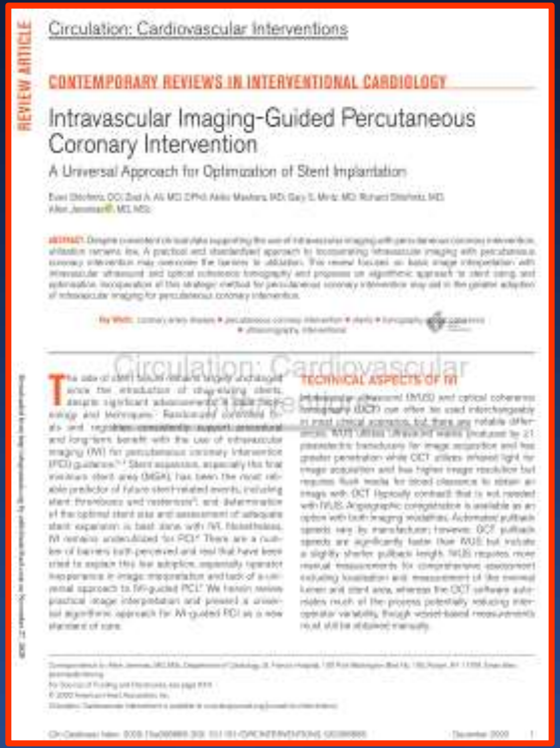
Intravascular Imaging-Guided PCI: A Universal Approach for Optimization of Stent Implantation



REVIEW ARTICLE

Circulation: Cardiovascular Interventions

CONTEMPORARY REVIEWS IN INTERVENTIONAL CARDIOLOGY

Intravascular Imaging-Guided Percutaneous Coronary Intervention

A Universal Approach for Optimization of Stent Implantation

TECHNICAL ASPECTS OF IVI

Education in Heart

Use of intracoronary imaging to guide optimal percutaneous coronary intervention procedures and outcomes

Gary S Mintz, Ziad Ali, Akiko Maehara

INTRODUCTION

IVUS versus OCT

Gary S. Mintz, MD

Cardiovascular Research Foundation

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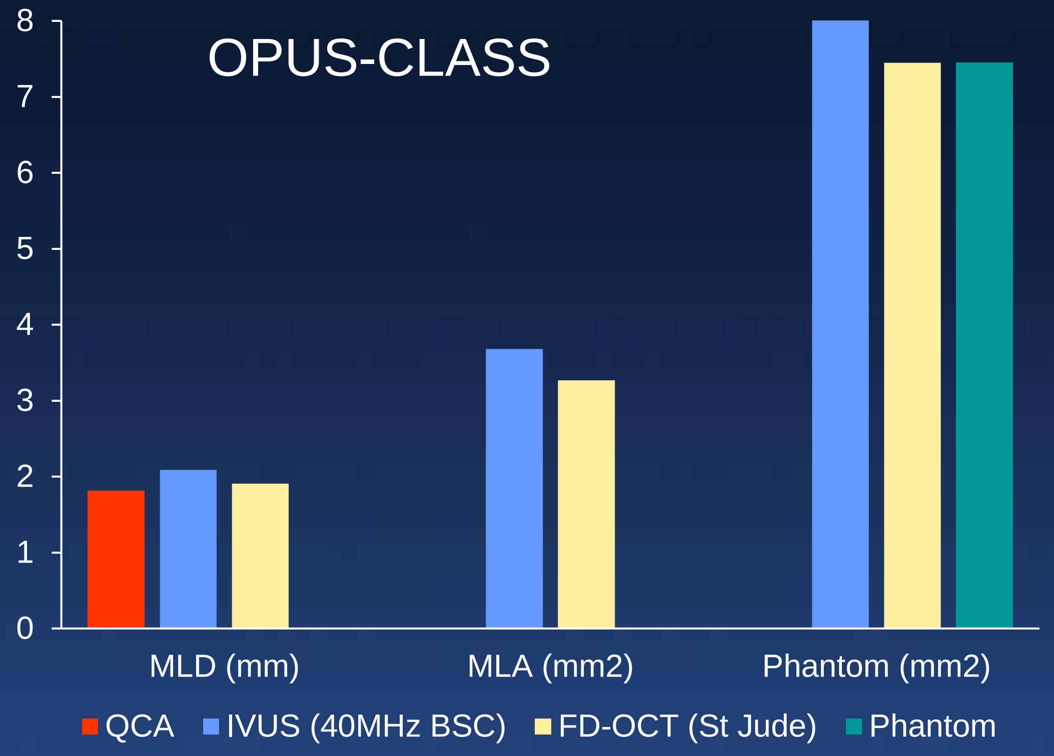
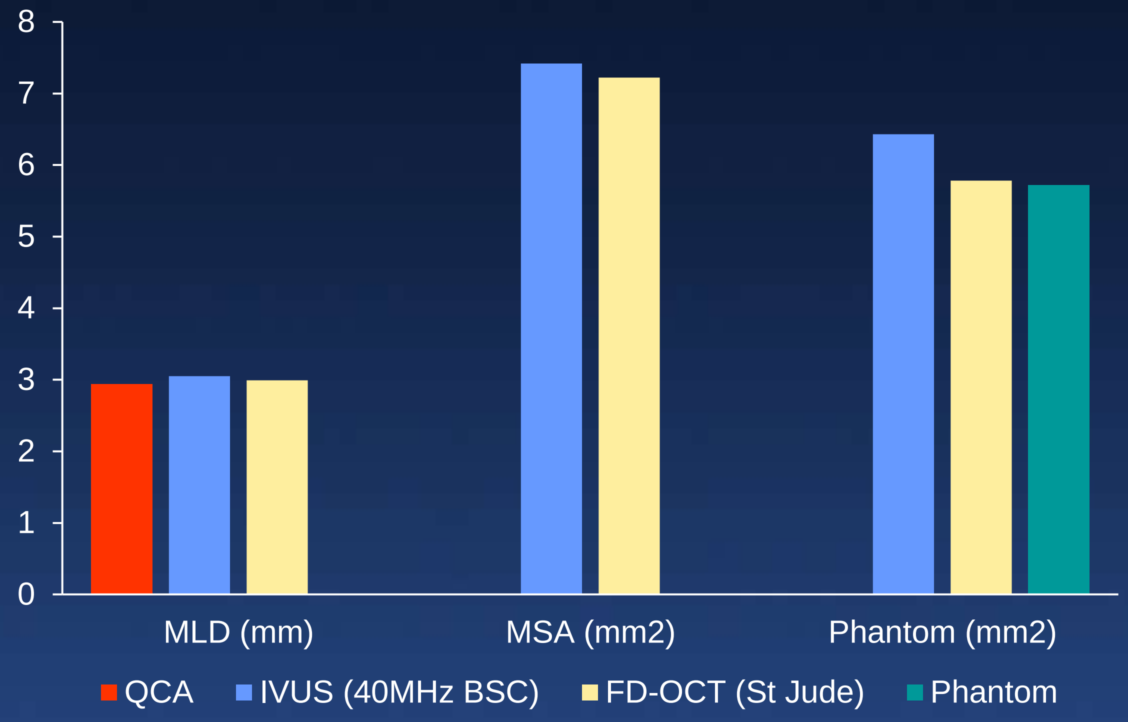
OCT vs IVUS vs QCA in Coronary Lesions and Phantoms





- IVUS-MLD - OCT-MLD = 0.18 mm
- QCA-MLD - OCT-MLD = -0.10 mm
- IVUS-MLA - OCT-MLA was significantly greater in non-stented vs stented segments (0.56 mm^2 vs. 0.25 mm^2; $p<0.007$).

- IVUS-MLA - OCT-MLA was significantly greater in non-stented vs stented segments (11.3% vs. 2.7%).

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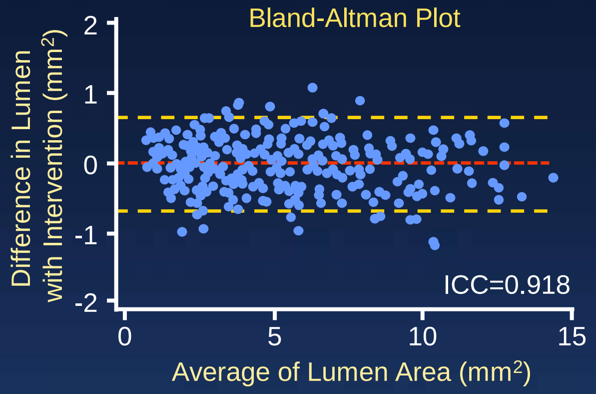
Kubo et al. JACC Cardiovasc Imaging 2013;6:1095-104
Kim et al. Int J Cardiol 2016;221:860-6

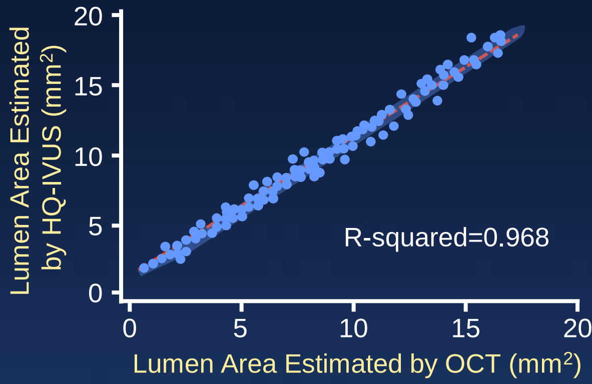
In vivo comparison of OCT vs HD-IVUS

- Pre-intervention. . .
  - no significant differences regarding proximal and distal reference lumen areas as well as in the assessment of MLA or lesion length.
  - Some lipid-predominant lesions on OCT were classified as fibrotic with HD-IVUS
  - OCT more frequently revealed the presence of plaque rupture or intraluminal thrombus
  - HD-IVUS enabled better visualization of the external elastic membrane

