Imaging & Physiology

The Clinical Value of OCT：European Consensus Document

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Disclosure Statement of Financial Interest

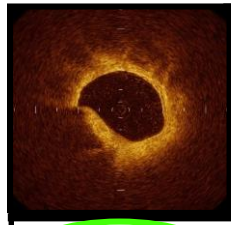
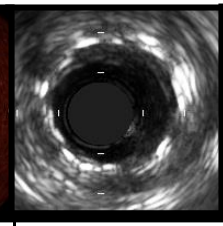
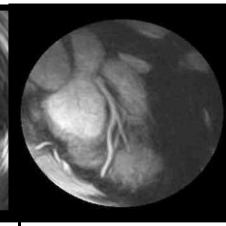
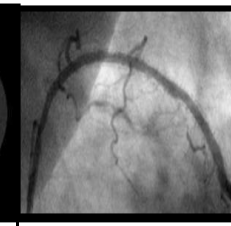
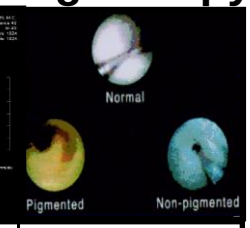
Takashi Akasaka, MD, PhD

Within the past 12 months, I or my spouse/partner have had a financial interest/arrangement or affiliation with the organization(s) listed below.

- **Grant/Research Support** : **Abbott Vascular Japan**
  Boston Scientific Japan
  Nipro Inc.
  Terumo Inc.

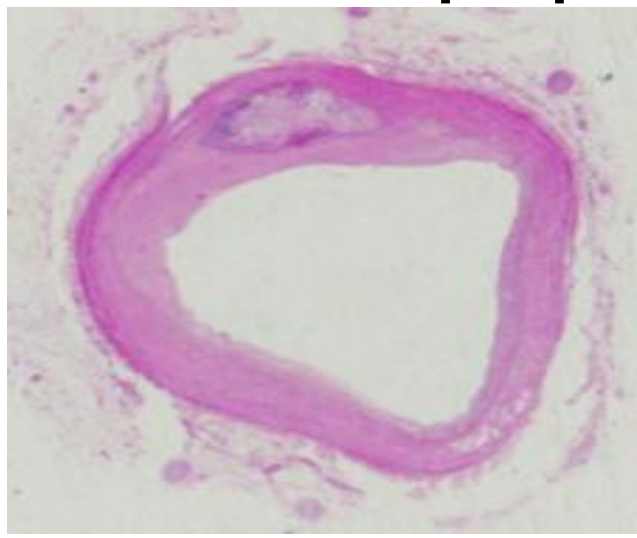
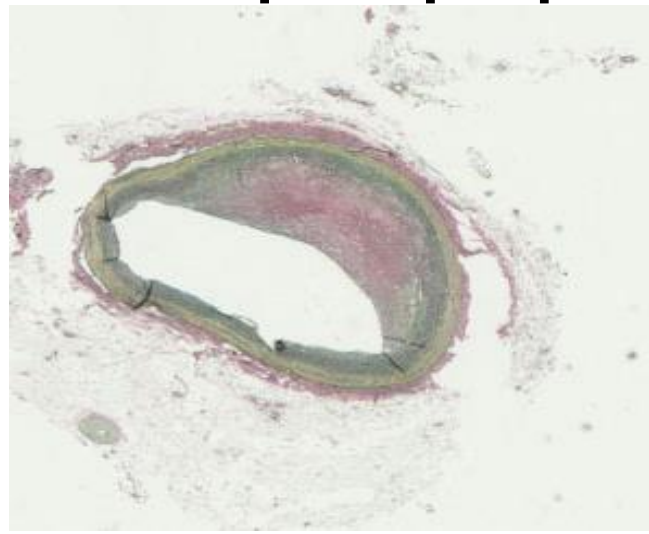
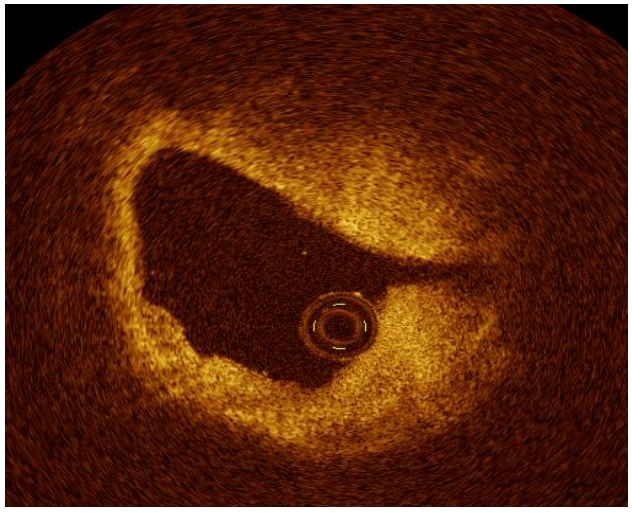
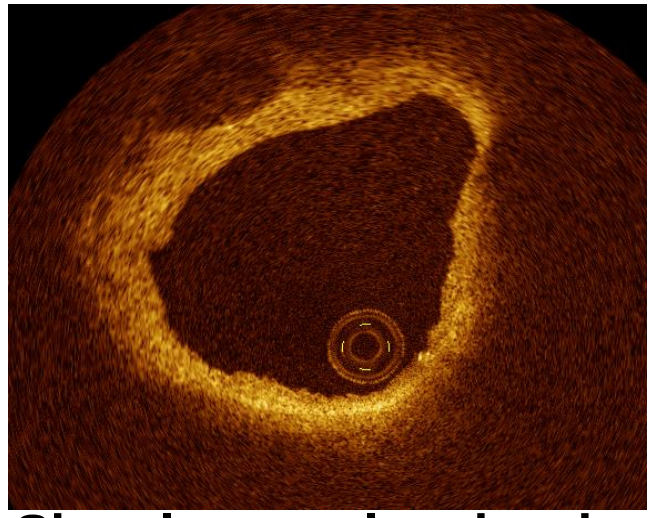
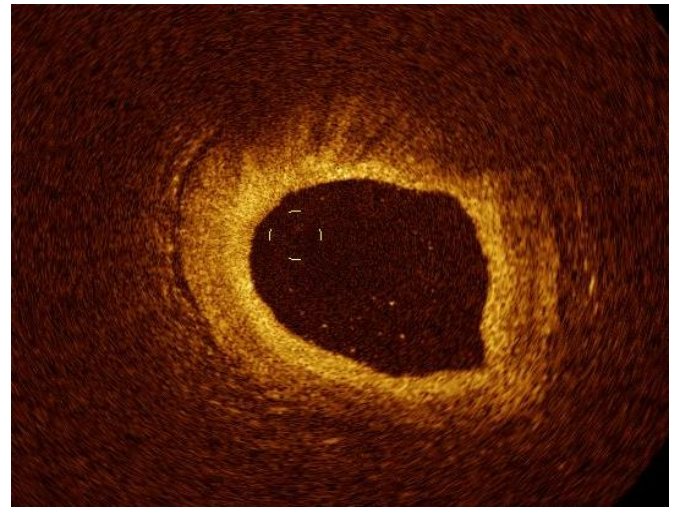
- **Consulting Fees/Honoraria** : **Abbott Vascular Japan**
  Daiichi-Sankyo Pharmaceutical Inc.
  Nipro Inc.
  Terumo Inc.

Comparison among various coronary imaging

	OCT	IVUS	MRI	CAG	MDCT	Angioscopy
						
Resolution	10 – 15	80 – 120	80 – 300	100-200	300	<200
Probe Size	140	700	1000	N/A	N/A	800
Contact	No	Yes	No	No	No	No
Ionizing Radiation	No	No	No	Yes	Yes	No
Imaging Target	Layer	Layer	Density	Blood Flow	Density	Surface
Other	Tissue Characterization	N/A	N/A	Flow Only	CT number	Surface Only

Each modality may have advantages and disadvantages.

OCT vs histology

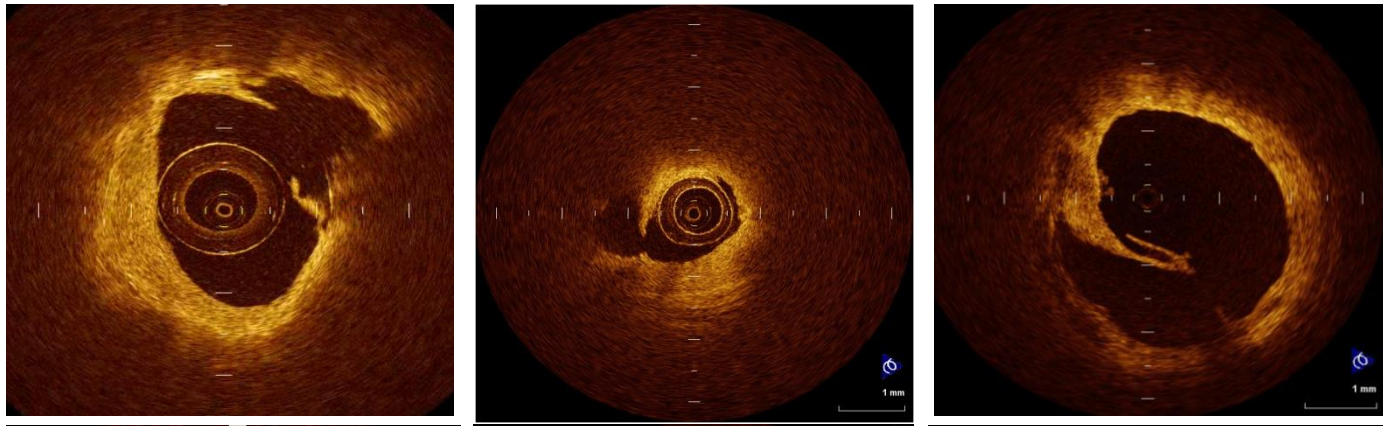
Fibrous plaque	Fibro-calcific plaque	Fibro-lipidic plaque
		
		
Signal rich, homogenous	Signal poor, clear border	Signal poor, diffuse border

Yabushita H, et al. Circulation, 106:1640-1645, 2002
Kume T, et al. Am J Cardiol 97: 1172 - 1175, 2006

Demonstration of various causes in ACS

Plaque rupture

60 – 70 %

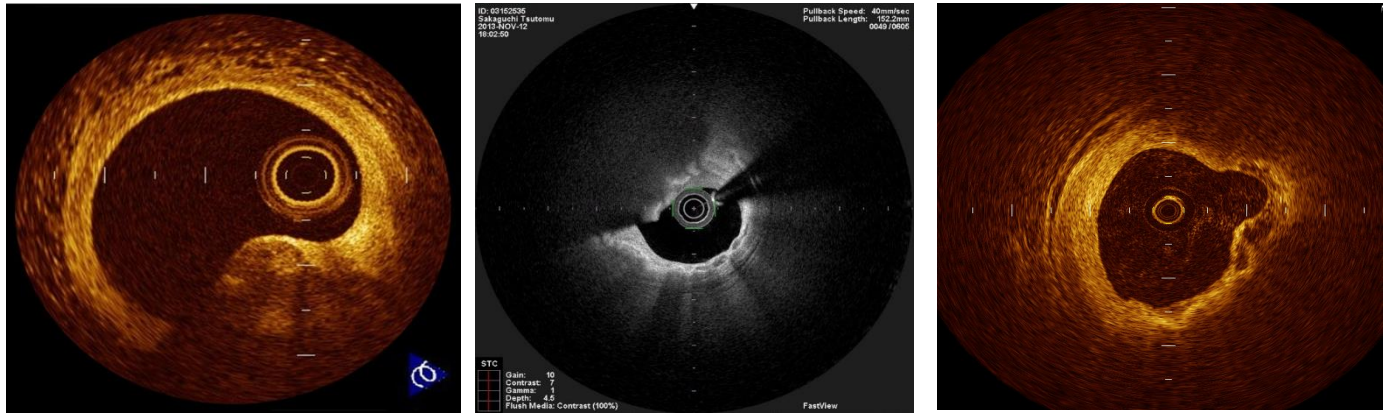


Plaque erosion

20 – 30 %

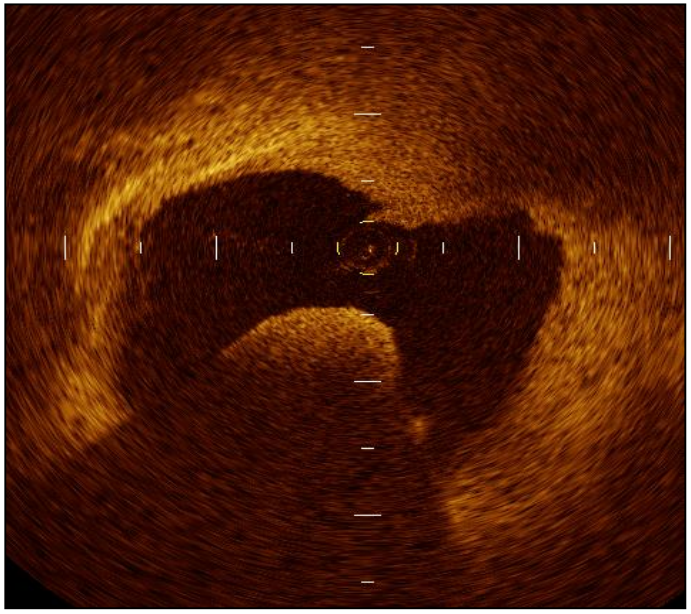
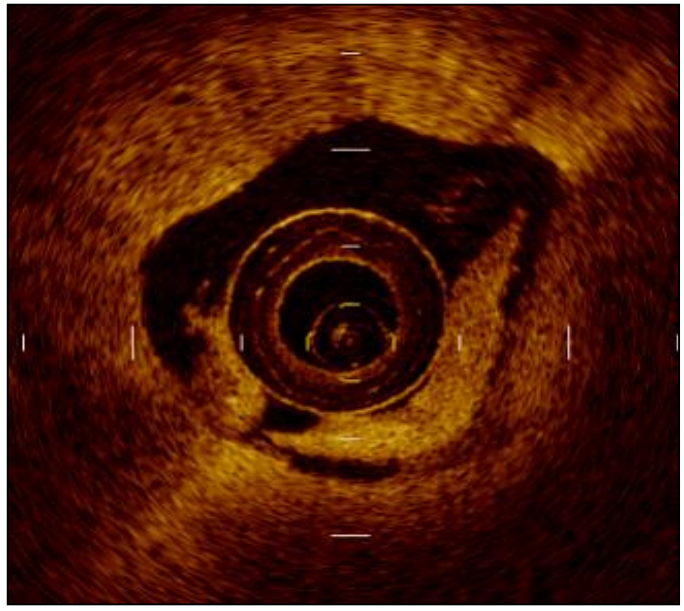
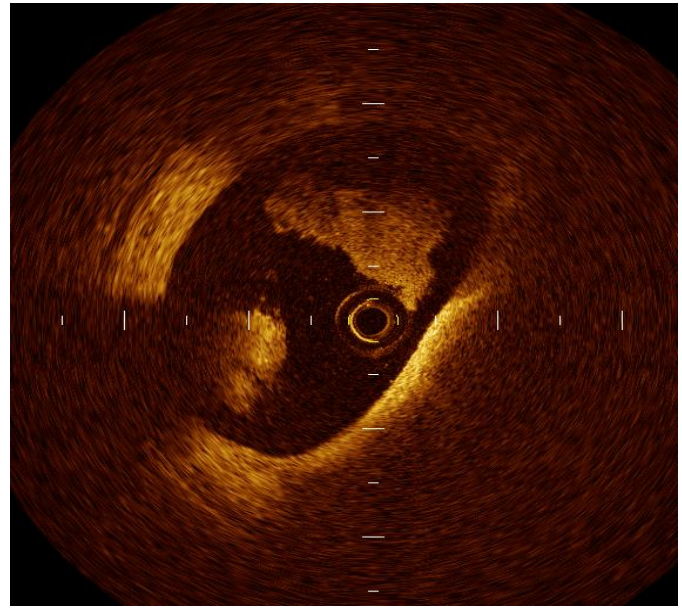
Calcified nodule

5 – 6 %



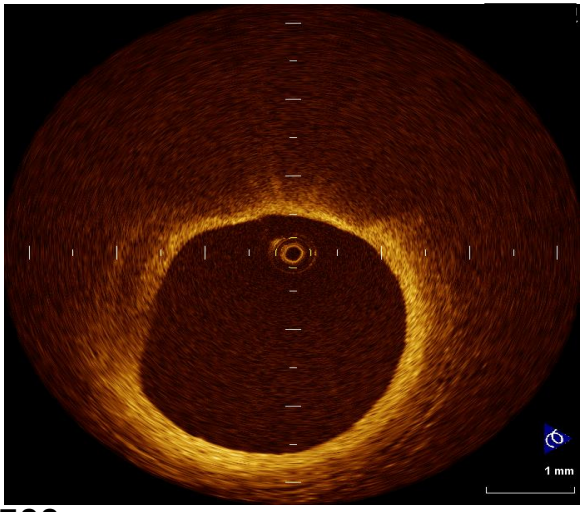
Kubo T, Akasaka T, et al. (J Am Coll Cardiol 50:933-939,2007)

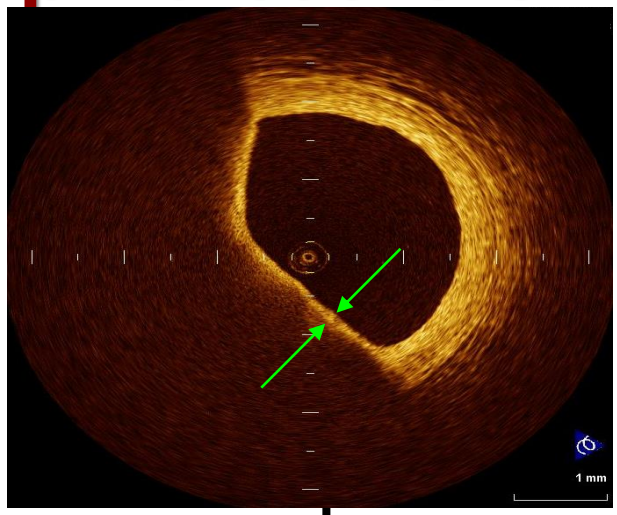
Red & white thrombus

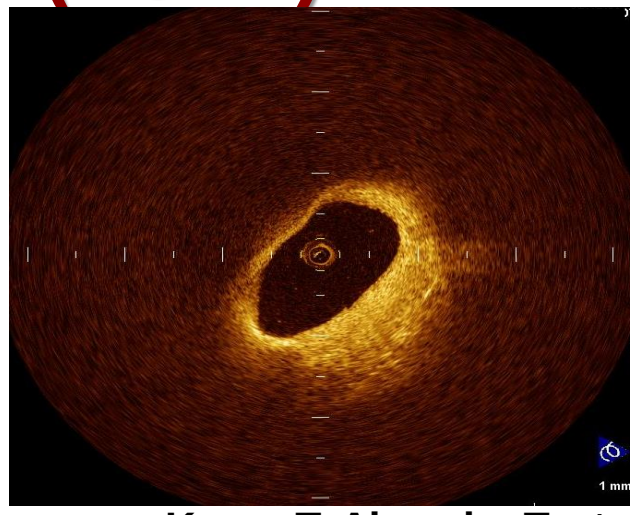
Red thrombus	White thrombus	Mixed thrombus
		
Protrusion mass with shadow	Protrusion mass without shadow	Protrusion mass with & without shadow

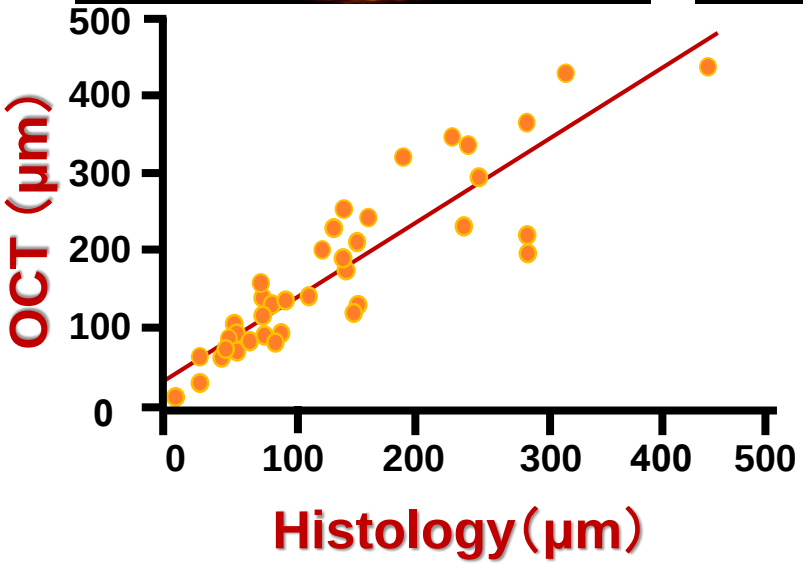
Kume T, Akasaka T, et al. (Am J Cardiol 97:1713-1717, 2006)
Kubo T, Akasaka T, et al. (J Am Coll Cardiol 50:933-939,2007)

