Application of Intravascular Imaging in Stent Failure

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Friday, 6th May 2023, Time 13:35-13:55 (20 mins), Venue Art Hall, Level 4

Disclosure

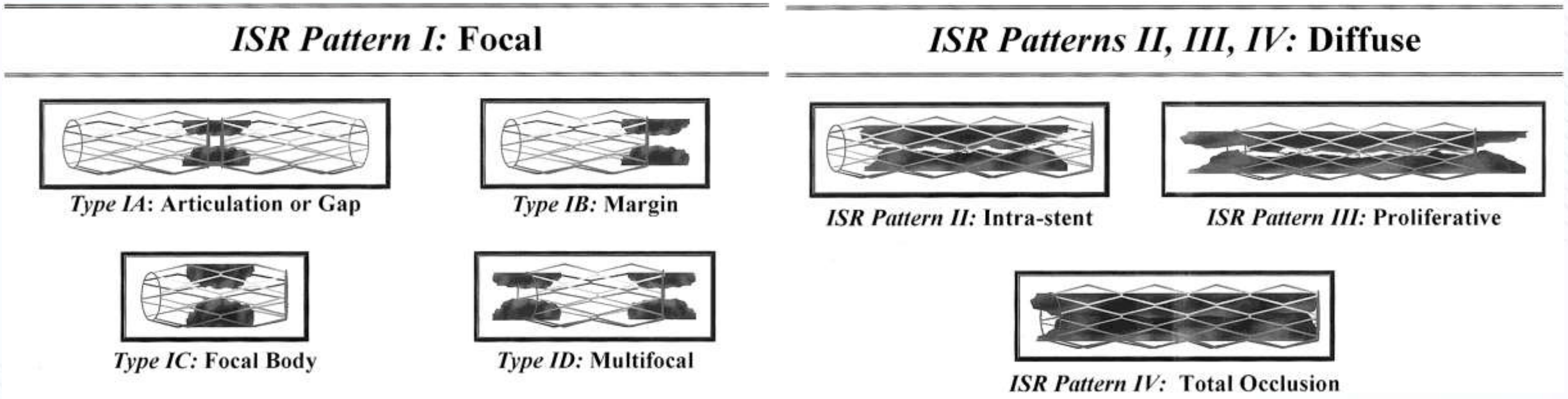
Within the past 12 months, with respect to the content of this presentation, I, **Pannipa Suwannasom**, have had a financial interest/arrangement or affiliation with the organization(s) listed below:

Affiliation/Financial Relationship	Company
Lecturing or consultancy fees	• Abbott Vascular • Biotronik • Boston Scientific • Medtronic • Terumo • Philips
Research funding	• Medtronic

Outline of the talk

- **Detection of the problem(s):** What is/are the underlying mechanism?
- **Image interpretation**: Key findings
- **Planning for treatment:** How IVI-guided treatment decision?
- **Prediction of the recurrent events:** Post intervention assessment

Mehran Classification

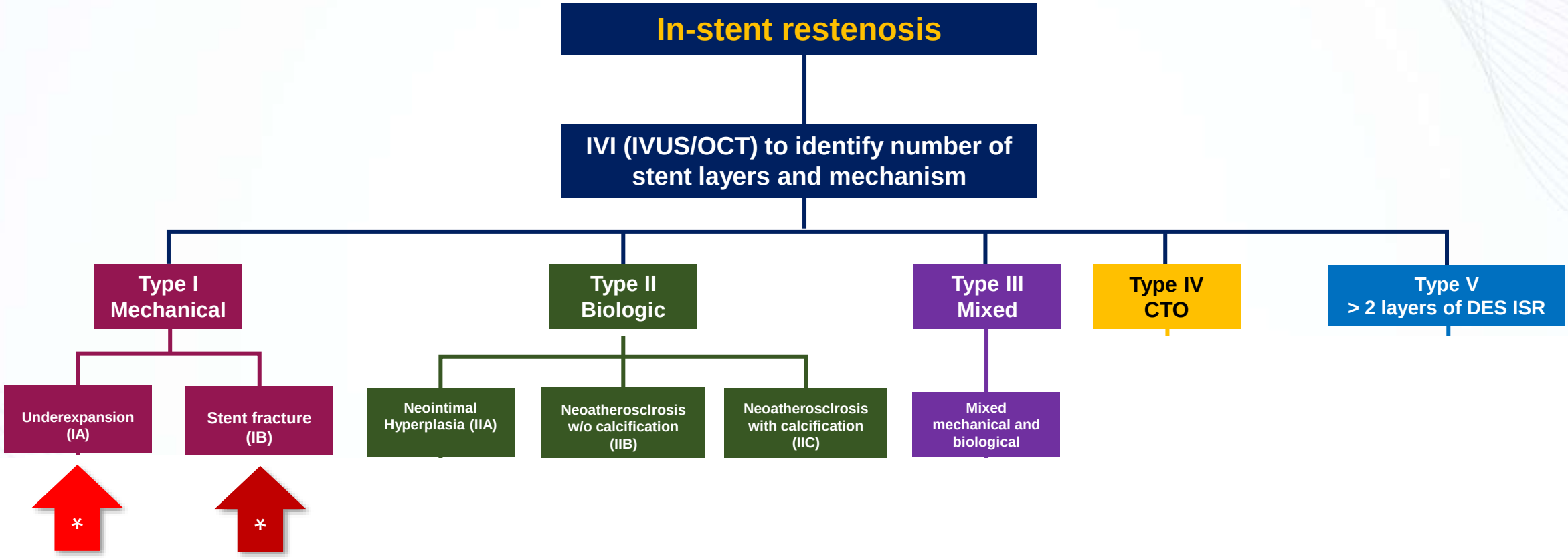


Limitations of Mehran's classification:

- specific to BMS-ISR and detailed 4 patterns of ISR.
- less relevant to DESs.
- provide no insight into the mechanism of stent failure and do not dictate applicable treatment.

Mehran R, et al. Circulation. 1999;100:1872–1878; Shlofmitz E, et al. Circulation: Cardiovascular Interventions. 2019;12:e007023

Waksman ISR Classification

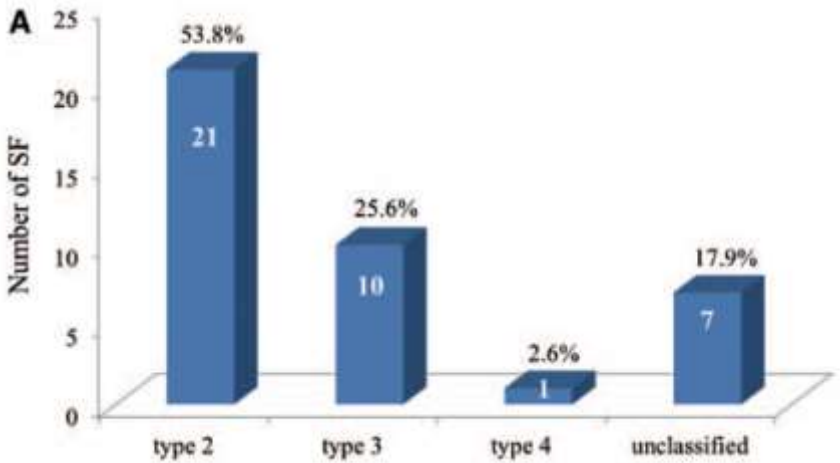


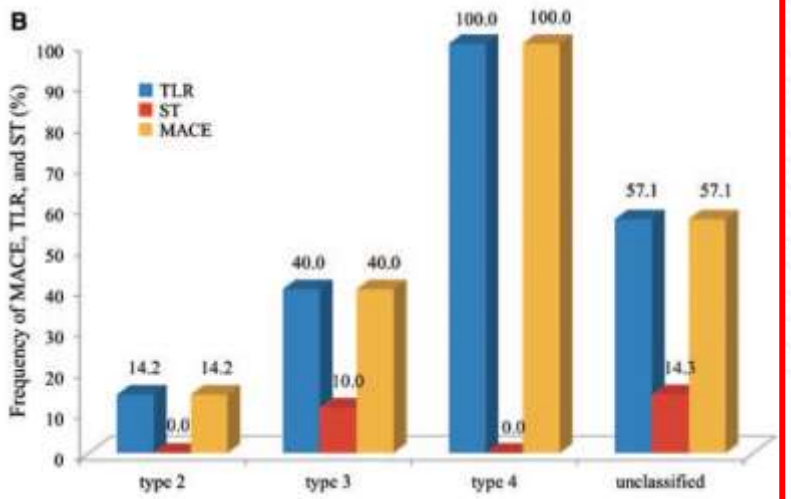
Failure to adequately address mechanical issues appears to increase the risk of future ISR recurrence

Shlofmitz E, et al. Circ Cardiovasc Interv. 2019;12:e007023

Nature of stent fracture (Data from Japan and China)

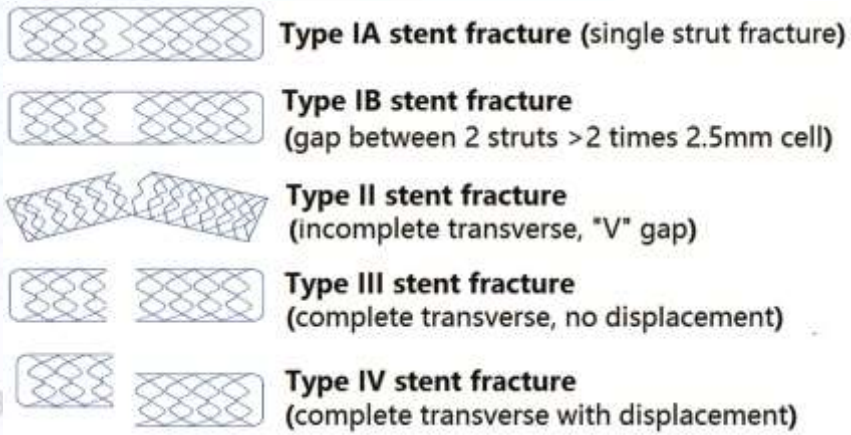
- Data from 2 hospitals in Japan, n= 1035 patients, 1339 lesions undergoing EES
- FU angiography 6 to 9 months after index procedure
- *2.9% of lesions*
- Ostial stent location and lesions with hinge motion, tortuosity, or calcification

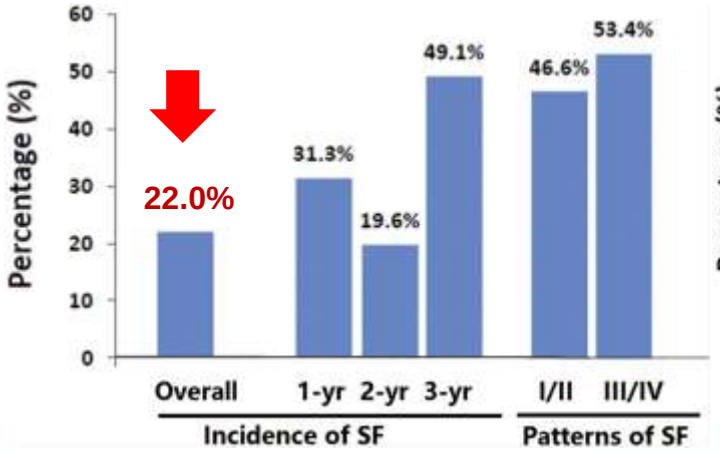


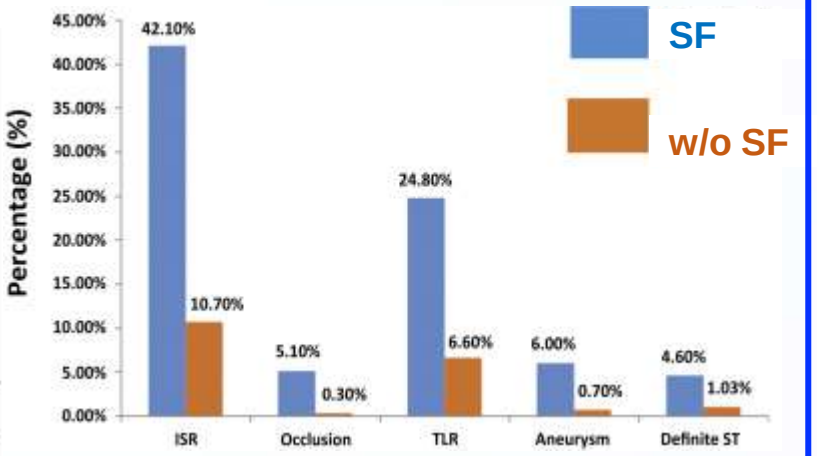


Kuramitsu S, et al. Circulation: Cardiovascular Interventions. 2012;5:663–671

- 4 centers in China, n=6,555
- Routine follow-up angiography at 9 to 12 months post-procedure was encouraged for all patients.







Kan J, et al. J Am Coll Cardiol Intv 2016;9:1115–23

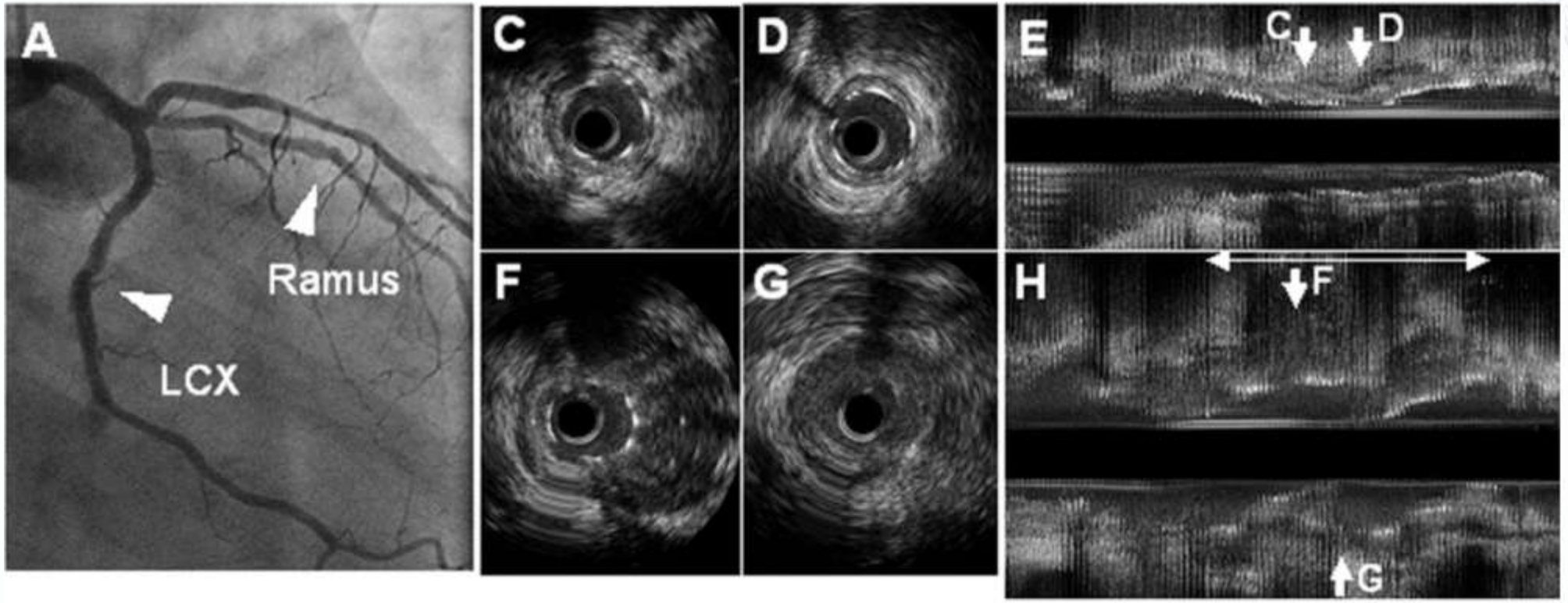
When should we think about stent fracture?

	Odds Ratio	95% Confidence Interval	p-value
RCA stent	10.816	3.026-18.553	<0.001
Stainless stent	2.601	1.509-4.484	0.001
Stent length > 25 mm	2.444	1.130-5.010	0.006
Hinge motion	7.447	4.569-21.387	<0.001
Overlapping	4.037	1.814-8.060	0.001
Stent/vessel ratio < 0.8	5.289	1.155-6.284	<0.001
Multiple stents	5.224	3.839-7.108	<0.001

Kan J, et al. J Am Coll Cardiol Intv 2016;9:1115–23

How can we detect strut fractures?