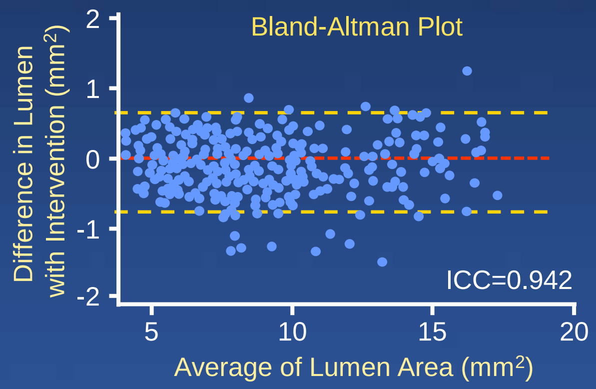
- Post-intervention. . .
  - HD-IVUS was comparable to OCT in the estimation of MSA
  - OCT more frequently detected the presence of tissue protrusion as well as both the number and percentage of malapposed struts
  - OCT more frequently identified the presence of stent-edge dissections

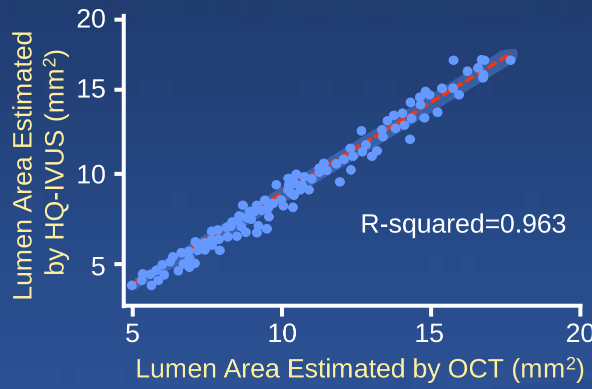
Pre-intervention





Post-intervention





Garcia-Guimaraes et al. JACC Cardiovasc Imaging. 2020;13:519-21

Predictors of DES Early ST, Restenosis, MACE, or DoCE

	IVUS		OCT
	Early ST	Restenosis/MACE	Restenosis/MACE/DoCE
Small MSA or underexpansion in stable lesions Small MLA in ACS/MI lesions	•Fujii et al. J Am Coll Cardiol 2005;45:995-8 •Okabe et al. Am J Cardiol. 2007;100:615-20 •Liu et al. JACC Cardiovasc Interv. 2009;2:428-34 •Choi et al. Circ Cardiovasc Interv 2011;4:239-47	•Sonoda et al. J Am Coll Cardiol 2004;43:1959-63 •Hong et al. Eur Heart J 2006;27:1305-10 •Doi et al JACC Cardiovasc Interv. 2009;2:1269-75 •Fujii et al. Circulation 2004;109:1085-1088 •Kang et al. Circ Cardiovasc Interv 2011;4:9-14 •Choi et al. Am J Cardiol 2012;109:455-60 •Song et al. Catheter Cardiovasc Interv 2014;83:873-8 •Kang et al. PLoS One 2015;10(10):e0140421 •Hong et al. JAMA 2015;314(:2155-63. •Lee et al. Rev Esp Cardiol 2017;70:88-95 •Katagiri et al. Catheter Cardiovasc Interv. 2019 Jan 31. doi: 10.1002/ccd.28105. •Kim et al. EuroIntervention. 2019 Dec 10. pii: EIJ-D-19-00762. •Park et al. JACC Cardiovasc Interv 2020;13:1403-13 •Ladwiniec et al. EuroIntervention 2020;16:201-9 •Sugane et al. Atherosclerosis, in press	•Prati et al. JACC Cardiovasc Imaging 2015;8:1297-305 •Prati et al. Circ Cardiovasc Interv. 2016;9. pii: e003726. •Soeda et al. Circulation 2015;132:1020-9 •Matsuo et al. Cathet Cardiovasc Interv 2015;87:E9-14 •Prati et al. EuroIntervention 2018;14:e443-e451 •Katsura et al. Catheter Cardiovasc Interv 2020: 10.1002/ccd.28871
Edge problems (geographic miss, secondary lesions, large plaque burden, dissections, etc)	•Fujii et al. J Am Coll Cardiol 2005;45:995-8 •Okabe et al., Am J Cardiol. 2007;100:615-20 •Liu et al. JACC Cardiovasc Interv. 2009;2:428-34 •Choi et al. Circ Cardiovasc Interv 2011;4:239-47	•Sakurai et al. Am J Cardiol 2005;96:1251-3 •Liu et al. Am J Cardiol 2009;103:501-6 •Costa et al, Am J Cardiol, 2008;101:1704-11 •Kang et al. Am J Cardiol 2013;111:1408-14 •Kobayashi et al. Circ Cardiovasc Interv. 2016;9:e003553 •Calvert et al. Catheter Cardiovasc Interv 2016;88:340-7 •Park et al. JACC Cardiovasc Interv 2020;13:1403-13	•Prati et al. JACC Cardiovasc Imaging 2015;8:1297-305 •Prati et al. Circ Cardiovasc Interv. 2016;9. pii: e003726. •Ino et al. Circ Cardiovasc Interv. 2016;9:e004231 •Prati et al. EuroIntervention 2018;14:e443-e451 •van Zandvoort et al. Circ Cardiovasc Interv. 2020;13:e008685
Protrusion in ACS/MI Irregular Protrusion	•Choi et al. Circ Cardiovasc Interv 2011;4:239-47 •Hong et al. Int J Cardiol 2013;168:1674-5		•Prati et al. Circ Cardiovasc Interv. 2016;9. pii: e003726. •Soeda et al. Circulation 2015;132:1020-9
Stent length (>40mm)		•Hong et al. Eur Heart J 2006;27:1305-10	
Asymmetry/Eccentricity		•Suwannasom et al. JACC Cardiovasc Interv 2016;9:1231-42 (not significant at long term follow-up: JACC Cardiovasc Interv 2018;11:1013-5)	
Acute malapposition			•Souteyrand et al. Eur Heart J. 2016;37:1208-16

Acute malapposition is detected in 14% by IVUS and 50% by OCT after routine stenting

	Study	#	IVUS	OCT
Hong et al. Circulation. 2006;113:414-9	AMC	683	7%	
Steinberg et al. JACC Cardiovasc Interv 2010;3:486-94	Combined TAXUS	1200	8%	
Guo et al. Circulation 2010;122:1077-84	HORIZONS-AMI	263	36%	
Kang et al. Circ Cardiovasc Interv 2011;4:562-9.		403	7%	
Van der Hoven et al. JACC Cardiovasc Interv 2008;1:192-201	MISSION-AMI	184	35%	
Bezerra et al. JACC Cardiovasc Interv 2013;6:228-36		26	42%	96%
Kubo et al. JACC Cardiovasc Imaging 2013;6:1095-1104	OPUS-CLASS	100	14%	39%
Im et al. Circ Cardiovasc Interv 2014;7:88-96		356		62%
Kawamori et al. EHJ Cardiovasc Imaging 2013;14:865-75		40		65%
Shimamura et al. EHJ Cardiovasc Imaging 2015;16:23-8		77		100%
Soeda et al. Circulation 2015;132:1020-9		1001		39%
Prati et al. JACC Cardiovasc Imaging 2015;8:1297-305	CLI-OPCI-II	1002		49%
Bernelli et al. Circ J 2016;80:895-905	OCTAVIA	114		72%
Kim et al. J Interv Cardiol 2016;29:216-24		122		48%
		168	37%	
Wang et al. J Am Heart Assoc. 2016;5. pii: e004438. doi: 10.1161	ADAPT-DES	2430	13%	
Prati et al. Circ Cardiovasc Interv. 2016;9. pii: e003726	CLI-OPCI ACS	588		48%
Ali et al. Lancet. 2016;388:2618-28	ILUMIEN III	304		36%
		146	18%	
Agarwal et al. Catheter Cardiovasc Interv 2017;90:225-232		110		75%
Lee et al. Circ Cardiovasc Interv. 2018;11:e007192	DETECT-OCT	390		45%
Ladwiniec et al. Eurointervention 2020;16:201-9	NOBLE	224	5%	
Overall			**14%**	**50%**

Events related to acute stent malapposition (6426 pts)

	Study		F-U	Acute malapposition	No acute malapposition
Steinberg et al. JACC Cardiovasc Interv 2010;3:486-94	**Combined TAXUS**	**IVUS**	**9 mos**	8.2% MACE	10.7% MACE
Van der Hoeven et al. JACC Cardiovasc Interv 2008;1:192-201	**MISSION-AMI**	**IVUS**	**9 mos**	0% ST	0% ST
Guo et al. Circulation 2010;122:10-77-84	**HORIZONS-AMI**	**IVUS**	**13 mos**	0% ST	0% ST
Soeda et al. Circulation 2015;132:1020-9		**OCT**	**1 yr**	4.4% DoCE	4.8% DoCE
Prati et al. JACC Cardiovasc Imaging 2015;8:1297-305	**CLI-OPCI-II**	**OCT**	**1 yr**	13% MACE	10% MACE
Wang et al. J Am Heart Assoc. 2016;5. pii: e004438. doi: 10.1161	**ADAPT-DES**	**IVUS**	**2 yrs**	5.2% MACE (0.65% ST)	4.5% MACE (0.43% ST)
Prati et al. Circ Cardiovasc Interv. 2016;9. pii: e003726.	**CLI-OPCI-ACS**	**OCT**	**9 mos**	12.8% MACE	12.4% MACE
Ladwiniec et al. Eurointervention 2020;16:201-9	**NOBLE**	**IVUS**	**5 yrs**	33% MACCE (8% mortality, 0% ST)	21% MACCE (6% mortality, 1% ST)

