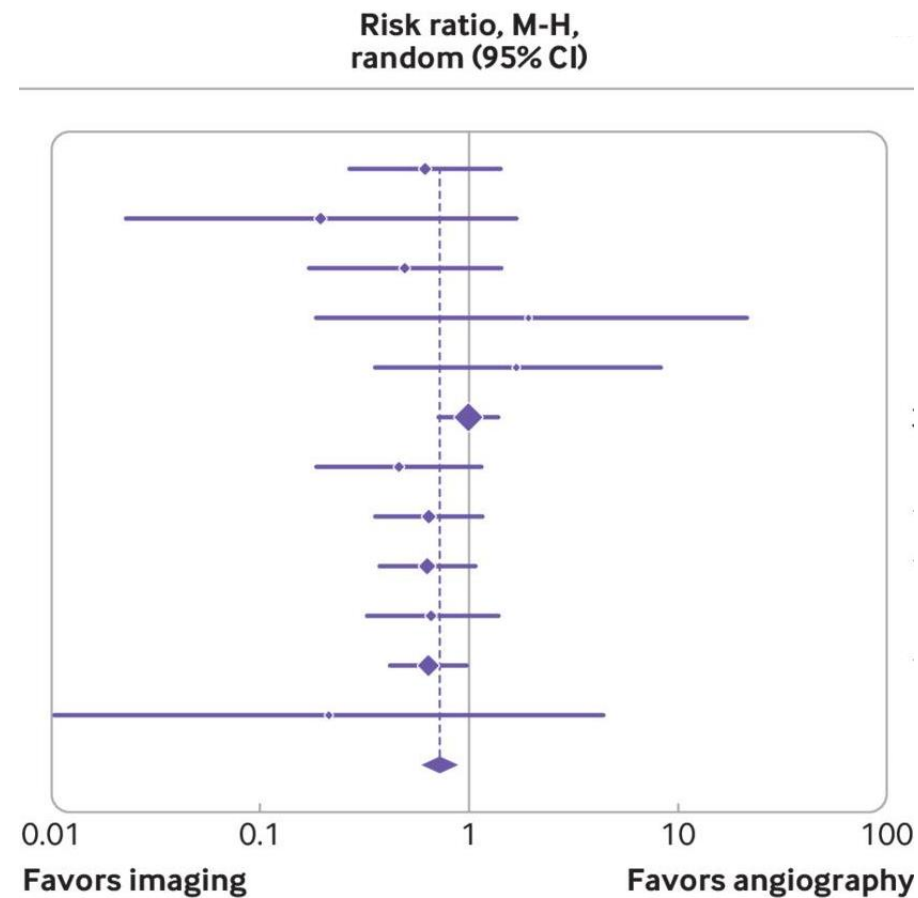
Cardiac Death



MI



TVR



Guideline Recommendations on IVUS-Guidance for LM PCI

2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization

- In patients undergoing coronary stent implantation, **IVUS** can be useful for procedural guidance, particularly in cases of **left main or complex coronary artery stenting**, to reduce ischemic events
- In patients with stent failure, IVUS or OCT is reasonable to determine the mechanism of **stent failure**

IIa

B

IIa

C

Lesson #1:

Use IVUS in Complex PCI !

Role of Intravascular Imaging for PCI Guidance?

Optimize Acute Stent Results

IVUS-Guided Complex PCI in IRIS-DES Registry

- From IRIS-DES Registry (NCT01186133) Between 2008 and 2017.
- A total 9525 patients with single complex coronary lesions were enrolled in this analysis.
- Complex coronary lesions were included
 1. LMCA
 2. Bifurcation
 3. Diffuse lesion (>30mm)
 4. Severely calcified lesion
 5. In-stent restenosis
- Primary outcome : composite of cardiac death, target vessel MI and TVR

IVUS-Guided PSP

Under the Intracoronary Imaging Guidance

Inspection of lesion characteristic by IVUS

Calcification
Plaque burden and configuration
Opening of side branch

Selection of stent size and length by IVUS

Stent landing zone configuration
Lesion length
Reference vessel size

Surveillance of stent outcomes

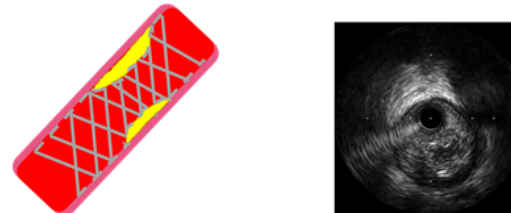
Stent apposition
Stent area
Procedural complications

P Pre-dilation



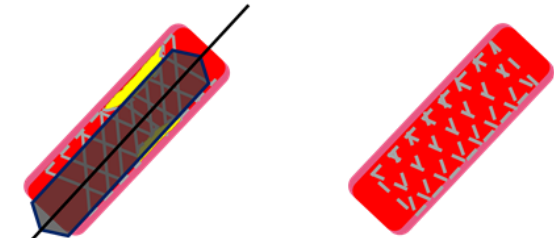
Lesion pre-modification for stent delivery and expansion:
High pressure balloon
Cutting or scoring balloon
Rota-ablation

S Stent Sizing



Full lesion coverage
Adequate stent size

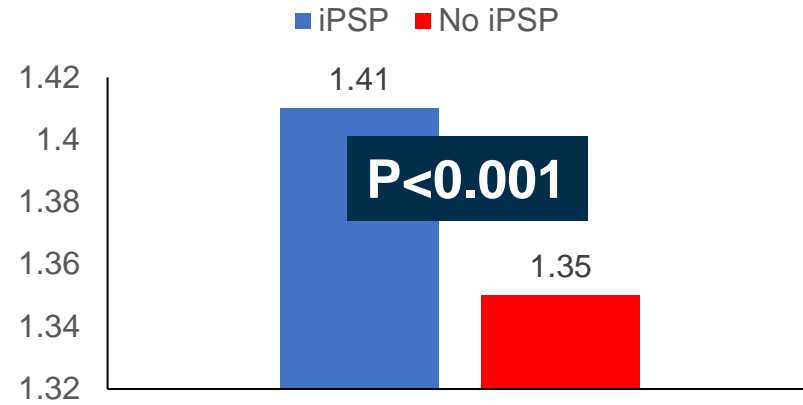
P Post-dilation



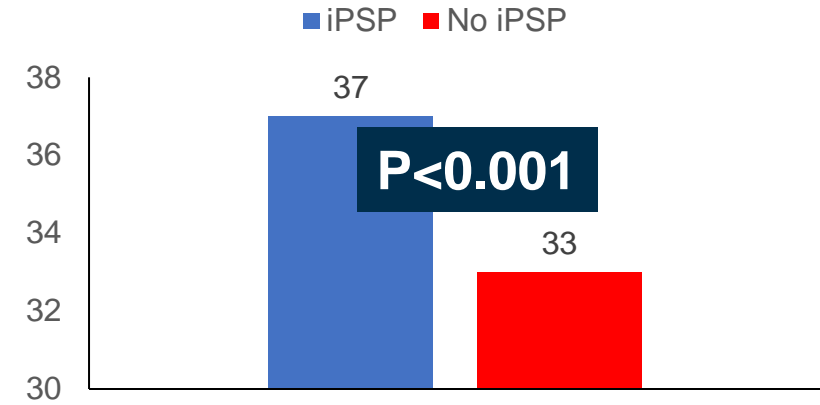
Complete stent apposition
Sufficient stent area
No geographic miss
No procedural complications

IVUS-Guided PSP, What Is Different?

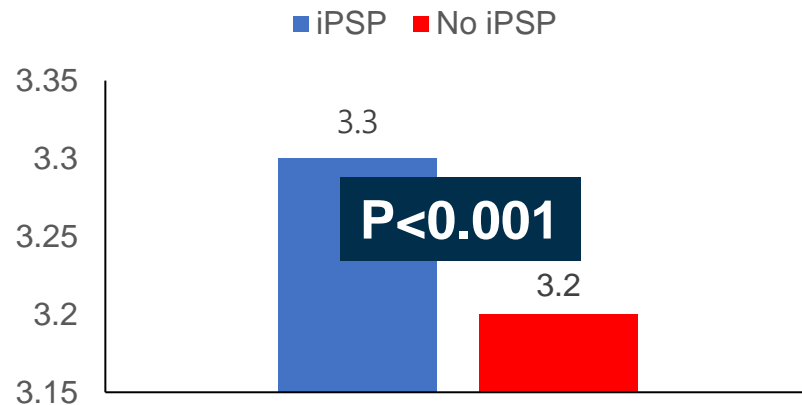
Stent Number



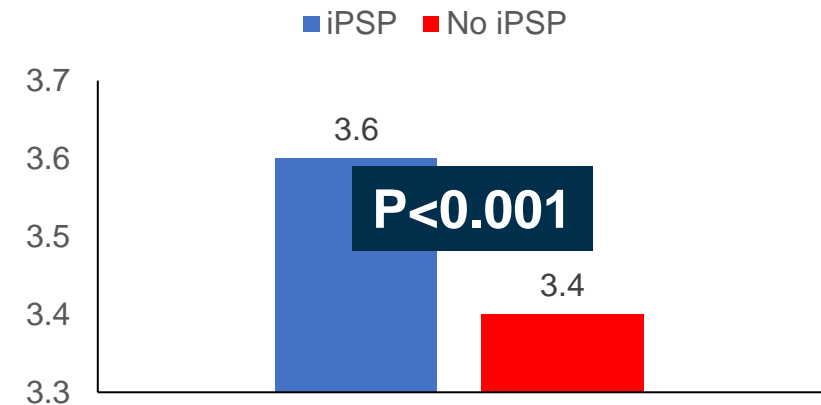
Stent Length (mm)



Stent Diameter (mm)



Final Balloon Size (mm)



Imaging-Guided Complex PCI – Better Clinical Outcome

	Crude cumulative incidence (%)			Multivariate analysis		PS matching		IPTW	
	iPSP	No iPSP	P	HR (95% CI)	P	HR (95% CI)	P	HR (95% CI)	P
Primary outcome	5.7	8.0	0.001	0.74 (0.61-0.90)	0.003	0.71 (0.56-0.90)	0.005	0.71 (0.63-0.81)	<0.001
Cardiac death	2.3	3.6	0.003	0.73 (0.53-0.99)	0.047	0.78 (0.53-1.15)	0.20	0.62 (0.51-0.75)	0.003
Target vessel MI	0.2	0.5	0.19	0.68 (0.30-1.55)	0.36	0.78 (0.29-2.09)	0.62	0.65 (0.38-1.10)	0.10
TVR	3.4	4.6	0.02	0.73 (0.57-0.94)	0.02	0.68 (0.50-0.92)	0.01	0.74 (0.63-0.87)	<0.001

Post-dilation was the Most Significant Event Predictor Among 3 Components of iPSP

	Univariate analysis		Multivariate analysis*	
	HR (95% CI)	P value	HR (95% CI)	P value
Pre-dilation	0.89 (0.69-1.15)	0.374	0.84 (0.64-1.11)	0.216
Stent-sizing	0.79 (0.67-0.93)	0.004	0.89 (0.74-1.07)	0.219
Post-dilation	0.79 (0.67-0.94)	0.006	0.80 (0.67-0.96)	0.016

Post-Balloon Size was Larger With IVUS

Pre-dilation	IVUS	Post-dilation	No. of patients (%)	Stent diameter (mm)	Post balloon size (mm)	Annualized event rate	Adjusted HR (95% CI)	P value
No	No	Yes	129 (1.4)	3.04 ± 0.41	3.10 ± 0.81	3.04 %	0.81 (0.35-1.85)	0.613
				Δ +0.05 (P=0.550)				
Yes	No	Yes	1719 (18.0)	3.08 ± 0.38	3.12 ± 0.86	3.07 %	0.80 (0.53-1.21)	0.297
				Δ +0.04 (P=0.104)				
No	Yes	Yes	309 (3.2)	3.43 ± 0.41	3.79 ± 0.70	2.04%	0.72 (0.39-1.35)	0.306
				Δ +0.35 (P<0.001)				
Yes	Yes	Yes	3374 (35.4)	3.26 ± 0.39	3.58 ± 0.60	1.98%	0.63 (0.42-0.93)	0.022
				Δ +0.32 (P<0.001)				

*With IVUS,
I Can Implant Bigger Stent,
With Higher Pressure Post-dilation,
Safely.*

Small Details Make a Big Difference !

Lesson #2:

Obtain Maximal MSA under IVUS-Guidance!

*IVUS-Guided **Left Main / Bifurcation** PCI*

Why Do We Need IVUS for LM Bifurcation PCI?

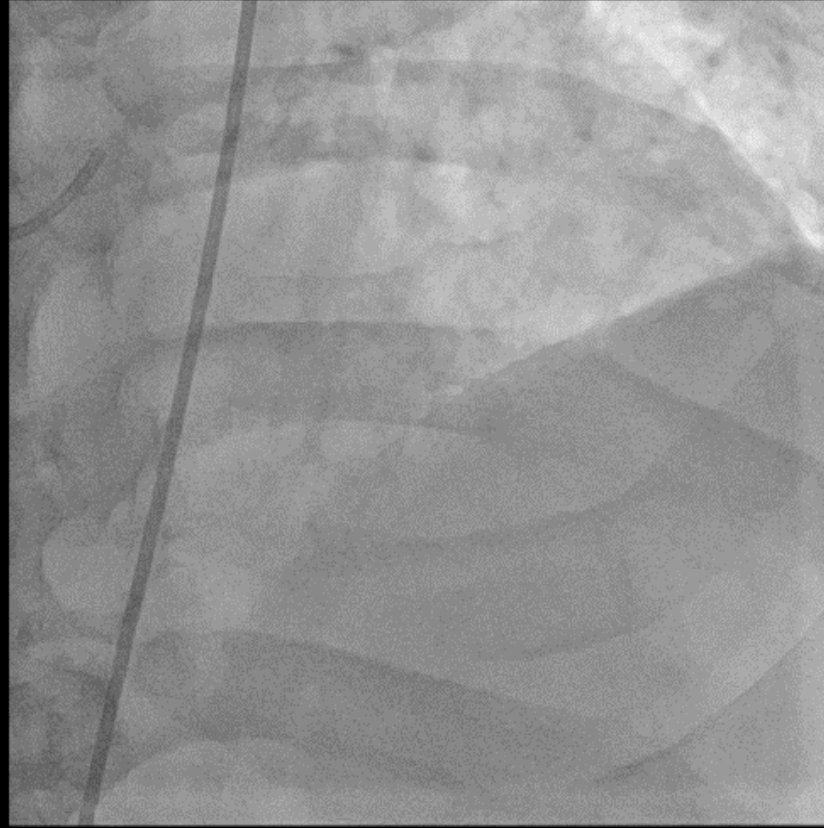
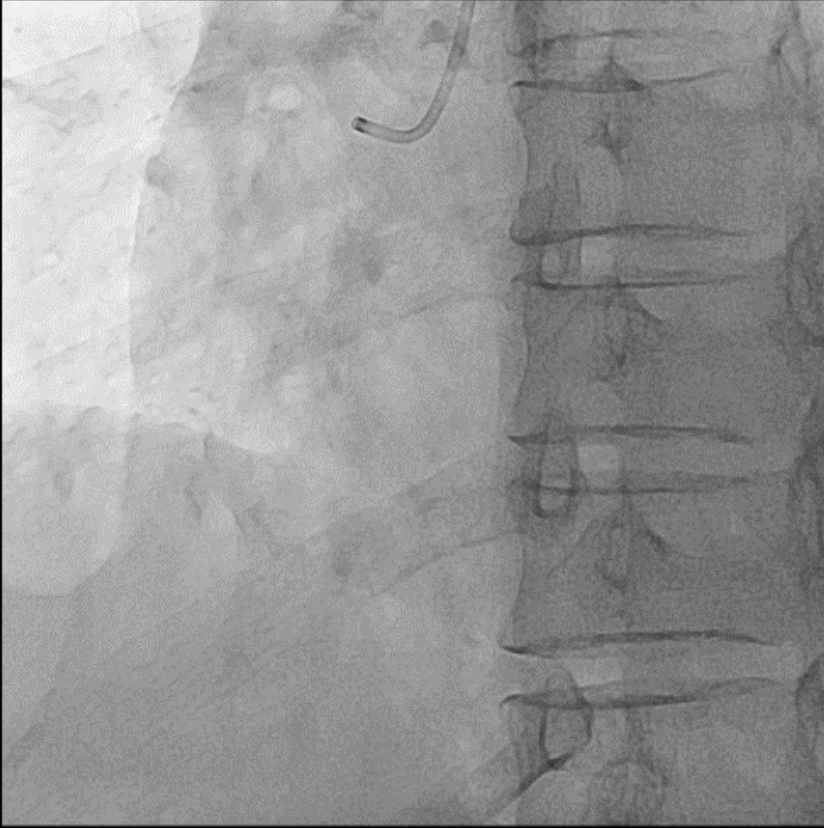
- **Planning & Guiding the PCI**

- Stent Strategy (1-stent vs. 2-stent) by Accurate SB Evaluation
- Reference Vessel Size Measurement
- Select Bigger Stent & Balloons Under Vessel Size

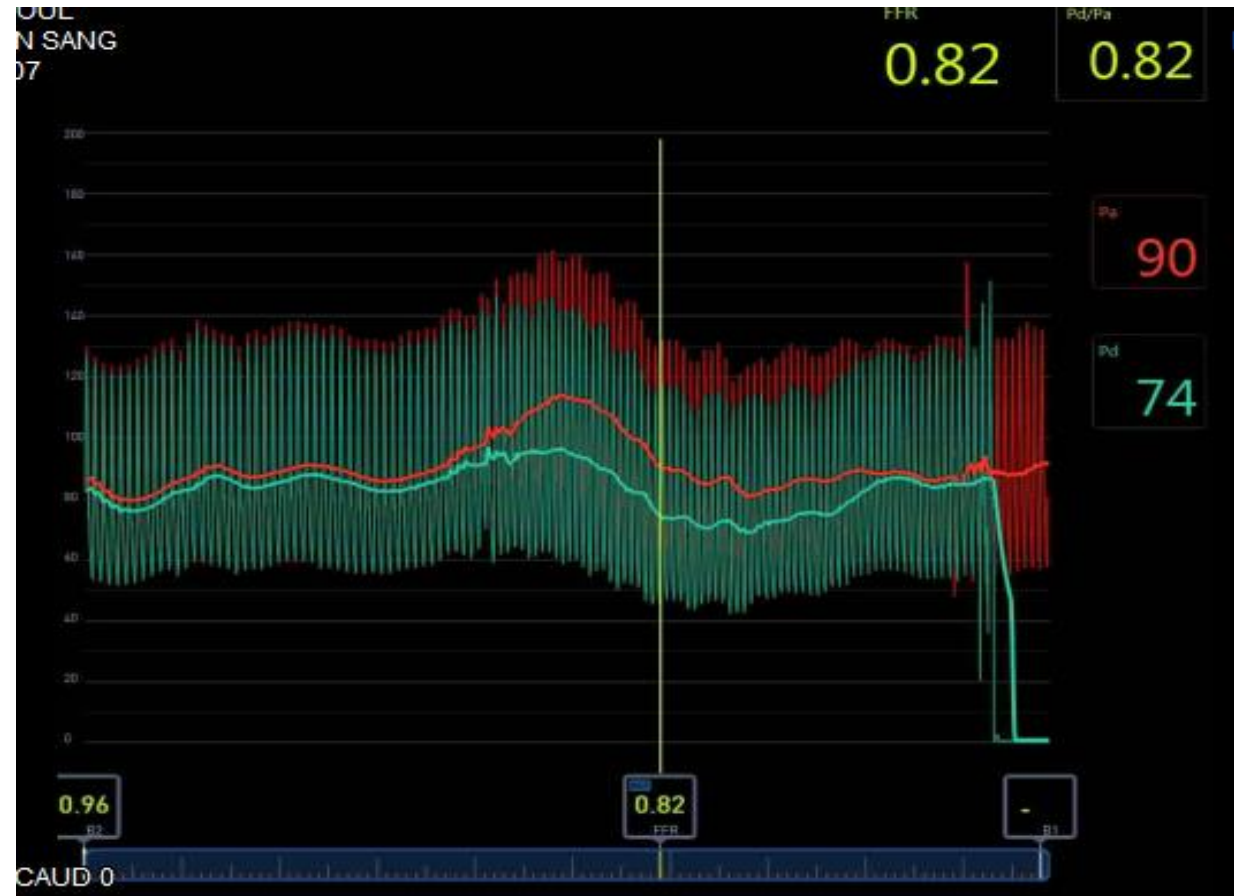
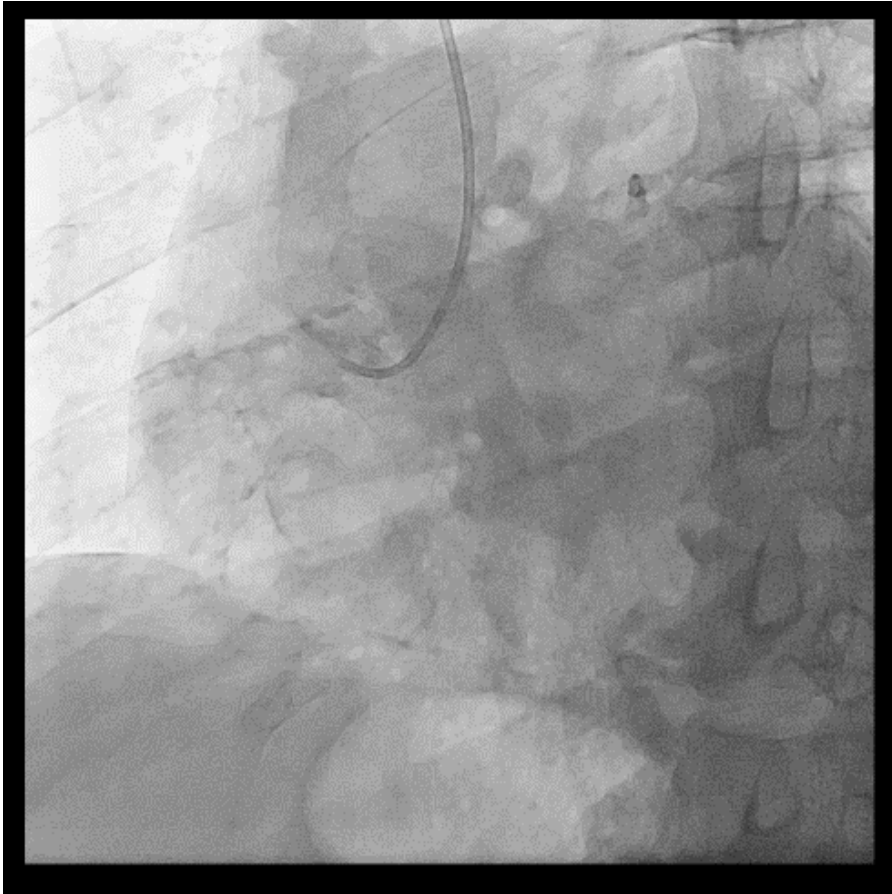
- **Final Assessment after PCI**

- Evaluate Stent Expansion, Strut Apposition, Edge Problems

84/M, NSTEMI, Referred for LM + 3VD

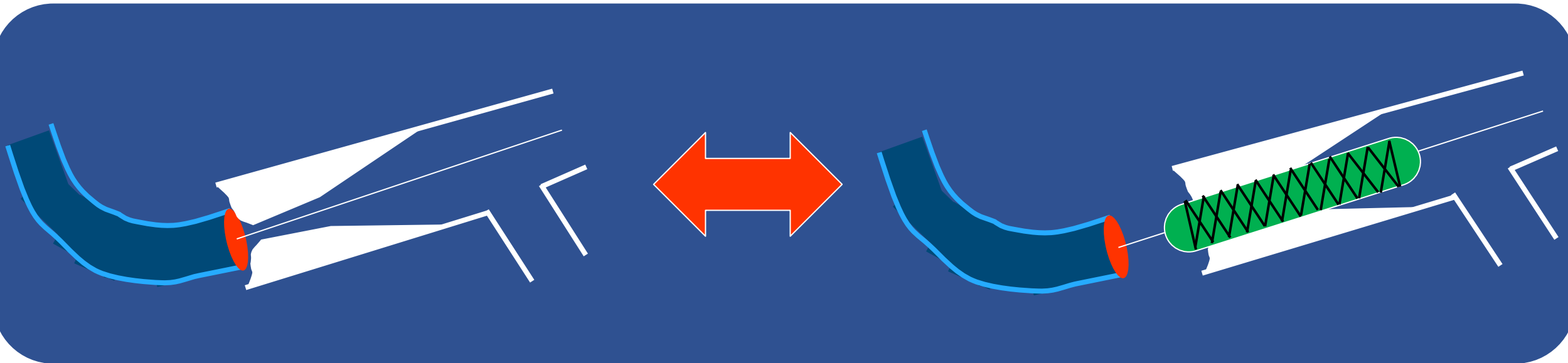
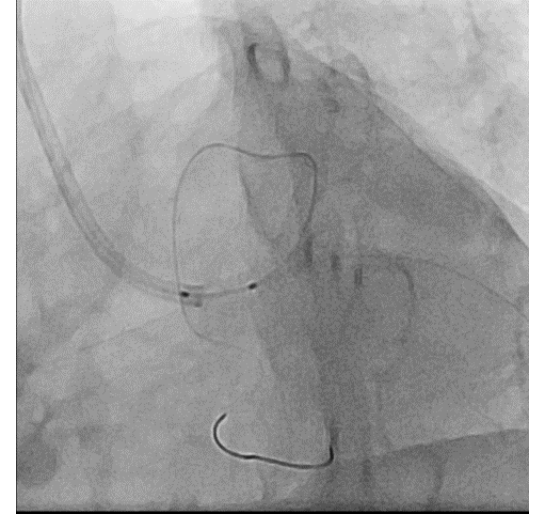


RCA – FFR guided defer (0.82)

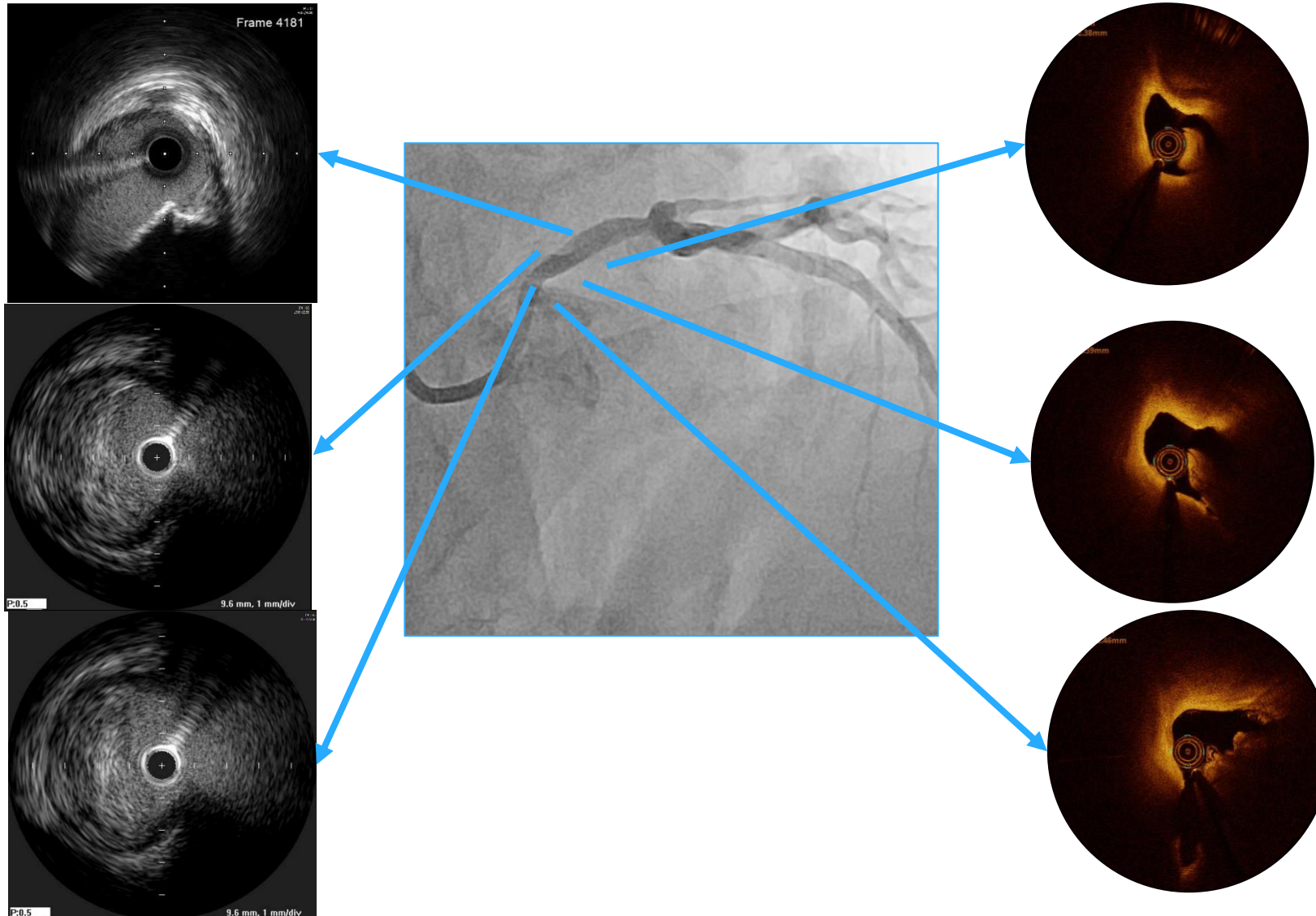


For LM PCI, I Prefer Large (7 or 8 Fr) JL GC with Side Hole

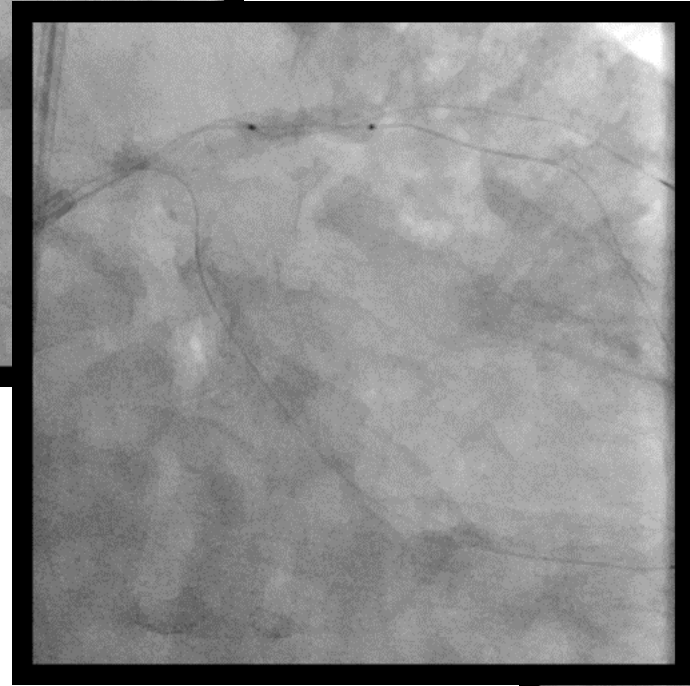
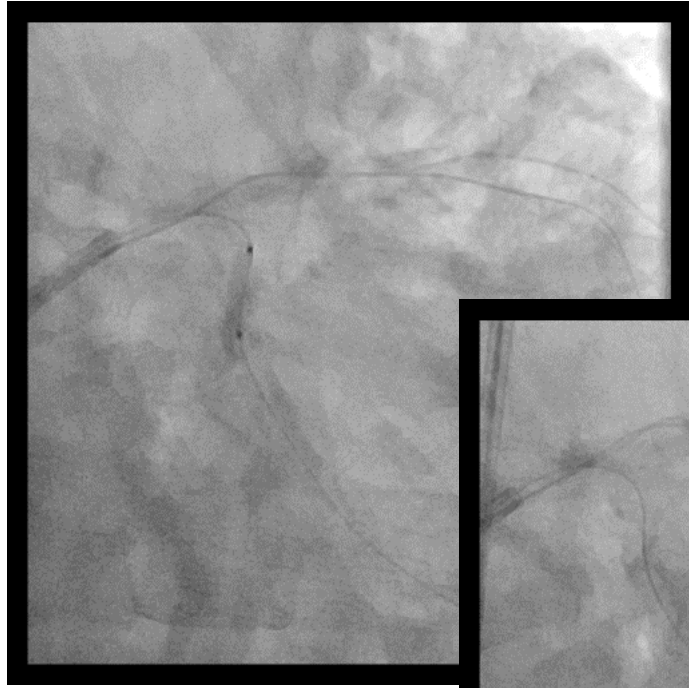
- Minimize Ostial Injury
- Easy Back-and-Forth Motion during Procedure
- Safer Hemodynamics with Side Hole