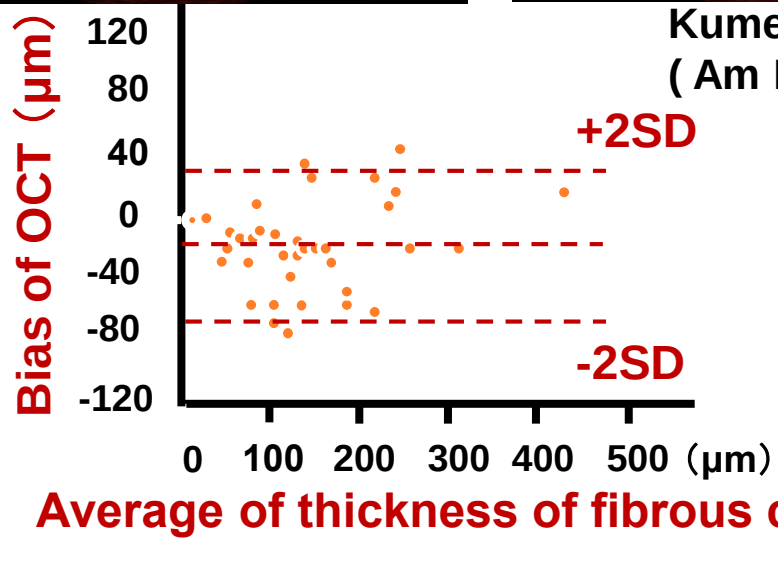
Thin-cap fibroatheroma (TCFA)









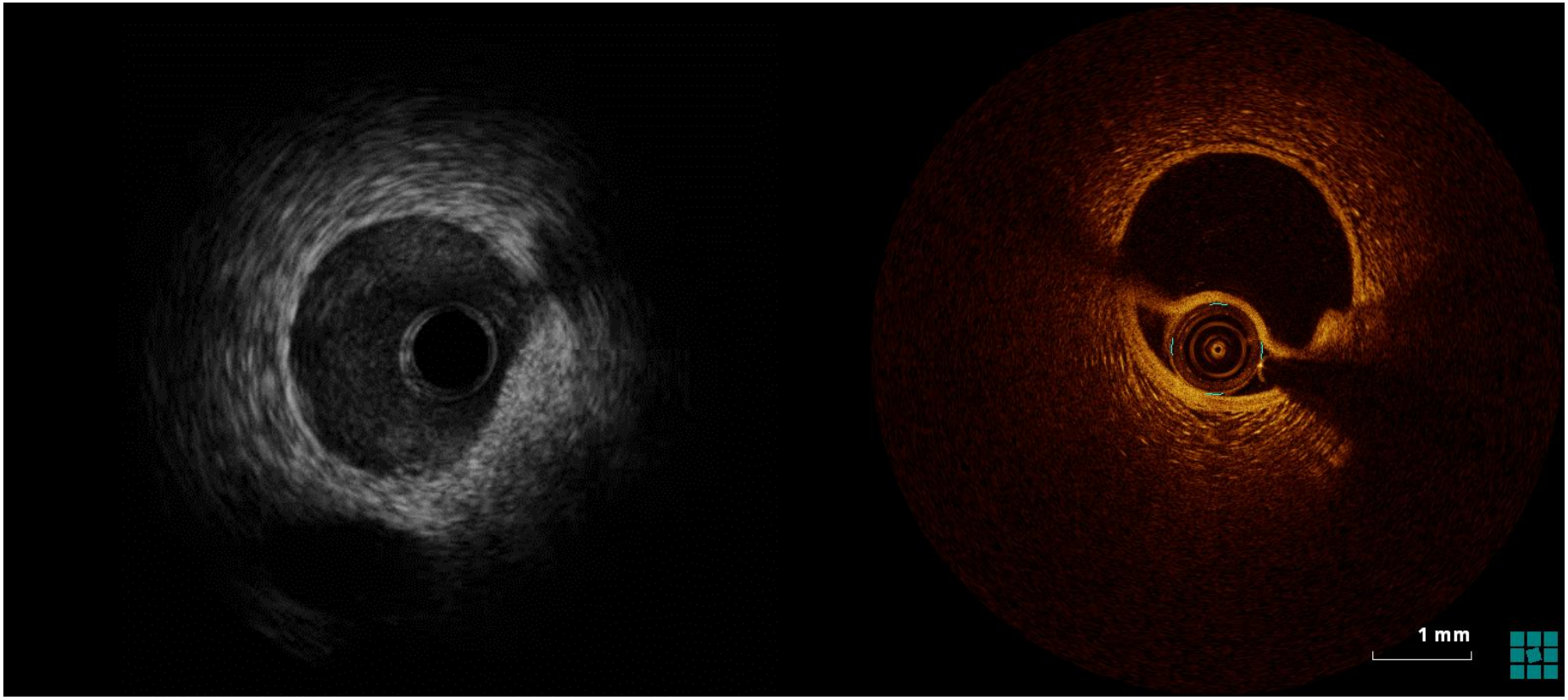


Kume T, Akasaka T, et al
(Am Heart J.152:755, 2006)

TCFA is demonstrated by the thin high intensity layer with rapid attenuation of the signals, and the cap thickness is measured by the thickness from the surface of the lumen to the portion just starting the attenuation.

Coronary Imaging of SCAD

IVUS **OCT**



ESC European Society of Cardiology
European Heart Journal (2018) **00**, 1–96
doi:10.1093/eurheartj/ehy394

2018 ESC/EACTS Guidelines on myocardial revascularization

**The Task Force on myocardial revascularization
Society of Cardiology (ESC) and European Asso
Cardio-Thoracic Surgery (EACTS)**

**Developed with the special contribution of the E
Association for Percutaneous Cardiovascular In**

**Authors/Task Force Members: Franz-Josef Neumann* (ESC
(Germany), Miguel Sousa-Uva*[1] (EACTS Chairperson) (Po
(Sweden), Fernando Alfonso (Spain), Adrian P. Banning (U
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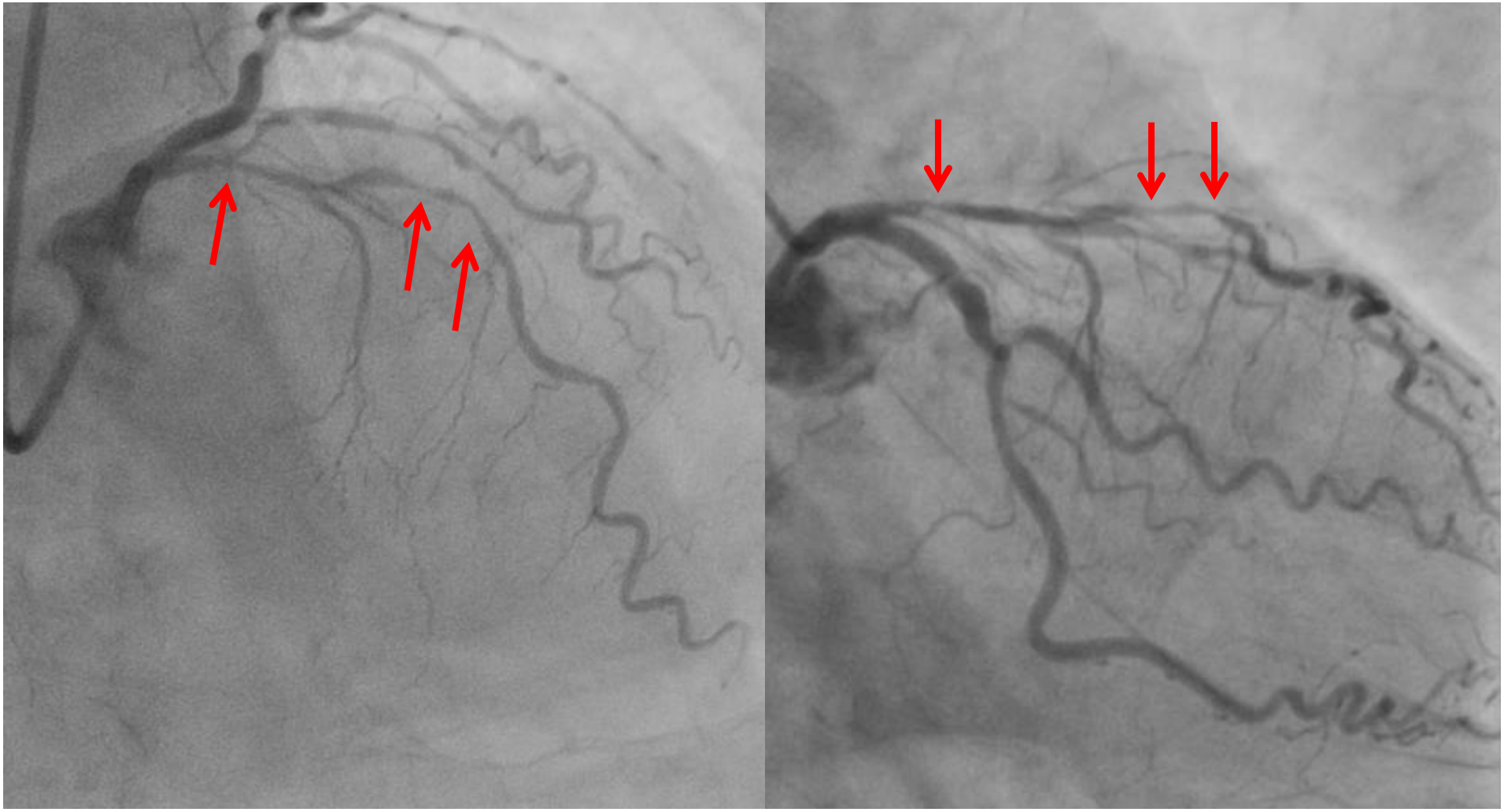
(Ger
Adna
Josef
Dirk
(Swit
Docum
Co-or
(Norw
(Canad

Recommendations on intravascular imaging for procedural optimization

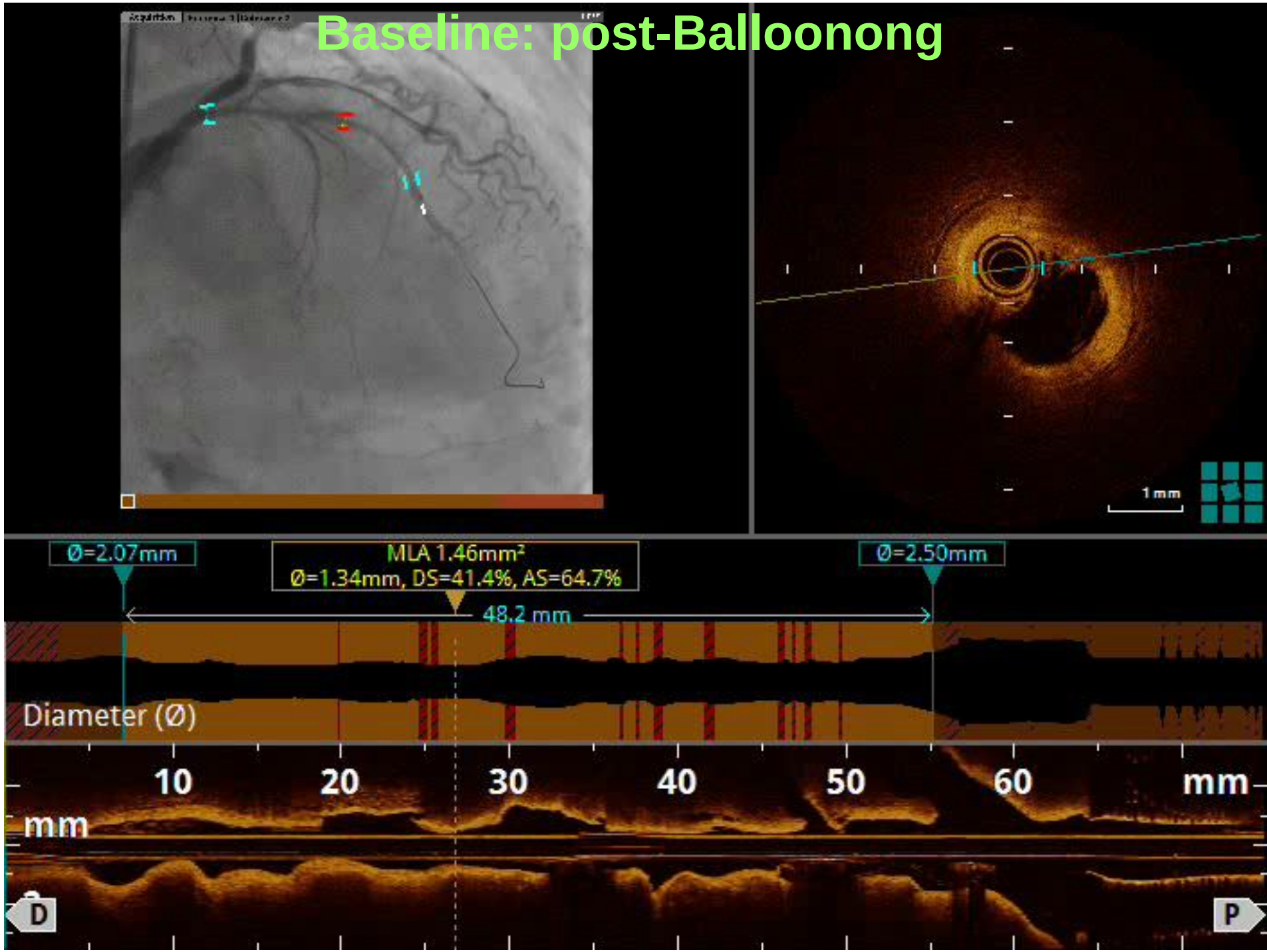
Recommendations	Class[a]	Level[b]
IVUS or OCT should be considered in selected patients to optimize stent implantation.[603,612,651–653]	IIa	B
IVUS should be considered to optimize treatment of unprotected left main lesions.[35]	IIa	B

Restenosis		
DES are recommended for the treatment of in-stent restenosis of BMS or DES.[373,375,378,379]	I	A
Drug-coated balloons are recommended for the treatment of in-stent restenosis of BMS or DES.[373,375,378,379]	I	A
In patients with recurrent episodes of diffuse in-stent restenosis, CABG should be considered by the Heart Team over a new PCI attempt.	IIa	C
IVUS and/or OCT should be considered to detect stent-related mechanical problems leading to restenosis.	IIa	C

Coronary angio. (Pre PCI)

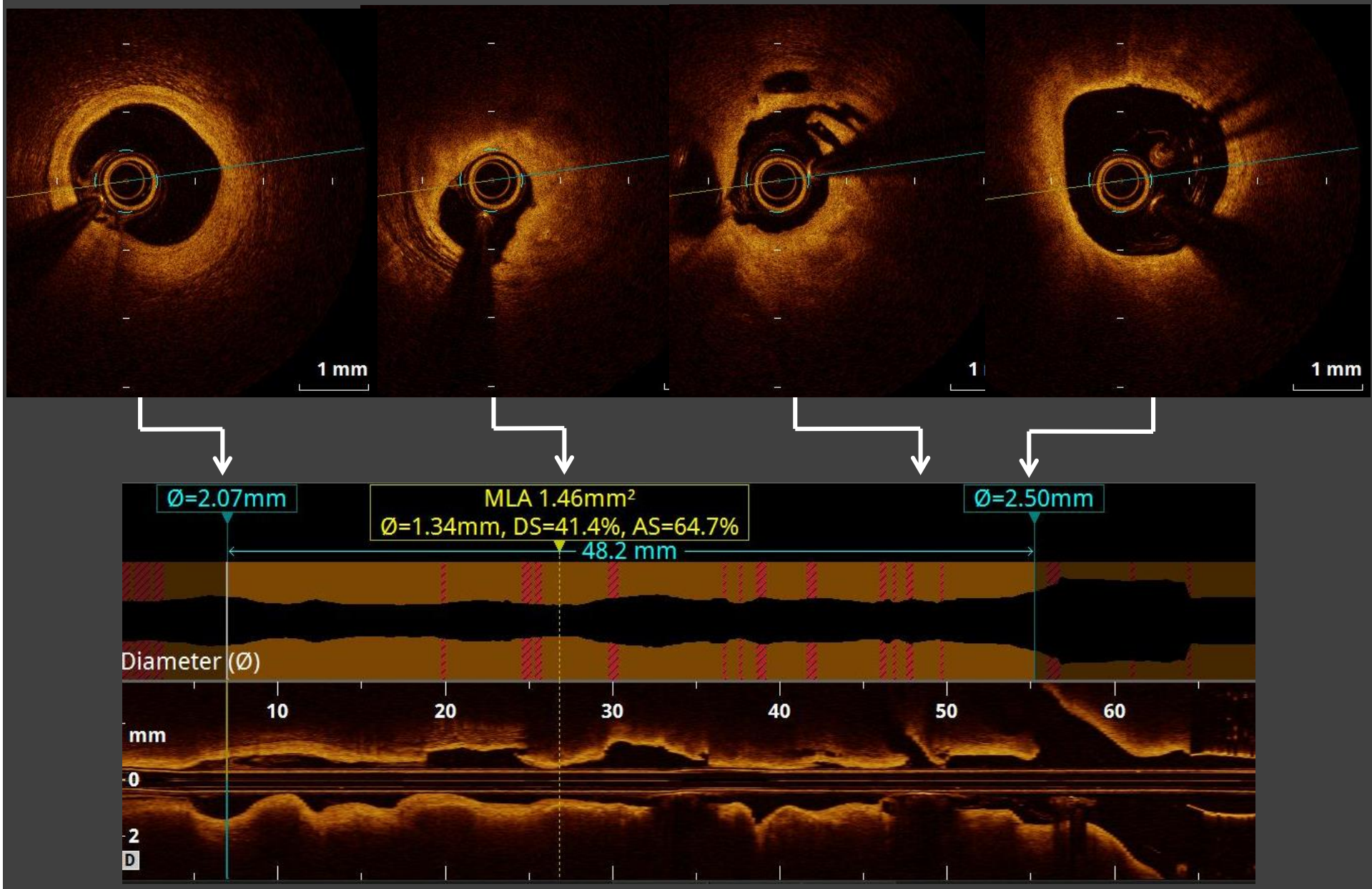


Baseline: post-Balloonong



Baseline: post-Balloonong

Distal reference ***MLA site*** ***Bifurcation site*** ***Prox. Reference***



Stent sizing

ESC European Society of Cardiology

European Heart Journal (2018) **00**, 1–20
doi:10.1093/eurheartj/ehy285

*FAST*TRACK 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 Meneveau[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]*