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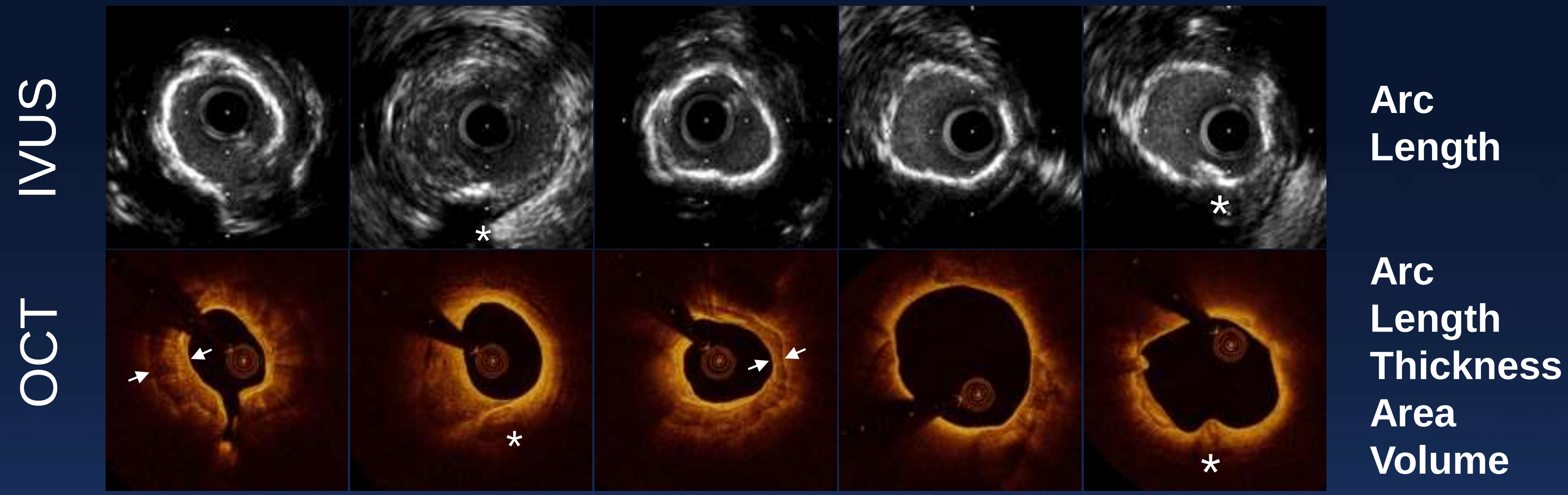

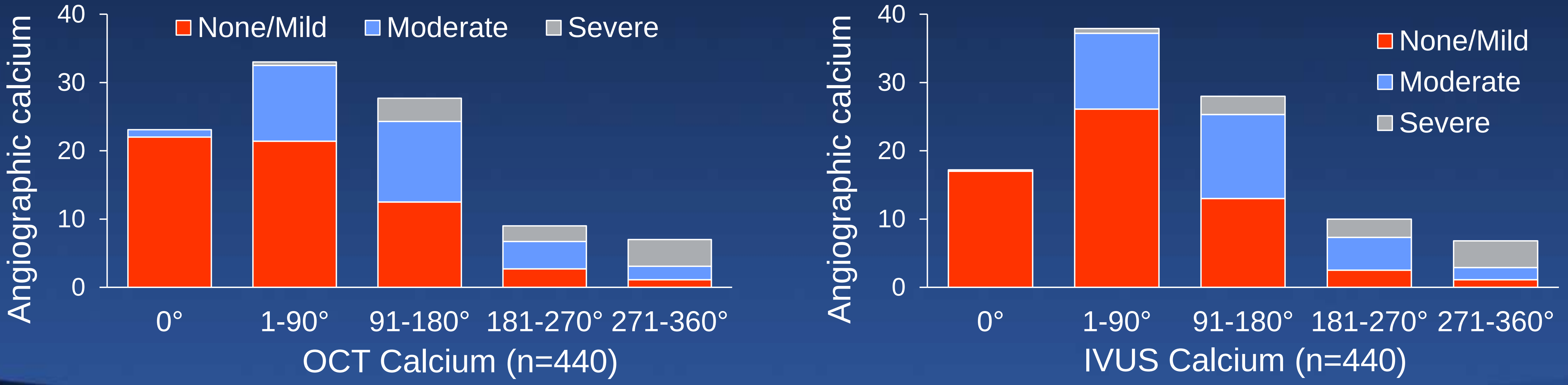

Wang et al. JACC Cardiovasc Imaging 2017;10:869-79
Mintz and Guagliumi. Lancet 2017;390:793-809

OCT calcium scoring system predicting stent expansion

Test cohort of 128 pts						
	Regression Coefficient	95% CI	P-value	Calcium Score		
Maximum calcium angle (per 180°)	-7.43	-12.6 to -2.21	<0.01	Maximum calcium angle	≤180°	0
					>180°	2
Maximum calcium thickness (per 0.5 mm)	-3.40	-6.35 to -0.45	0.02	Maximum calcium thickness	≤0.5mm	0
					>0.5mm	1
Calcium length (per 5 mm)	-3.32	-4.09 to -0.55	0.01	Calcium length	≤5mm	0
					>5mm	1

Validation cohort of 133 pts						
Score	0 (n=27)	1 (n=45)	2 (n=34)	3 (n=3)	**4 (n=24)**	P-value
MSA, mm^2	7.2 (5.4, 9.2)	6.3 (5.2, 8.4)	5.9 (4.8, 8.0)	6.7 (5.8, 7.1)	**5.7 (4.4, 7.4)**	0.21
Stent expansion at target lesion calcium, %	99 (93, 108)	98 (86, 109)	86 (77, 100)	98 (83, 104)	**78 (70, 86)**	<0.01
Stent expansion at MSA, %	91 (84, 95)	85 (78, 93)	80 (73, 93)	80 (73, 85)	**69 (60, 77)**	<0.01

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Fujino et al. EuroIntervention 2018;13(18):e2182-e2189

IVUS calcium score predicting stent expansion (as a continuous variable) in lesions with calcium >270°

Test cohort of 97 pts						
	Regression Coeff	95% CI	P-value	Cut-off	Calcium Score	
Length of calcium >270° (per 5mm)	-5.5	-9.7, -1.2	0.01	5.0	≤5mm	0
					>5mm	1
Calcium Nodule	-10.2	-16.3 to -4.2	0.0009		absent	0
					present	1
Vessel diameter (per 1mm)	8.6	2.7 to 14.4	0.004	3.5	>3.5mm	0
					≤3.5mm	1
Circumferential calcium	-14.3	-25.0 to -3.5	0.009		absent	0
					present	1

Stent underexpansion (<70%) in the validation cohort of 97 pts						
	Cut-off	C-statistics	Sensitivity	Specificity	PPV	NPV
Score	≥2	0.85 [0.77, 0.93]	89%	63%	48%	94%

In 67 lesions without angiographically visible calcium, but with a maximum IVUS angle of superficial calcium >270°, there were none with a calcium score of 4 and only 1 with stent underexpansion.

