The role of imaging in defining the mechanism of stent failure

Mauro Echavarría Pinto MD, MSc, PhD

Cardiólogo Intervencionista

Hospital General ISSSTE Querétaro

Facultad de Medicina, Universidad Autónoma de Querétaro

Potential conflicts of interest

Speaker's name: Mauro Echavarría Pinto

☑ I have the following potential conflicts of interest regarding the topics of this presentation:

Speaker at educational events: Philips/Volcano Corporation, Abbot, Boston,

Proctor: Boston, Phillips, Levbeth

Case presentation

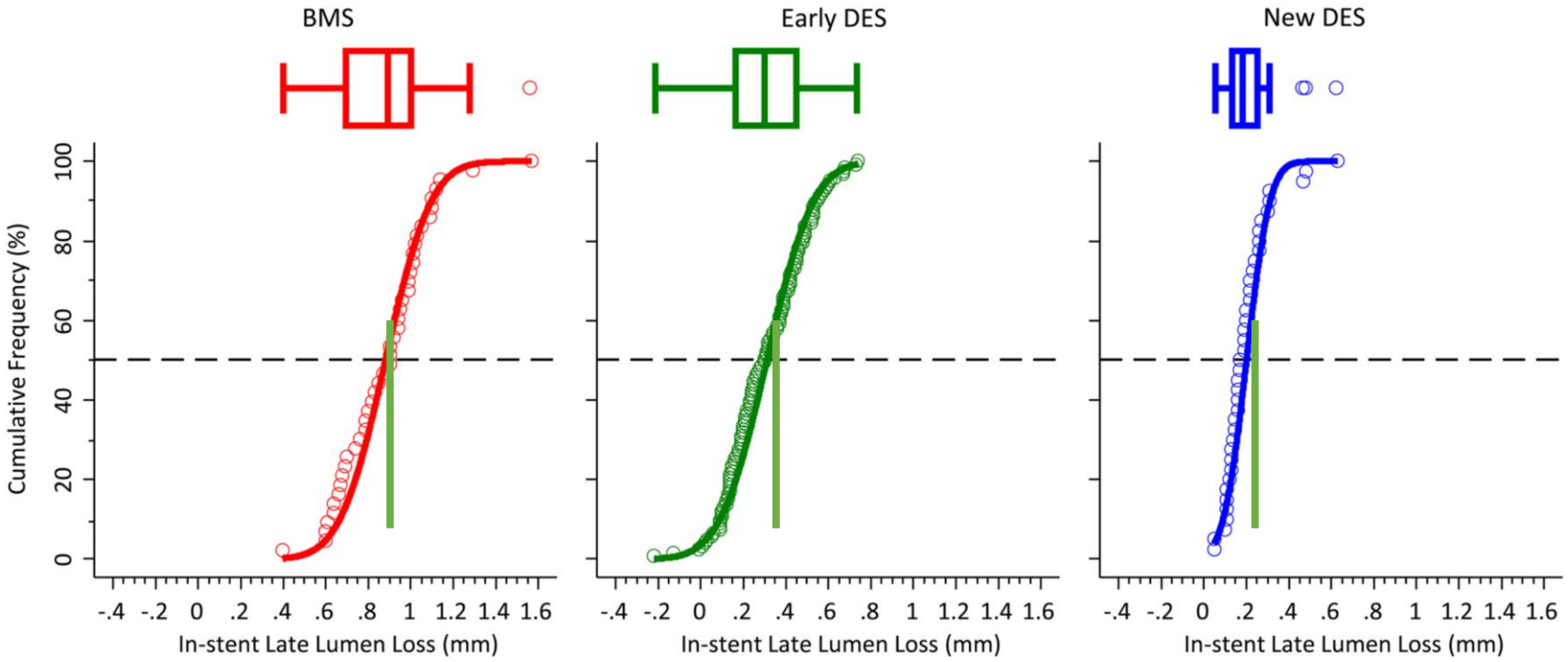
- 67 yo male
- Diabetes and hypertension
- Stable angina 4 years ago -previous PCI to LAD with DES: no more details available

- Current clinical presentation
  - Recent onset progressive typical angina CCS II /III
  - Normal ECG
  - Normal troponinx2

Stent failure as cause of new-onset unstable angina

Report of a European Society of Cardiology-European Association of Percutaneous Cardiovascular Interventions task force on the evaluation of coronary stents in Europe: executive summary (Meta-analysis of 158 RCT trials)

Stents lose lumen over time

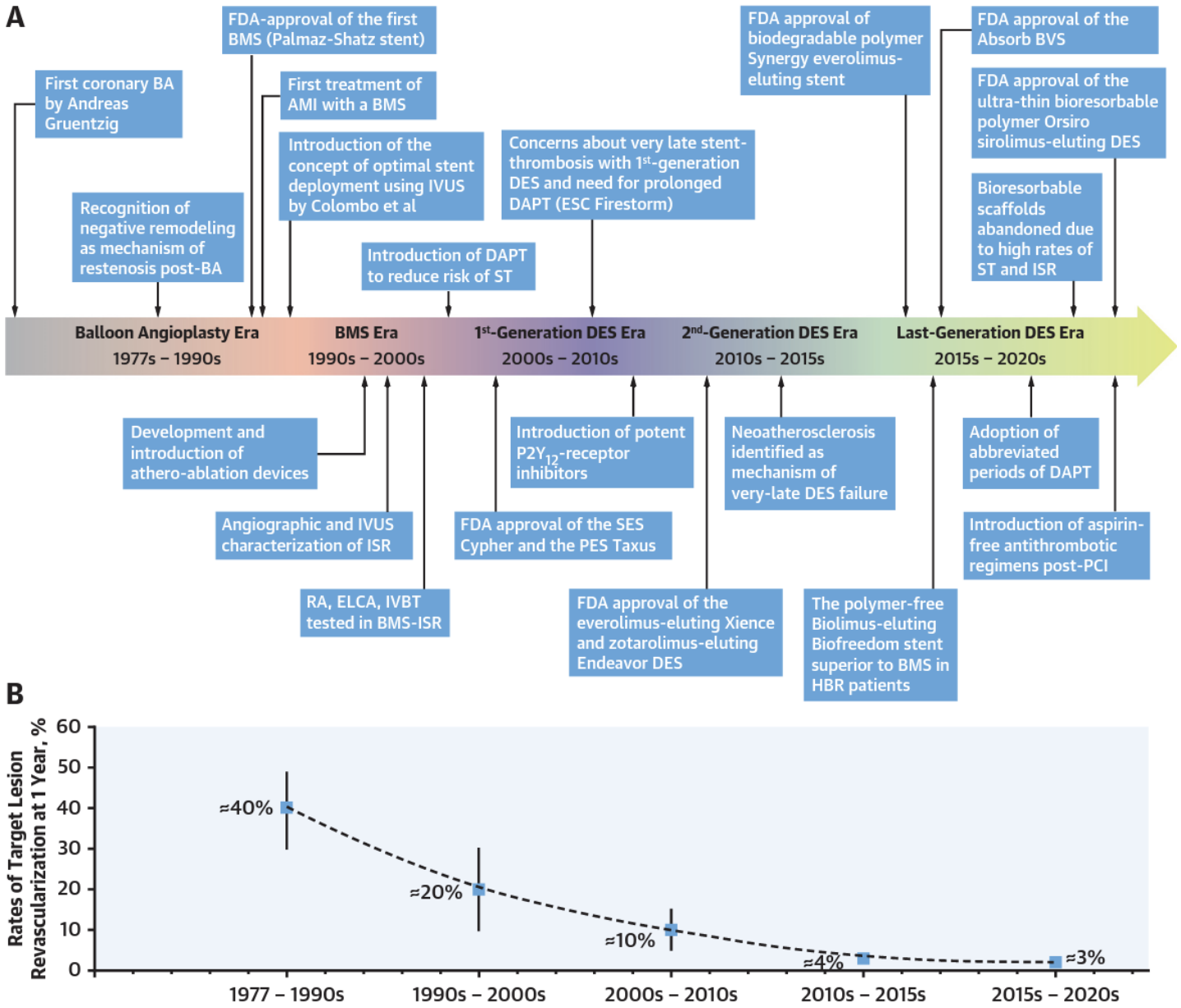


Systematic review results: median, interquartile range and cumulative frequency of in-stent late lumen loss.
BMS, bare metal stents; DES, drug-eluting stents.

Byrne et al. European Heart Journal 2015.
doi:10.1093/eurheartj/ehv203

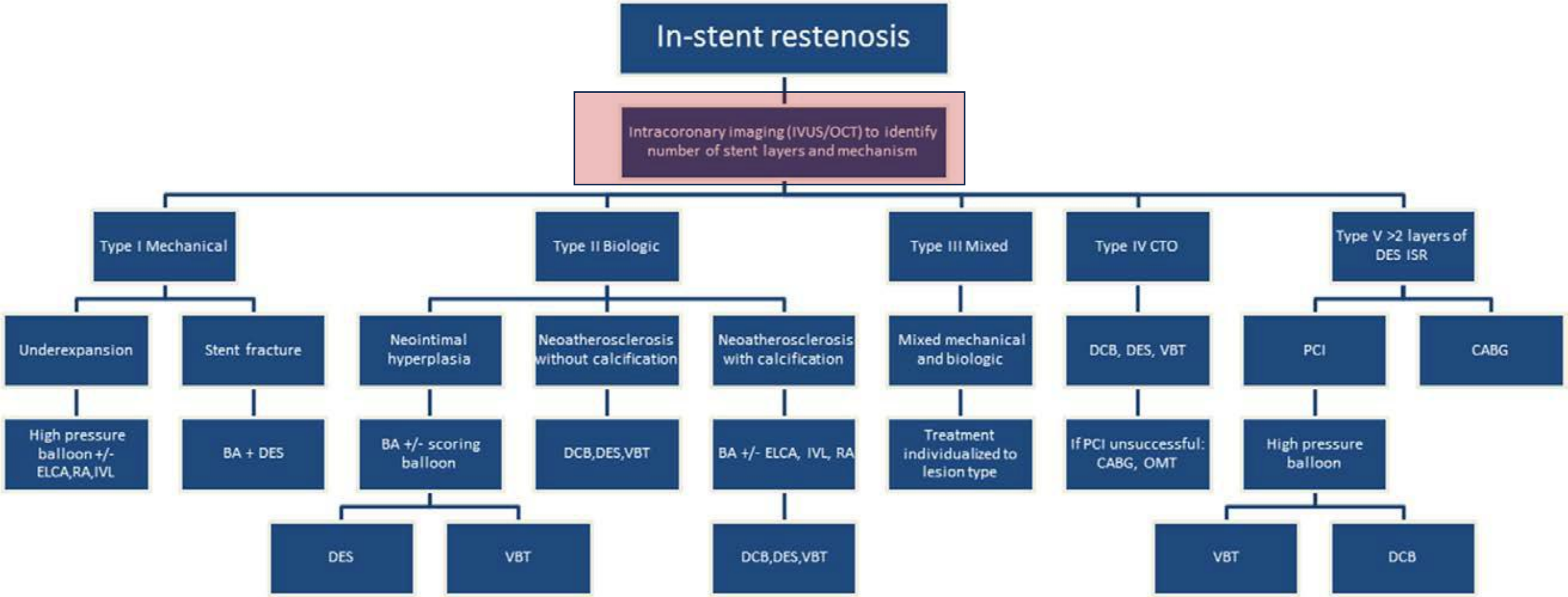
Stent lumen loss:

Leads to clinical events in 3% of patients at 1 year



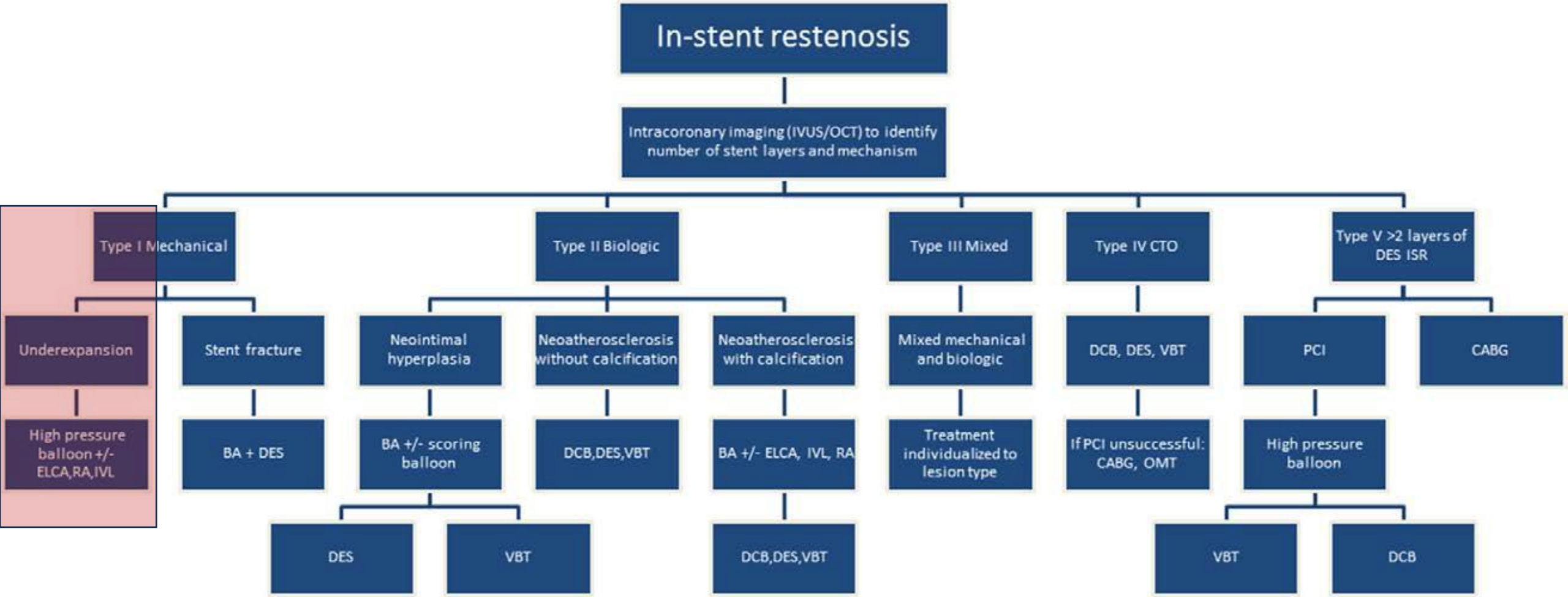
Giustino G, et al. J Am Coll Cardiol. 2022 Jul 26;80(4):348-372.

Coronary stent failure



Waksman et al. Circ Cardiovasc Interventions 2020

Coronary stent failure



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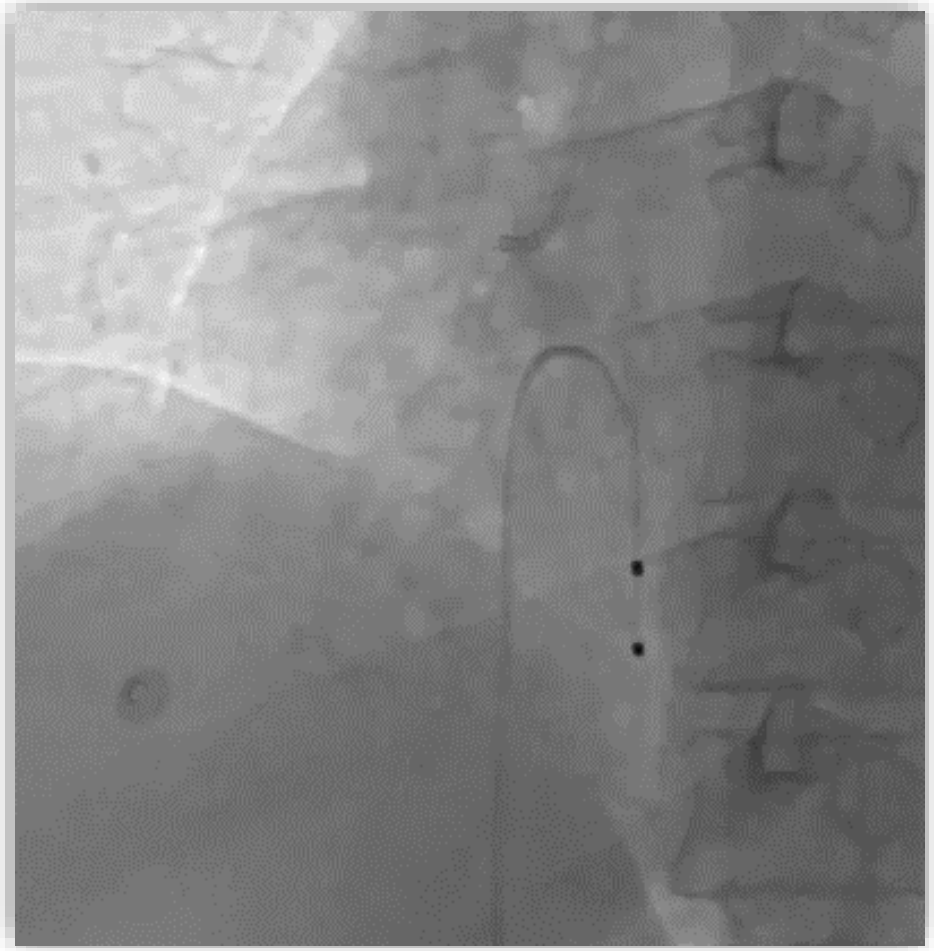
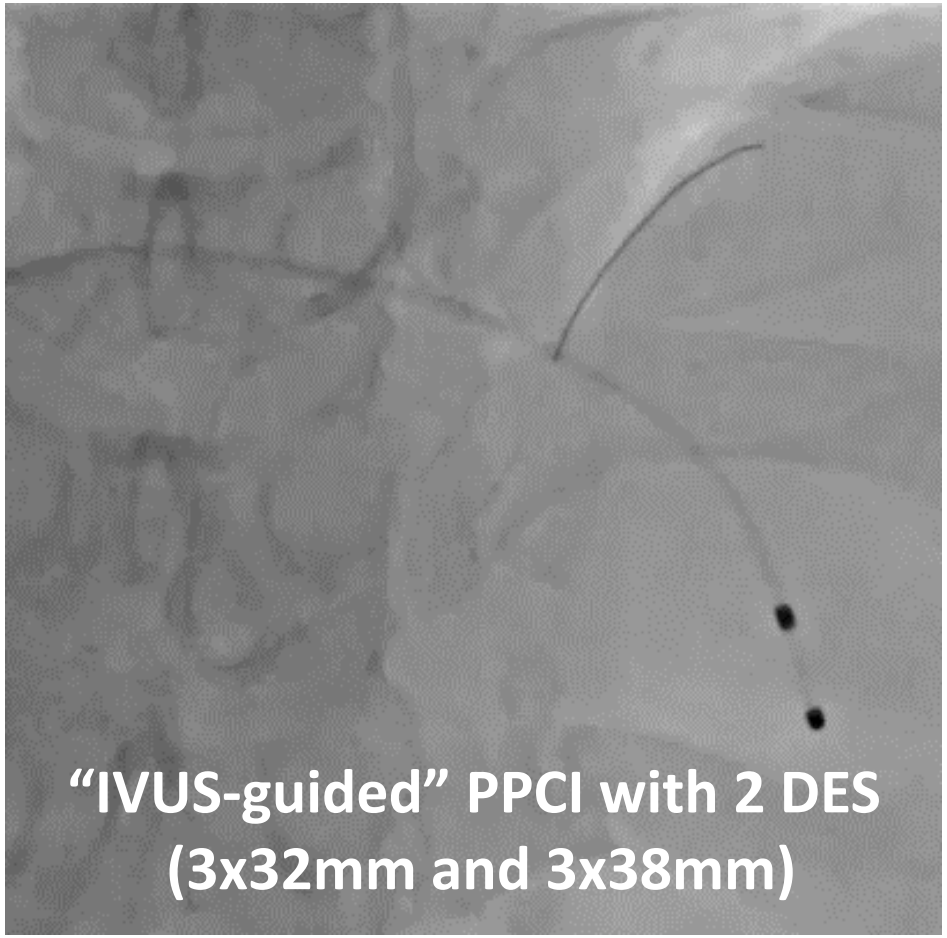
Angio-guided PCI always looks great (or at least OK) and can hide a bad PCI result