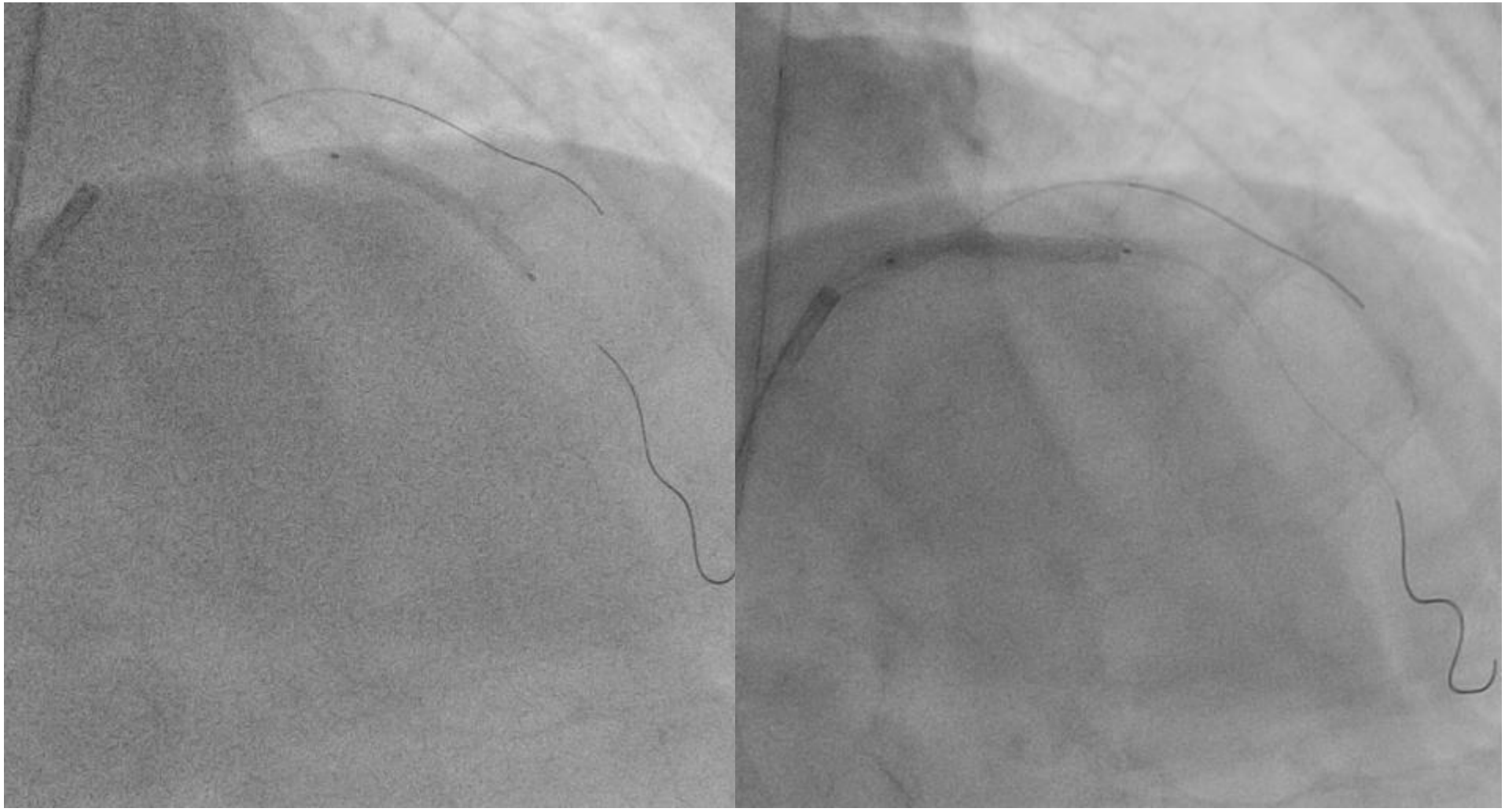
Coordinating editor: Prof Patrick W. Serruys, MD, PhD, Imperial College, London, UK

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

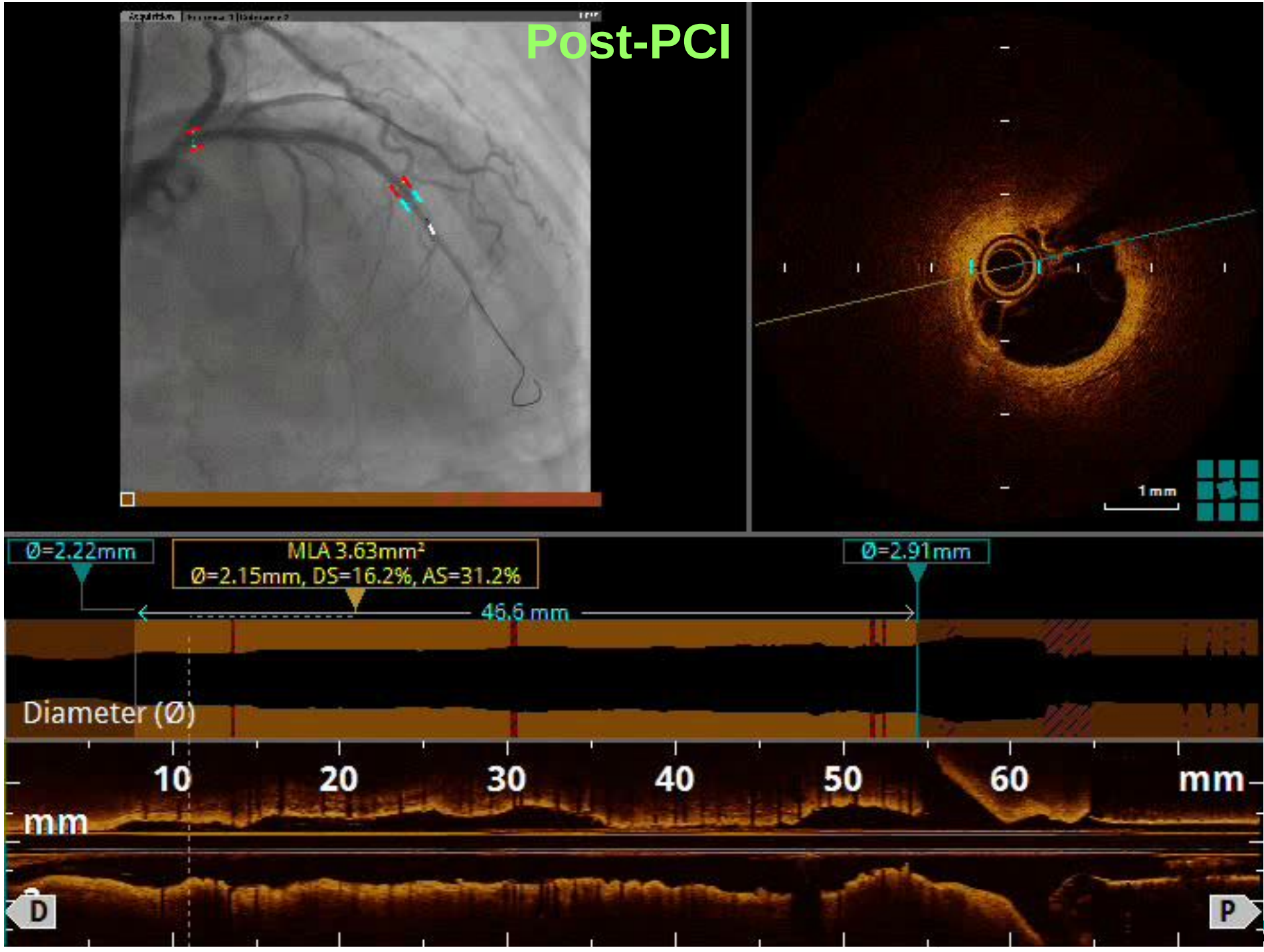
- The beneficial effect of imaging-guided PCI does not appear to be strictly linked to the algorithm used for stent sizing by IVUS or OCT.
- From a practical standpoint, a distal lumen reference based sizing may represent a safe and straightforward approach with subsequent optimization of the mid and proximal stent segments. Specifically, the mean distal lumen diameter with up rounding stent (0–0.25 mm) may be used (e.g. 3.76 → 4.0 mm), or the mean EEM (2 orthogonal measurements) with down rounding to the nearest 0.25 mm stent size (e.g. 3.76 → 3.5 mm).
- When using OCT, an EEM reference based sizing strategy appears feasible, although more challenging than a lumen based approach for routine clinical practice.
- Appropriate selection of the landing zone is crucial as residual plaque burden (<50%) and particularly lipid rich tissue at the stent edge is associated with subsequent restenosis.
- Co-registration of angiography and IVUS or OCT is a useful tool to determine stent length and allows for precise stent placement.

Räber L, et al. Eur Heart J 2018 May 22. doi: 10.1093/eurheartj/ehy285

PCI for #6-7

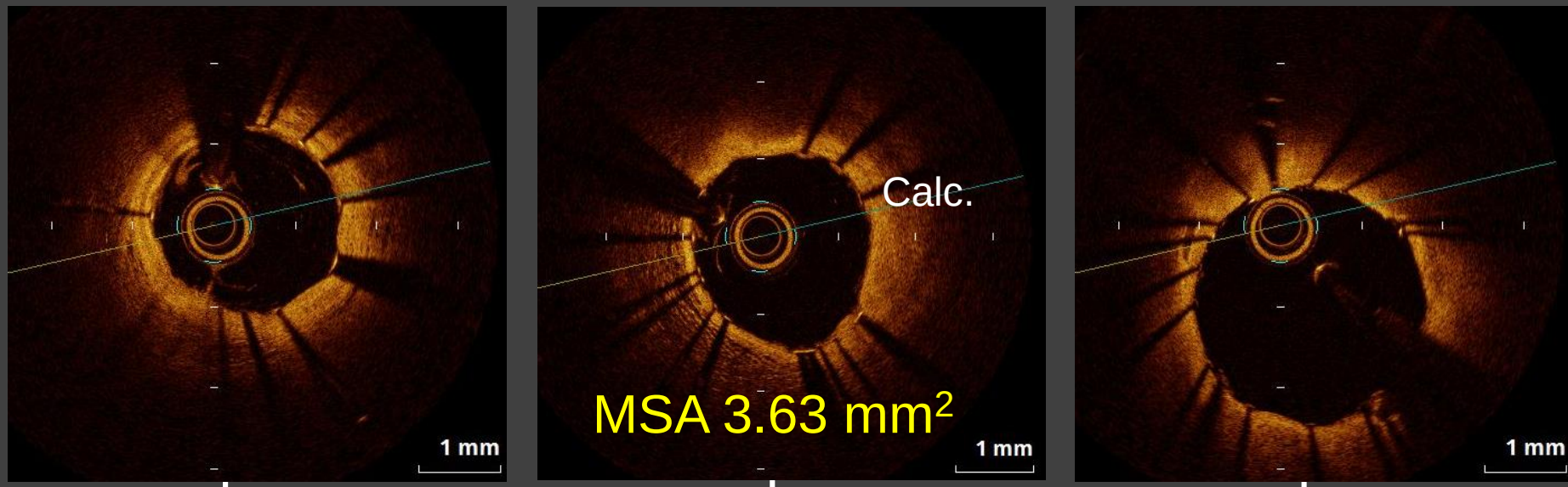


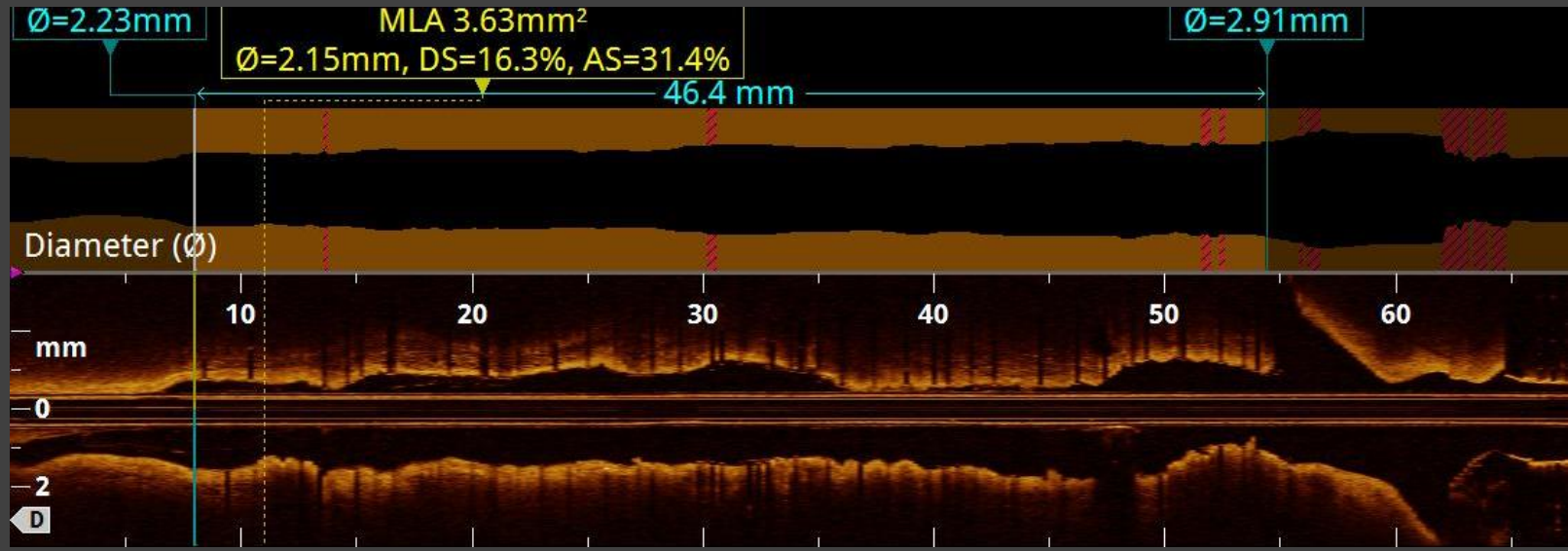
EES : 2.5*26mm / 2.75*26mm (14atm.)


Post-PCI
1 mm
Ø=2.22mm
MLA 3.63mm²
Ø=2.15mm, DS=16.2%, AS=31.2%
Ø=2.91mm
46.6 mm
Diameter (Ø)
10
20
30
40
50
60
mm
mm
D
P

Post-PCI

Distal reference ***MSA site*** ***Prox. Reference***

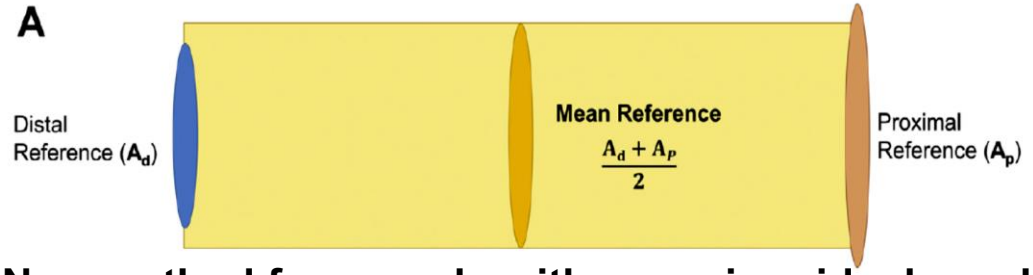




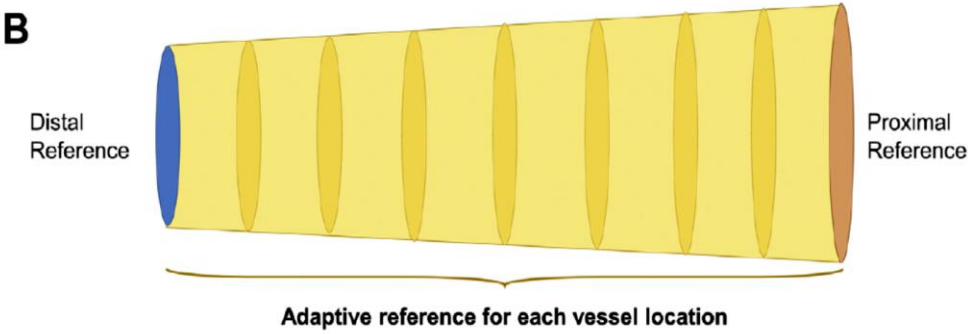
Volumetric Stent Expansion Assessment

Nakamura D, et al. J Am Coll Cardiol Intv 2018;11:1467-1478

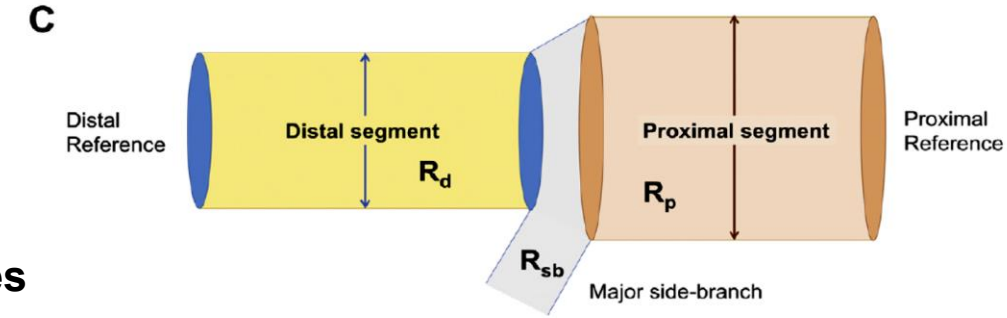
Conventional Method



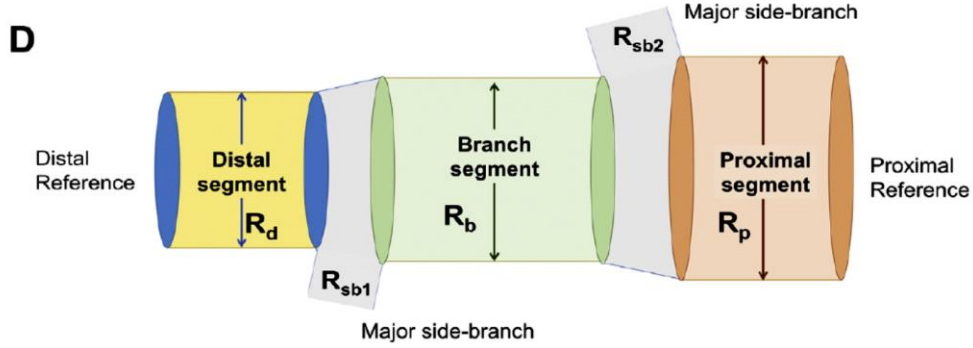
New method for vessels with no major side -branches



Method for vessels with 1 major side -branches

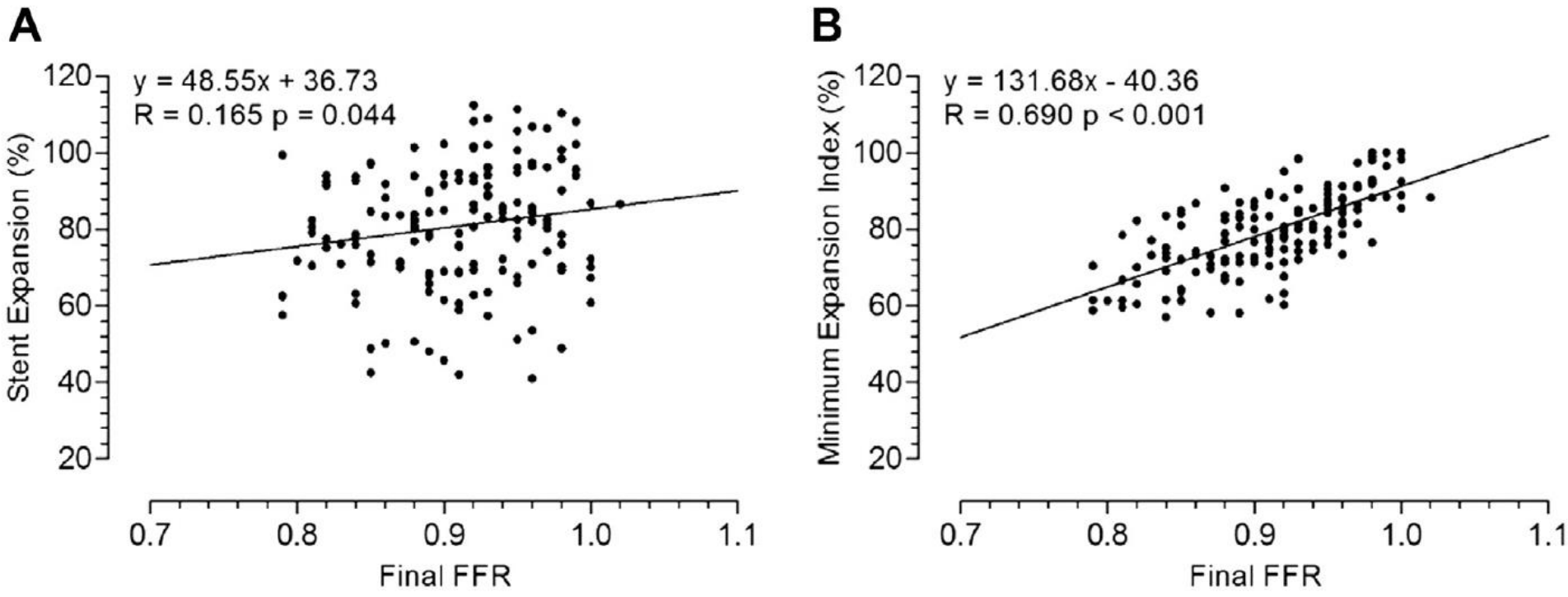


Method for vessels with 2 major side -branches



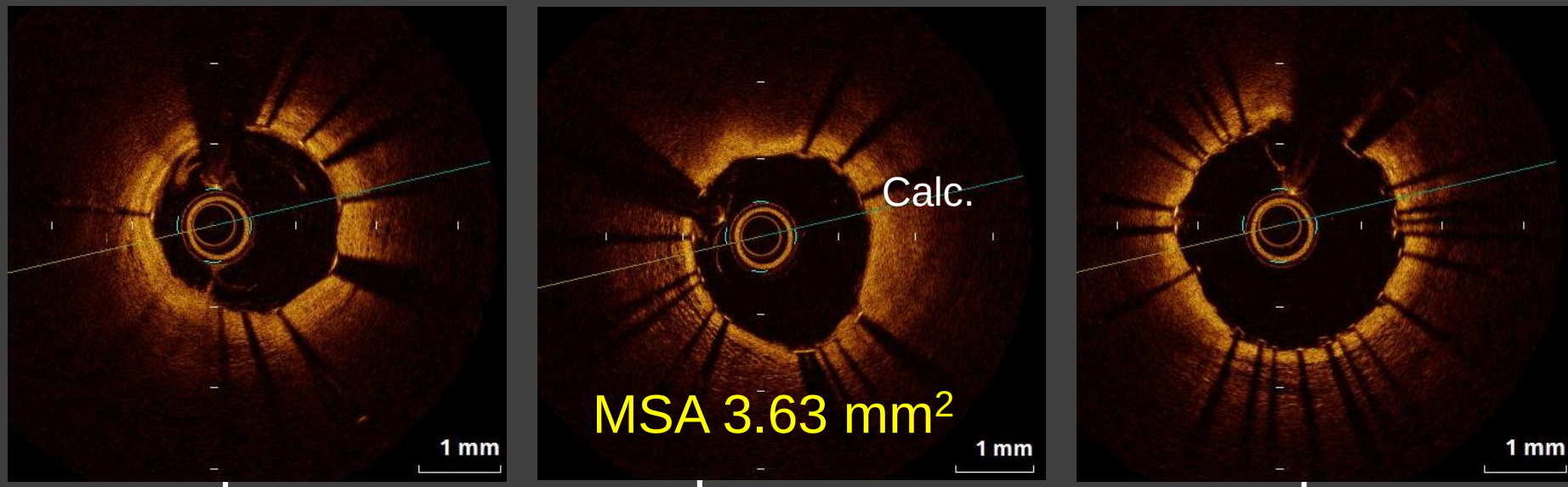
Correlation of %AS with Final FFR Value for Conventional Method and New Volumetric Method