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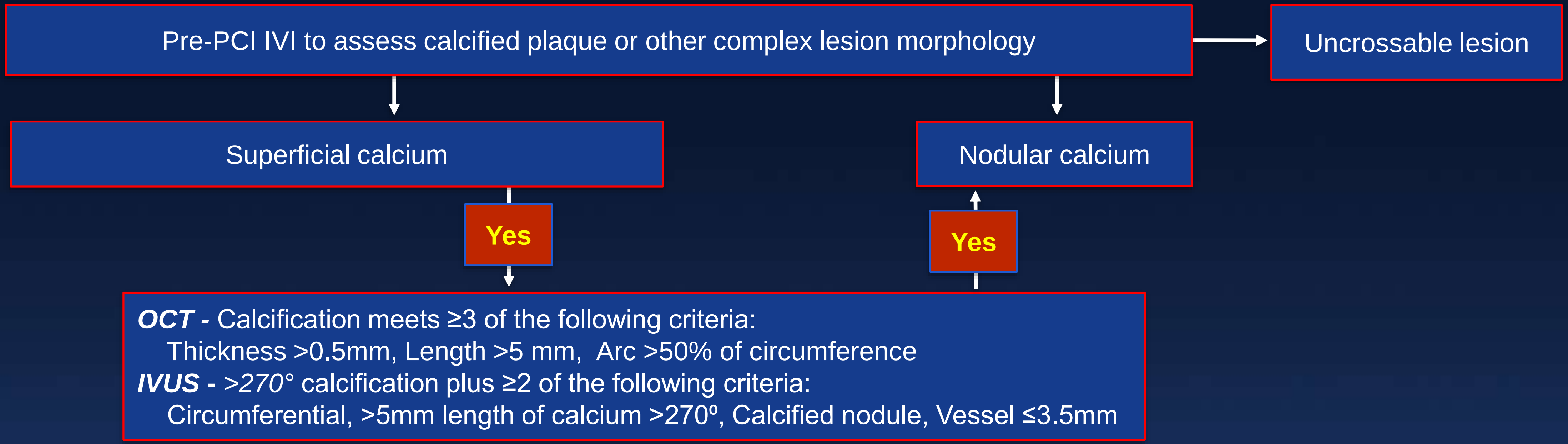
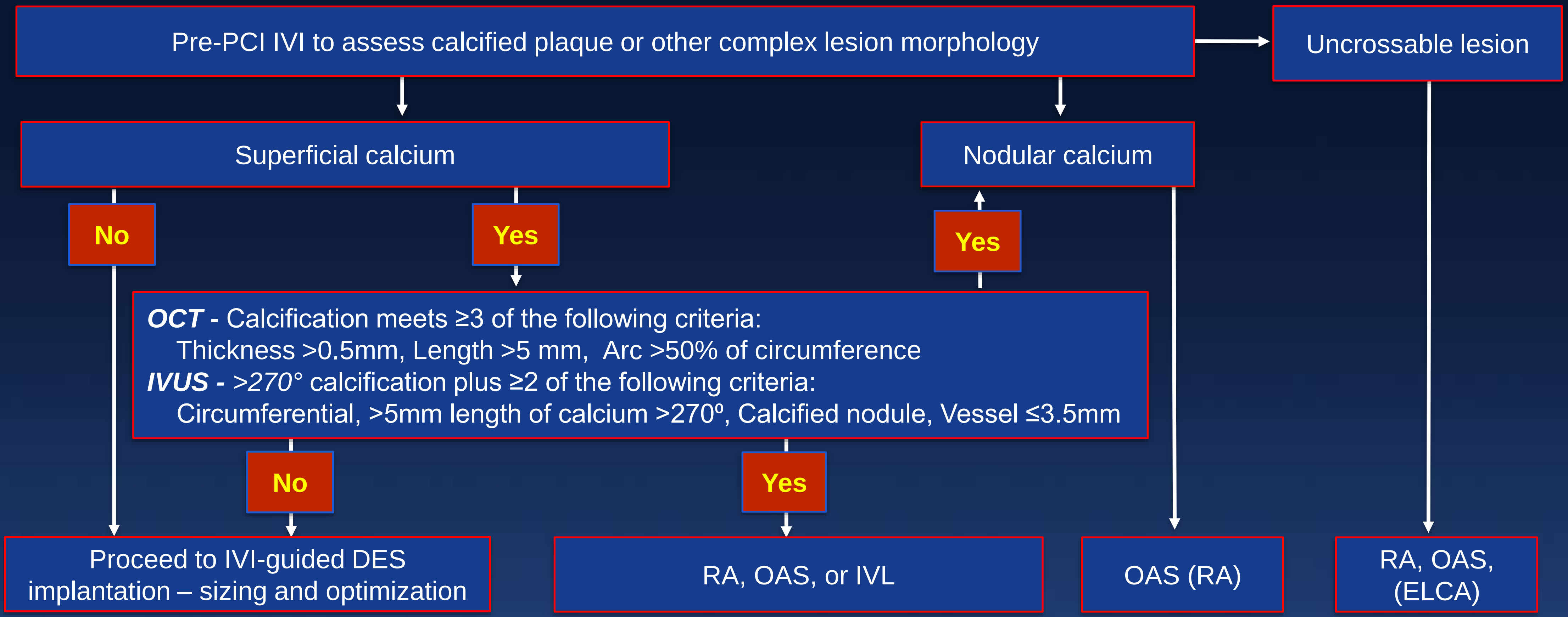
Zhang et al. Circulation Cardiovasc Interv, in press



Mintz et al. Heart. 2020 Nov 30:heartjnl-2020-316745



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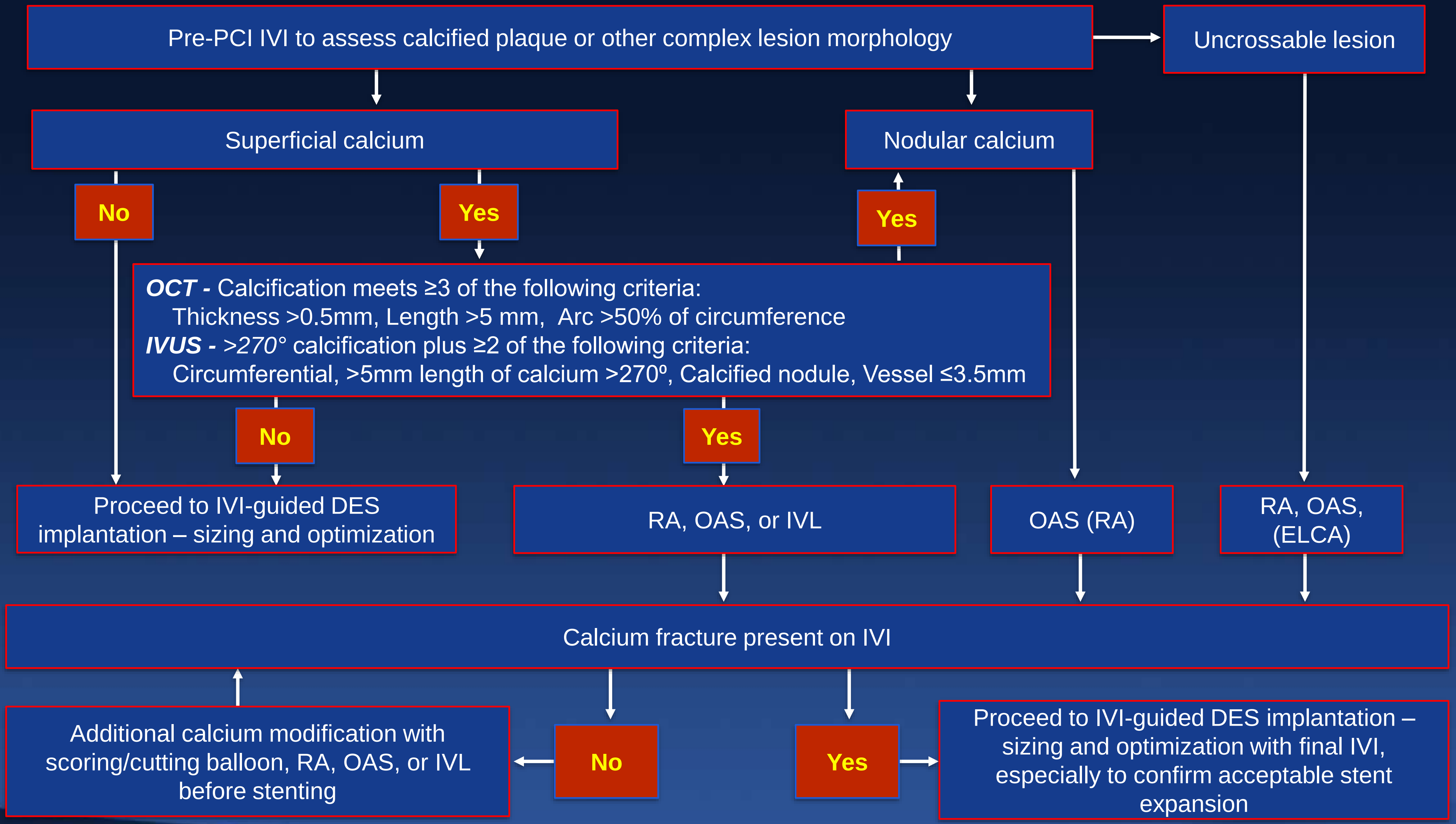

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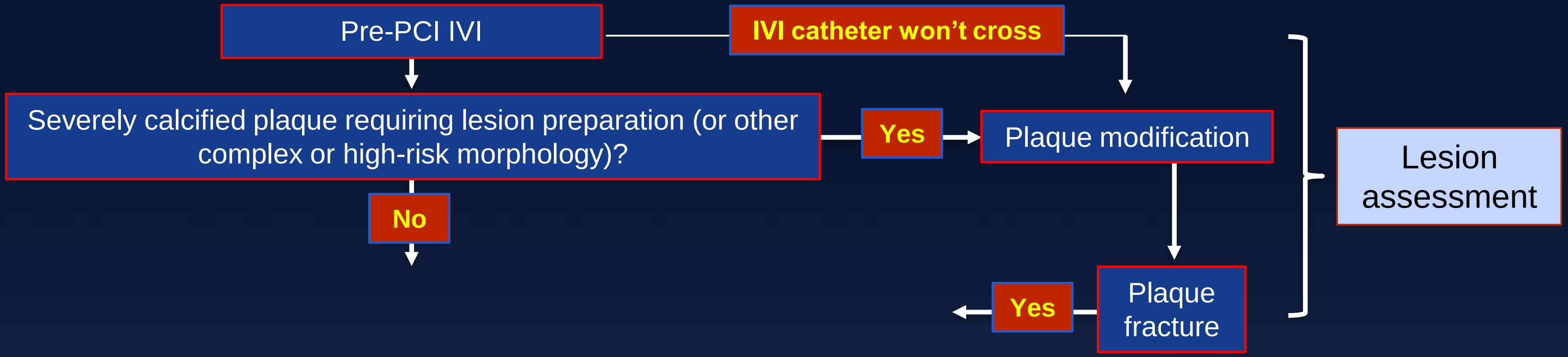
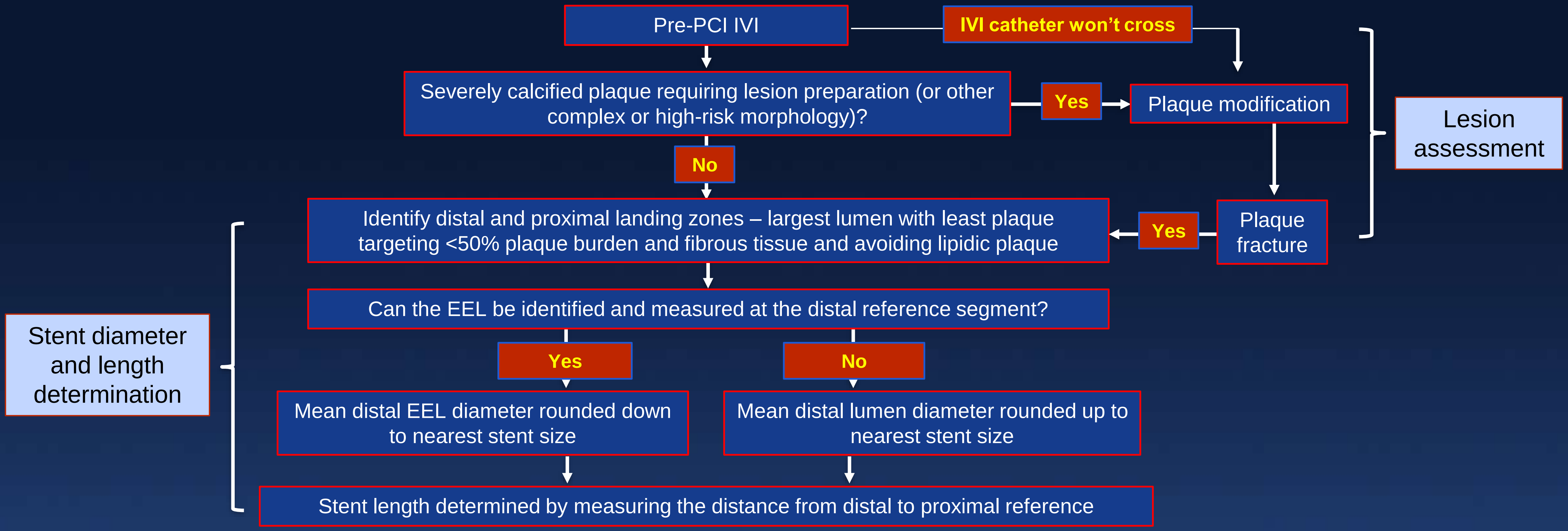
Mintz et al. Heart. 2020 Nov 30:heartjnl-2020-316745