IVUS criteria for strut fracture: Doi classification

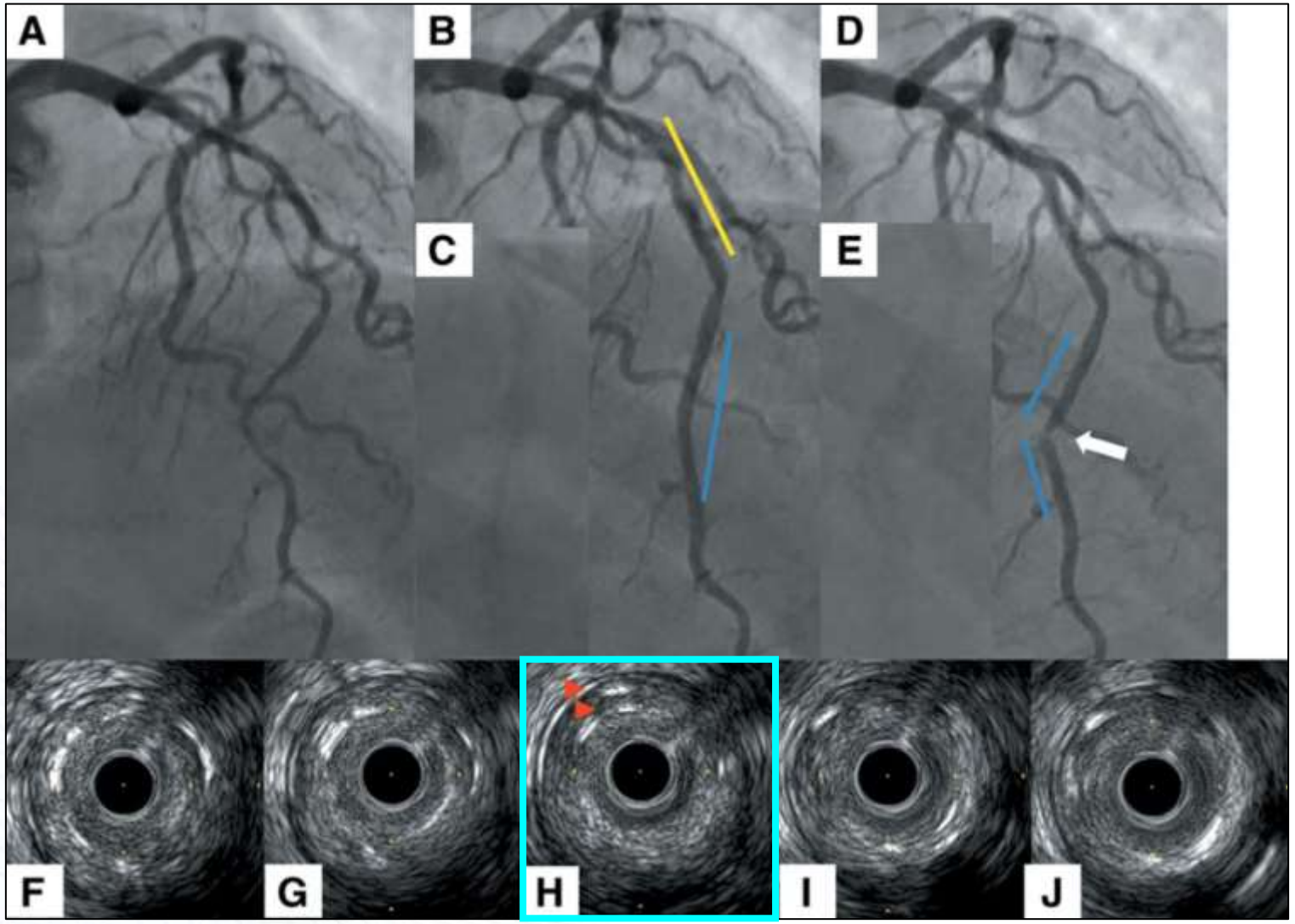


- **Complete**
  - complete separation of the stent into ≥2 pieces separated by image slices with no visible struts

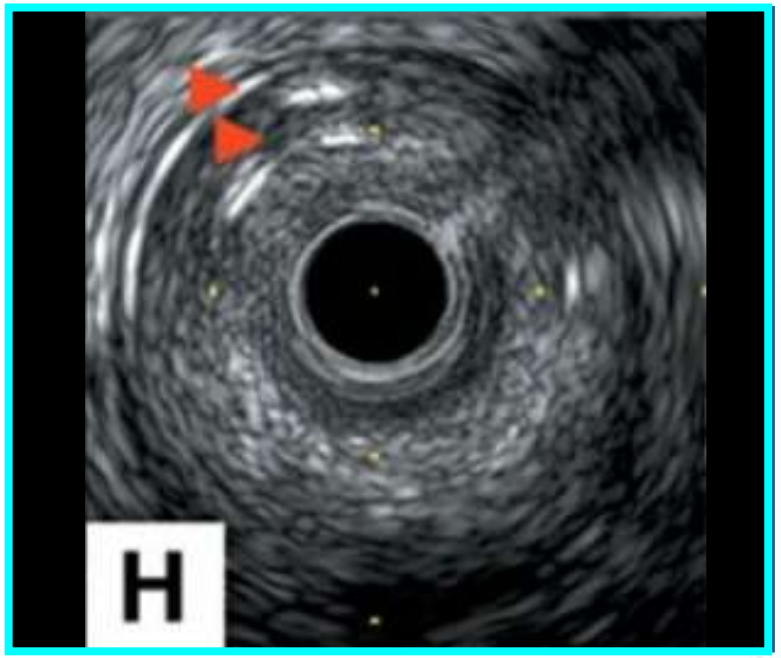
Doi H, et al. Am J Cardiol 2009;103:818–823

How can we detect strut fractures?

IVUS criteria for strut fracture: Doi classification



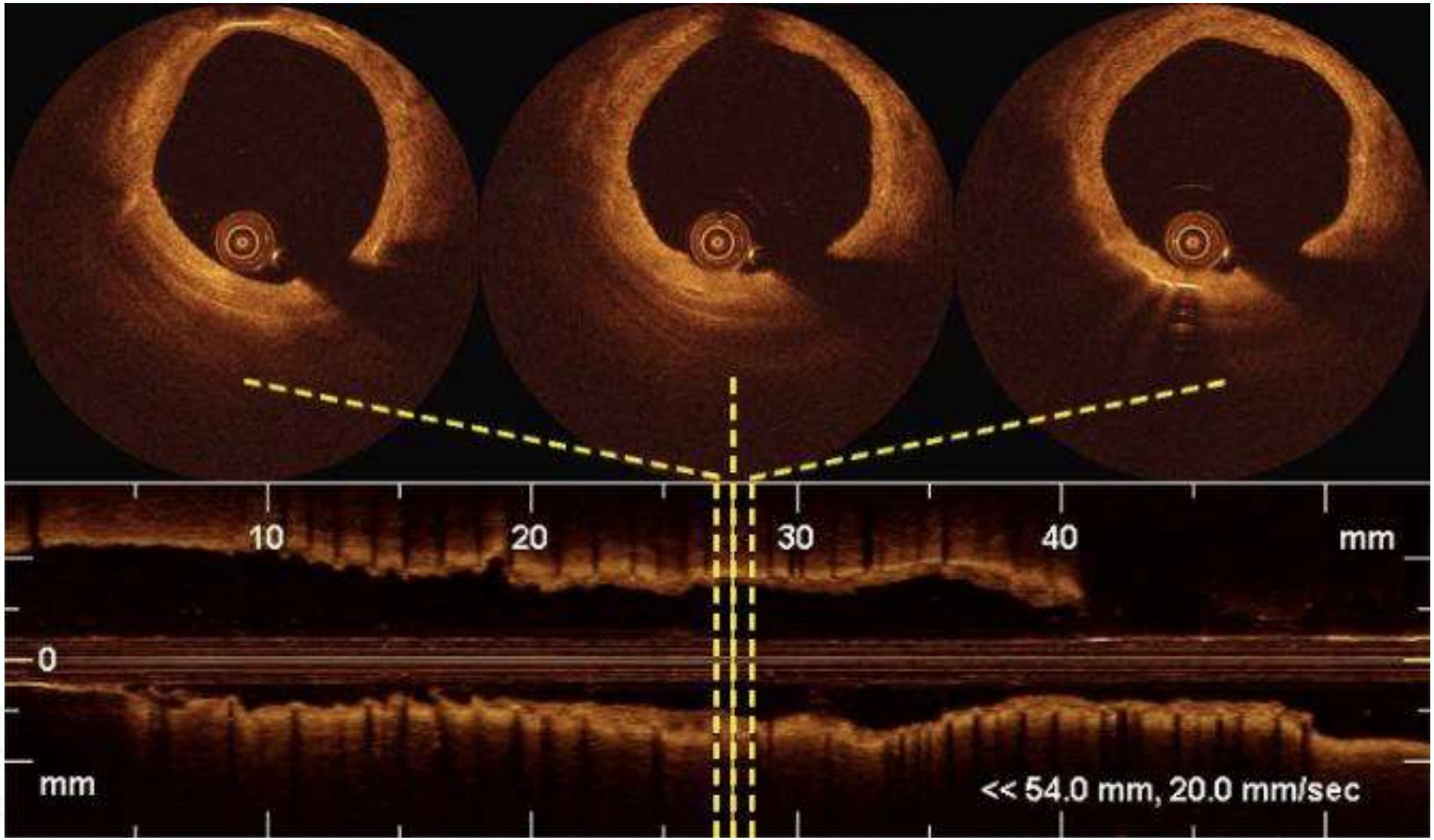
- **Partial**
  - the absence of struts over ≥1/3 of the stent circumference



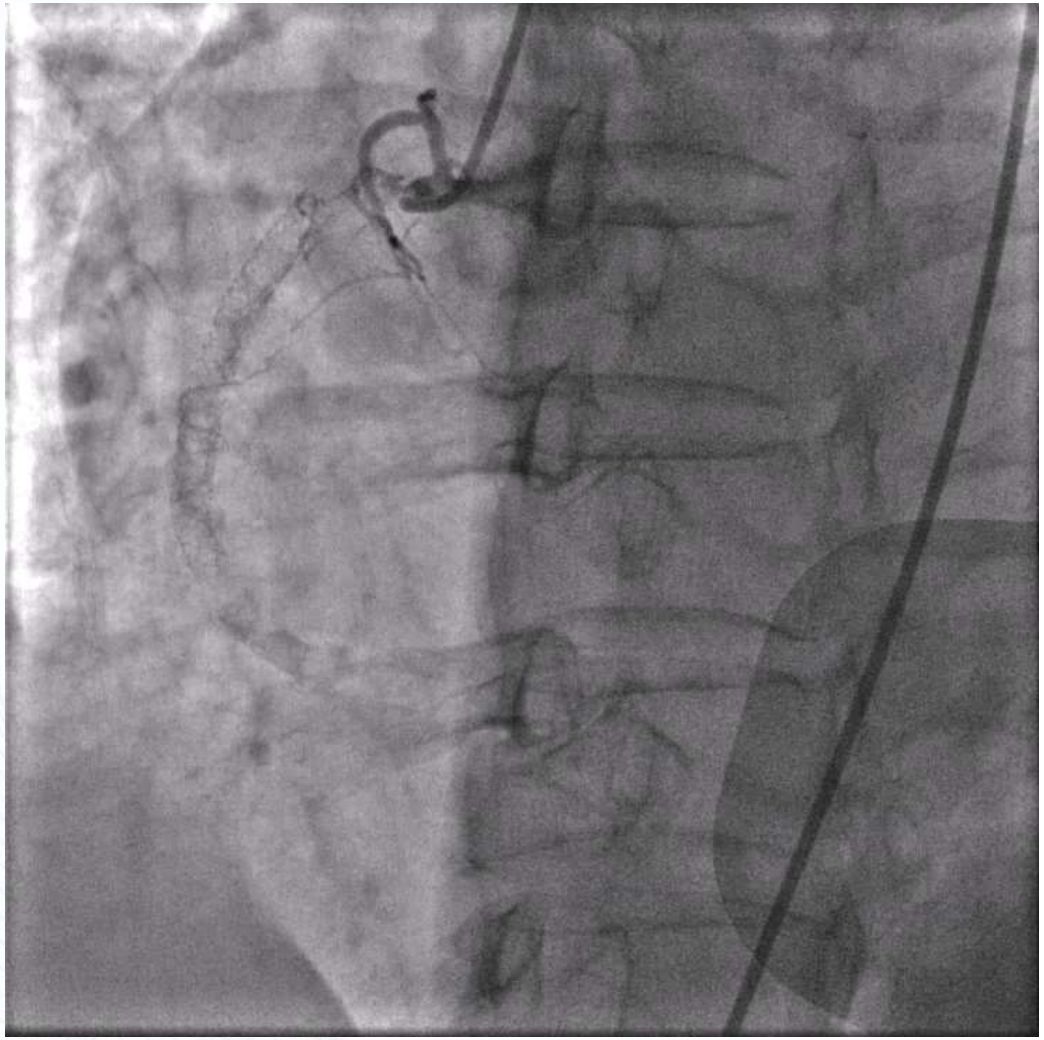
Doi H, et al. Am J Cardiol 2009;103:818–823, Kuramitsu S, et al. Circulation: Cardiovascular Interventions. 2012;5:663–671

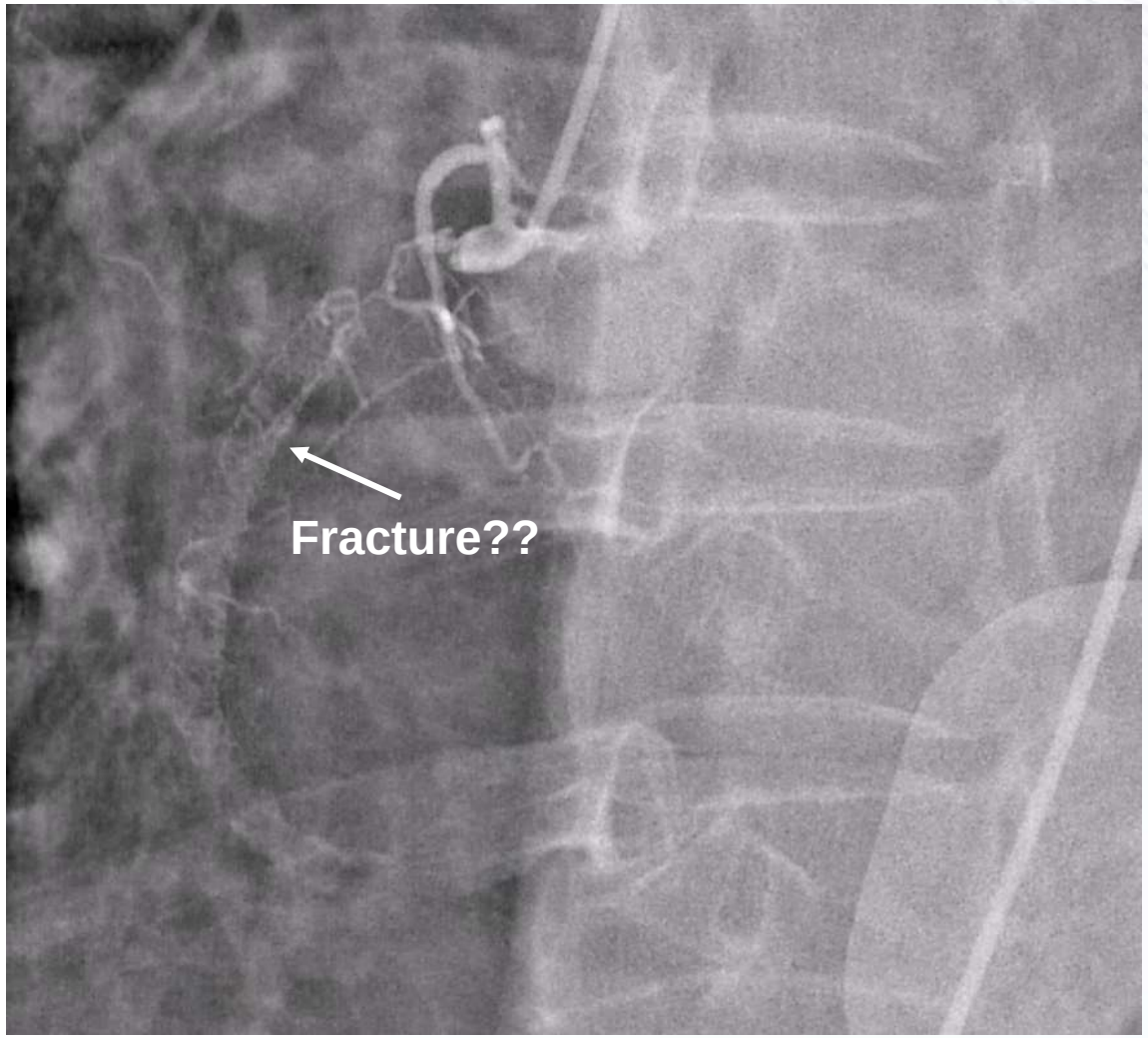
How can we detect strut fractures?

OCT Findings in Strut Fracture

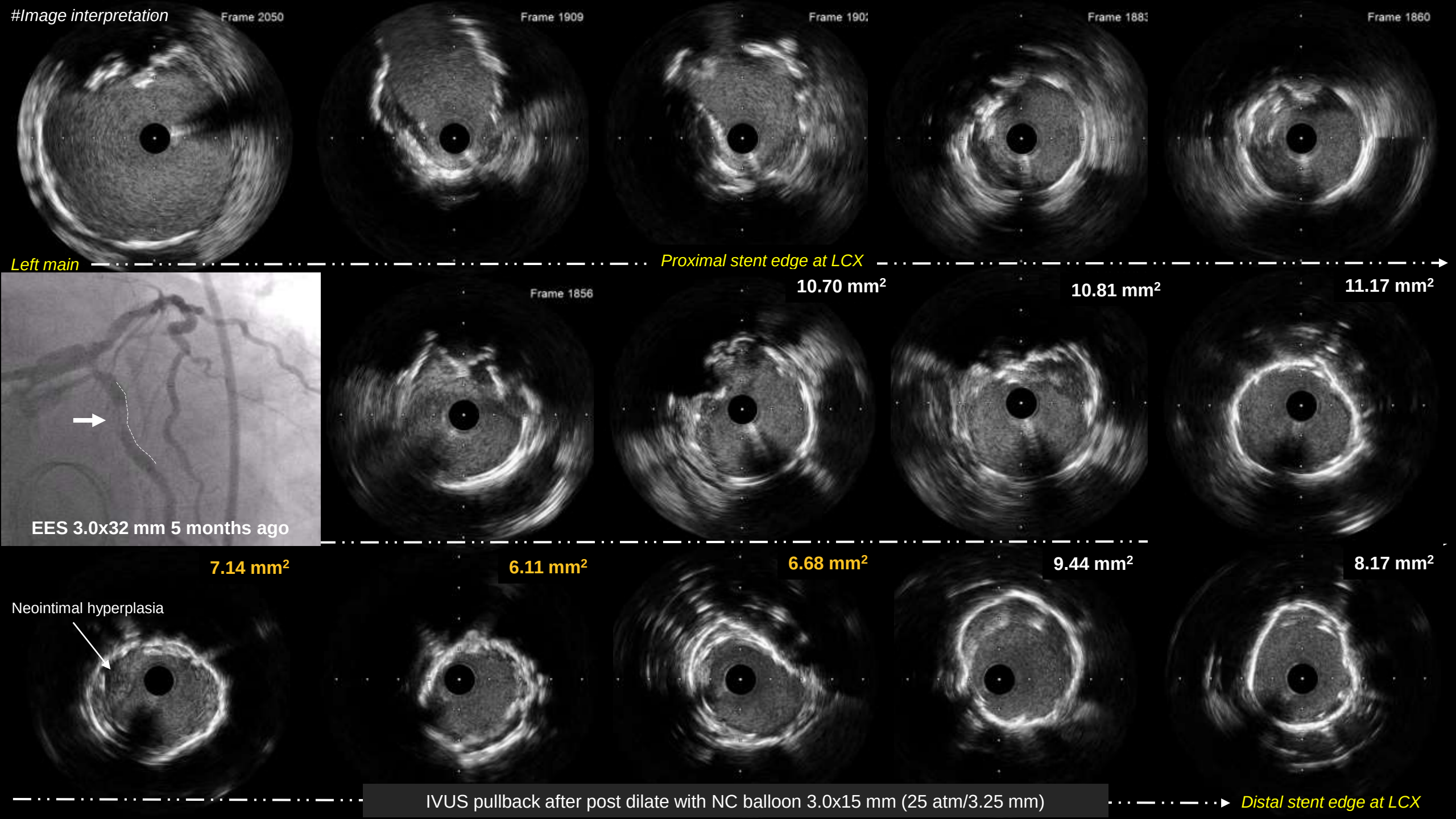


What is the common procedure the operators frequently forget when dealing with stent failure?