56 yo patient admitted with inferior STEMI, “IVUS-guided” PCI

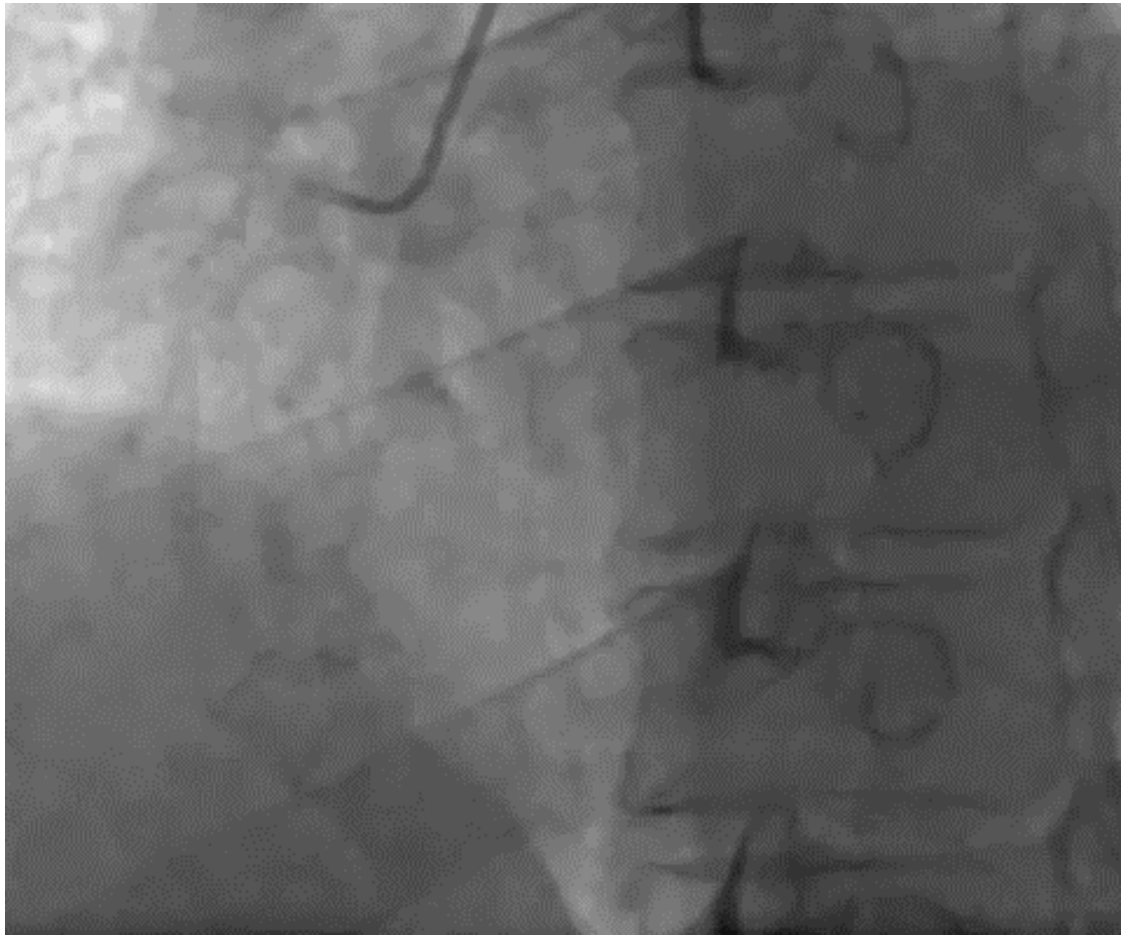


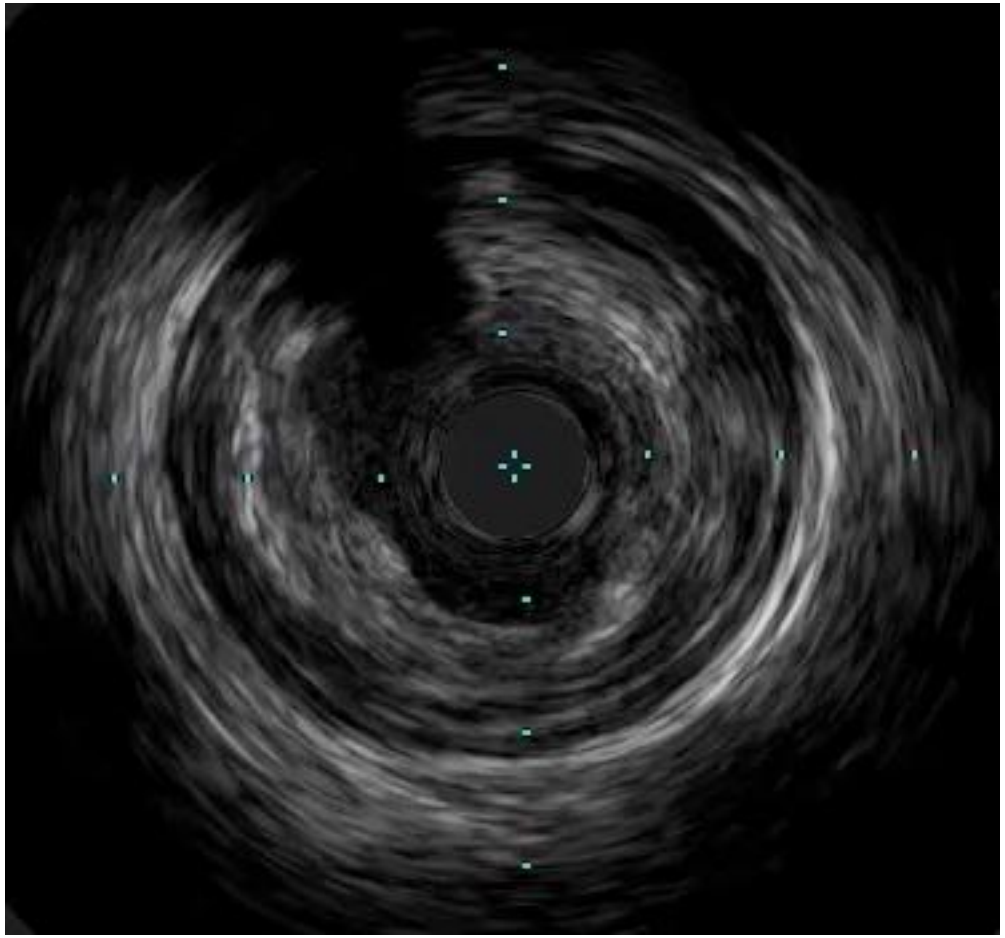


“IVUS-guided” PPCI with 2 DES (3x32mm and 3x38mm)

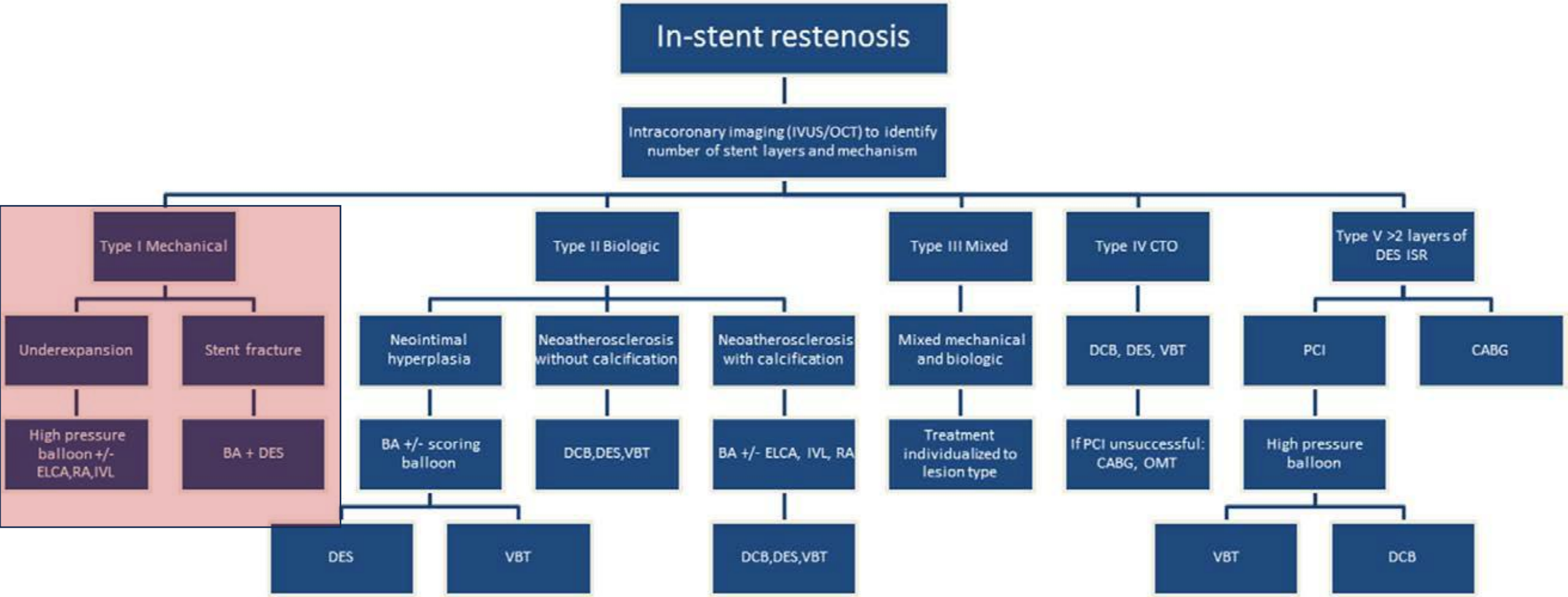
Angio-guided PCI always looks great (or at least OK) and can hide a bad PCI result

3 months later, readmitted because of Non-STEMI





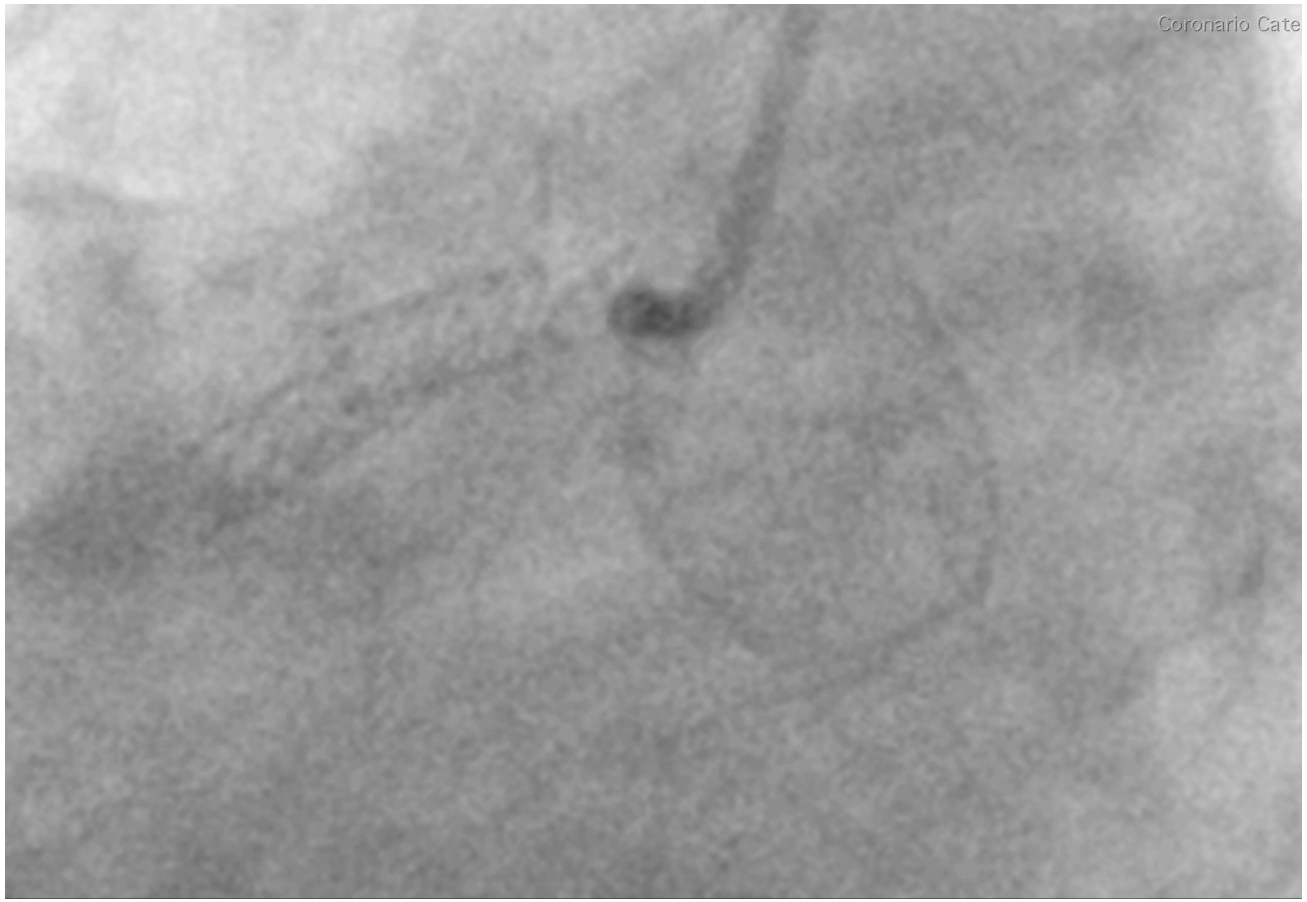
Coronary stent failure



Waksman et al. Circ Cardiovasc Interventions 2020

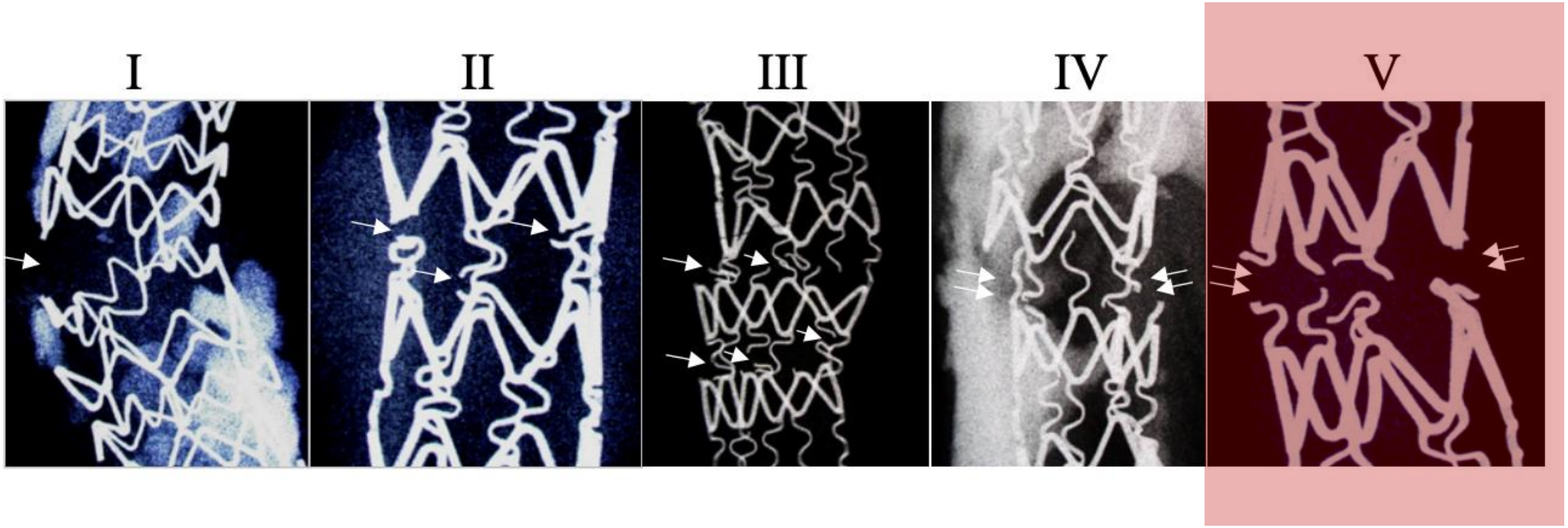
Coronary stent fracture

- 82 yo male
- MVD treated with CABG 30 years ago
- Now CCS II with normal LV and inferolateral wall ischaemia
- ISR of ostial RCA due to stent fracture
- Patent LIMA
- High bleeding risk



Coronary stent fracture

Classification



“67% of the grade V fracture lesions were associated with adverse pathologic findings at fracture sites “

Nakazawa et al. J Am Coll Cardiol 2009;54: 1924–31

Coronary stent fracture

Clinical impact

Table 1: The incidence of SF, adverse clinical outcome, and percentage of TLR in patients with SF

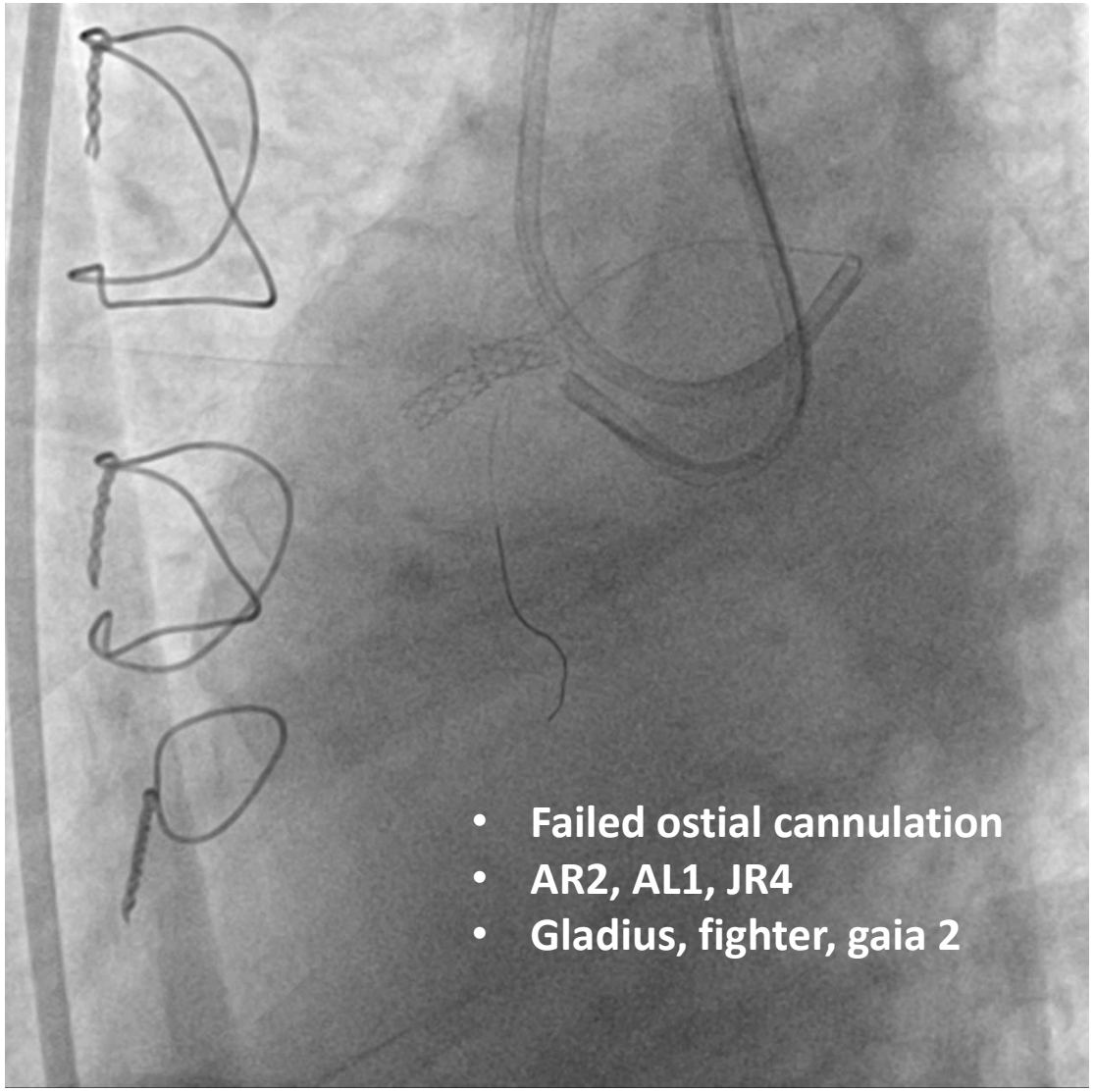
Study	Incidence	Adverse clinical outcome	TLR (%)
Lee *et al.*,[16]	1.9%	60% ISR and 10% ST	70
Lee[17]	1.5%	53.3% ISR	53.3
Ino *et al.*,[9]	4.9%	33% ISR	28
Chung[30]	0.84%	65% ISR	30
Aoki *et al.*,[24]	3.1%	37.5% ISR	50
Umeda *et al.*,[25]	7.7%	15.2% ISR	9
Park *et al.*,[48]	0.89% for SES 0.09% PES	41.7%	33.3
Chakravarty *et al.*,[39] meta-analysis of eight studies	Mean incidence 4%	38%	17

TLR: Target lesion revascularization; SES: Serolimus-eluting stent; PES: paclitaxel-eluting stents; ISR: Instent restenosis

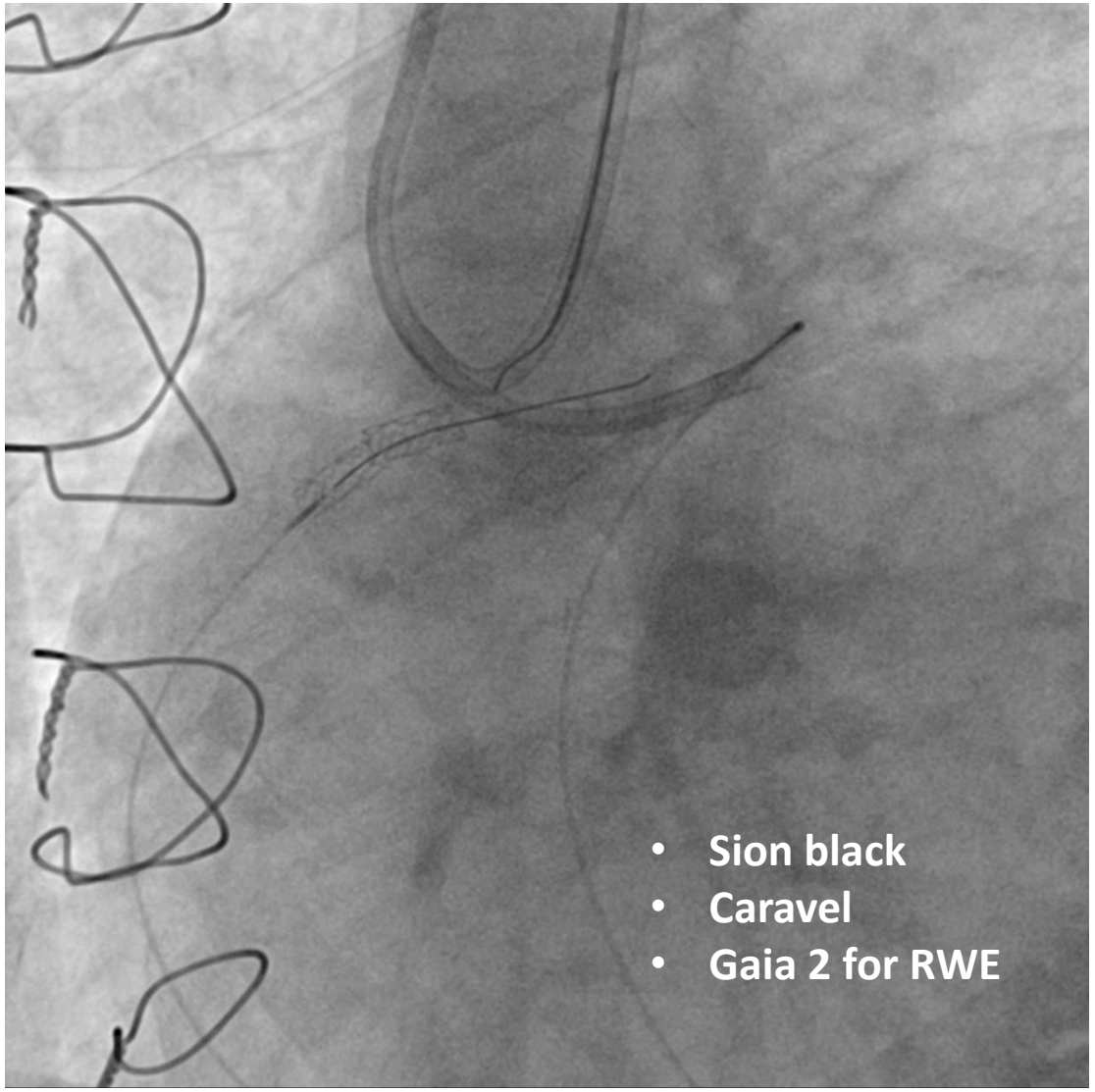
Stent fracture is associated with a very high rate of adverse clinical outcomes