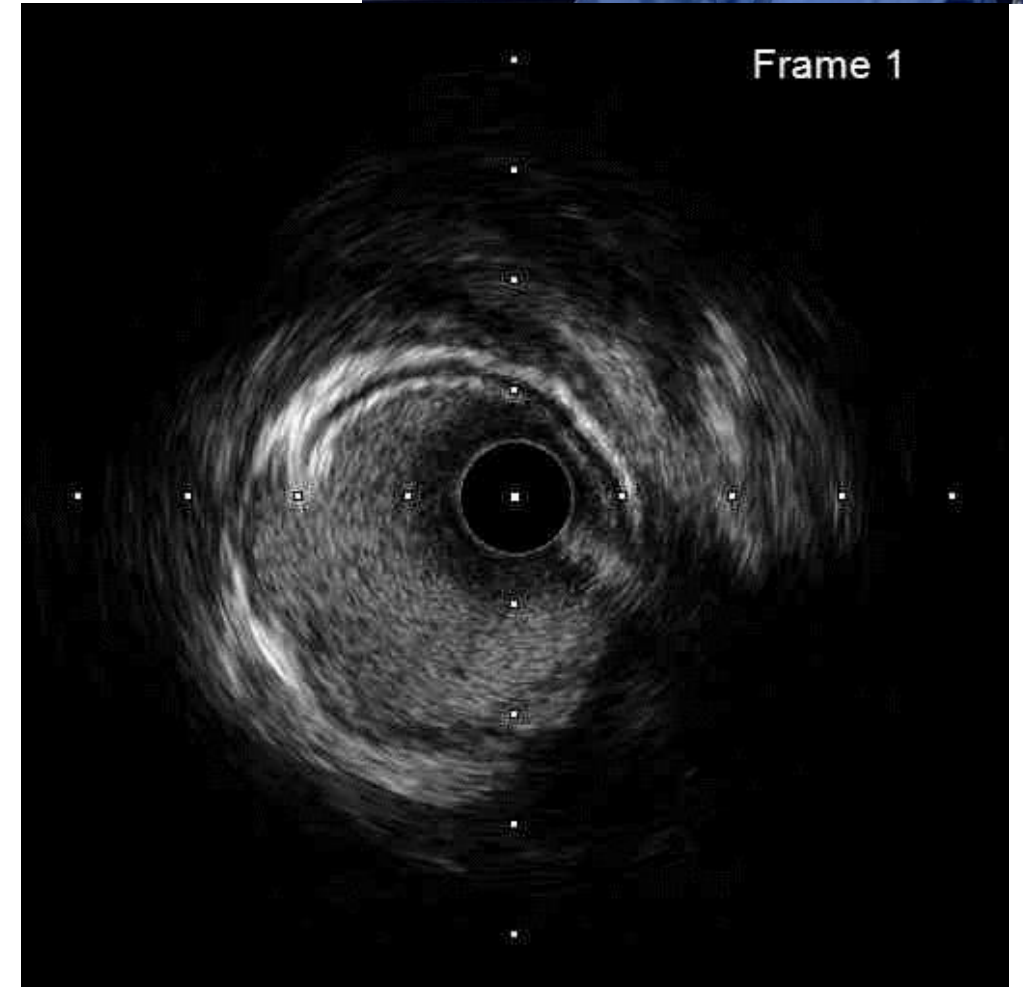
IVUS : Better for Ostial Evaluation



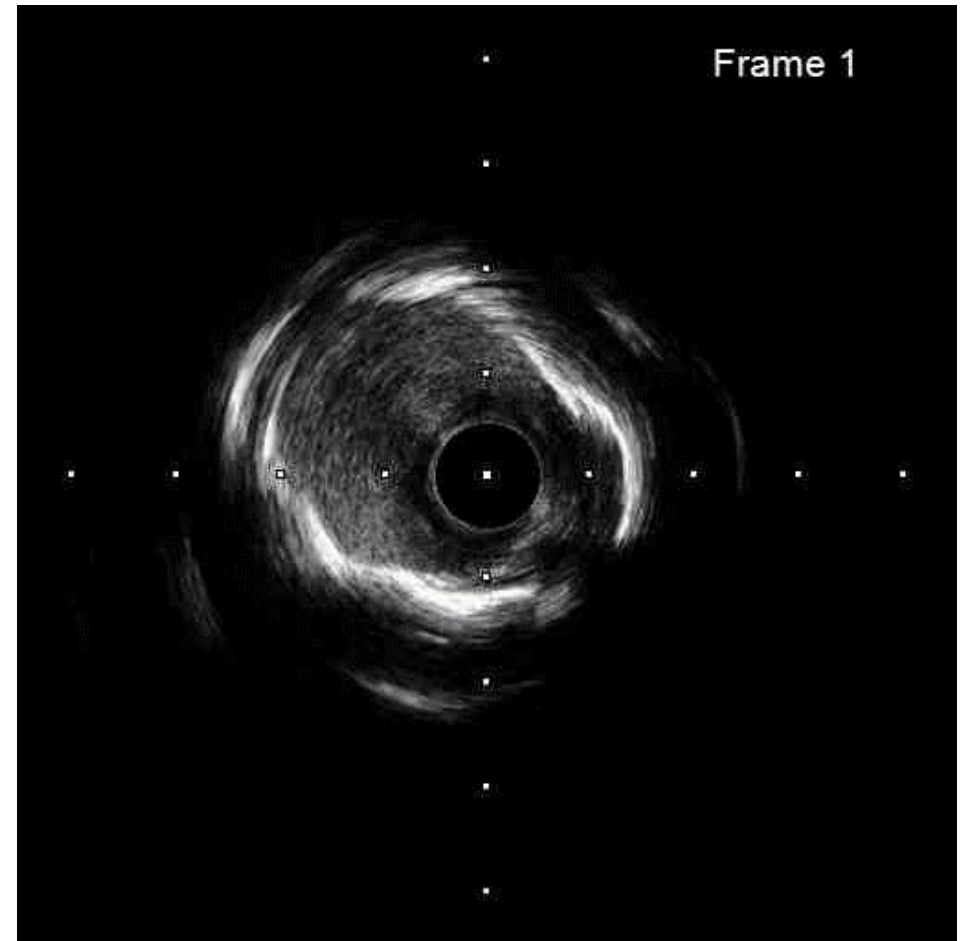
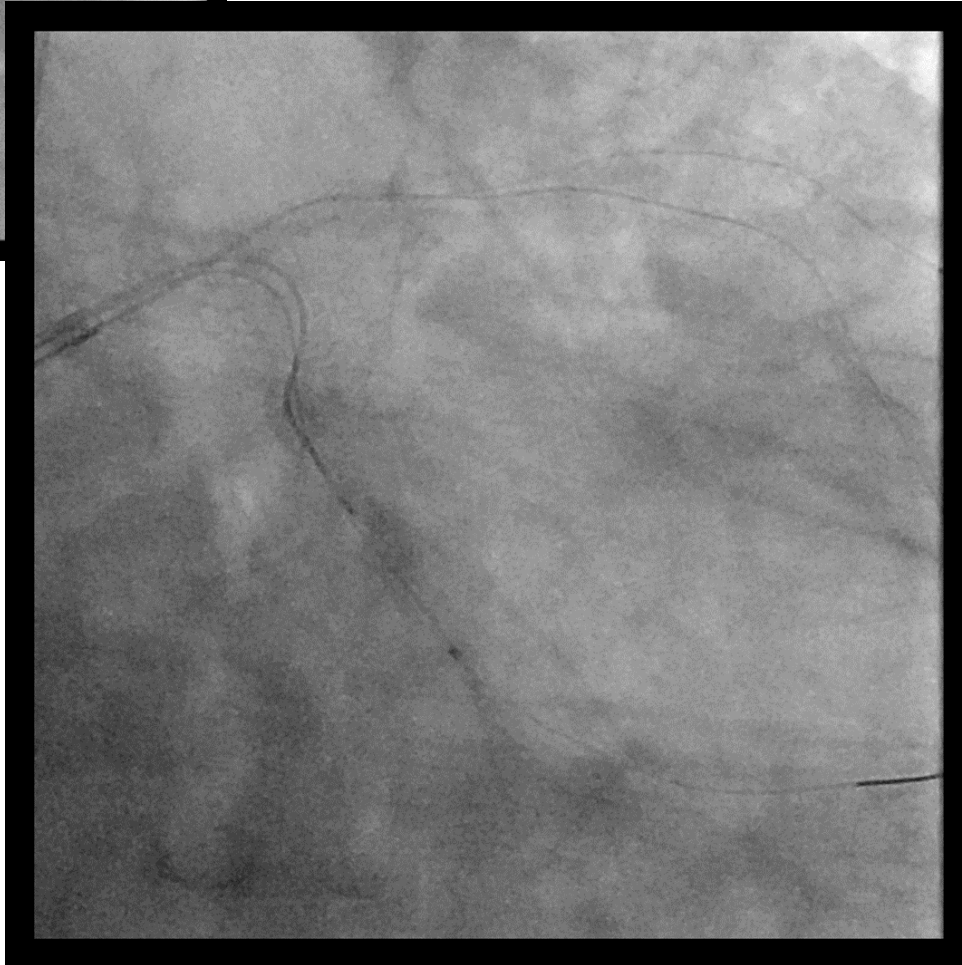
Pre-dilation



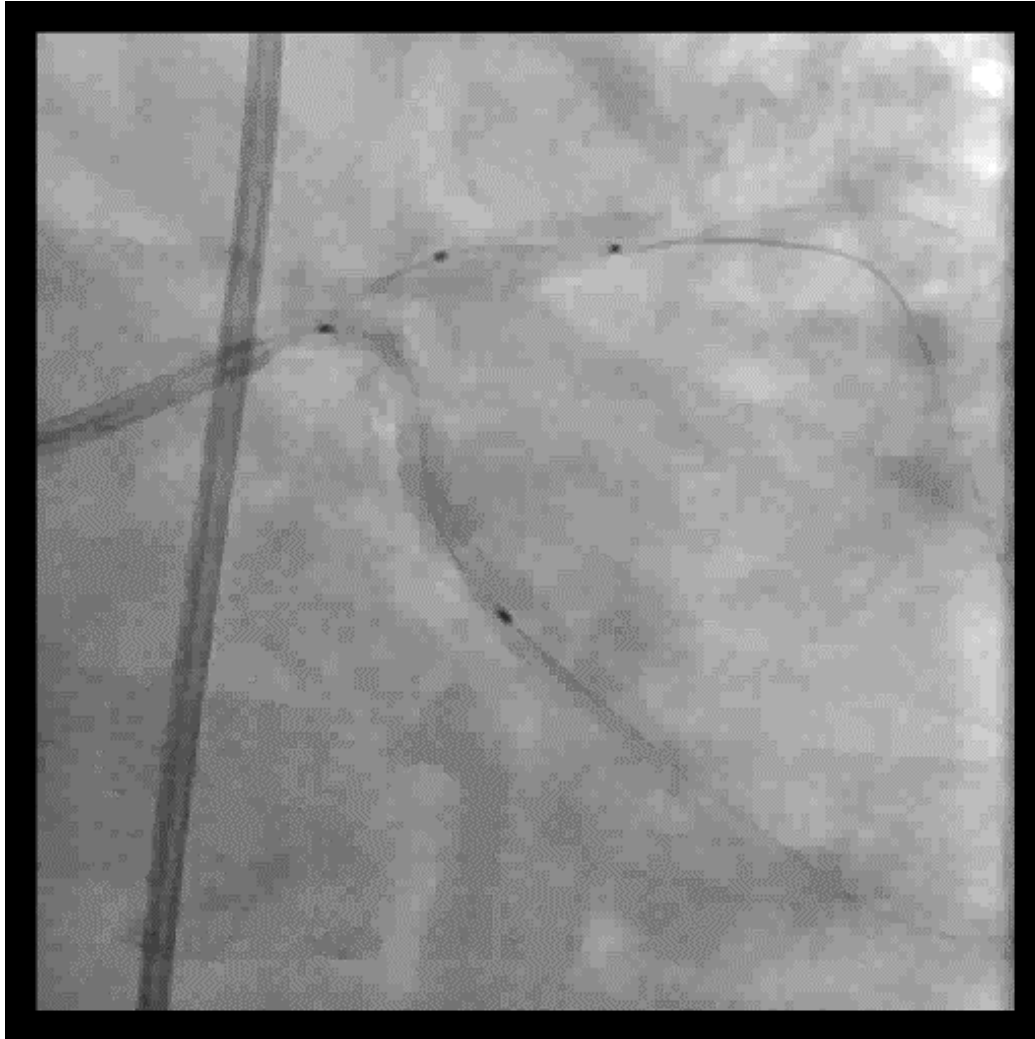
IVUS Evaluation - LAD



IVUS Evaluation - LCX



Upfront 2-stent with CRUSH technique



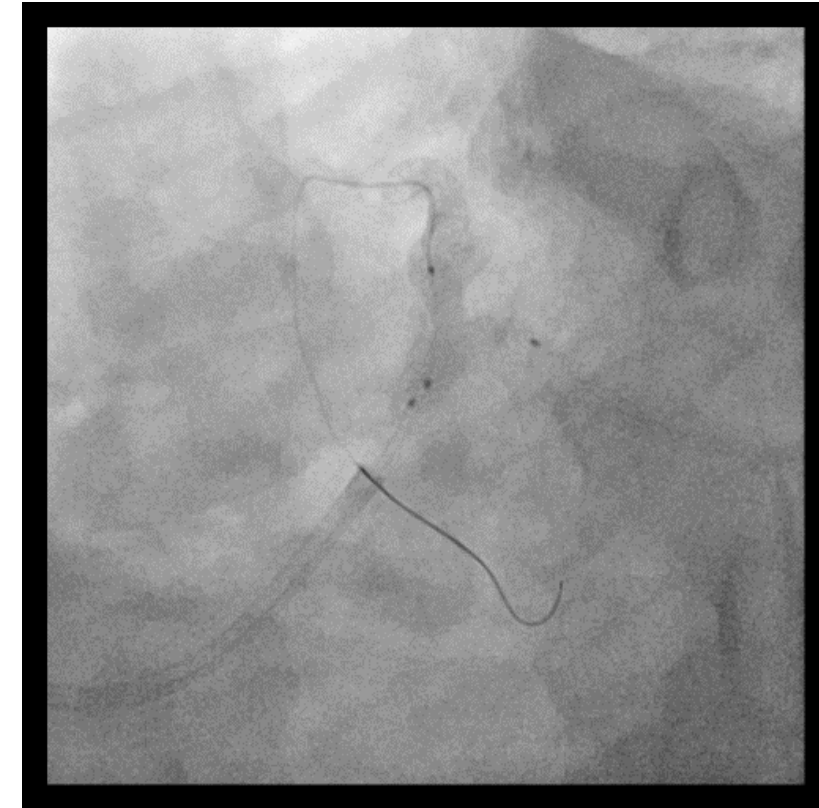
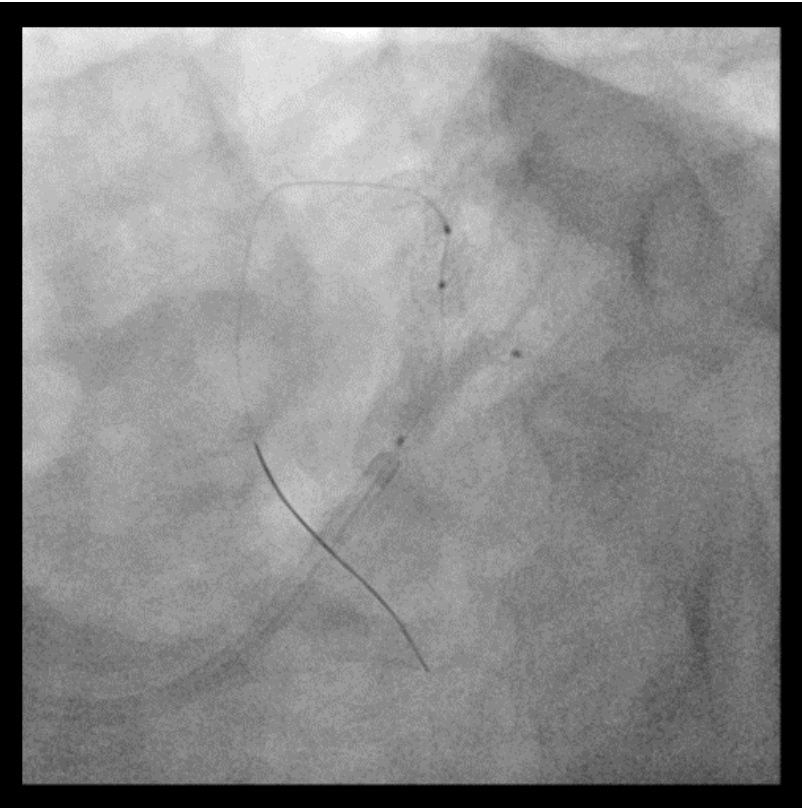
LCX DES 2.75 * 33 mm



3.0 * 15 mm NC Balloon

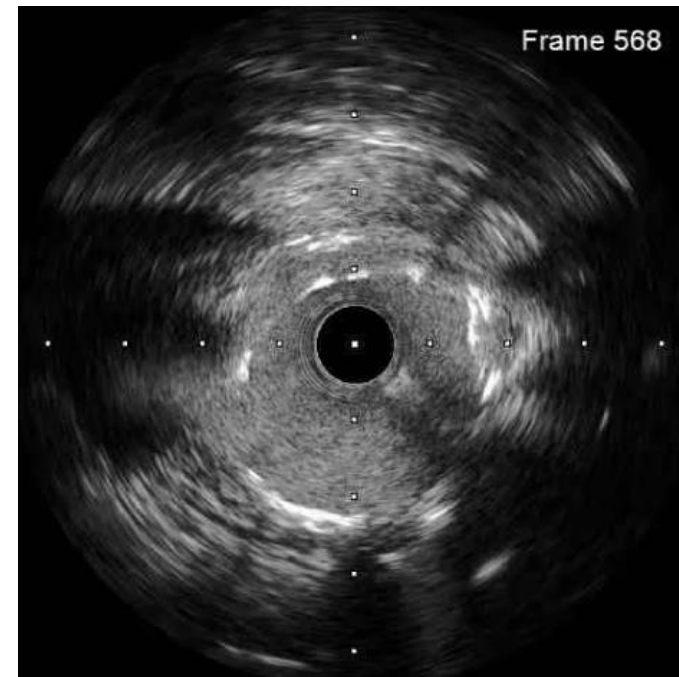
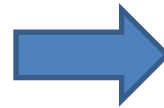
Sequential High-pressure Balloon Inflation

: To Obtain Sufficient Stent Cross-sectional Area



Adequate Balloon Size is Important

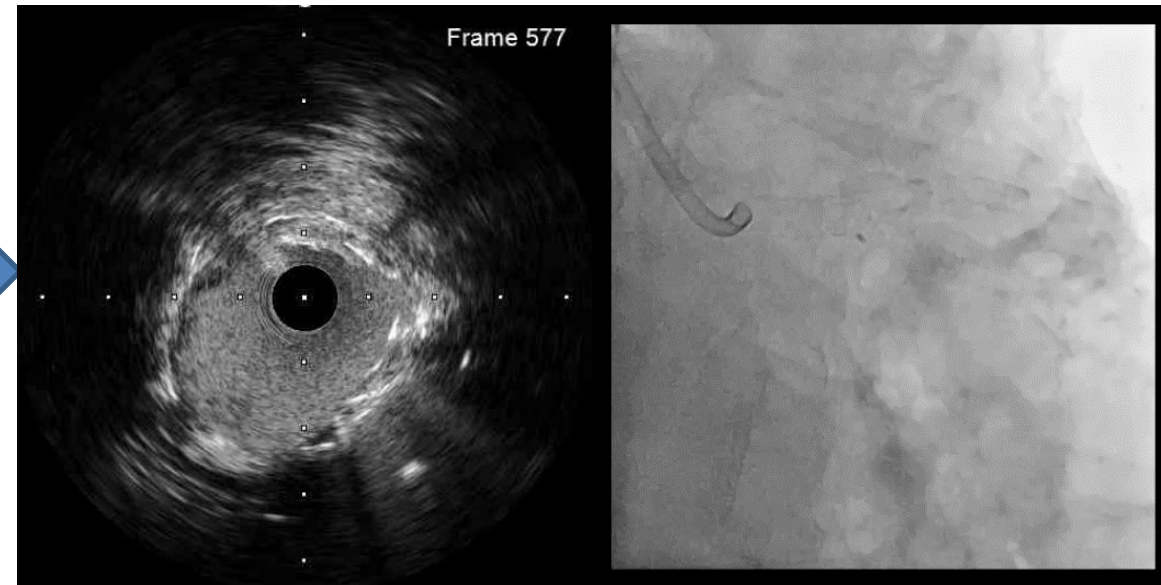
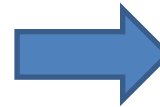
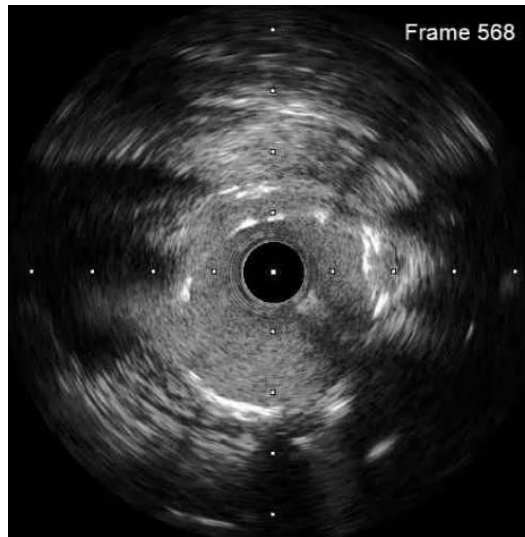
- Small-sized balloons make under-expansion & malapposition, especially at POC area
- IVUS review & applying bigger NC balloons made better results



Kissing Balloon with
3.5 & 3.0 mm NC

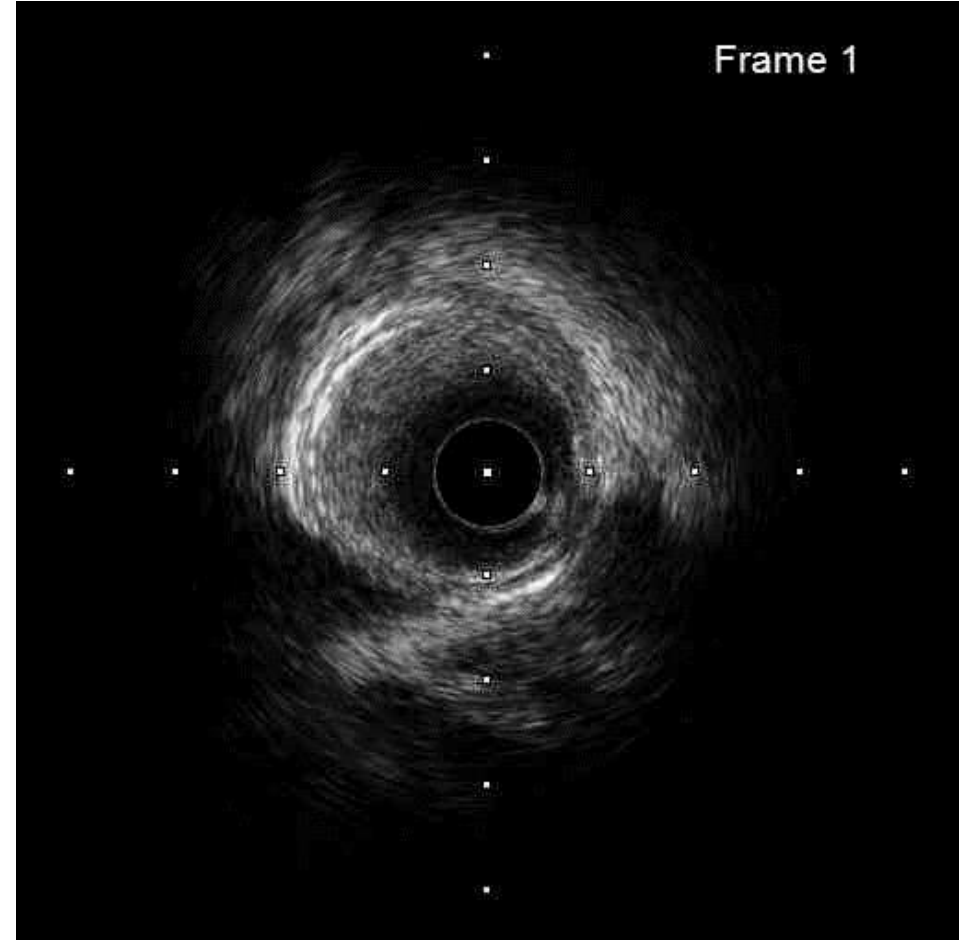
Adequate Balloon Size is Important

- Small-sized balloons make under-expansion & malapposition, especially at POC area
- IVUS review & applying bigger NC balloons made better results

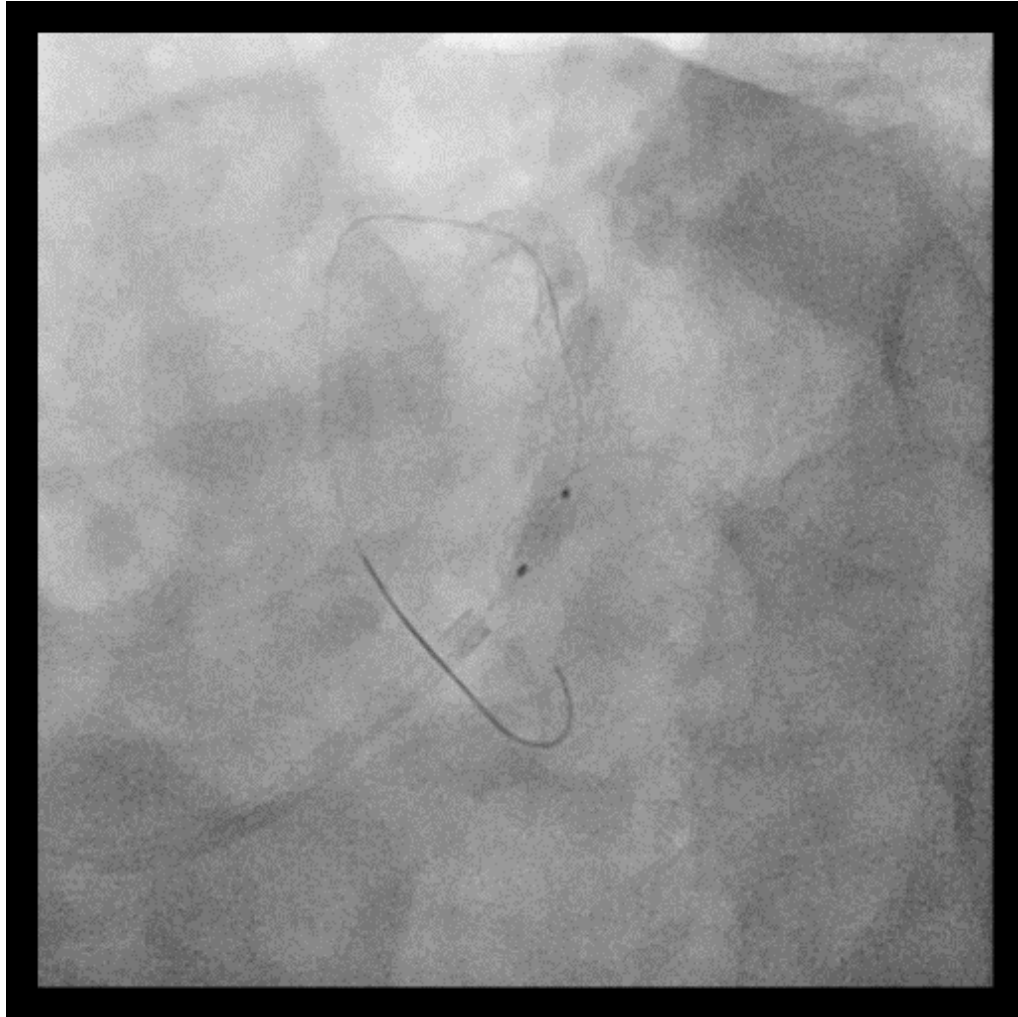


Kissing Balloon with
4.0 & 3.5 mm NC

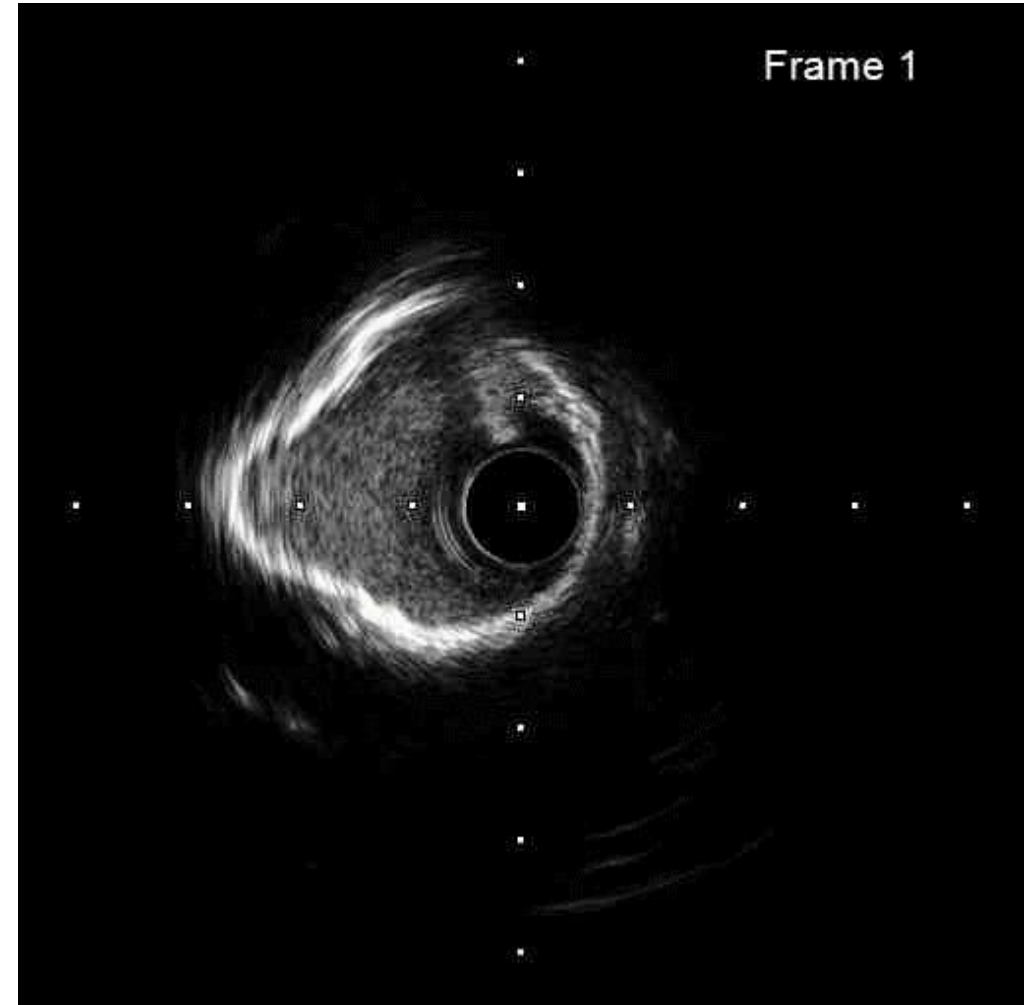
IVUS after KB



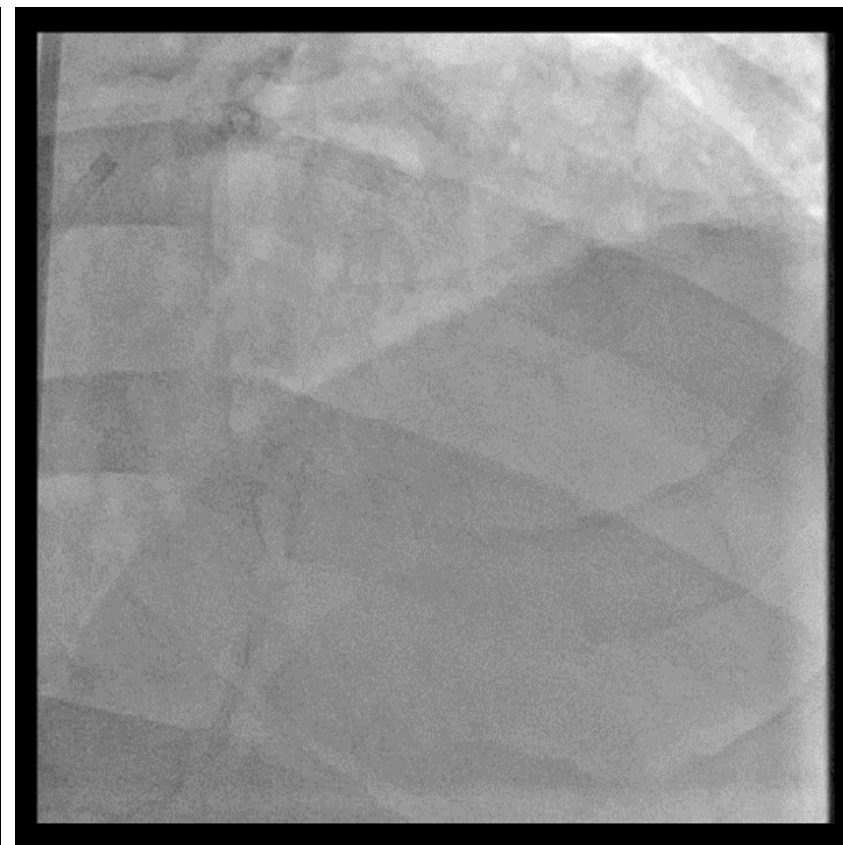
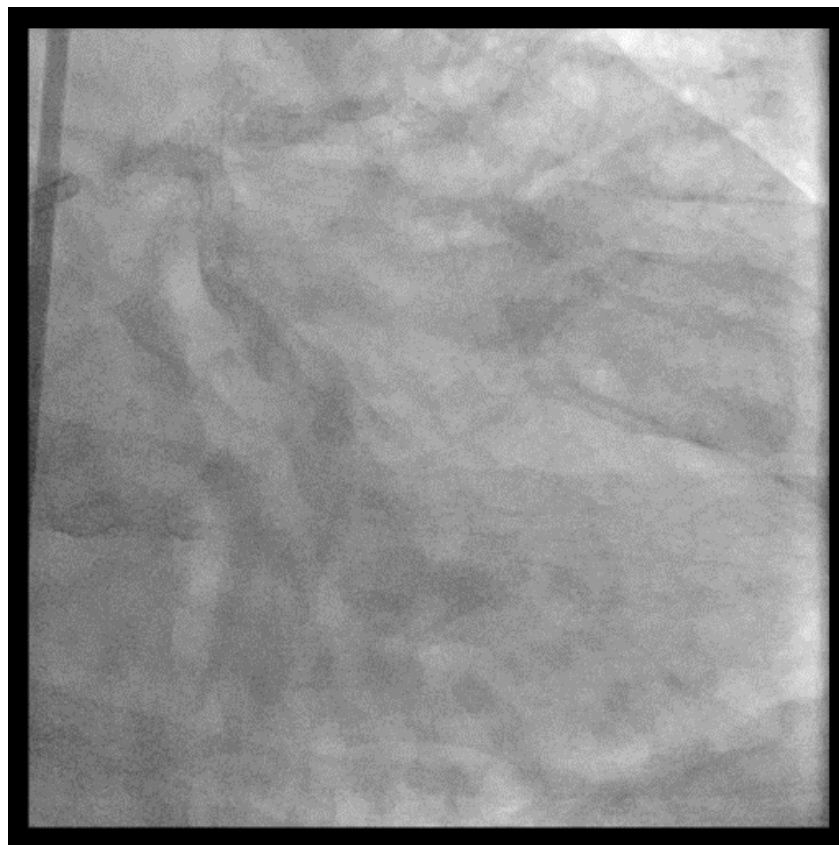
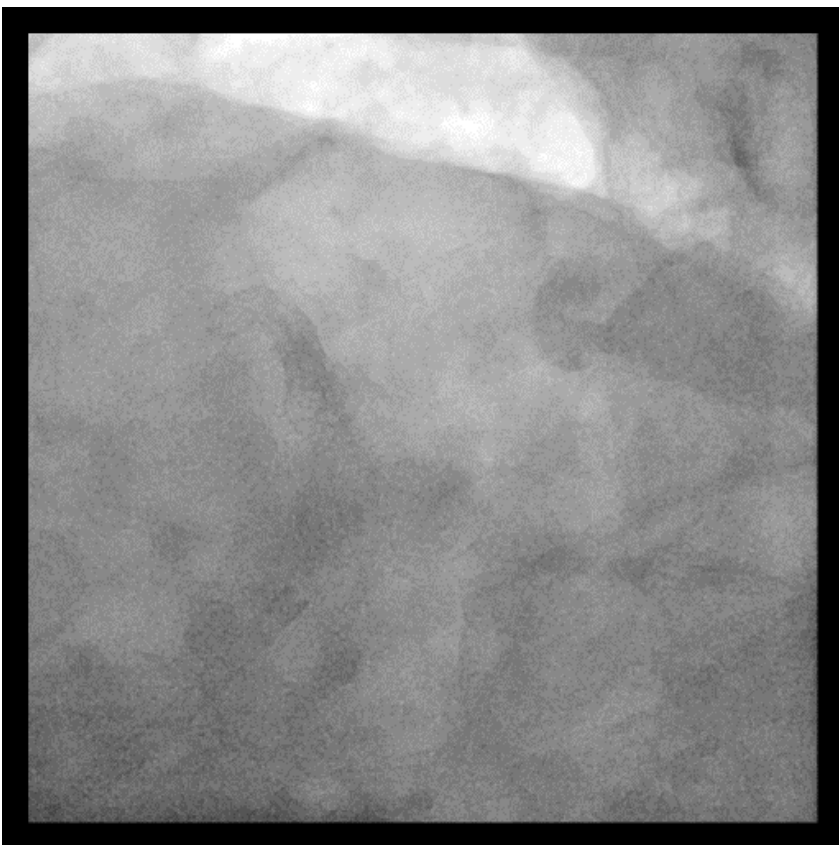
Additional LM ostial Balloon