#Image interpretation



Waksman ISR Classification

BMS-ISR:
69% neointimal hyperplasia
14% stent underexpansion
8% co-dominant pathologies

In-stent restenosis

IVI (IVUS/OCT) to identify number of stent layers and mechanism

DES-ISR:
59% Tissue proliferation
18% stent underexpansion
16% co-dominant pathologies

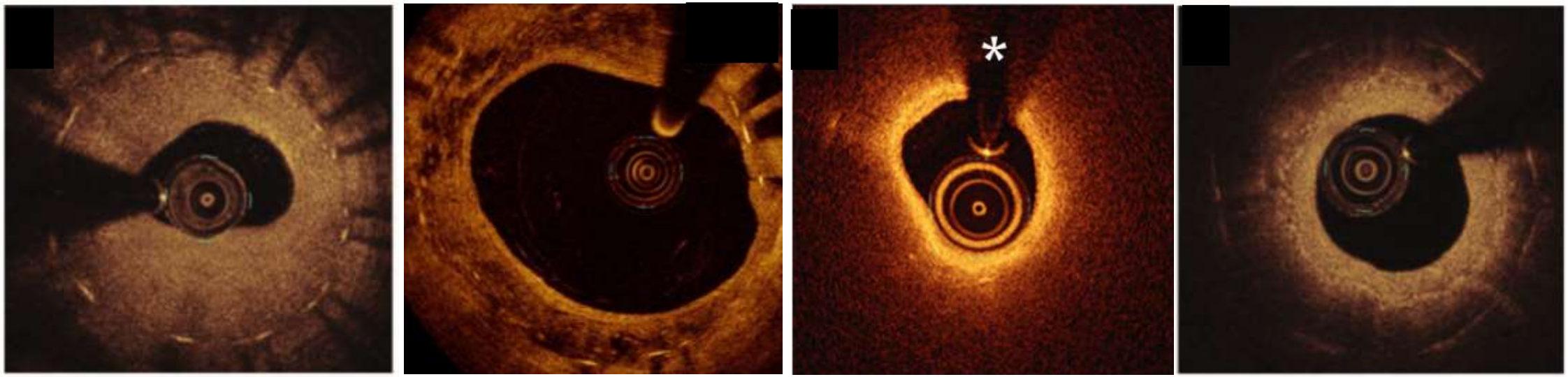
- **Type I Mechanical**
  - Underexpansion (IA)
  - Stent fracture (IB)
- **Type II Biologic**
  - Neointimal Hyperplasia (IIA)
  - Neoatherosclrosis w/o calcification (IIB)
  - Neoatherosclrosis with calcification (IIC)
- **Type III Mixed**
  - Mixed mechanical and biological
- **Type IV CTO**
- **Type V > 2 layers of DES**

OCT should be the first option!

- **Treatment strategy**
- **Potential complications**
- **Prognosis**

Shlofmitz E, et al. Circ Cardiovasc Interv. 2019;12:e007023

Four OCT tissue pattern

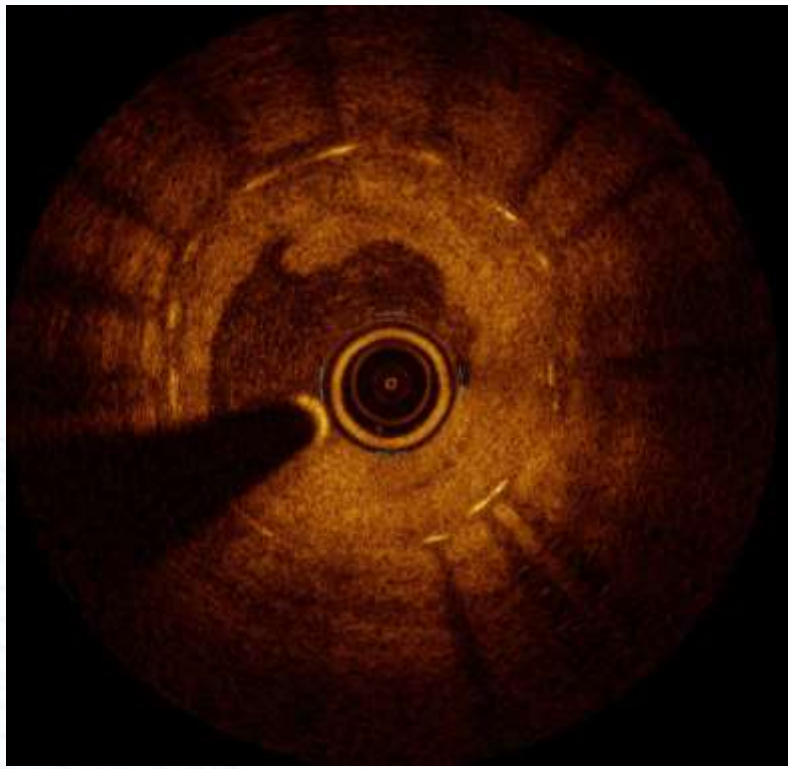


Homogeneous	Heterogeneous	Attenuated	Layered
uniform high signal intensity, low back-scatter, typical of areas of high smooth muscle cell content	mixed signal intensity, may represent presence of proteoglycan-rich neointimal or early neoatherosclerotic plaque	superficial high signal intensity, high back-scatter, likely indicative of lipid-core plaque	superficial high signal intensity with deep low signal intensity often in peri-strut areas

Kilickesmez K, et al. Int J Cardiol Heart Vessel. 2014 Mar 19;3:68-74;
Tada T, et al. Eur Heart J – Cardiovasc Imaging (2014) 15, 307–315; Alfonso F, et al. EuroIntervention 2022;18:e103-e123

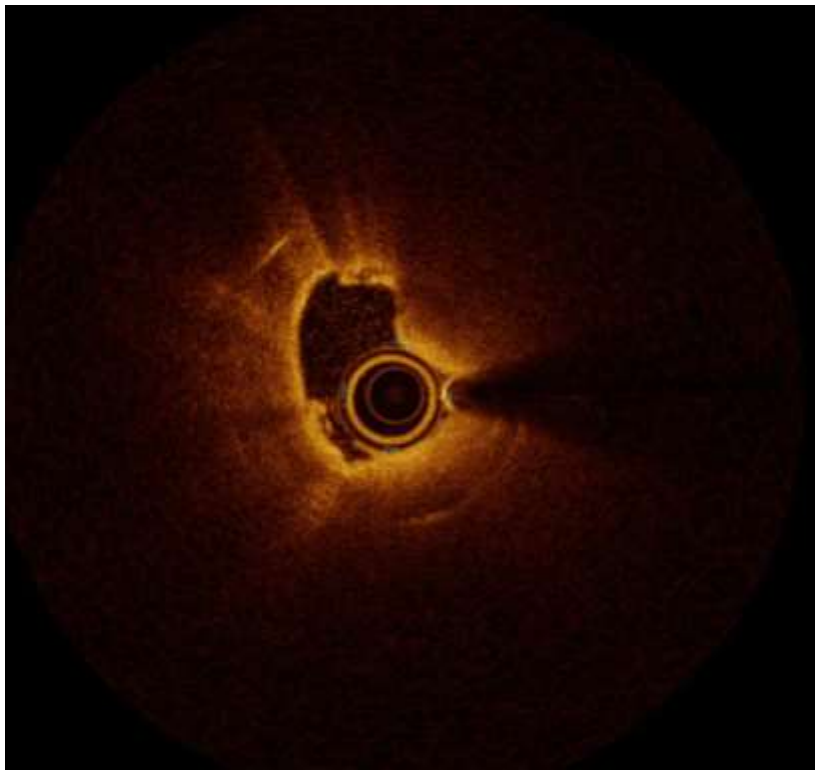
Waksman Classification: ISR Type II

Neointimal hyperplasia (IIA)



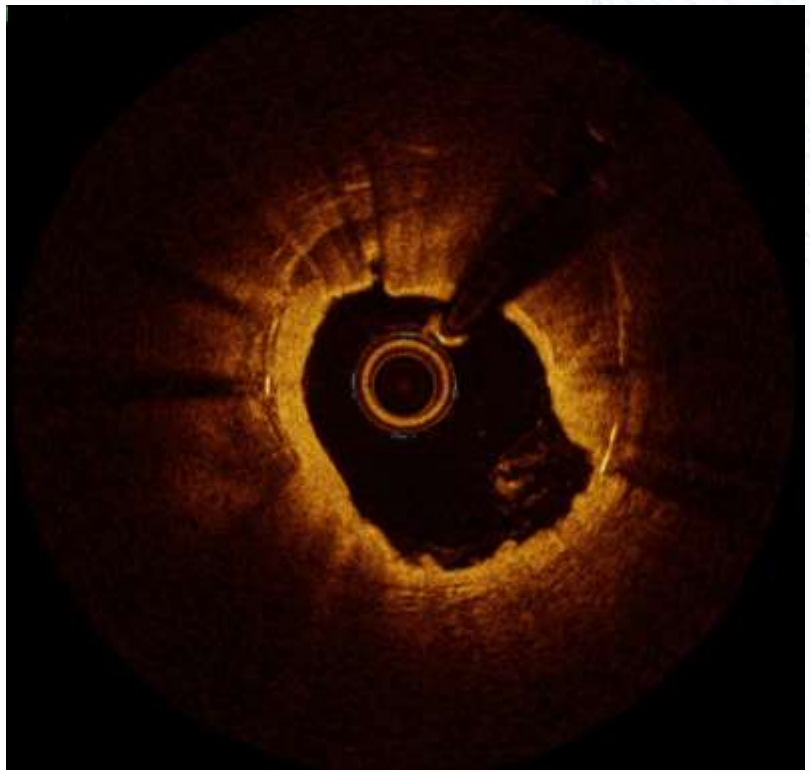
Female 55 YO, present with unstable angina 6 months after two DES implantation from mid to distal LAD

Neoatherosclerosis without calcification (IIB)



Male 57 YO, present with NSTEMI. History of DES implantation at LCX since 2008 and active smoker.

Neoatherosclerosis with calcification (IIC)



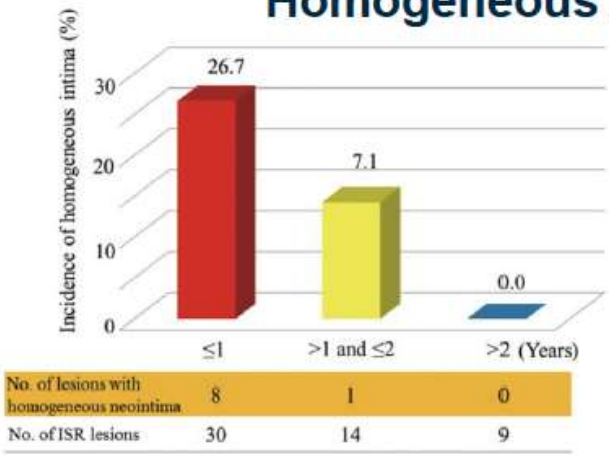
Male 66 YO, present with chest pain on exertion 1 month PTA. History of DES implantation at LAD since 2007

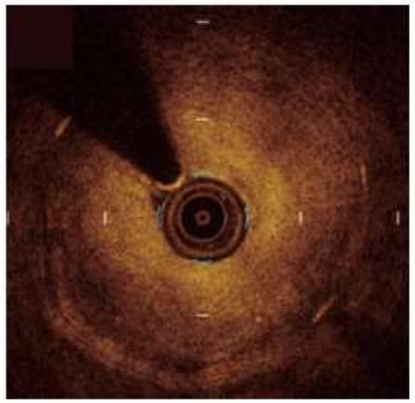
Difference of Tissue Characteristics Between Early and Late Restenosis After 2nd-Gen DES Implantation

- Neointimal tissue characteristics differed between early-ISR and late-ISR after second-generation DES implantation.
- early-ISR was mainly caused by neointimal hyperplasia,

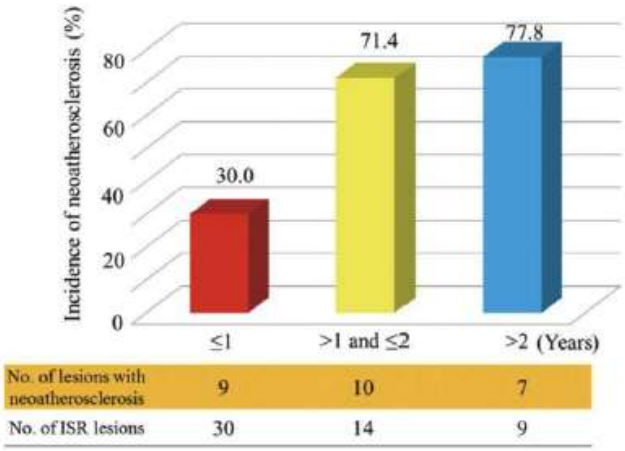
  whereas
- neoatherosclerosis was the main mechanism of late-ISR.

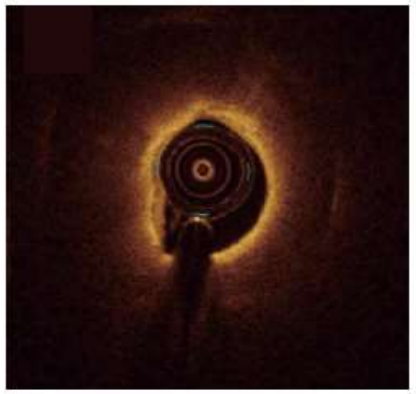
Homogeneous intima





Neoatherosclerosis





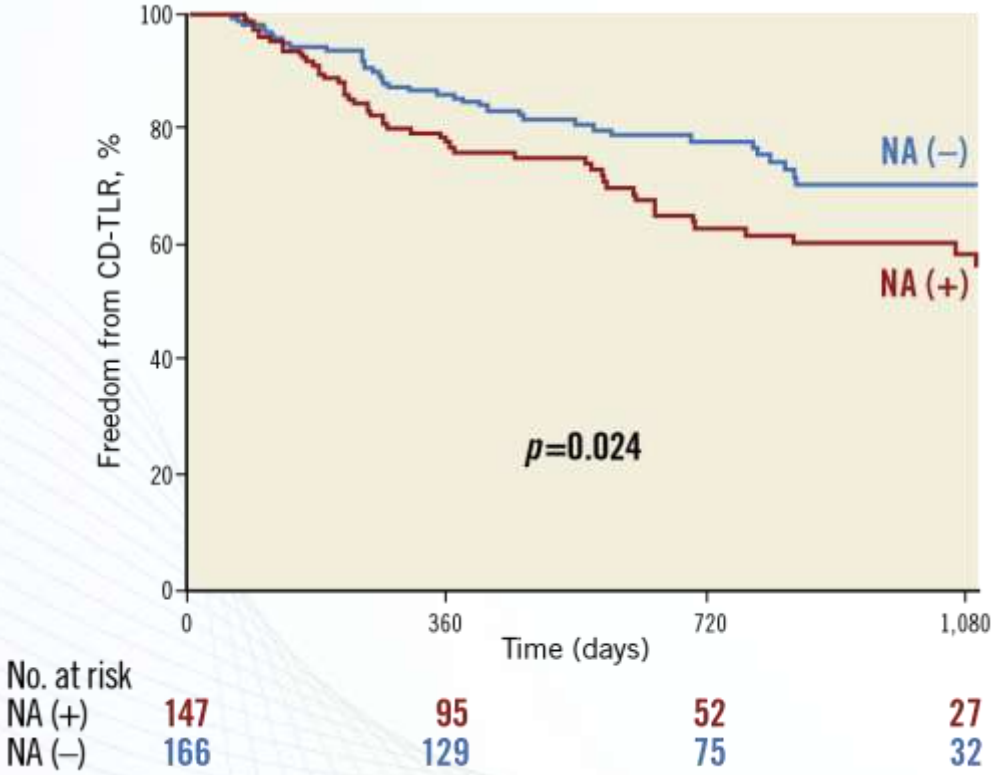
OCT analysis between early in-stent restenosis (E-ISR; within the first year) and late ISR (L-ISR; beyond the first year) at the MLA segment