Mintz et al. Heart. 2020 Nov 30:heartjnl-2020-316745



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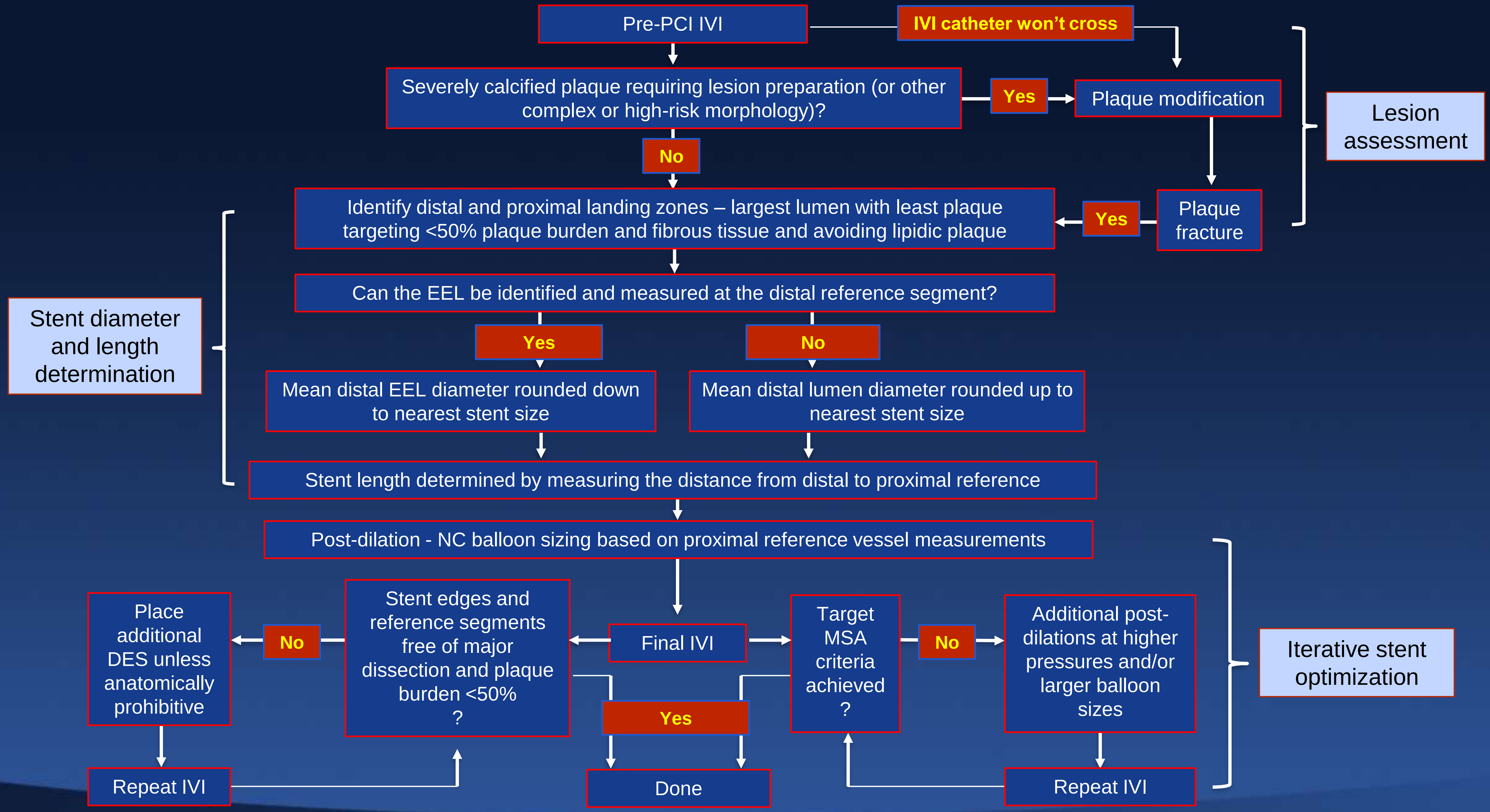
Mintz et al. Heart. 2020 Nov 30:heartjnl-2020-316745



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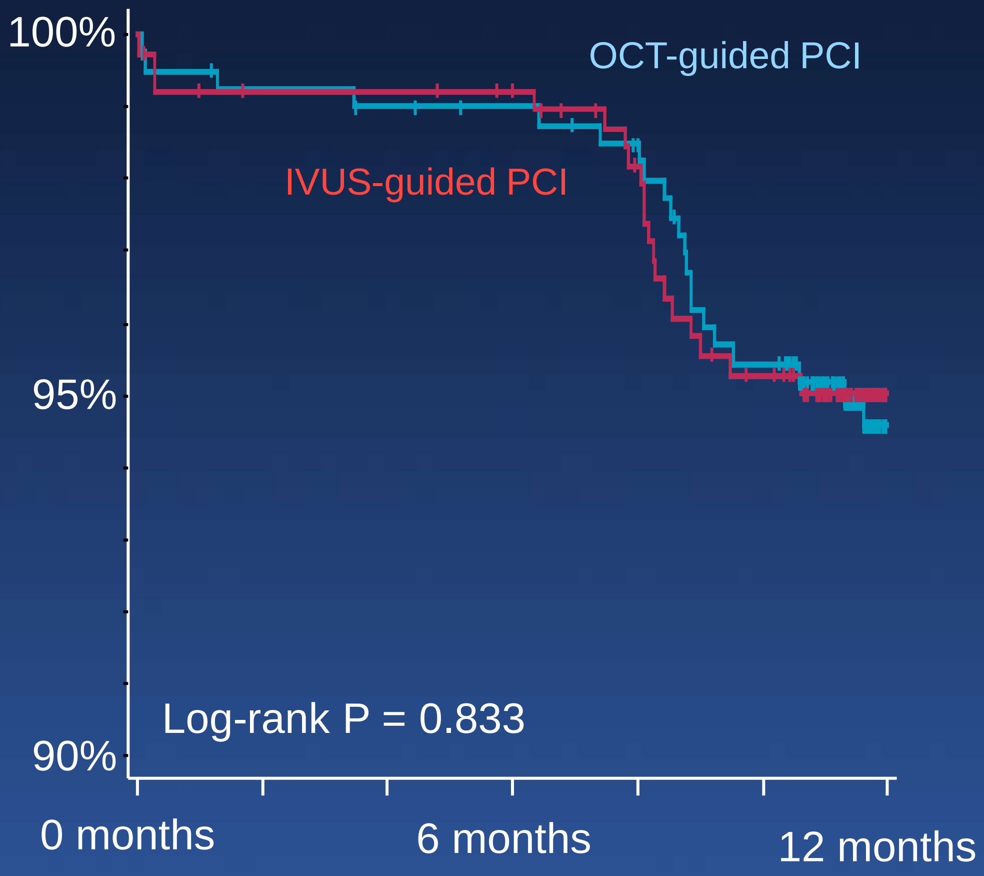
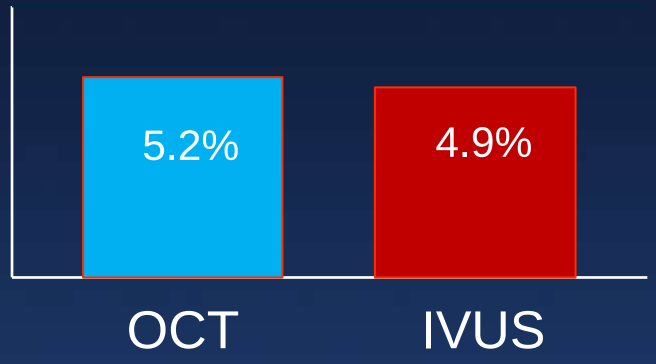
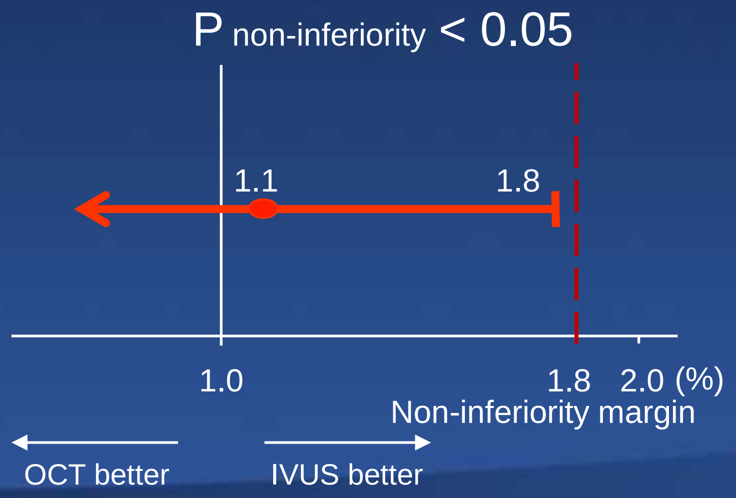
Mintz et al. Heart. 2020 Nov 30:heartjnl-2020-316745