4.0 * 8 mm NC Balloon

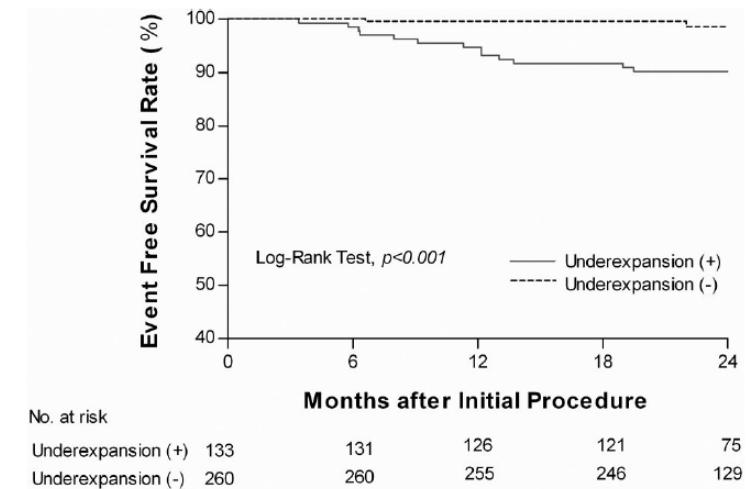
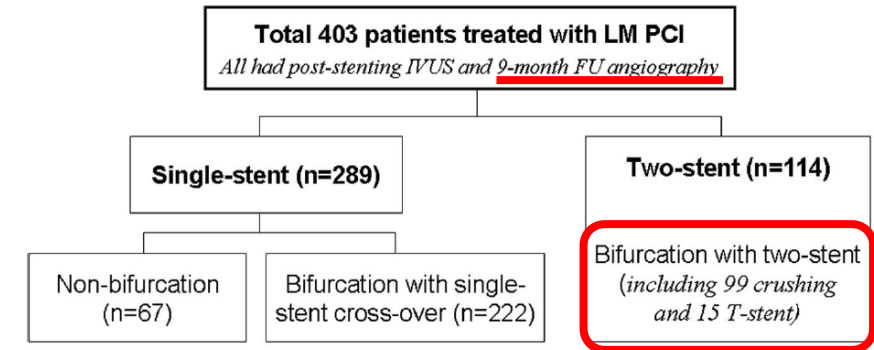
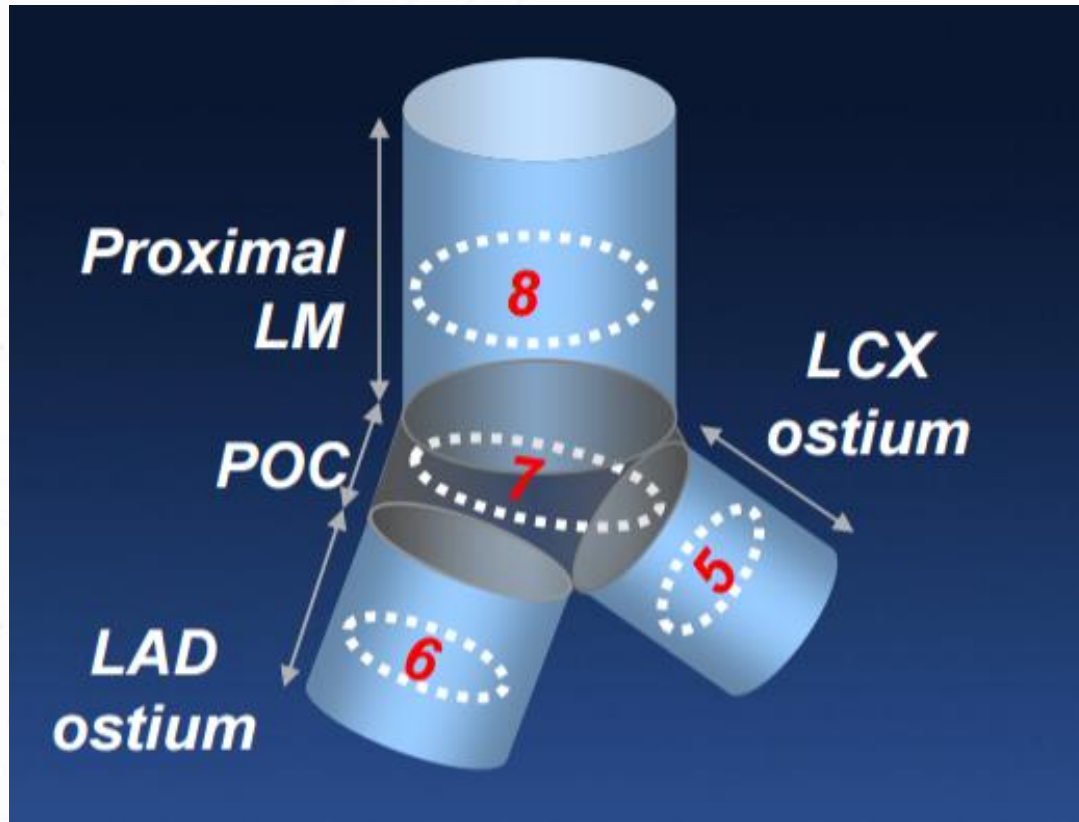


Final CAG



LM IVUS MSA Criteria

Asan Medical Center Criteria



Kang SJ, et al. Circ Cardiovasc Interv 2011;4:562-9

Optimal MSA Criteria For LM Crush Technique Based on Long-Term (5-Year) Clinical Outcomes

292 Patients

- Treated By Crush Technique
- Complete IVUS Imaging

Patients with unprotected LM bifurcation lesion who underwent upfront two-stent technique from March 2005 to Dec 2019 (N=479)

Excluded, N = 187

5 patient underwent simultaneous kissing stents

15 patients underwent classic T-stenting

88 patients without IVUS-guidance

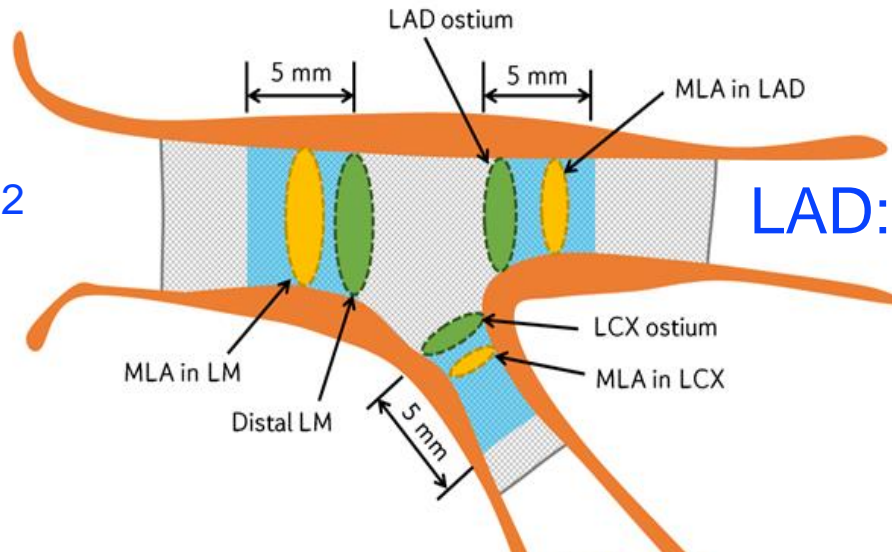
18 patients without poststenting IVUS from LAD-pullback

61 patients without poststenting IVUS from LCX-pullback

Patients who underwent two-stent PCI with crush technique and had complete poststenting IVUS images from both LAD and LCX pullback (N=292)

ROC Curve Analysis

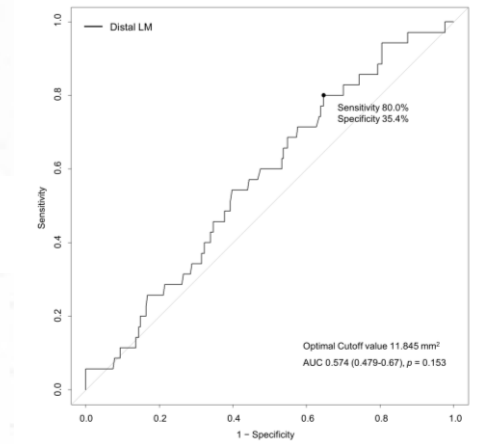
LM: 11.8 mm²



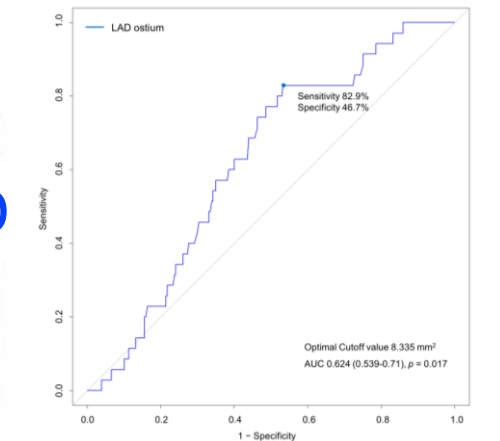
LAD: 8.3 mm²

LCX: 5.7 mm²

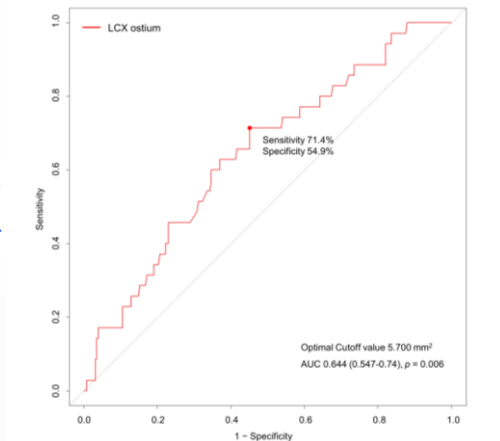
LM



LAD



LCX

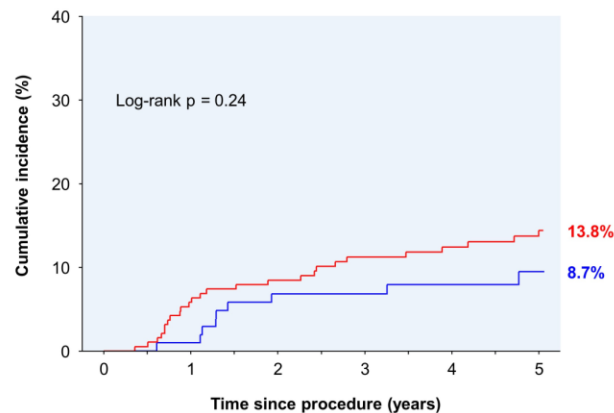


	Cutoff point	AUC (95% CI)	Sensitivity	Specificity	P value
IVUS-measured MSA (mm²)					
Distal LM	11.8	0.57 (0.48–0.67)	80.0%	35.4%	0.153
LAD ostium	8.3	0.62 (0.54–0.71)	82.9%	46.7%	0.017
LCX ostium, by LCX pullback	5.7	0.64 (0.55–0.74)	71.4%	54.9%	0.006

LM<11.8 mm²: 64.7%

A

Major Adverse Cardiac Events

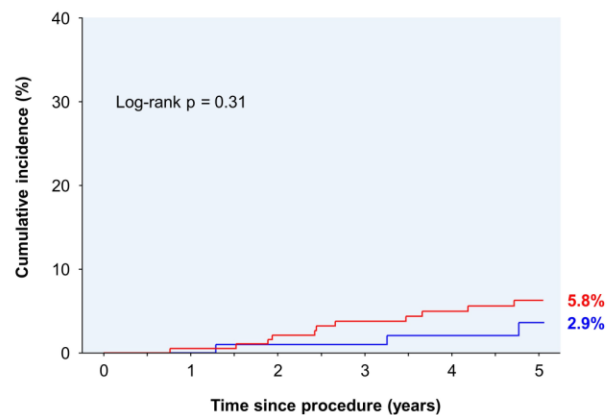


No. at risk

LM MSA < 11.8 mm ²	189	178	173	155	141	125
LM MSA ≥ 11.8 mm ²	103	102	94	87	67	56

D

All-Cause Death



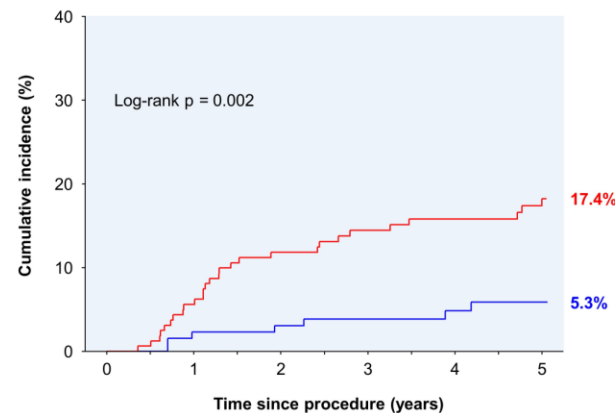
No. at risk

LM MSA < 11.8 mm ²	189	188	185	168	152	135
LM MSA ≥ 11.8 mm ²	103	103	100	93	72	60

LAD<8.3 mm²: 55.1%

B

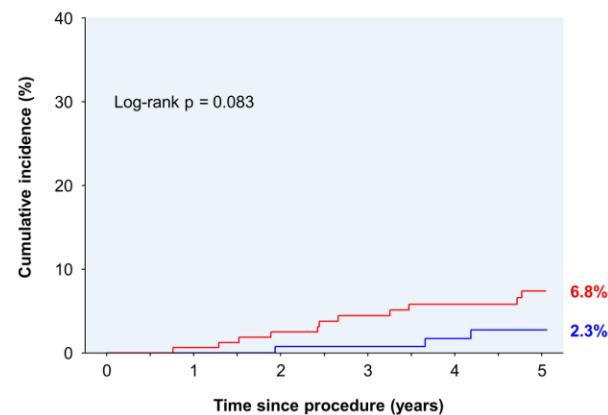
Major Adverse Cardiac Events



No. at risk

LAD MSA < 8.3 mm ²	161	152	142	128	114	98
LAD MSA ≥ 8.3 mm ²	131	128	125	114	94	83

All-Cause Death



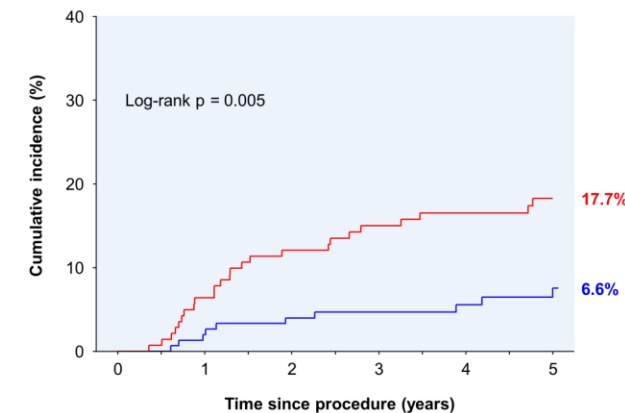
No. at risk

LAD MSA < 8.3 mm ²	161	160	157	143	128	111
LAD MSA ≥ 8.3 mm ²	131	131	128	118	96	84

LCX<5.7 mm²: 48.3%

C

Major Adverse Cardiac Events

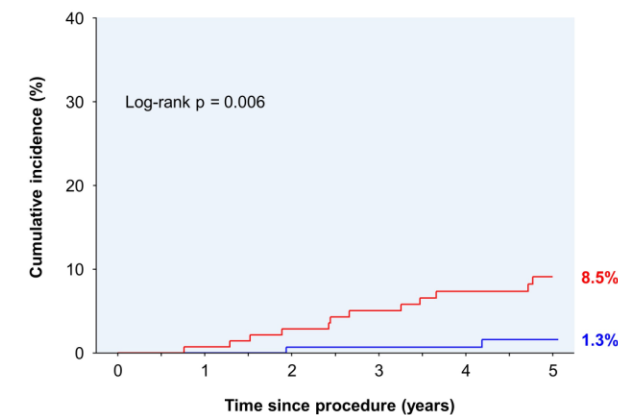


No. at risk

LCX MSA < 5.7 mm ²	141	132	124	114	103	93
LCX MSA ≥ 5.7 mm ²	151	148	143	128	105	88

:

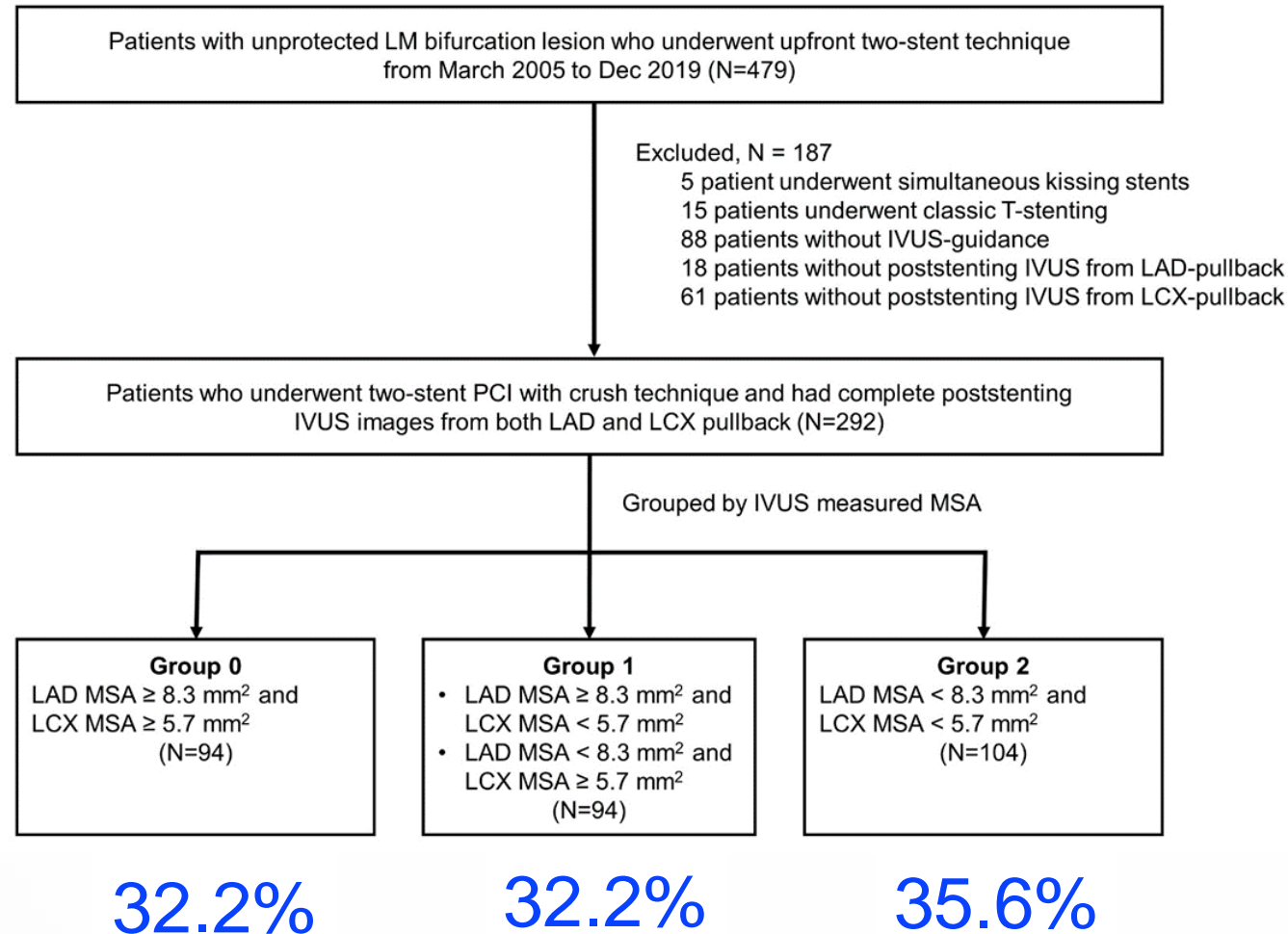
All-Cause Death



No. at risk

LCX MSA < 5.7 mm ²	141	140	137	127	114	103
LCX MSA ≥ 5.7 mm ²	151	151	148	134	110	92

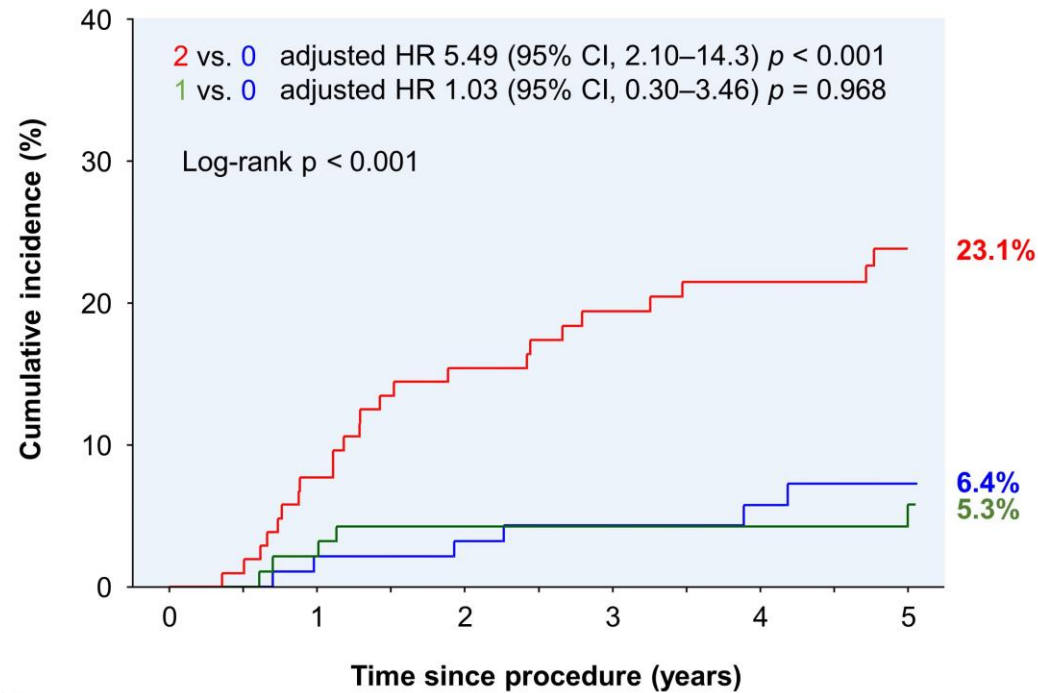
Incidence of Under-expansion of LM Segments and Outcomes



Incidence of Under-expansion of LM Segments and Outcomes

A

Major Adverse Cardiac Events

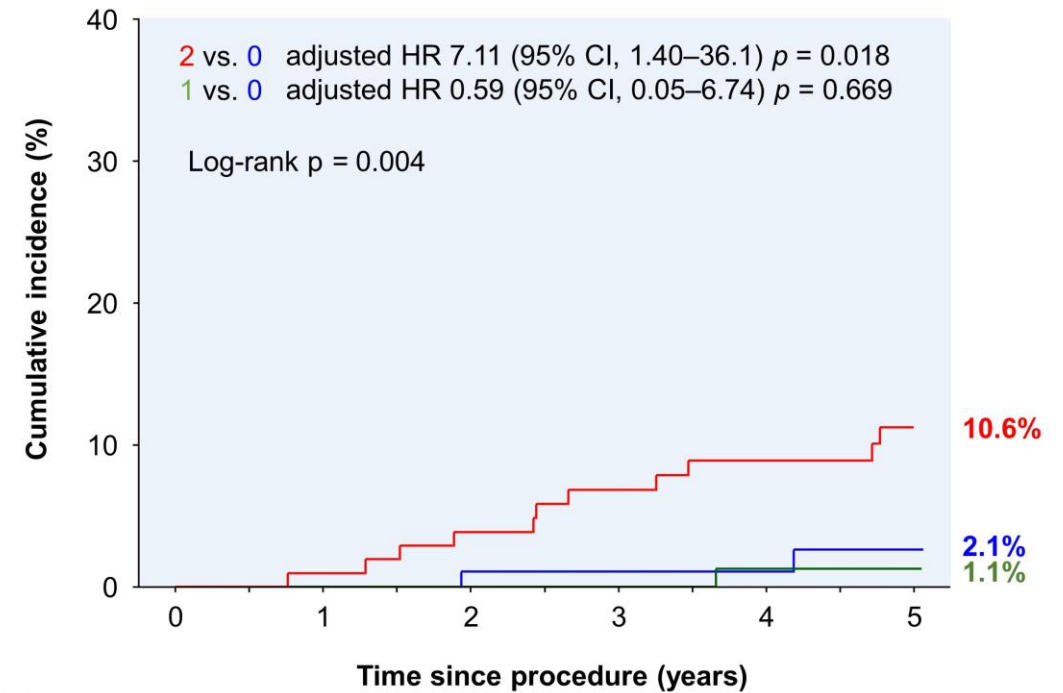


No. at risk

Group 2	104	96	88	79	73	64
Group 1	94	92	90	84	71	63
Group 0	94	92	89	79	64	54

B

All-Cause Death



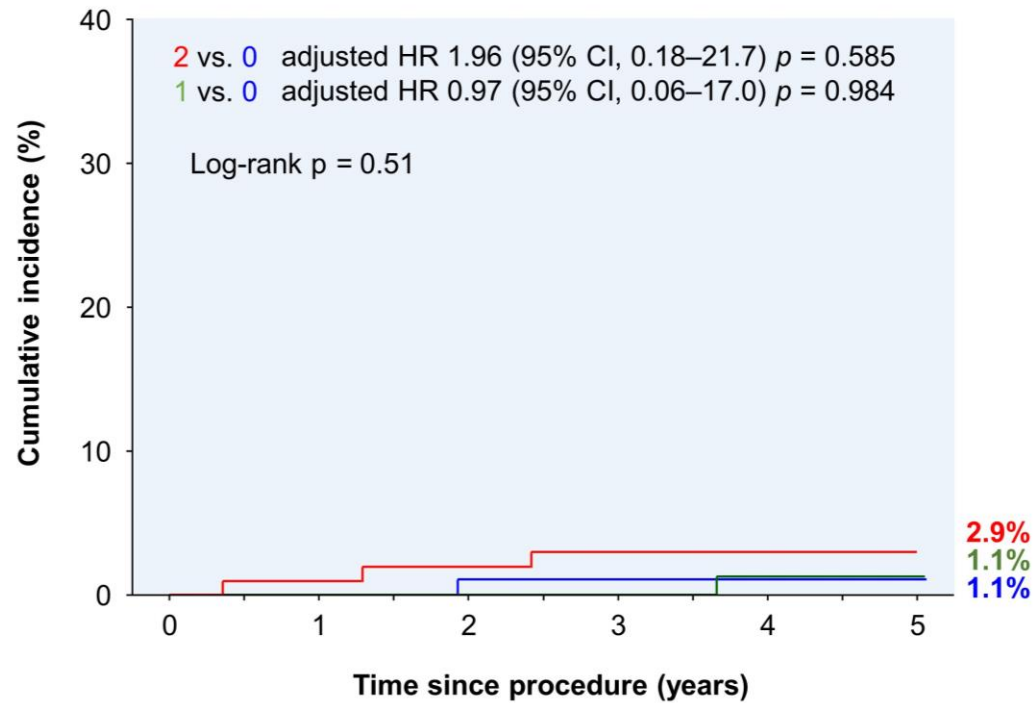
No. at risk

Group 2	104	103	100	91	84	74
Group 1	94	94	94	88	74	66
Group 0	94	94	91	82	66	55

Incidence of Under-expansion of LM Segments and Outcomes

C

Myocardial Infarction

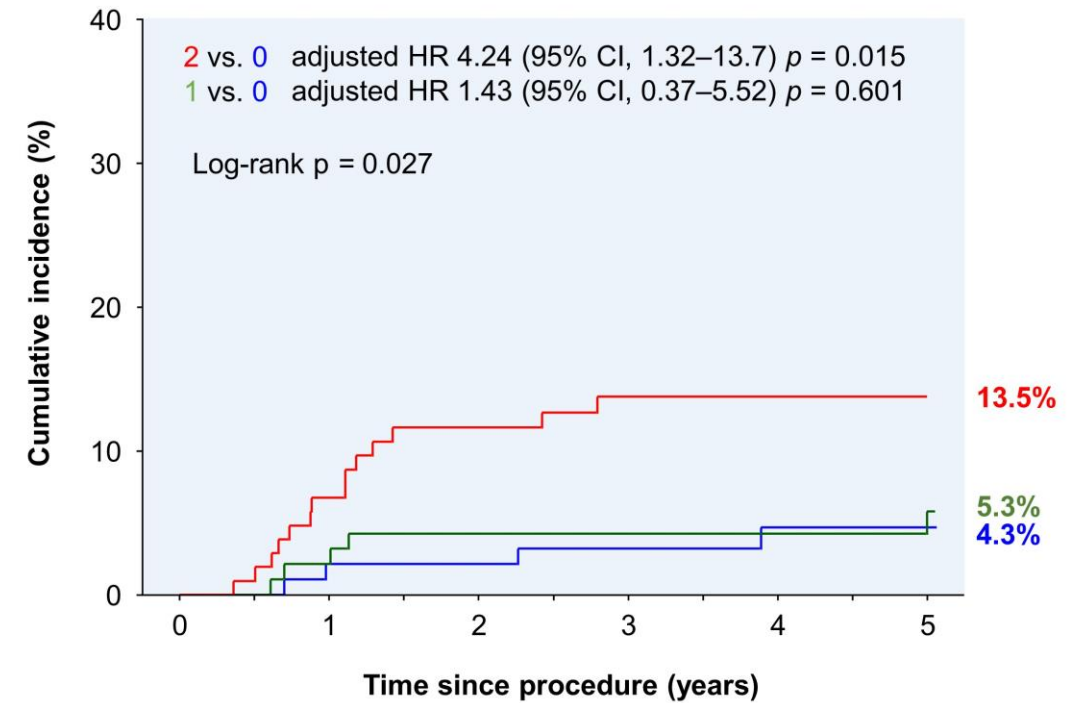


No. at risk

Group 2	104	102	98	89	82	72
Group 1	94	94	94	88	74	66
Group 0	94	94	90	81	65	54

D

Target Lesion Revascularization



No. at risk

Group 2	104	96	88	79	73	64
Group 1	94	92	90	84	71	63
Group 0	94	92	90	80	65	55

Lesson #3:

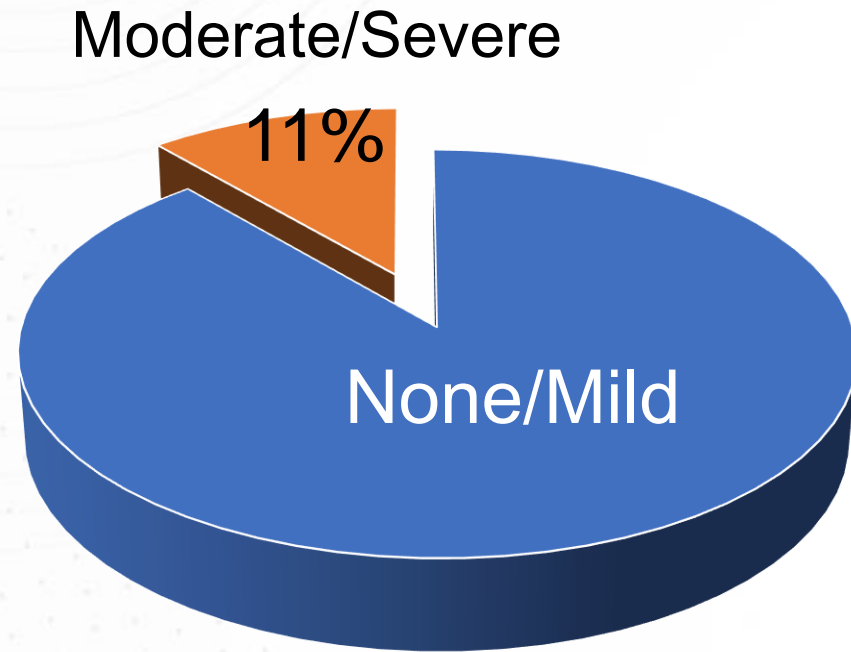
Larger Lumen should be obtained after

LM 2-stent PCI,

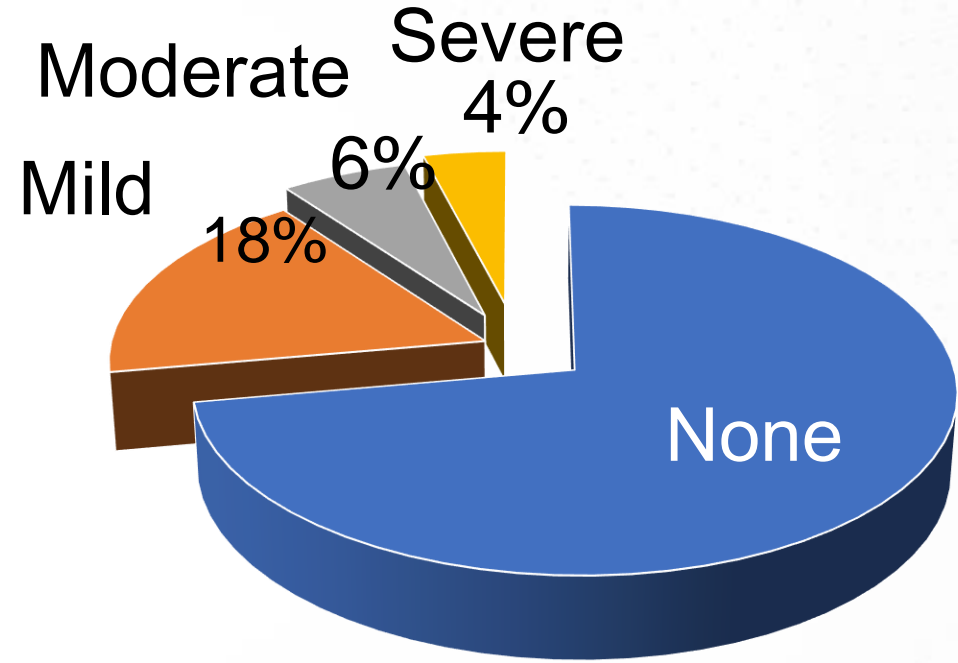
Especially at **LCX ostium !!**

*IVUS-Guided **Calcified / Tortuous Lesion** PCI*

Prevalence of Calcium by Angiographic severity from IRIS-DES Registry

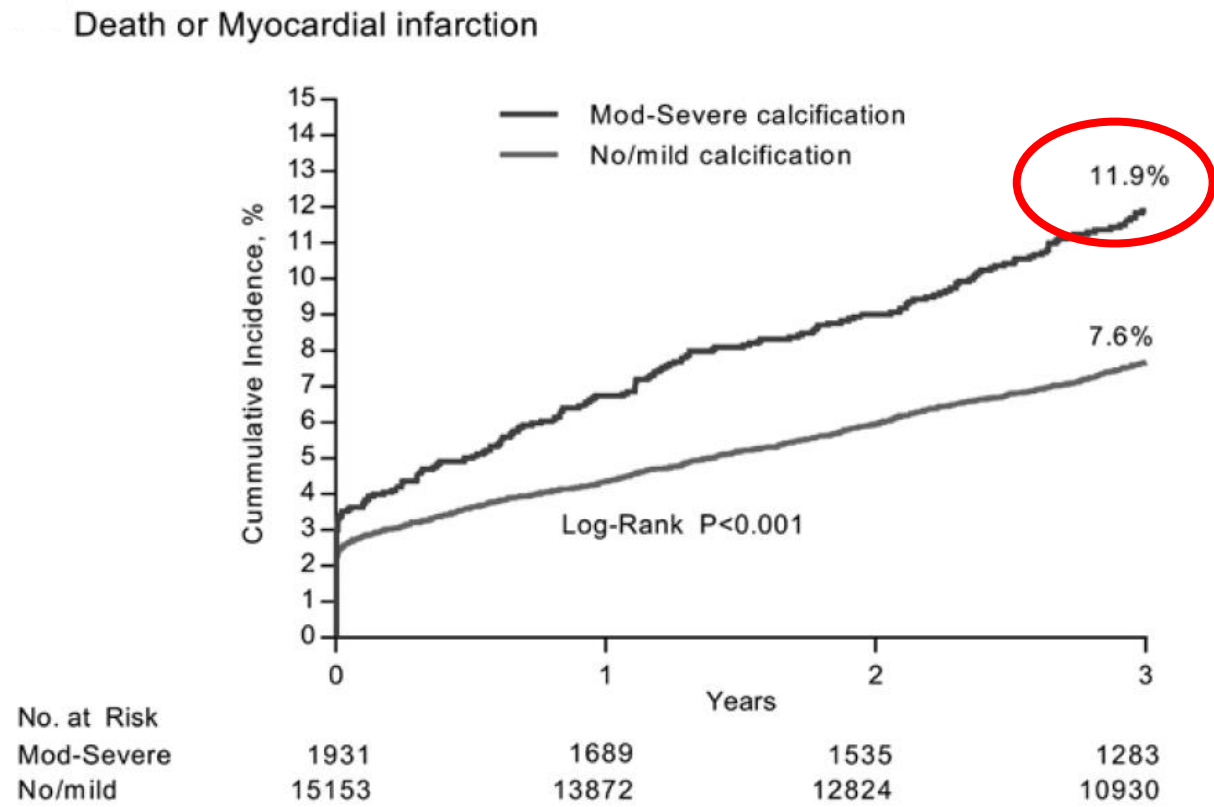
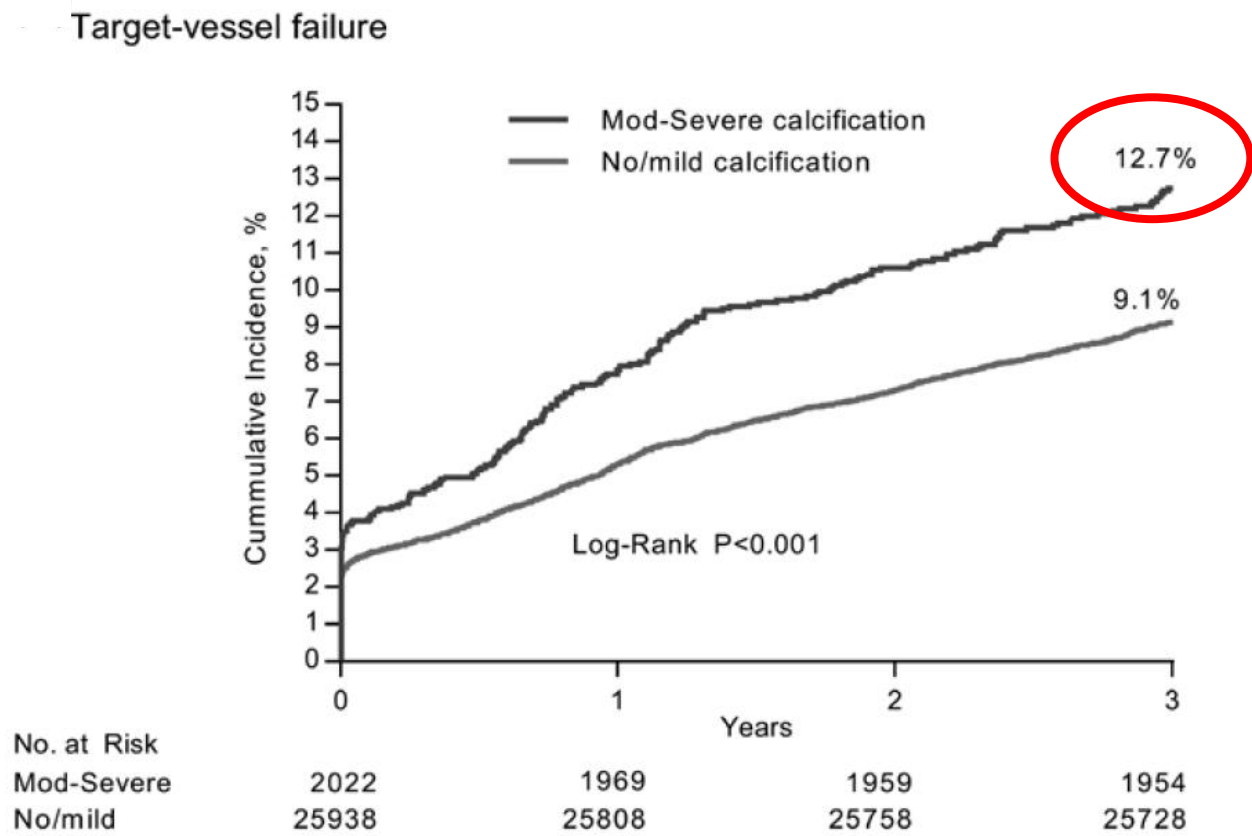


Number of Patient

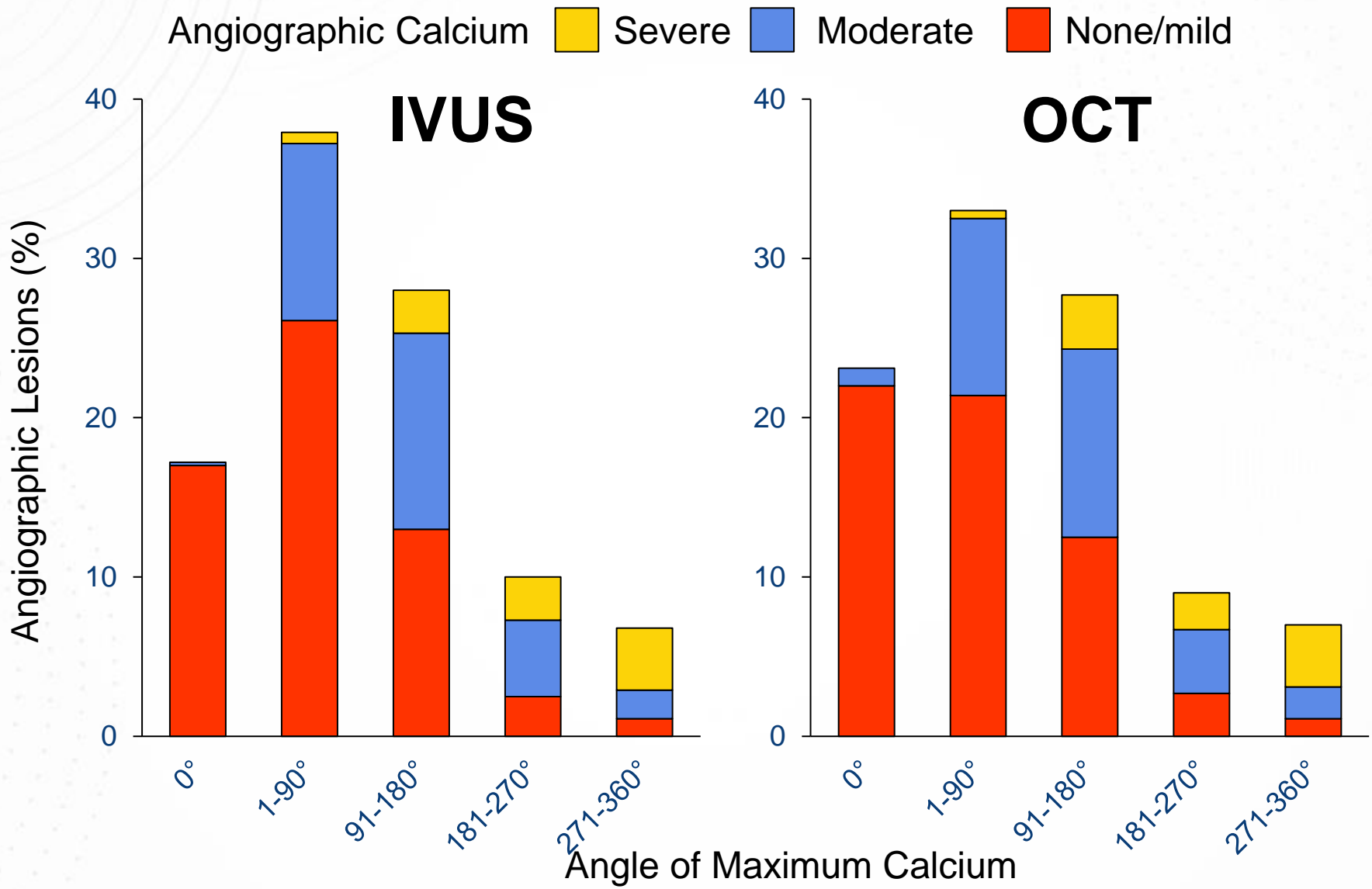


Number of Lesion

Clinical Outcome by Angiographic Calcium Severity from IRIS-DES Registry



Discrepancy btw IVUS/OCT and Angiographic Calcium



Lesson #4:

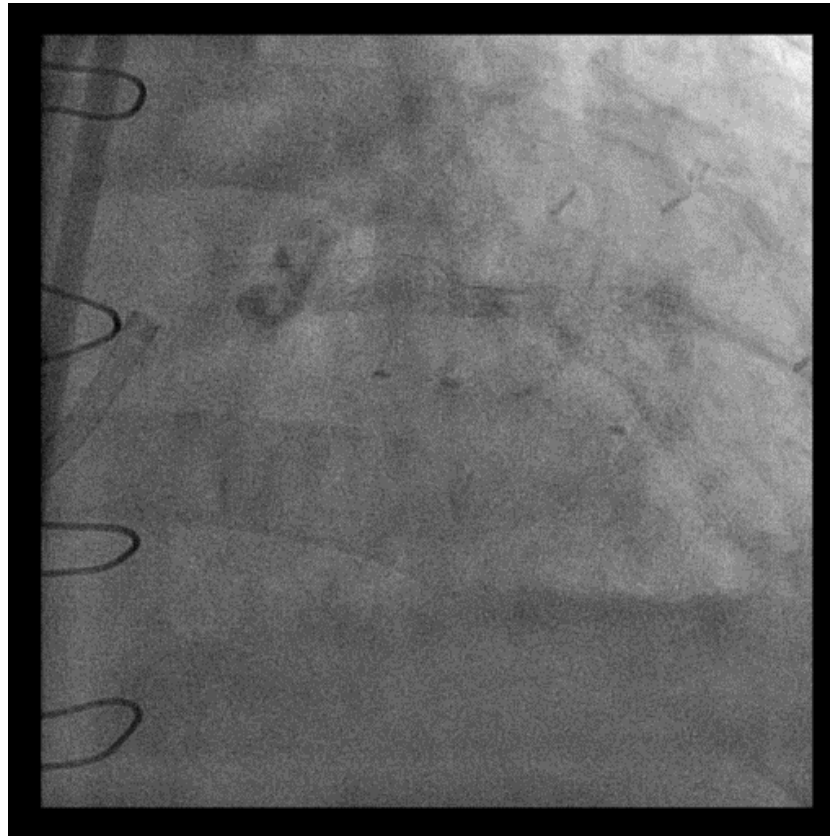
Frequently, Calcium is Invisible in Angiography

→ Evaluate IVUS !!

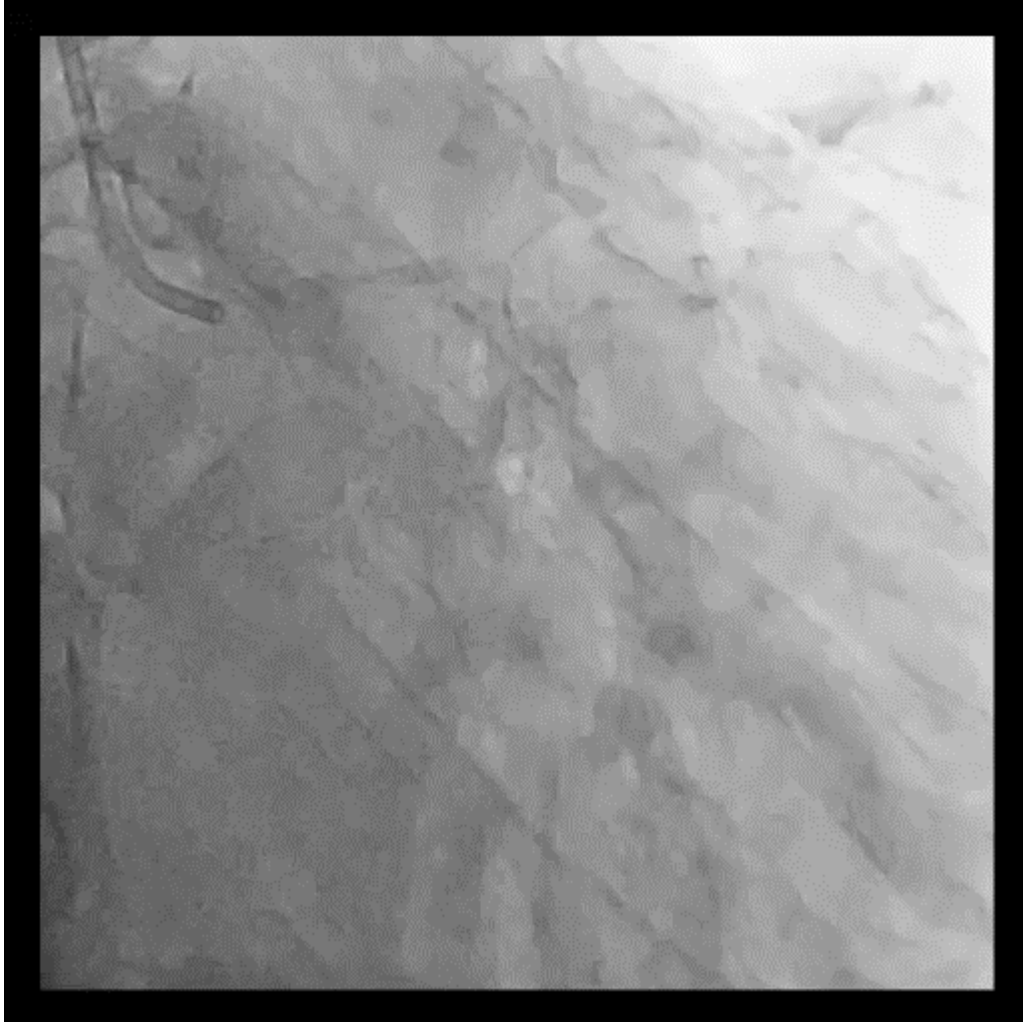
PCI for Heavily Calcified Lesion

1. Lesion preparation
2. Lesion preparation
3. Lesion preparation

Do not Stent on Poorly Prepared Calcification

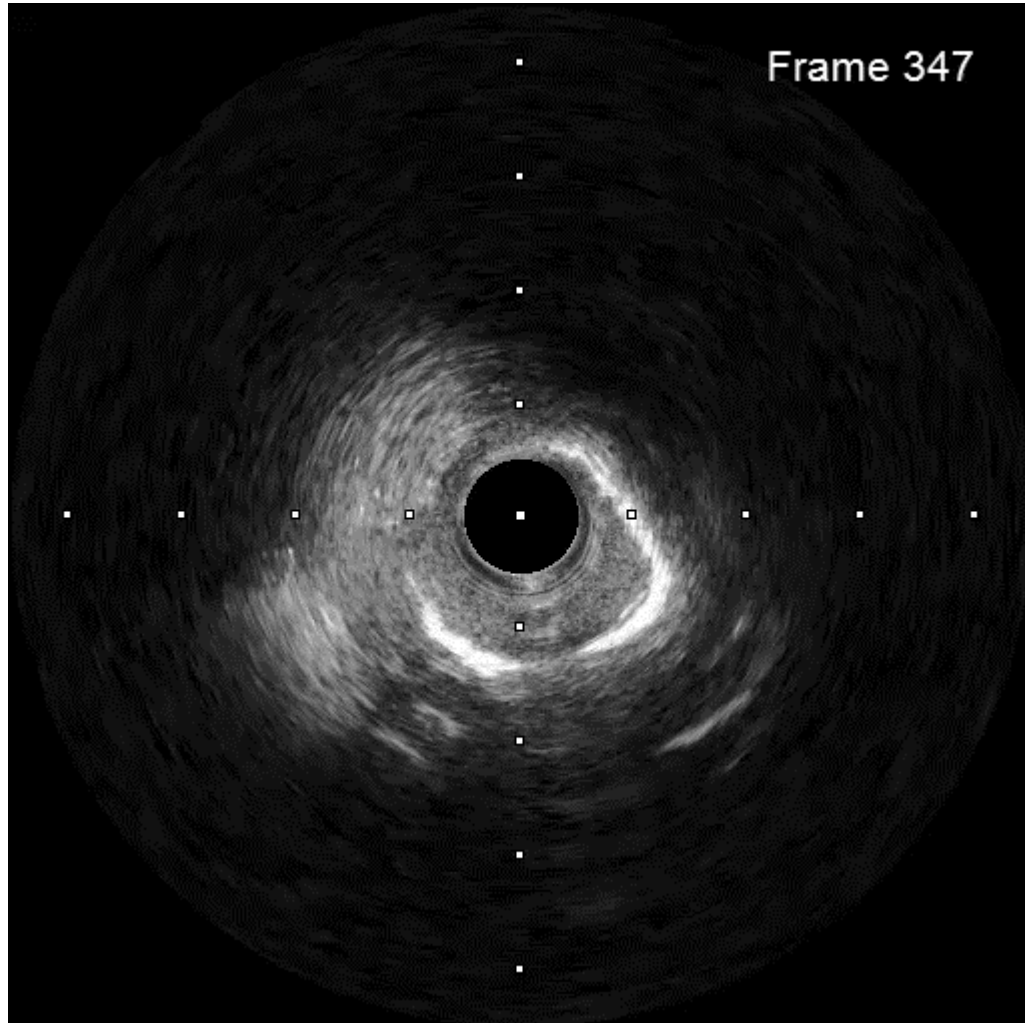


M/57, Unstable angina



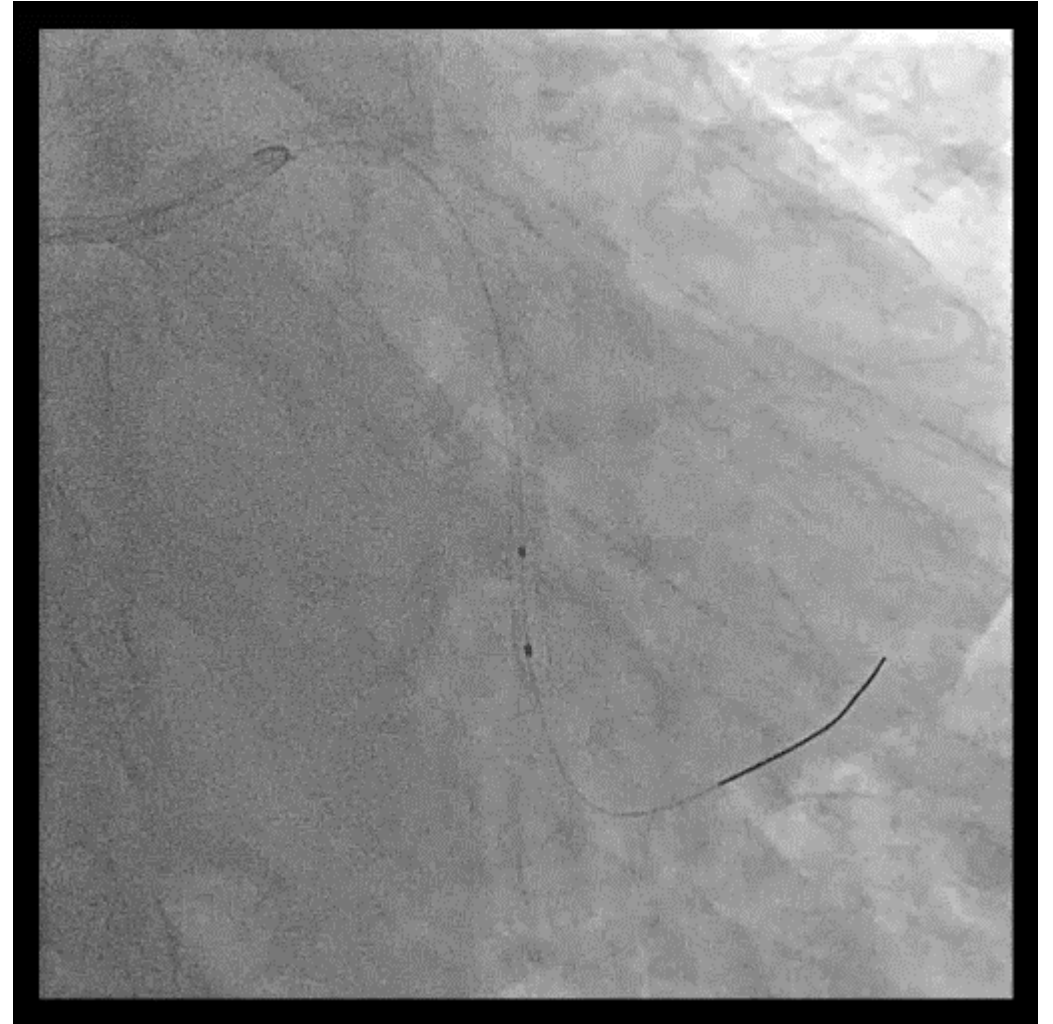
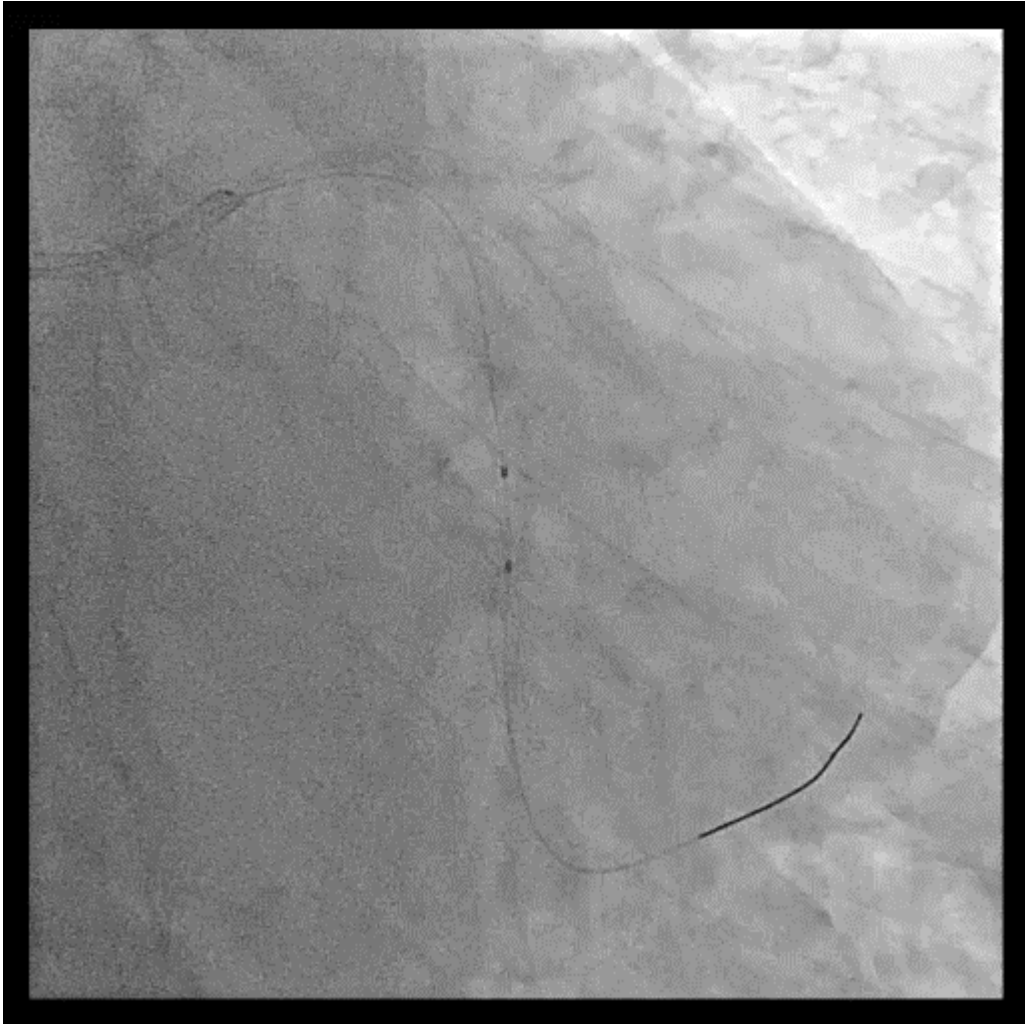
2.5 * 15 mm Compliant Balloon

M/57, Unstable angina



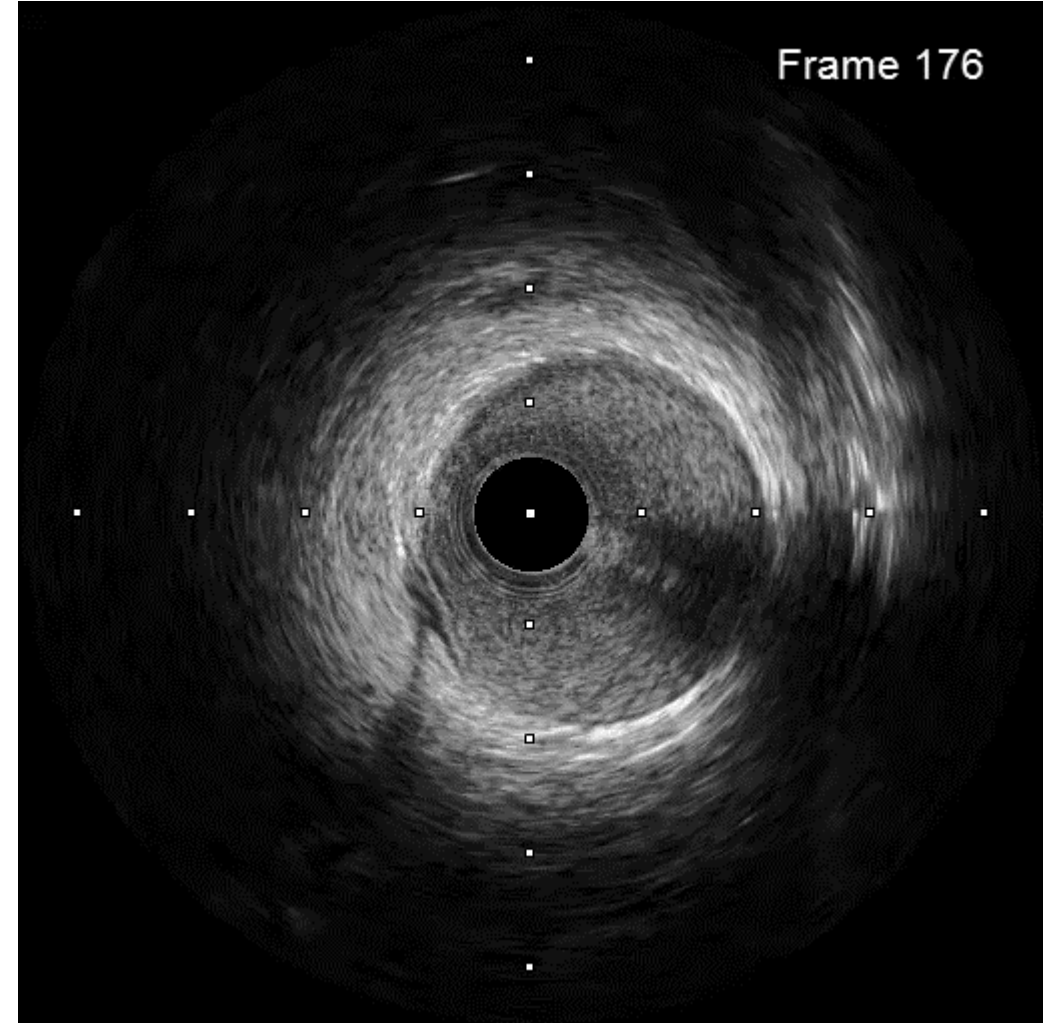
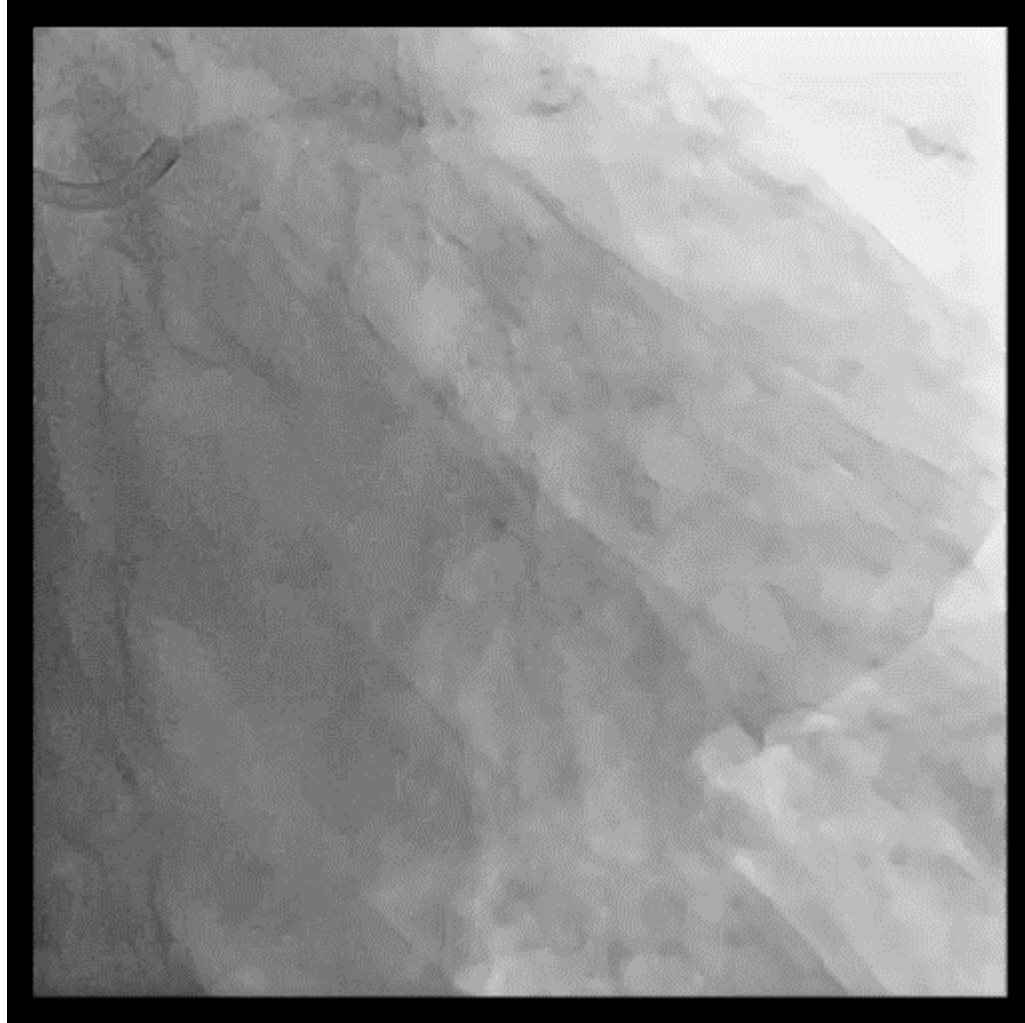
3.5 * 28 mm DES