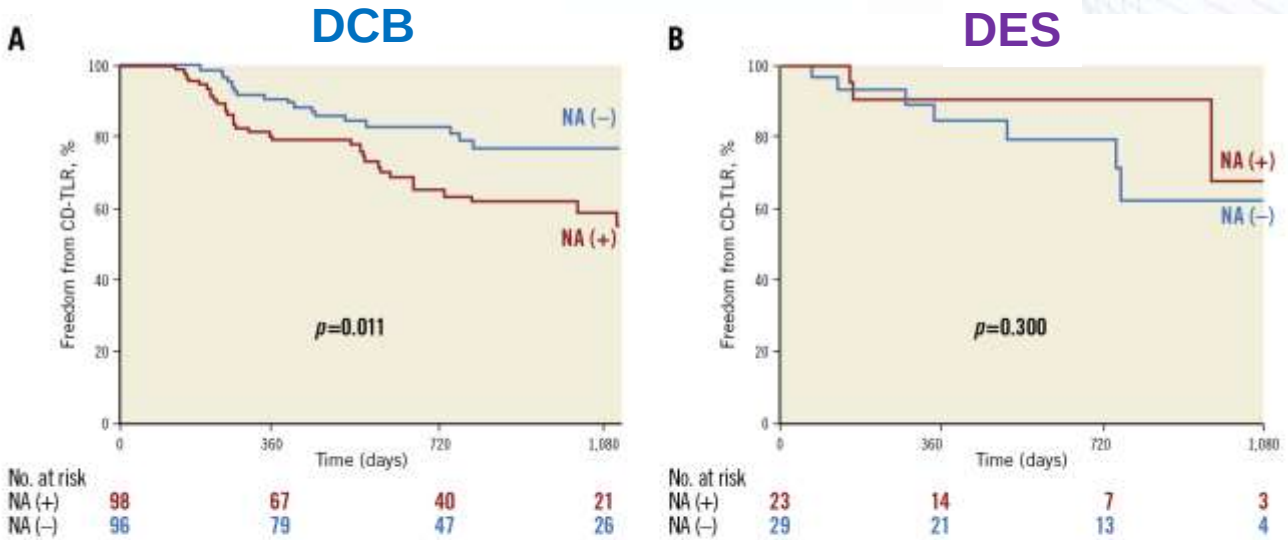
	E-ISR (n=30)	L-ISR (n=23)	P value
Quantitative analysis			
Lumen area, mm²	1.5±1.0	1.3±0.7	0.65
Stent area, mm²	5.7±2.1	5.4±1.7	0.86
NIH area, mm²	4.2±2.1	4.1±1.7	0.89
Qualitative analysis			
Homogeneous intima	8 (26.7)	1 (4.4)	0.02
Heterogeneous intima	13 (43.3)	6 (26.1)	0.19
Lipid-laden	9 (30.0)	16 (69.6)	<0.01
Neoatherosclerosis	9 (30.0)	17 (73.9)	<0.01
TCFA-like pattern	0 (0.0)	6 (26.1)	<0.01
Intimal disruption	1 (3.3)	1 (4.4)	0.85
Calcification	0 (0.0)	0 (0.0)	NE
Macrophage infiltration	1 (3.3)	6 (26.1)	0.01
Neovascularization	2 (6.7)	6 (26.1)	0.049
Thrombus	3 (10.0)	2 (8.7)	0.87
Thrombus with shadow	3 (10.0)	0 (0.0)	0.06
Thrombus without shadow	0 (0.0)	2 (8.7)	0.06

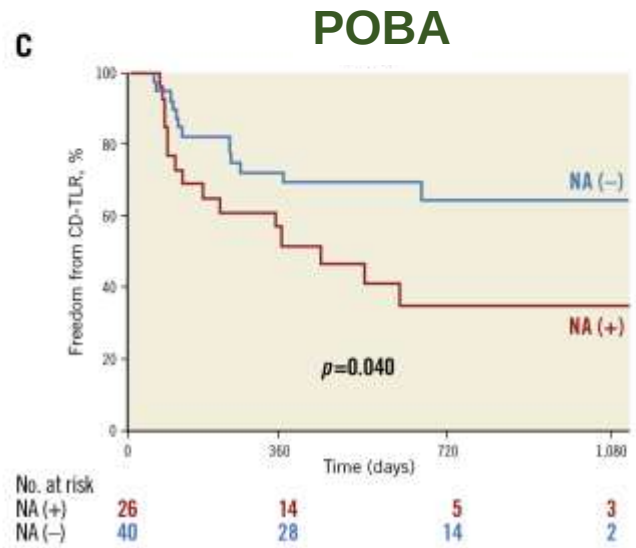
Jinnouchi H, et al. Circ J. 2017 Mar 24;81(4):450-457

Neoatherosclerosis in ISR lesions was the predictor of clinically driven target lesion revascularization (CD-TLR)

- 313 ISR lesions in 311 patients were enrolled.
- The primary outcome was clinically driven target lesion revascularisation (CD-TLR). CD-TLR was defined as any revascularisation procedure of the target lesion in the presence of angiographic restenosis and signs or symptoms of ischaemia

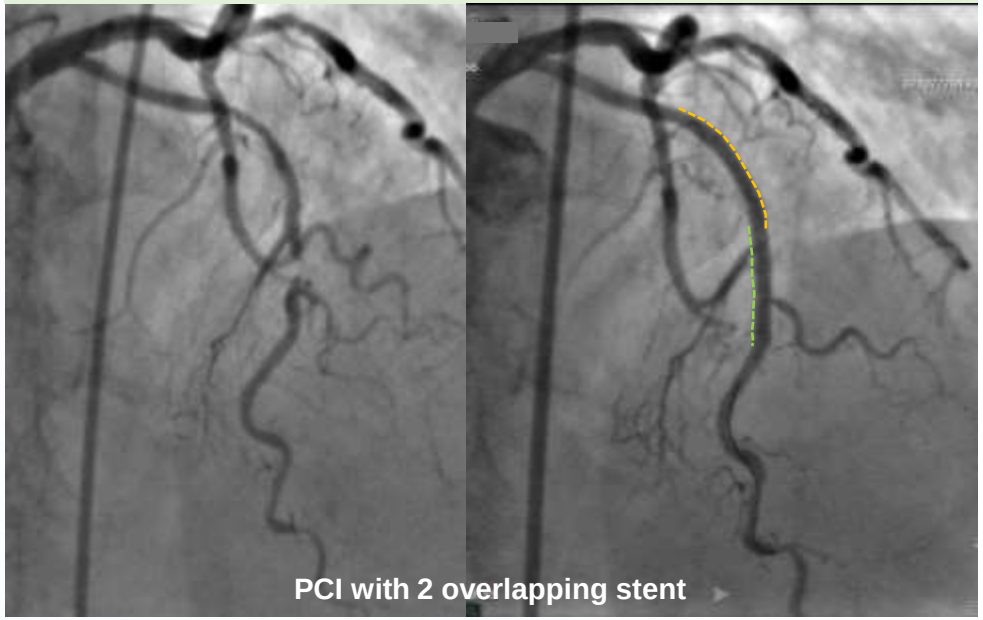




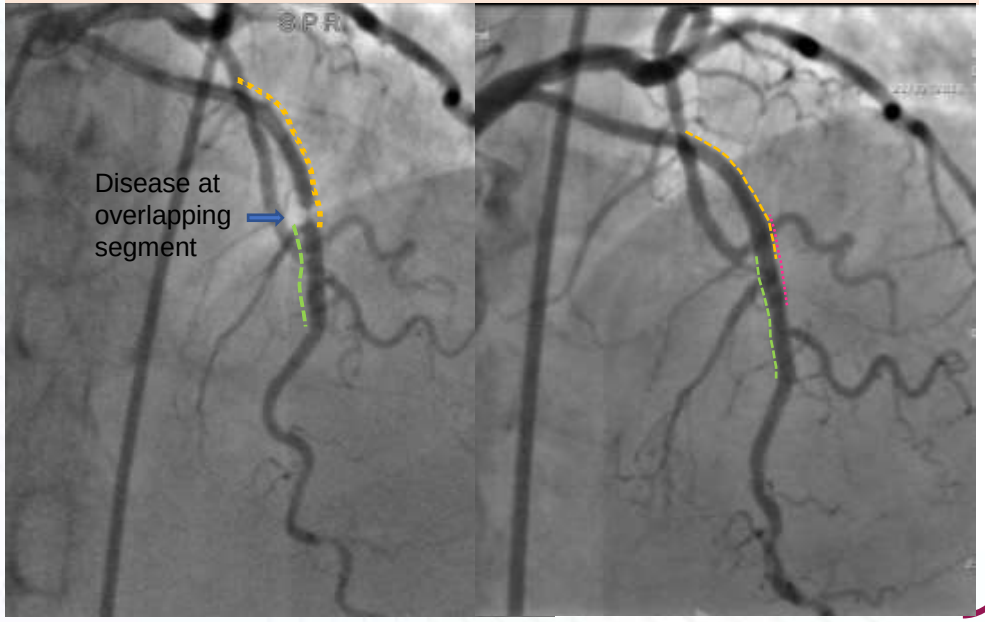


Nakamura D, et al. EuroIntervention 2021;17:489-496

NSTEMI July 2018



NSTEMI December 2018

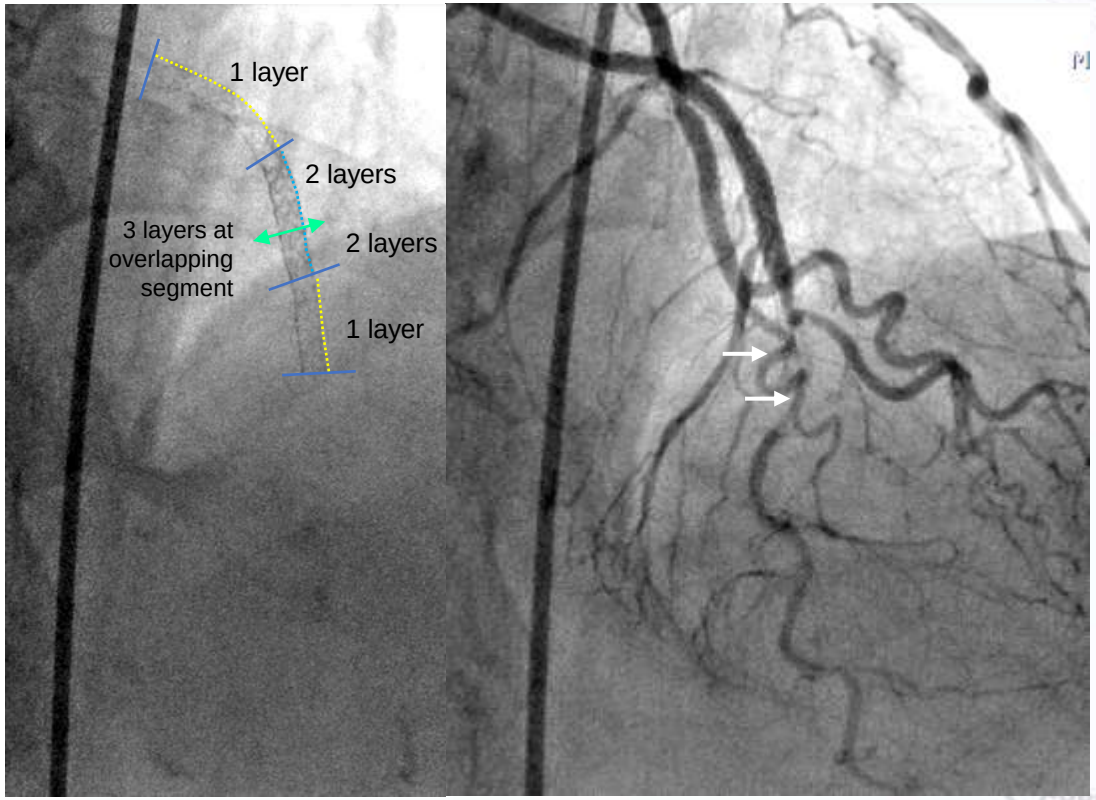


Angio-guided PCI !!

Mrs. O, 62 YO, Type 2 DM, dyslipidemia

- **NSTEMI Jul 2018:**
  - EES 2.5x15 mm overlapping EES 2.5x28 mm
- **NSTEMI Dec 2018:** focal ISR → BES 2.75x14 mm
- **Unstable angina Sep 2019**

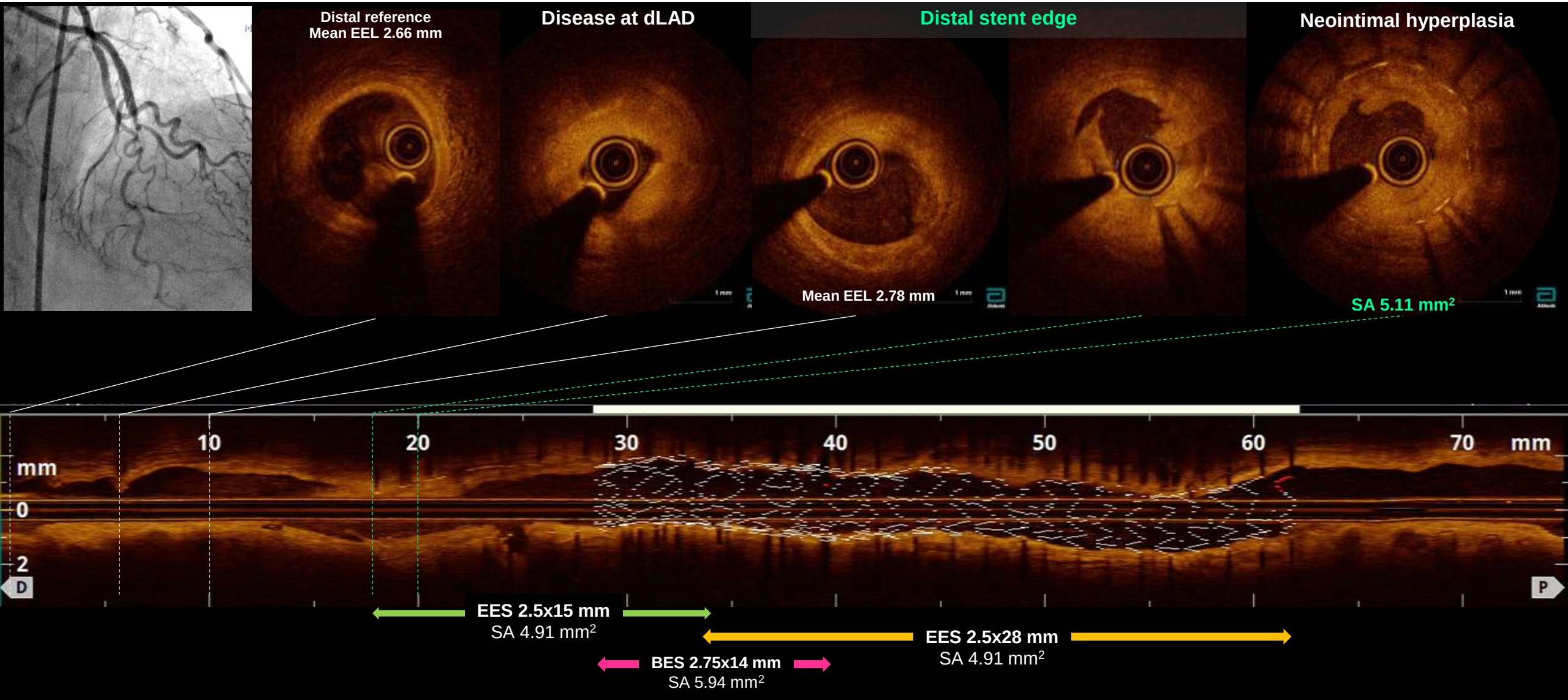
Unstable angina September 2019



OW

Causes of ISR from OCT: Type III Mixed

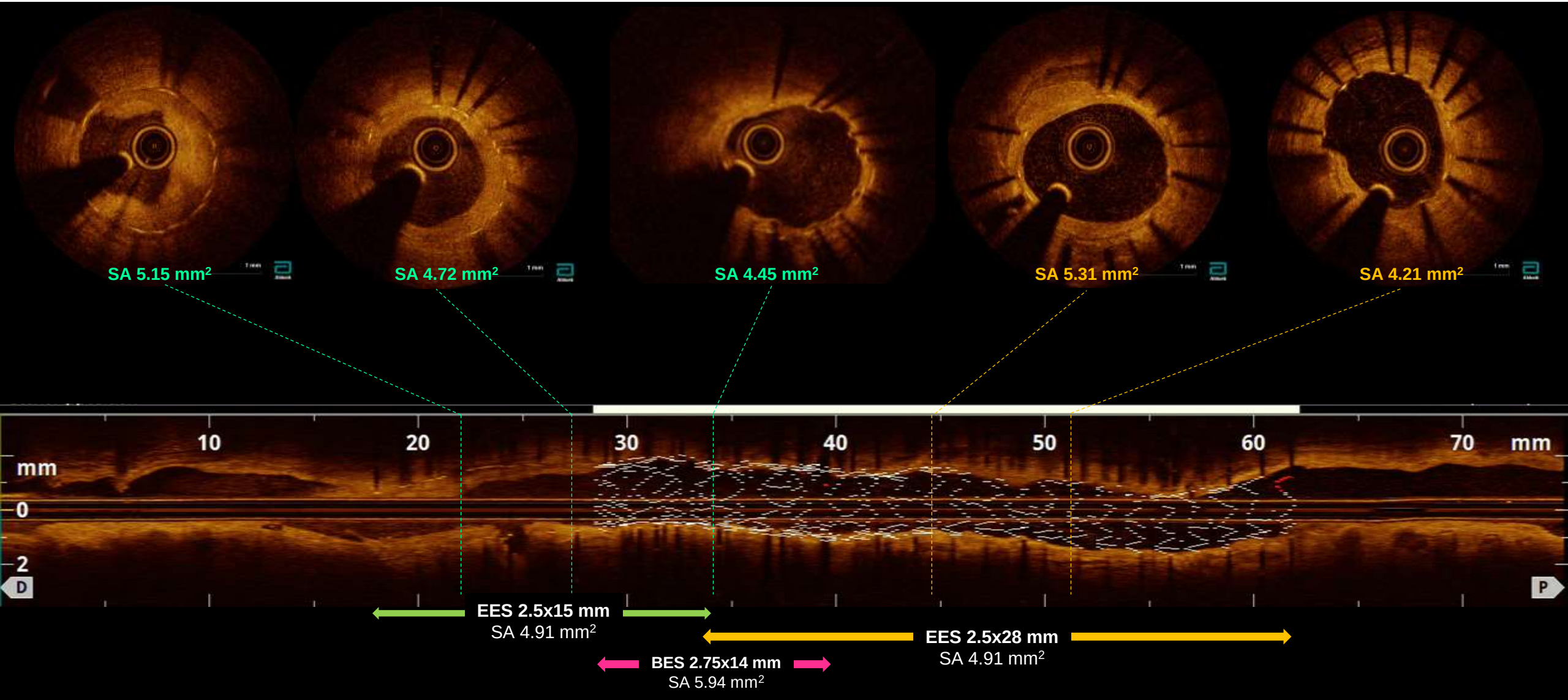
Geographical missed, edge of stent landed at disease segment
Neointimal hyperplasia (IIA)



