When to Use IVUS, OCT, and VH (and others)

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TCT2011

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Modalities

- FFR (or iFR)
- IVUS (with or without VH, iMAP, or IB-IVUS)
- OCT
- NIRS (with or without IVUS)
- Some combination of the above
- (ICE or TEE)

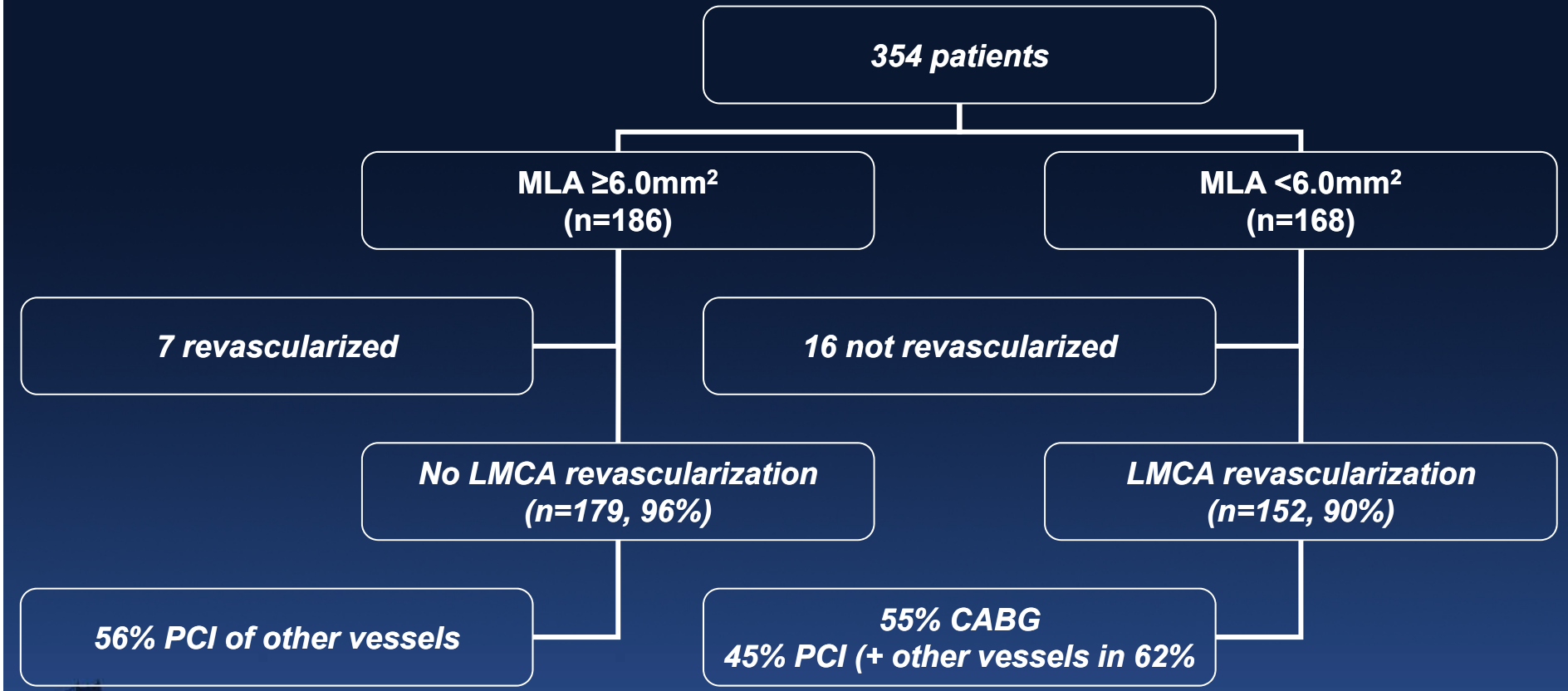
Clinical questions

- Is this lesion flow-limiting?
  - LMCA
  - Non-LMCA
- Pre-intervention lesion assessment (ie., what is the culprit?)
- What is the likelihood of embolization during stent implantation?
- How do I optimize acute stent results (size, length, expansion, edge coverage)?
- Is this jailed sidebranch significant?
- Is this "other" lesion a vulnerable plaque that is at risk for future events?
- Why did this stent thrombose or restenose?

Is this lesion significant?

	Abizaid AJC 1998; 82: 423-8	Nishioka JACC 1999; 33: 1870-8	Takagi. Circ. 1999; 100: 250-5	Briguori AJC 2001; 87: 136-41	Takayama CCI 2001;53:48-55	Lee AJC 2010; 105: 1378-84	Kang Circ CV Interv 2011; 4:65-71	Ahn Jacc CV Interv 2011;4:665-71	Ben-Dor Eurointervention 2011;7:225-33	Tahk ACC 2011	Koo Jacc CV Interv 2011;4: 803-11
	CFR	SPECT	FFR	FFR	FFR	FFR	FFR	SPECT	FFR	FFR	FFR
N	112	70	51	53	14	94	236	170	92	110	267
% abnormal	40%	65%	49%	23%	50%	40%	21%	26%	26%	41%	33%
IVUS											
Ref lumen (mm^2)	8.3 7.4	11.9 10.6	9.3	7.8	10.3	5.5 5.9	7.6				7.8 6.7
MLA (mm^2)	4.4	4.3	3.9	3.9	3.5	2.3	2.6	2.1			3.0
MLA Cut-off (mm^2)	***4.0***	***4.0***	***3.0***	***4.0***	***n/a***	***2.0***	***2.4***	***2.1***	***3.2***	***3.2***	***2.75***
Other determinants of ischemia	*•LL*				*•MLA/LL*	*•LL •Plaque burden*	*•Plaque burden •LAD*	*•Plaque burden*	*•Vessel size*	*•Prox-Mid •LL*	*•Prox-Mid •LAD •Vessel size*
QCA											
Length (mm)			14	8.5	17.9	15.1		21.2			16.5
QCA Ref (mm)			3.0	3.1	2.9	2.7		3.3			3.1
DS (%)			46	52	53			55			50