Mohsen ML et al. Heart Views 2013;14:72-81

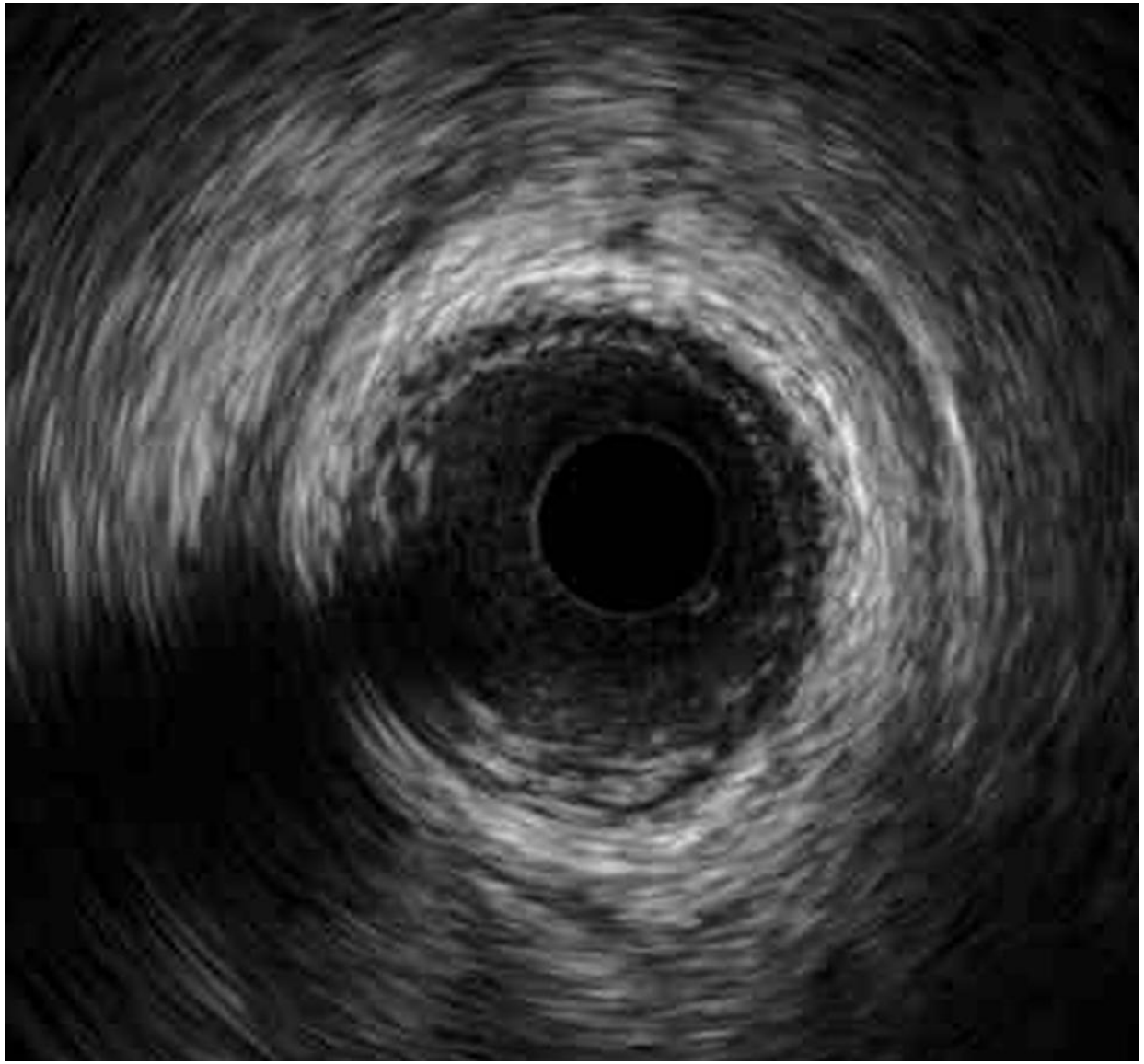
Failed AWE



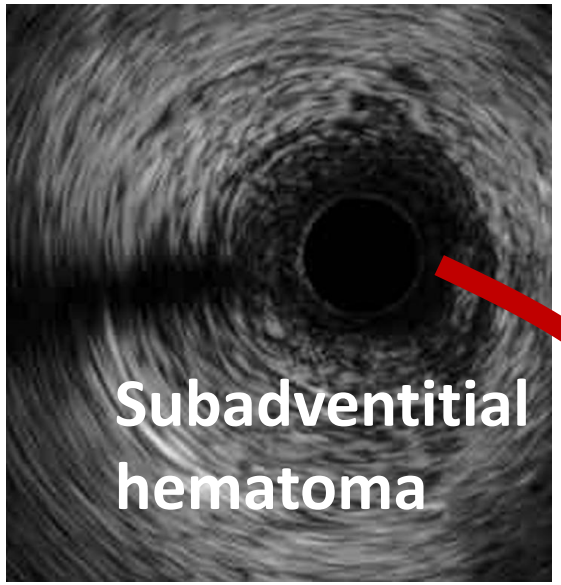
Successful RWE

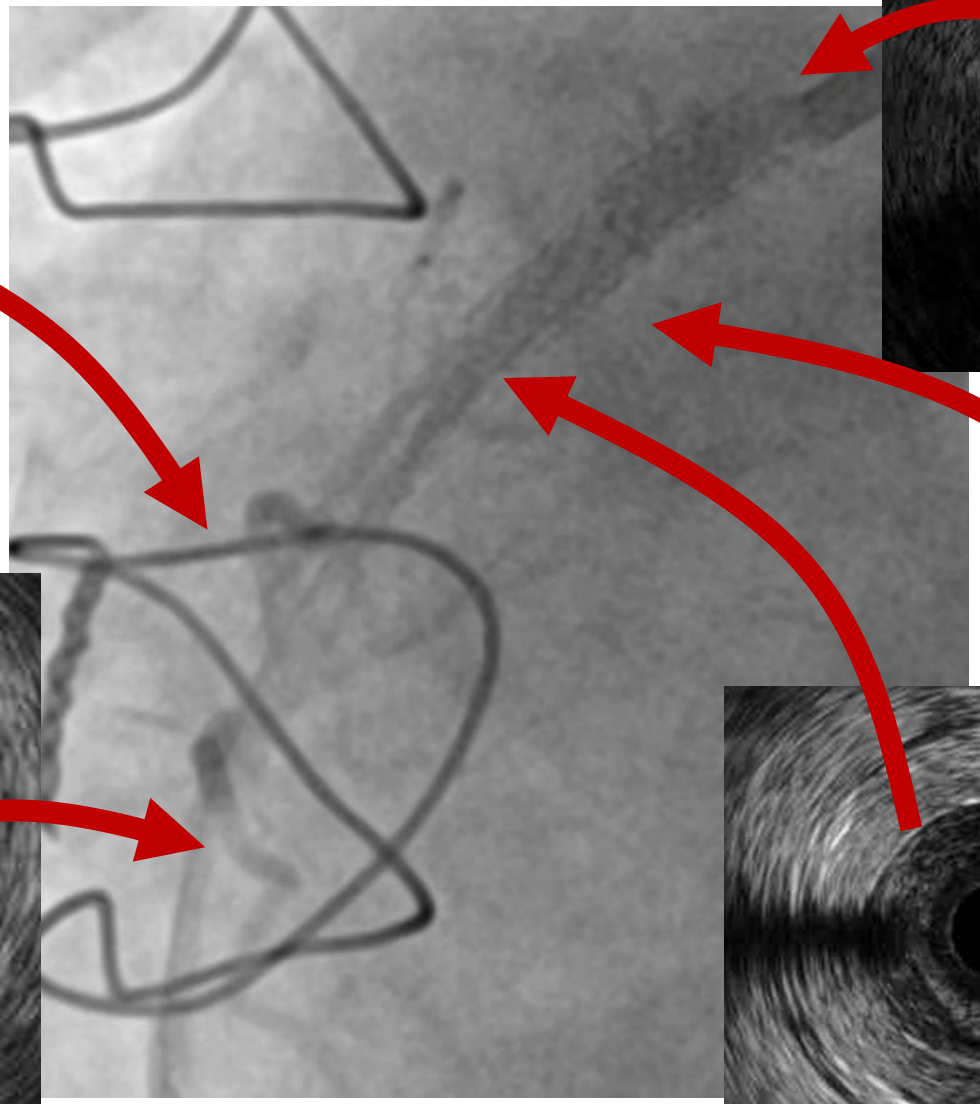


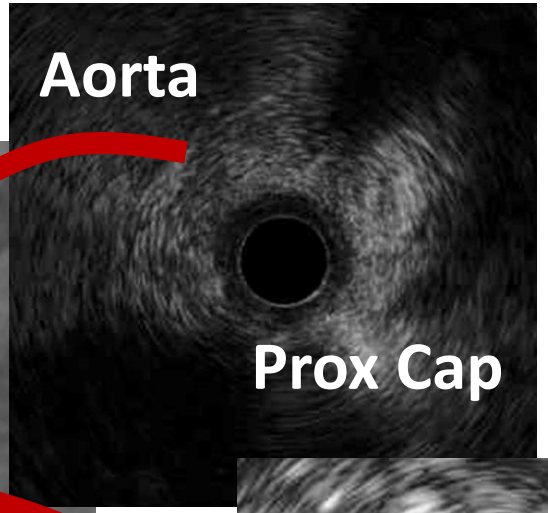
IVUS in stent fracture

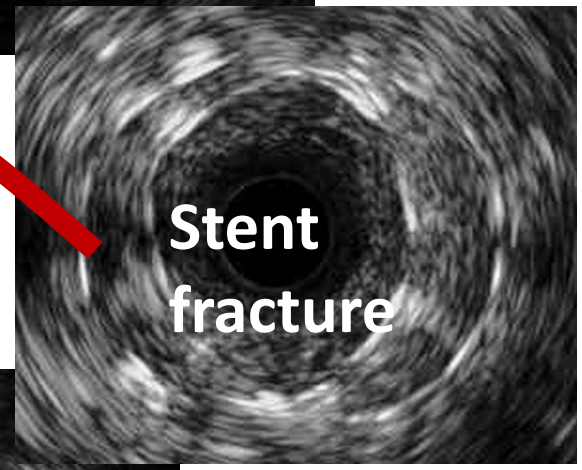


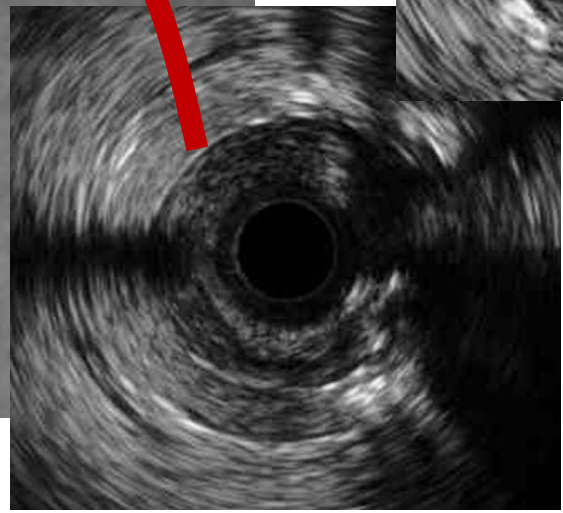
IVUS findings





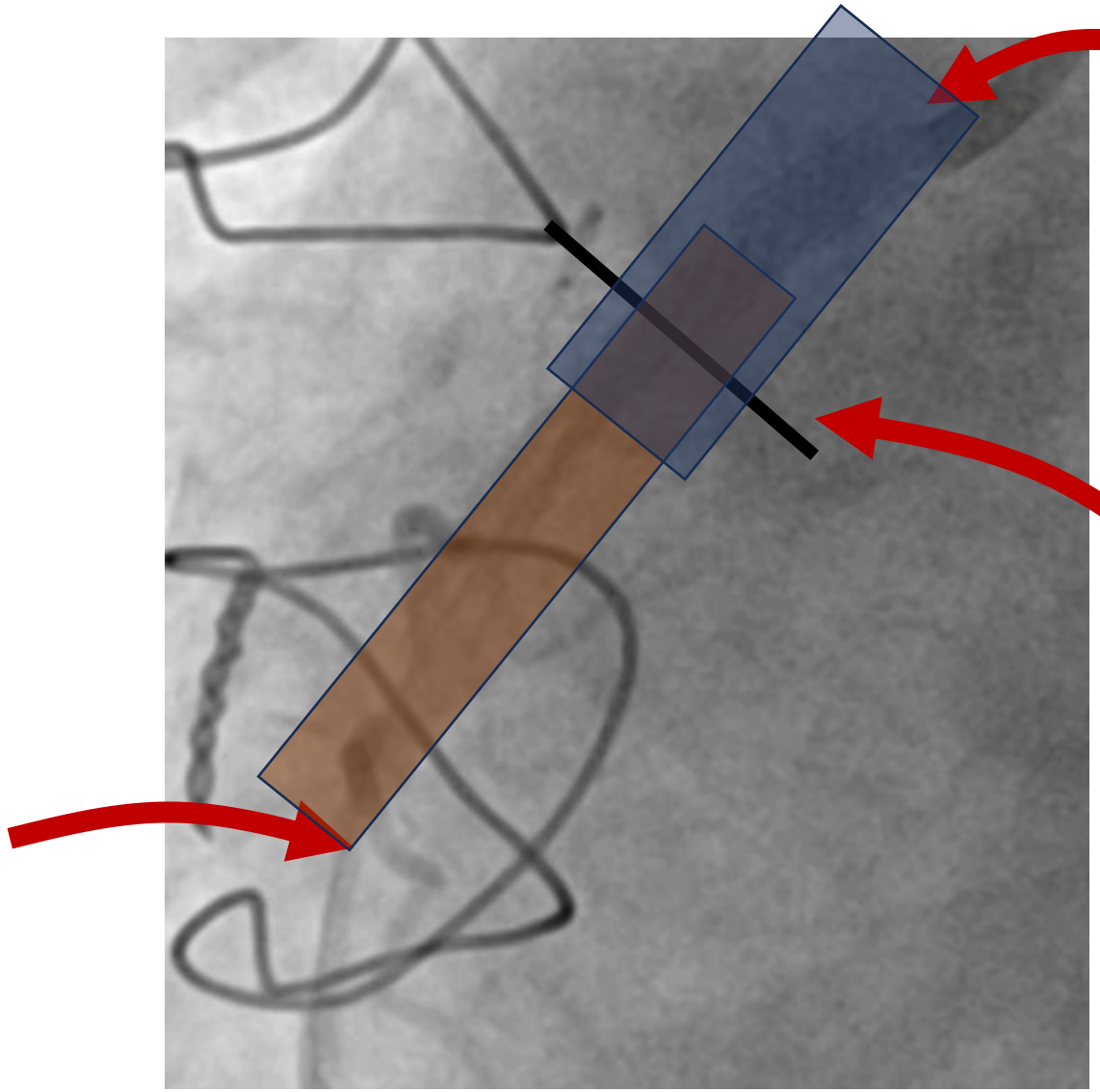






Distal stent edge Subadventitial haematoma

Plan: stent overlap over stent fracture

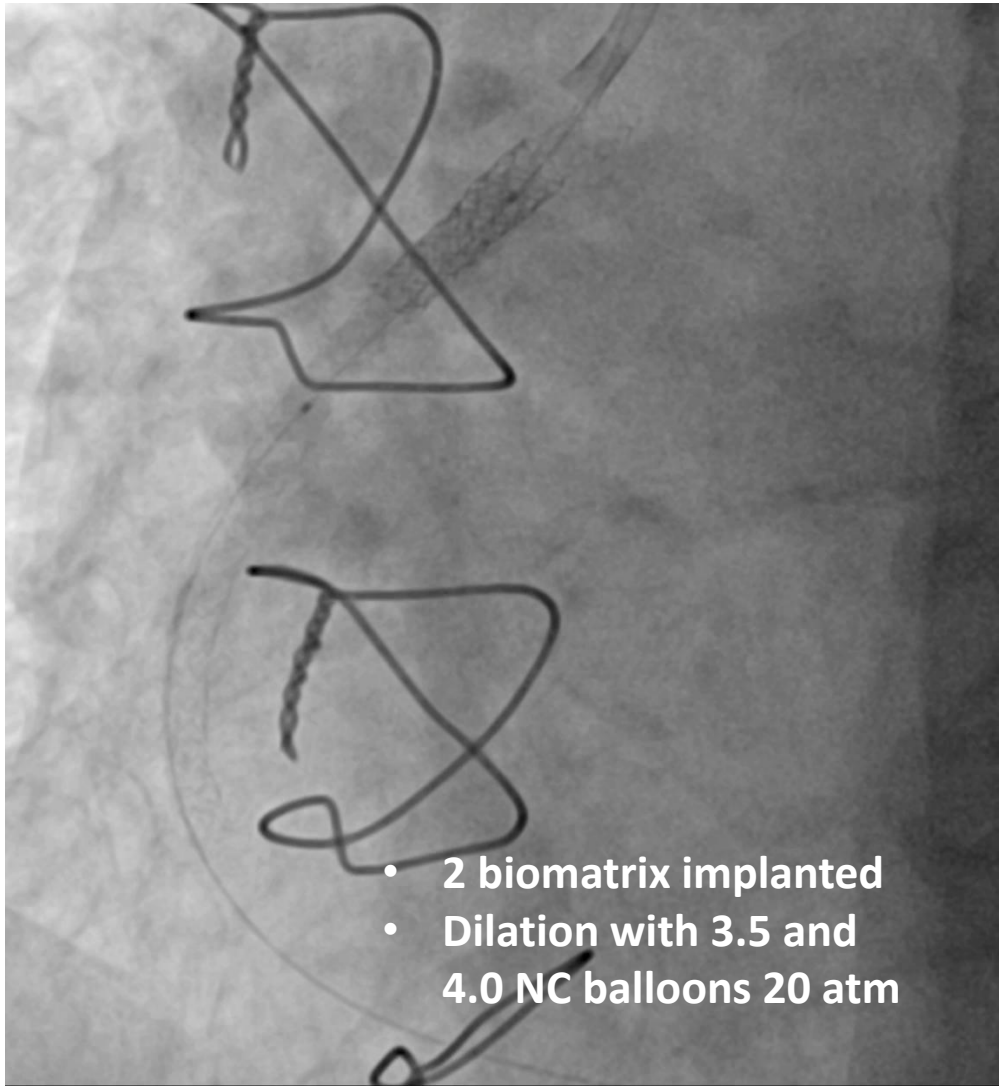


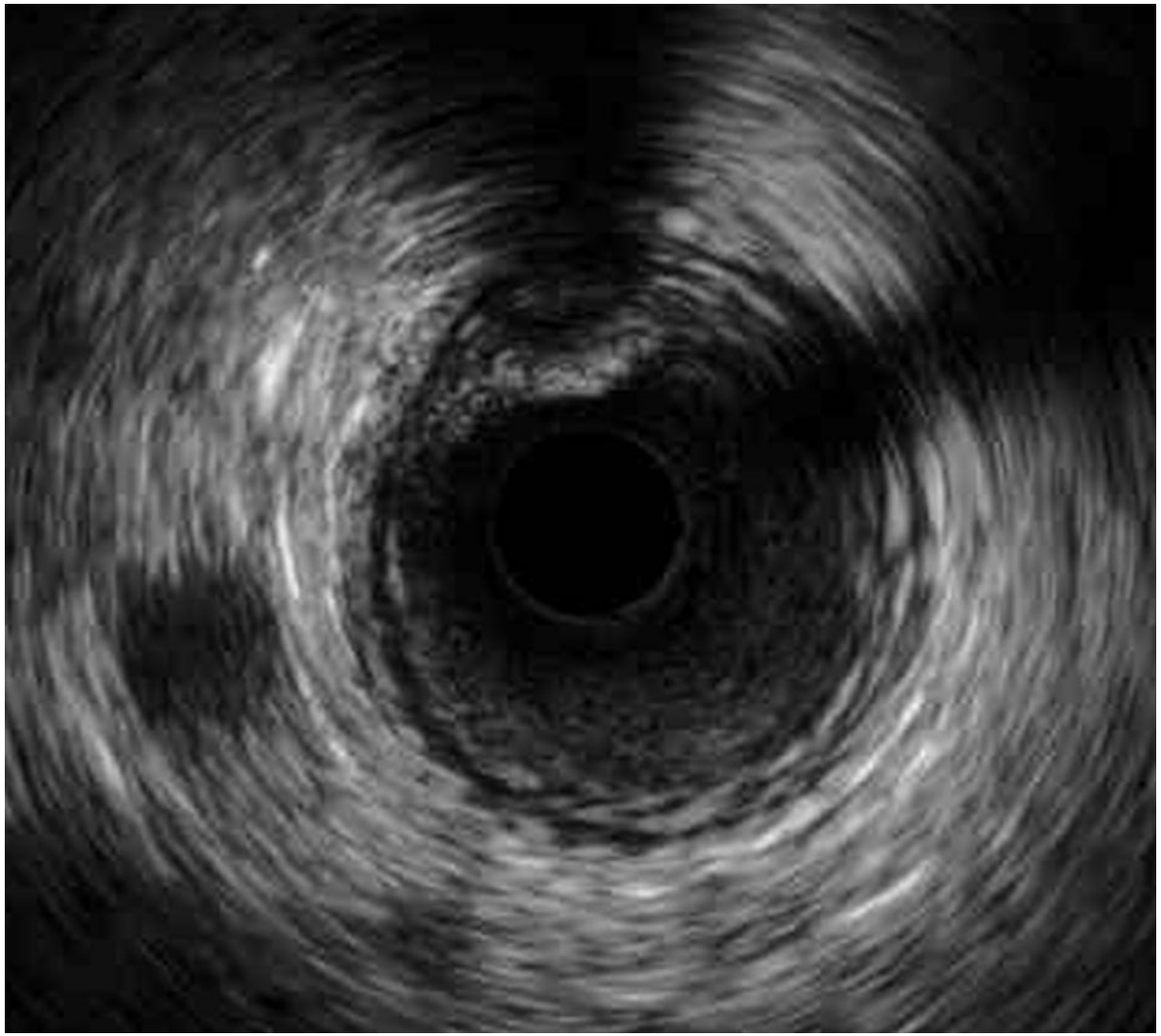
DES
4x19mm

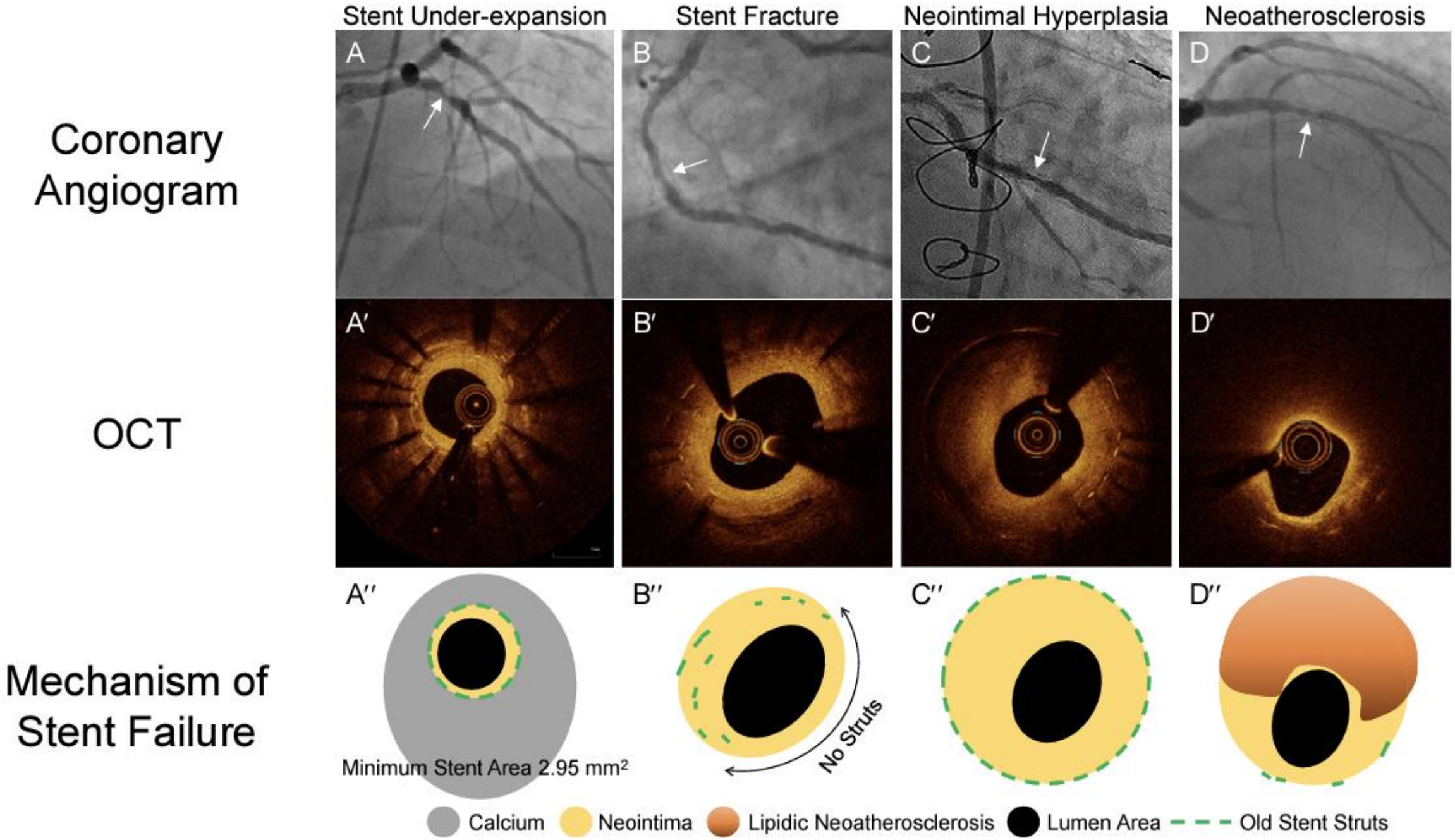
Stent fracture

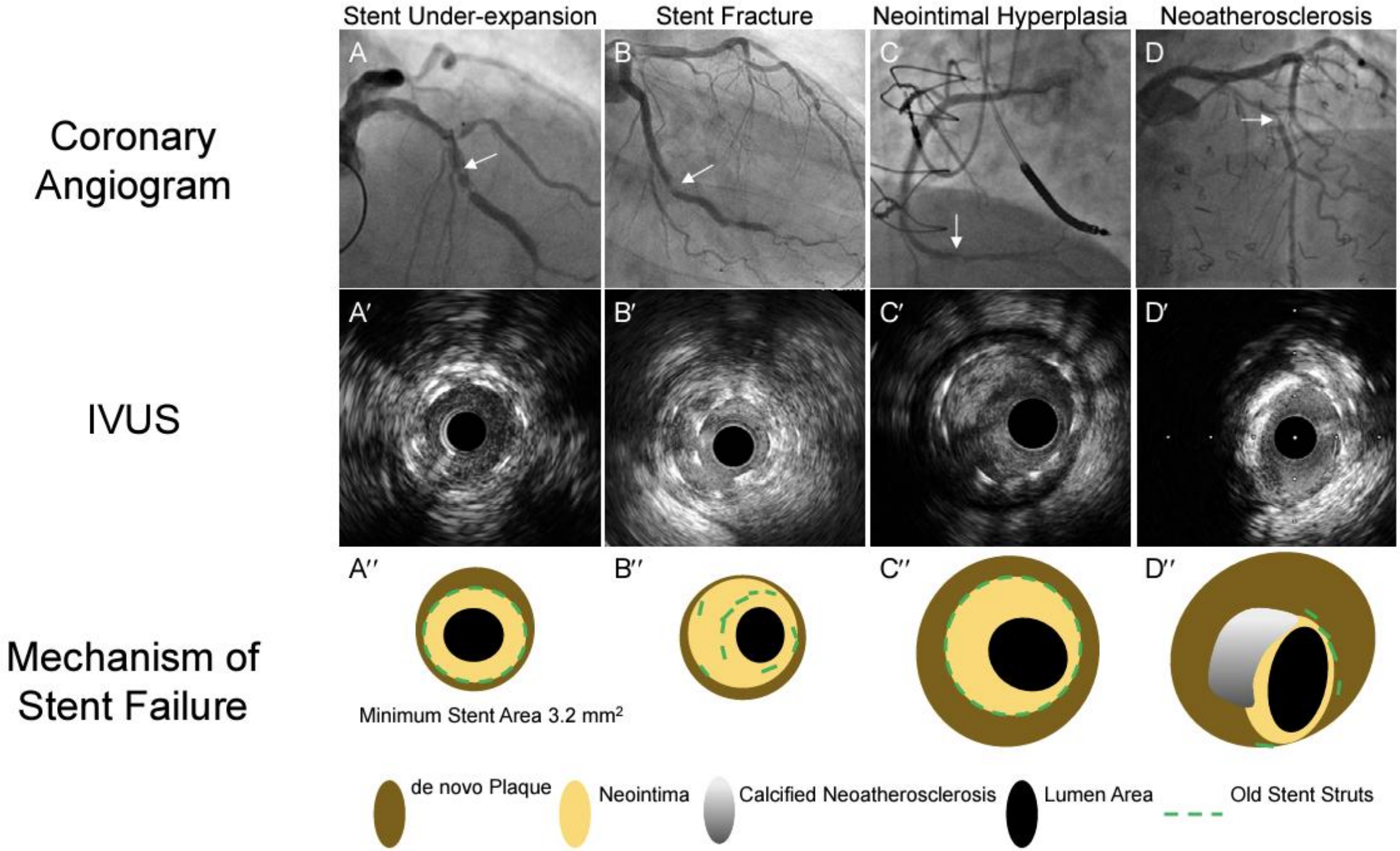
DES
3x36mm

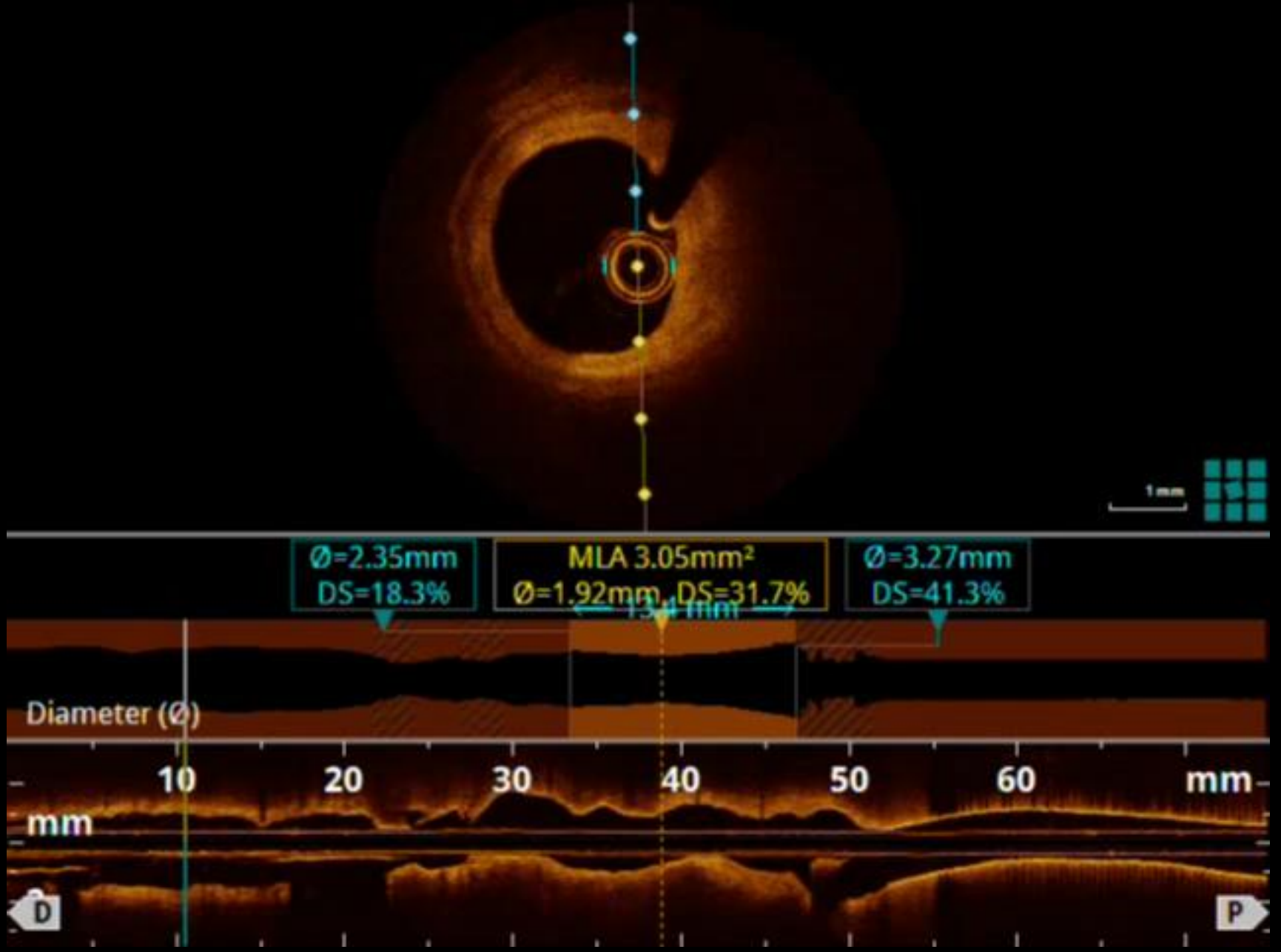
Final result






Stent Under-expansion
Stent Fracture
Neointimal Hyperplasia
Neoatherosclerosis
Coronary Angiogram
OCT
Mechanism of Stent Failure
A
B
C
D
A′
B′
C′
D′
A″
B″
C″
D″