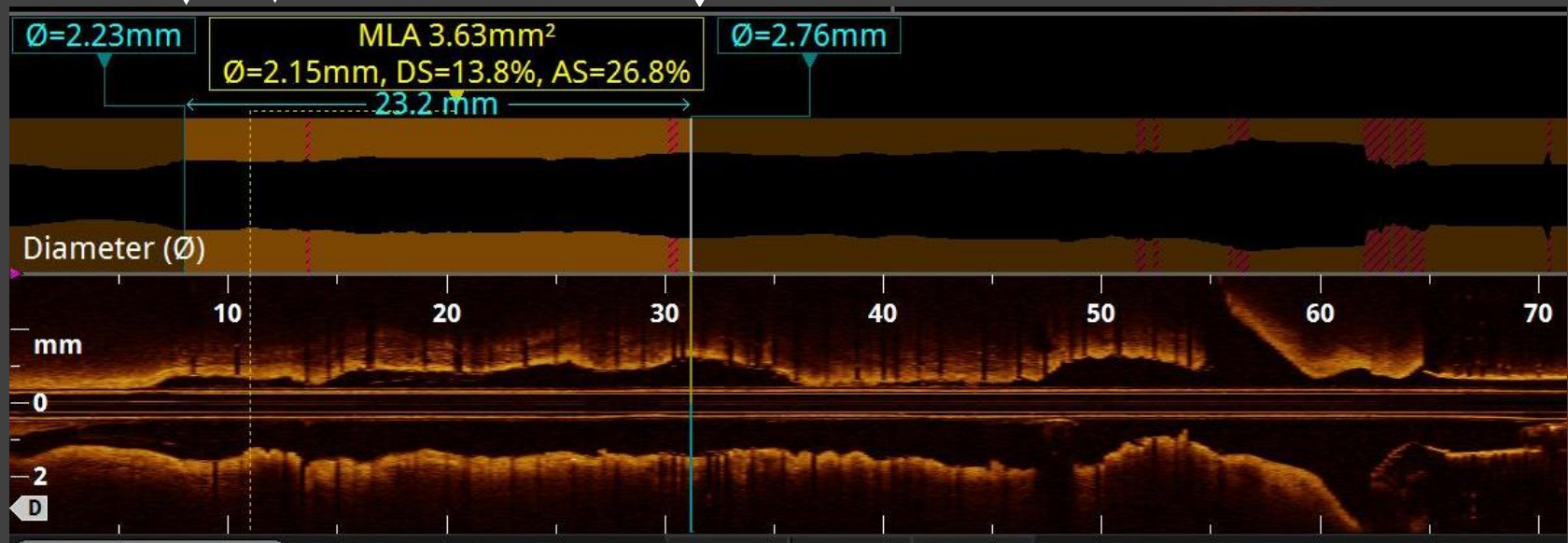
Nakamura D, et al. J Am Coll Cardiol Intv 2018;11:1467-1478



Post-PCI

Distal reference ***MSA site*** ***Prox. Reference***

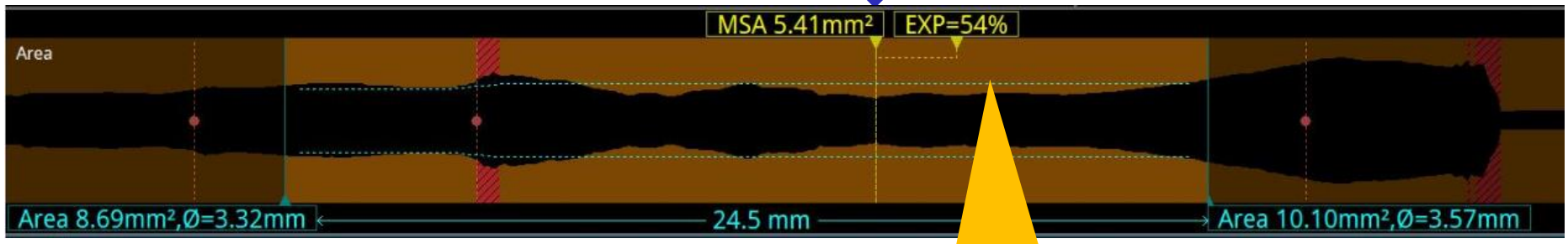




Calculation of Stent Expansion: Taper Reference

- Calculation of ideal lumen frame by frame based on proximal & distal lumen
- Ideal lumen is demonstrated based in HK Model taking the branch diameter into account
- Stent expansion (EXP%) can be assessed frame by frame based on this ideal reference

Cross section with lowest expansion index along the entire stented segment
EXP%= (Stent area/Reference area)



Distal Reference Area

Autodetection of branch & area

Demonstration of ideal expansion taking distal & proximal reference & side branch diameter into account

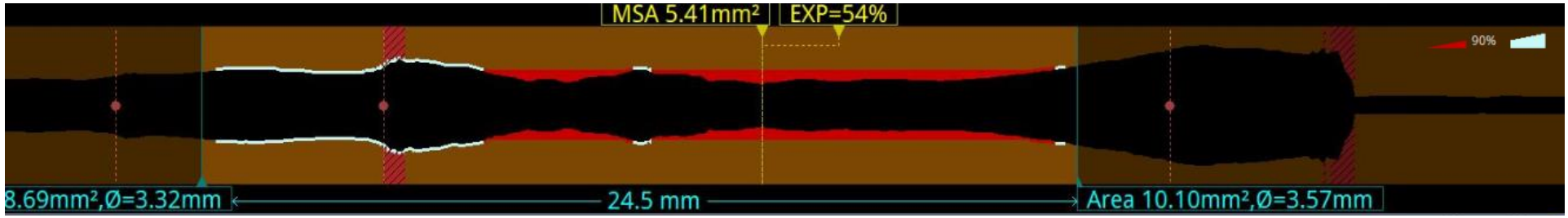
Proximal Reference Area

Post-treatment: Endpoint Assessment & Indicator

Calculation of Stent Expansion: Taper Reference

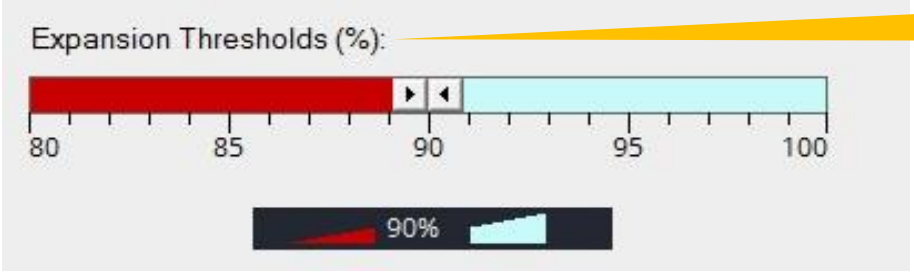
- Calculation of ideal lumen frame by frame based on proximal & distal lumen
- Ideal lumen is demonstrated based in HK Model taking the branch diameter into account
- Stent expansion (EXP%) can be assessed frame by frame based on this ideal reference

Demonstration of stent expansion indicator



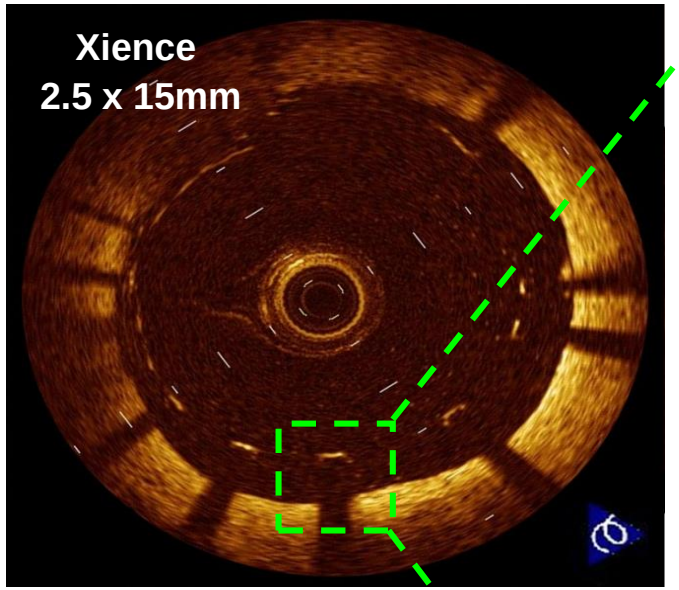
Demonstration of stent expansion indicator after auto-detection of stent

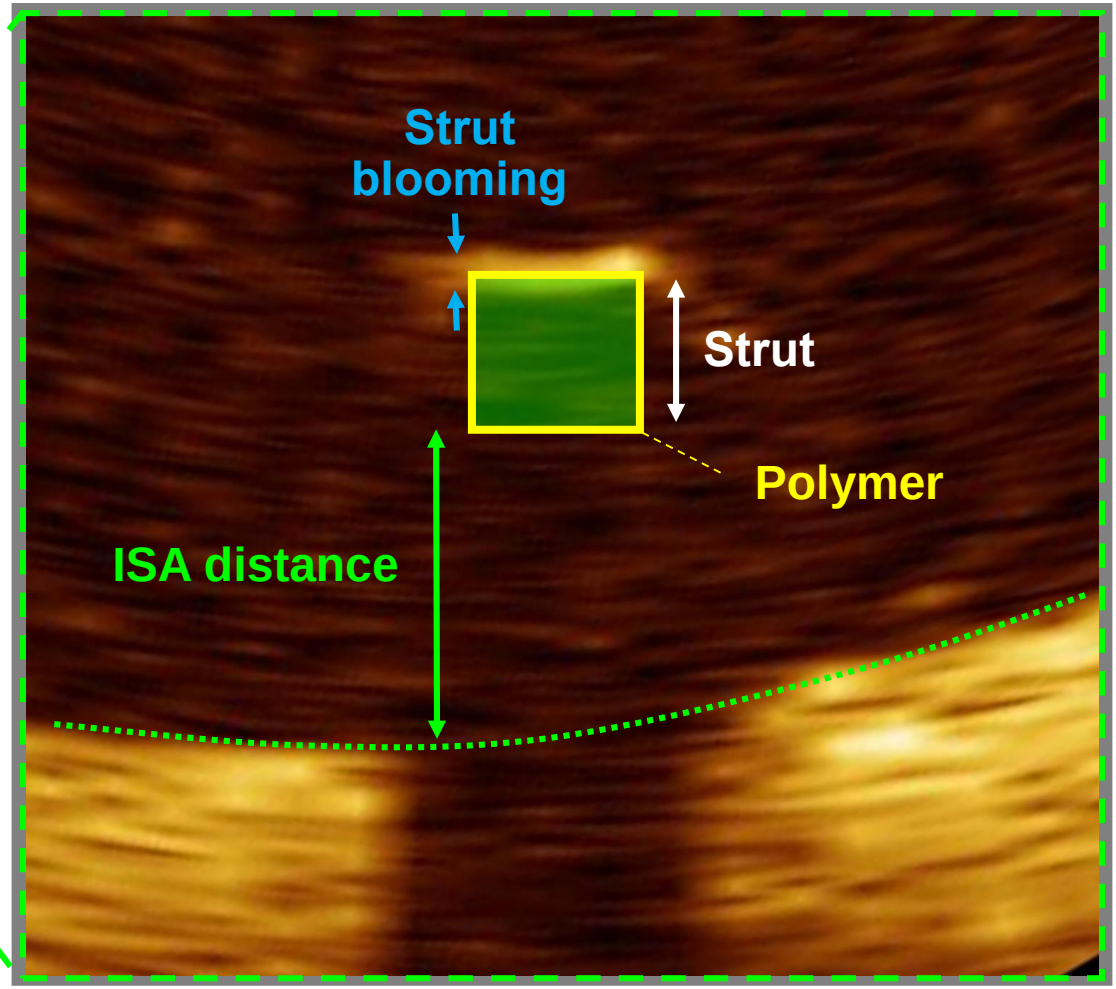
- **Underexpansion is demonstrated by red color (default is set as 90%)**
- **Well expanded stent is demonstrated by white blue**



Thresholds can be set individually
2 different (color) set is available

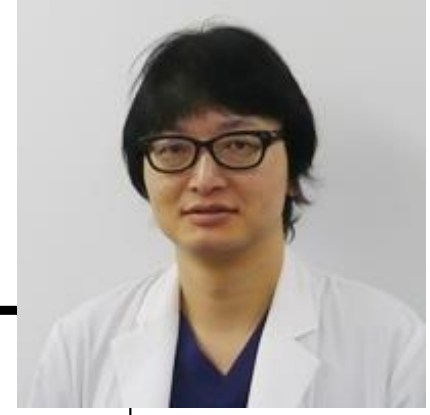
Definition of incomplete stent appostion (ISA)



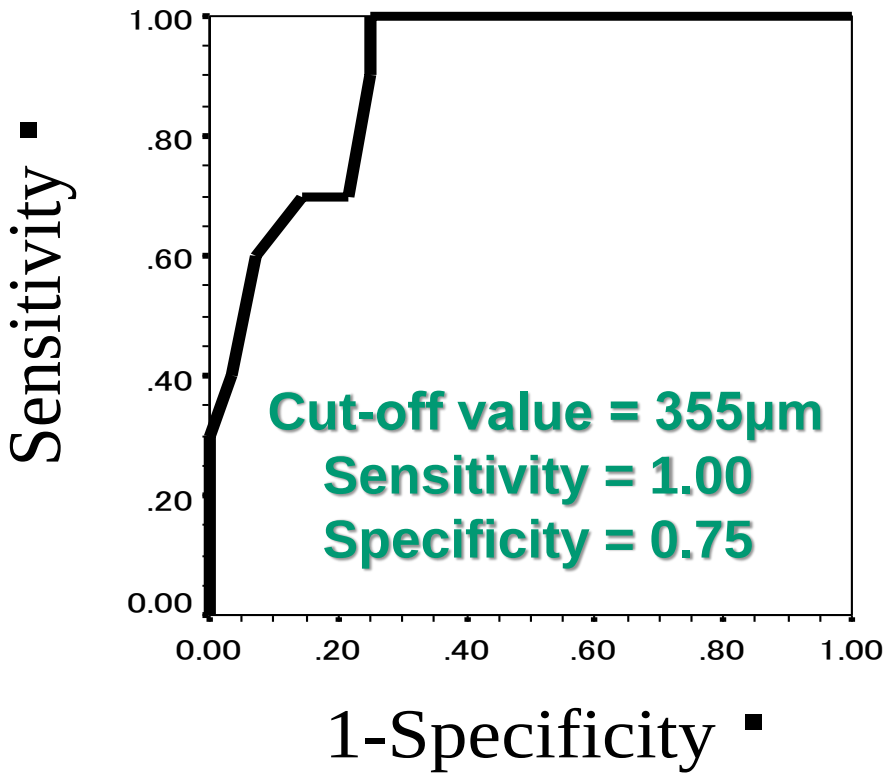


ISA was defined as a ISA distance of >100 μm in EES and >170 μm in SES.

ROC curve analysis of maximum ISA distance for predicting persistent ISA (Subanalysis of RESET study)

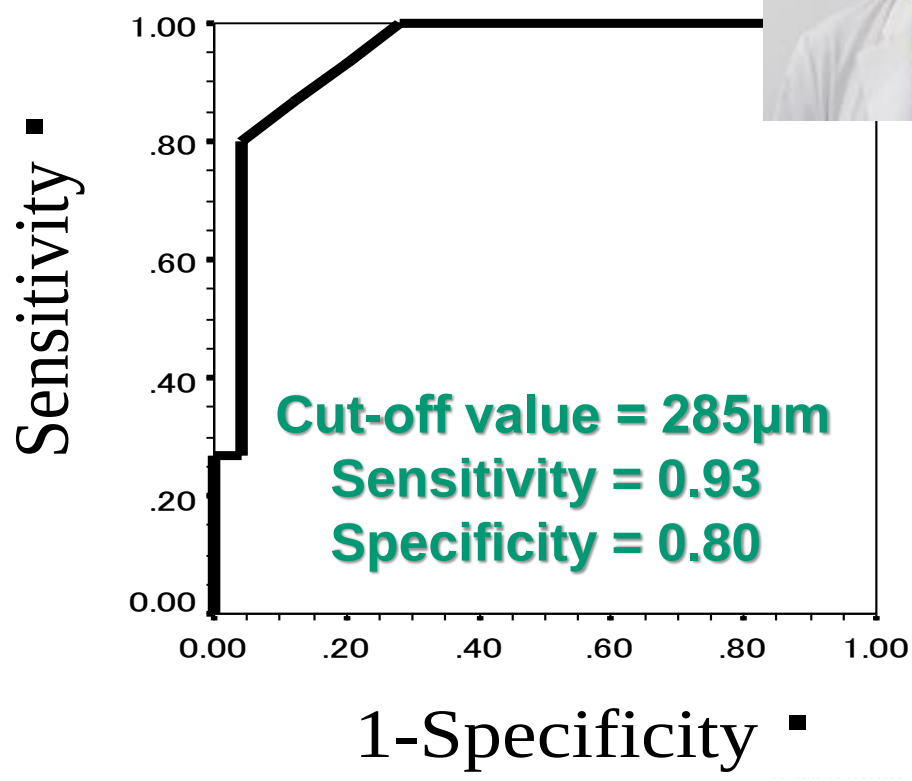


EES



ROC curve analysis identified a maximum ISA distance of EES > 355μm with as separating persistent from resolved ISA (sensitivity 100%, specificity 75%, area under the curve = 0.905; 95%CI, 0.812 to 0.999).