OW

Causes of ISR from OCT: Type III Mixed

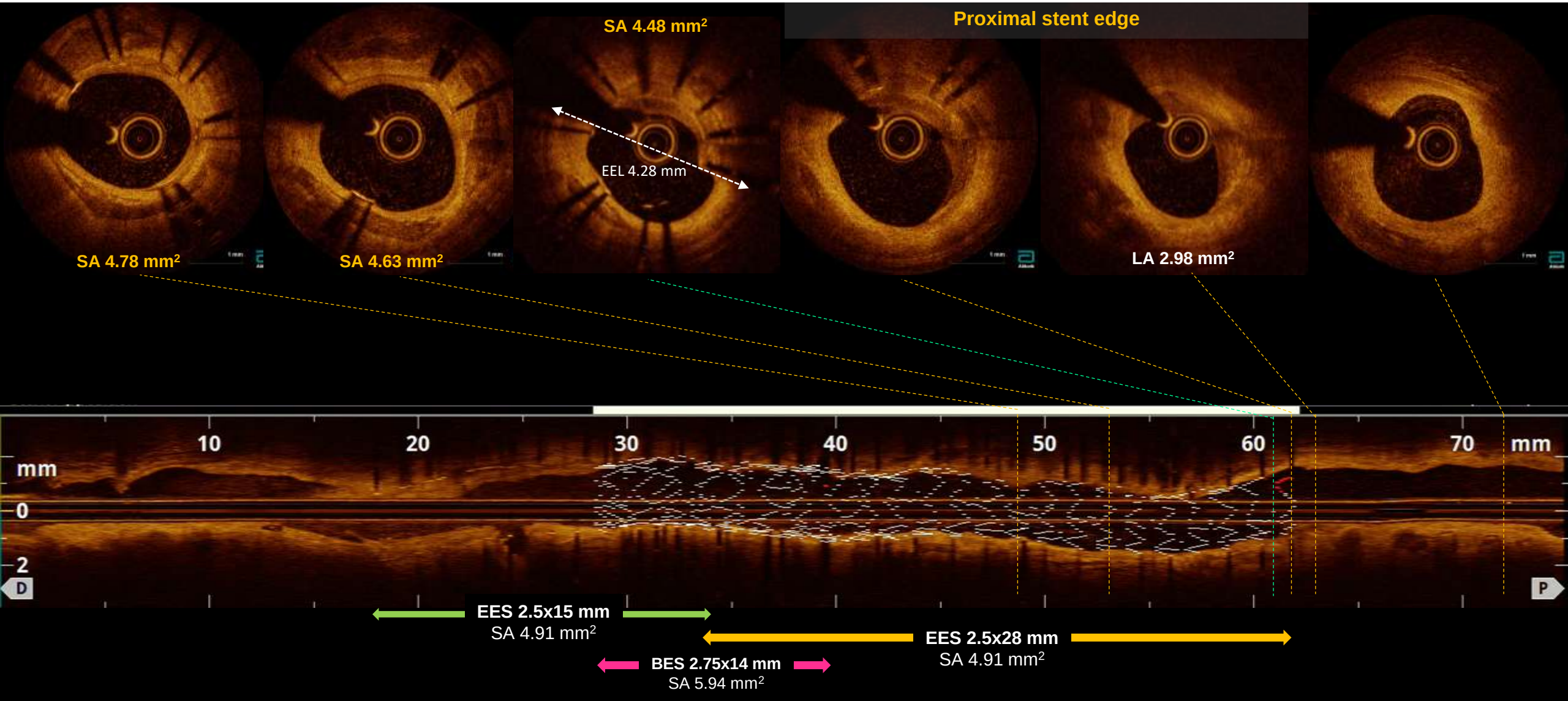
Neointimal hyperplasia (IIA): homogenous



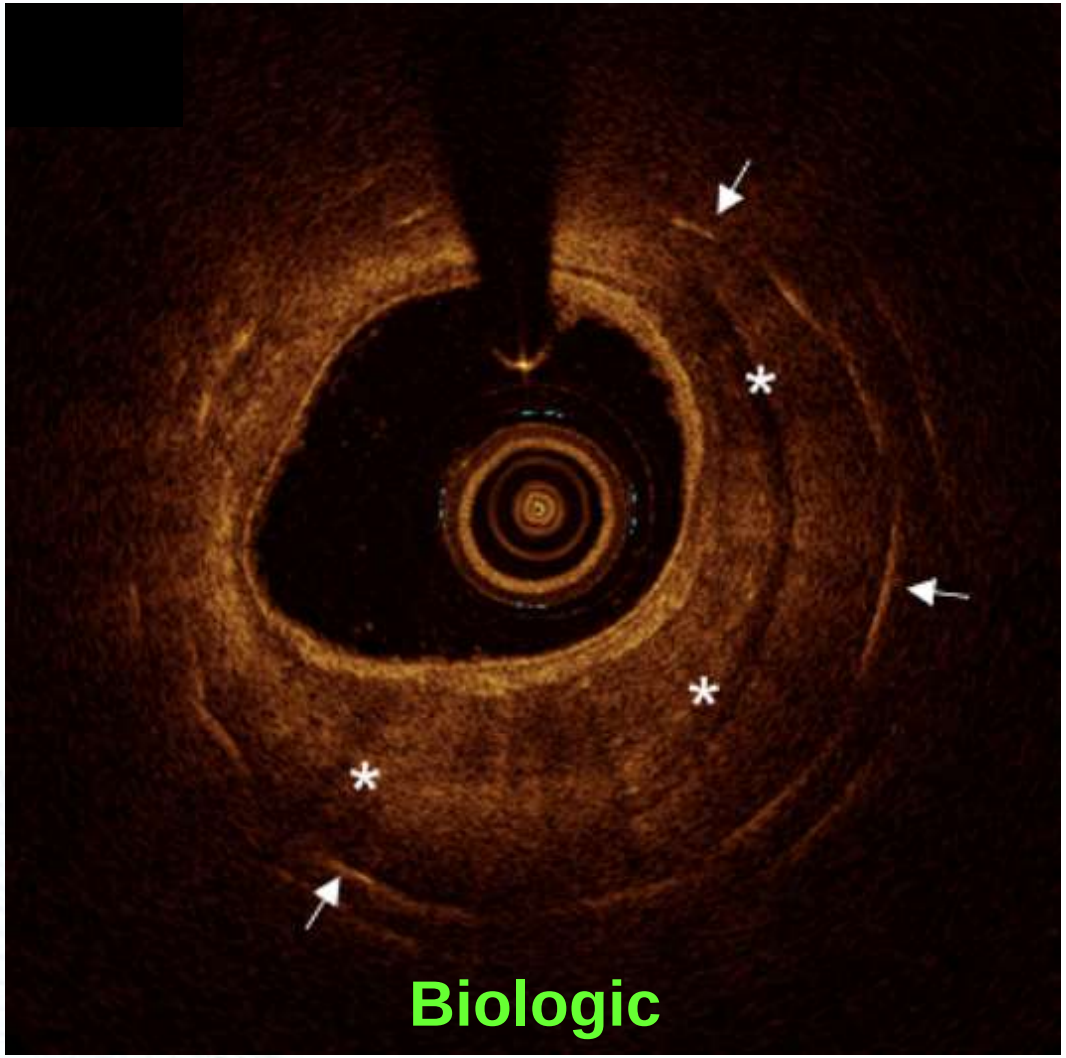
OW

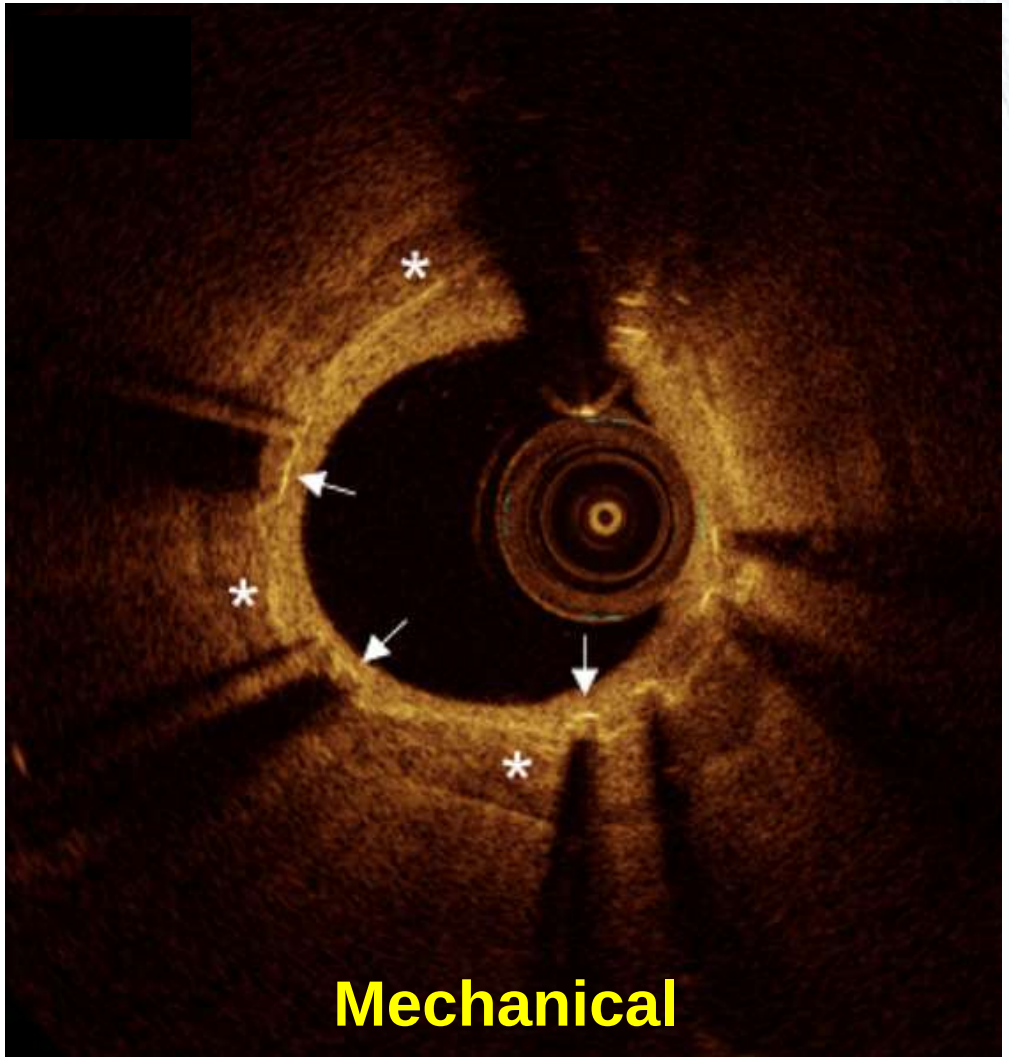
Other findings

Stent undersizing, Neointimal hyperplasia (IIA): heterogenous



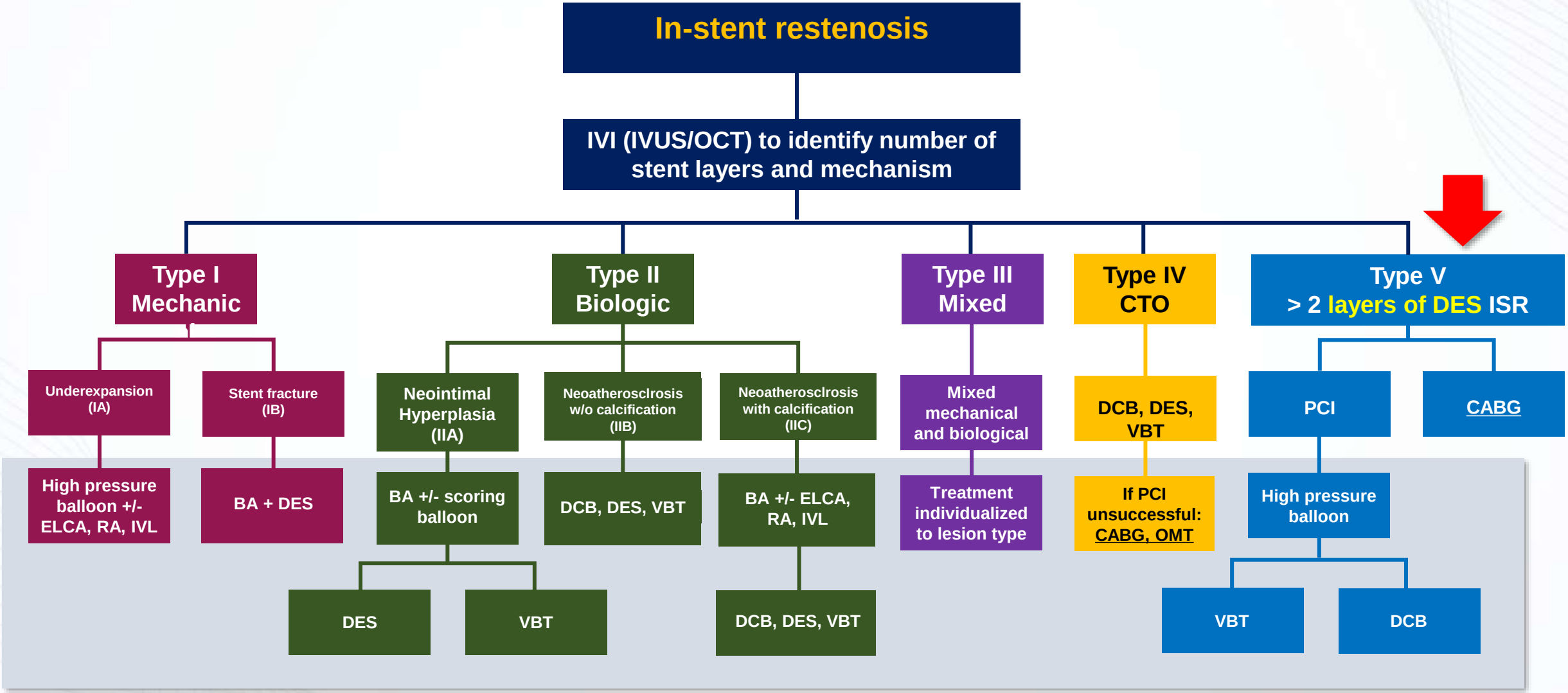
Neoatherosclerosis with calcification vs. Stent underexpansion from calcified plaque





Yin D, et al. EuroIntervention. 2019 Aug 13 [Epub ahead of print]

Application of IVI for the treatment of ISR



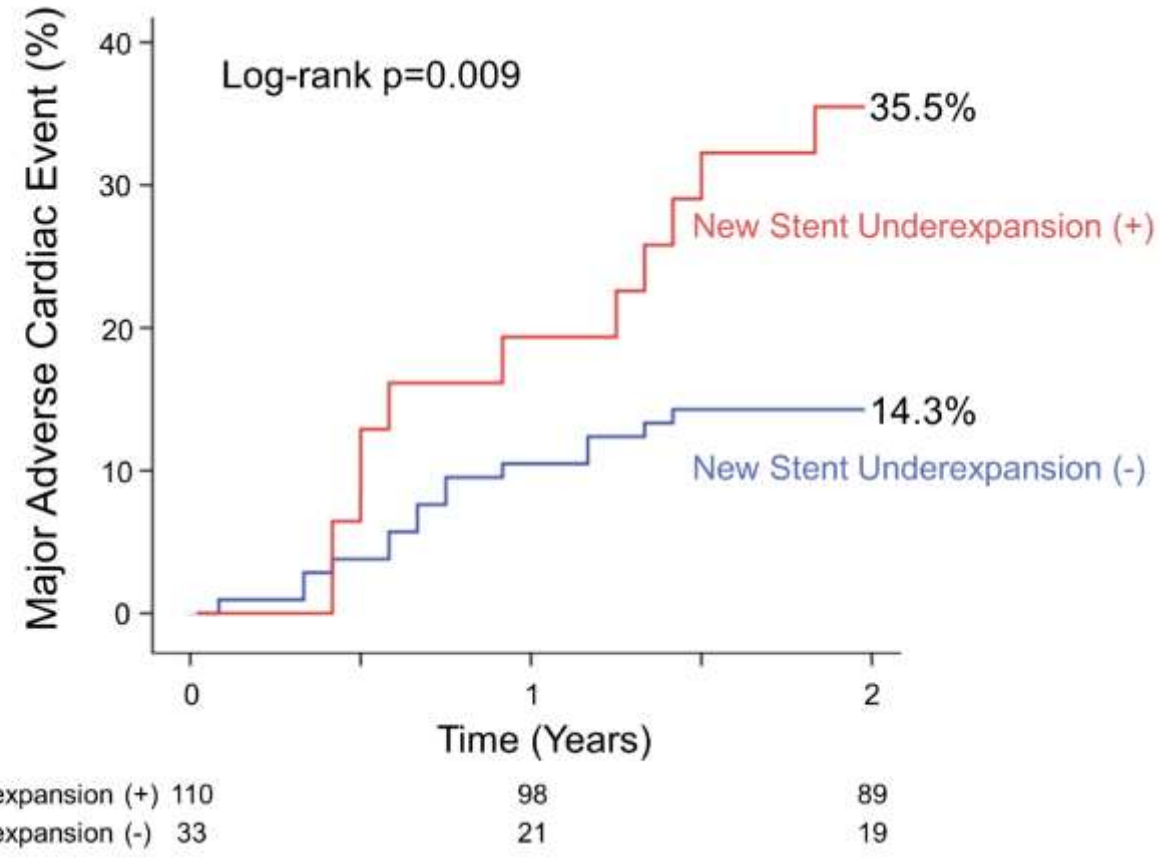
Shlofmitz E, et al. Circ Cardiovasc Interv. 2019;12:e007023

Prognostic value of stent expansion and neointima morphology

New stent underexpansion was defined as MSA <4.5mm^2 and MSA/average of reference lumen area <70%.