Prospective application of predefined IVUS criteria for revascularization of intermediate left main coronary artery lesions: Results at 2 years from the LITRO study



De La Torre Hernandez et al. J Am Coll Cardiol 2011;58:351-8

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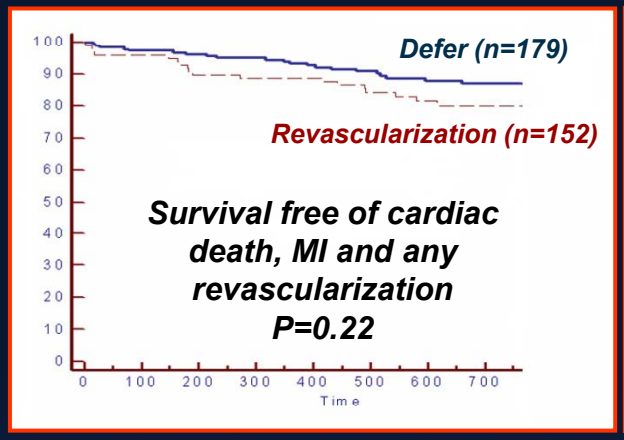
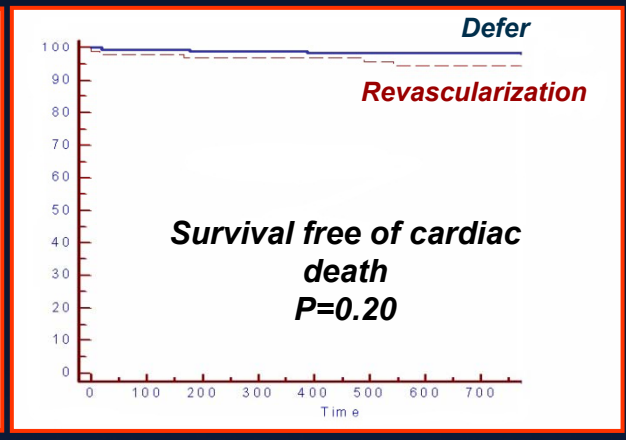
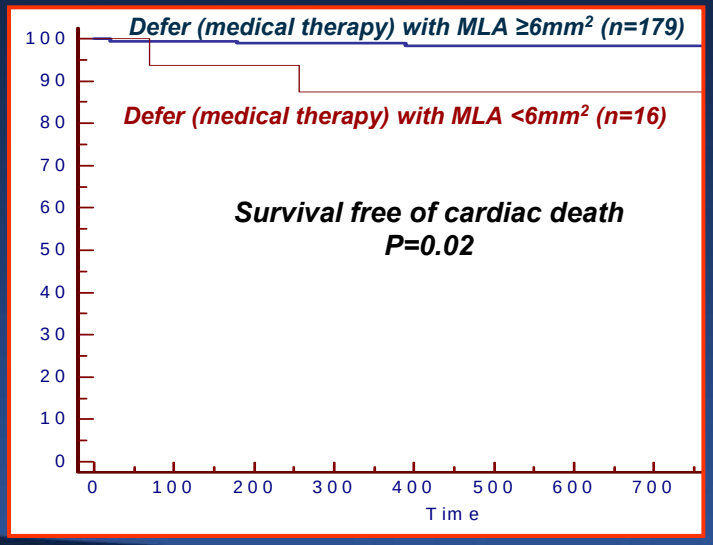
Clinical outcome of patients with vs without revascularization





Clinical outcome of patients without revascularization according to the MLA



In the group of 16 patients with MLA <6mm² who were treated medically, cardiac death-free survival to 2 years was 86% (97.7% in the deferred group; p=0.04), and survival free of cardiac death, MI, and revascularization was 62.5% (87.3% in the deferred group; p=0.02).

De La Torre Hernandez et al. J Am Coll Cardiol 2011;58:351-8

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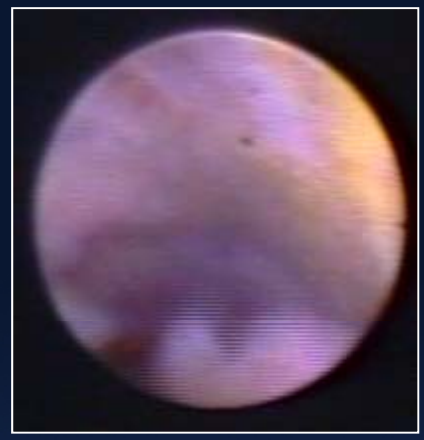
IVUS vs FFR in LMCA Disease

- There is more agreement between IVUS and FFR in assessing LMCA than in assessing non-LMCA lesions
  - Limited variability in LMCA length
  - Limited variability in amount of supplied myocardium
  - Large LMCA size
- Both have theoretical and practical limitations
  - FFR
    - Proximal LAD and/or LCX disease affects FFR of LMCA
    - Especially with ostial lesions, must avoid guiding catheter damping
  - IVUS
    - Especially in distal LMCA lesions, it is necessary to image from both the LAD and LCX to identify the MLA in the LMCA and disease in the LAD and/or LCX
    - Especially with ostial lesions, it is necessary to disengage the guiding catheter

What is the culprit?