OPINION: Randomized trial of IVUS vs OCT-guided DES implantation in ~800 patients

Primary endpoint: Target vessel failure (cardiac death, target vessel related MI, clinically driven TVR)-free survival

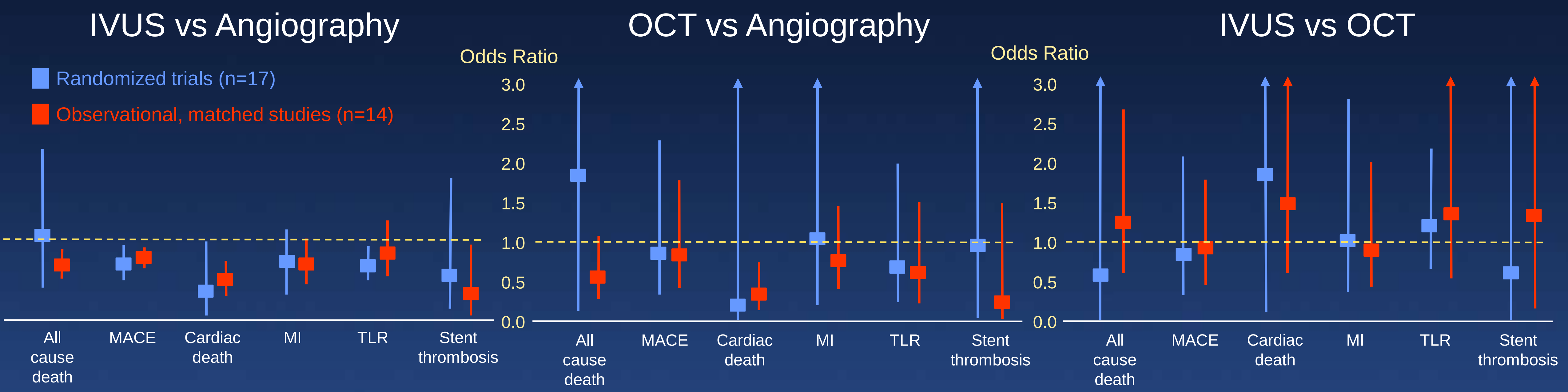






Kubo et al. Eur Heart J 2017;38:3139-47

Bayesian network meta-analysis of 31 studies and 17,882 pts comparing clinical outcomes of PCI with BMS and/or DES implantation guided by angiography, IVUS, or OCT



- Angiography (29 studies; 8434 pts), IVUS (17 studies; 7825 pts), OCT (7 studies; 1623 pts)
- Angiography vs IVUS (24 studies; 14295 pts), Angiography vs OCT (4 studies; 2092 pts), IVUS vs OCT (2 studies; 1045 pts), Angiography vs IVUS vs OCT (1 study; 450 pts)

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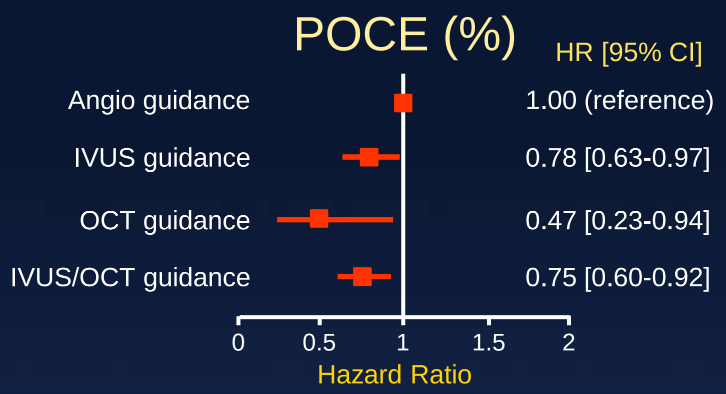
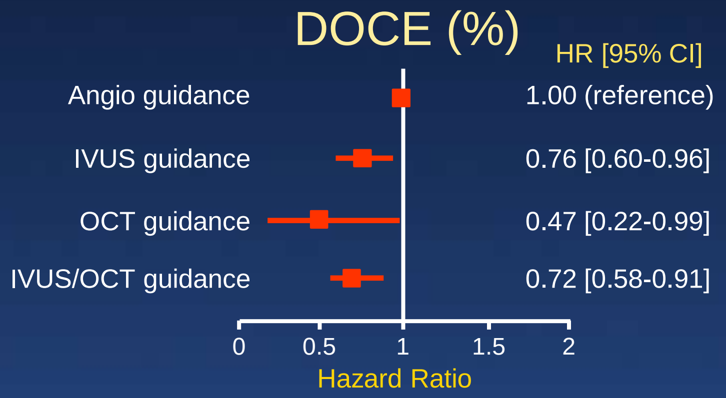
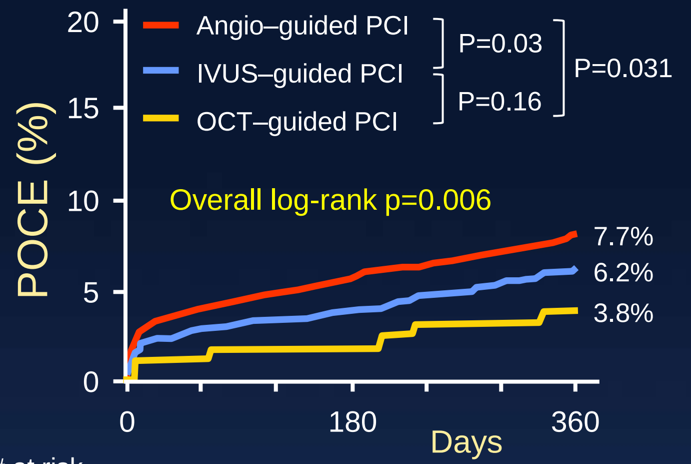
Buccheri et al. J Am Coll Cardiol Intv 2017;10:2488-98.

IVUS and OCT-guided primary PCI in the KAMIR Registry

- KAMIR (Korean AMI Registry) is an online, open-label registry at 20 sites that was established in 2011 with the help of the Korean NIH
- From 11/2011 to 12/2015, 11,731 STEMI pts underwent 1° PCI: 9072 with angio-guidance and 2333 with IVUS and 277 with OCT to optimize stent expansion, apposition, and lesion coverage.

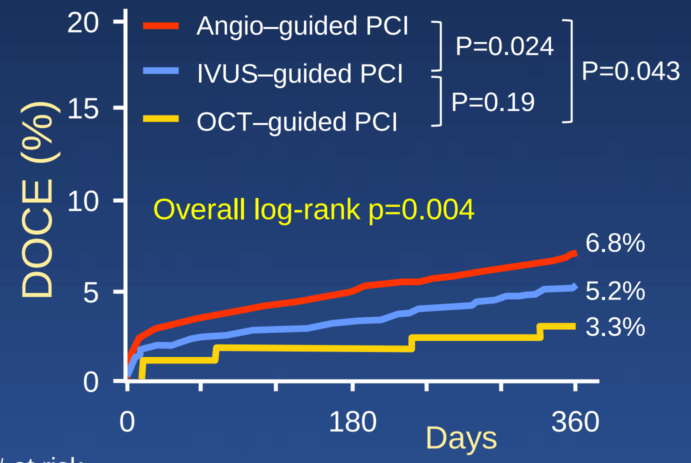






at risk

Angio	5679	5321	5260	5181	5061	4904	3432
IVUS	1658	1581	1571	1551	1511	1448	972
OCT	209	205	204	203	200	197	145



at risk

Angio	5679	5335	5284	5213	5102	4949	3472
IVUS	1658	1587	1576	1562	1522	1461	979
OCT	209	205	204	203	202	198	146

In the propensity-score matched cohort, difference in POCE was mainly driven by reduced all-cause mortality with IVUS (4.9% vs. 7.0%; log-rank p=0.002) and OCT (1.9% vs. 7.0%; log-rank p=0.004). The difference in DOCE was mainly driven by reduced cardiac mortality in IVUS (3.6% vs. 5.2%; log-rank p=0.009) and OCT-guided PCI (1.4 vs. 5.2%; log-rank p=0.014).