Minimum Stent Area 2.95 mm²
No Struts
Calcium
Neointima
Lipidic Neoatherosclerosis
Lumen Area
Old Stent Struts

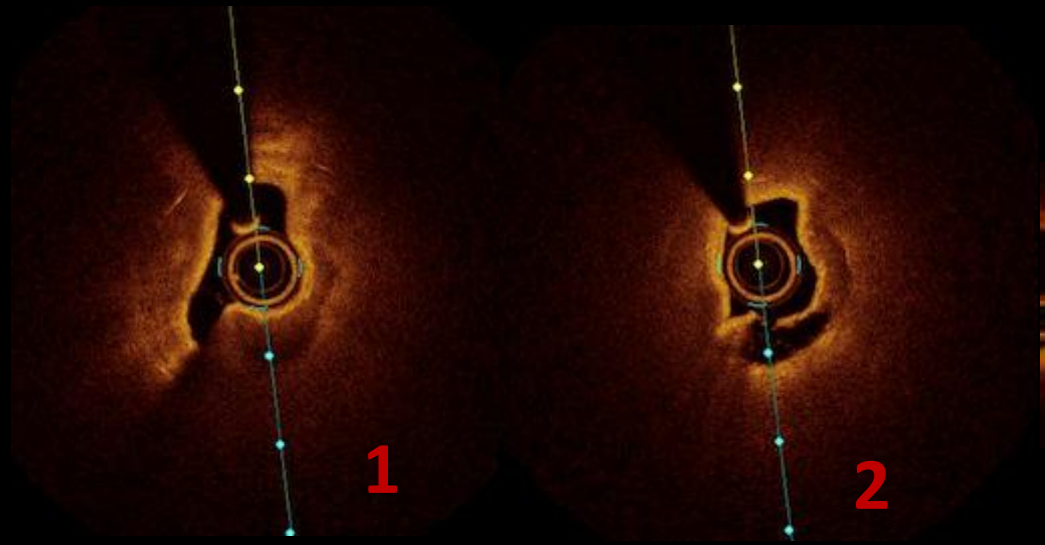

Stent Under-expansion
Stent Fracture
Neointimal Hyperplasia
Neoatherosclerosis
Coronary Angiogram
IVUS
Mechanism of Stent Failure
A
B
C
D
A′
B′
C′
D′
A″
B″
C″
D″
Minimum Stent Area 3.2 mm²
de novo Plaque
Neointima
Calcified Neoatherosclerosis
Lumen Area
Old Stent Struts

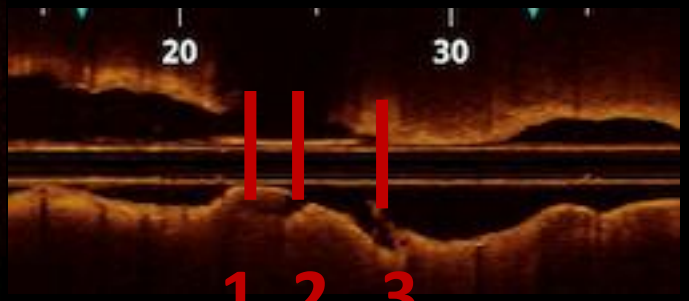

1 mm
Ø=2.35mm
DS=18.3%
MLA 3.05mm²
Ø=1.92mm, DS=31.7%
Ø=3.27mm
DS=41.3%
Diameter (Ø)
10
20
30
40
50
60
mm
mm
D
P

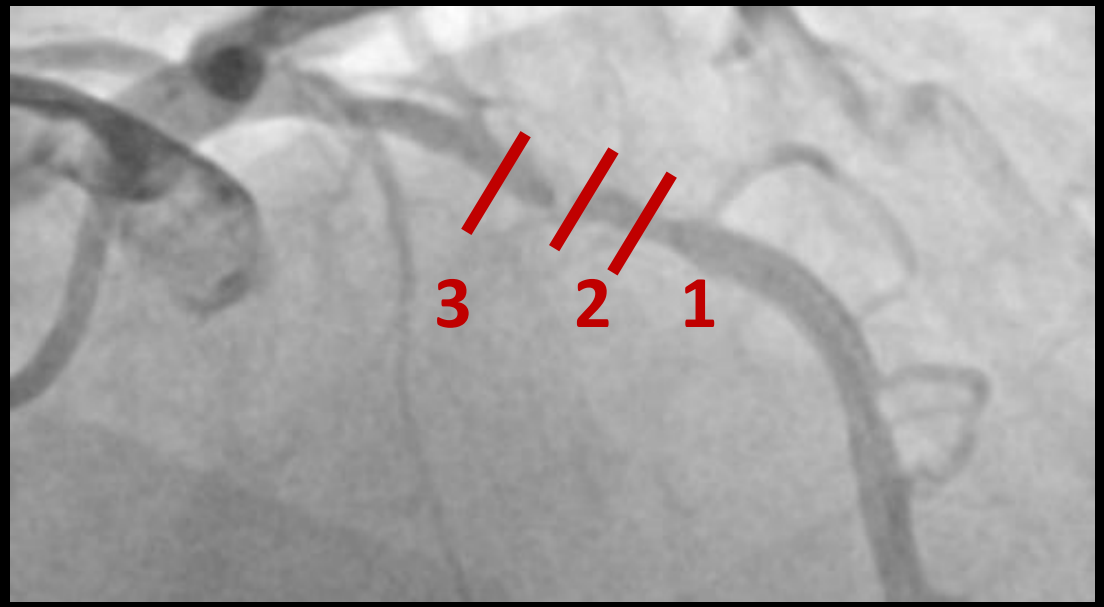
MLD MAX: morphology

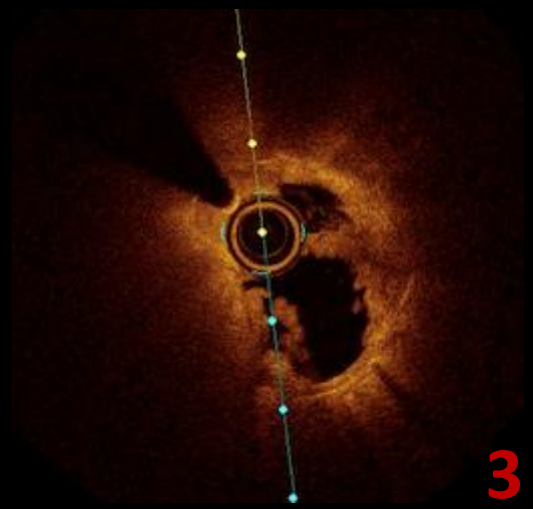
1. Ruptured plaque

2. Mostly lipidic neoatherosclerosis

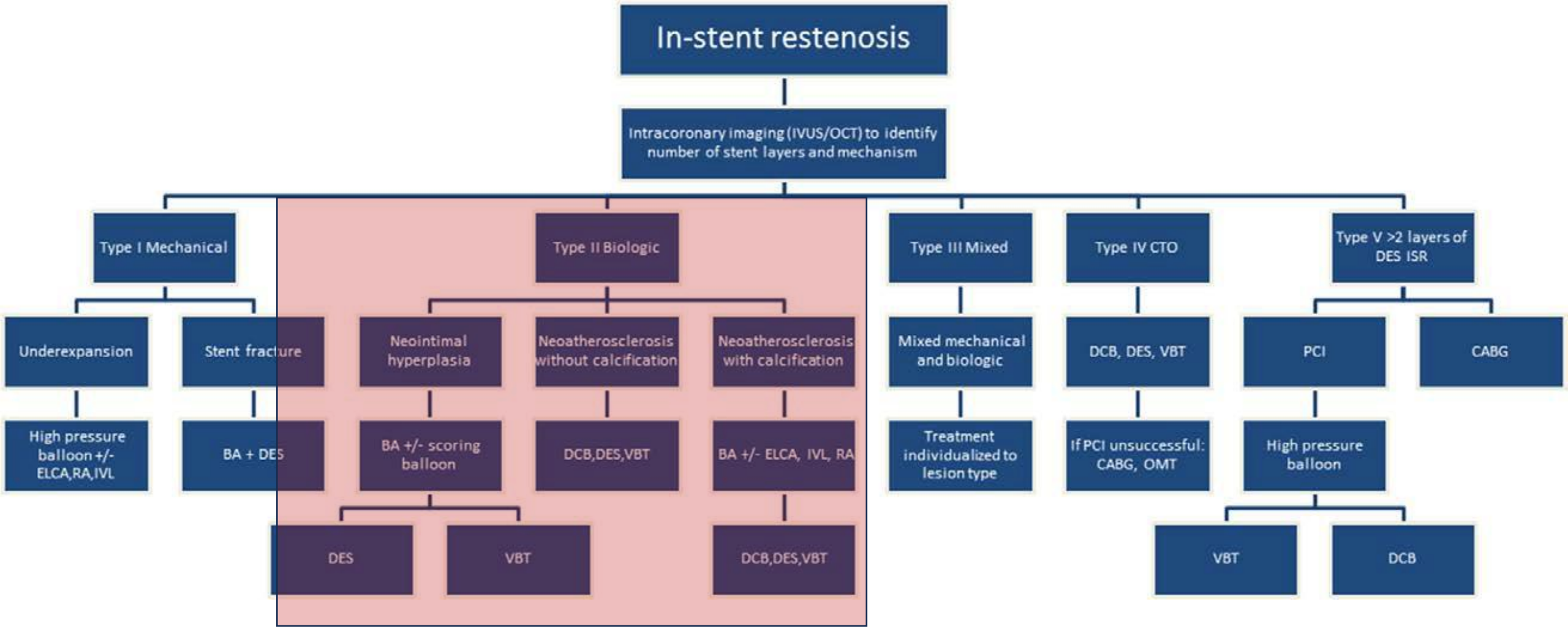








Coronary stent failure



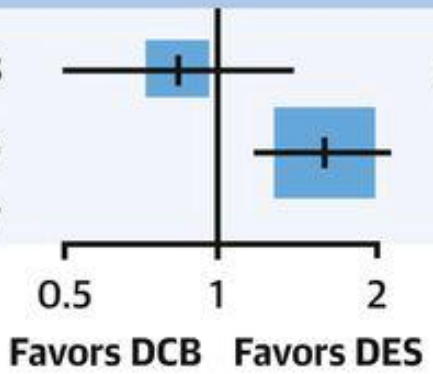
Waksman et al. Circ Cardiovasc Interventions 2020

DES or DEB for ISR?