Red Thrombus *White Thrombus* *Plaque Rupture*






However, too much thrombus is the enemy of OCT

Kubo et al. Circulation 2006;114:II-64
Kubo et al. J Am Coll Cardiol 2007;50:933-9

What is the likelihood of distal embolization during stent implantation?

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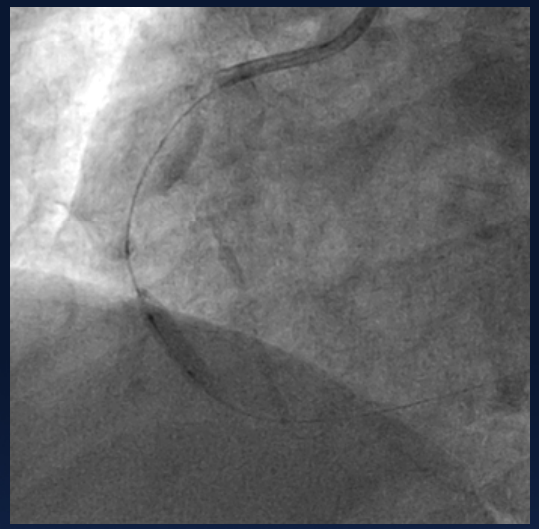

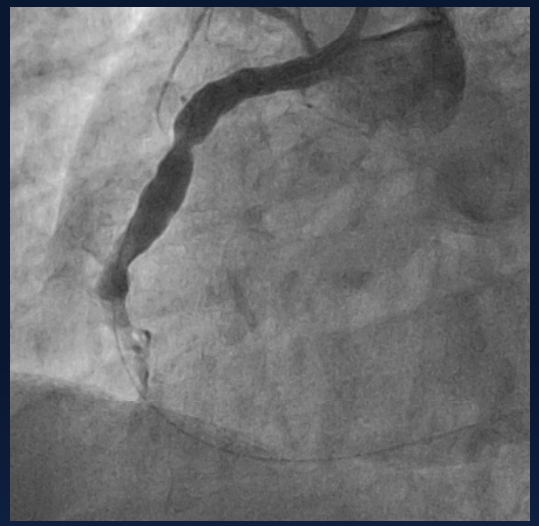

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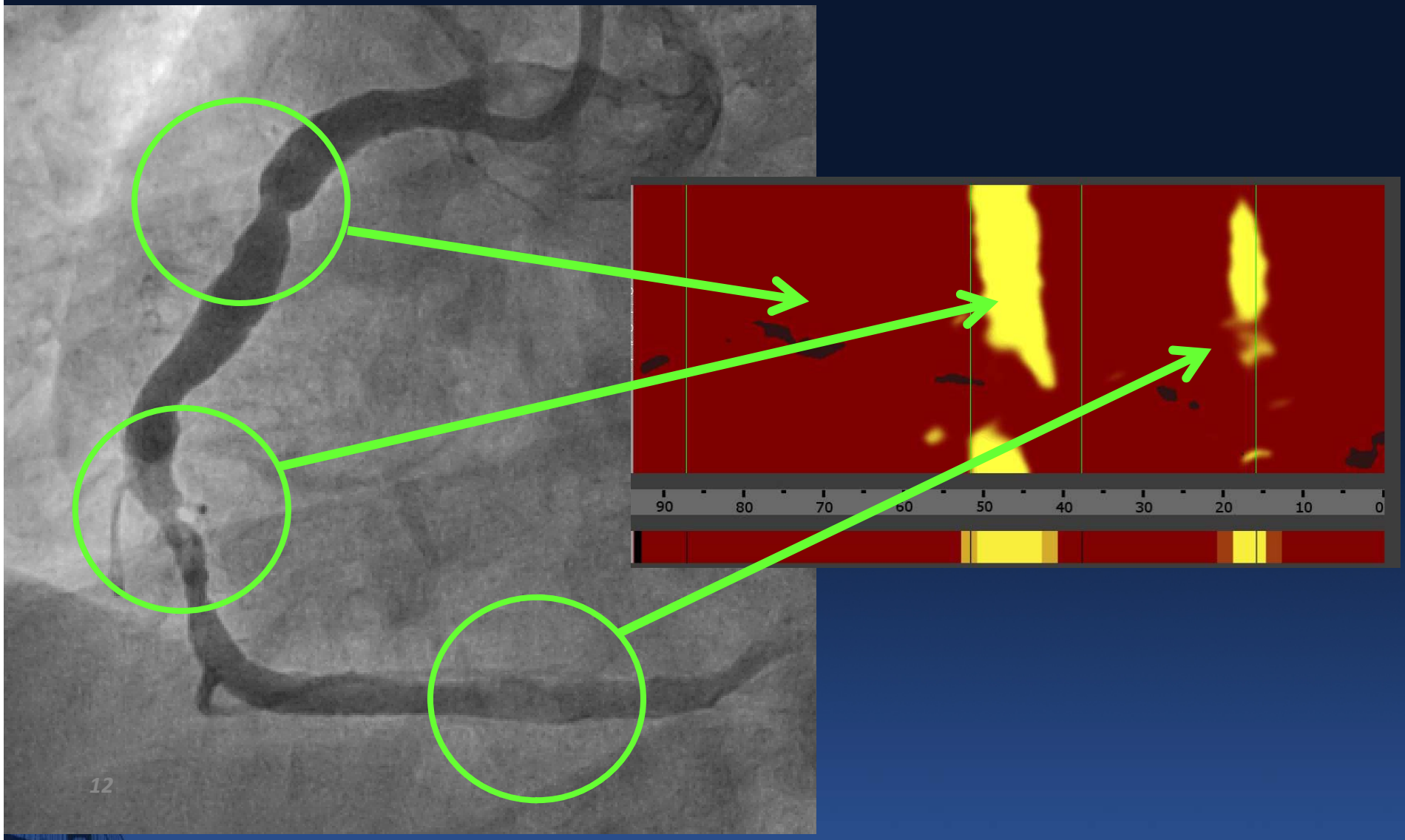