M/57, Unstable angina



2.5 * 10 mm NC Balloon at 30 atm
3.25 NC at 28 atm

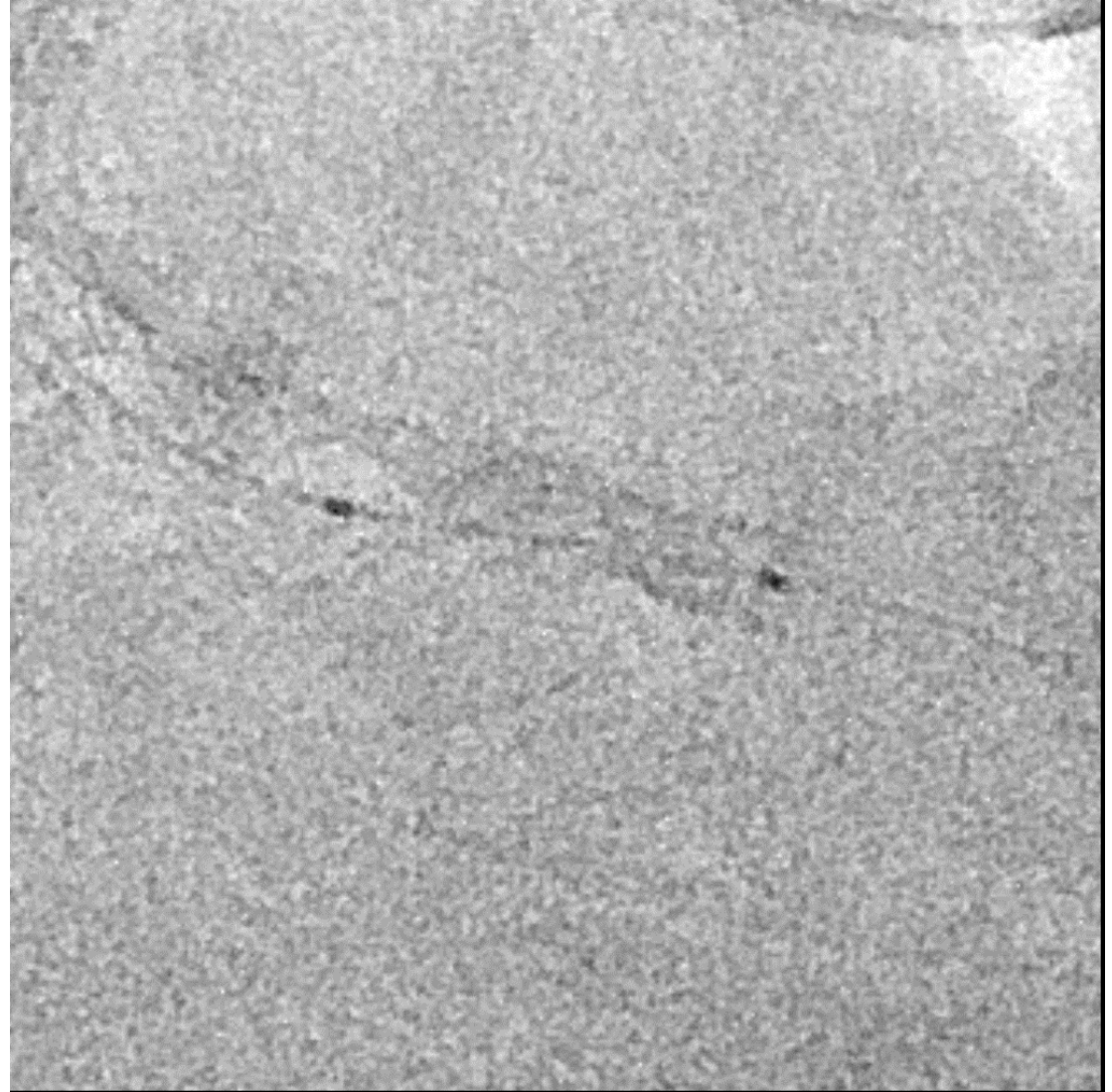
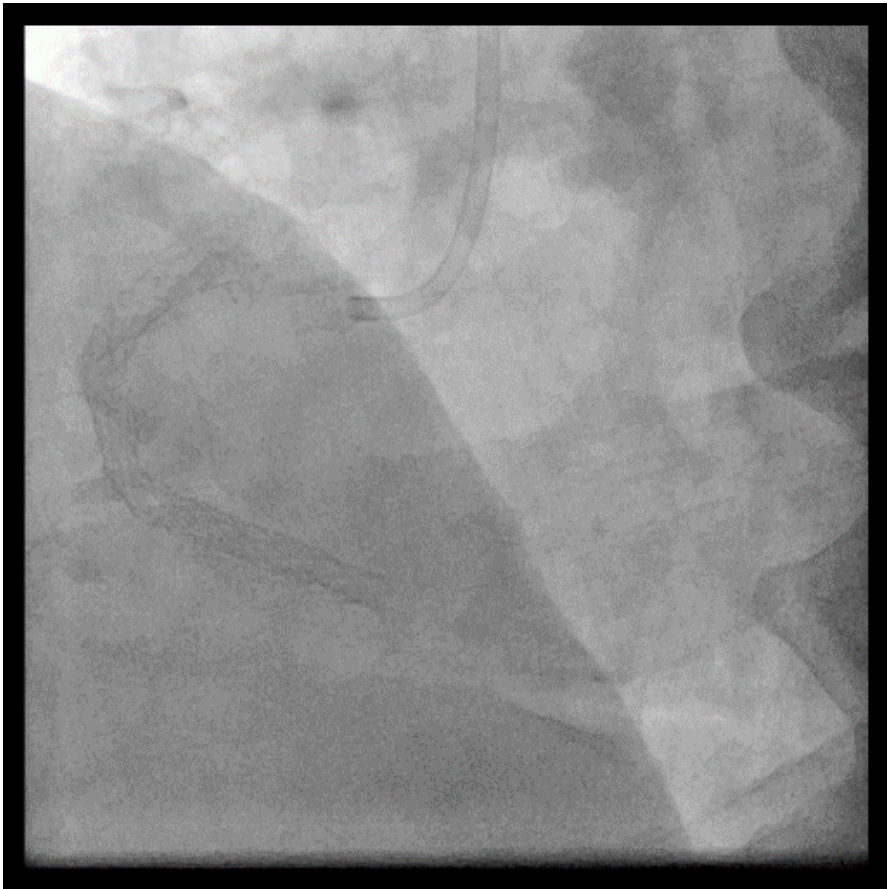
M/57, Unstable angina



Expansion at 34 atm in Under-expanded Stent

M/72

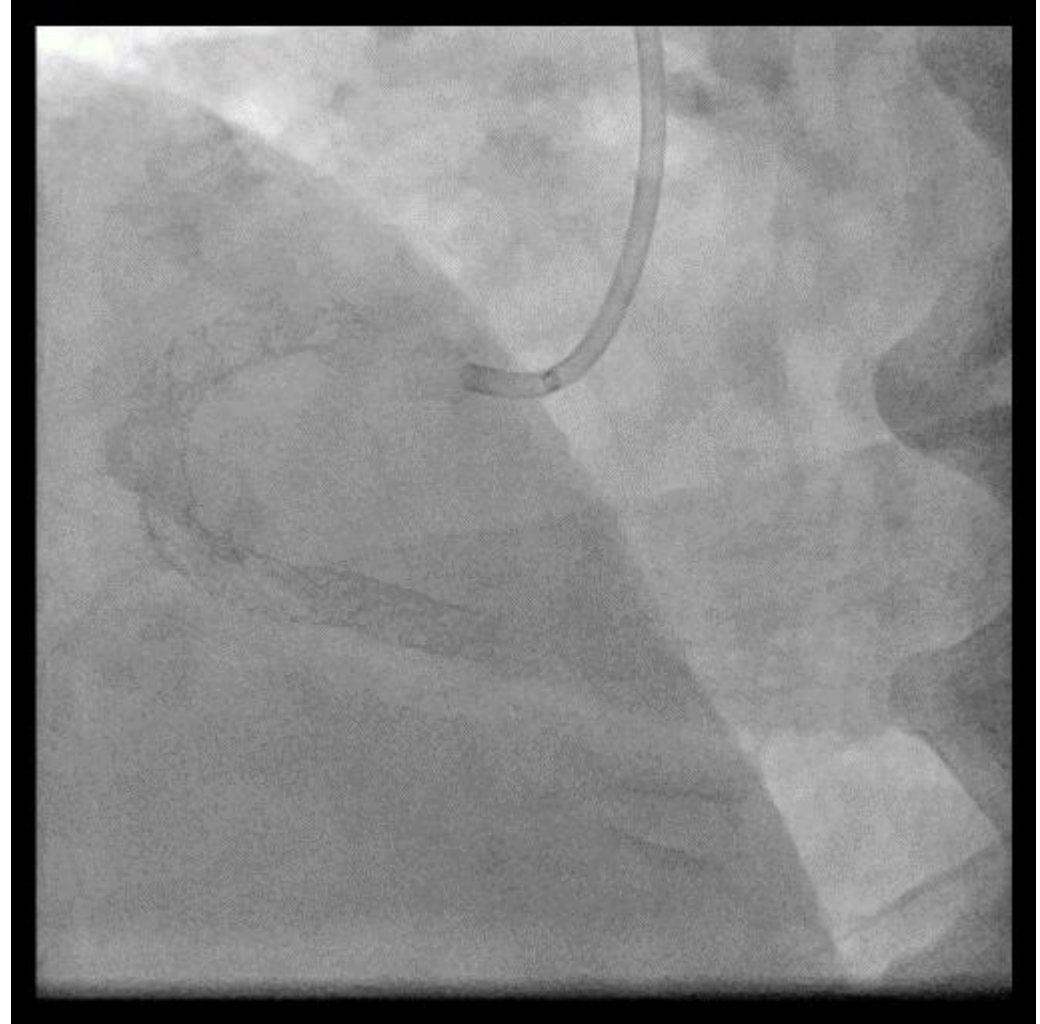
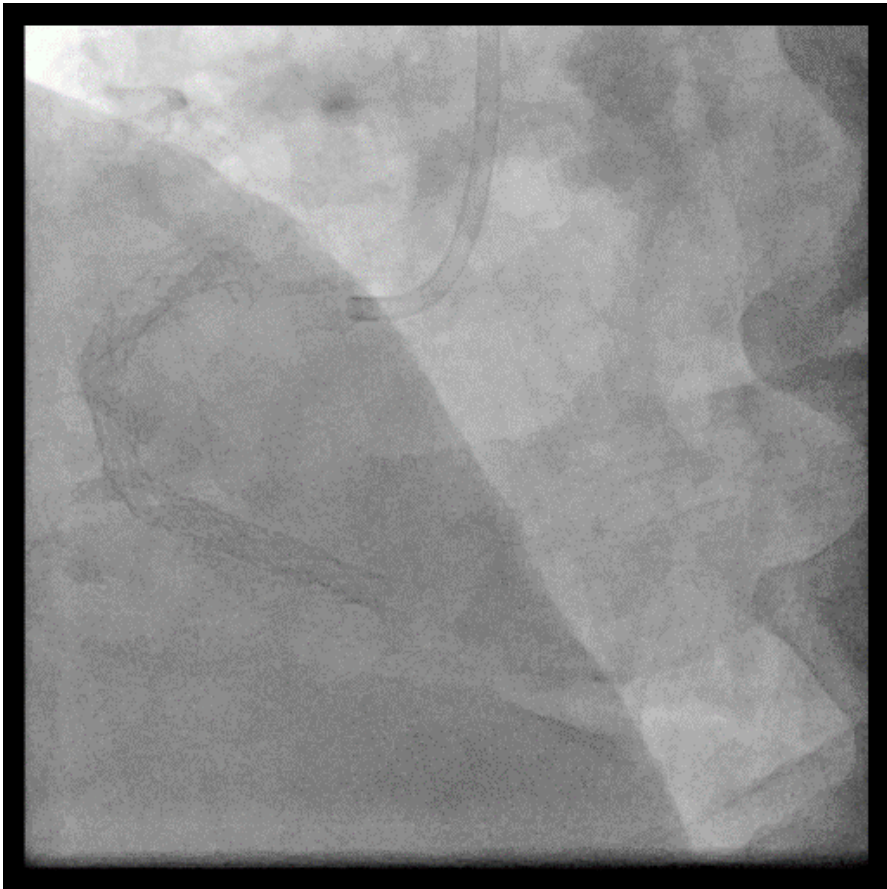
s/p RCA PCI 25 years-ago



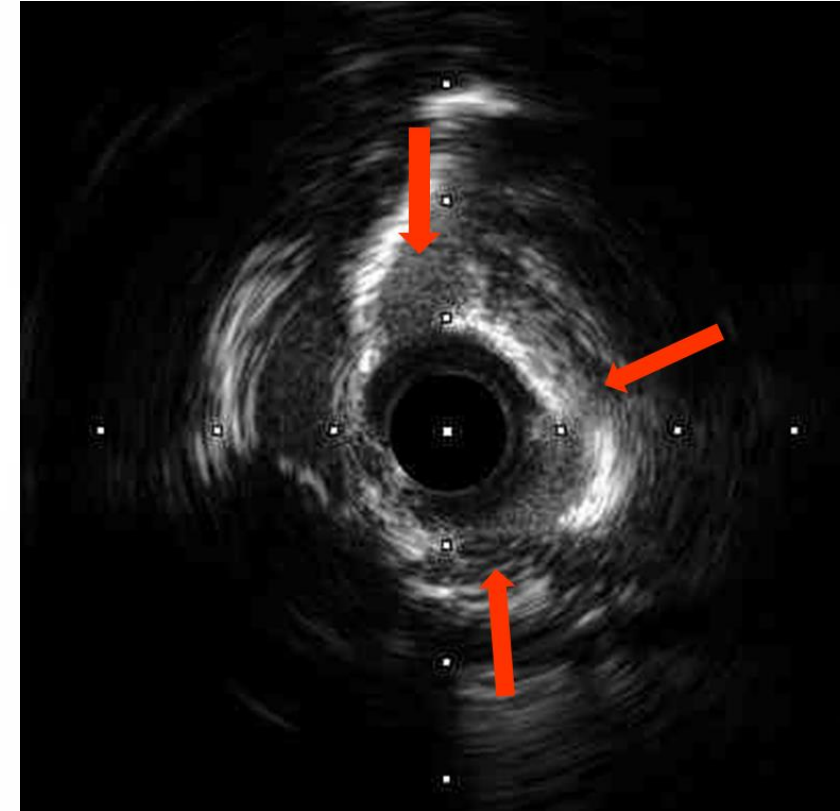
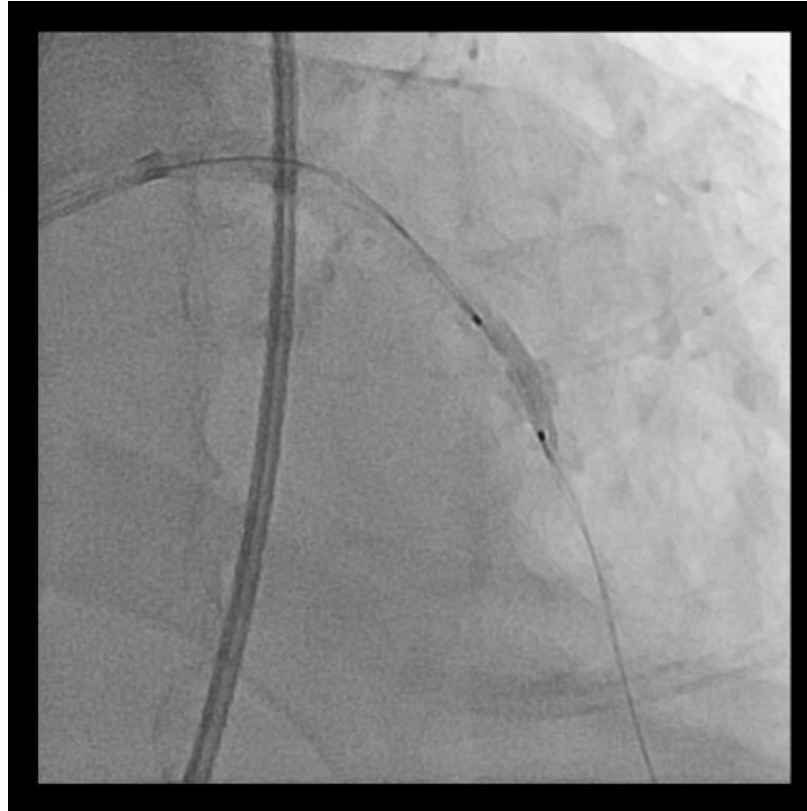
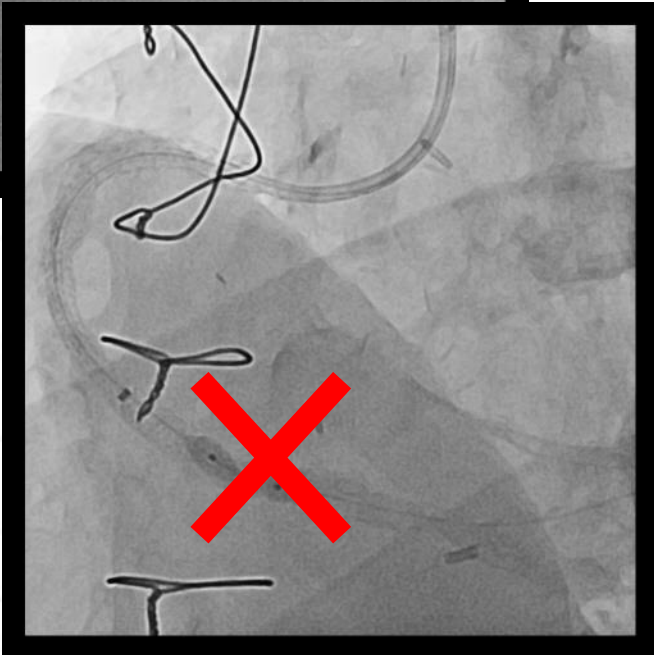
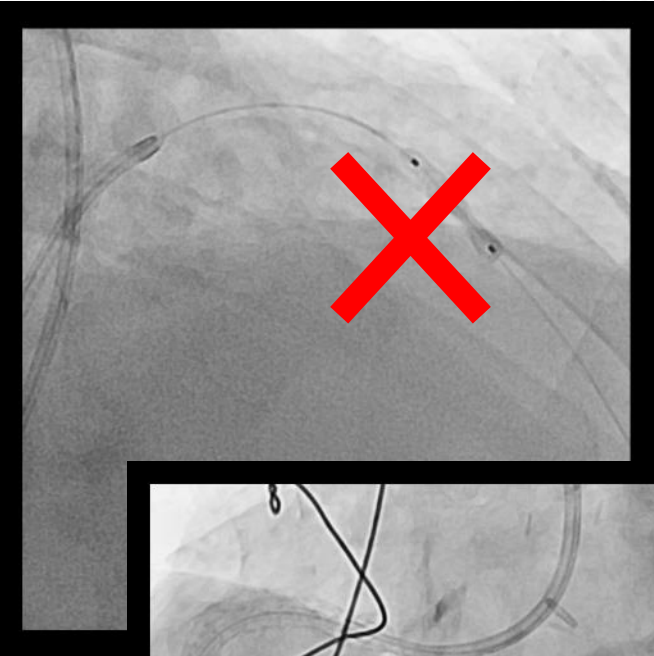
Expansion at 34 atm in Under-expanded Stent

M/72

s/p RCA PCI 25 years-ago



Confirm the Calcium Breakage



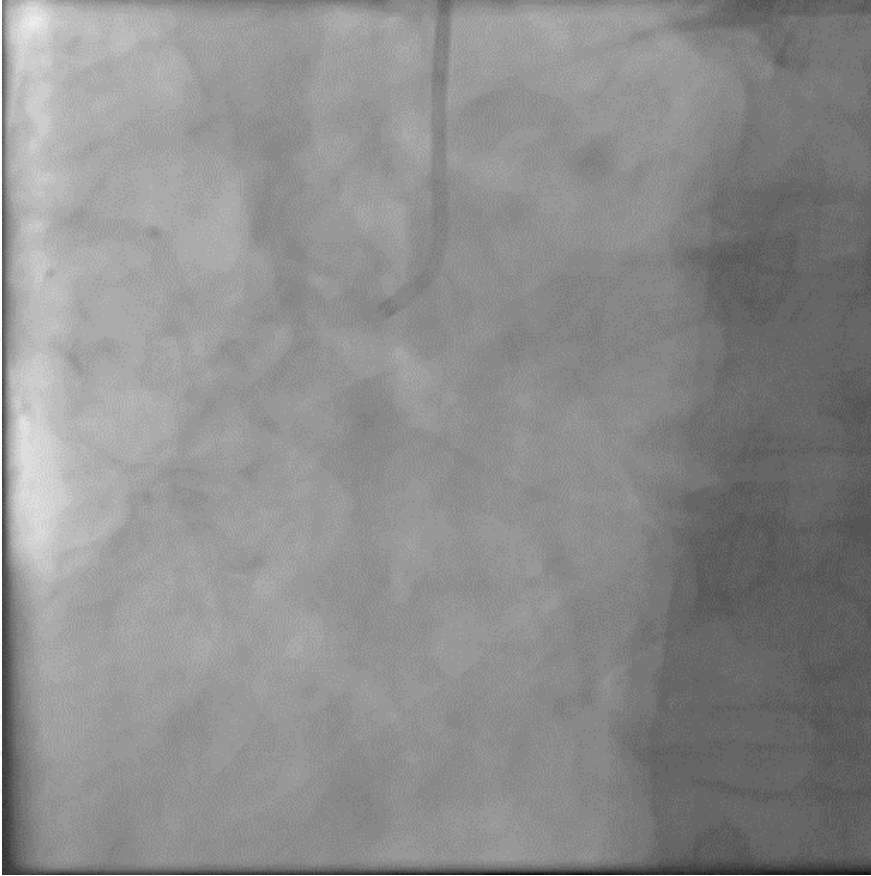
Lesson #5:

Never Put the Stent

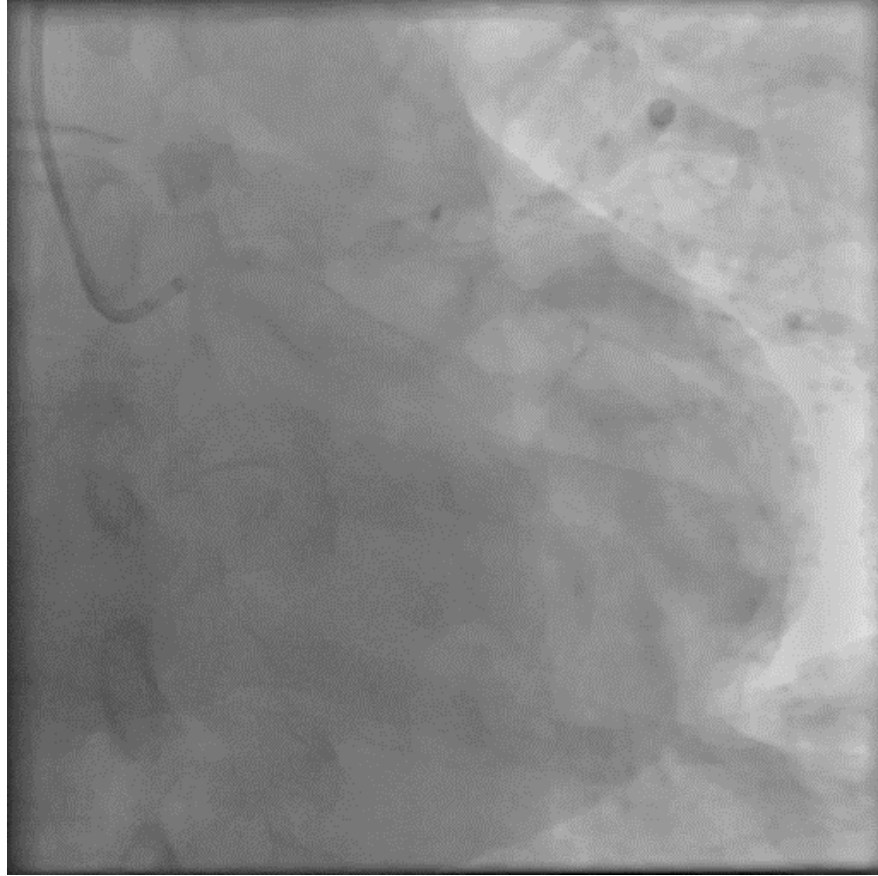
Before Optimal Lesion Preparation !

(Check by IVUS / Stent Booster)

76y Man with effort angina

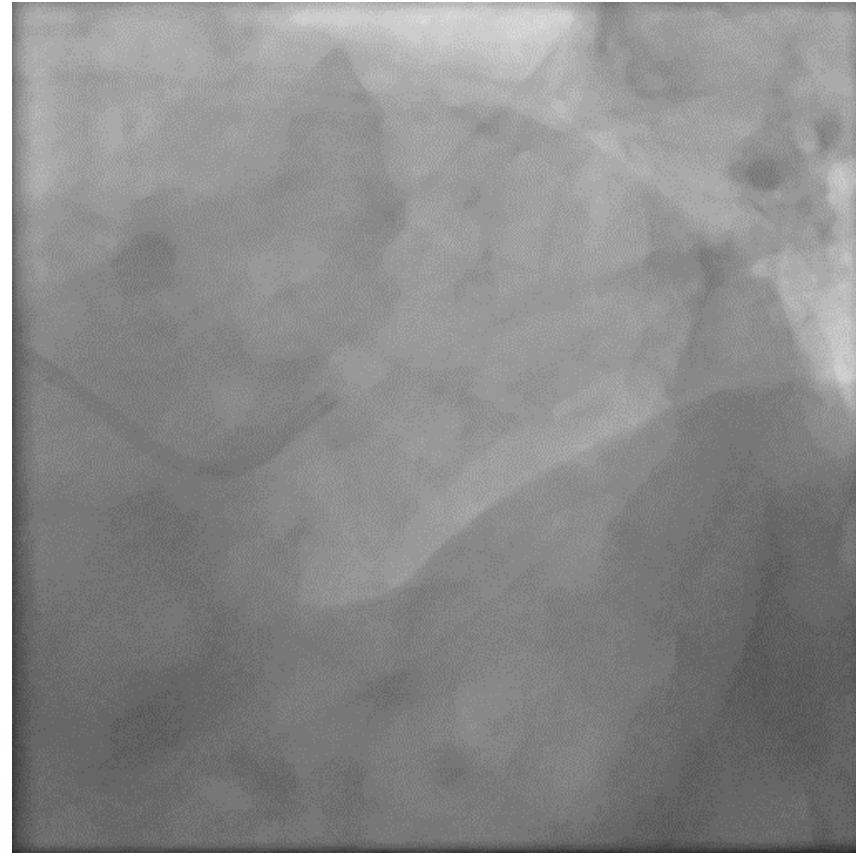
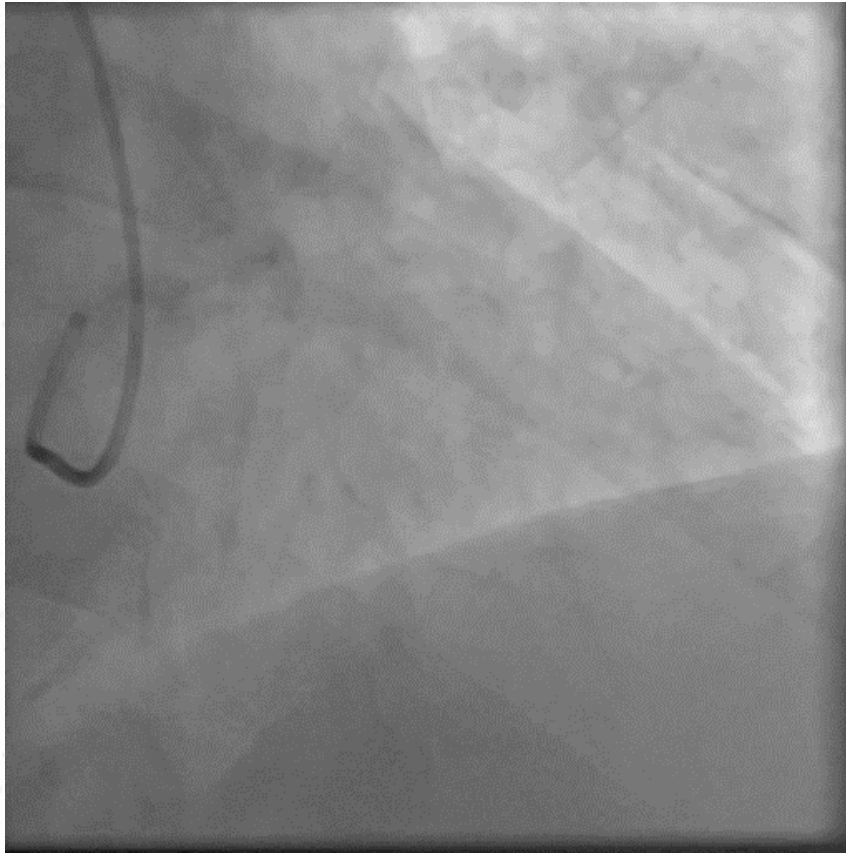


RCA CTO



LAD Calcific disease
With dLCX CTO

LM-LAD disease with Severe Calcification



Emerge NC 2.0(20) mm 28 atm

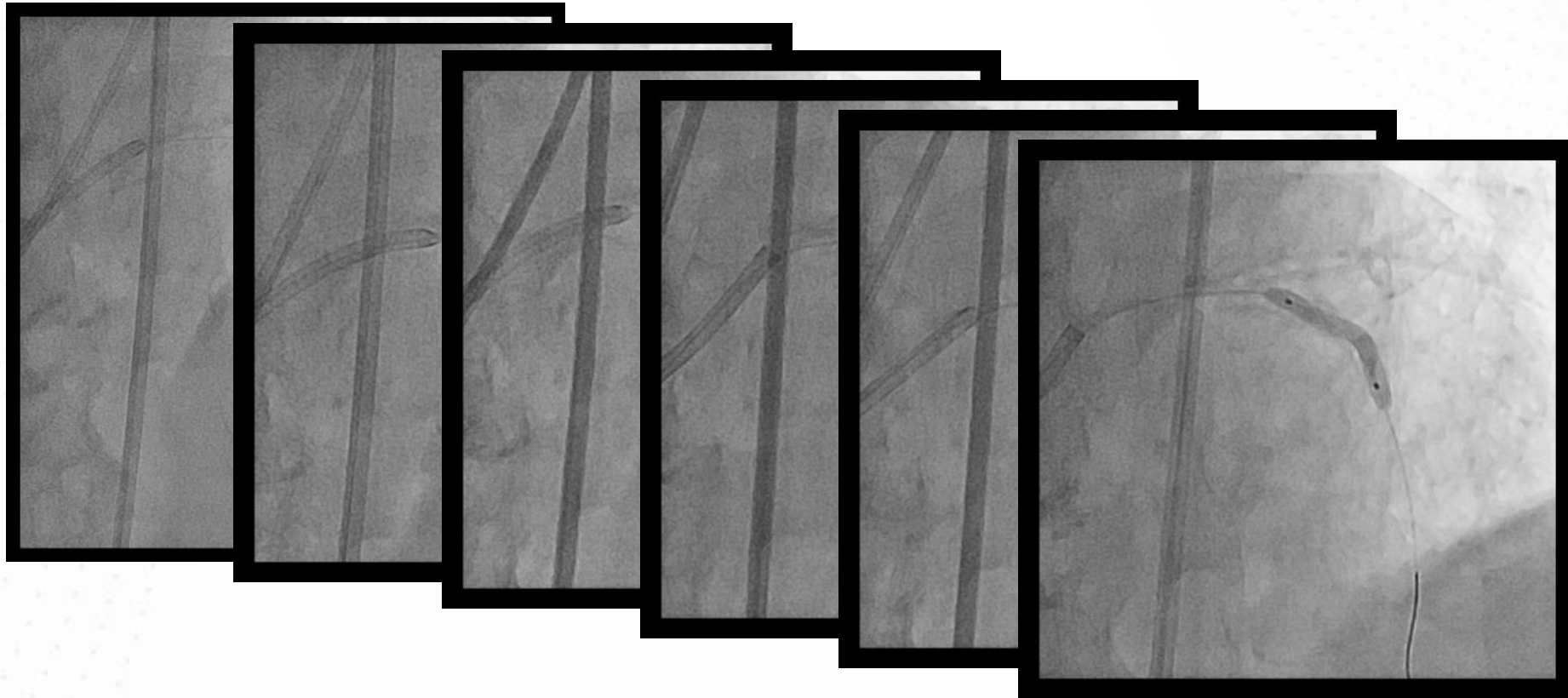
Sapphire NC 2.5(18) mm 28 atm

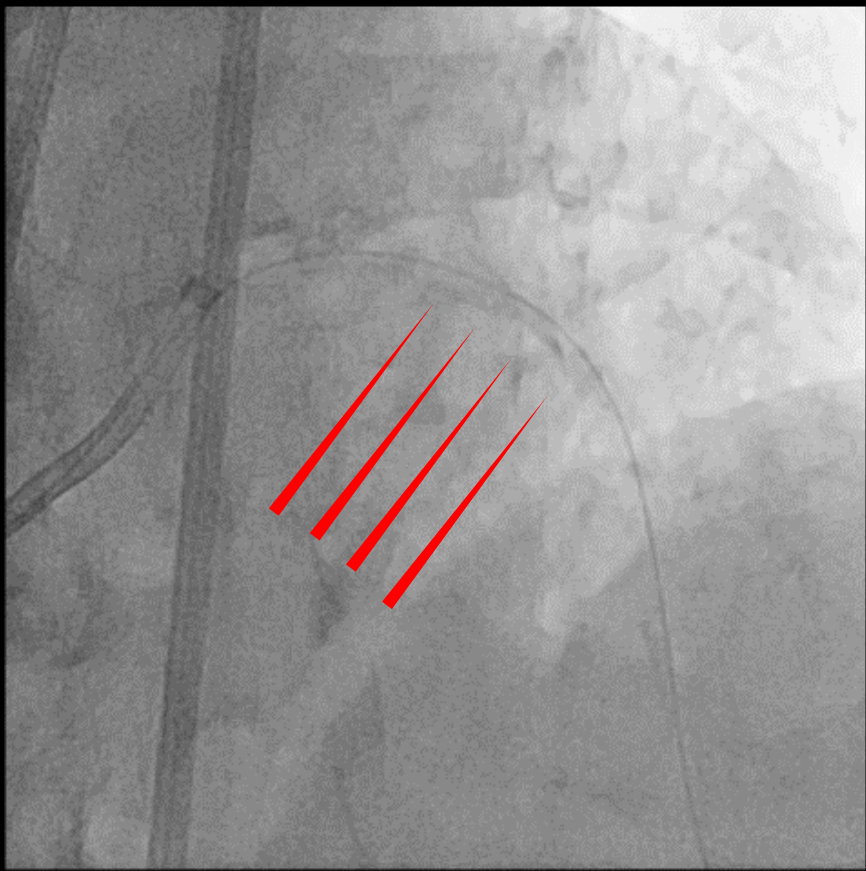
Emerge NC 2.75(20) mm 25 atm....Still not opened