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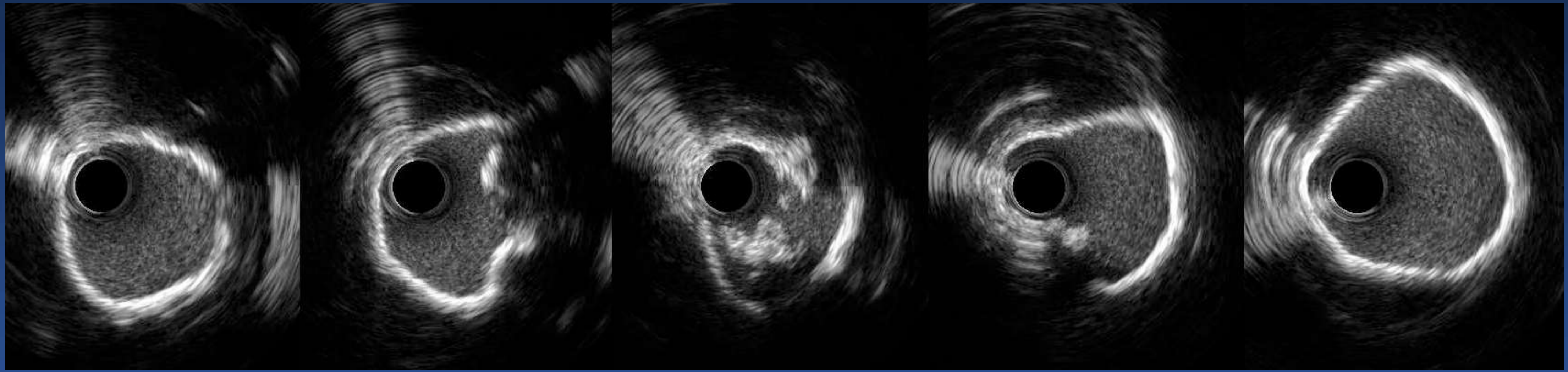
Kim et al. Catheter Cardiovasc Interv 2020;95:696-703

45 year-old male with CCS class 2 chest pain.

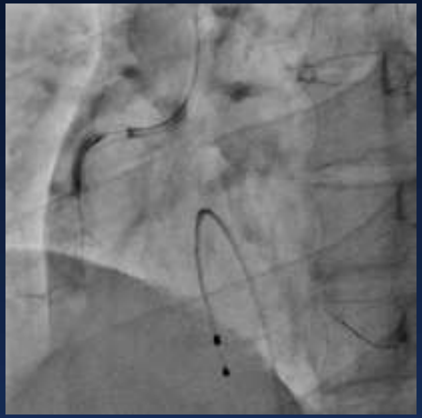
- Coronary risk factors
  - Type 1 diabetes mellitus
  - Hypertension
  - Current smoker
- Past medical history
  - Chronic renal failure on hemodialysis

c/o Myong Hwa Yamamoto and Masahiko Ochiai
Showa University Northern Yokohama Hospital
Yokohama, Japan

	Calcium Score	
Length of calcium >270°	≤5mm	0
	>5mm	1
Calcium Nodule	absent	0
	present	1
Vessel diameter	>3.5mm	0
	≤3.5mm	1
Circumferential calcium	absent	0
	present	1

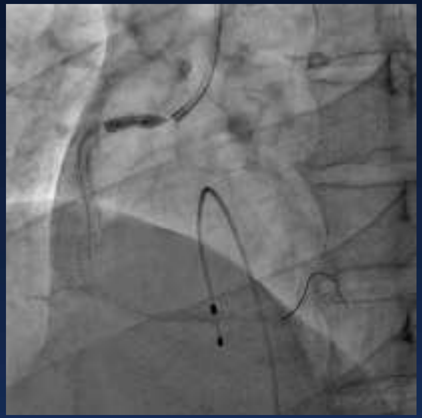


0 → 5mm → 20mm

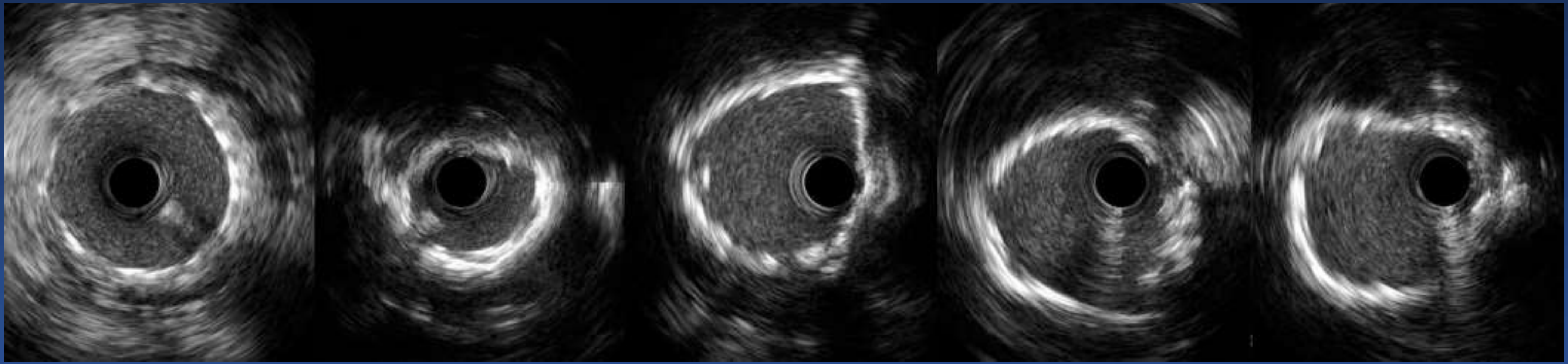


Balloon pre-dilation

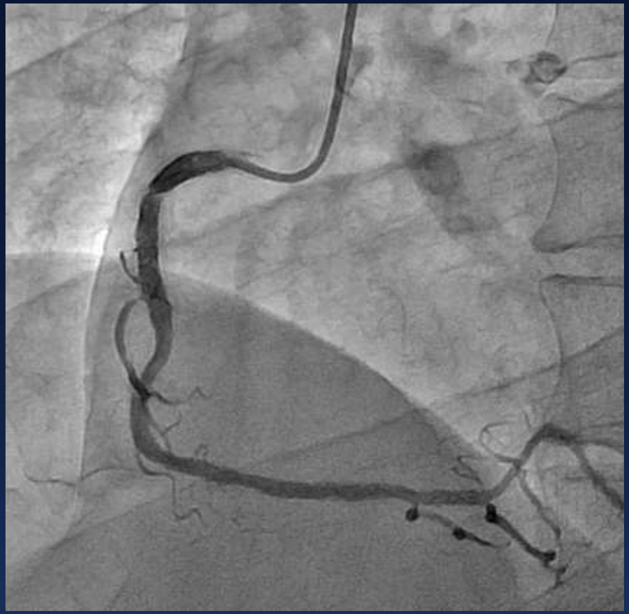
Promus Premier
3.0*38mm@18atm



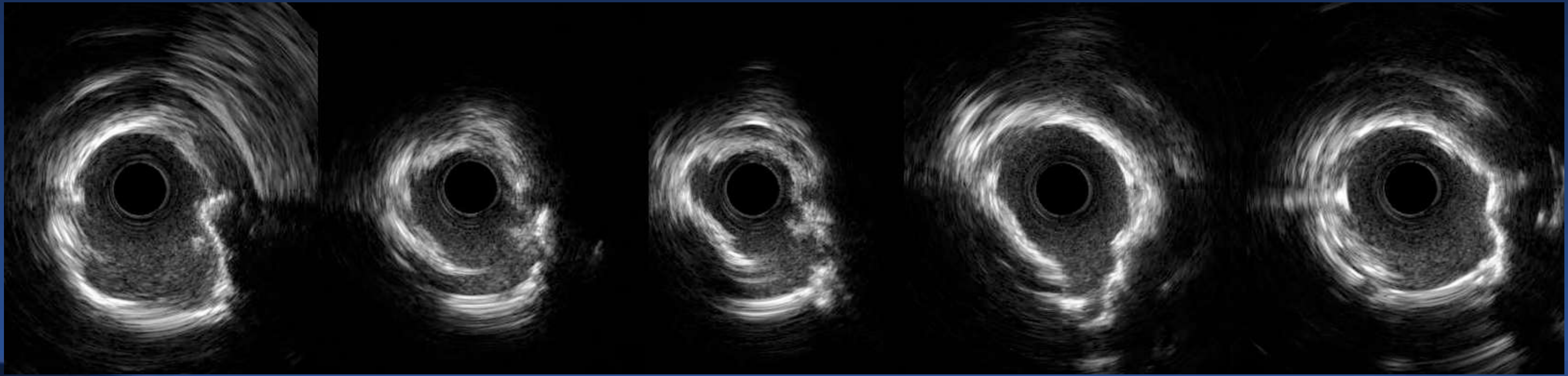
Balloon post-dilation
Quantum 4.0mm@24atm