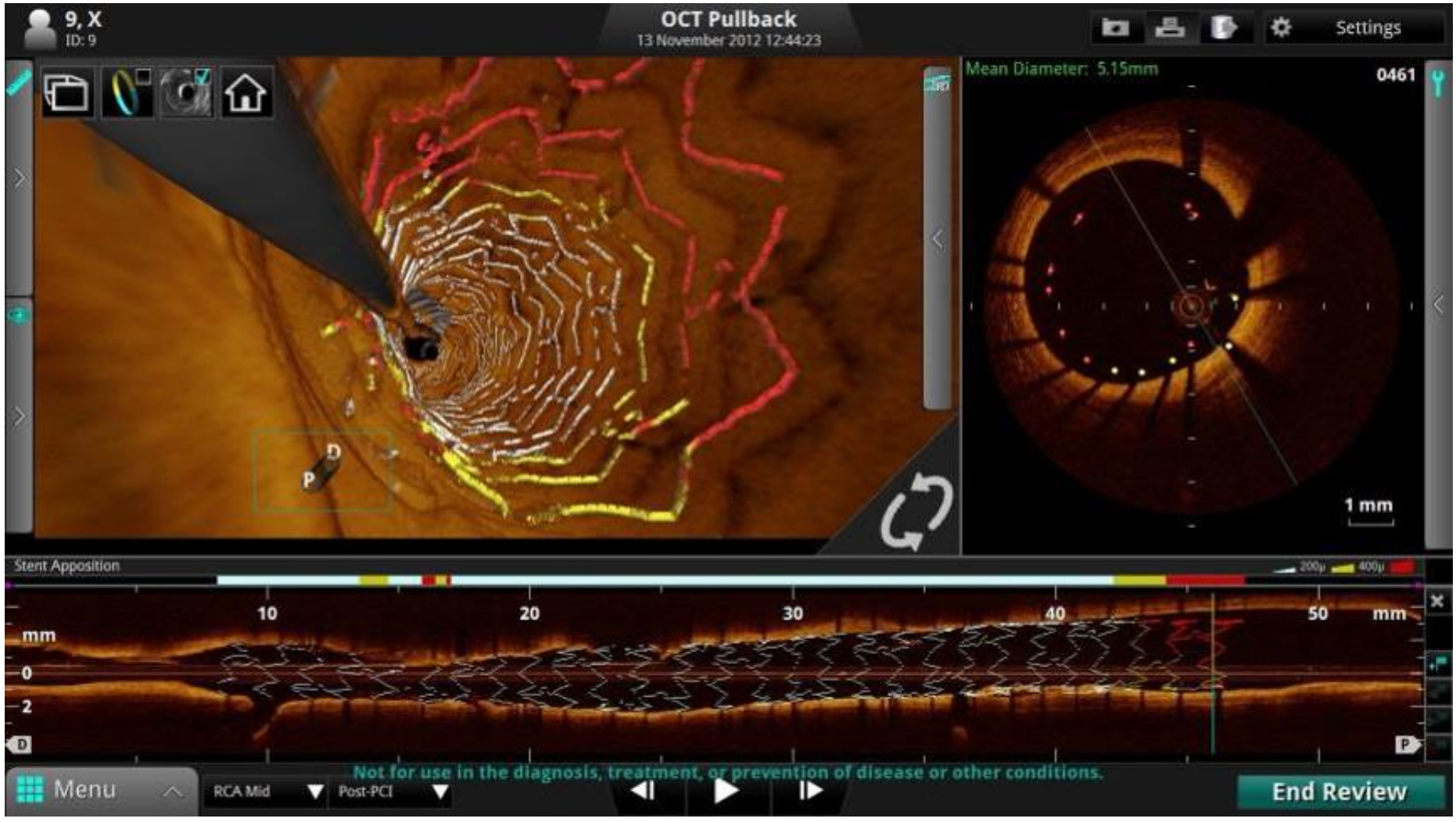
SES



ROC curve analysis identified a maximum ISA distance of SES > 285μm with as separating persistent from resolved ISA (sensitivity 93%, specificity 80%, area under the curve = 0.947; 95%CI, 0.878 to 1.015).

Shimamura K. et al, Eur Heart J CV Imaging 2015;16:23-28

New Development in OCT

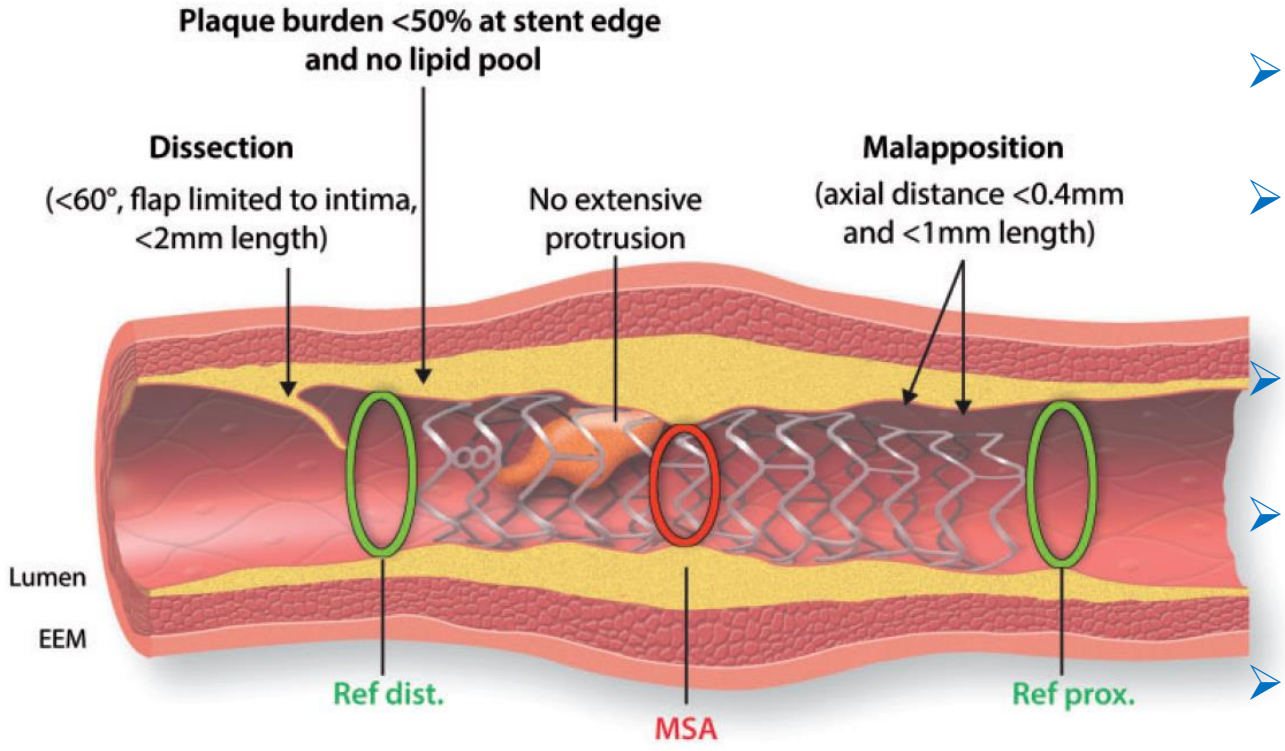


3-D reconstruction and auto-detection of stent incomplete apposition can be demonstrated as fly through image by new OCT.

The Clinical Value of OCT for PCI

- Angio-coregistration may allow us to understand the lesion and reference site on angiography and OCT at the same time.
- Newly developed expansion indicator can provide us the site and degree of under-expansion by color coded image.
- Apposition indicator demonstrates the site and degree of incomplete apposition by color coded bar and 3D-image.

Post PCI optimization



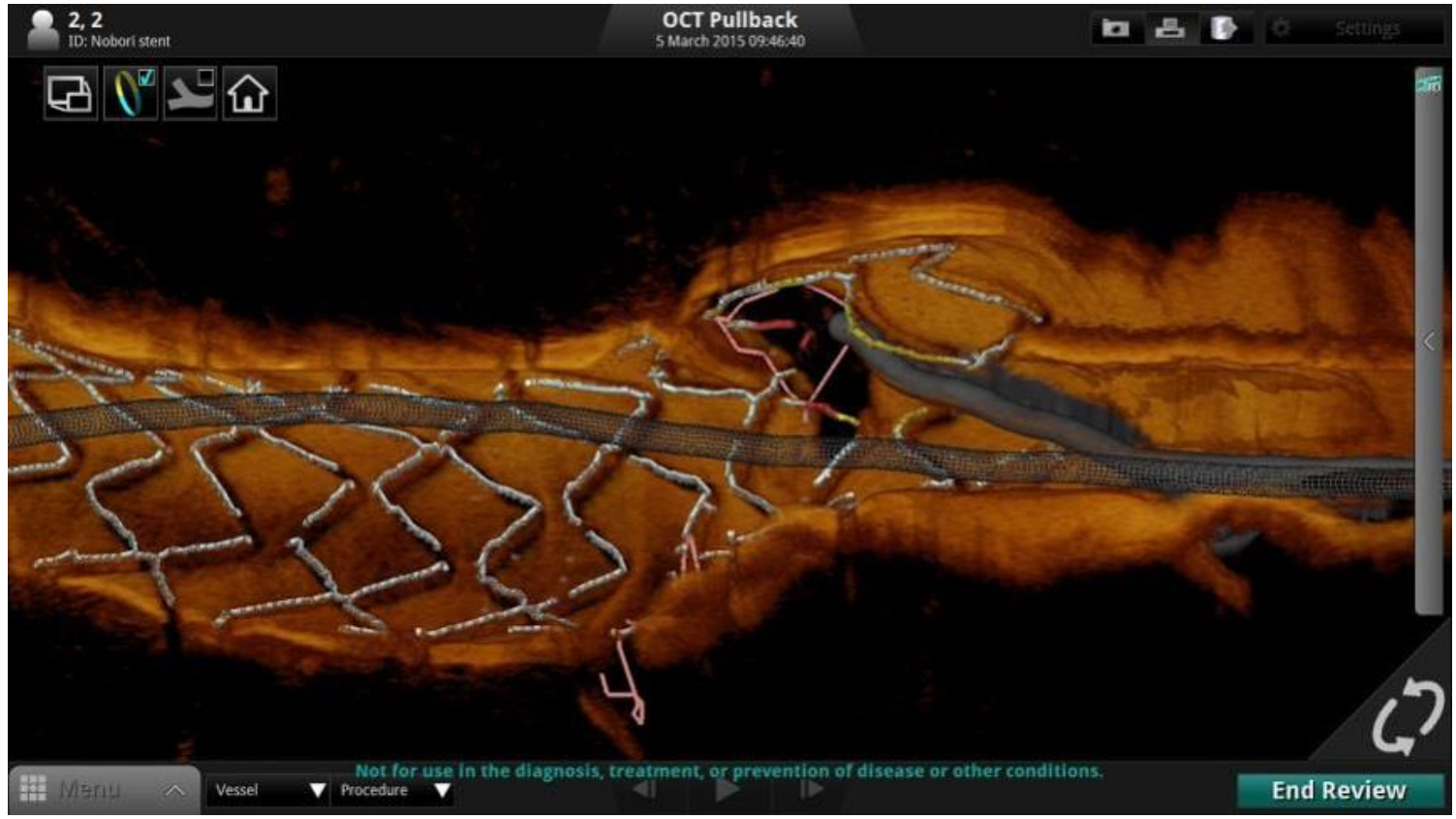
MSA>5.5cm² (IVUS) and >4.5cm² OCT

MSA/average reference lumen > 80%

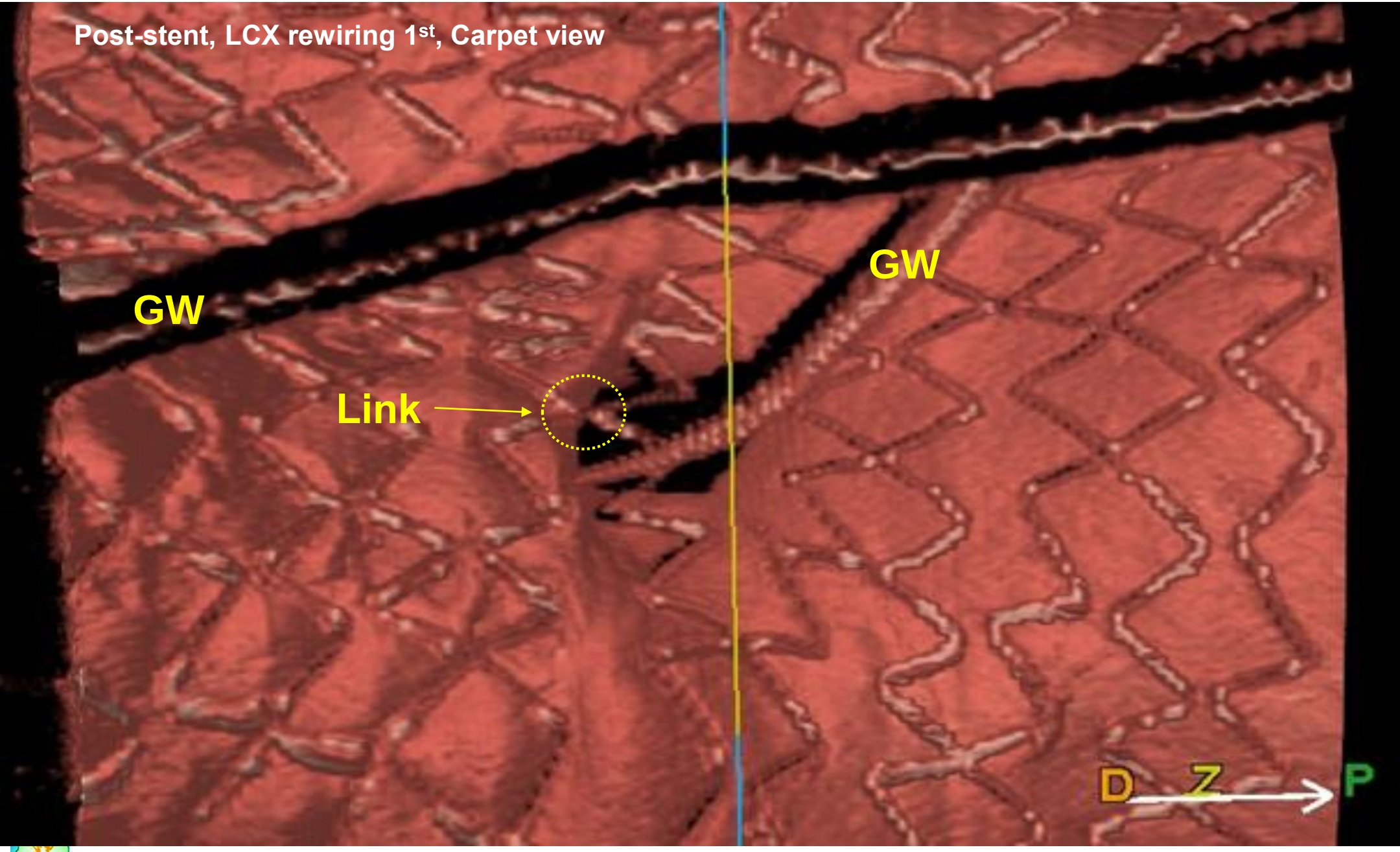
- MSA>4.5 cm_2, or > 80% of RA.
- Malaposition <400μm distance, <1mm length.
- No extensive protrusion.
- Distal landing: PB < 50%
  No lipid pool
- Distal edge dissection: <60˚
  Flap: limited to intima
  < 2 mm length

Raber L, et al. Eur Heart J 2018 May 22. doi: 10.1093/eurheartj/ehy285

New Development in OCT

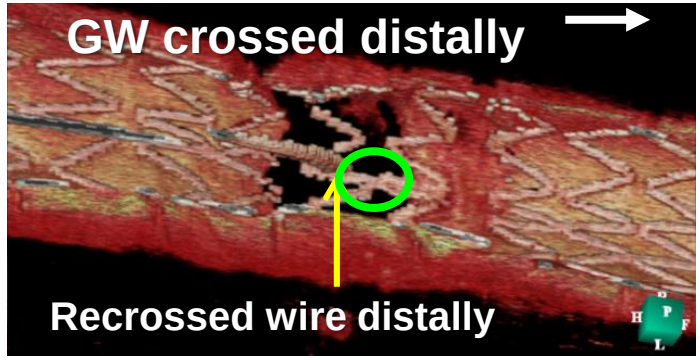


Re-crossing wire position in the jailed side branch can be easily identified by newly developed OCT software and improvement of side branch KBT procedure could be expected by the guidance of new OCT.

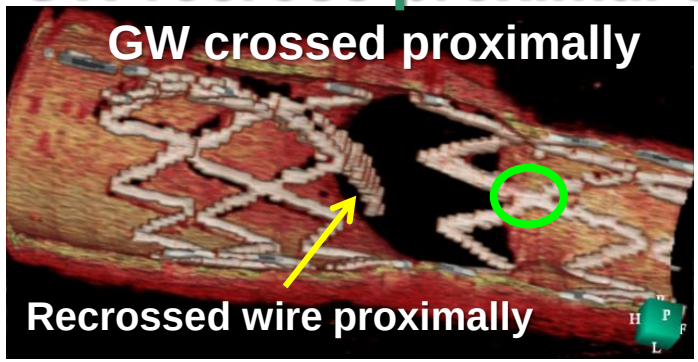

Post-stent, LCX rewiring 1st, Carpet view
GW
GW
Link
D
Z
P

Link connecting to carina type

GW recross distal cell



GW recross proximal cell

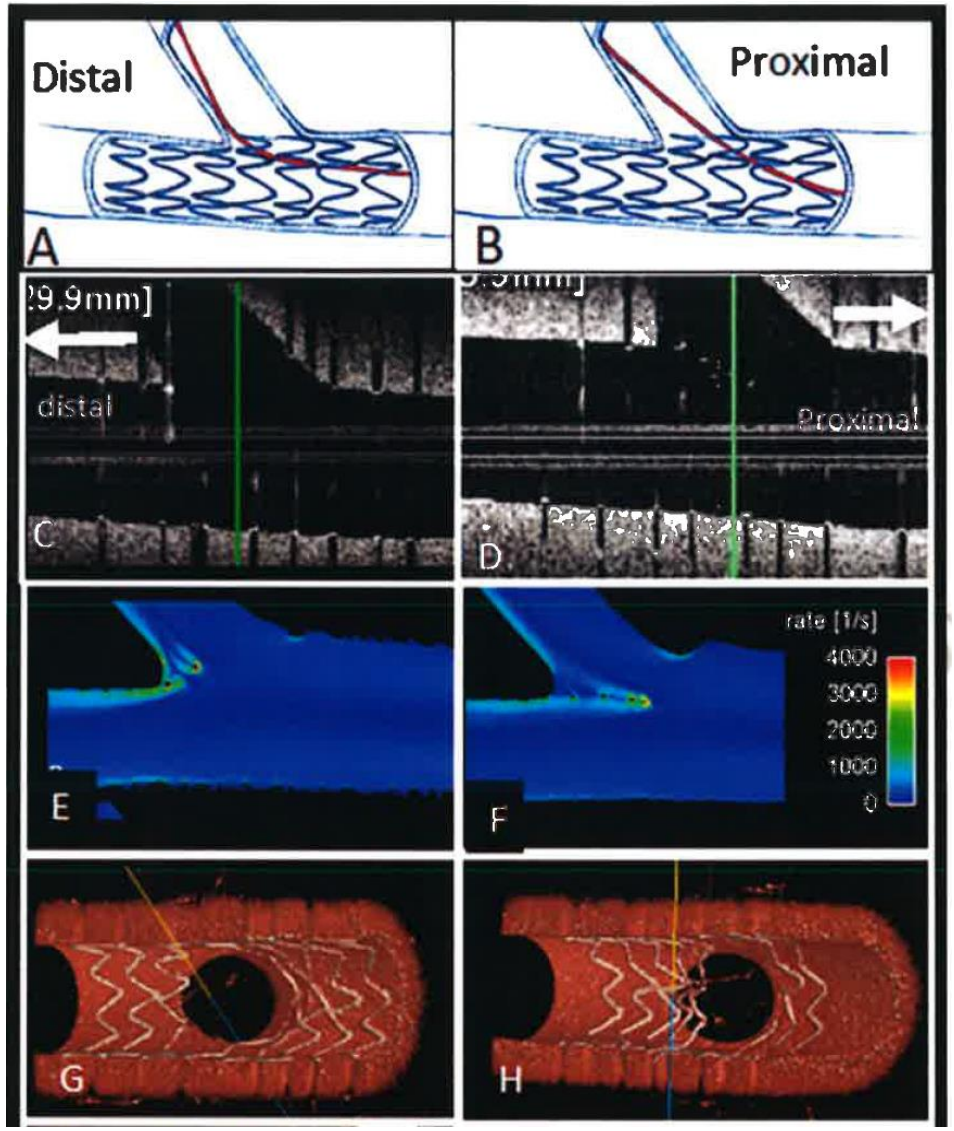


suboptimal

Impact of the rewiring position

Strut malapposition & shear stress

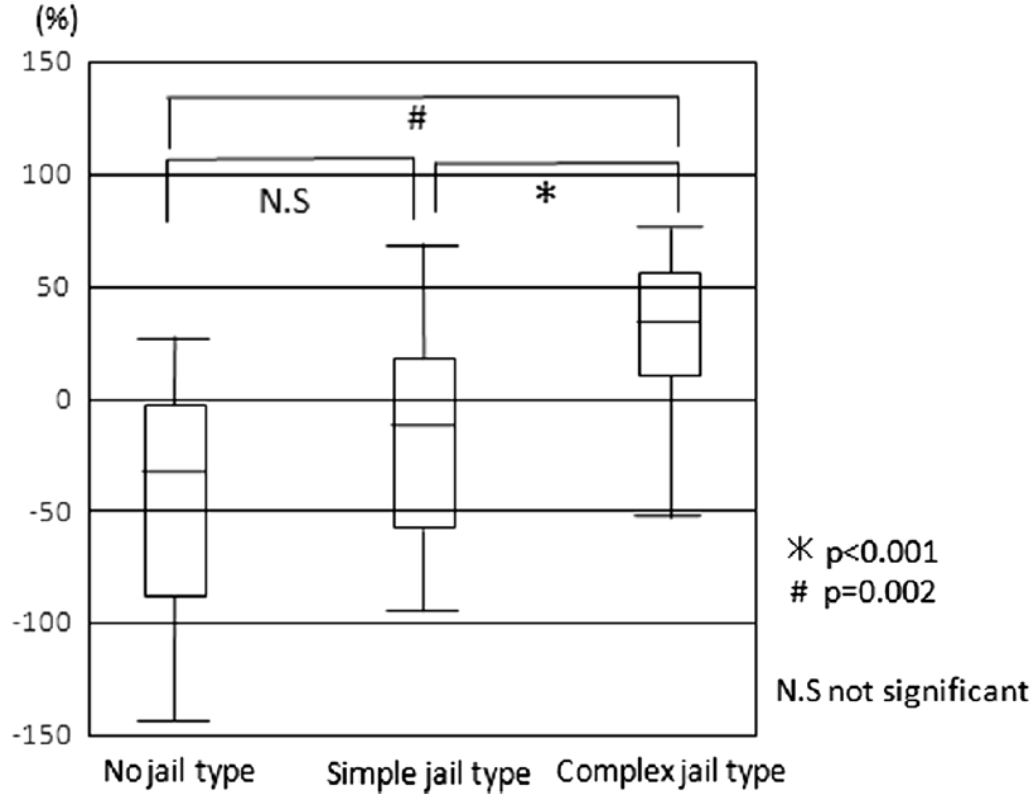
Onuma Y, et al. EuroInterv 2018, doi: 10.4244/EIJ-D-18-00391