Cutting balloon 2.75(10) mm 12 atm

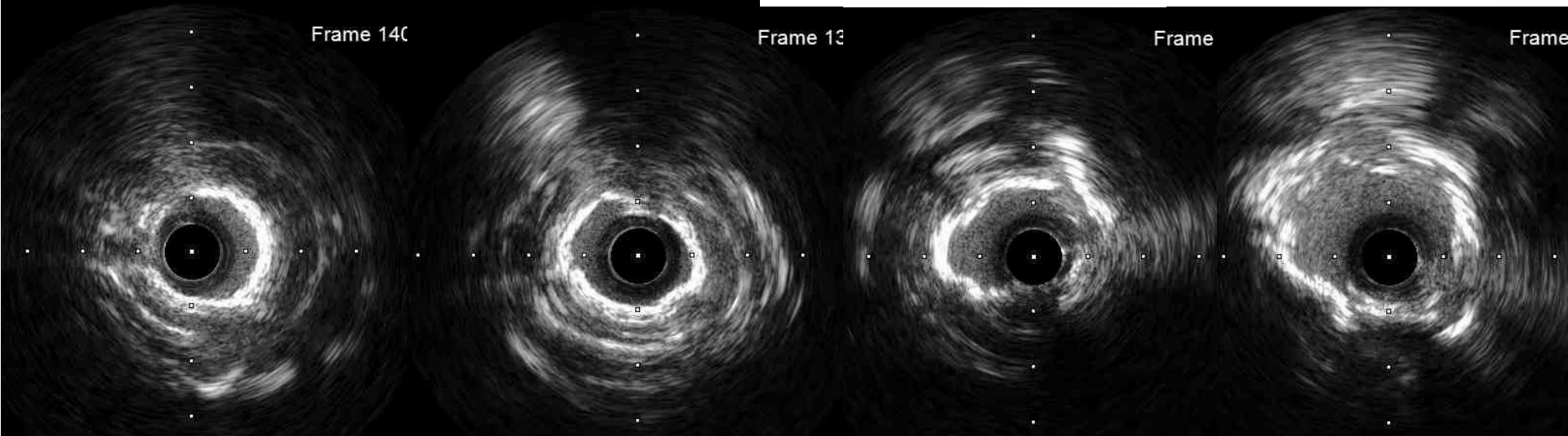
Selectthru NC 2.75(8) mm 24 atm

Selectthru NC 2.75(20) mm 20 atm, **upto 34 atm...Finally it was opened !**

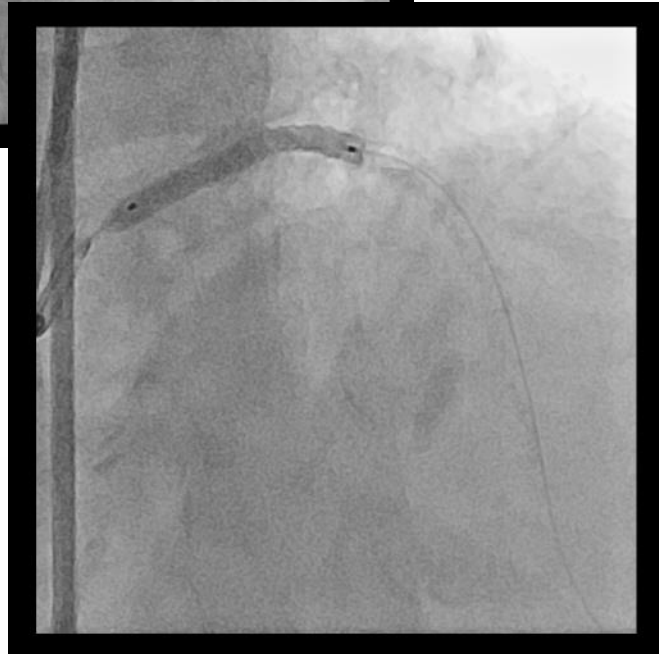
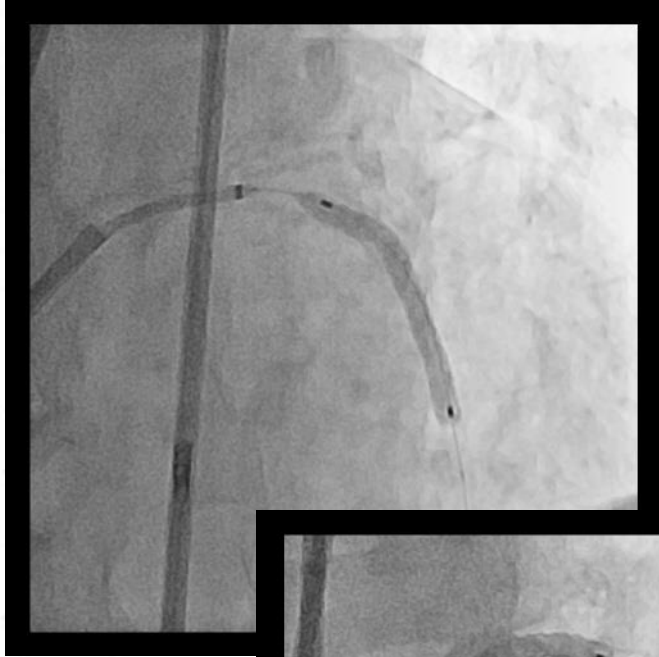




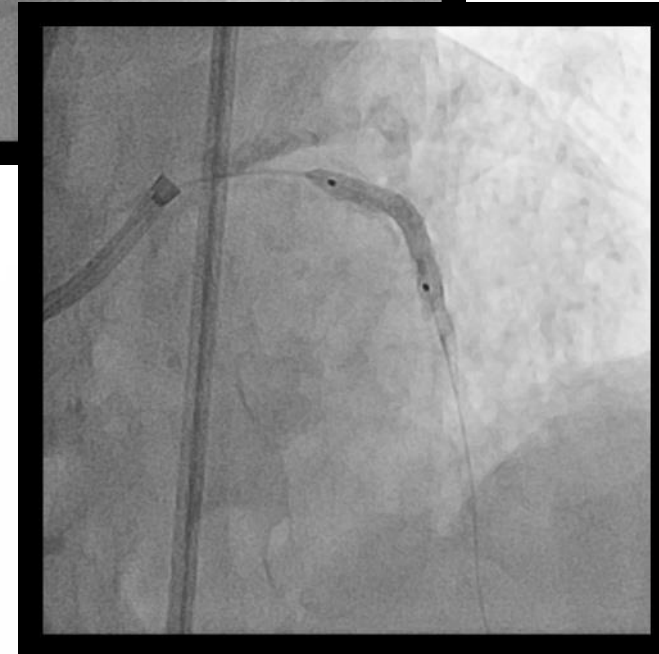
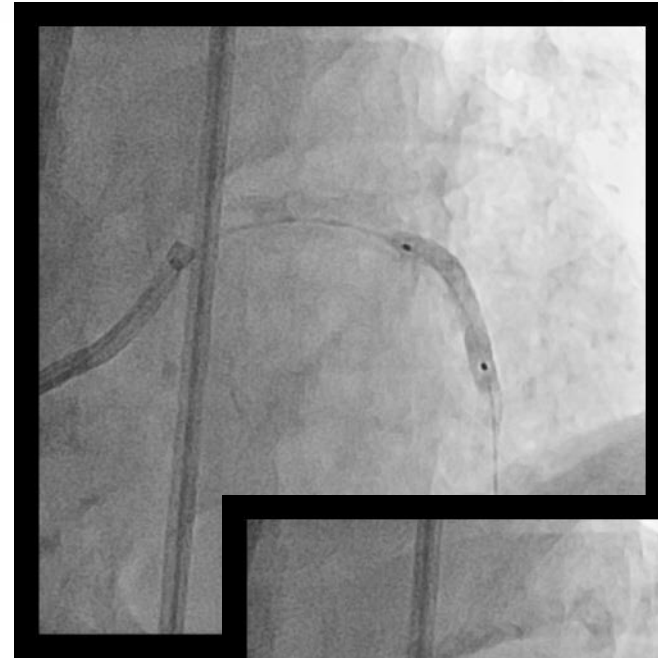
IVUS showed ring-like
encircling heavy calcification
With balloon-induced breakage

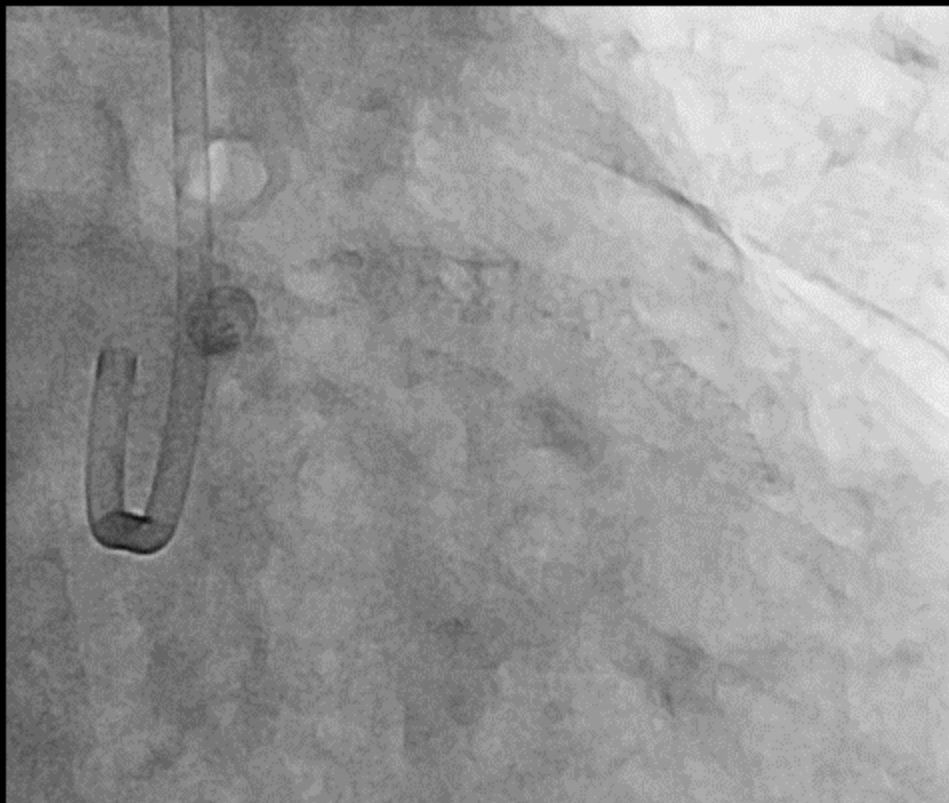


Xience Sierra 3.25(28) + 3.25(33mm)
Under Guidezilla back-up

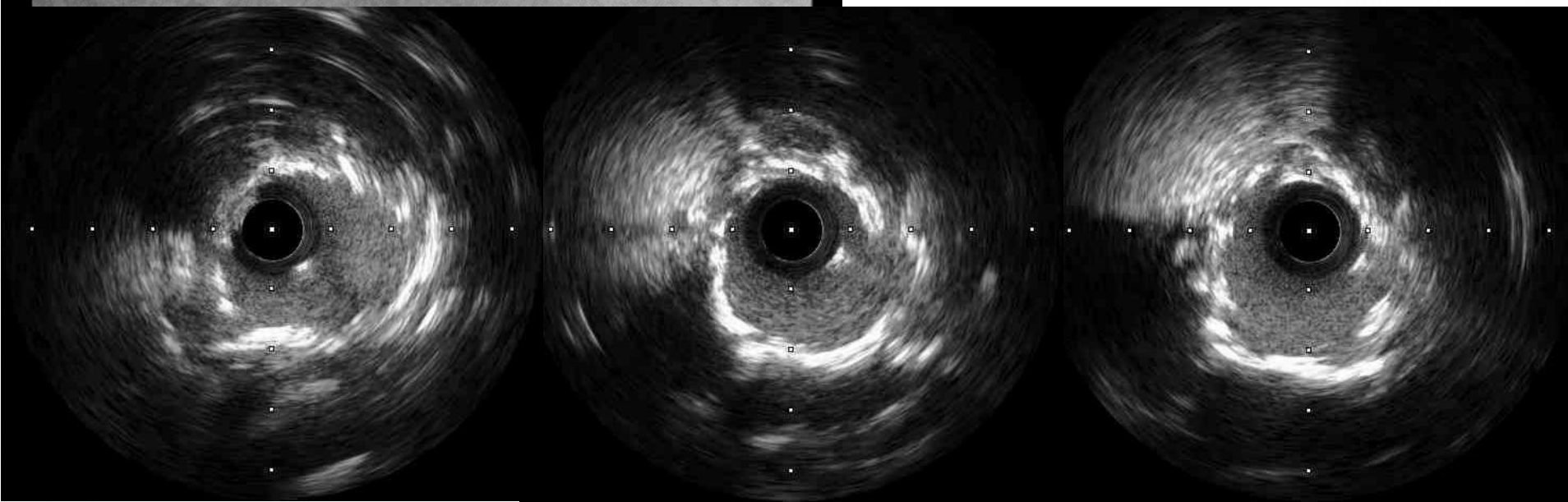


Post-dilation with
Emerge NC 2.75 (20mm) upto 24 atm &
Sapphire NC 4.5(10) upto 20 atm

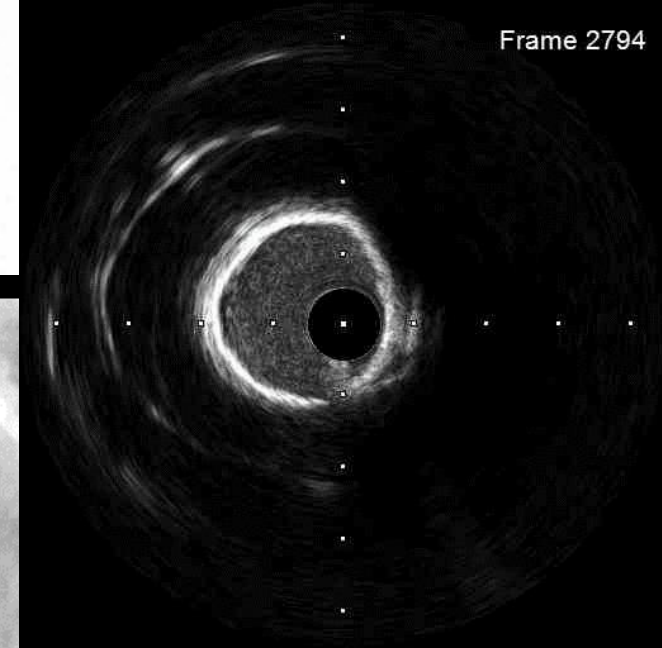
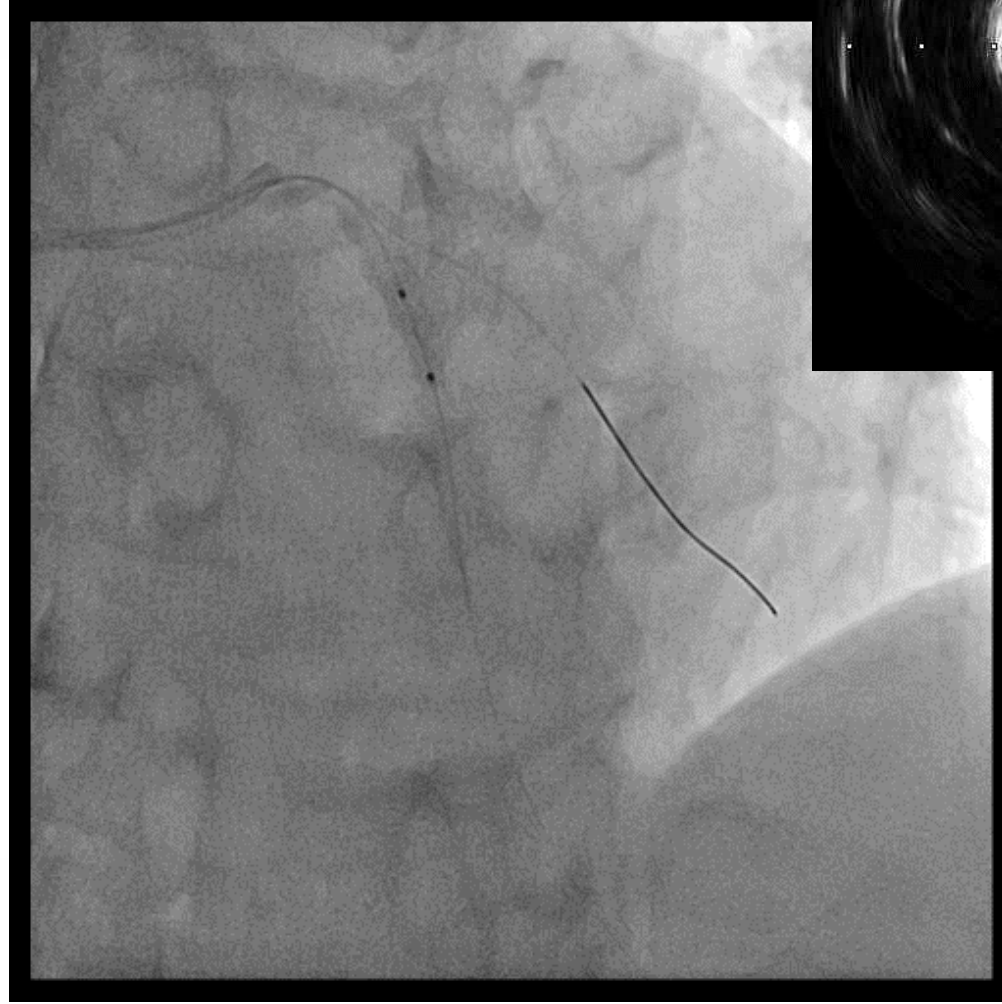




Final IVUS showed
Well-apposed stents with
MLA 6.8 mm^2 at mLAD.

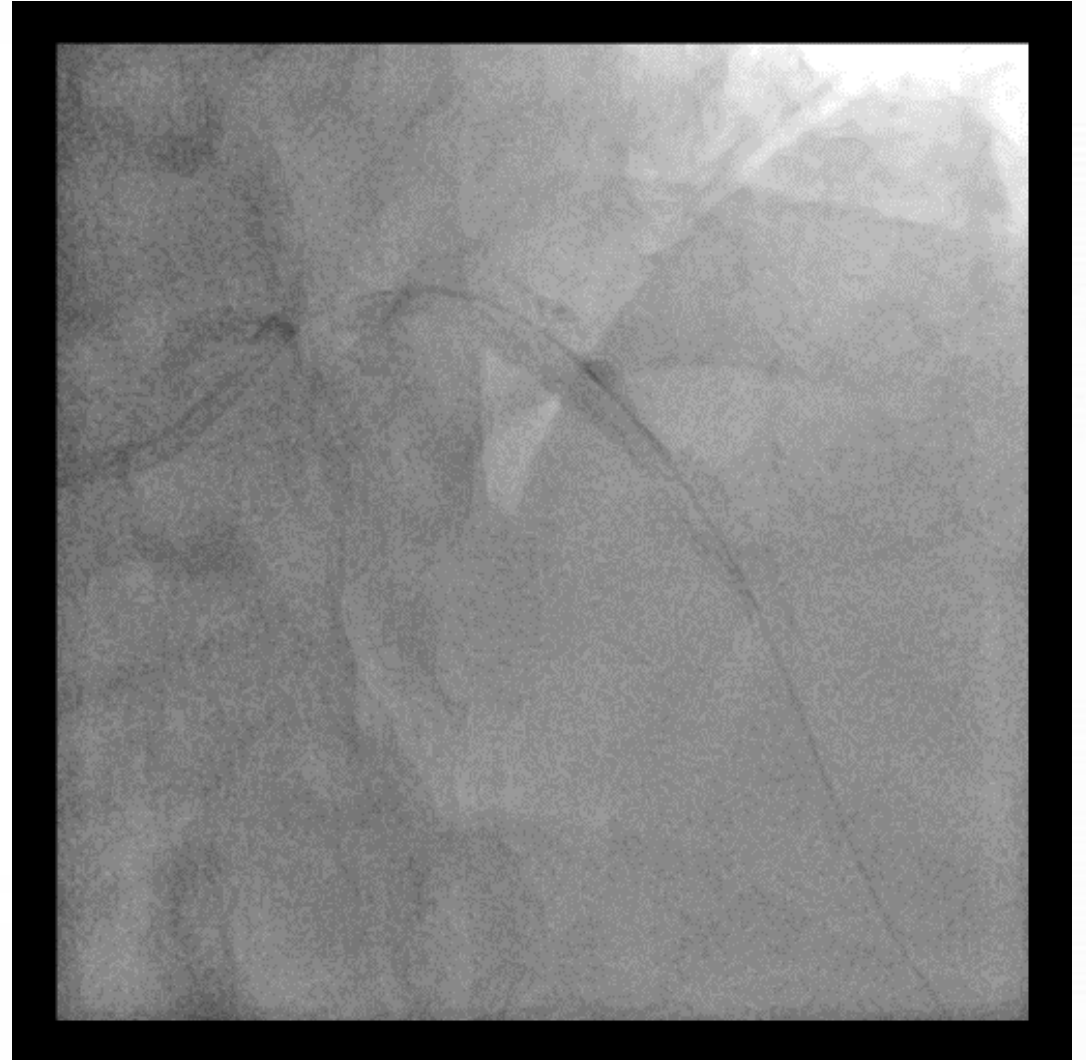
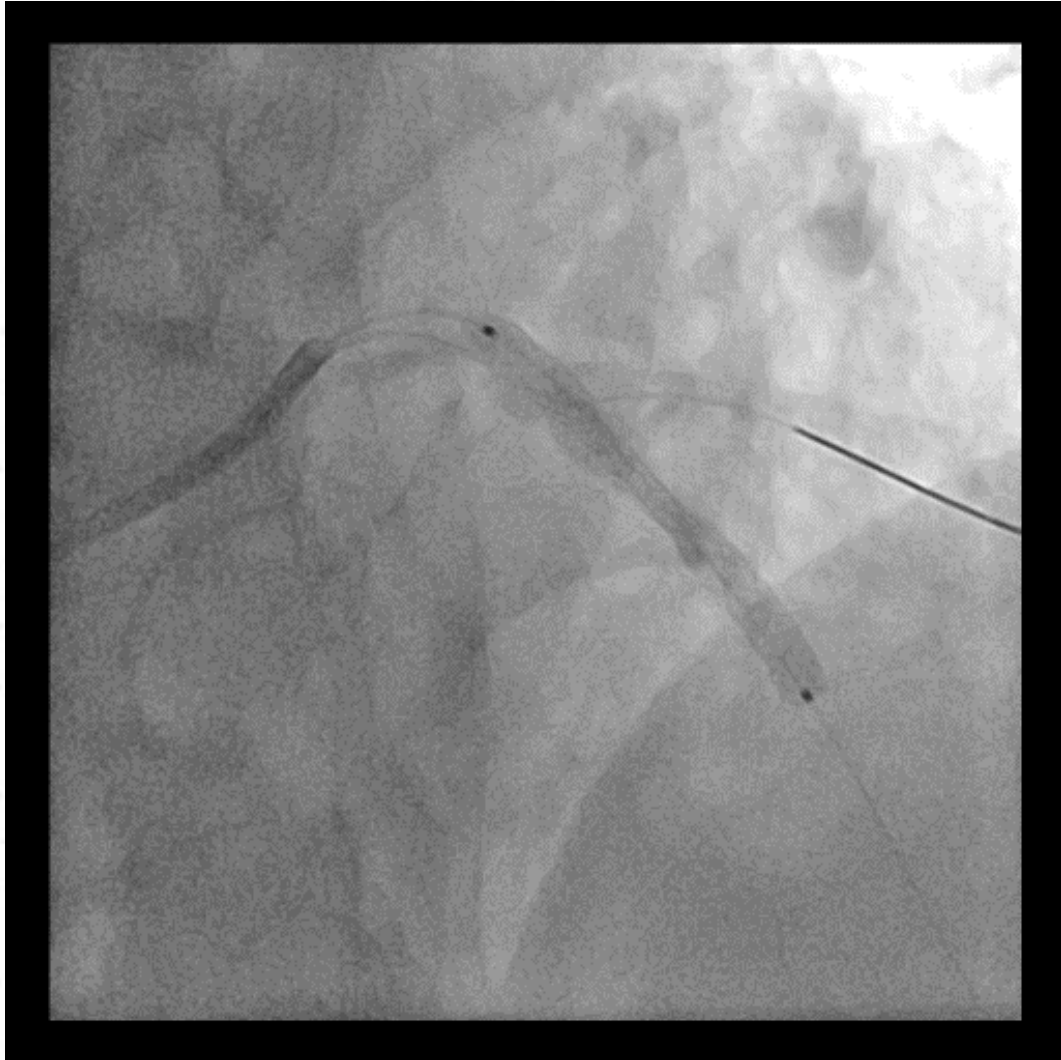


65/M, Stable Angina, DM



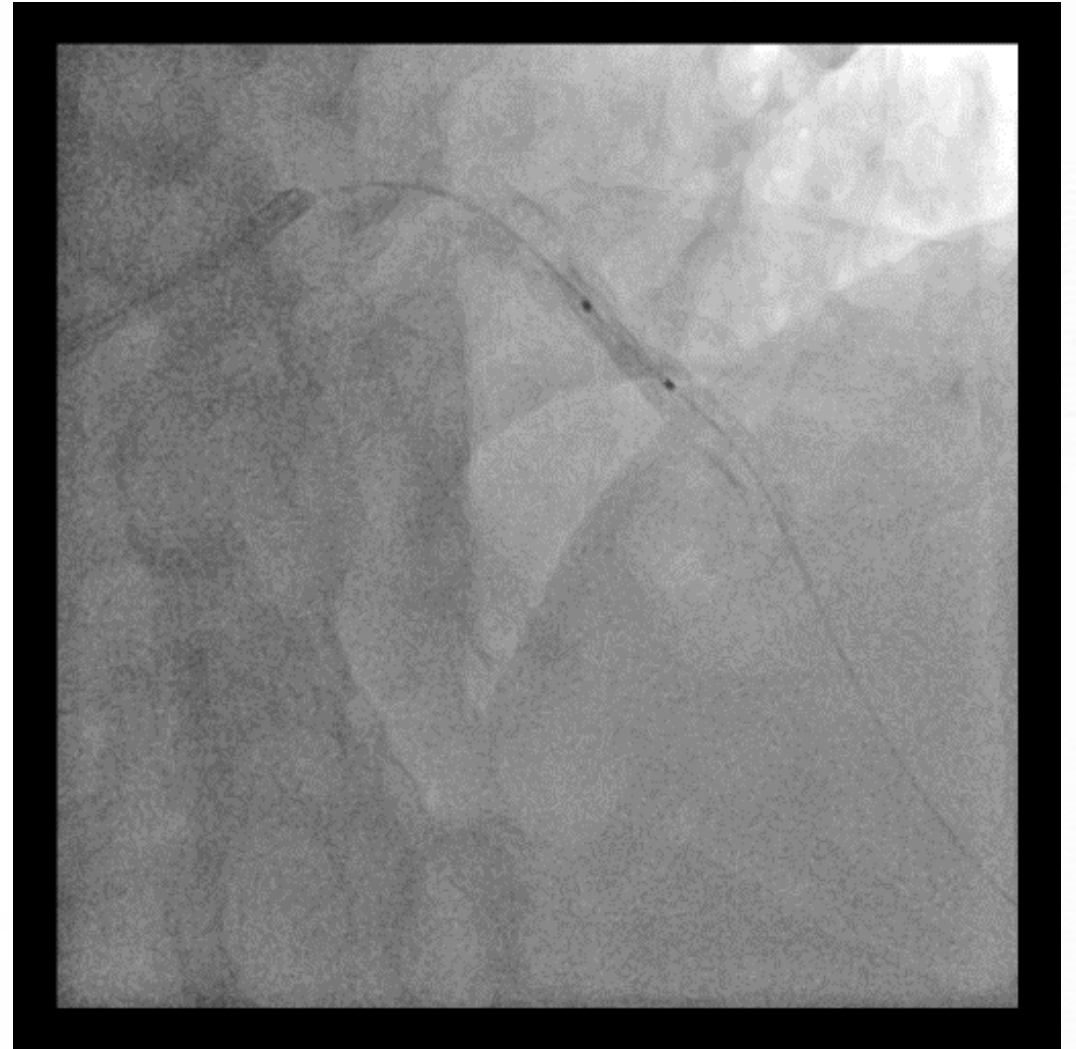
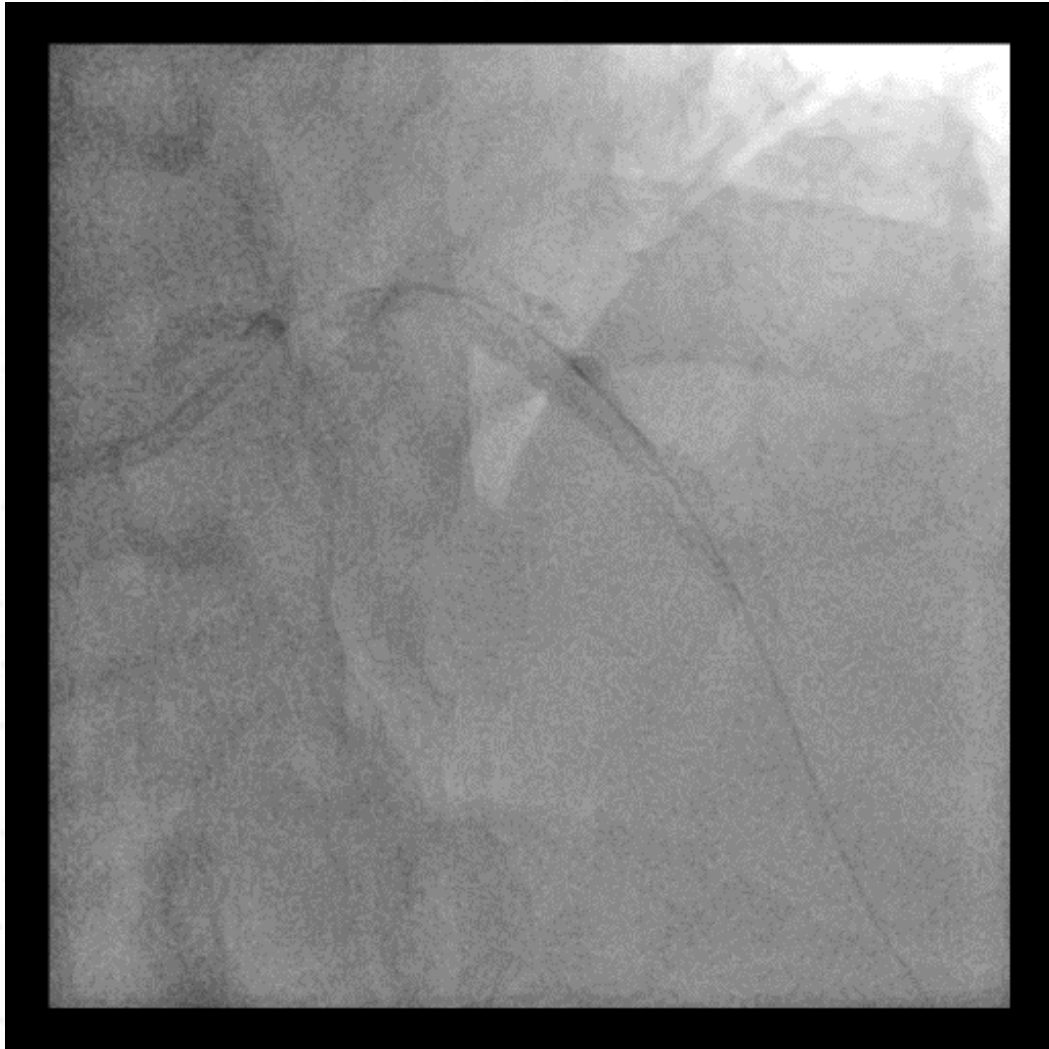
2.5 compliant balloon followed by Cutting 3(10) upto 16 atm

Stent should not be implanted before checking the full expansion of the NC Balloon