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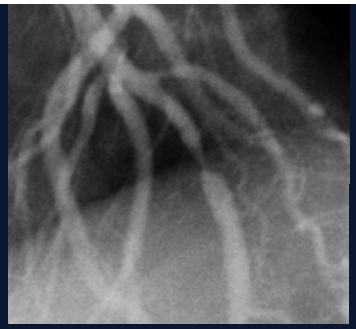
COLOR Registry

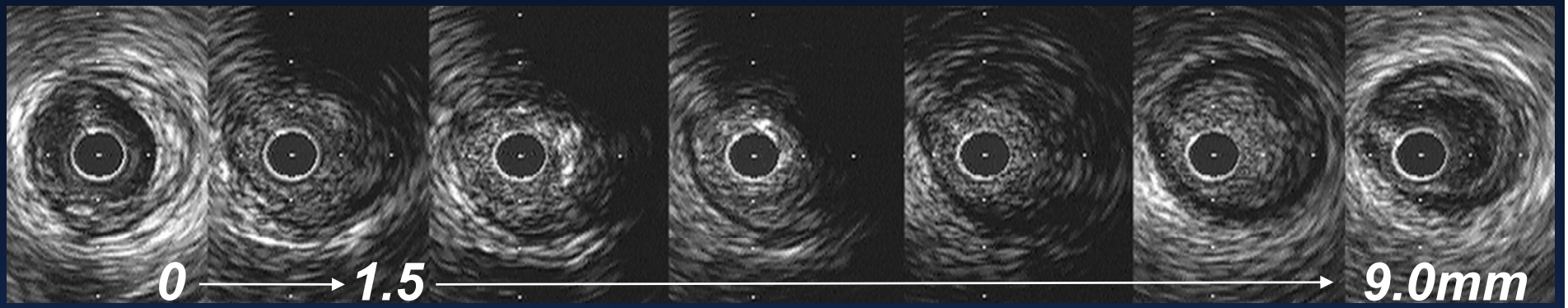
- 62 patients undergoing stenting were studied pre-PCI using NIRS
  - Peri-procedure MI (cTnI >3x normal) occurred in 9 patients
  - Predictors:

	RR	95% CI	p
$maxLCBI_{4mm}$ >500	12.0	3.3-48	0.0002
LDL >100mg/dL	5.4	1.4-23	0.03
Angiographic complex plaque	3.5	0.91-14	0.15
Angiographic DS >75%	3.1	0.92-11	0.14

Goldstein et al. Circ Cardiovasc Interv 2011;4:429-437

Attenuated Plaque





- *Attenuated plaques were seen in 39.6-78.0% of STEMI, 17.6% of NSTEMI, and 0% of stable angina.*
- *Attenuate plaques were associated with more fibroatheromas and a larger necrotic core (on VH-IVUS).*
- *In ACS or MI pts with attenuated plaques (1) the level of CRP was higher, (2) angiographic thrombus and initial coronary flow <TIMI 2 were more common, and (3) no-reflow or flow deterioration post-PCI was also more common.*
- *In STEMI patients with attenuated plaques, the amount, not the presence, of attenuated plaque predicted no-reflow post stent implantation*
- *Attenuated plaques contained the highest NIRS probability of lipid core, and by VH-IVUS, 93.5% of attenuated plaques contained confluent necrotic core and were classified as fibroatheromas*

(Lee et al. JACC Cardiovasc Interv. 2009;2:65-72)
(Wu et al, Am J Cardiol 2010;105:48-53)
(Okura et al, Circ J 2007;71:648-53)
(Wu et al. JACC Cardiovasc Interv 2011;4:495-502)
(Pu et al. Eur Heart J, in press)