DAEDALUS: Pooled individual pt data from all 10 RCT comparing DCB vs DES for the treatment of ISR. N=2,099 lesions

One-Stage Analysis

	DCB	DES	HR [95% CI]	p_W	$p_{interaction}$	HR_{adj} [95% CI]	p_{Wadj}	$p_{interaction}$
BMS-ISR	30 / 372	32 / 338	0.83 [0.51-1.37]	0.476	0.033	0.78 [0.46-1.32]	0.355	0.012
DES-ISR	114 / 649	67 / 599	1.58 [1.16-2.13]	0.003		1.74 [1.24-2.45]	0.001	
	144 / 1,021	**99 / 937**						

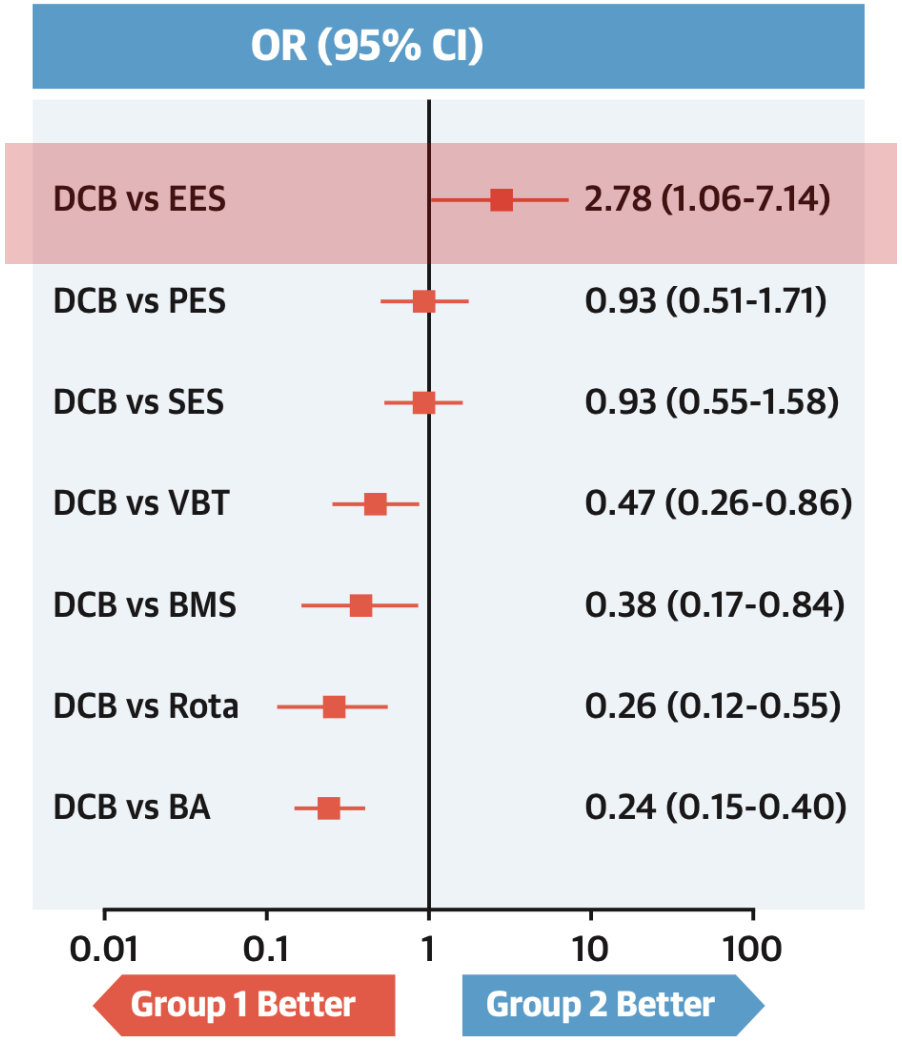


1. BMS stent failure: better DCB
2. DES-stent failure: better DES

Giacoppo D et al. J Am Coll Cardiol 2020;75:2664–78

DCB or DES for ISR?

Network meta-analysis of 29 RCT including 5973 ISR patients



Giustino G, et al. J Am Coll Cardiol. 2022 Jul 26;80(4):348-372.

DCB or DES for iSR?

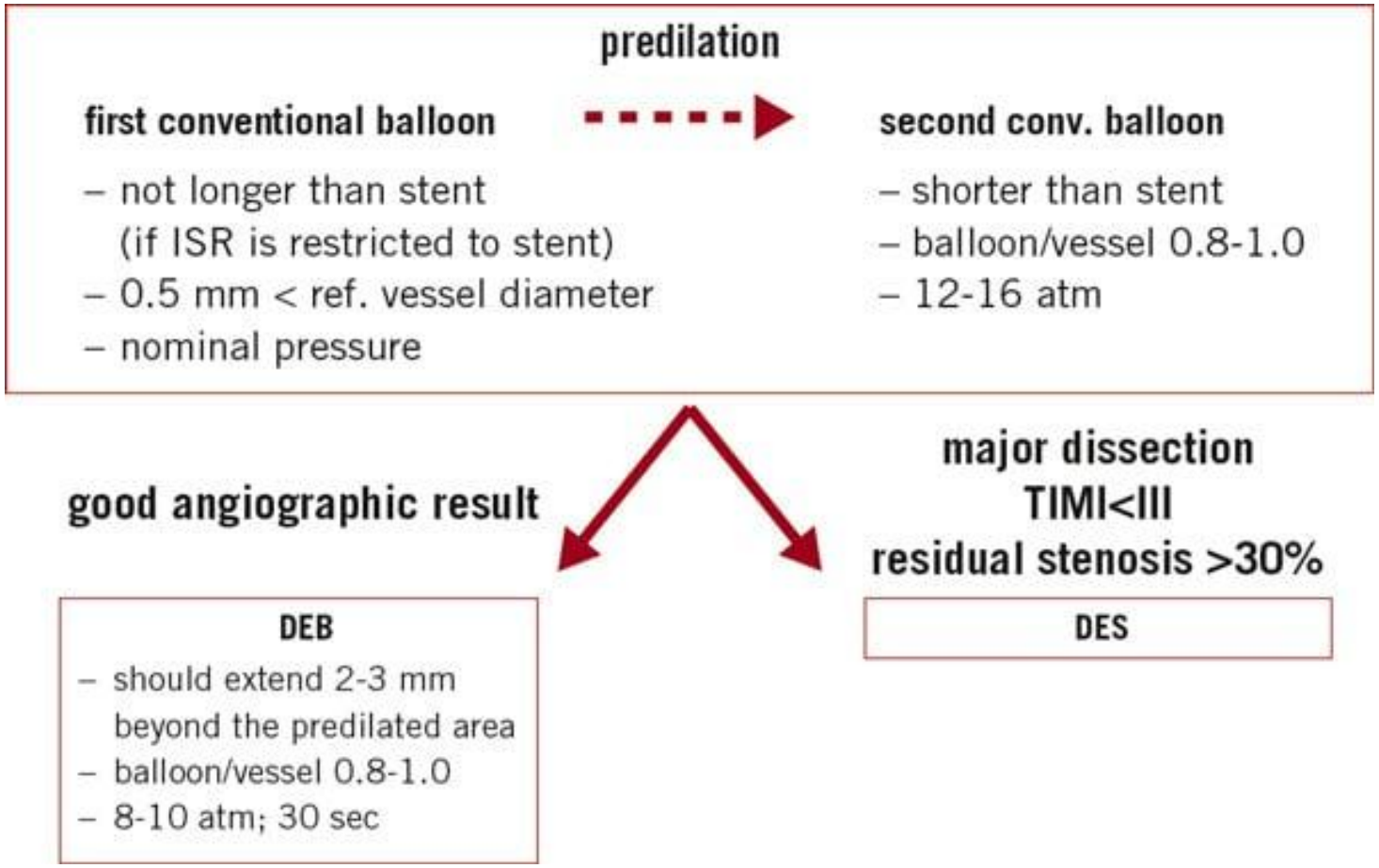
TABLE 4 Factors Favoring the Use of Drug-Coated Balloons vs DES Implantation in ISR

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

BMS = bare-metal stent; DAPT = dual antiplatelet therapy; DES = drug-eluting stent; ISR = in-stent restenosis.

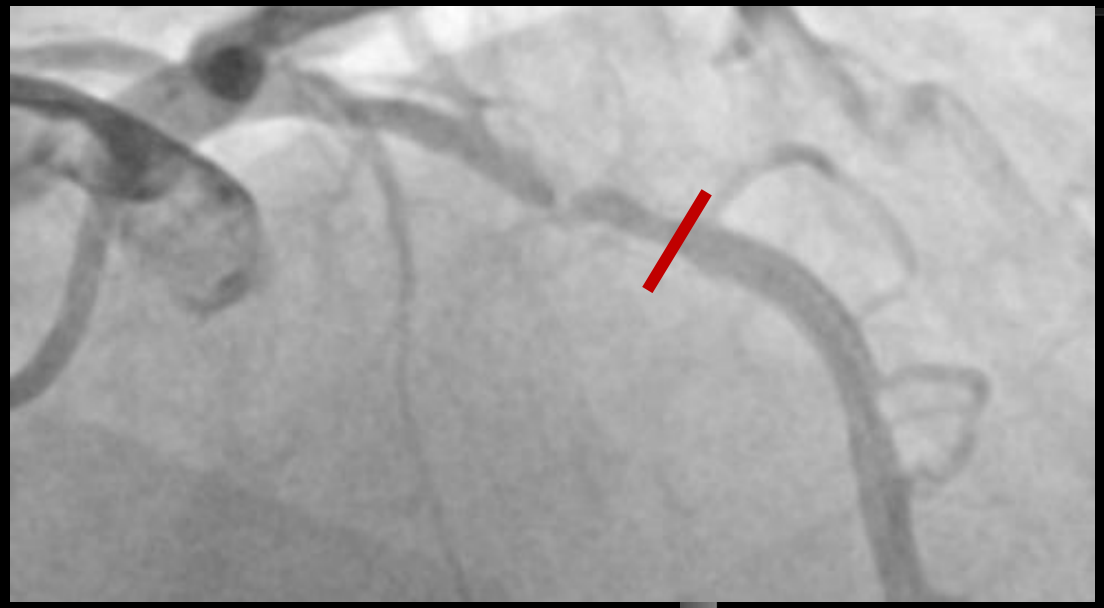
Giustino G, et al. J Am Coll Cardiol. 2022 Jul 26;80(4):348-372.

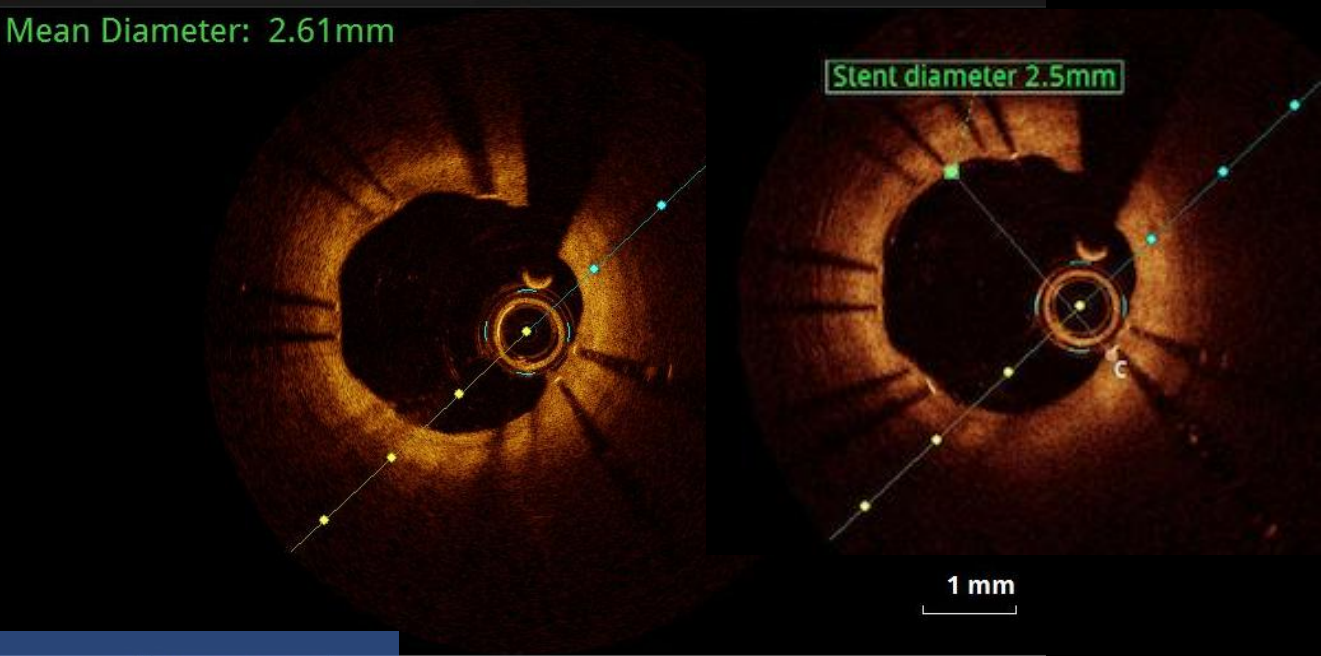
How to use the drug-eluting balloons: recommendations by the German consensus group

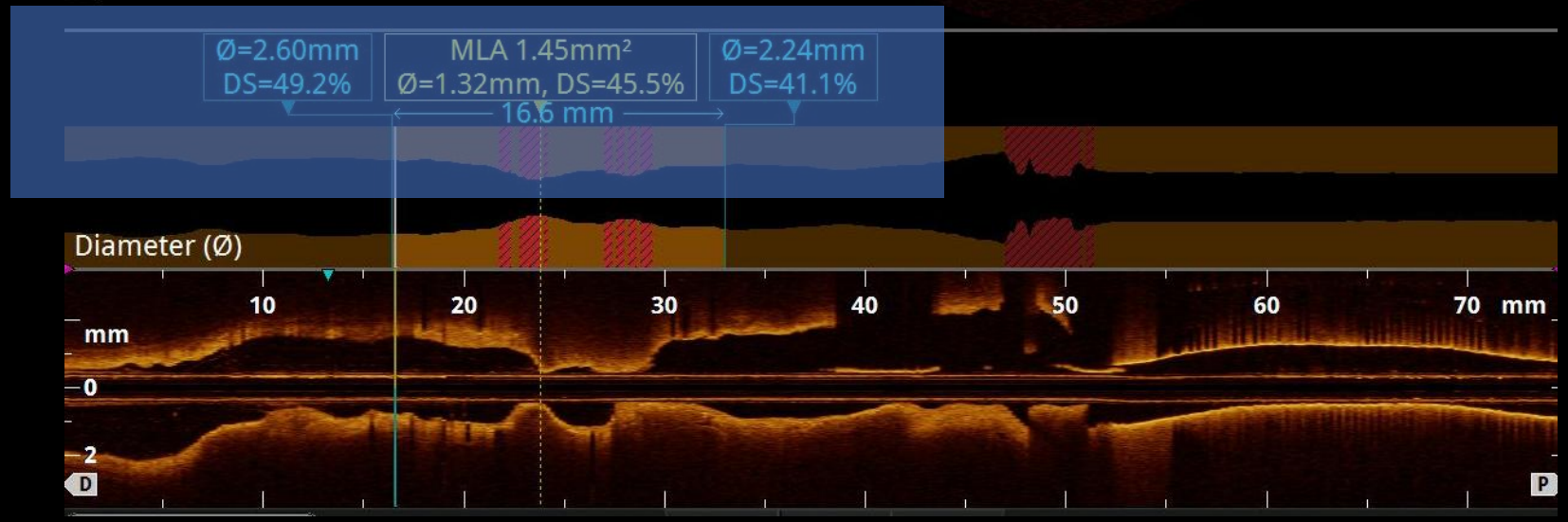


Klaber et al. EuroIntervention 2011;7:K125-K128

MLD MAX: length and diameter of previous stent, distal



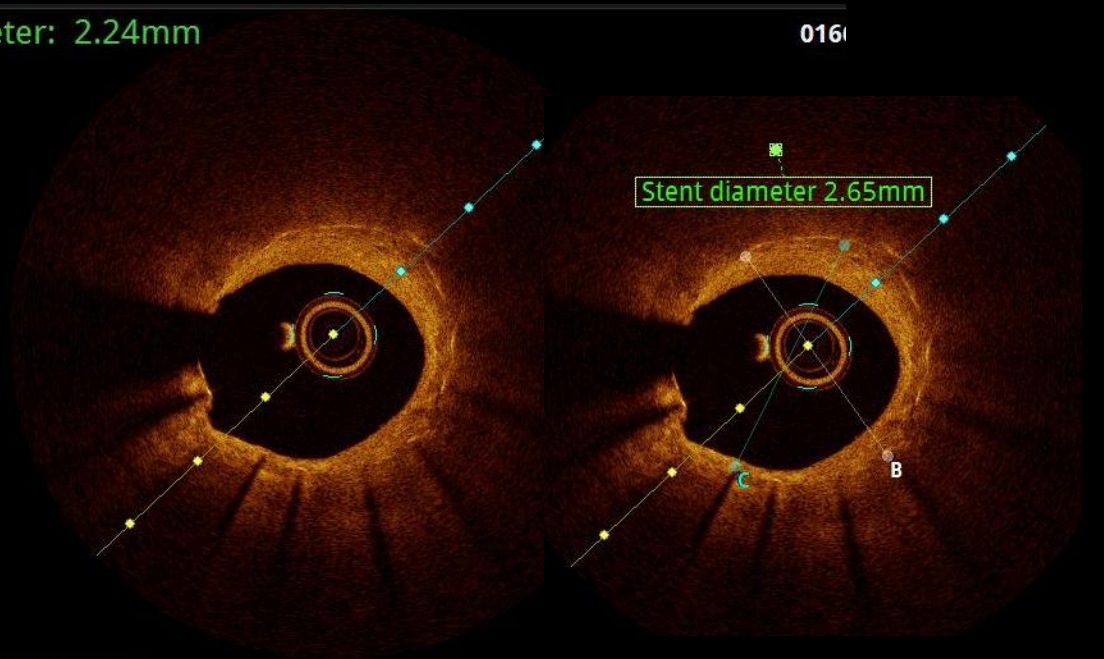


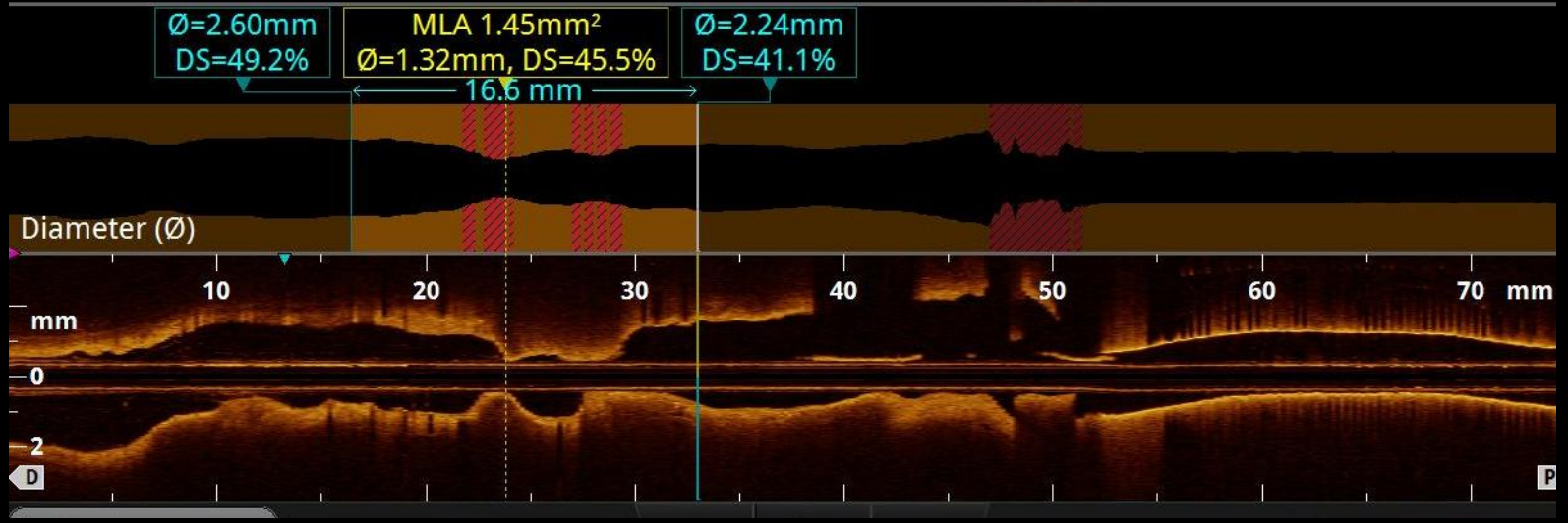


Distal side
diameter: 2.5mm
Stent length: 16mm

Acquisition – *Interpretation* – Reaction

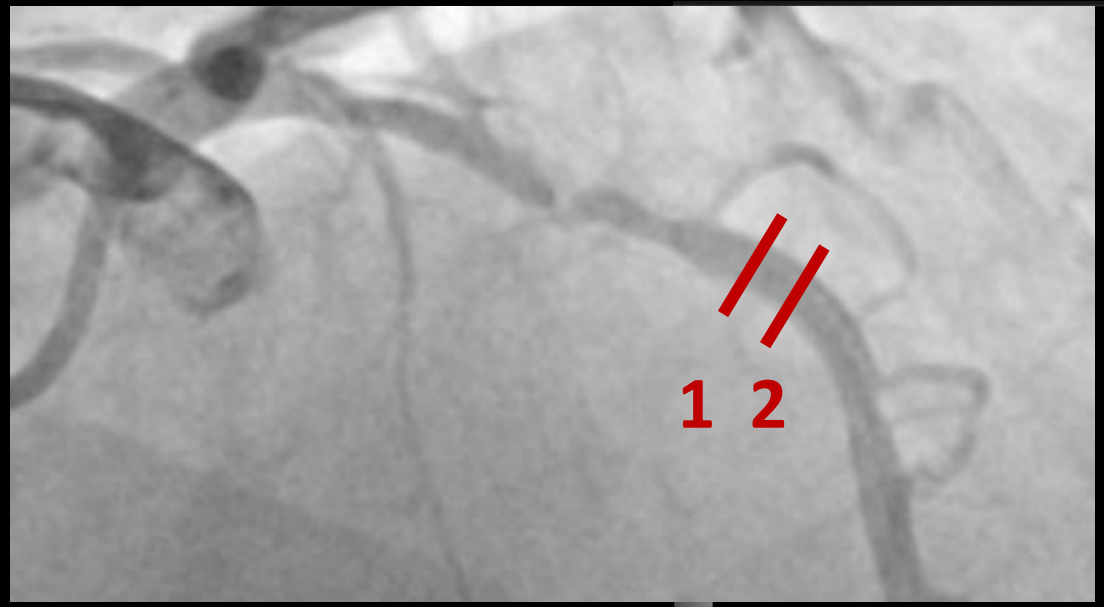
MLD MAX: length and diameter of previous stent, proximal