Comparison of % reduction of the side branch flow area

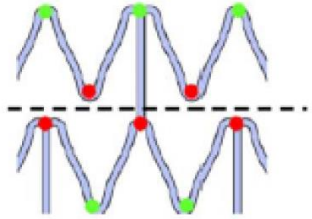
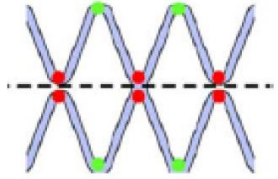
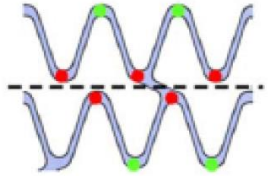
Comparison among each jailed type

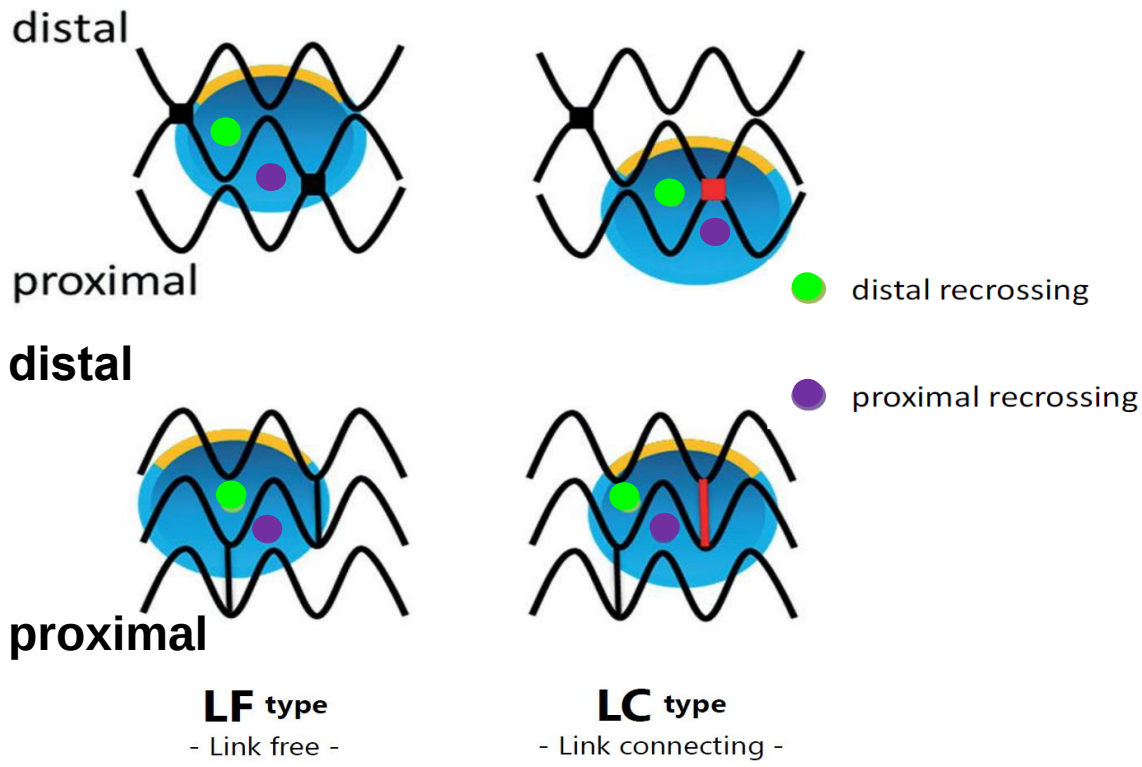
Nakamura T, et al. Int J CV Imag 2017;33: 797 – 806



Residual stent strut on the surface of bifurcation orifice may reduce the side branch flow area during follow up.

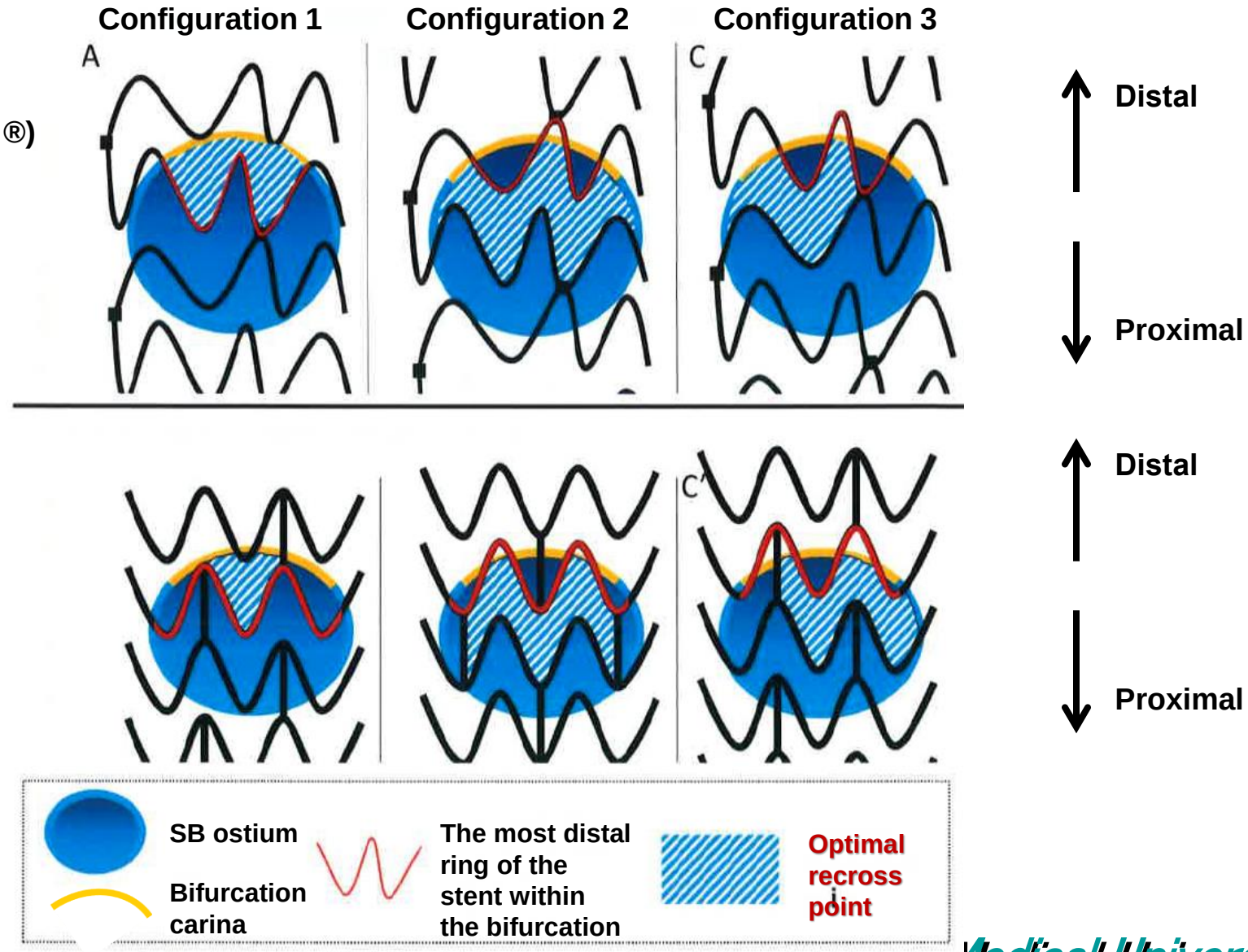
Stent design based on the rink position & wire re-cross point at bifurcation orifice

Peak to Valley (P-V) DES	Peak to Peak (P-P) DES
XIENCE	Synergy Resolute Onyx Ultimaster
	Peak to Peak  Offset Peak to Peak 



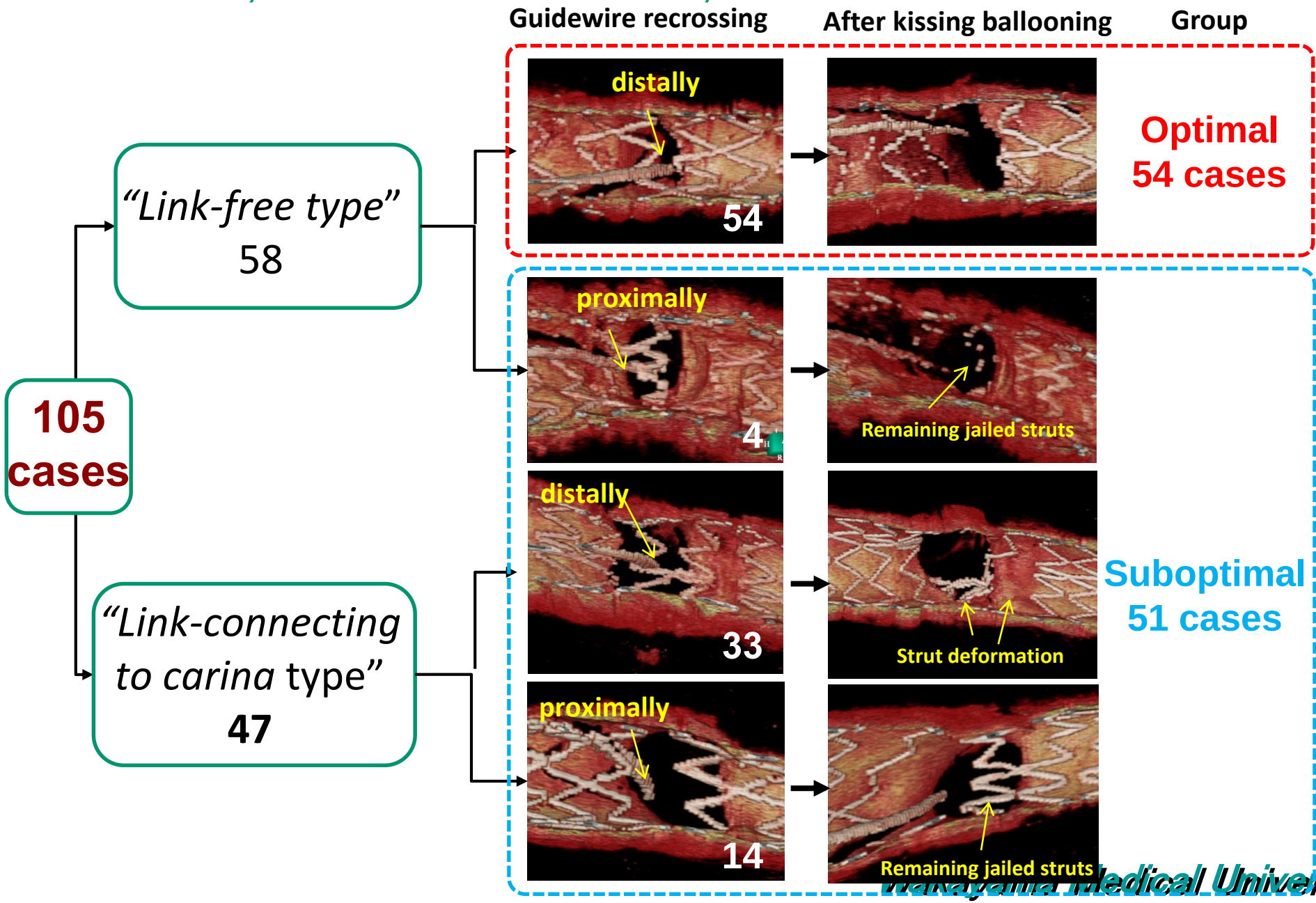
Optimal rewiring point in side branch ostium accoroding to different configurations of overhanging struts

Onuma Y, et al. EuroInterv 2018;accepted



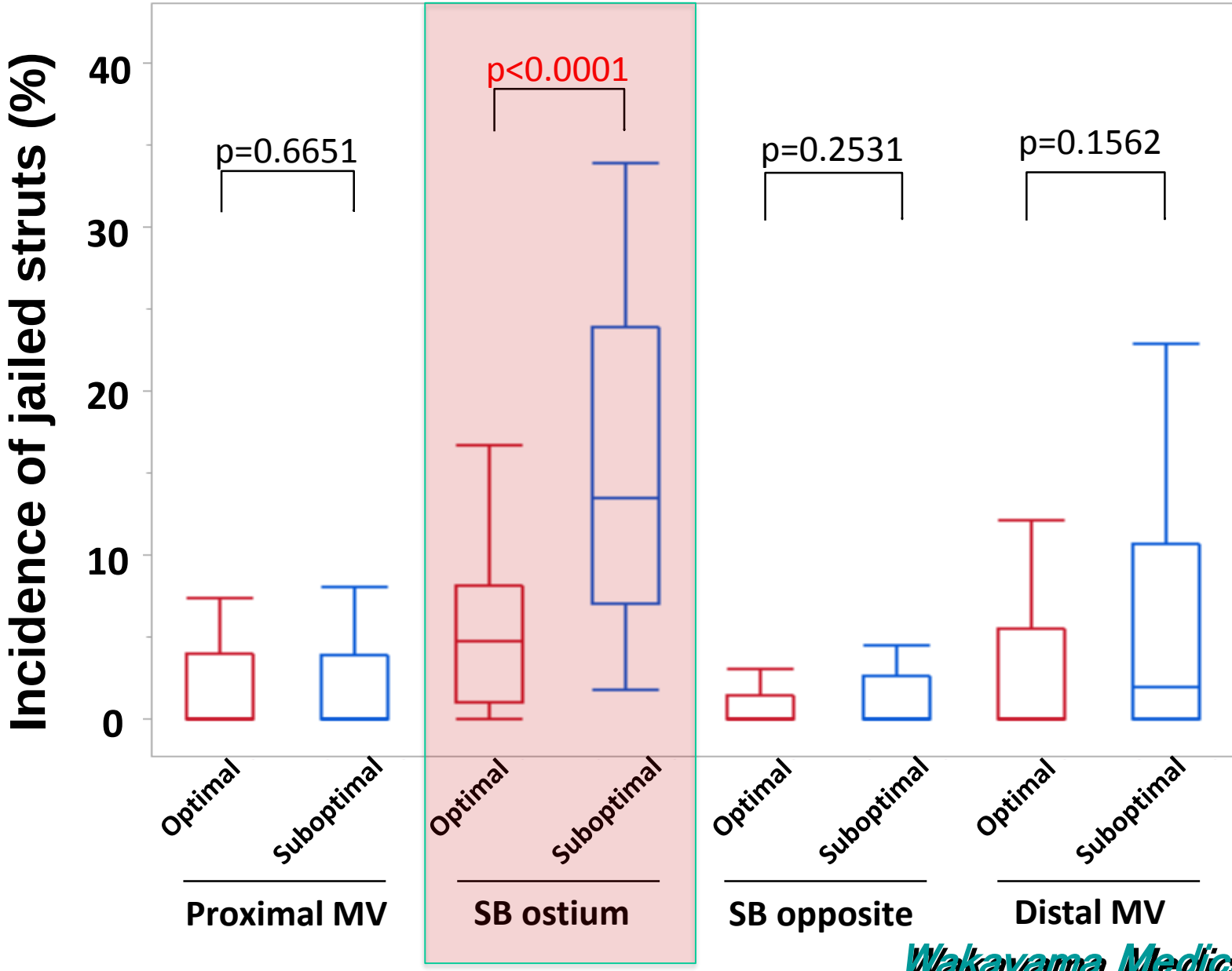
Frequency of jailing configuration & GW rewiring position

Okamura T, et al. EuroIntervention 2018;13:e1785-e1793



Incidence of ISA at each segment

Okamura T, et al. EuroIntervention 2018;13:e1785-e1793



Angiographic ISR at 9 Month

Okamura T, et al. EuroIntervention 2018;13:e1785-e1793

	All	Optimal	Suboptimal	P value
n	87	48	39	
ISR	12(13.8%)	4(8.3%)	8(20.5%)	0.1254
PMV	0(0%)	0(0%)	0(0%)	-
DMV	1(1.1%)	1(2.1%)	0(0%)	1.0000
Side Br Orifice	12(13.8%)	4(8.3%)	8(20.5%)	0.1254

Japanese registry for 3-D OCT guided bifurcation stenting

Study population

600 bifurcation lesions

Side branch opening guided by 3-D OCT:400
Optimal
Suboptimal

No side branch opening:200

Primary endpoint

Incidence of side branch restenosis at 1 year.

Secondary endpoint

MACE at 3 years

PI

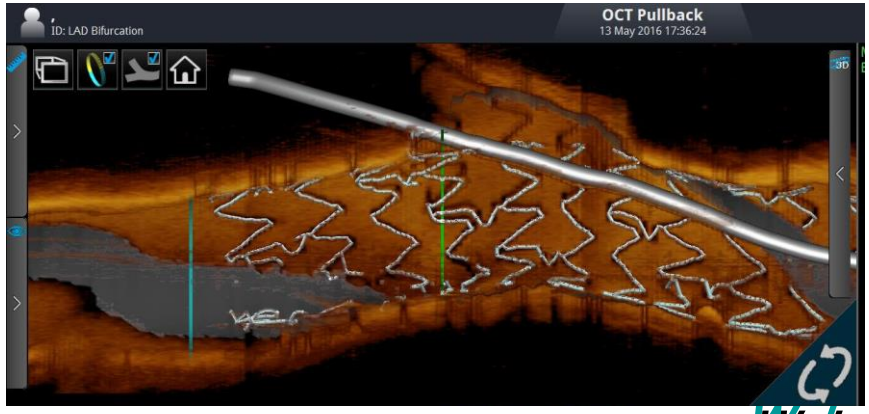
Dr. Junya Shite (Osaka Nakatsu Saiseikai Hospital)

Improvement of 3-D stent rendering demonstration

Clear demonstration of stent strut & side branch wire by using bifurcation mode

Present

AptiVue



The Clinical Value of OCT for PCI

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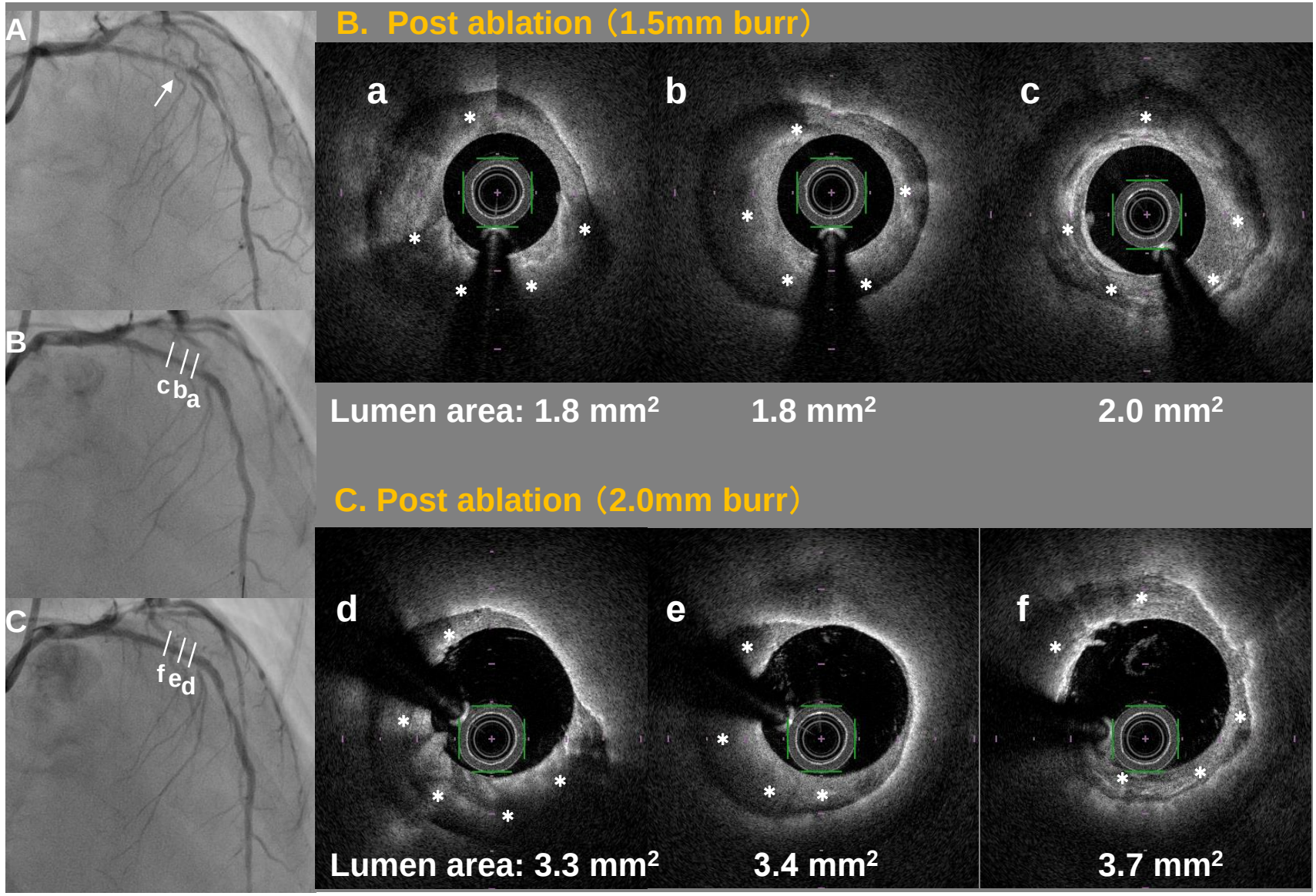
- Apposition indicator demonstrates the site and degree of incomplete apposition by color coded bar and 3D-image.
- 3D-reconstruction image might indicate the strut & rink position on the side-branch orifice precisely and demonstrate the relation between side-branch wire and stent cell in detail.