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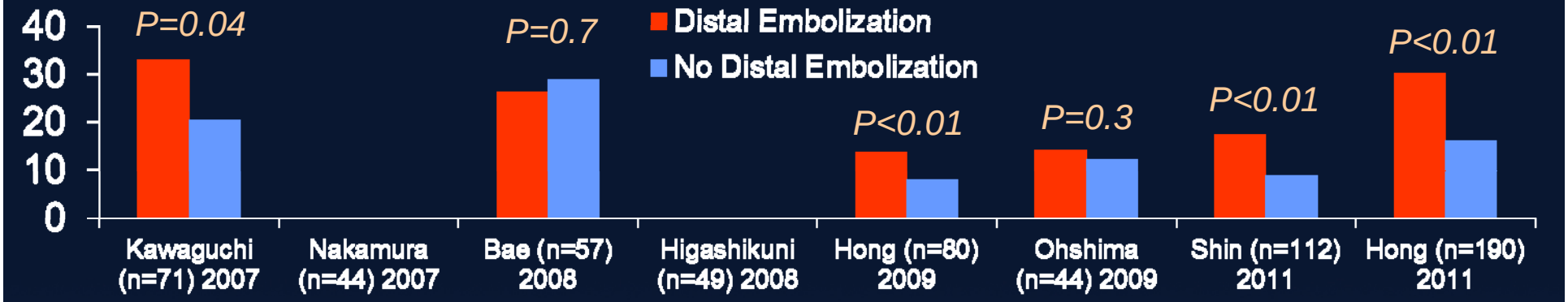
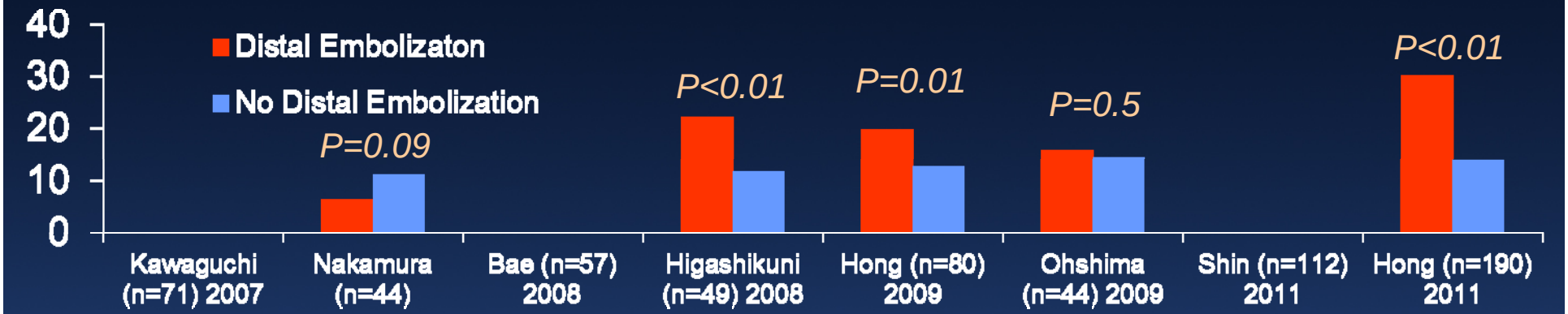
VH-IVUS and Peri-procedural MI





- *Kawamoto (n=44) 2007: NC was an independent predictor of the tertile with the greatest # of HITS*
- *Bose (n=55) 2008: Strong correlations between NC and the maximum increase in cardiac biomarkers*
- *Yamada (n=30) 2010: IMR improved post-PCI in the non-VH-TCFA group, but worsened in the VH-TCFA group*
- *Hong (n=190) 2011: ≥1 VH-TCFA or multiple VH-TCFAs more common in no-reflow*

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Claessen et al, JACC Cardiovasc Imaging, in press

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OCT and peri-procedural MI

- OCT-TCFAs were more common in the no-reflow group than in the normal reflow group (50% vs. 16%, P=0.005). The frequency of no-reflow and deterioration of final TIMI blush increased according to the arc of lipid
  - Tanaka et al. Eur Heart J 2009;30:1348-55
- Independent predictors of post-PCI MI (cTnI >3x ULN) were OCT-TCFA (OR=10.47, p<0.001), type B2/C lesions (OR=3.74, p=0.008)
  - Lee et al. Circ Cardiol Intv 2011;4:378-86
- Independent predictors of post-PCI CK-MB elevation were attenuated plaque (OR=3.49, p=0.003) and OCT ruptured plaque (OR=2.92, p=0.017)
  - Lee et al. J Am Coll Cardiol Intv 2011;4:483-91

How do I optimize acute DES results?

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IVUS Predictors of DES Thrombosis & Restenosis

	Thrombosis	Restenosis
Small MSA or MLA or underexpansion	•*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. Circulation Cardiovasc Interv. 20011;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 in press*
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. Circulation Cardiovasc Interv. 20011;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*