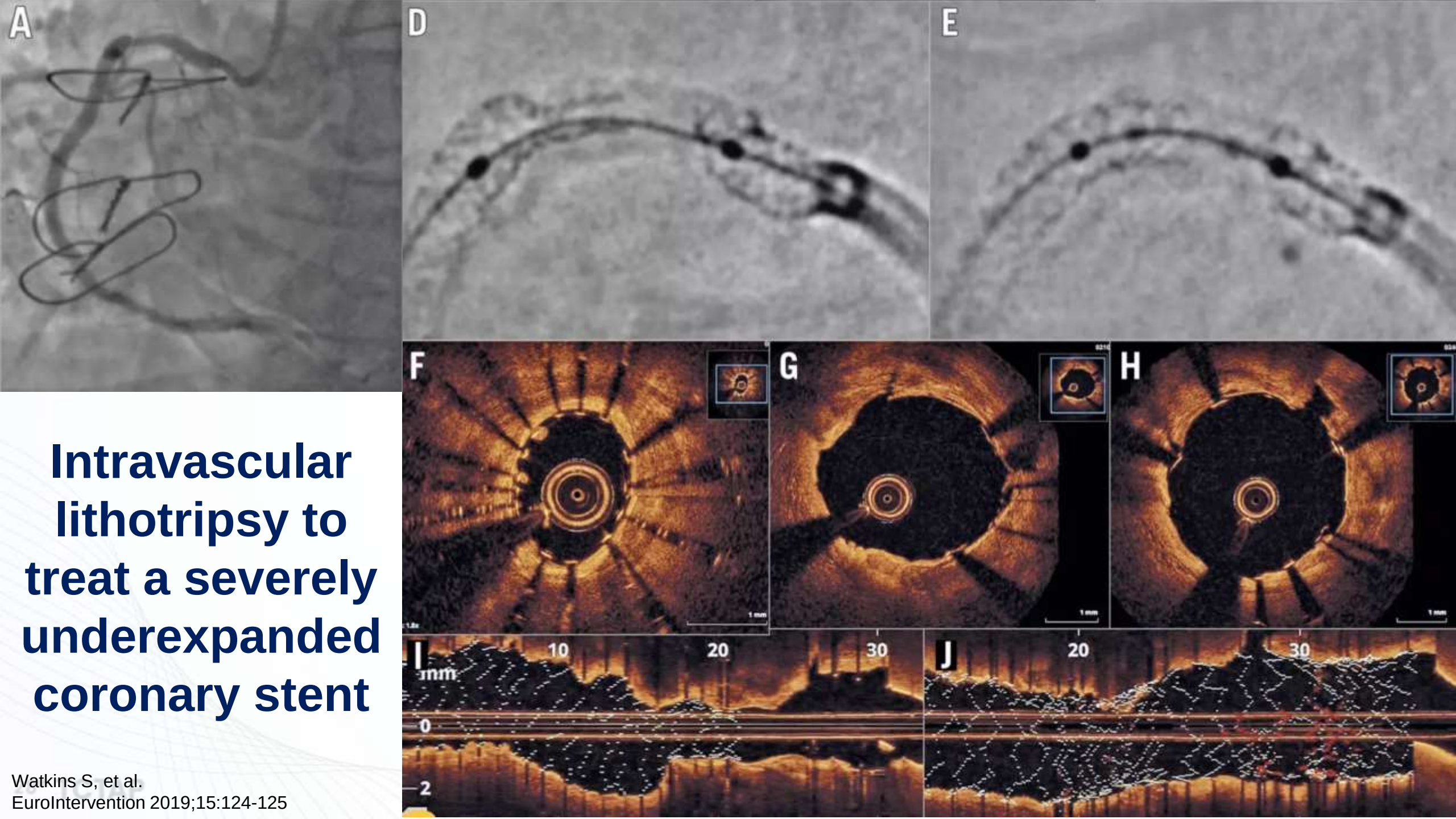
- **Old stent underexpansion**
- **multiple layers of old stent**
- **maximum calcium angle >180°**
- **maximum calcium thickness >0.5 mm**

independently associated with new stent underexpansion



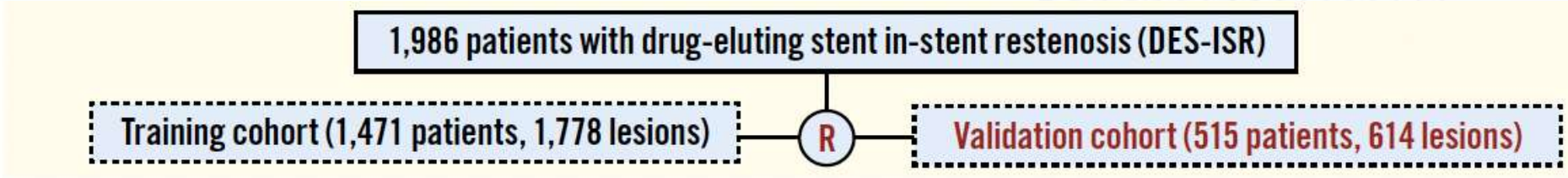
Yin D, et al. EuroIntervention. 2019 Aug 13 [Epub ahead of print]

Intravascular lithotripsy to treat a severely underexpanded coronary stent

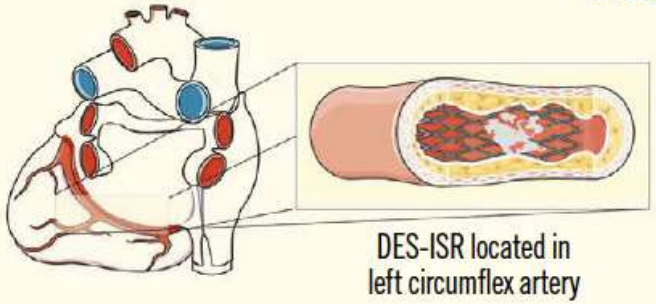


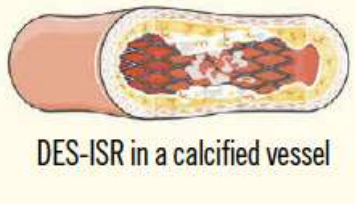
Watkins S, et al.
EuroIntervention 2019;15:124-125

ISAR score to predict the risk of repeat PCI for recurrent DES-ISR



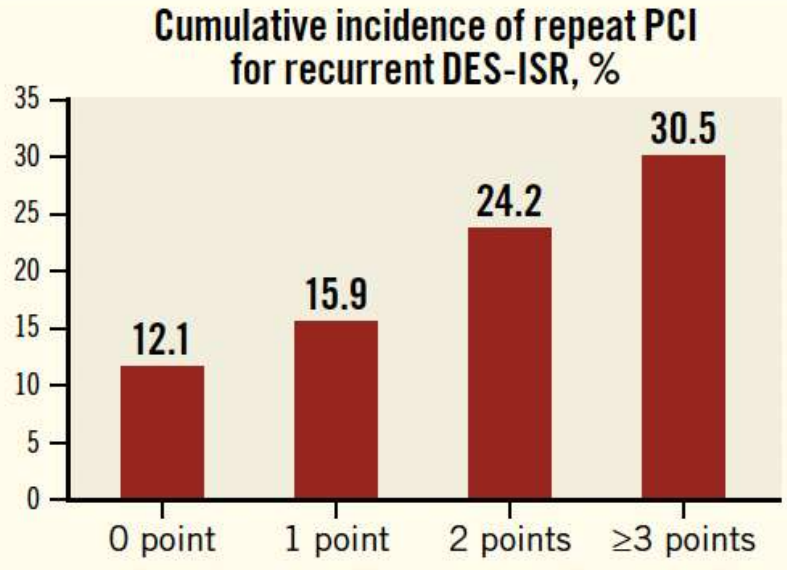
4 independent predictors of recurrent DES-ISR





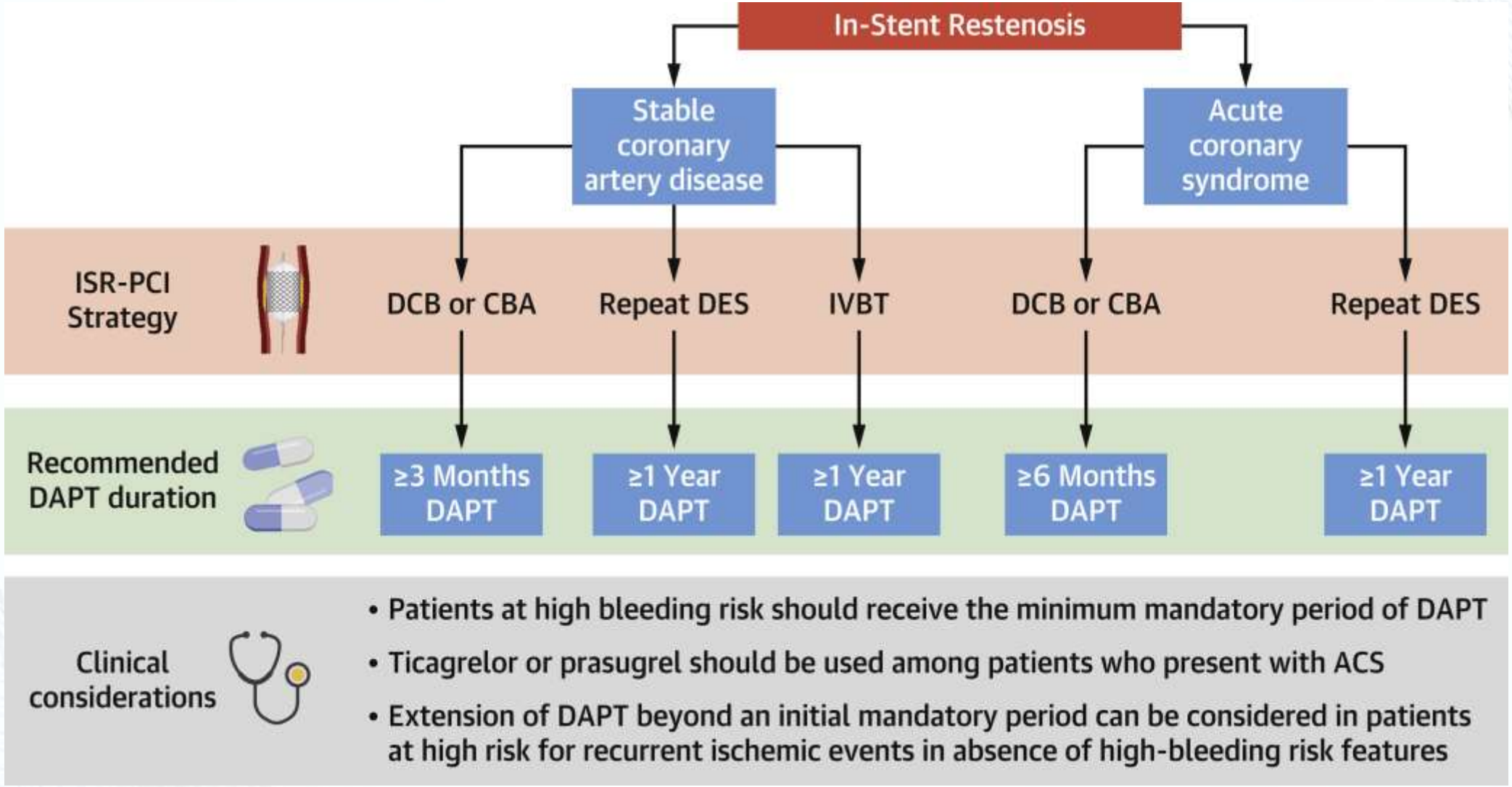
(Angiographic-based)

In left circumflex artery	+1 point
Stenosis morphology, non-focal	+1 point
Arterial calcification	+1 point
Restenosis interval <6 months	+1 point
ISAR score	/4 points



Coughlan J., et al. EuroIntervention 2023;18:e1328-e1338

Proposed Antithrombotic Treatment After PCI for ISR



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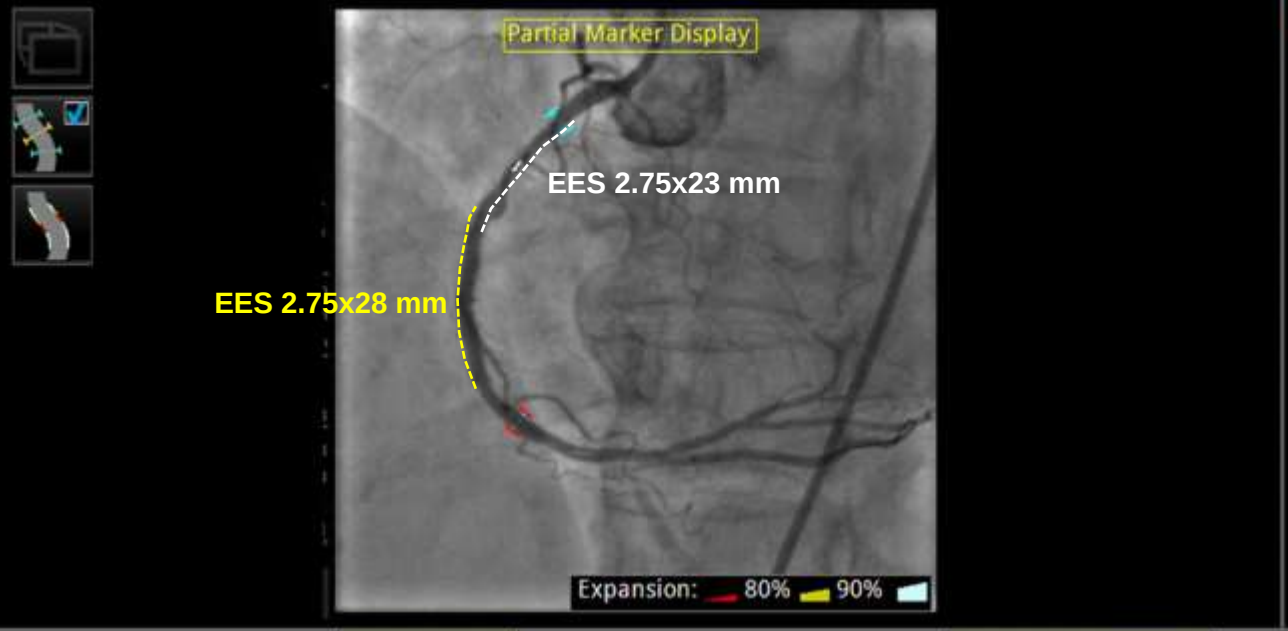
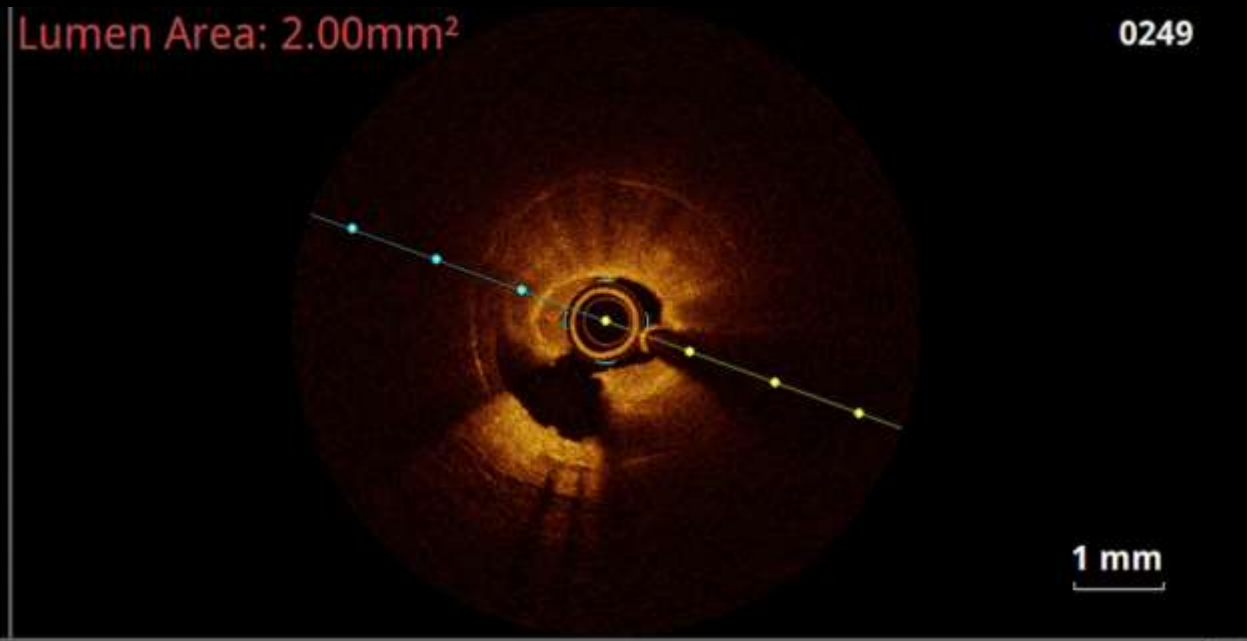
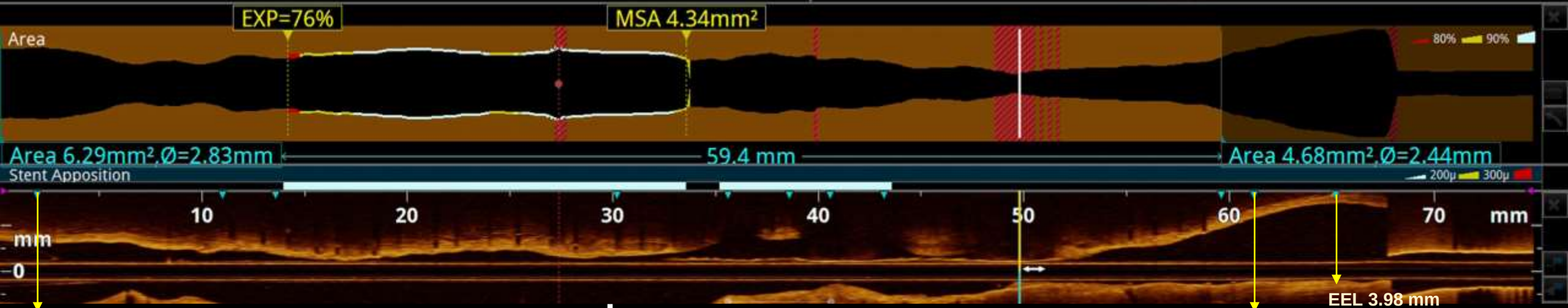
How intracoronary imaging help on decision making?