Case; 60's y.o. Female (Effort AP, Colon cancer)

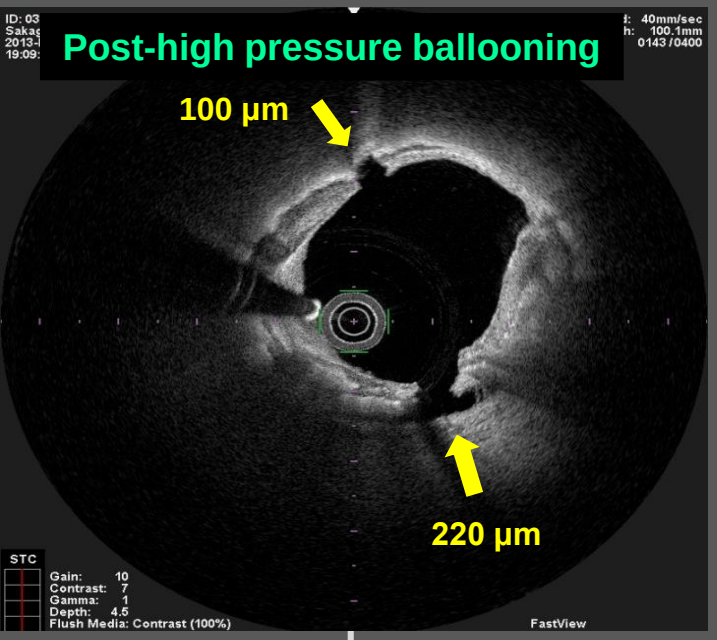


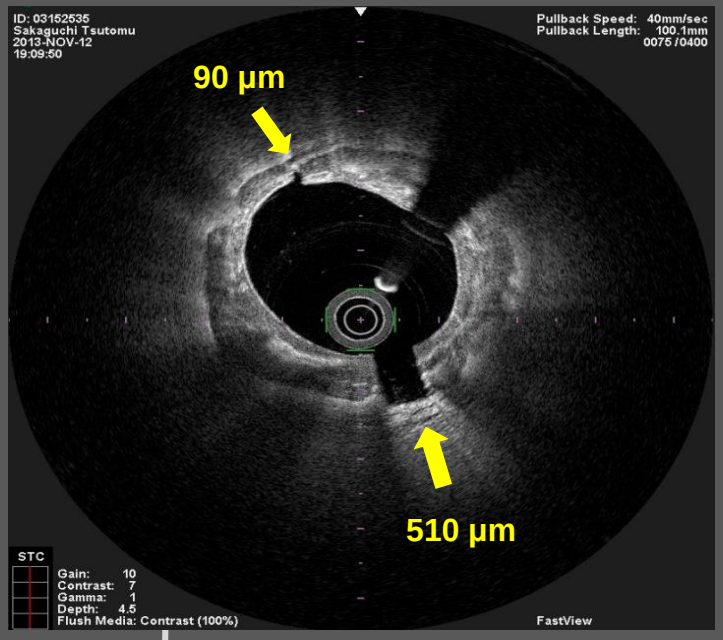
Non-stent strategy was selected because of colon cancer ope.

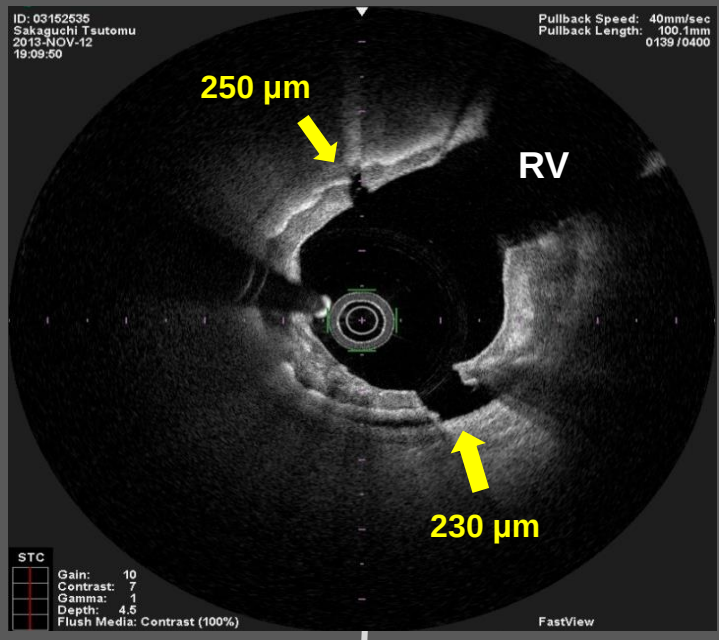
Broken calcium plate

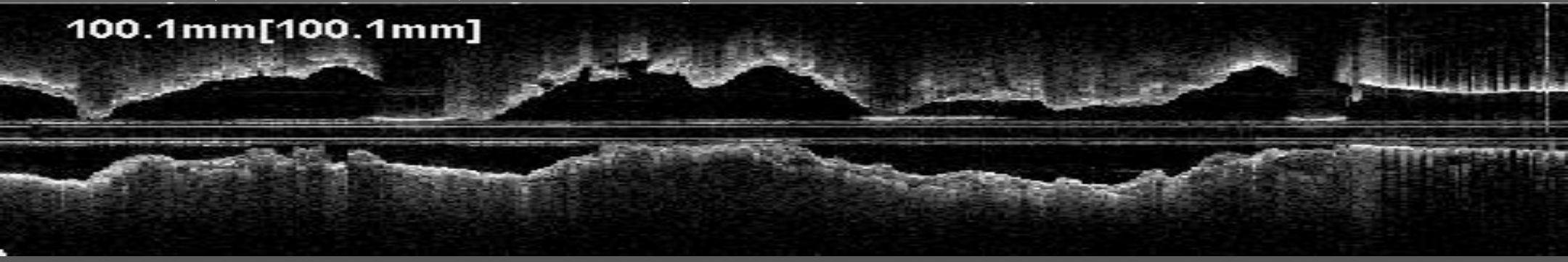
Broken calcium plate

Broken calcium plate

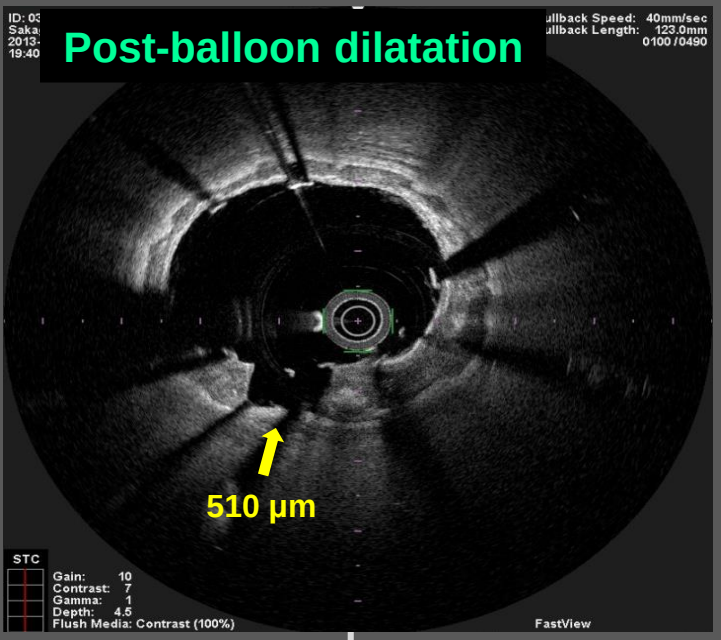




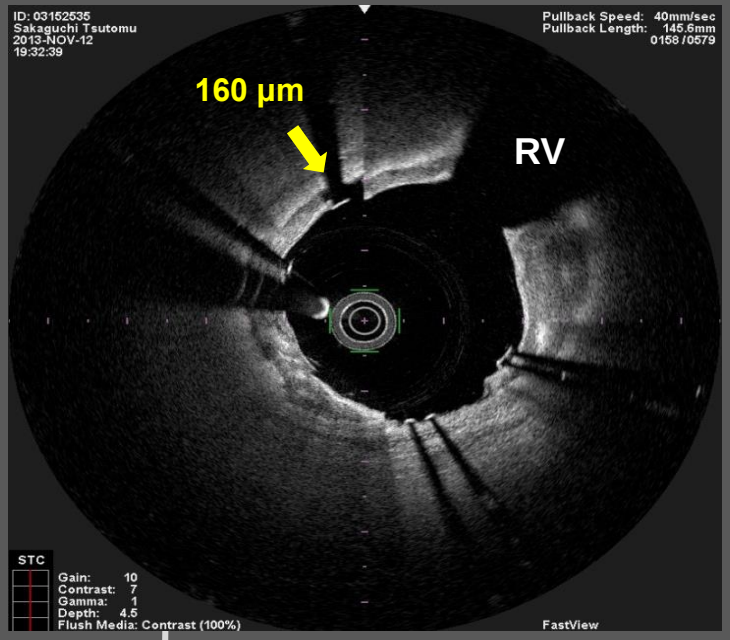




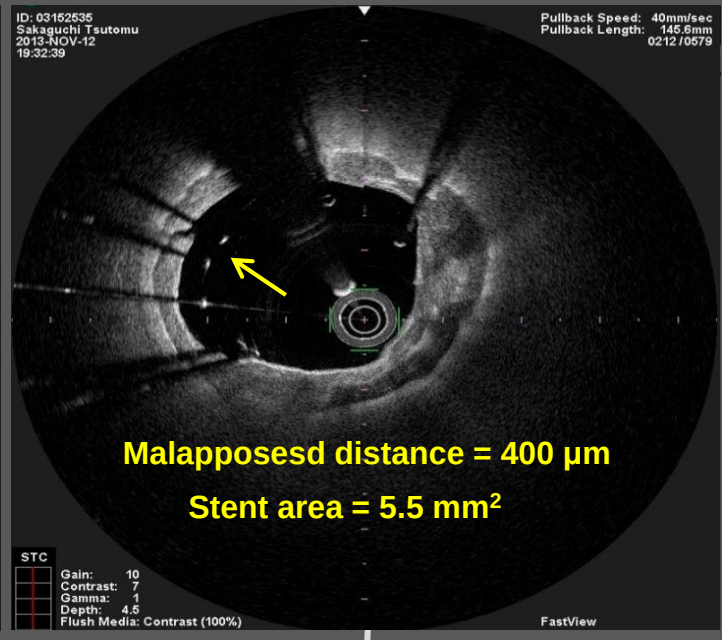
Broken calcium plate

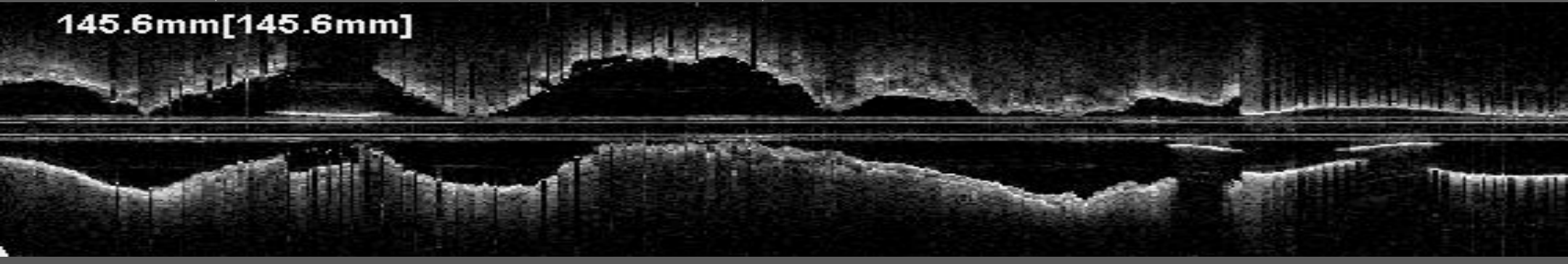


Broken calcium plate



Stent malappsoition

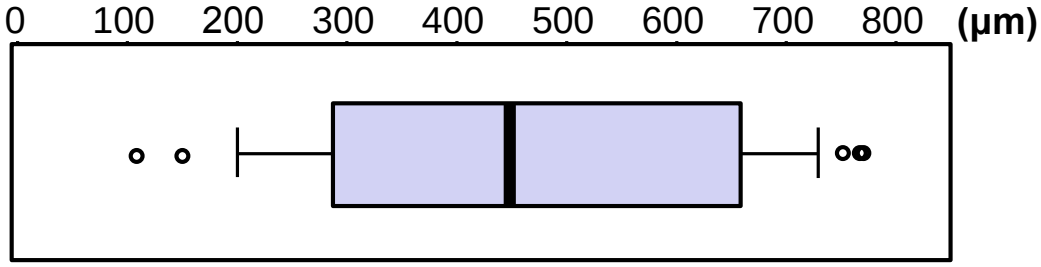




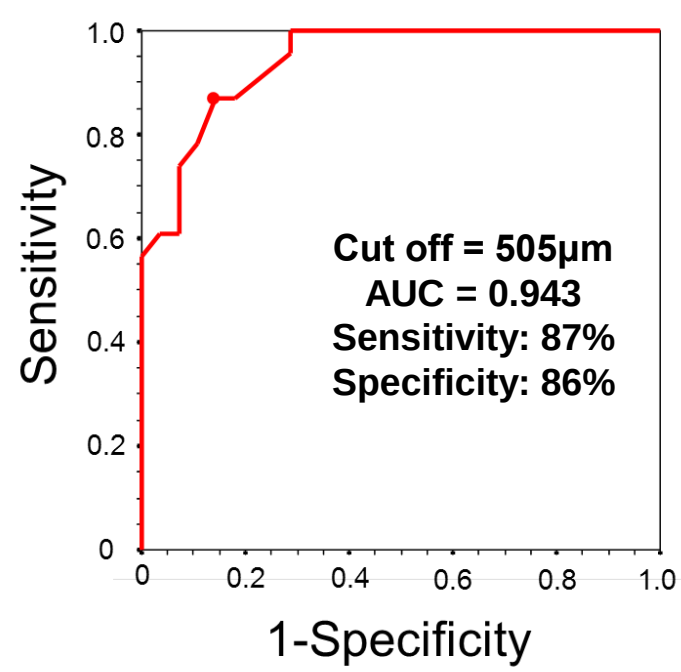
Prediction of calcium plate fracture by ballooning

OFDI was performed to assess vascular response immediately after high pressure ballooning in 61 patients with severe calcified coronary lesion.

Thickness distribution of calcium fracture



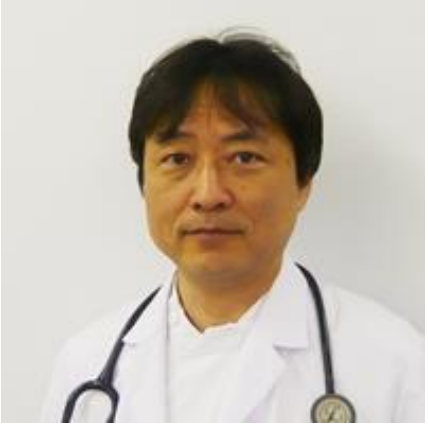
Median = 450μm; Lower quartile = 300μm; Upper quartile = 660μm; Minimum = 110μm; and Maximum = 770μm.



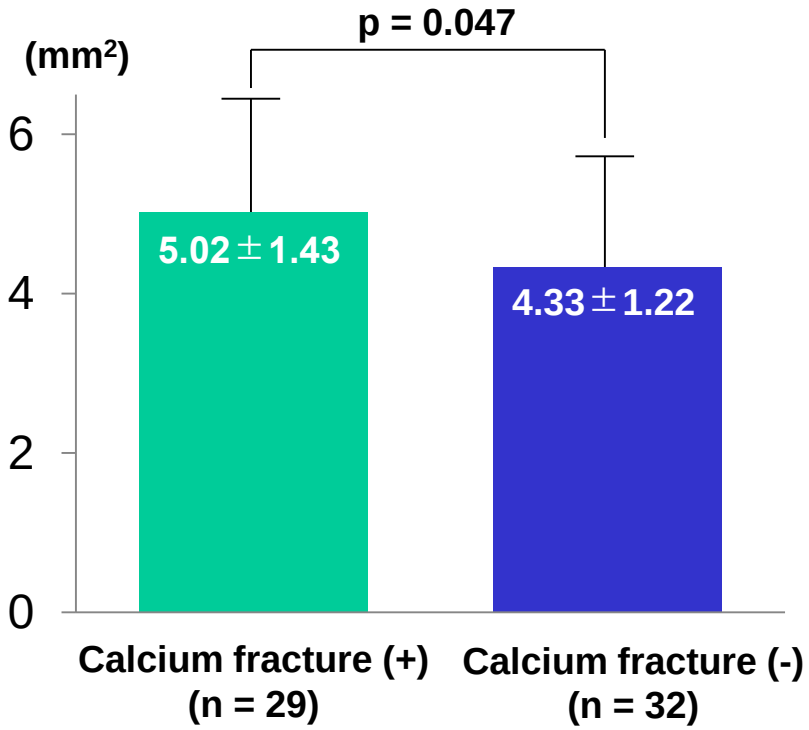
Conclusion: A calcium plate thickness < 505 μm was the corresponding cut-off value for predicting calcium plate fracture by high pressure ballooning.