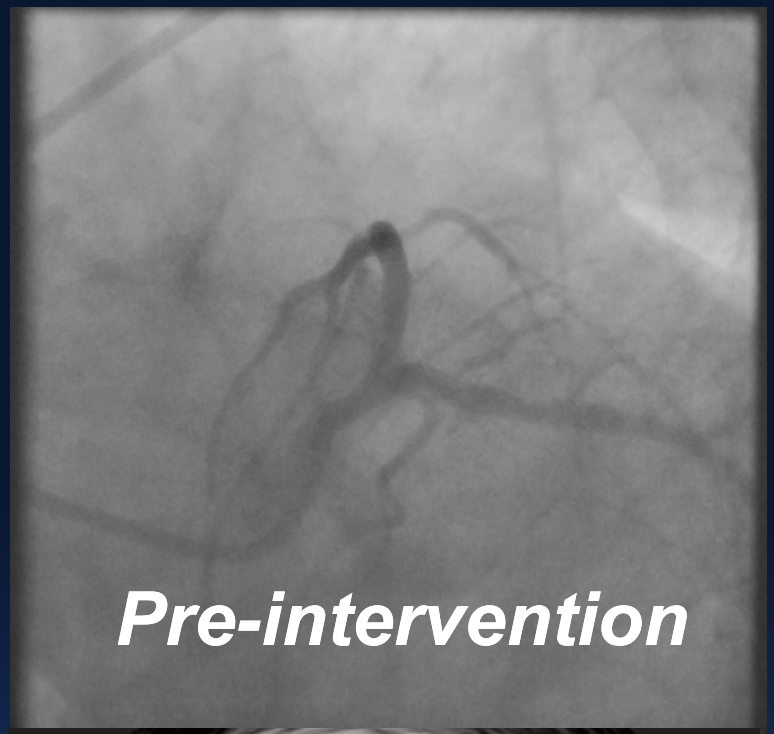
Randomized comparison of IVUS vs OCT-guided stenting with blinded cross-over imaging (n=70)

	IVUS	OCT	P-value
Imaging success	94.3%	9.1%	<0.0001
Use of distal protection	2.9%	22.9%	0.03
Final inflation pressure, atm	16.1±4.7	13.5±3.4	0.03
Final balloon diameter, mm	3.2±0.4	3.4±0.6	0.3
Proximal edge			
Plaque burden, %	37.1±10.1	45.7±10.9	0.001
Plaque burden >50%	8.6%	31.4%	0.04
MSA, mm^2	7.1±2.1	6.1±2.2	0.04
Focal expansion	80±13%	65±14%	0.001
Distal edge			
Plaque burden, %	33.3±6.4	40.3±8.8	<0.001
Plaque burden >50%	2.9%	11.4%	0.4

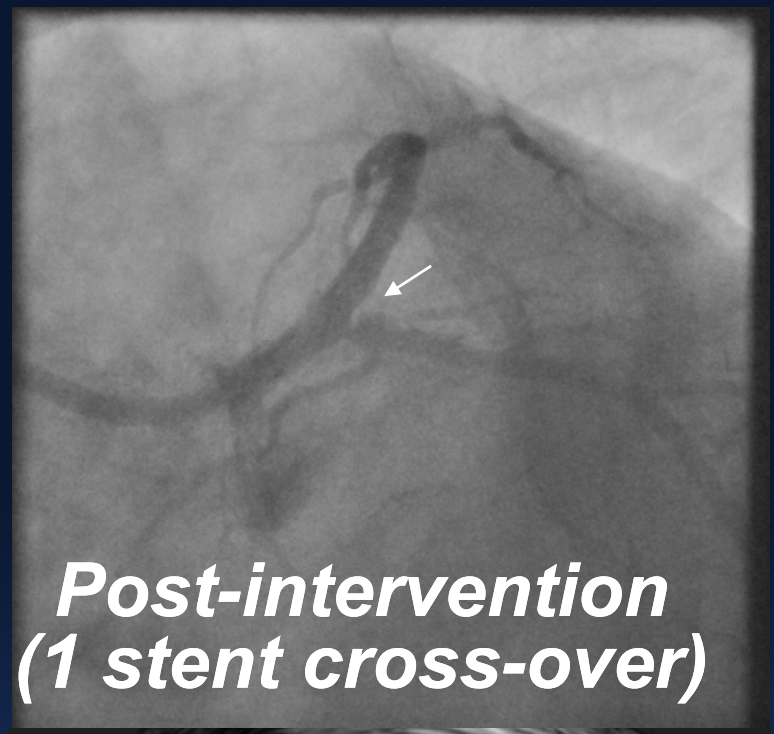
All OCT findings including the frequency of stent malapposition and the percentage of cross sections with malapposed strute were not significantly different between the groups.

Courtesy of Kenya Nasu, TCT 2011

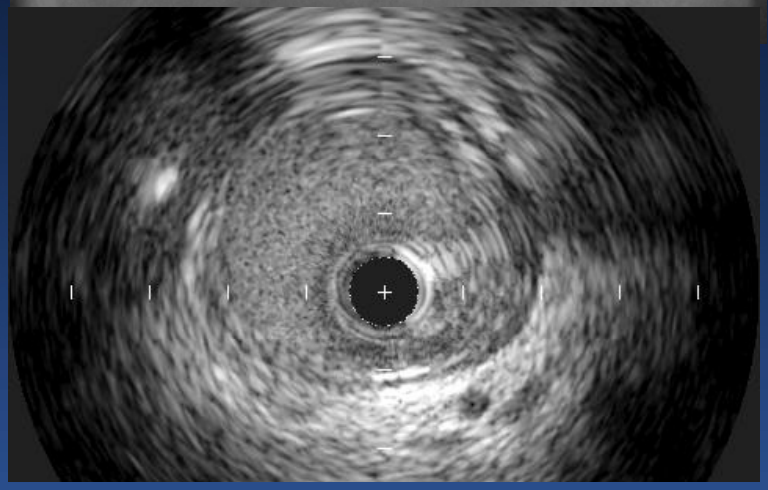
Is this jailed sidebranch significant?