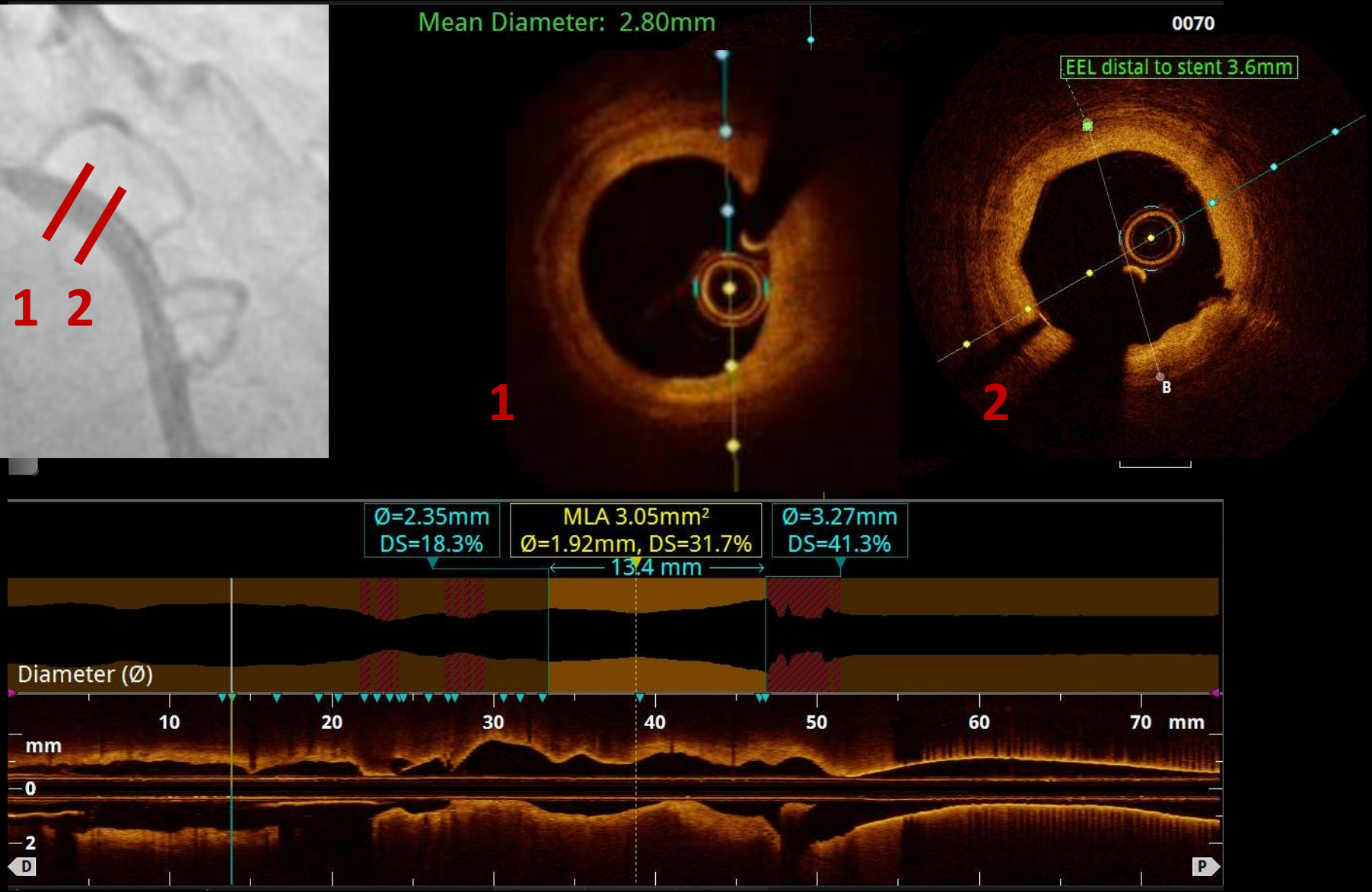




Proximal side diameter: 2.65mm
2.75x16mm stent (most likely)

MLD MAX: distal landing zone





Good distal landing zone:

1. Lumen: 2.8mm
2. EEL: 3.6mm

(previous stent: 2.75mm)

ESC European Society of Cardiology

European Heart Journal (2018) 0, 1–20
doi:10.1093/eurheartj/ehy285

FASTTRACK CLINICAL RESEARCH
Coronary artery disease

Clinical use of intracoronary imaging. Part 1: guidance and optimization of coronary interventions. An expert consensus document of the European Association of Percutaneous Cardiovascular Interventions

Endorsed by the Chinese Society of Cardiology

Lorenz Räber[1], Gary S. Mintz[2], Konstantinos C. Koskinas[1], Thomas W. Johnson[3], Niels R. Holm[4], Yoshinubo Onuma[5], Maria D. Radu[6], Michael Joner[7,8], Bo Yu[9], Haibo Jia[9], Nicolas Menevau[10,11], Jose M. de la Torre Hernandez[12], Javier Escaned[13], Jonathan Hill[14], Francesco Prati[15], Antonio Colombo[16], Carlo di Mario[17], Evelyn Regar[18], Davide Capodanno[19], William Wijns[20], Robert A. Byrne[21], and Giulio Guagliumi[22]*

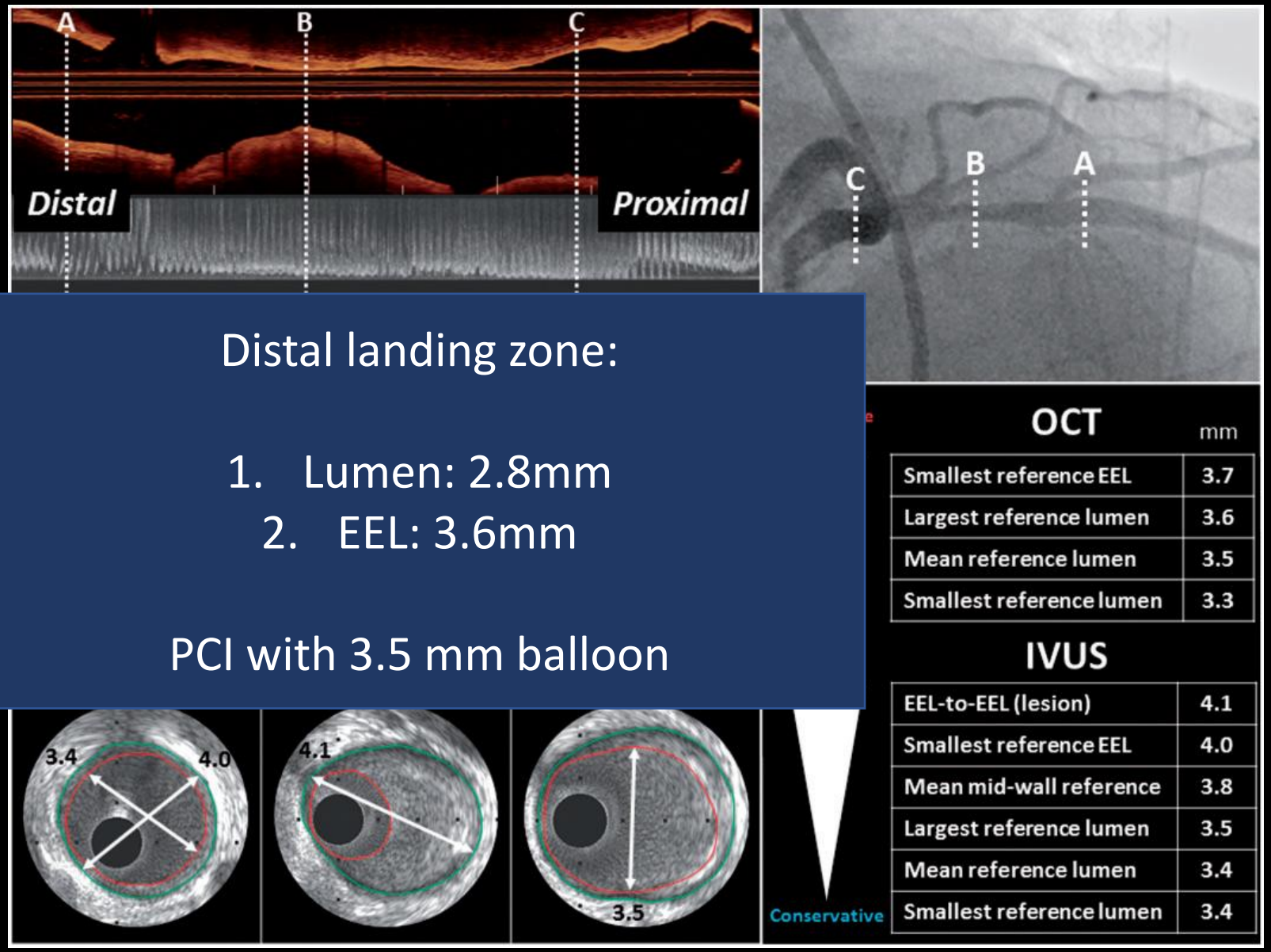
Coordinating editor: Prof Patrick W. Serruys, MD, PhD, Imperial College, London, UK

Document Reviewers: Fernando Alfonso[23], Ravinay Bhindi[24], Ziad Ali[25], Rickey Carter[26]

Raber et al. European Heart Journal (2018) 0; 1-20

EAPCI consensus

1. Distal lumen reference may represent a safe and straight forward approach for stent selection
2. Up round stent 0-0.25mm
3. Landing zones selection is crucial

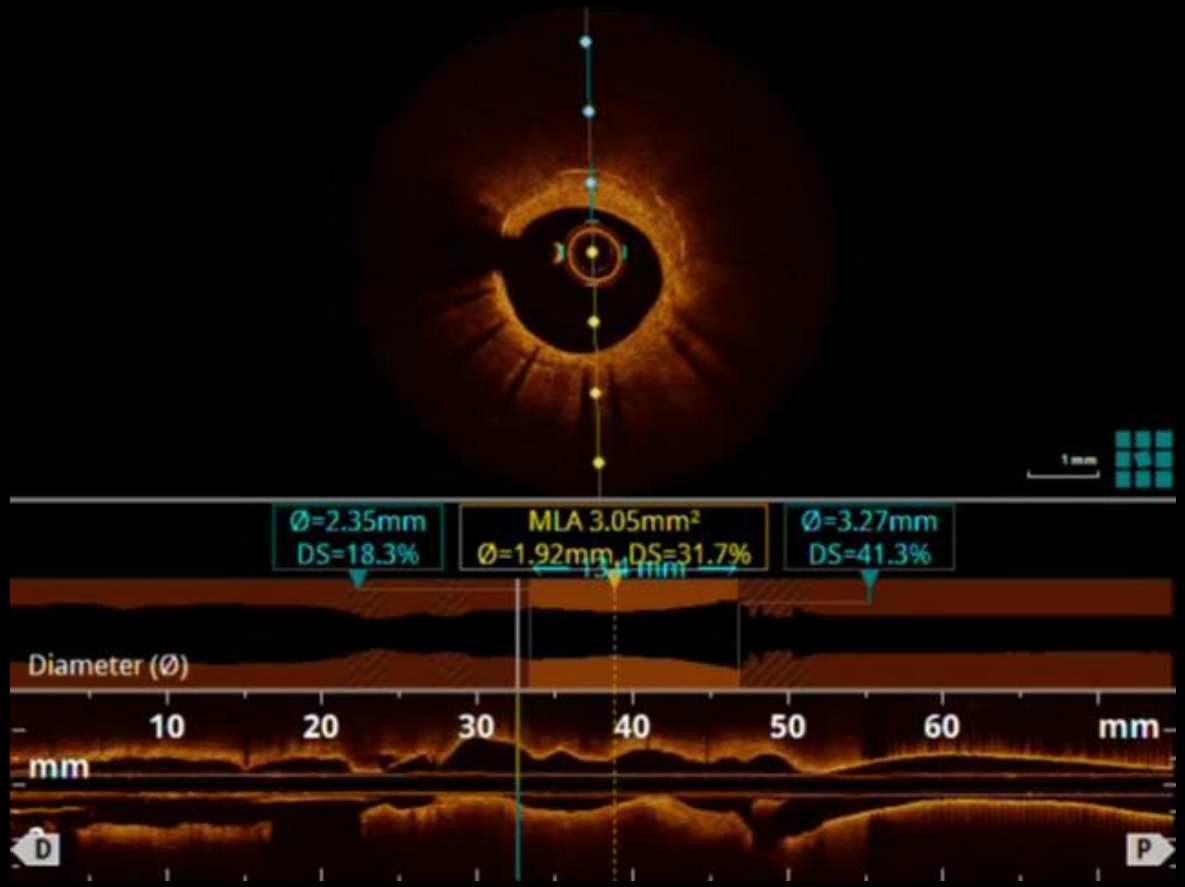


Raber et al. European Heart Journal (2018) 0; 1-20

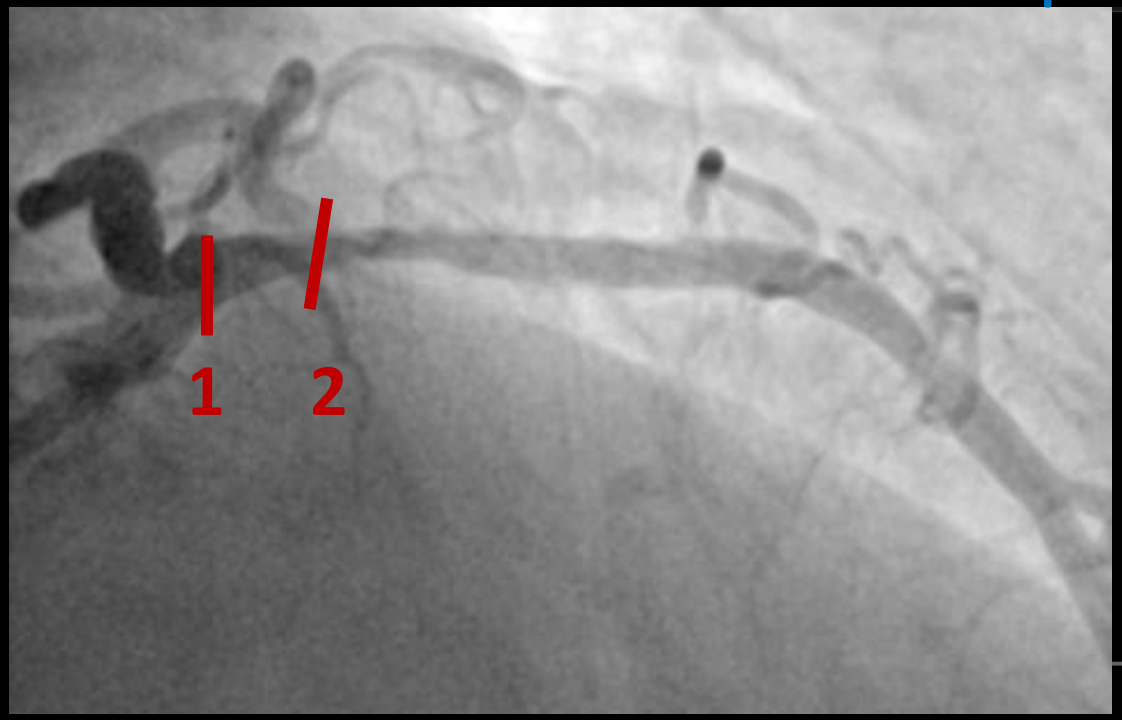
Angioplasty

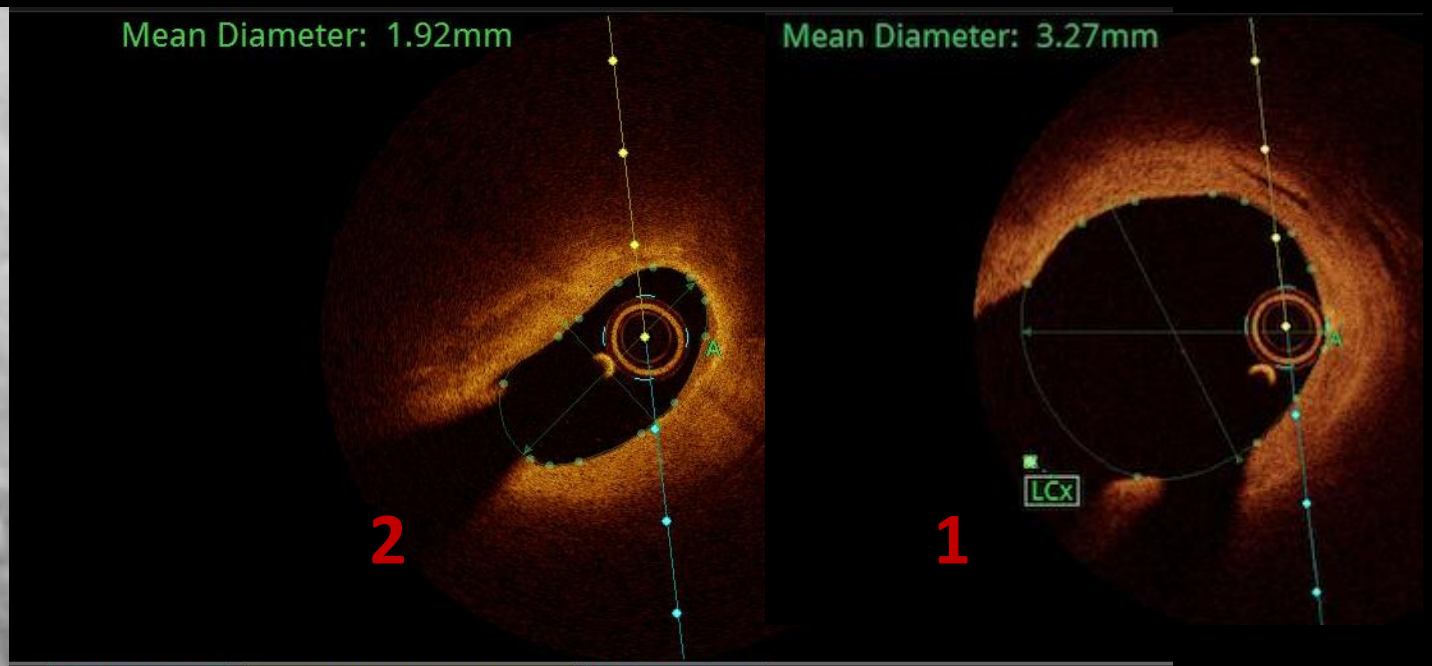
Stent predilation with 3.0x10mm NC balloon at 24 atm