Stent expansion=45%

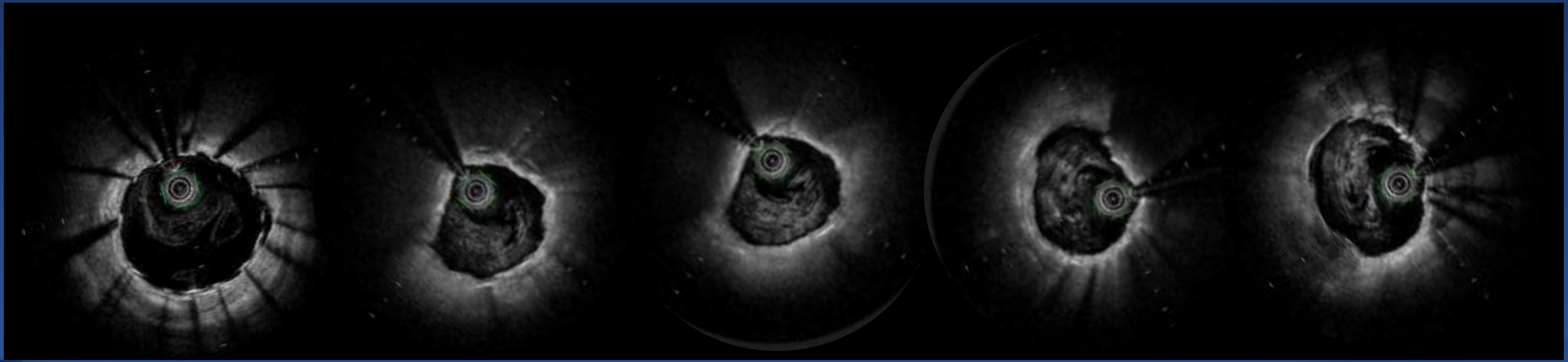


Two months later

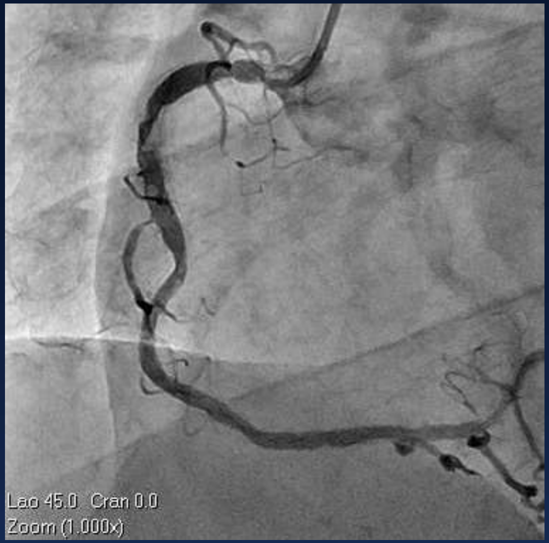


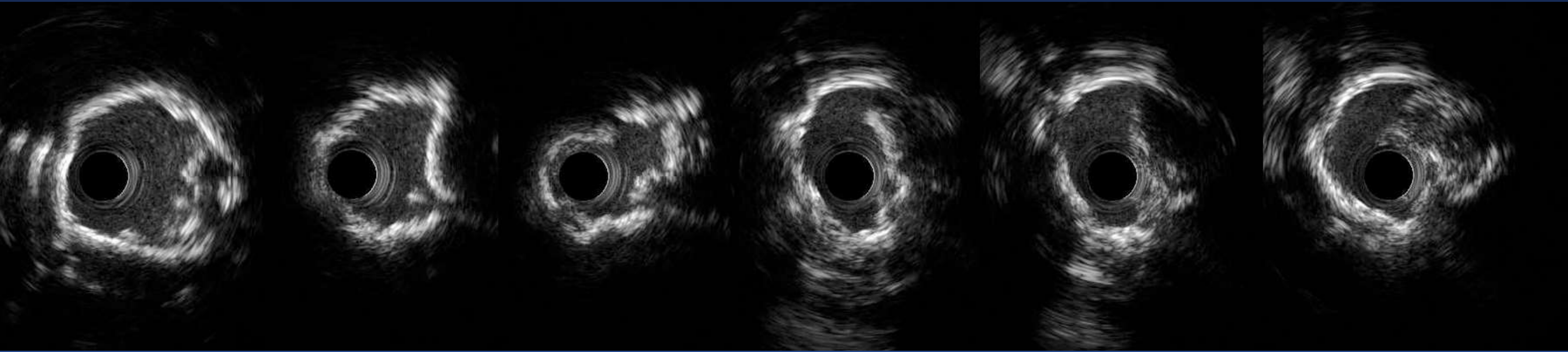
Standard NC balloon
3.5mm@20atm

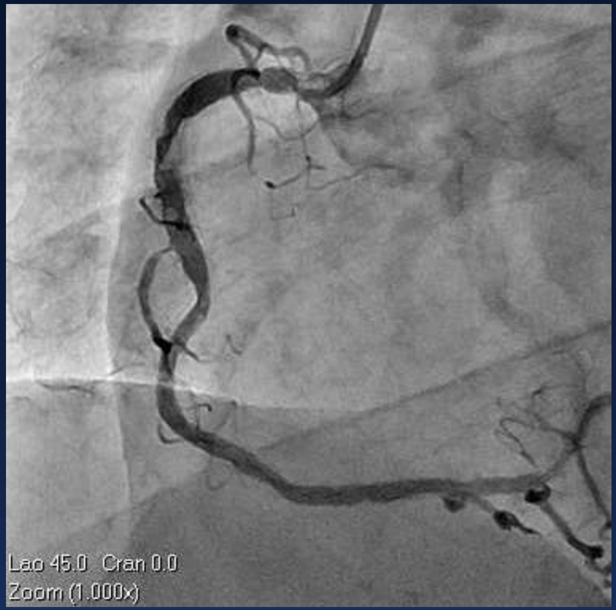
Drug-coated balloon
3.5mm@20atm



Another two months later



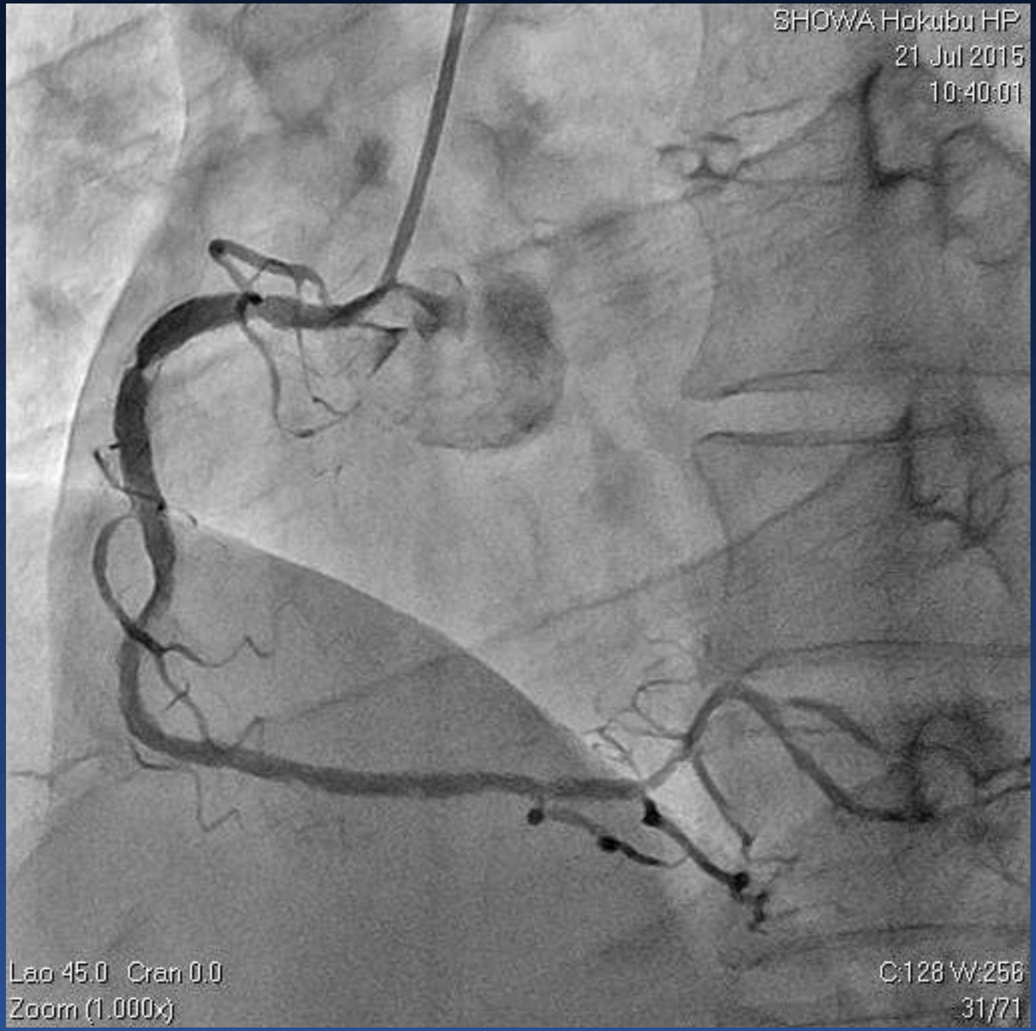




Pre-dilation
3.75mm@20atm

Nobori
3.5*14mm@16atm

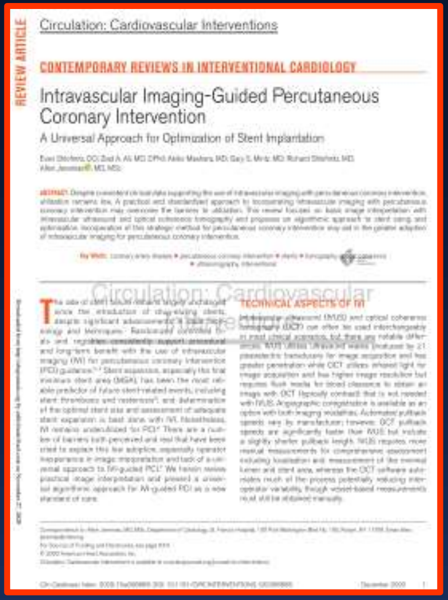
Another one month later



	IVUS	OCT
Stent sizing & optimization	+++	+++
Ruptured plaque and thrombus	+	+++
Left main lesions	+++	+
Aorto-ostial lesions	+++	-
Calcium	++	+++
Chronic total occlusions	+++	-
In-stent restenosis	++	+++
Impaired renal function	+++	-

Shlofmitz et al. Circ Cardiovasc Interv. 2020:CIRCINTERVENTIONS120008686.
Mintz et al. Heart. 2020 Nov 30:heartjnl-2020-316745

- **80-90% of your PCI-guidance needs can be addressed with *__either IVUS or OCT__*. Pick one and get good at it!**
- **In the other 10-20% of cases and depending on your practice, it is important to know which patient, which lesion, and which clinical scenario will be better suited to IVUS vs OCT assessment and/or guidance.**



REVIEW ARTICLE

Circulation: Cardiovascular Interventions

CONTEMPORARY REVIEWS IN INTERVENTIONAL CARDIOLOGY

Intravascular Imaging-Guided Percutaneous Coronary Intervention

A Universal Approach for Optimization of Stent Implantation

Education in Heart

Use of intracoronary imaging to guide optimal percutaneous coronary intervention procedures and outcomes

Gary S Mintz, Ziad Ali, Akiko Maehara