Female 86 YO, present with NSTEMI.
History of PCI to prox-mid RCA with EES 2.75x28 mm overlapping with EES 2.75x23 mm since 2008







Mean EEL 3.38 mm

Stent area 6.69 mm²

Stent area 6.86 mm²

5 mm overlapping segment

EEL 3.56 mm

EEL 3.98 mm

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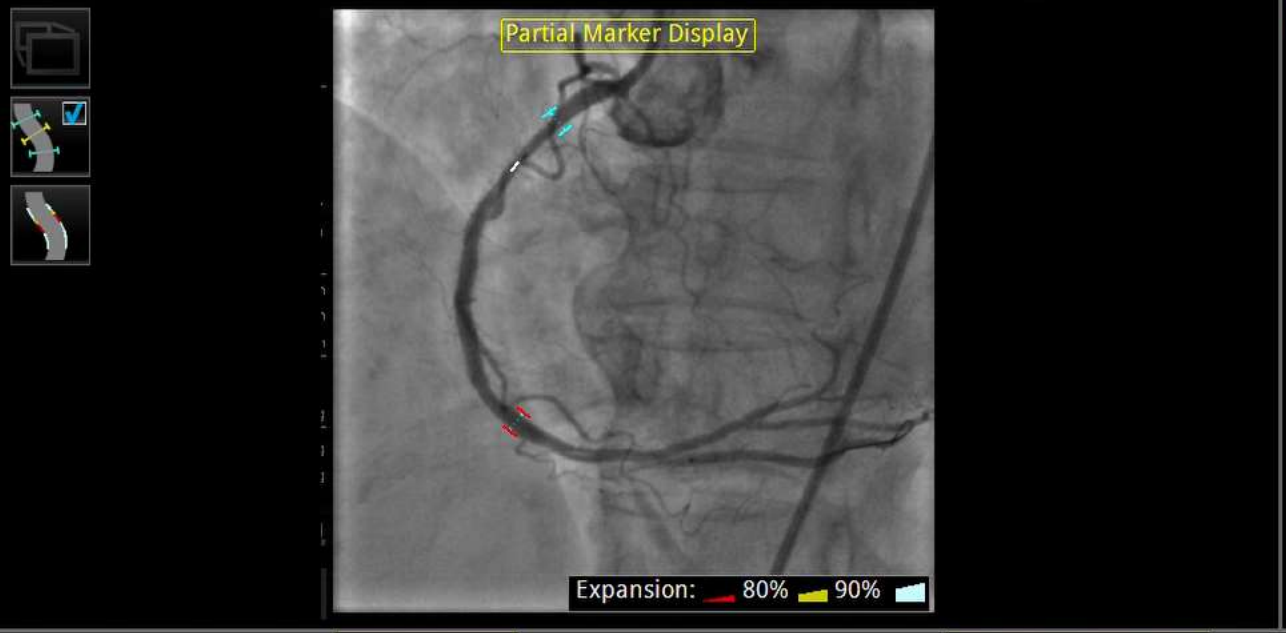

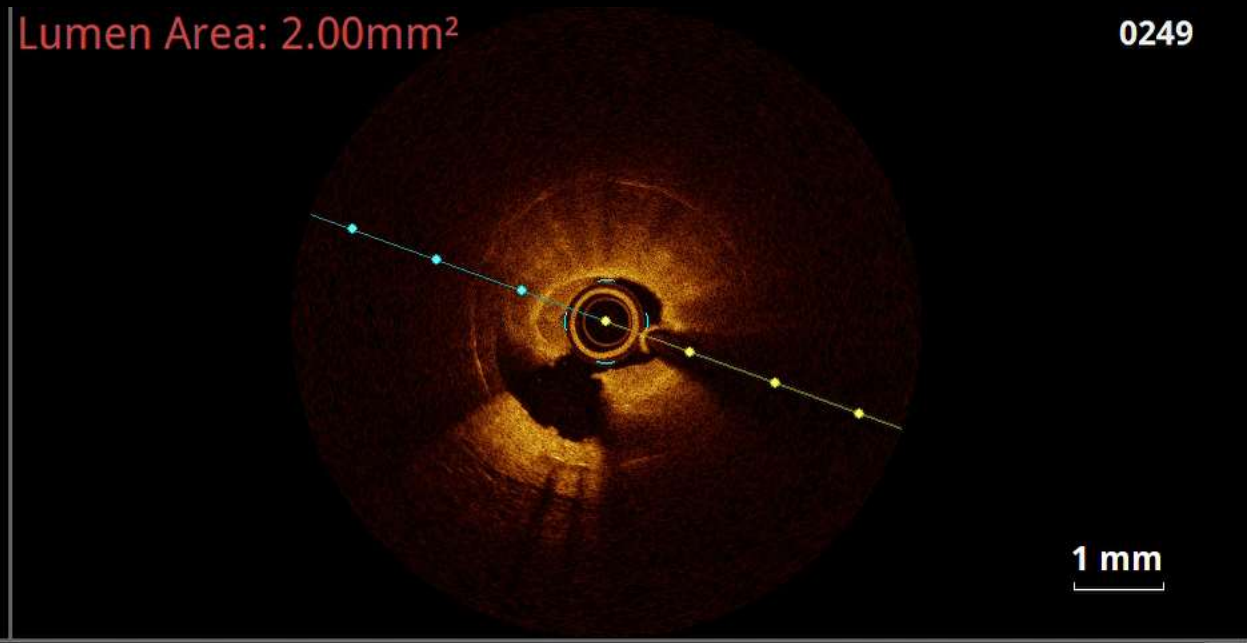

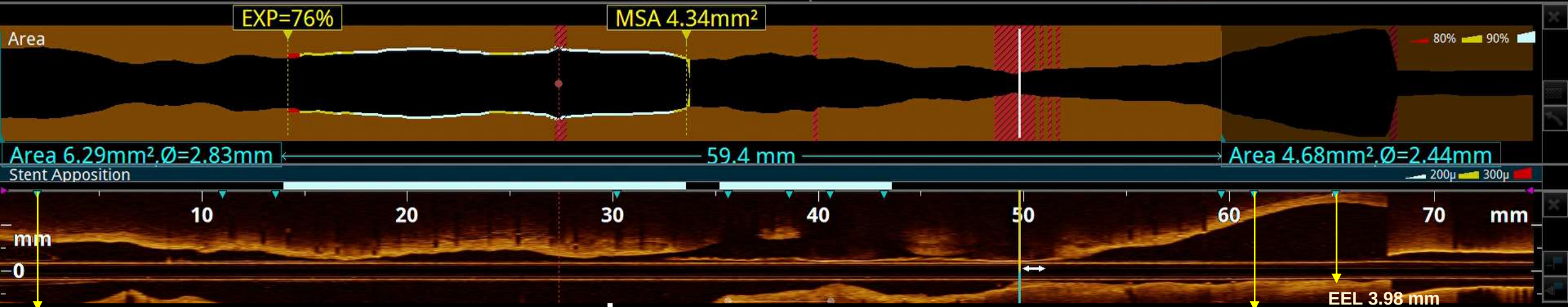

Mean EEL 3.38 mm

Stent area 6.69 mm²

Cage with calcified plaque
Stent area 6.86 mm²

5 mm overlapping segment

EEL 3.56 mm

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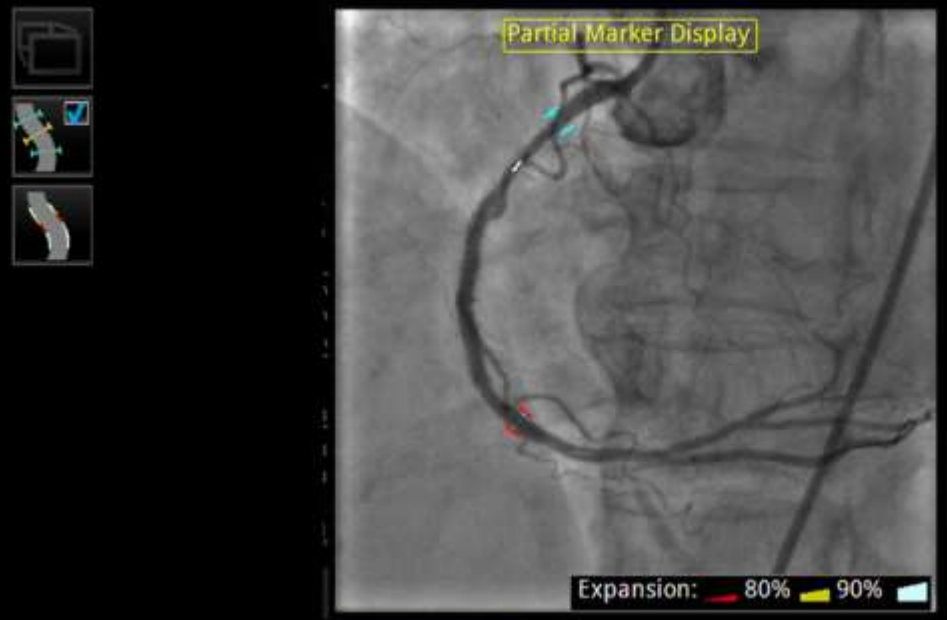
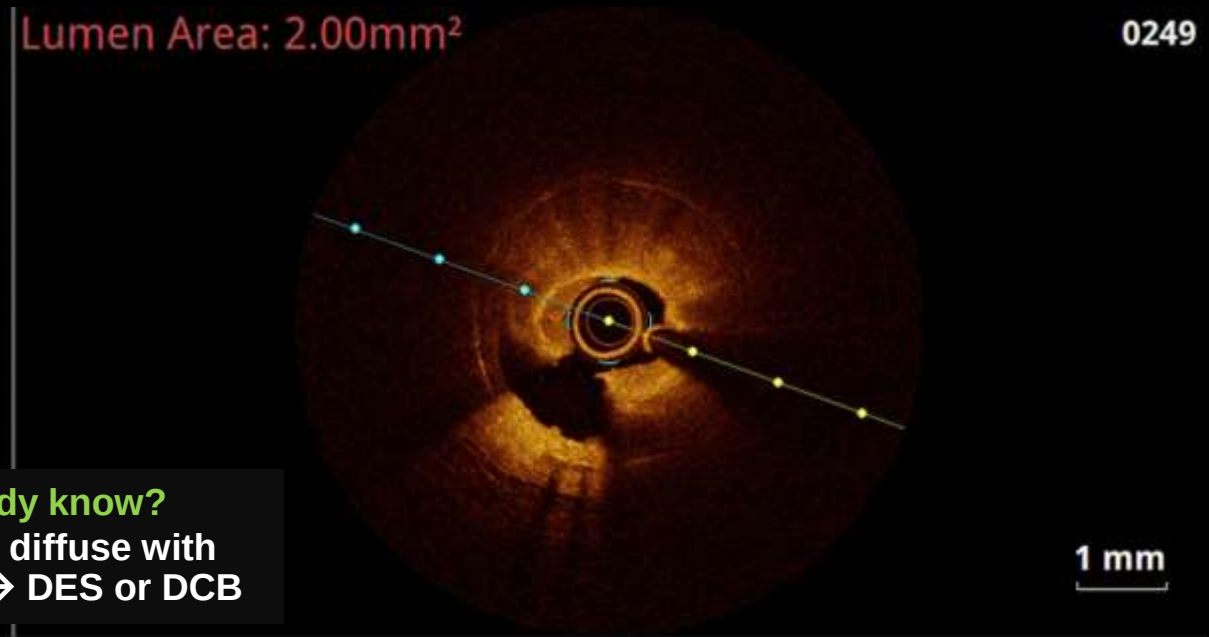
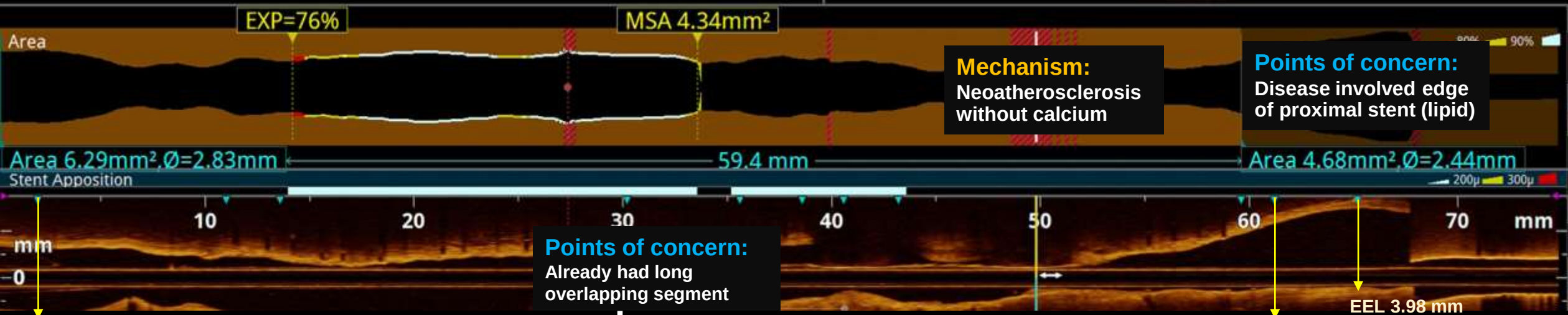




What we already know?

- 1-layer ISR diffuse with edge-ISR → DES or DCB



Mechanism:
Neoatherosclerosis without calcium

Points of concern:
Disease involved edge of proximal stent (lipid)

Points of concern:
Already had long overlapping segment

Mean EEL 3.38 mm

Stent area 6.69 mm²

Stent area 6.86 mm²

5 mm overlapping segment

EEL 3.56 mm

EEL 3.98 mm

Factors Favoring the Use of Drug-Coated Balloons vs DES Implantation in ISR

Favors Drug-Coated Balloon	Favors Repeated DES
• ISR with less aggressive pattern of ISR (eg, focal) with good lumen expansion after balloon dilatation	• ISR with more aggressive pattern of ISR (eg, diffuse or occlusive) at high risk of recurrence
• ISR of BMS	• ISR of DES
• Multilayer ISR	• Single-layer ISR
• Patients at high bleeding risk who cannot tolerate DAPT	• Presence of a stent-related mechanism (eg, stent fracture or stent gap)
• Major side branch involved to avoid jailing	• Suboptimal lumen expansion after balloon dilatation

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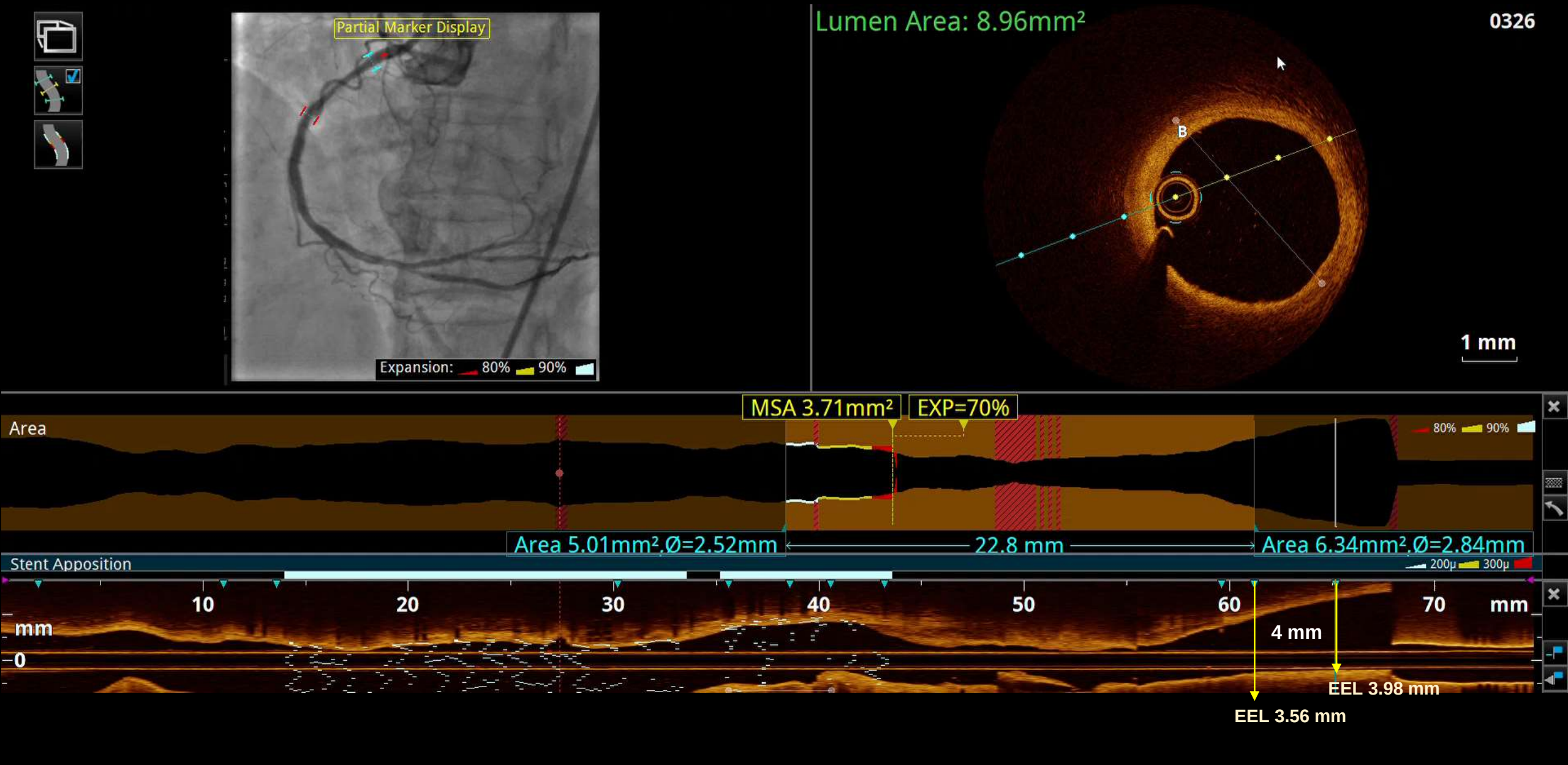
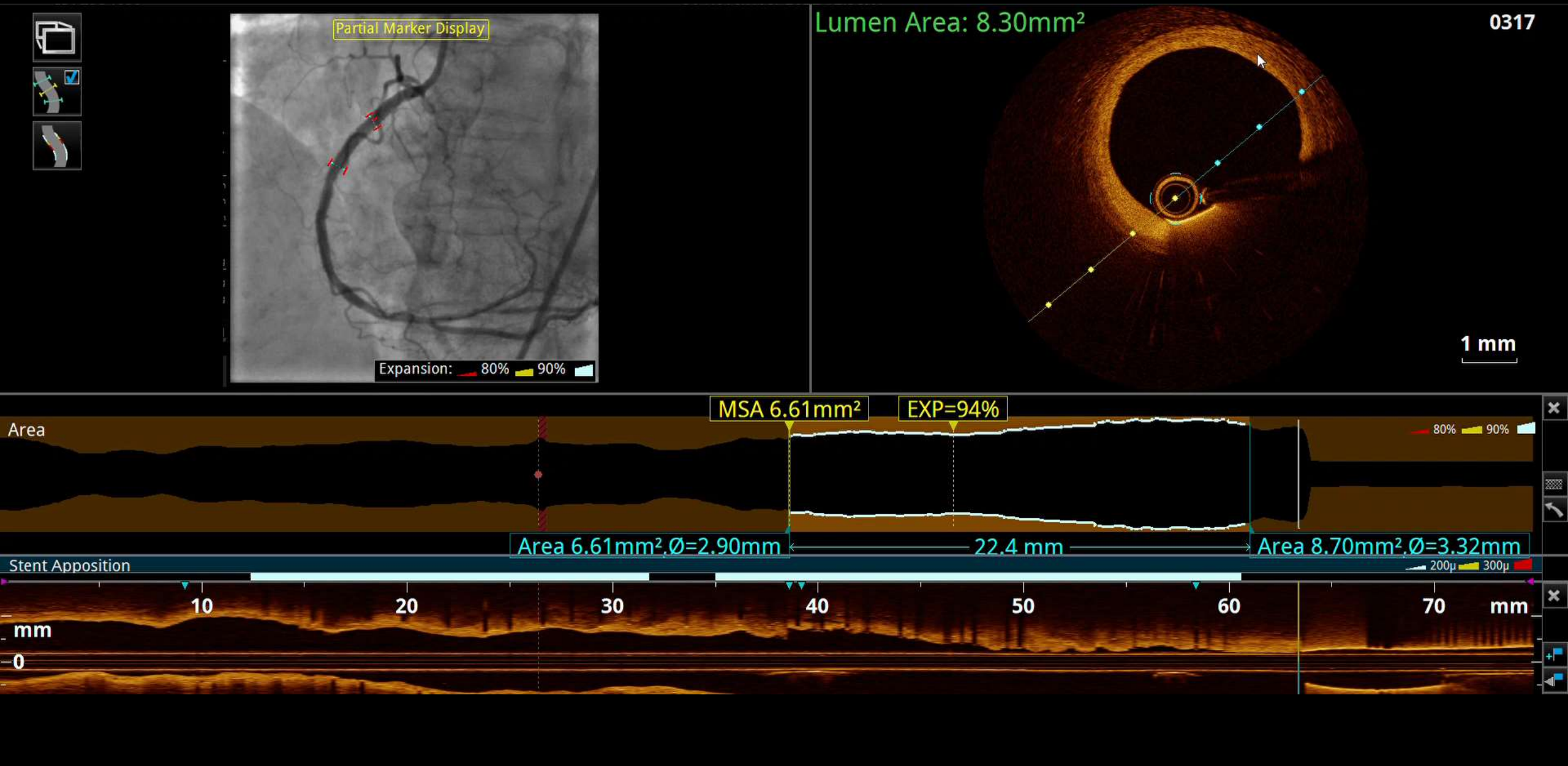
Neoatherosclerosis without calcification, disease involved proximal edge of stent.
Proximal RCA EEL 3.5-3.75 mm mid EEL 3.38 mm