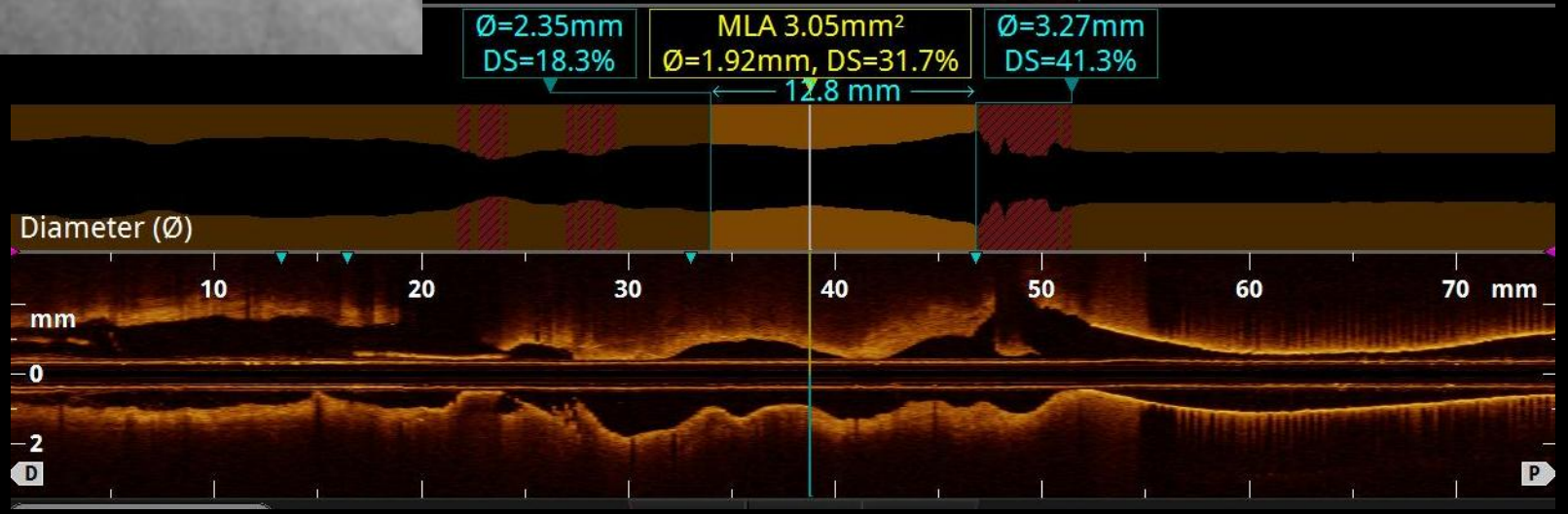
OCT of proximal LAD



MLD MAX: proximal lesion assessment





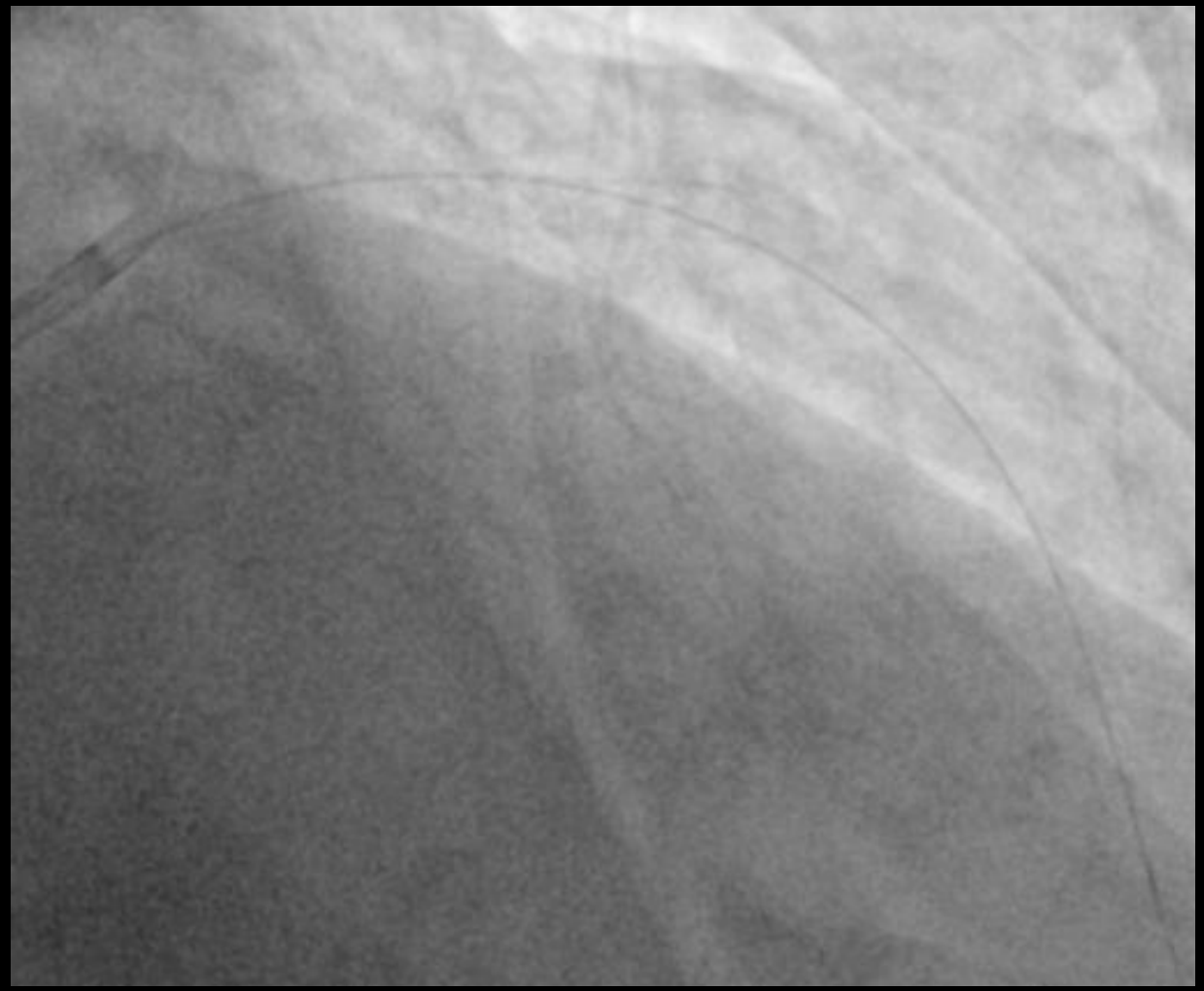


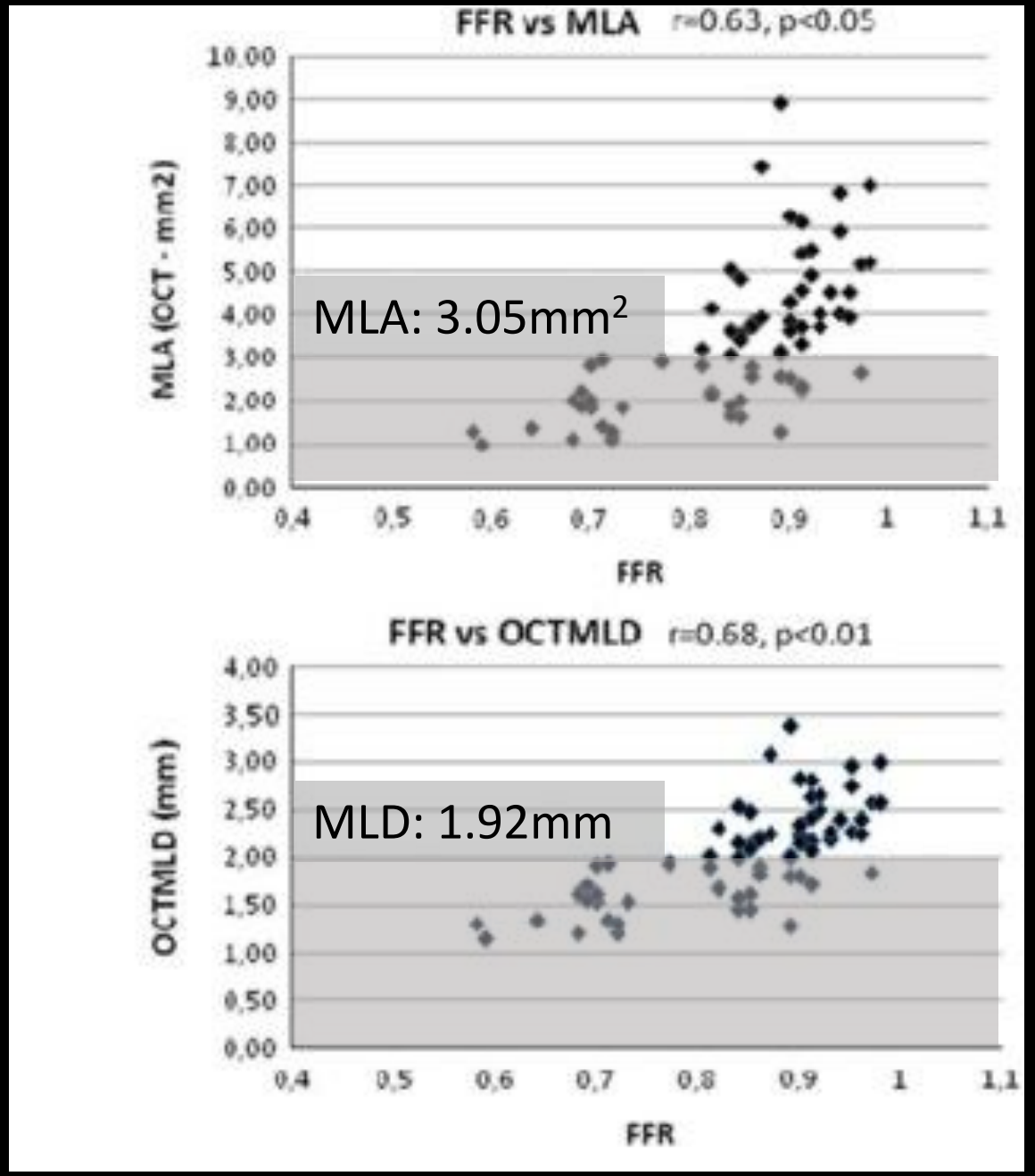
Proximal stenosis/landing zone

1. MLD: 1.92mm
2. MLA: 3.05mm^2

Acquisition – *Interpretation* – Reaction

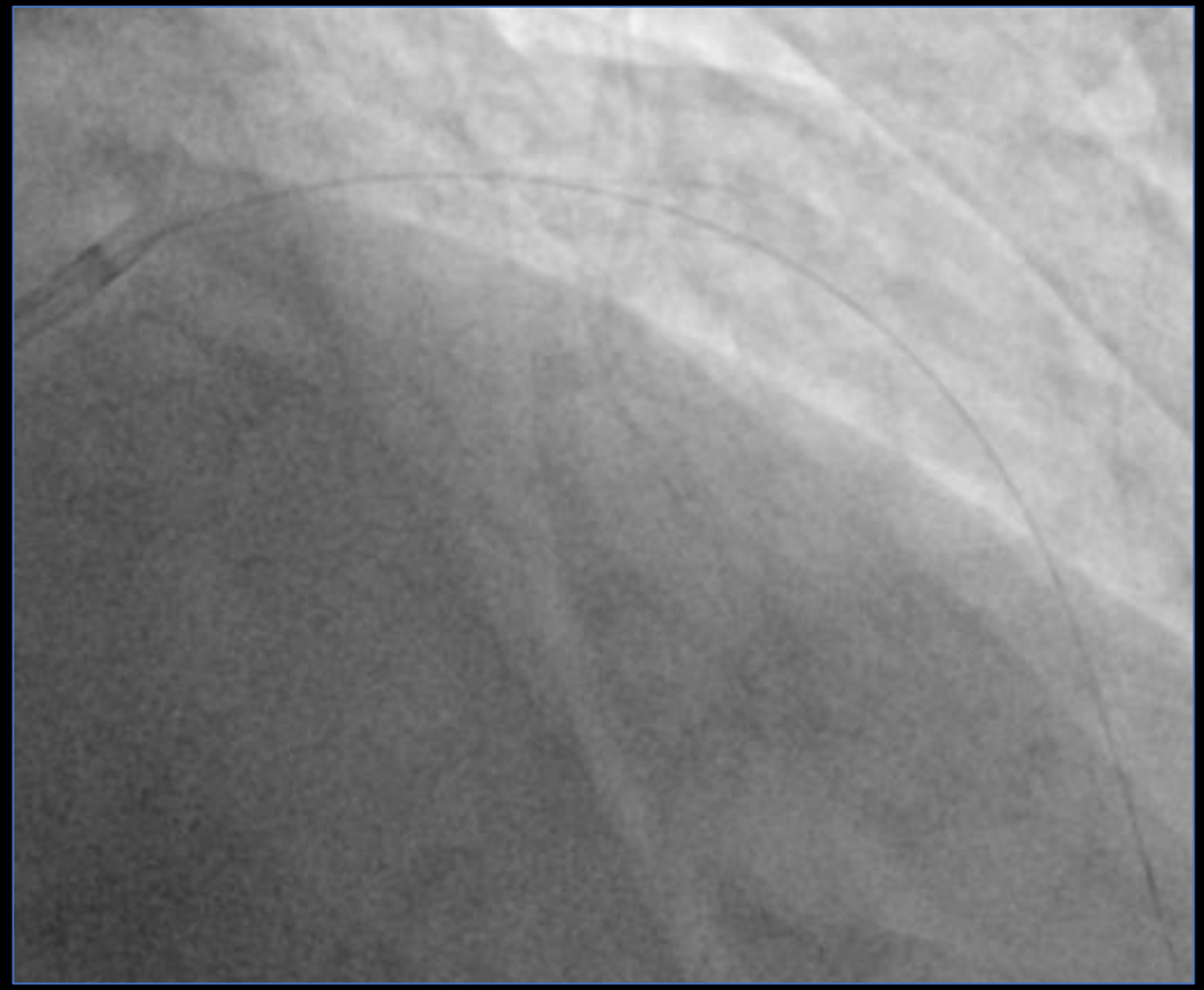
Proximal lesion assessment

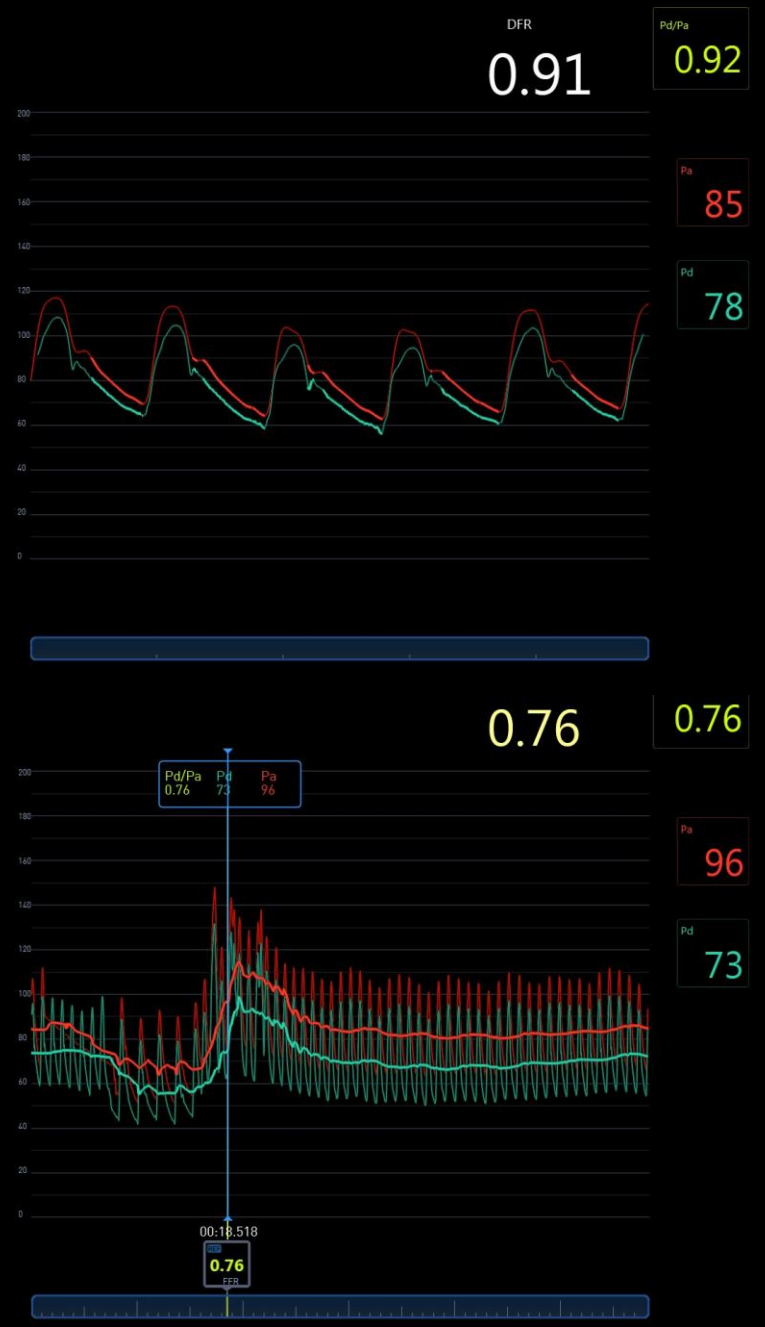




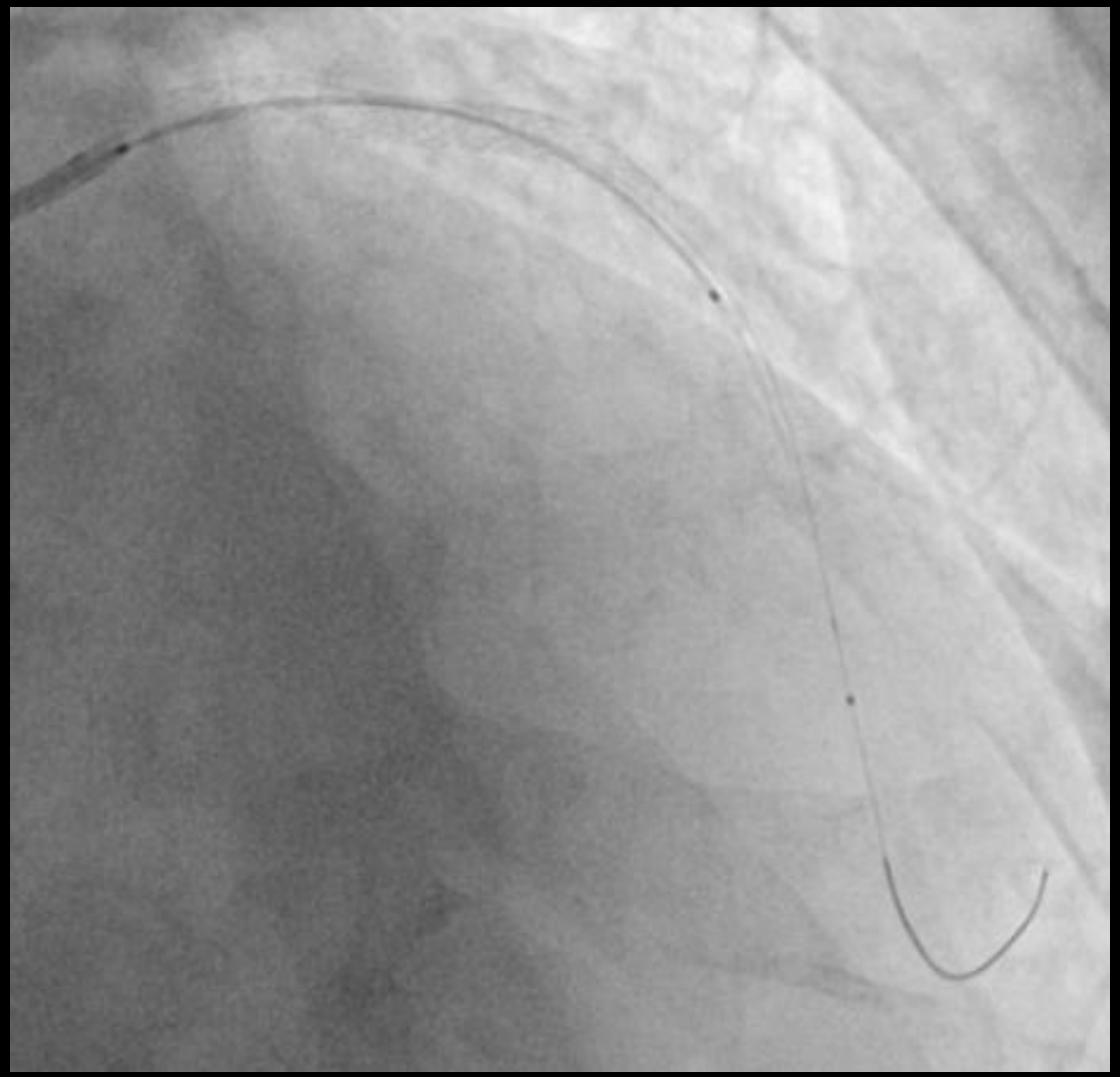
Palowsky et al. Int J Cardiovasc Imaging (2013) 29:1685–1691