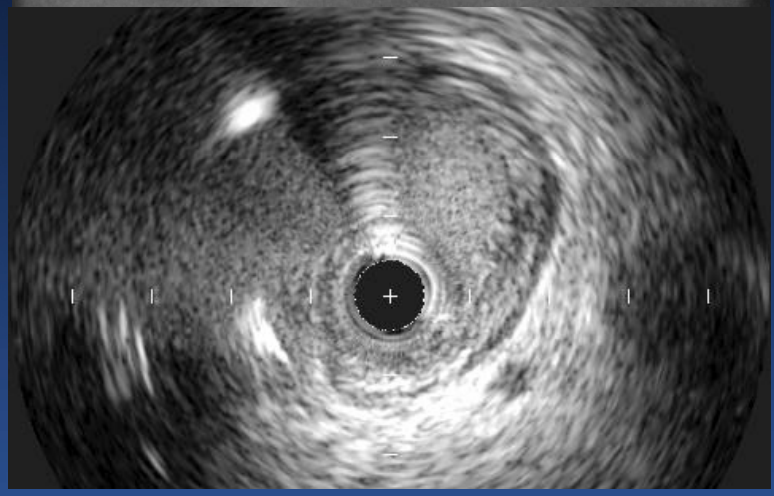


Pre-intervention



Post-intervention
(1 stent cross-over)





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FFR Assessment of Jailed Sidebranches

- *Koo et al, J Am Coll Cardiol 2005;46:633-7 (n=97 non-LMCA bifurcations)*
  - Optimal cutoff value for DS to predict FFR <0.75 was 85% (AUC of 0.85)
  - Only 27% of lesions with DS >75% had FFR <0.75.
  - At a mean follow-up of 9.6 months, in patients with an FFR >0.75, there were no adverse events or target vessel revascularizations.
- *Nam et al, Korean Circ J. 2011;41:304-7 (n=29 distal LMCA bifucations)*
  - No lesion with ≤50 %DS of the LCX ostium had FFR <0.80, 5/17 lesions with >50 %DS had FFR <0.80, 3/8 lesions with >70 %DS had FFR <0.80.
  - The best cut-off value to predict FFR <0.80 was angiographic DS > was 82%
- *Ahn et al, JACC Cardiovasc Interv, in press (n=230, 206 LAD/diagonal bifurcations)*
  - Among 67 sidebranches with >50% DS, 19 (28.4%) had FFR ≤0.80, and among 163 sidebranches with ≤50%, 22 (13.5%) had FFR ≤0.80
  - The optimal cutoff value to predict FFR ≤0.80 was DS or 54.9%
  - Kissing balloon inflations were performed in 72 and T-stenting in 4, 46.3% of lesions with FFR ≤0.80 and 29.6% of lesions with FFR >0.80. During a median follow up of 22.5 months, only 1 death, and 4 target vessel revascularization occurred.

Is this "other" lesion a vulnerable plaque?

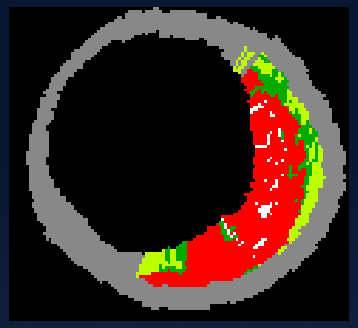
PROSPECT: Multivariable Correlates of Non Culprit Lesion Related Events

Independent predictors of lesion level events by Cox Proportional Hazards regression

Variable	HR [95% CI)	p
PB_{MLA} ≥70%	5.03 [2.51, 10.11]	<0.0001
VH-TCFA	3.35 [1.77, 6.36]	0.0002
MLA ≤4.0 mm^2	3.21 [1.61, 6.42]	0.001

Variables entered into the model: minimal luminal area (MLA) ≤4.0 mm^2; plaque burden at the MLA (PB_{MLA}) ≥70%; external elastic membrane at the MLA (EEM_{MLA}) <median (14.1 mm^2); lesion length ≥median (11.2 mm); distance from ostium to MLA ≥median (30.4 mm); remodeling index ≥median (0.94); VH-TCFA.

PROSPECT: Predictors of Non Culprit Lesion Events



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Stone et al. N Engl J Med 2011;364:226-35

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VIVA: Virtual Histology in Vulnerable Atherosclerosis

- *932 non-culprit lesions in 170 pts were identified with 3-vessel IVUS imaging*
- *At a median follow-up of 625 days, there were 18 culprit and non-culprit MACE in 16 pts*
- *14 revascularizations, 2 MIs, and 2 deaths*
- *Univariate predictors of non-culprit MACE*
- *Non-calcified VH-TCFA (p=0.025)*
- *MLA <4mm^2 (p=0.021)*
- *Plaque burden >70% (p<0.001)*
- *Remodeling index (p=0.014)*