Due to the presence of neoatherosclerosis with disease involve proximal edge of stent, SES 3.5x22 mm was implanted with minimal overlapped at previous overlapping segment. Post dilate with Pantera LEO 4.0x8 mm

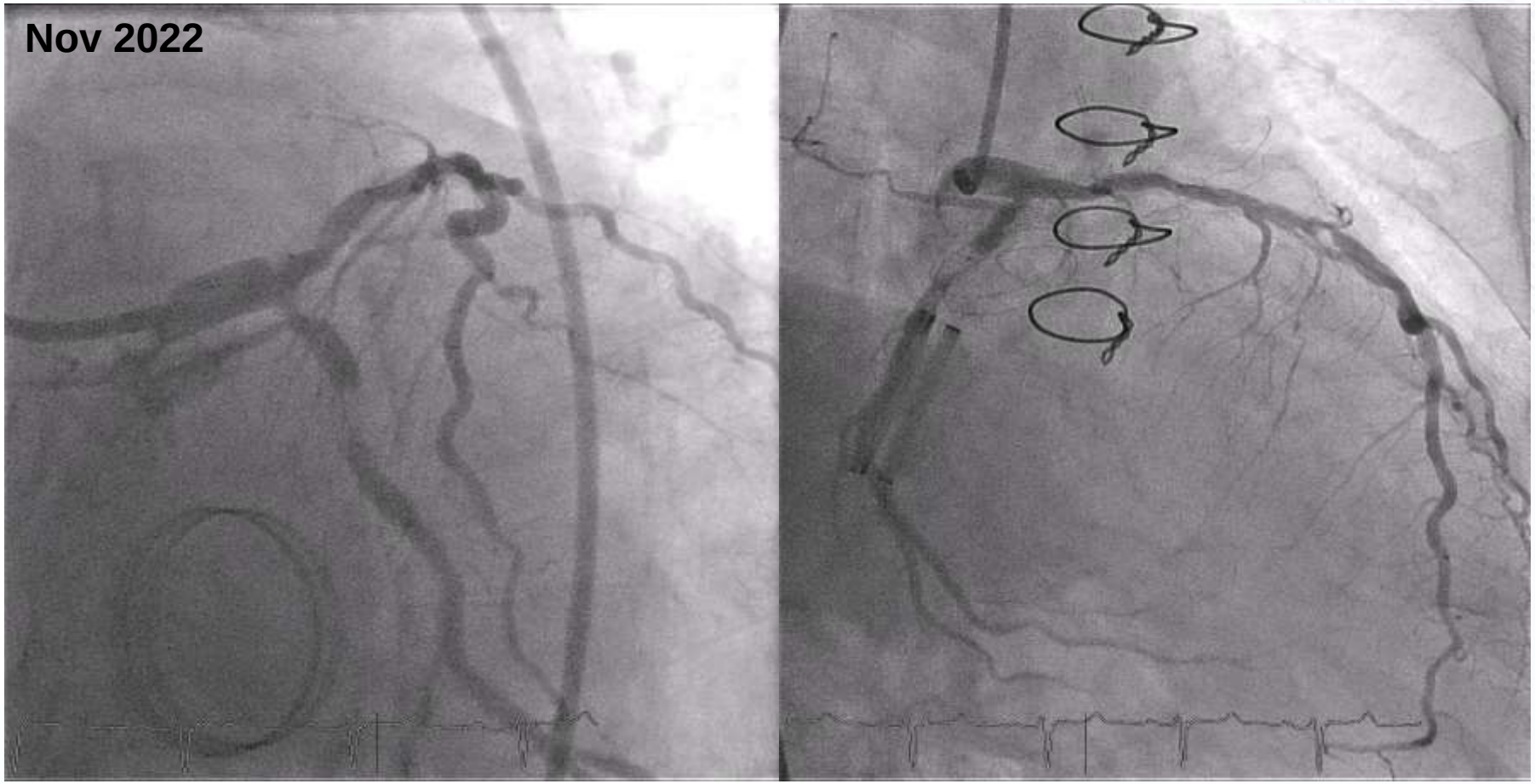


How would you treat this case?

Sternal wire or Coronary guidewire?

Male 60 YO, known case

- ESRD on HD 3 times/weeks
- RHD severe AS, severe MS S/P AVR and MVR with mechanical valve July 2020
- Atrial fibrillation
- DVD S/P CABG x1 SVG to dRCA July 2020
- Limb ischemia S/P bilat BK amputation June 2021
- Jun 2022, present with NSTEMI due to graft failure
  June 2022 S/P PCI to
  - i) Prox LCX with DES 3.0x32 mm
  - ii) SVG to RCA with DES 4.0x15 mm
  - Both lesions were treated under IVUS guidance
- Nov 2022, present with exertional angina CCS IV (5 months after previous event)

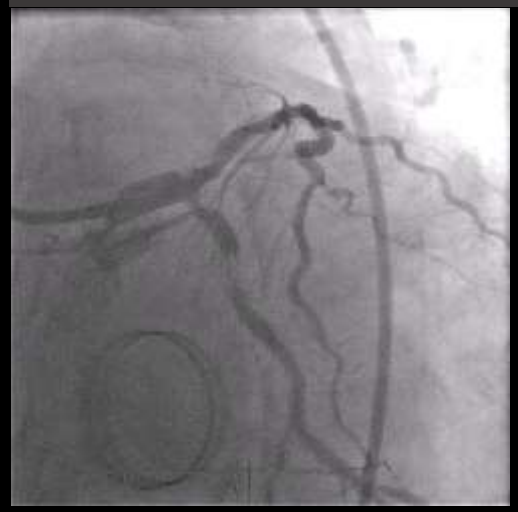


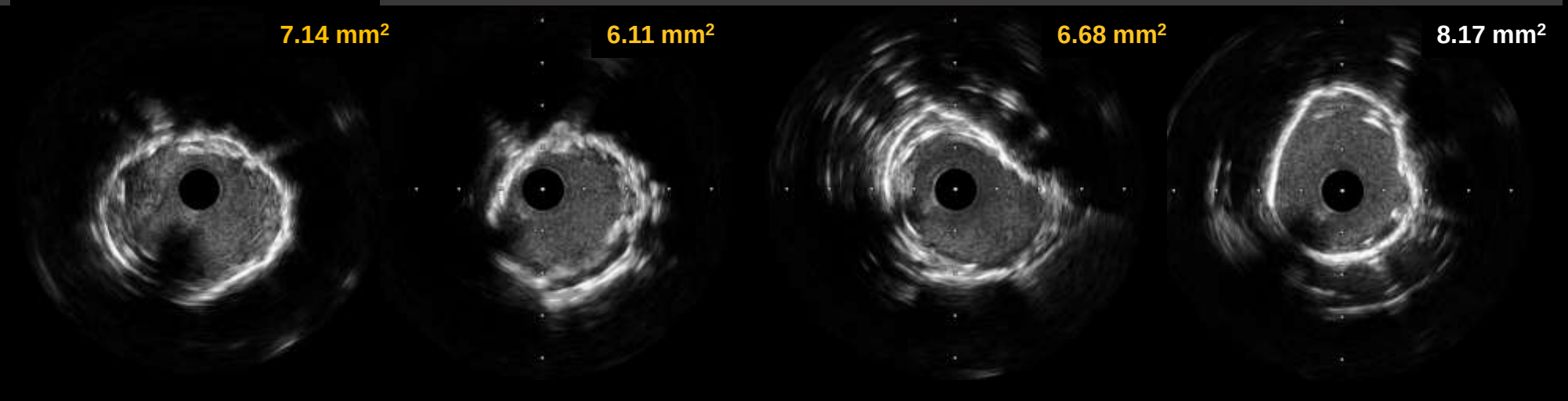
STS for isolated CAB

Risk of Mortality: 20.956%
Renal Failure: NA
Permanent Stroke: 1.315%
Prolonged Ventilation: 38.130%
DSW Infection: 0.443%
Reoperation: 23.395%
Morbidity or Mortality: 52.910%
Short Length of Stay: 6.643%
Long Length of Stay: 13.637%

Neointimal hyperplasia and Stent underexpansion

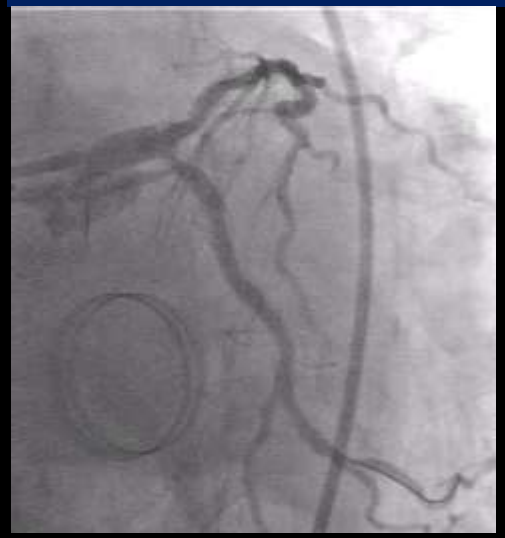
After post dilate with NC balloon 3.0x15 mm (25 atm/3.25 mm)

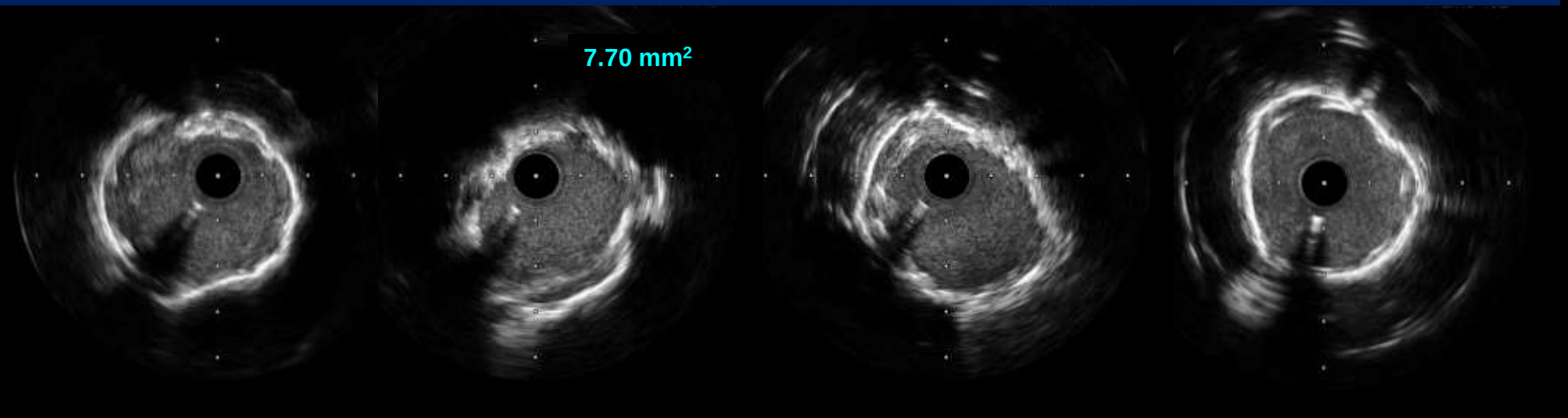




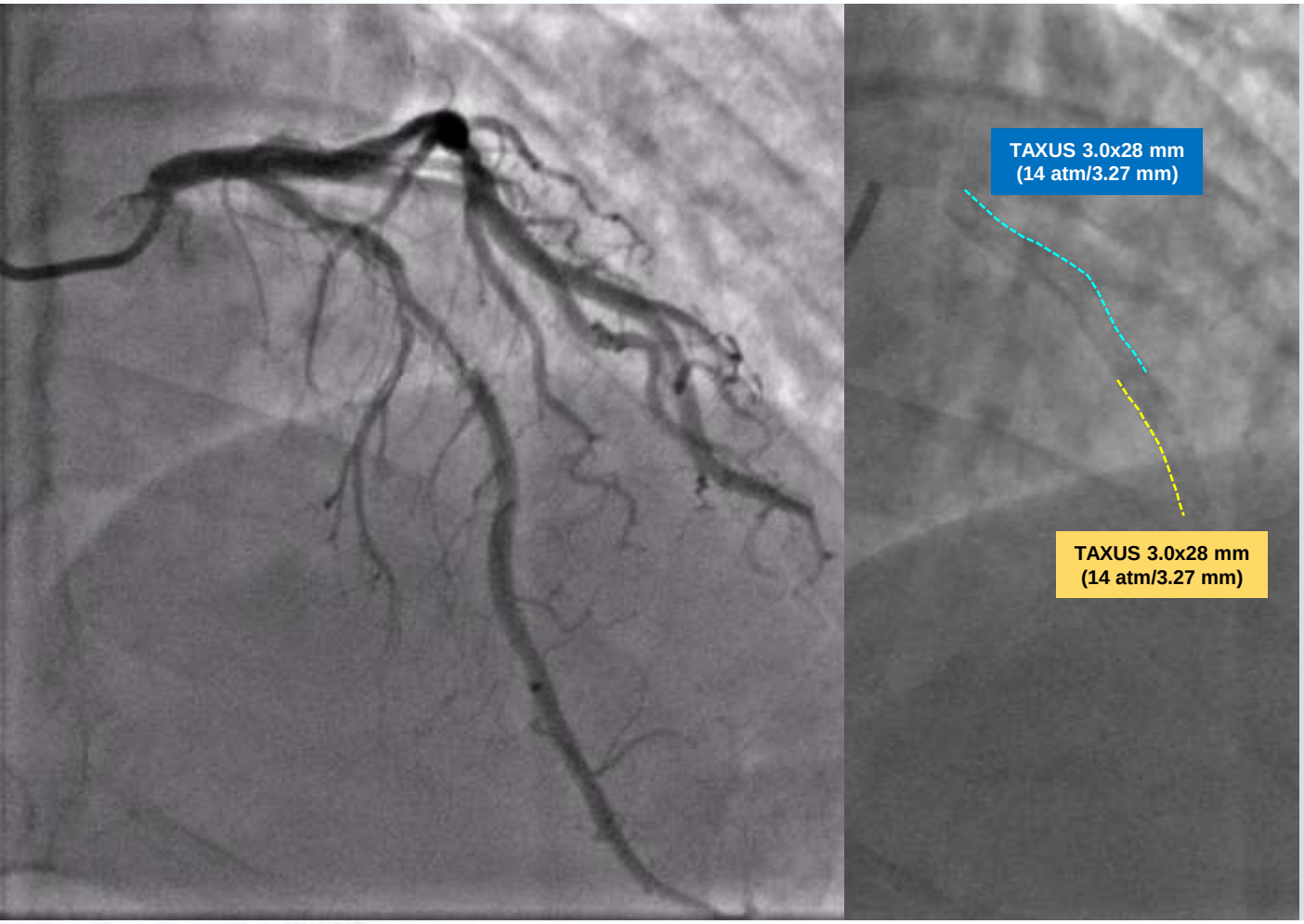
Distal stent edge at LCX

After post dilate with NC balloon 3.5x12 mm (18 atm/3.57 mm), followed by DCB 3.5x30 mm





Conclusion: Application of IVI in stent failure



- Type of stent: BMS vs. DES
- Early ISR vs. Late ISR

} Chart review & Hx taking

- Mechanism of ISR
  - Mechanical:
    - stent fracture
      → stent enhancement/3D-recon
    - stent underexpansion
  - Biological:
    - Tissue characteristics
- Identification of stent layers
- Post-procedural assessment
- Prognosis prediction

} IVI

- Dr. S, 65 YO neurosurgeon present with exertion angina for 1 month
- Primary PCI to proximal and mid LAD 2007