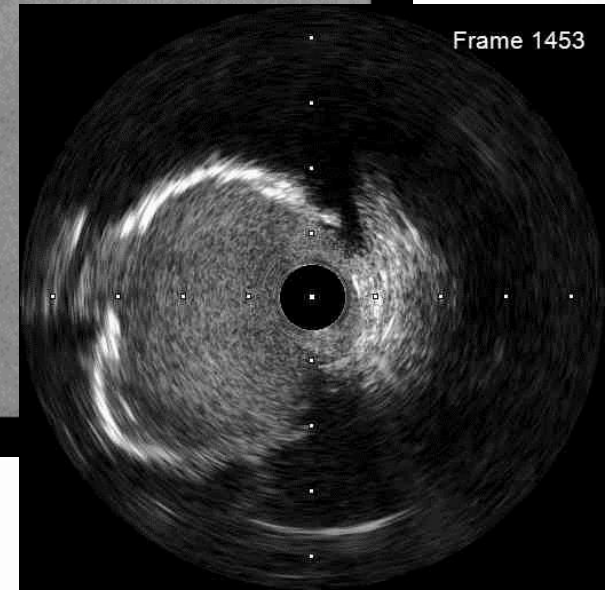
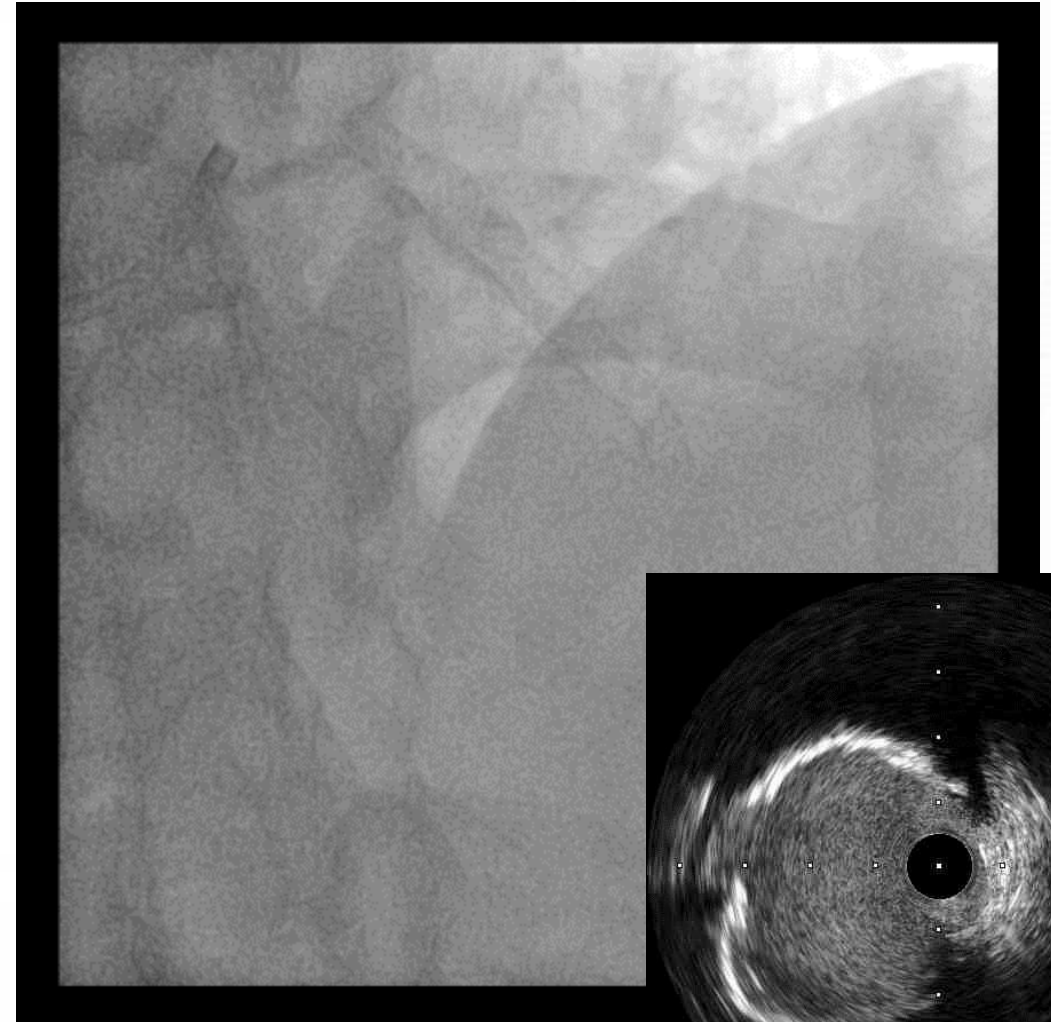
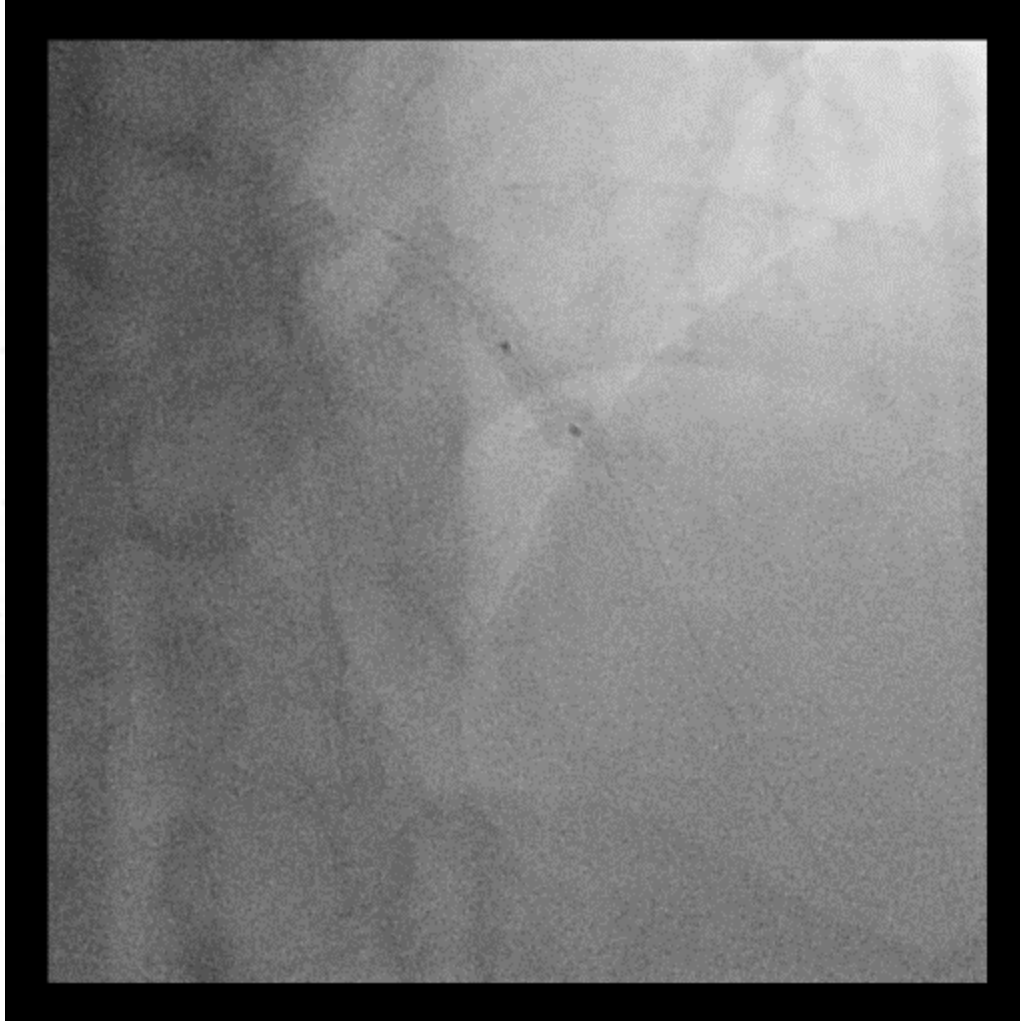
3.5(38) DES at 10 atm

Stent Does Not Expand



3.5(15), 3.75(10) NC Balloon at 30 atm

Finally Expanded with Very High-pressure Balloon



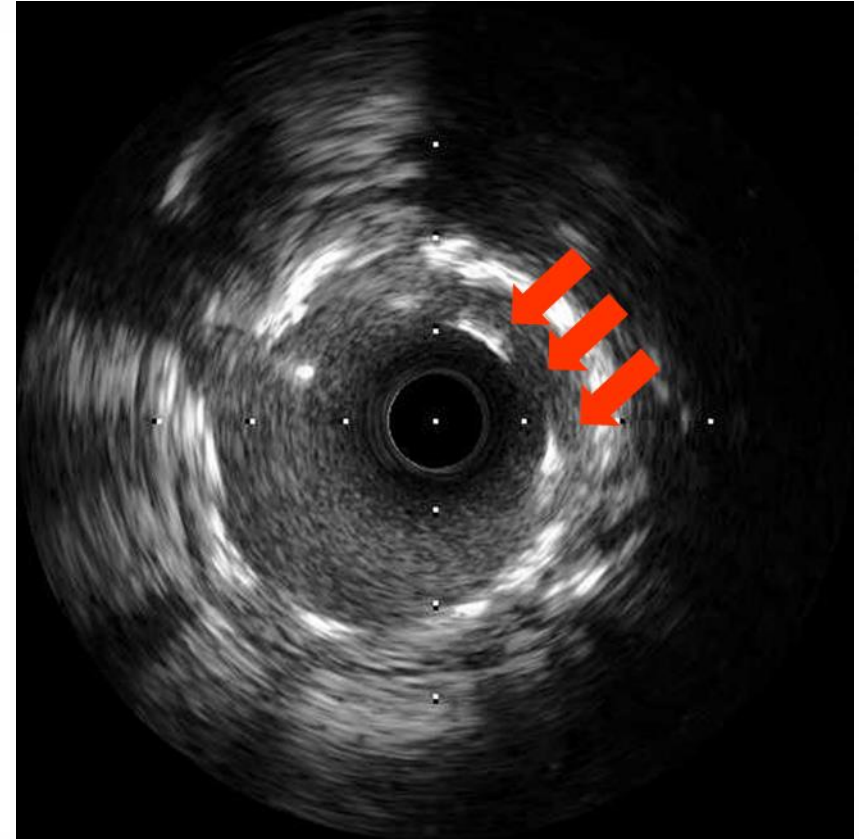
Selectthru NC 4.0 (10) at 34 atm

Vessel Size by Imaging

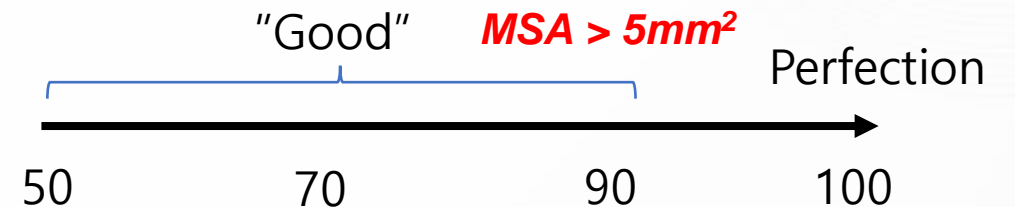
Perforation



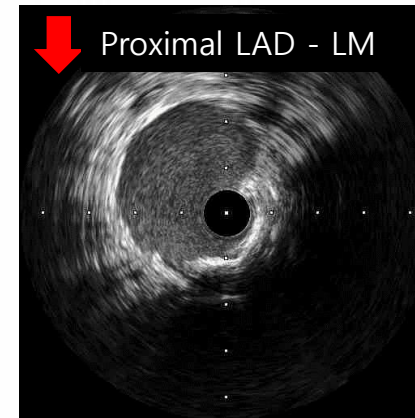
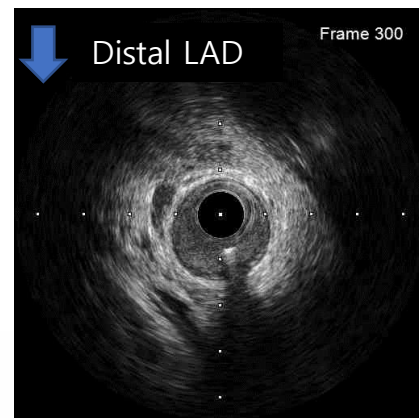
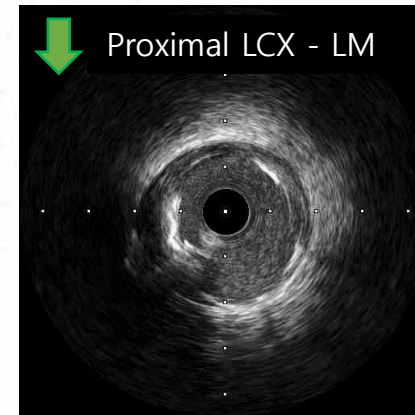
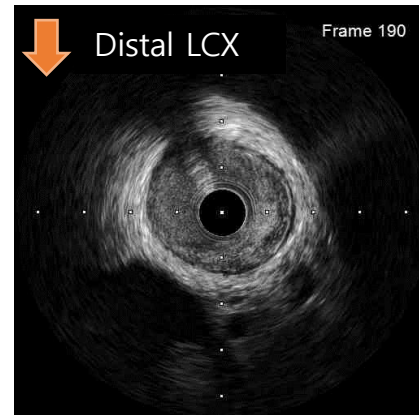
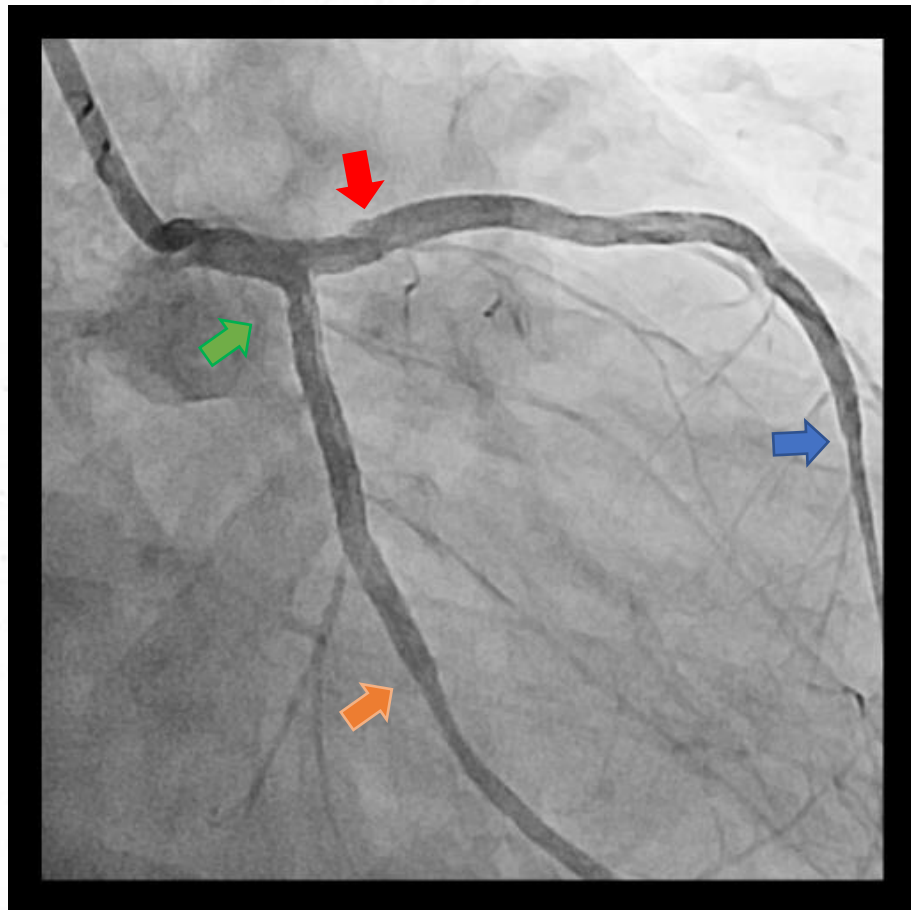
Underexpansion or Malapposition



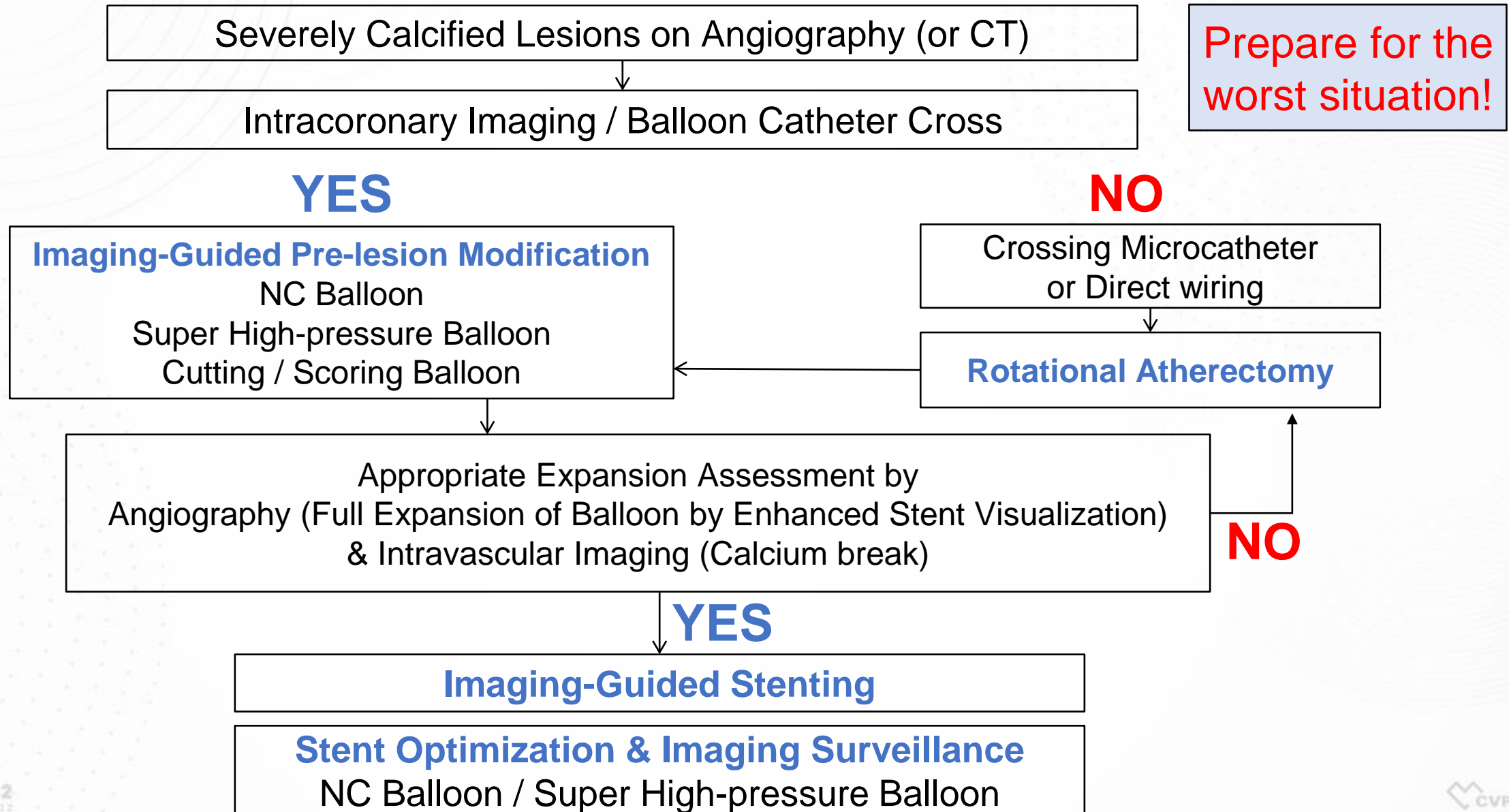
Perfection is the Enemy of Good



Post-IVUS Surveillance

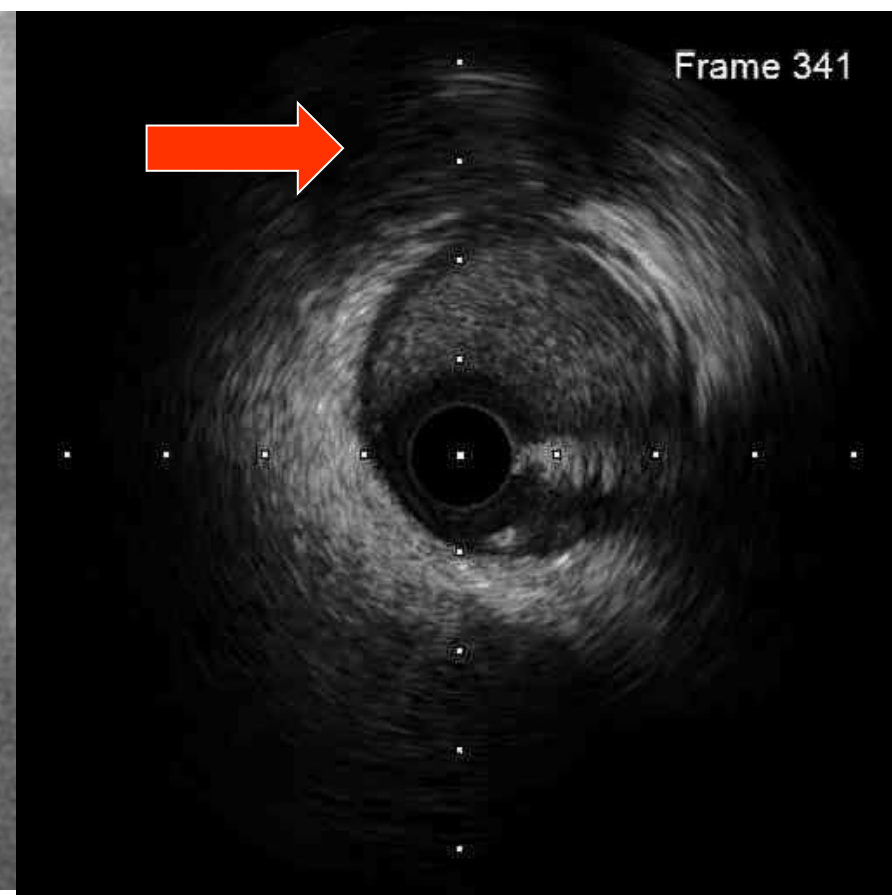
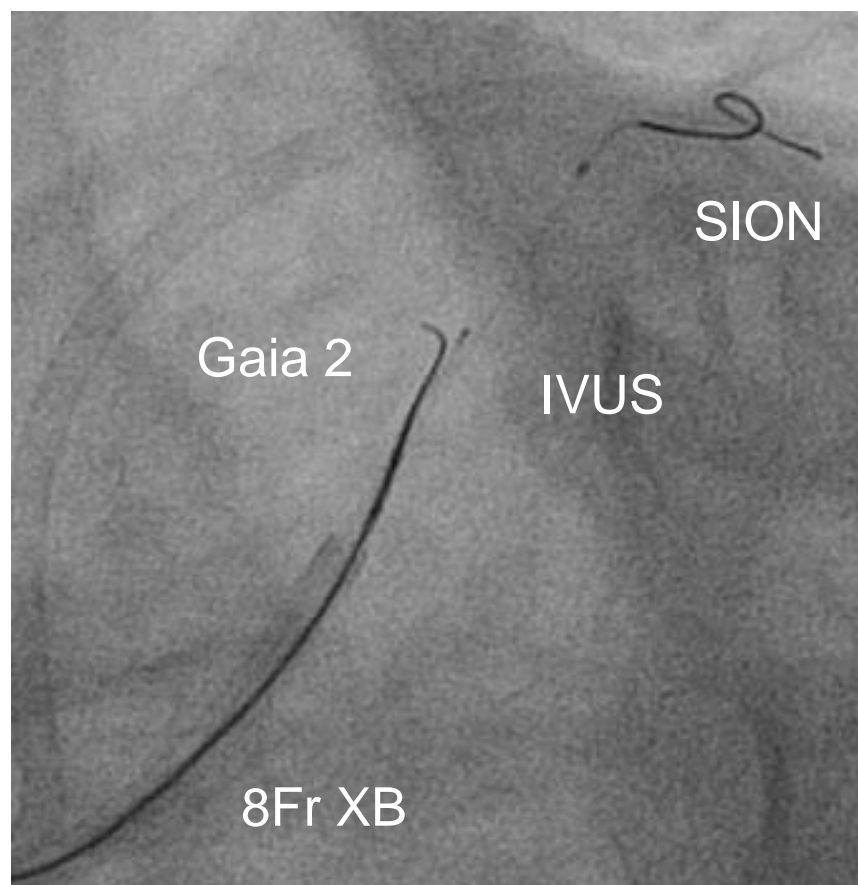
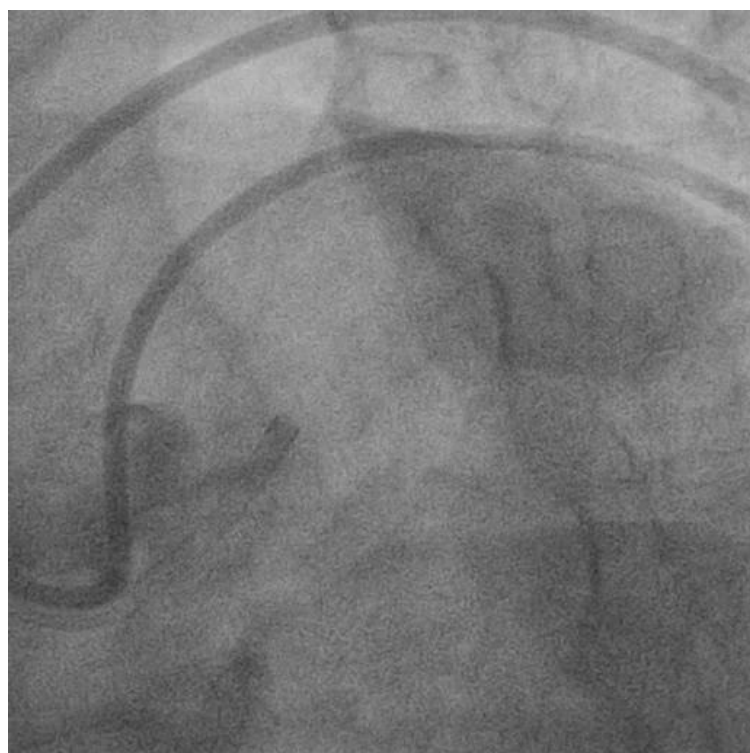


My Practical Approach to Calcified Lesions



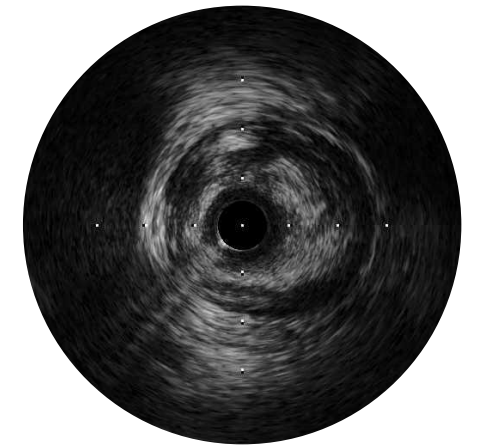
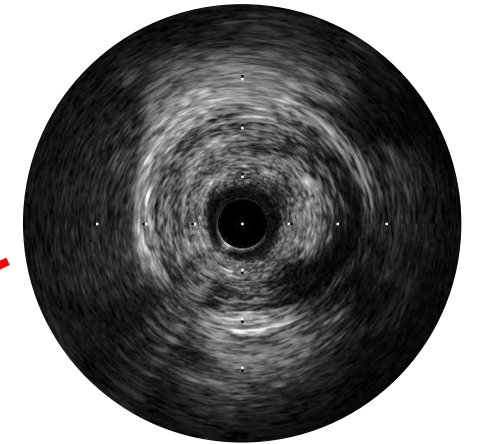
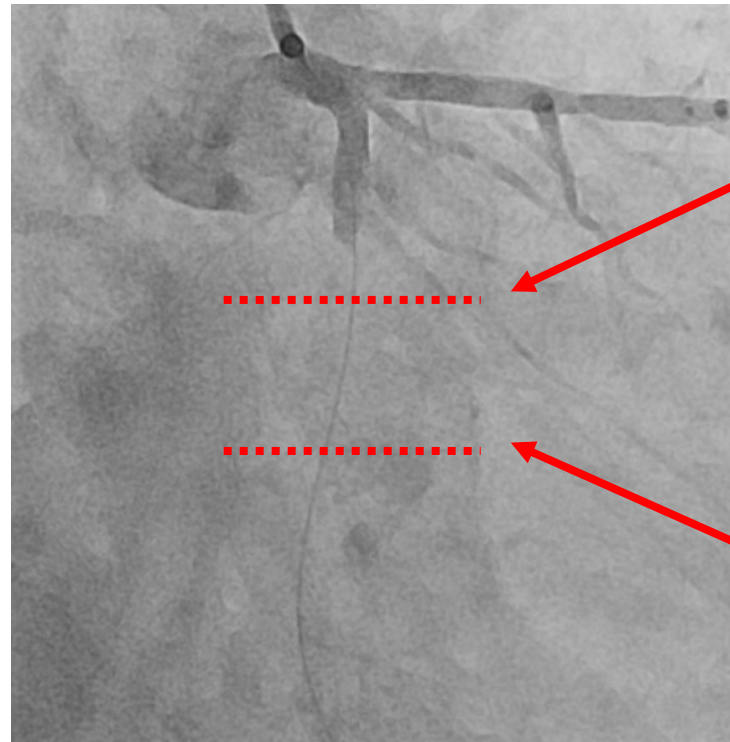
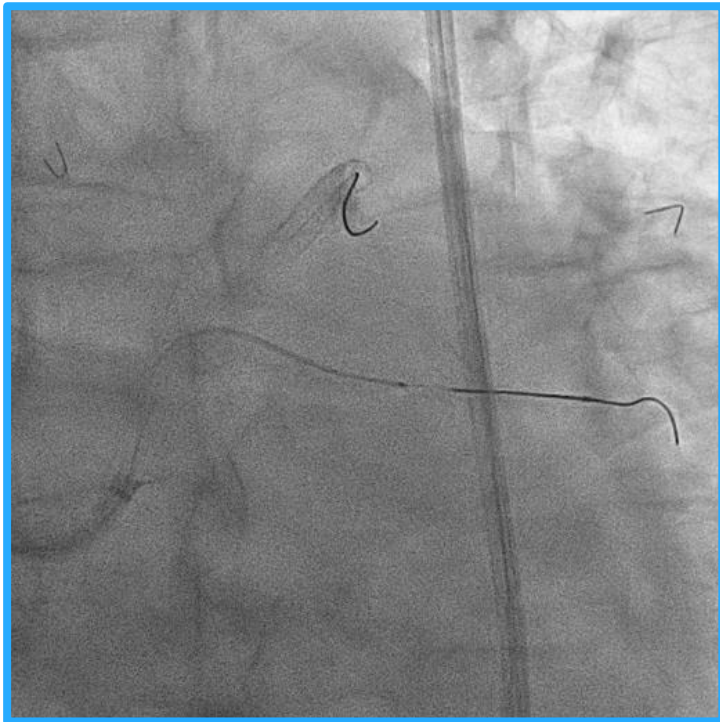
IVUS-Guided CTO PCI

IVUS can Guide Wiring in CTO PCI



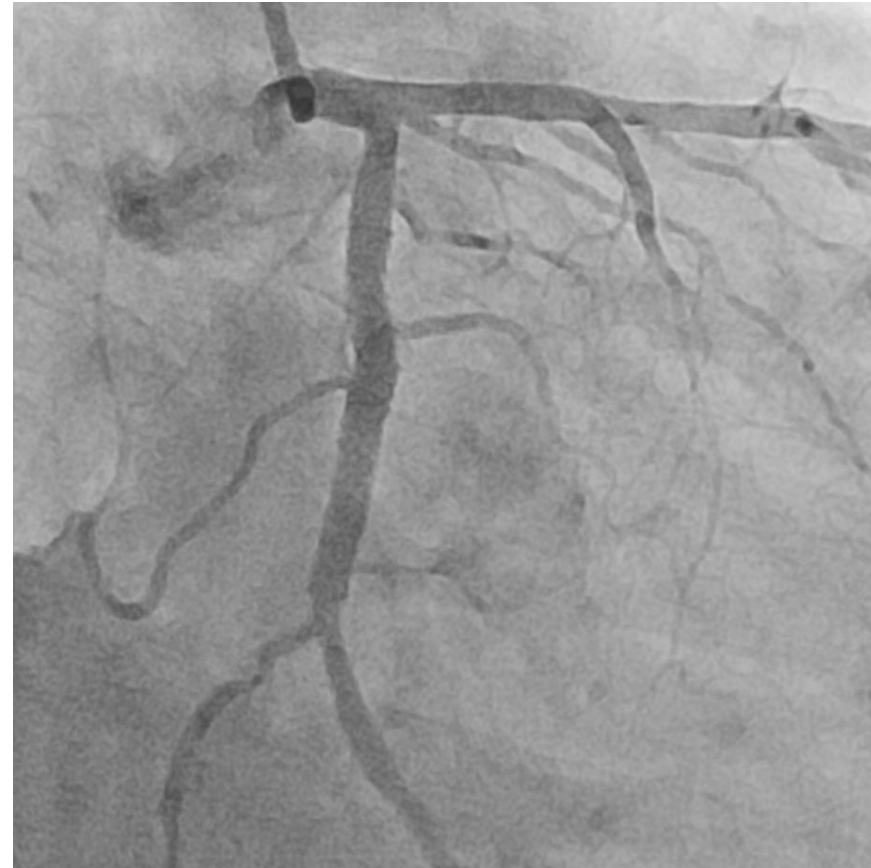
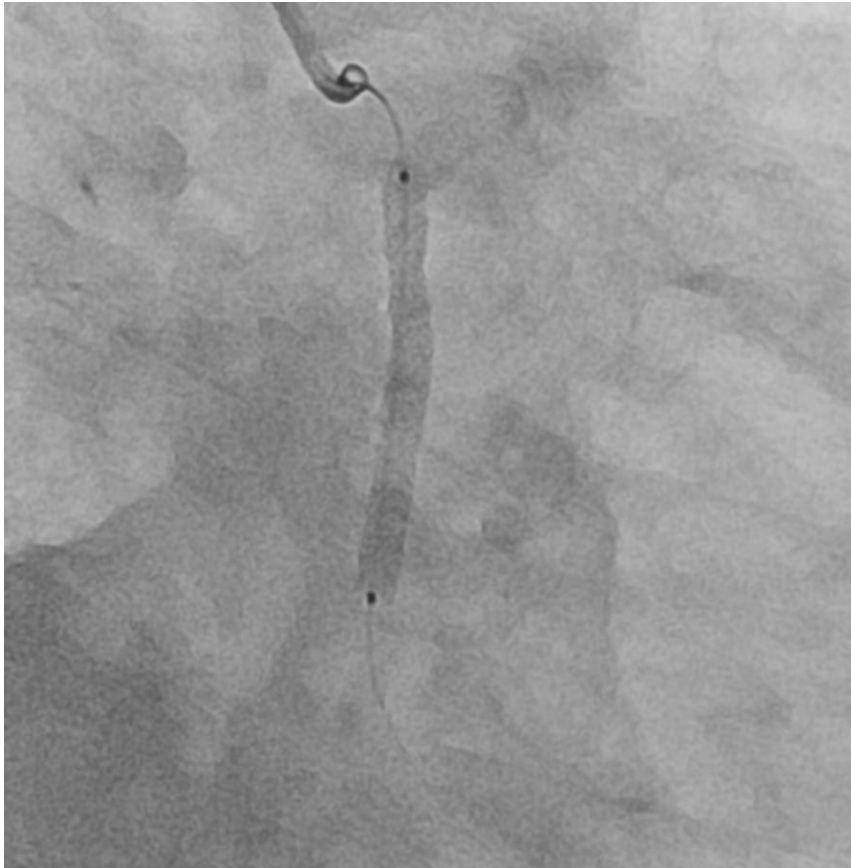
IVUS can See Un-visualized Vessel

No-reflow, STEMI, CTO...