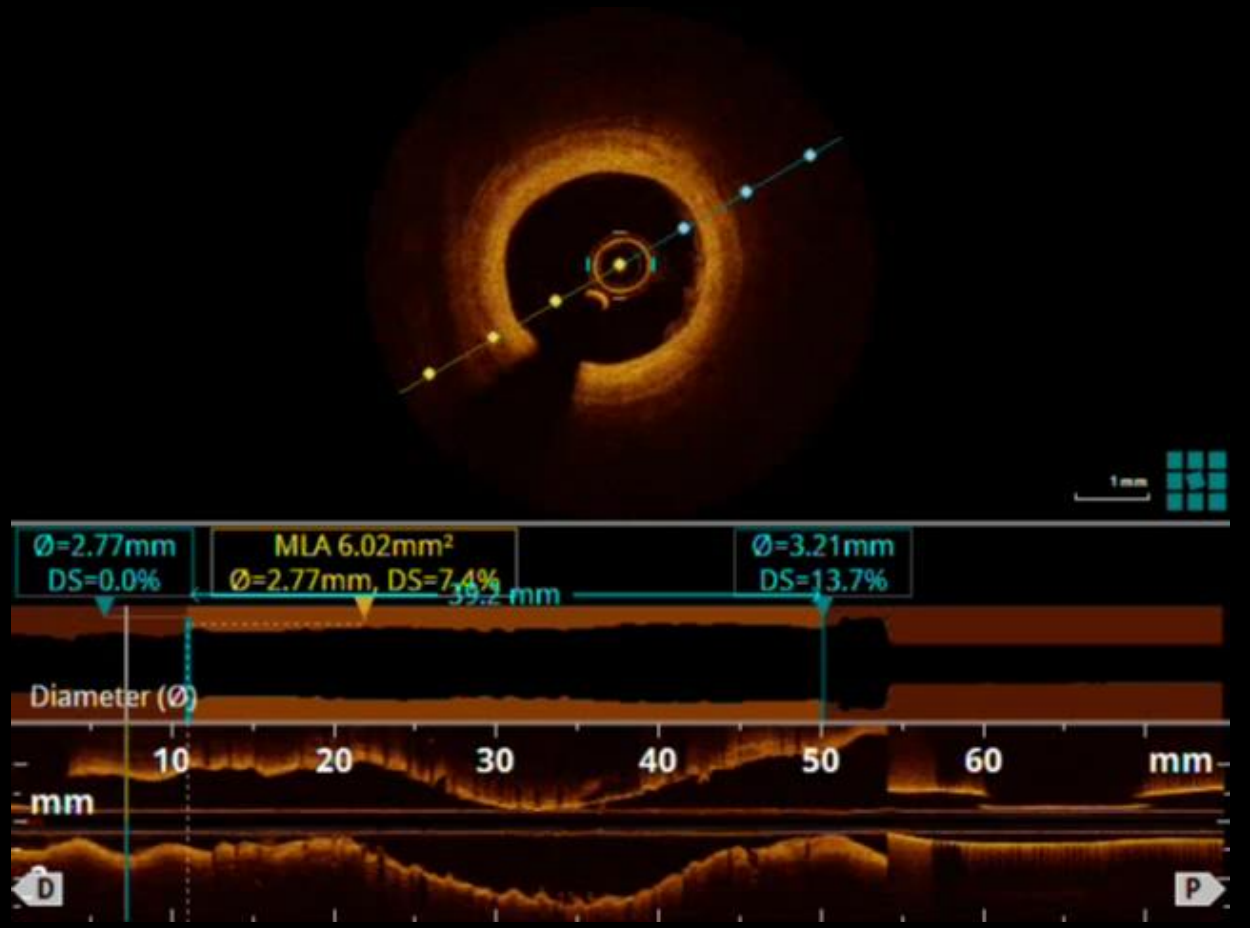
Proximal lesion assessment





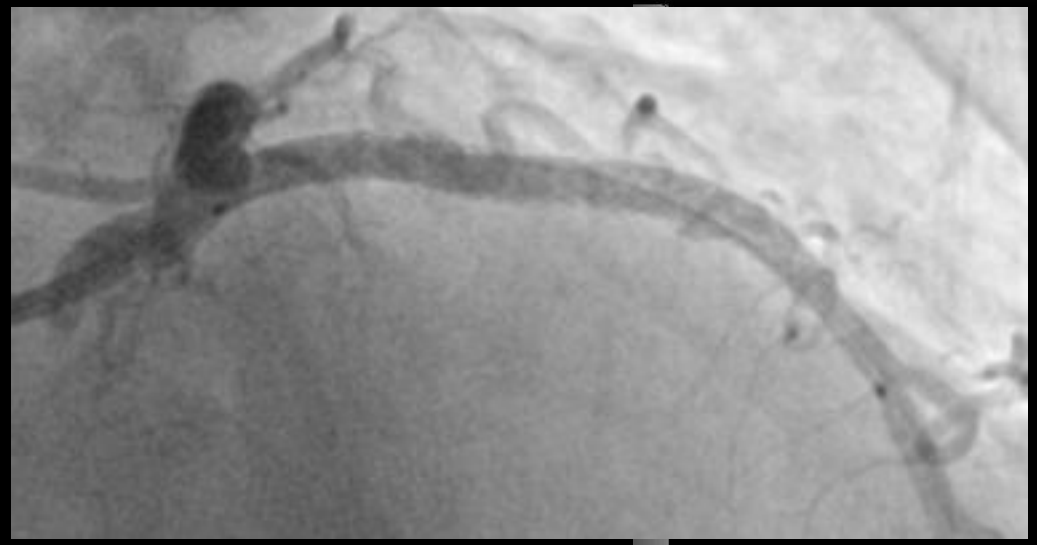
PCI with 3.5x38mm DES at 20 atm

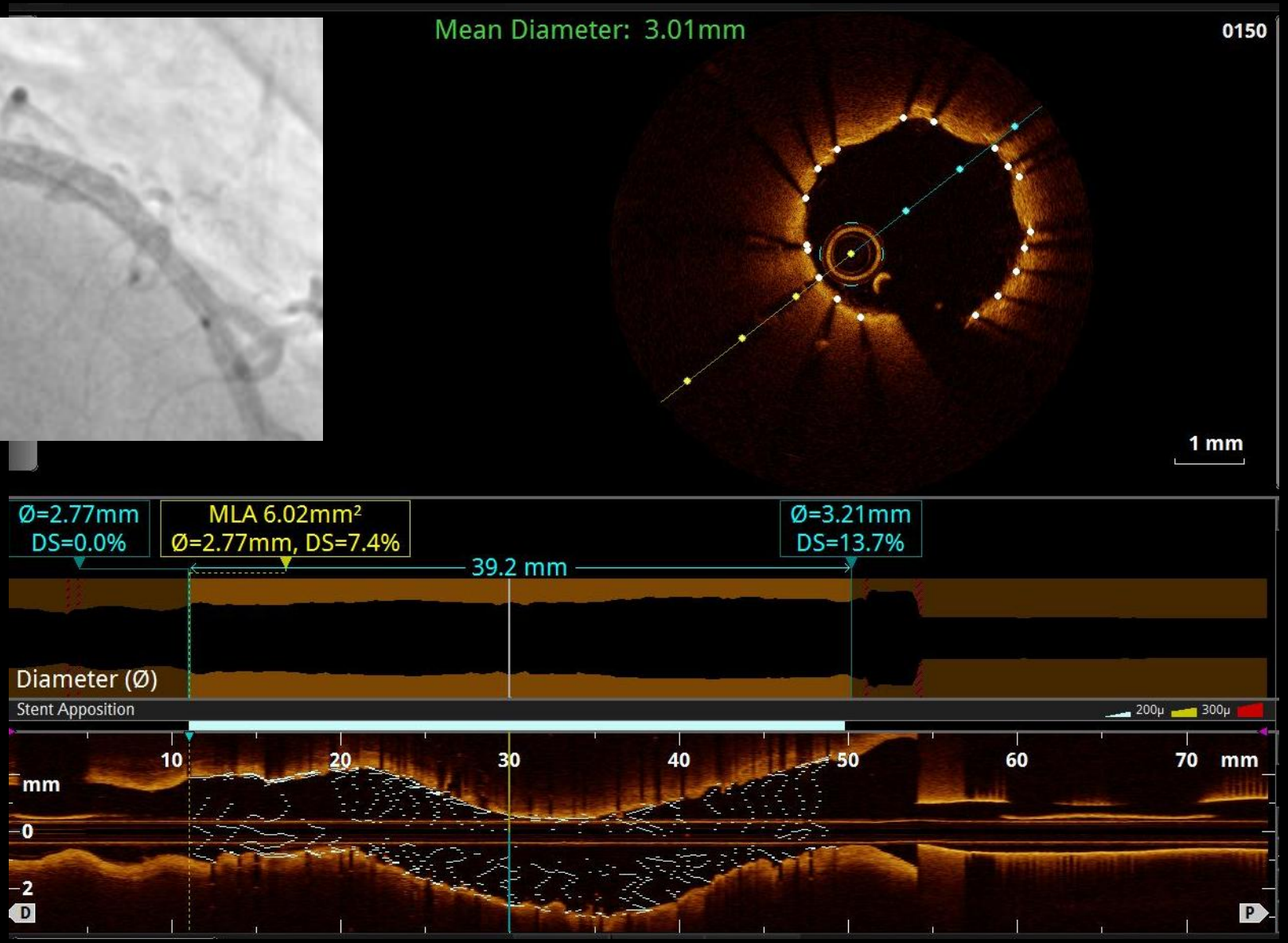




Acquisition – *Interpretation* – Reaction

MLD MAX: ok





1. Medial dissection: no
2. Apposition: ok
3. Stent expansion, conventional methodology: 92%

Intracoronary imaging is essential to understand and treat stent failure

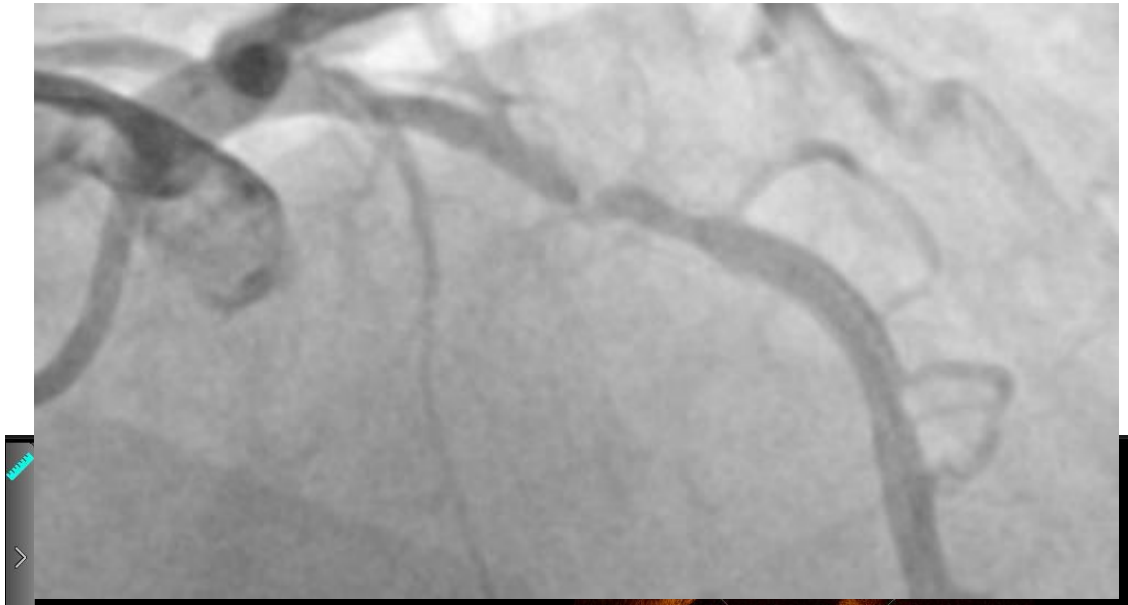
- I is the preferred technique to study in-stent restenosis and stent thrombosis

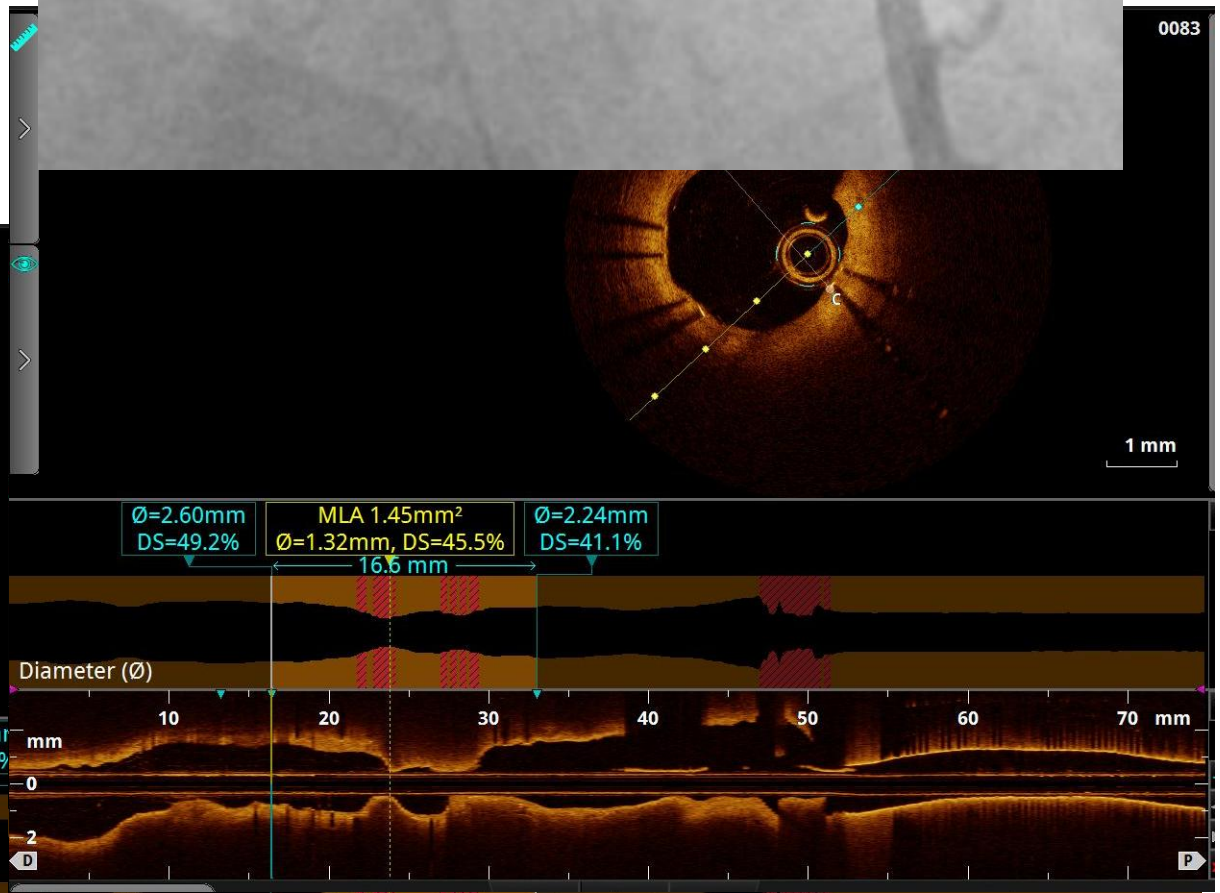
- Tailored treatment strategies based on the failure mechanism appear reasonable:

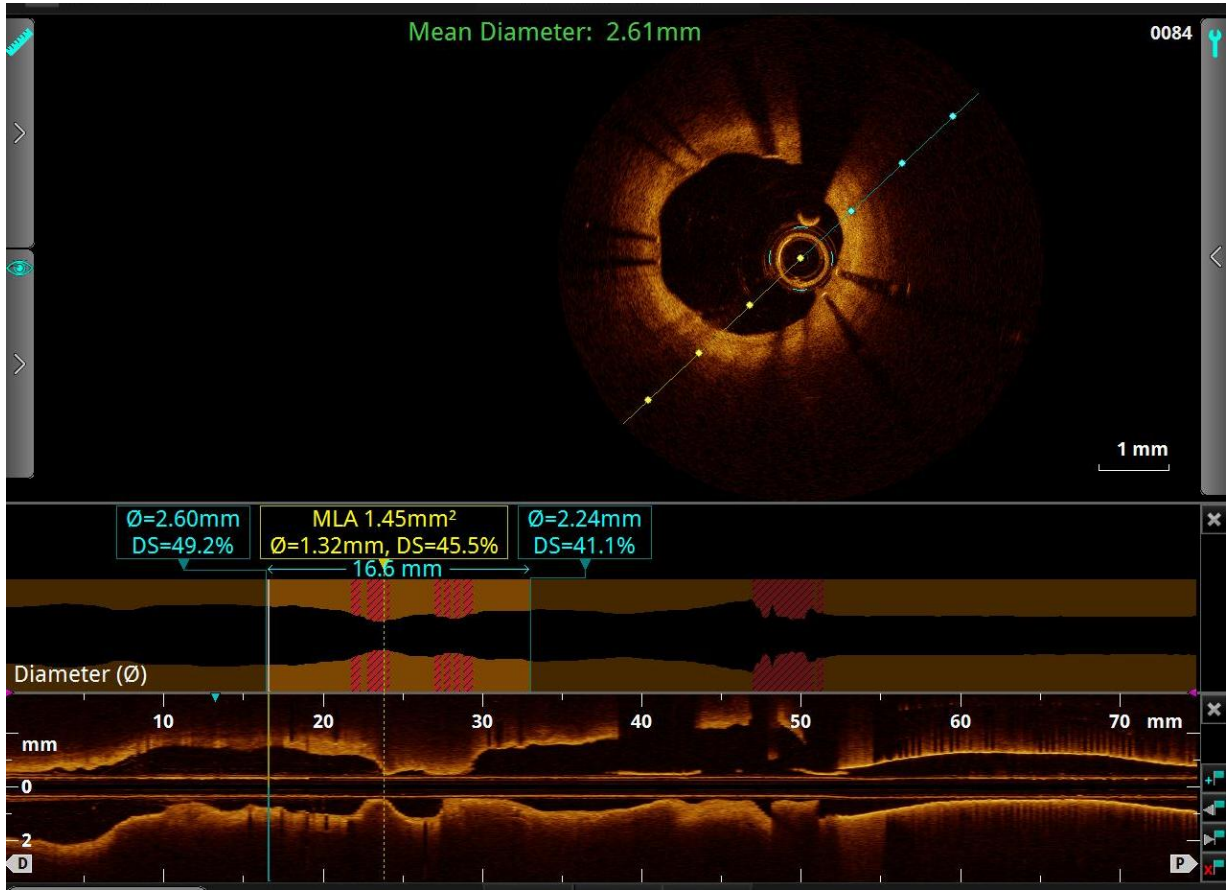
  - Postdilatation plus DCB only in case of malapposition/underexpansion-induced stent failure

  - Stent implantation in presence of neoatherosclerosis or mechanical stent failure

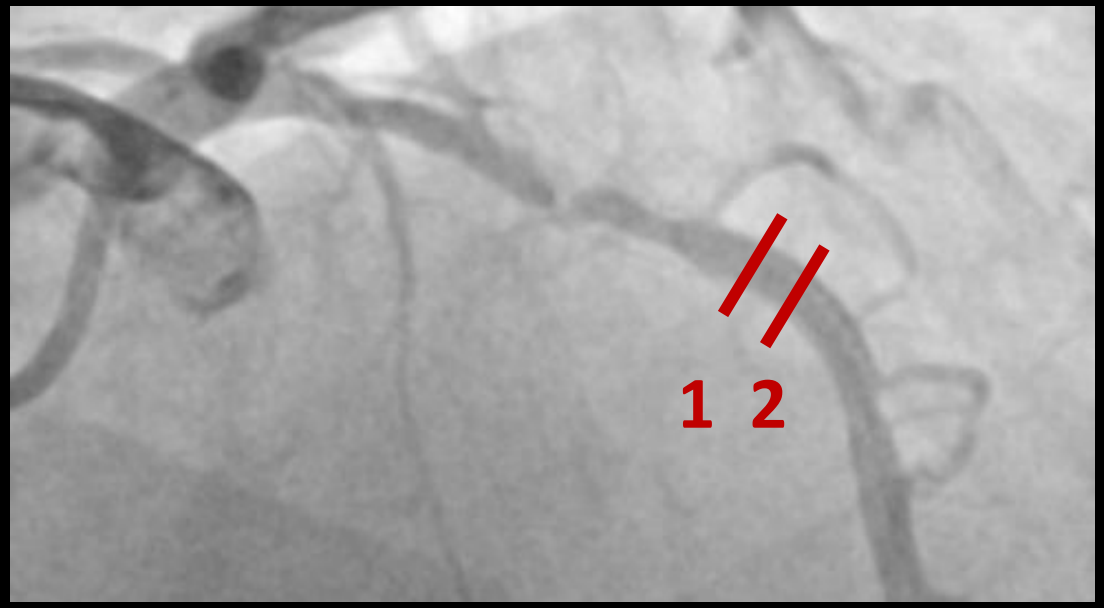
Raber et al. European Heart Journal (2018) 0; 1-20



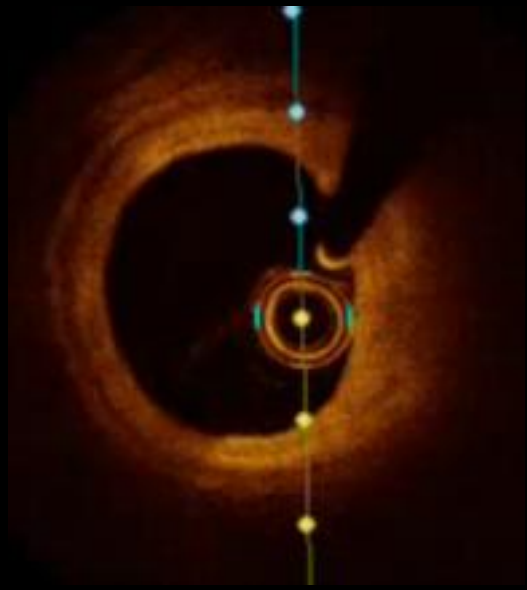

0083
1 mm
Ø=2.60mm
DS=49.2%
MLA 1.45mm²
Ø=1.32mm, DS=45.5%
Ø=2.24mm
DS=41.1%
16.6 mm
Diameter (Ø)
10
20
30
40
50
60
70 mm
mm
0
2
D
P


Mean Diameter: 2.61mm
0084
1 mm
Ø=2.60mm
DS=49.2%
MLA 1.45mm²
Ø=1.32mm, DS=45.5%
Ø=2.24mm
DS=41.1%
16.6 mm
Diameter (Ø)
10
20
30
40
50
60
70 mm
mm
0
2
D
P

MLD MAX: length and diameter



Distal landing zone



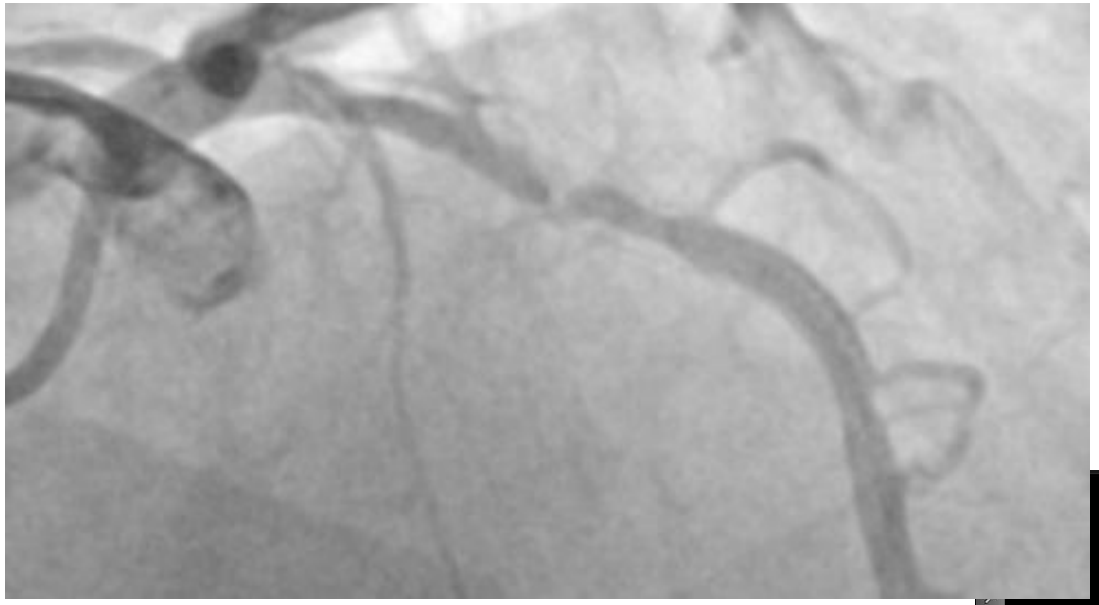
Good distal landing zone

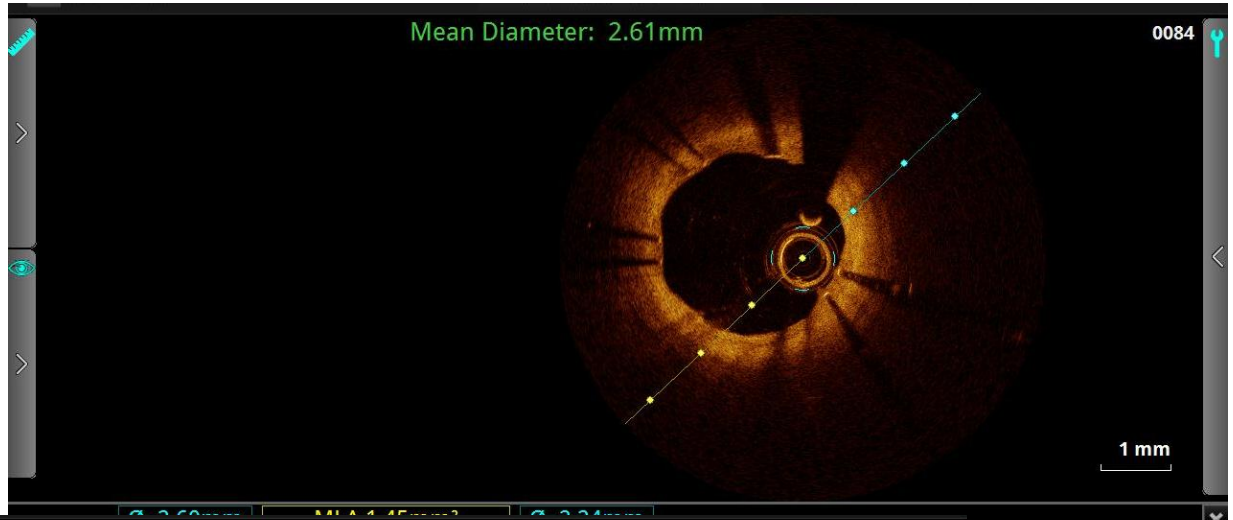
Distal landing zone:

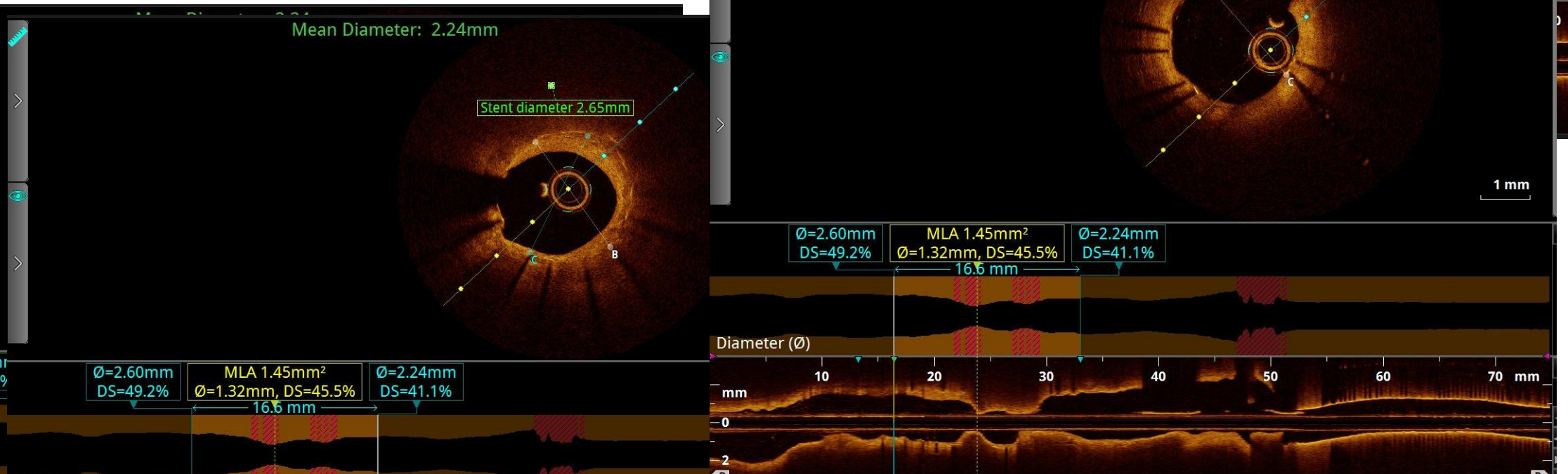
1. Lumen: 2.8mm
2. EEL: 3.6mm

(stent: 2.5mm)

PCI with 3.5 mm balloon




Mean Diameter: 2.61mm
0084
1 mm


Mean Diameter: 2.60mm
0083
Stent diameter 2.5mm
1 mm
Ø=2.60mm
DS=49.2%
MLA 1.45mm²
Ø=1.32mm, DS=45.5%
Ø=2.24mm
DS=41.1%
16.6 mm
Diameter (Ø)
10
20
30
40
50
60
70 mm
mm
0
2

Mean Diameter: 2.24mm
Stent diameter 2.65mm
Ø=2.60mm
DS=49.2%
MLA 1.45mm²
Ø=1.32mm, DS=45.5%
Ø=2.24mm
DS=41.1%
16.6 mm