Kubo, Akasaka et al. JACC Imag 2015;8:1228-9

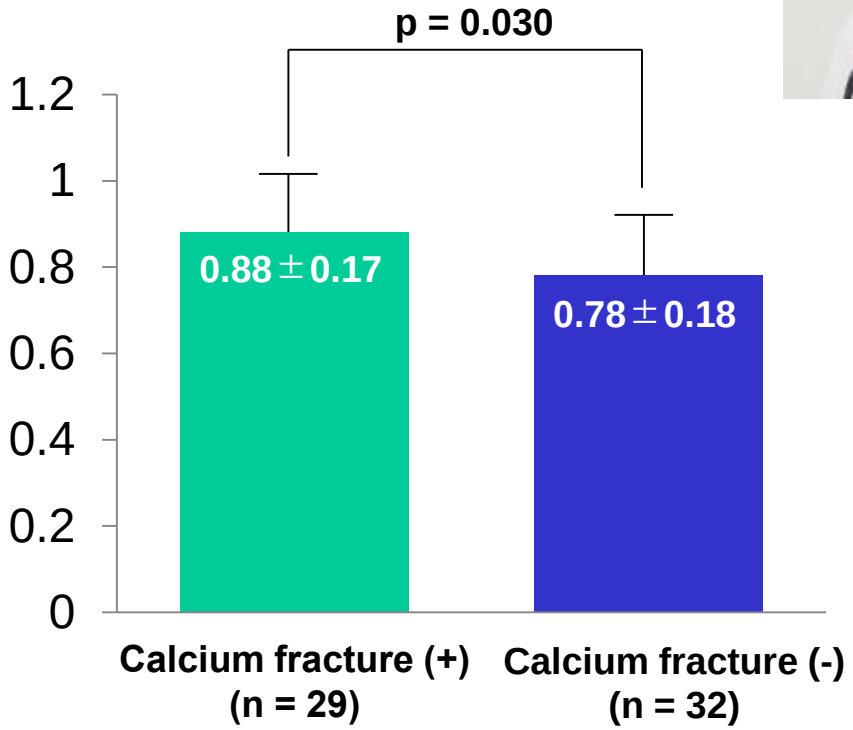
Stent expansion at post-PCI



Minimum stent area



Stent expansion index

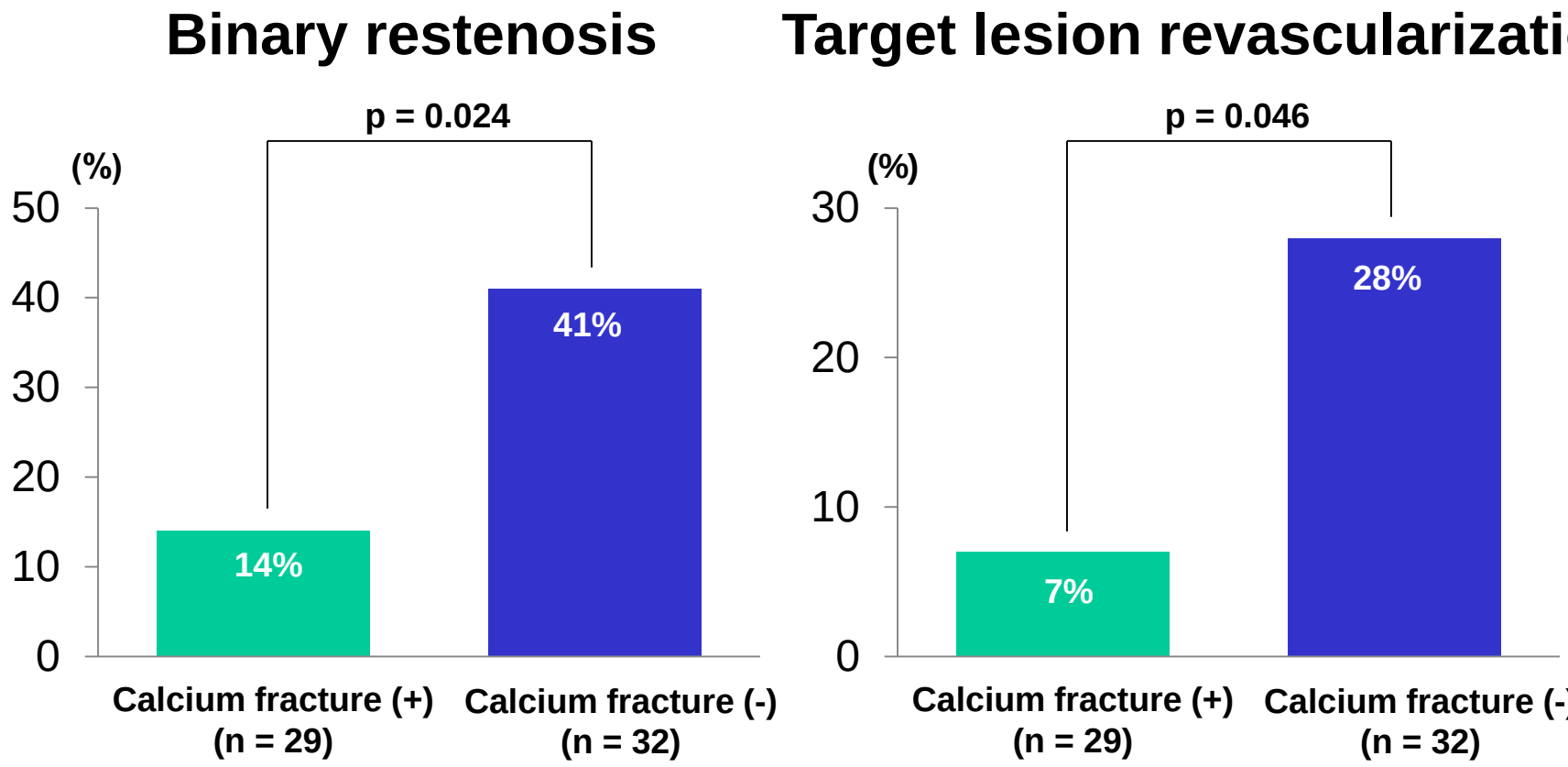


Minimum stent area and stent expansion index were significantly greater in the group with calcium fracture compared with the group without calcium fracture.

Kubo, Akasaka et al. JACC Imag 2015;8:1228-9

Wakayama Medical University

Restenosis and TLR at 10 months follow-up



The frequency of binary restenosis and target lesion revascularization was significantly lower in the group with calcium fracture compared with the group without calcium fracture.

Kubo, Akasaka et al. JACC Imag 2015;8:1228-9

The Clinical Value of OCT for PCI

- Angio-coregistration may allow us to understand the lesion and reference site on angiography and OCT at the same time.
- Newly developed expansion indicator can provide us the site and degree of under-expansion by color coded image.
- Apposition indicator demonstrates the site and degree of incomplete apposition by color coded bar and 3D-image.
- 3D-reconstruction image might indicate the strut & rink position on the side-branch orifice precisely and demonstrate the relation between side-branch wire and stent cell in detail.
- Calcium distribution and thickness can be easily identified, and rotational atherectomy may be safely performed by OCT.

OCT- vs. angio-guided PCI with DES or BMS

The retrospective Centro per la Lotta contro l'Infarto-Optimisation of Percutaneous Coronary Intervention (CLI-OPCI) study

Events at 1-year follow-up	Angiographic guidance group (n=335)	Angiographic plus OCT guidance group (n=335)	*p*-value
Death	23 (6.9%)	11 (3.3%)	0.035
Cardiac death	15 (4.5%)	4 (1.2%)	0.010
Myocardial infarction	29 (8.7%)	18 (5.4%)	0.096
Target lesion repeat revascularisation	11 (3.3%)	11 (3.3%)	1.0
Definite stent thrombosis	2 (0.6%)	1 (0.3%)	1.0
Cardiac death or myocardial infarction	43 (13.0%)	22 (6.6%)	0.006
Cardiac death, myocardial infarction, or repeat revascularisation	50 (15.1%)	32 (9.6%)	0.034

The use of OCT can improve clinical outcomes of patients undergoing PCI.

Prati F, et al., EuroIntervention 2012;8:823-829

Optimal vs Suboptimal OCT-guided PCI (CLI-OPCI ACS substudy)

	All Patients, 507	Patients With OCT Suboptimal Stent Deployment*, 280	Patients Without OCT Suboptimal Stent Deployment, 227	HR (CI)	*P* Value
DoCE (%)	61 (12.0)	50 (17.9)	11 (4.8)	4.12 (2.1–7.9)	<0.001
Cardiac death (%)	14 (2.8)	12 (4.3)	2 (0.9)	5.42 (1.2–24.4)	0.028
Myocardial infarction (%)	42 (8.3)	33 (11.8)	9 (4.0)	3.27 (1.6–6.9)	0.002
Periprocedural	12 (2.4)	8 (2.9)	4 (1.8)	1.69 (0.5–5.6)	0.671
During follow-up	30 (5.9)	25 (8.9)	5 (2.2)	4.57 (1.7–12.0)	0.002
Target lesion revascularization (%)	37 (7.3)	31 (11.1)	6 (2.6)	4.76 (2.0–11.4)	<0.001
Stent thrombosis (%)	25 (4.9)	21 (7.5)	4 (1.8)	4.65 (1.6–13.6)	0.005
Acute	5 (1.0)	3 (1.1)	2 (0.8)	1.29 (0.2–7.7)	0.782
Subacute	16 (3.1)	14 (5.0)	1 (0.4)	11.81 (1.6–89.8)	0.017
Late	2 (0.4)	3 (1.1)	0 (0.0)	0.00 (0.0–0.0)	0.257
Very late	2 (0.4)	1 (0.3)	1 (0.4)	1.33 (0.8–22.5)	0.843
Days of follow-up†	345 (219–540)	342 (205–540)	352 (230–540)		0.202

CI indicates confidence interval; DoCE, hierarchical device-oriented cardiovascular events (cardiac death, target vessel myocardial infarction, and target lesion revascularization); HR, hazard ratio; and OCT, optical coherence tomography.

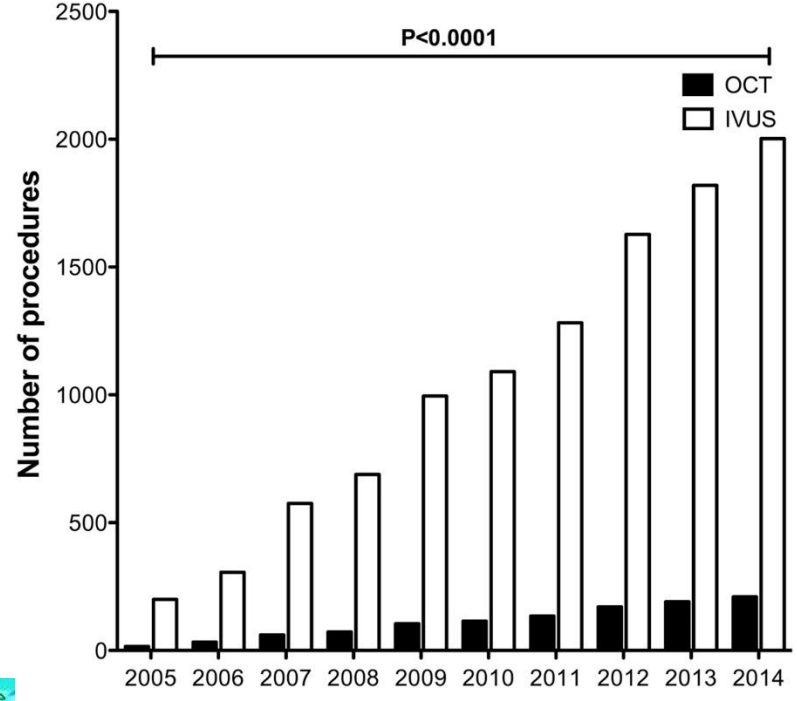
*Either in-stent minimum lumen area <4.5 mm^2, intrastent atherothrombotic tissue prolapse >500 μm, dissection >200 μm at the distal stent edge, distal or proximal reference narrowing.

Prati F, et al. Circ CV Interv 2016;9:e003726.

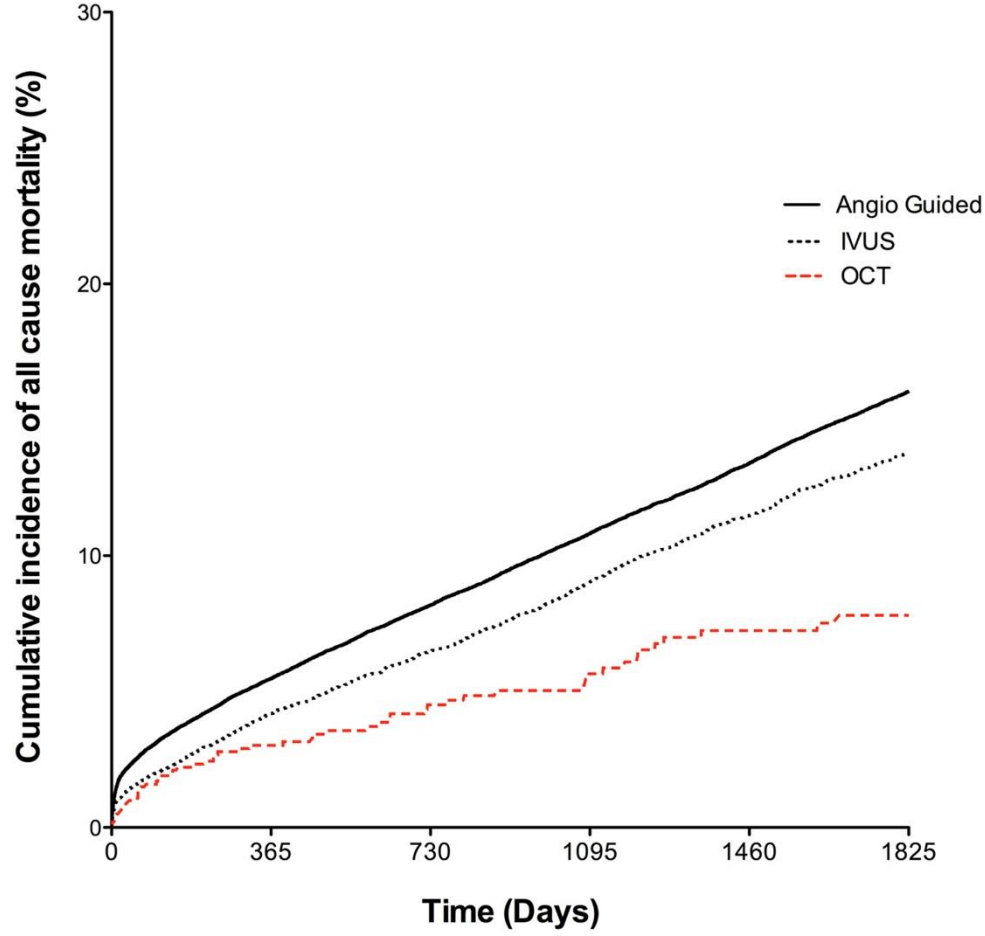
Angiography Alone Versus Angiography Plus Optical Coherence Tomography to Guide Percutaneous Coronary Intervention

Outcomes From the Pan-London PCI Cohort

Daniel A. Jones, MD, PhD,[a] Krishnaraj S. Rathod, MD,[a] Sudheer Koganti, MD,[a] Stephen
Zoe Astroulakis, MD, PhD,[c] Pitt Lim, MD,[c] Alexander Sirker, MD, PhD,[a] Constantinos O'
Ajay K. Jain, MD,[a] Charles J. Knight, MD,[a] Miles C. Dalby, MD,[d] Iqbal S. Malik, MBBS, F
Anthony Mathur, MD, PhD,[a] Roby Rakhit, MD,[e] Tim Lockie, MBChB, PhD,[e] Simon Redw
Philip A. MacCarthy, MBChB, PhD,[g] Ranil Desilva, MD, PhD,[d] Roshan Weerackody, MD,
Andrew Wragg, MD, PhD,[a] Elliot J. Smith, MD,[a] Christos V. Bourantas, MD, PhD[a]



Kaplan-Meier Curve Comparing All-Cause Mortality Among OCT-, IVUS- and Angio-guided PCI



Numbers at risk						
Angio Only	75046	66033	56182	51030	40053	28765
IVUS	10971	8954	7838	6632	5431	4242
OCT	1149	901	789	654	561	410

Jones DA, et al., J Am Coll Cardiol Intv 201811:1313-1321

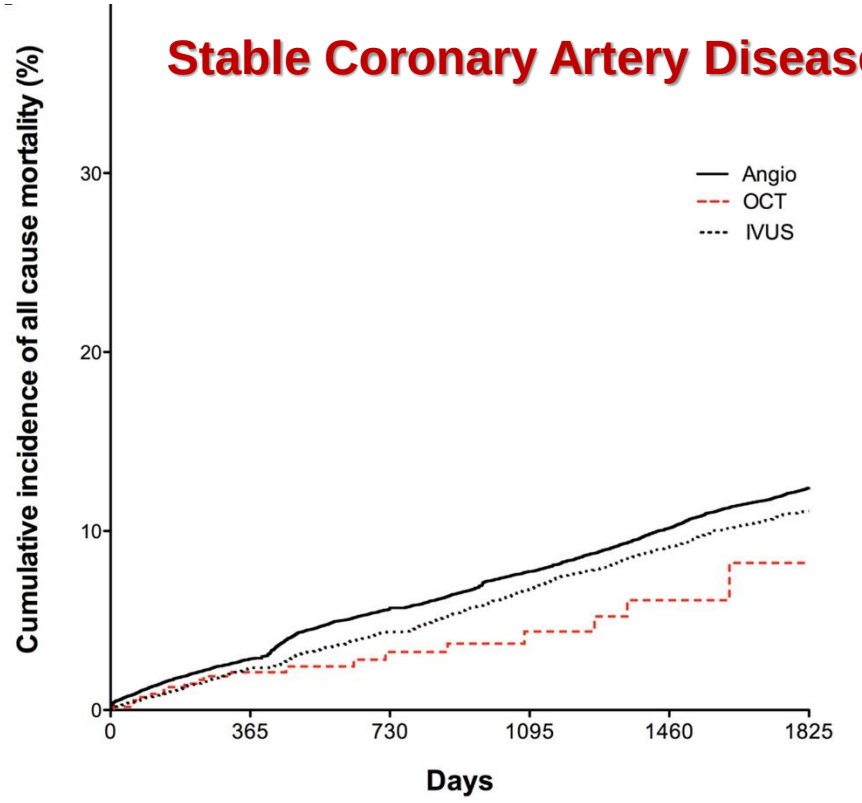
Angiography Alone Versus Angiography Plus Optical Coherence Tomography to Guide Percutaneous Coronary Intervention

Outcomes From the Pan-London PCI Cohort

Zoe Astro
Ajay K. Ja
Anthony
Philip A.
Andrew V

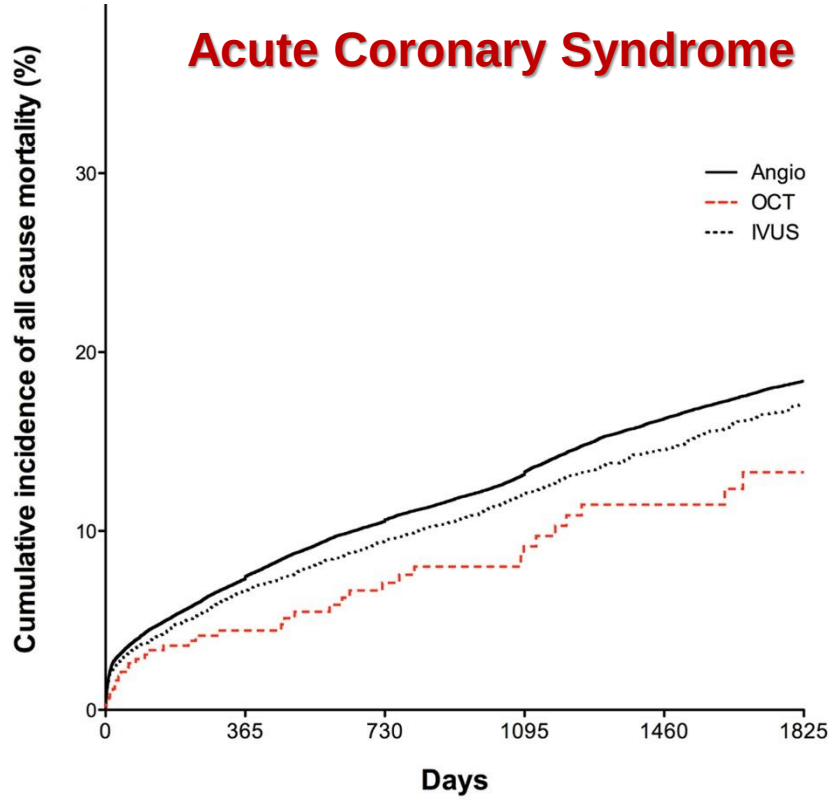
Kaplan-Meier Curve Comparing All-Cause Mortality Among OCT-, IVUS- and Angio-guided PCI

Stable Coronary Artery Disease



Numbers at risk						
Angio Only	43144	38185	33381	30130	26053	23765
IVUS	5911	4954	4358	3792	3135	2941
OCT	662	540	496	405	371	301

Acute Coronary Syndrome



Numbers at risk						
Angio Only	31902	28083	23182	21130	19053	15765
IVUS	5060	4254	3838	3272	2631	2242
OCT	487	420	389	314	261	201

Jones DA, et al., J Am Coll Cardiol Intv 201811:1313-1321

Take Home Message

The Clinical Value of OCT

- Several procedural advantages have been developed in OCT compared with other coronary imaging modalities, and additional improvement in soft ware could be expected

It is a good time to move from IVUS to OCT!!

- Although only a few reports about the improvement of prognosis have been reported by OCT-guided PCI, further improvement of PCI prognosis could be expected by OCT guidance, especially in specific lesions such as very complex, calcified or bifurcation lesion.

Thank you for your kind attention !!

Welcome to APSC 2020 in Kyoto, Japan!!