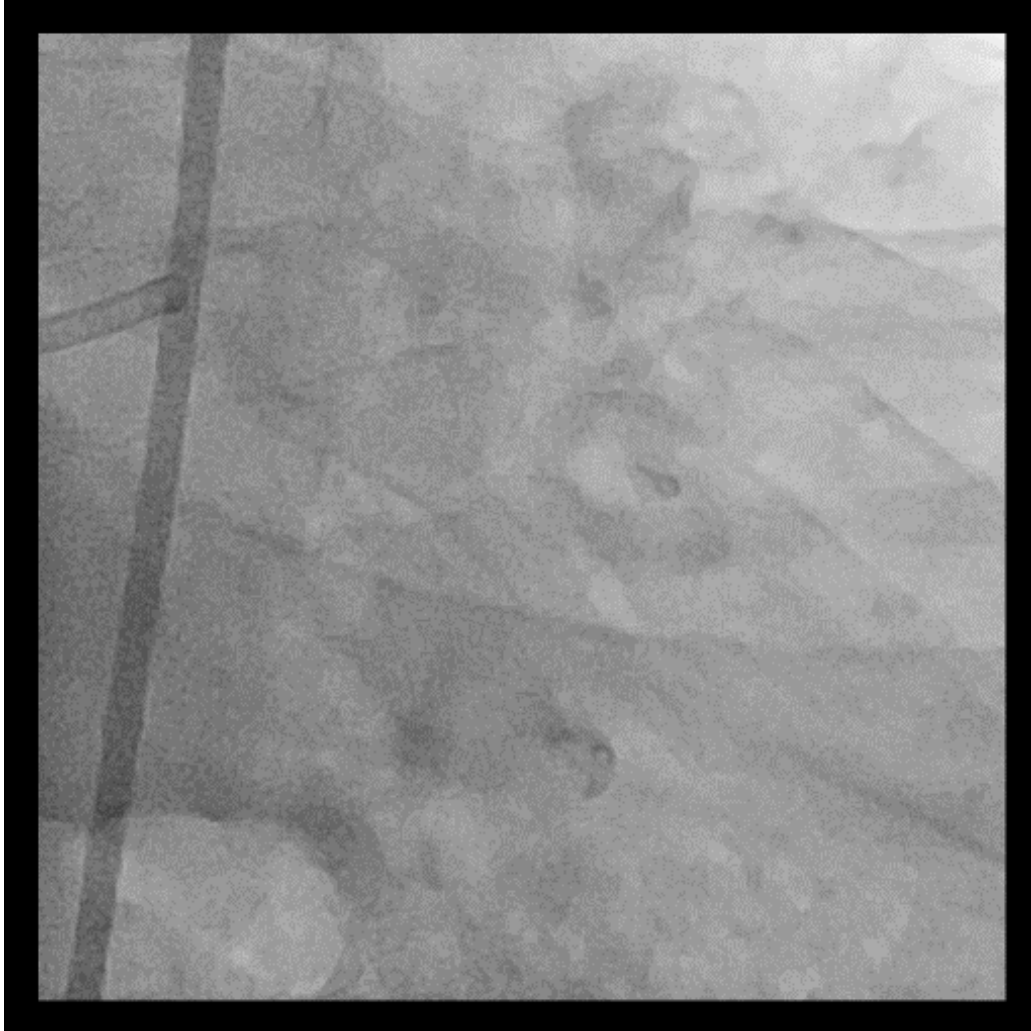


IVUS can See Un-visualized Vessel

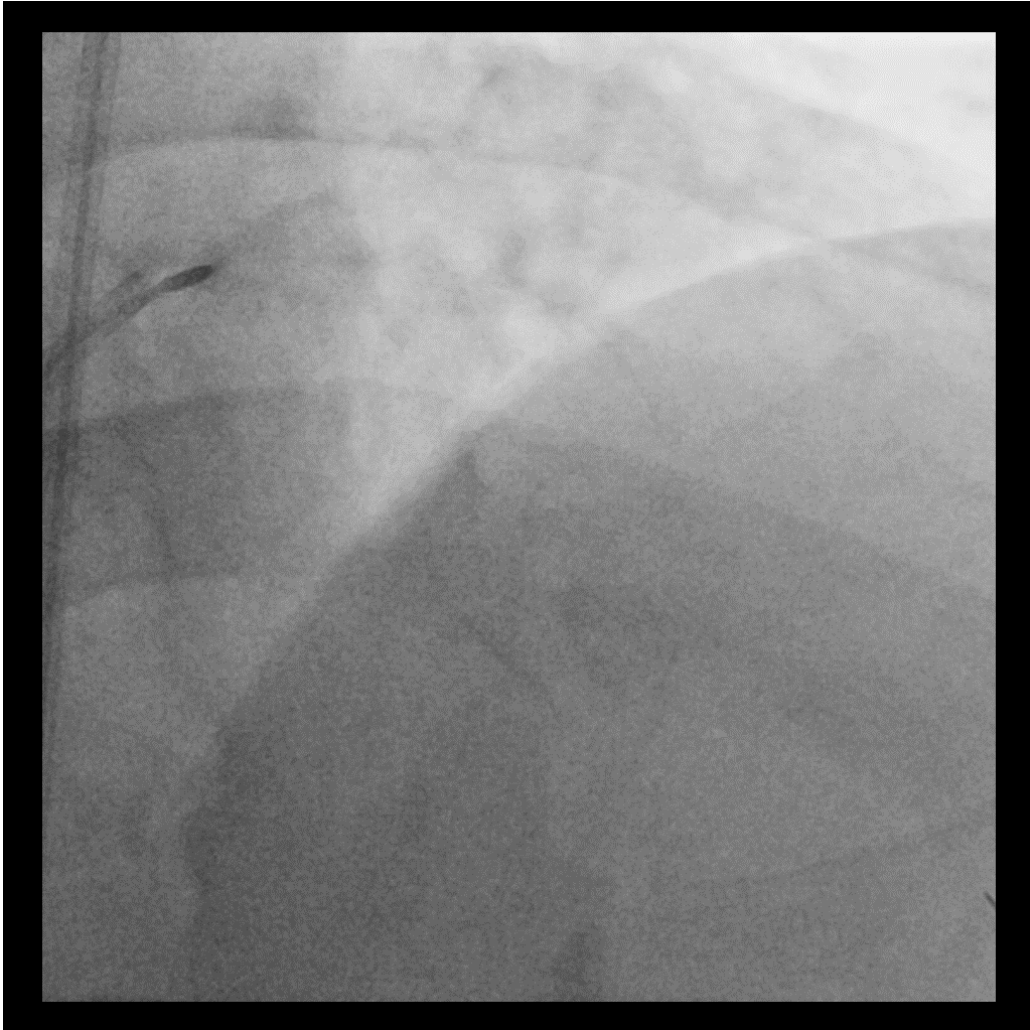
No-reflow, STEMI, CTO...



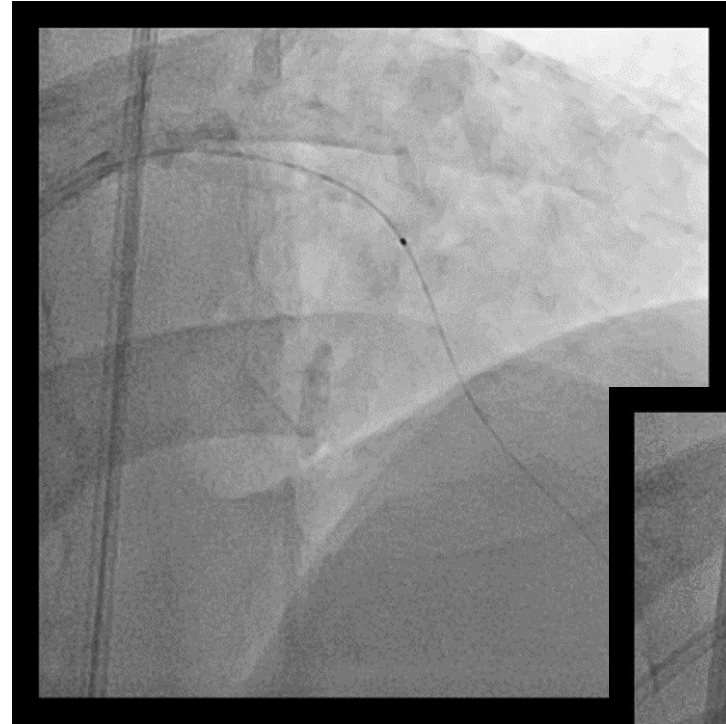
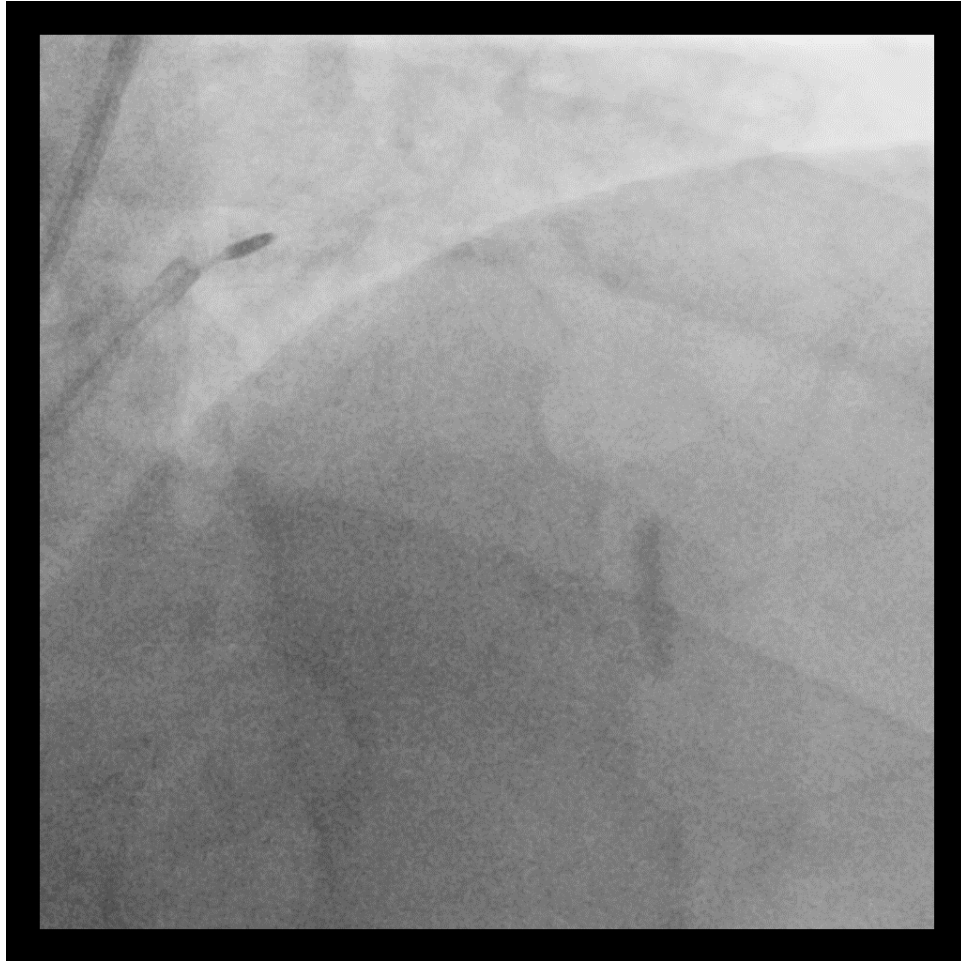
M/66 with Recent MI s/p RCA PCI



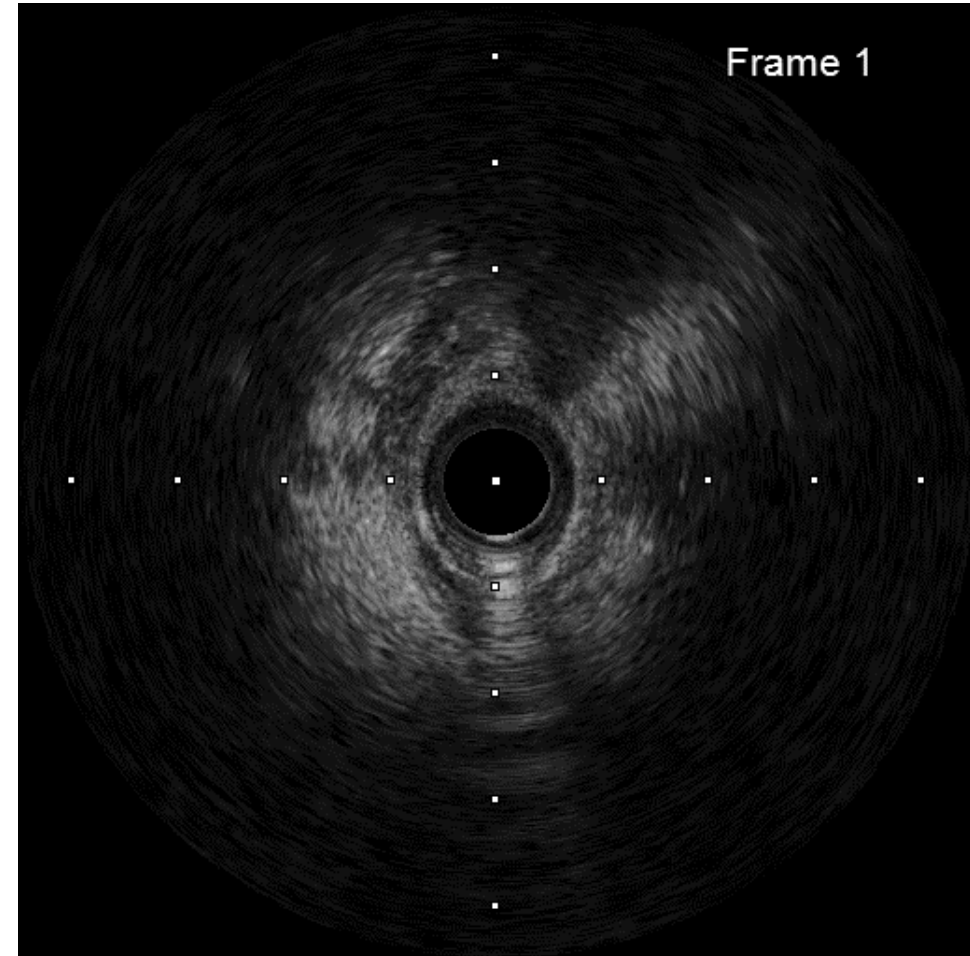
M/66 with LAD CTO



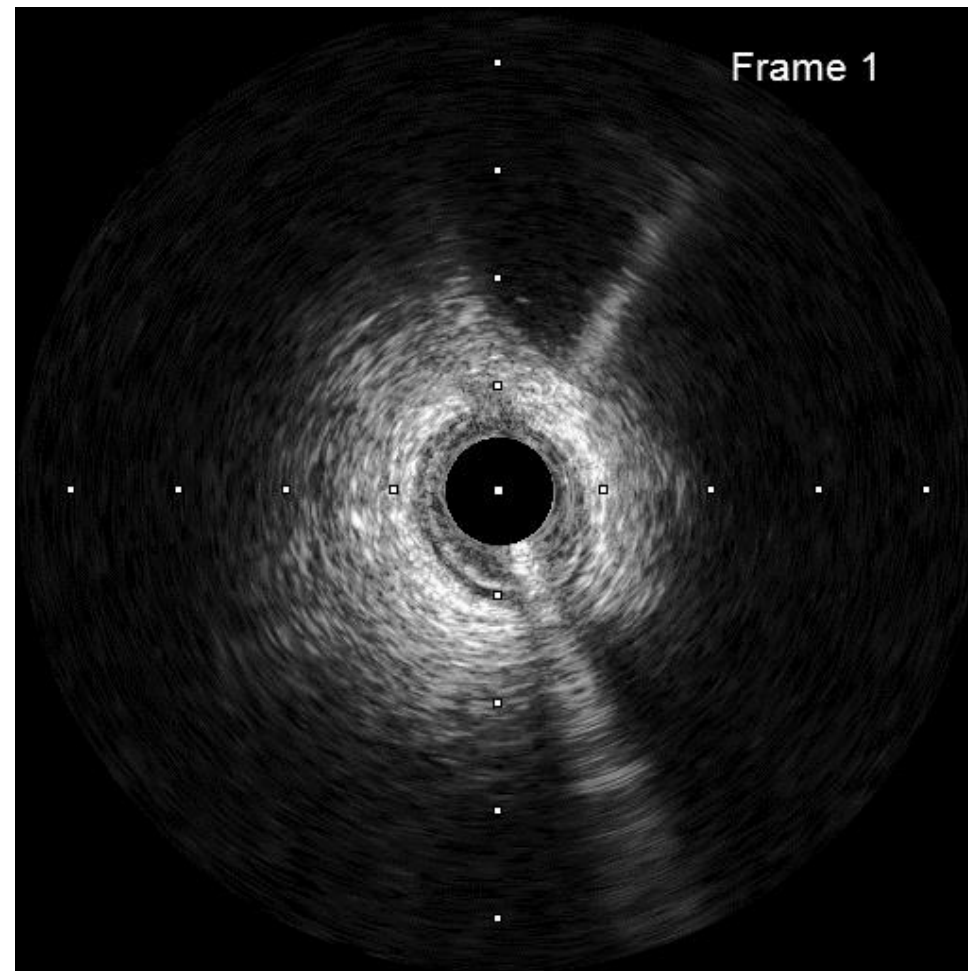
LAD CTO with Severe Calcification



LAD CTO with Poor Distal Vessel

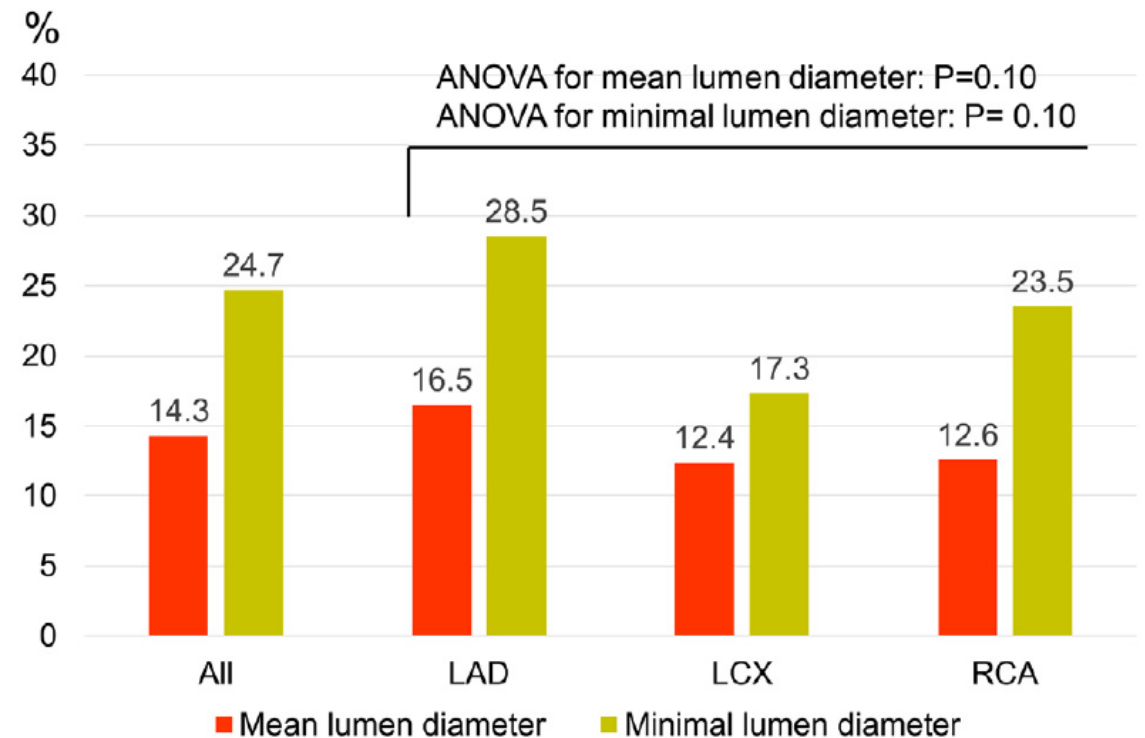


Final CAG



Stent Sizing in CTO with Poor Distal Vessel

- 507 FU Angiography after CTO PCI on 13.5 months in AMC
- Lumen diameter distal to CTO increased about 2.5mm



Lesson #6:

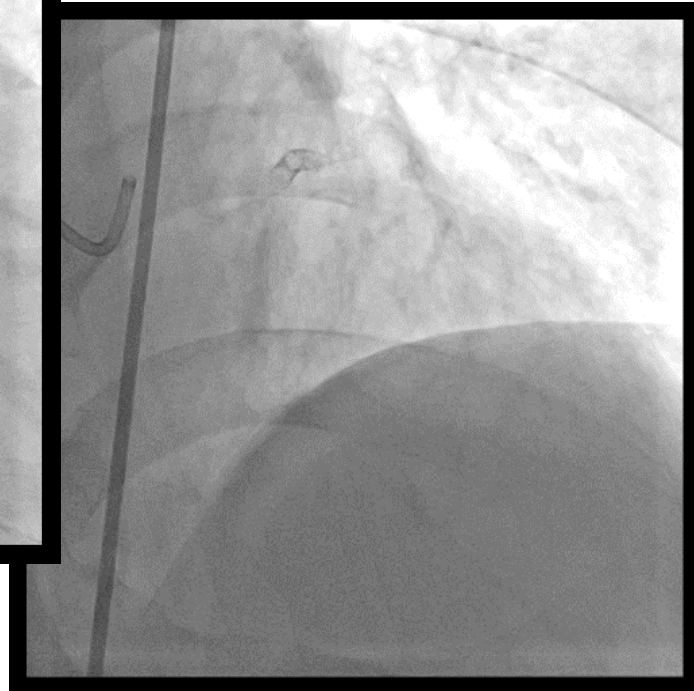
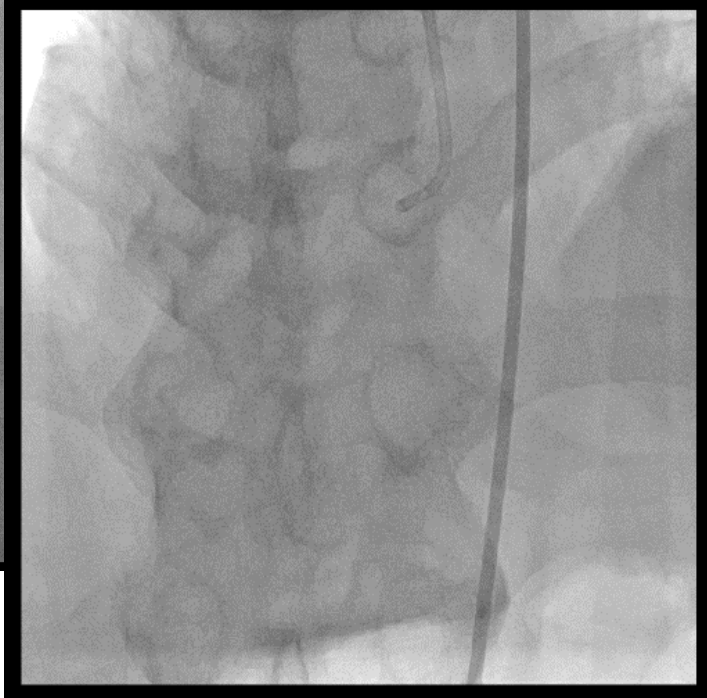
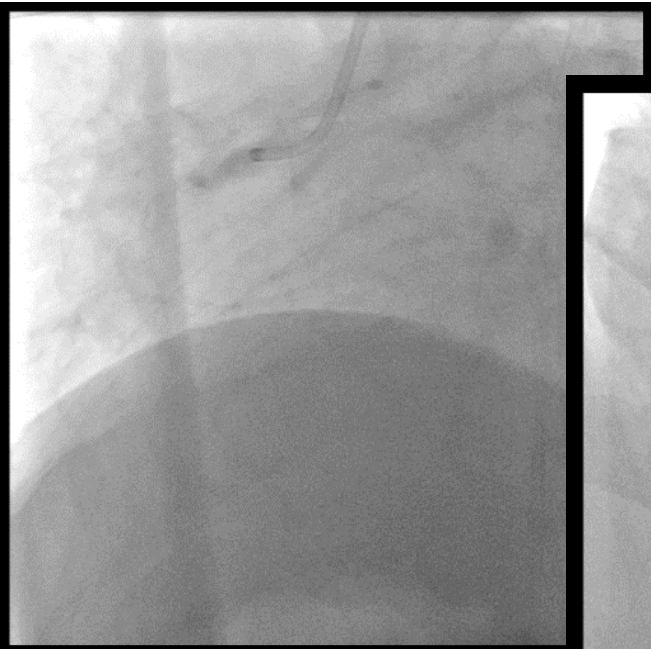
**Unclear in Angio, But Clear in IVUS
Stent Optimization is Still Important
in CTO PCI !**

*IVUS-Guided in **HF / CKD** Patients*

Minimal Contrast Procedure Available with IVUS

M/65, Angina, Diabetes, CKD (Cr 7.5), Not on dialysis

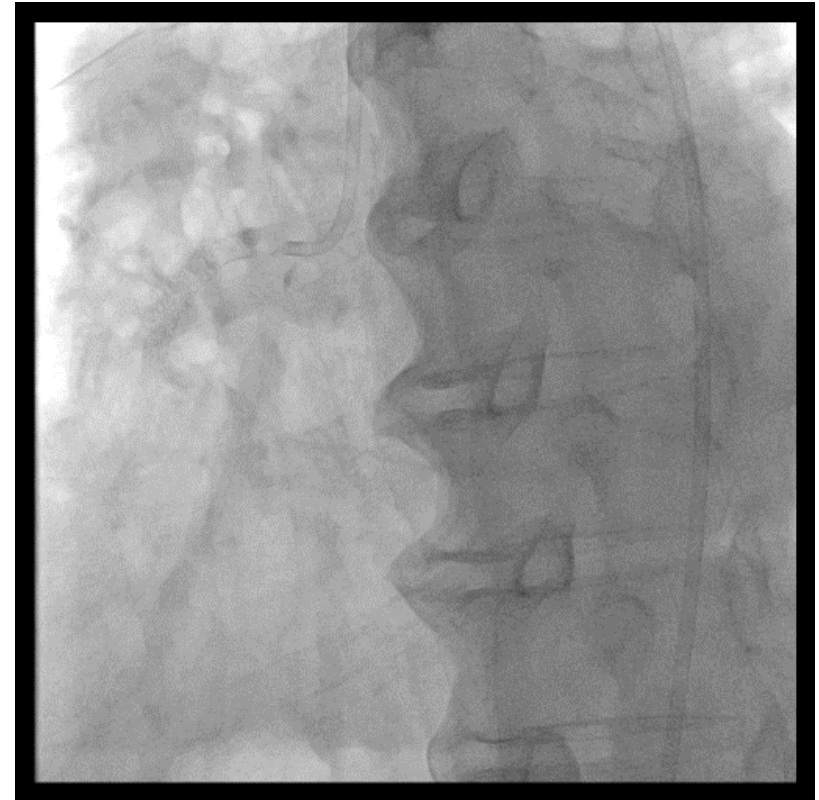
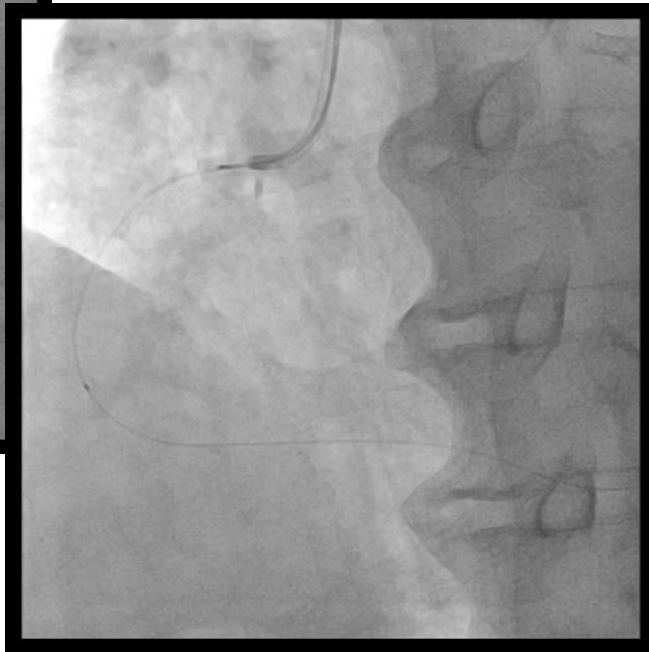
Biplane angiography with minimal contrast



Minimal Contrast Procedure Available with IVUS

M/65, Angina, Diabetes, CKD (Cr 7.5), Not on dialysis

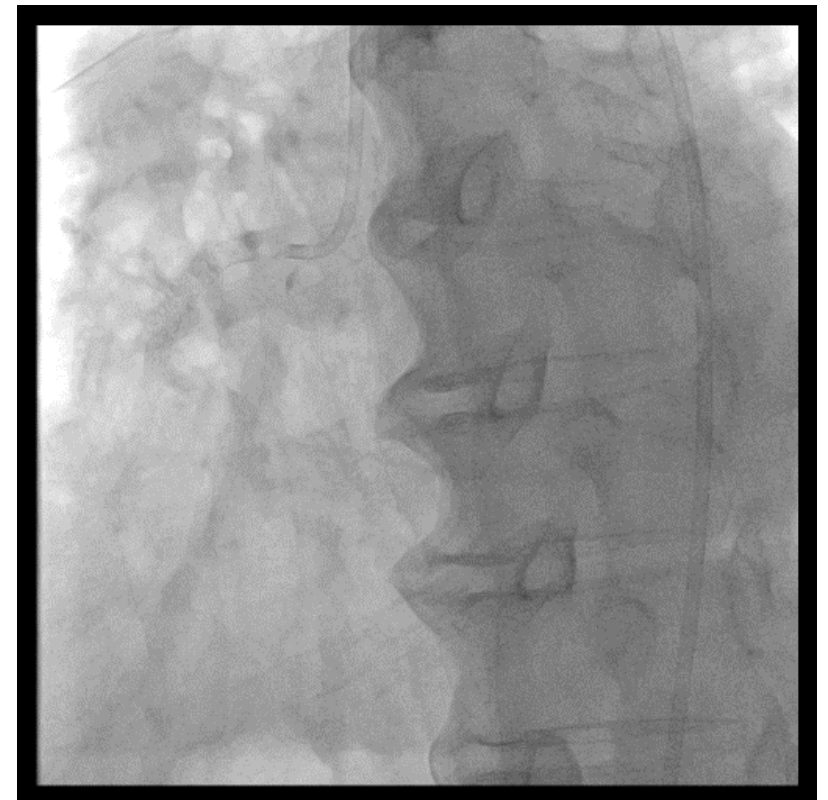
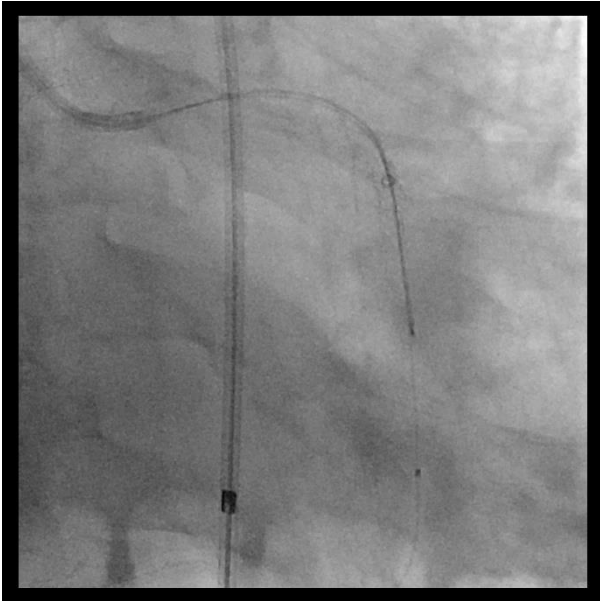
IVUS-guided PCI with minimal contrast



Minimal Contrast Procedure Available with IVUS

M/65, Angina, Diabetes, CKD (Cr 7.5), Not on dialysis

2-vessel PCI with < 10 cc contrast



Lesson #7:

IVUS Can Reduce Contrast Amount

Final Lesson :

Don't Stick to IVUS !

Not IVUSplasty, But Angioplasty.

The Key for Successful, Fluent Imaging-Guided PCI ?

Education of Cath Lab Professionals

He is the Keyman
For Successful
Imaging-guided PCI !



Summary

- IVUS–guided PCI is the evidence-based approach for the best clinical outcome.
- Imaging enables safe and effective PCI with larger stent & balloon, resulting in a larger final stent area.
- Team education is important for procedural fluency in routine use of imaging.
- Practice makes perfect. Routine use of intracoronary imaging would make perfect PCI team.

Thank You for Your Attention!