Calvert et al. JACC Cardiovasc Imaging 2011;4:894-901

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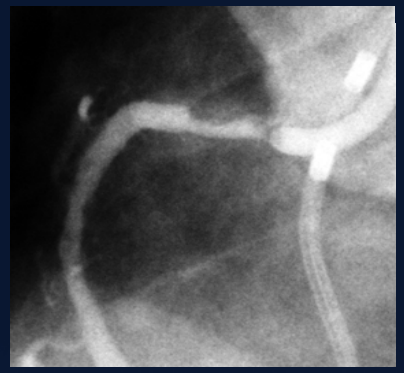
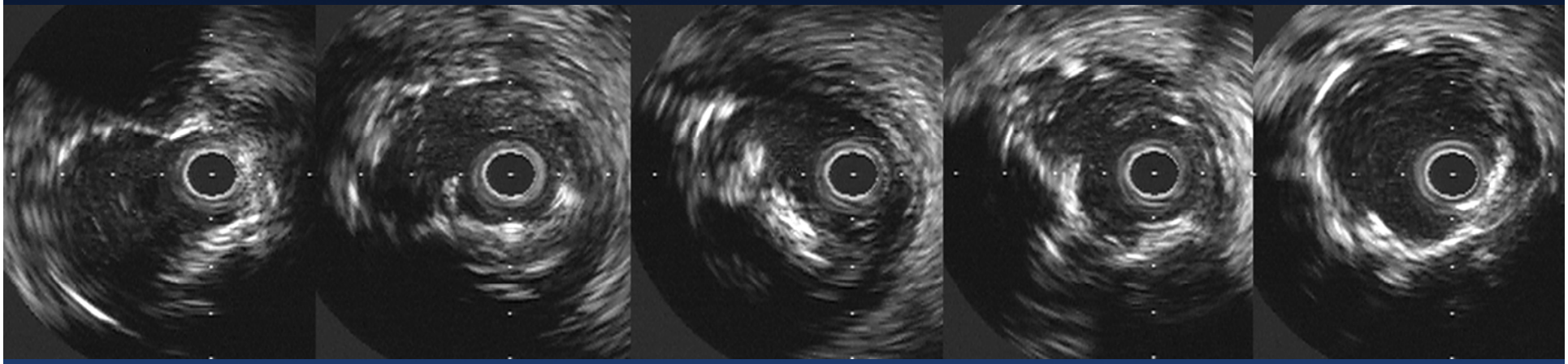
Why did this stent thrombose or restenose?

Causes (Findings) of Stent Failure (Thrombosis and Restenosis)

- Underexpansion
- Mechanical problems other than underexpansion
- Dissections or intramural hematomas at stent edges
- Intimal hyperplasia
- Neoatherosclerosis
- Thrombosis
- Uncovered stent struts
- Malapposition
- Stent fracture
- Stent compression



Proximal



0 → *2.5mm* → *10.0mm*

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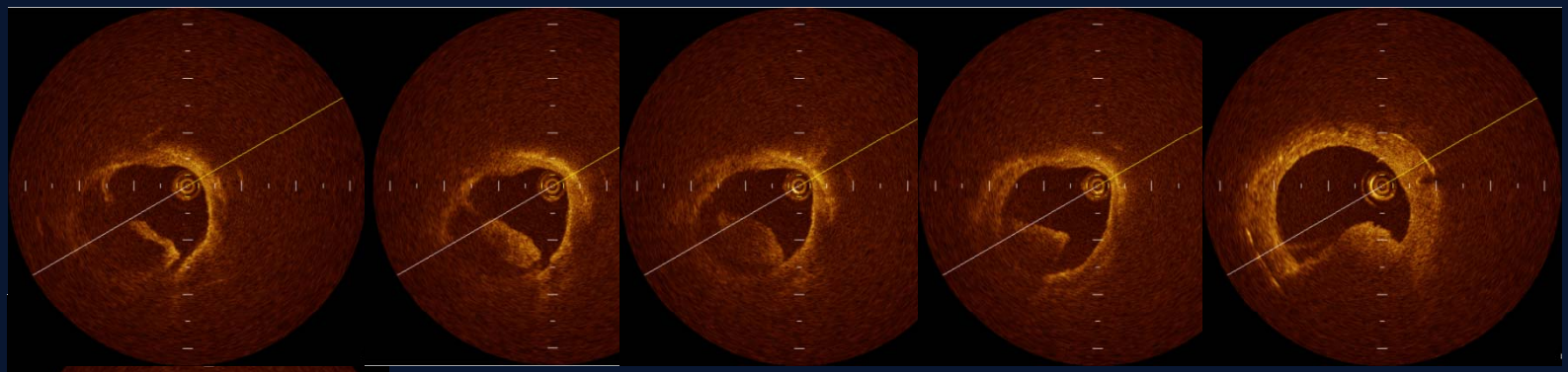
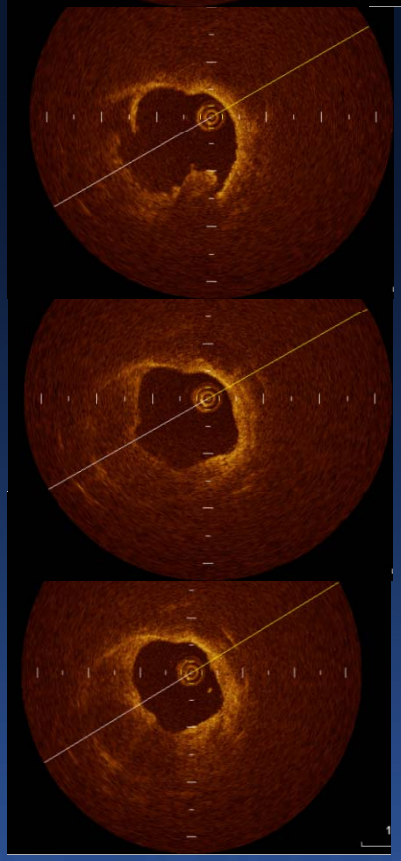
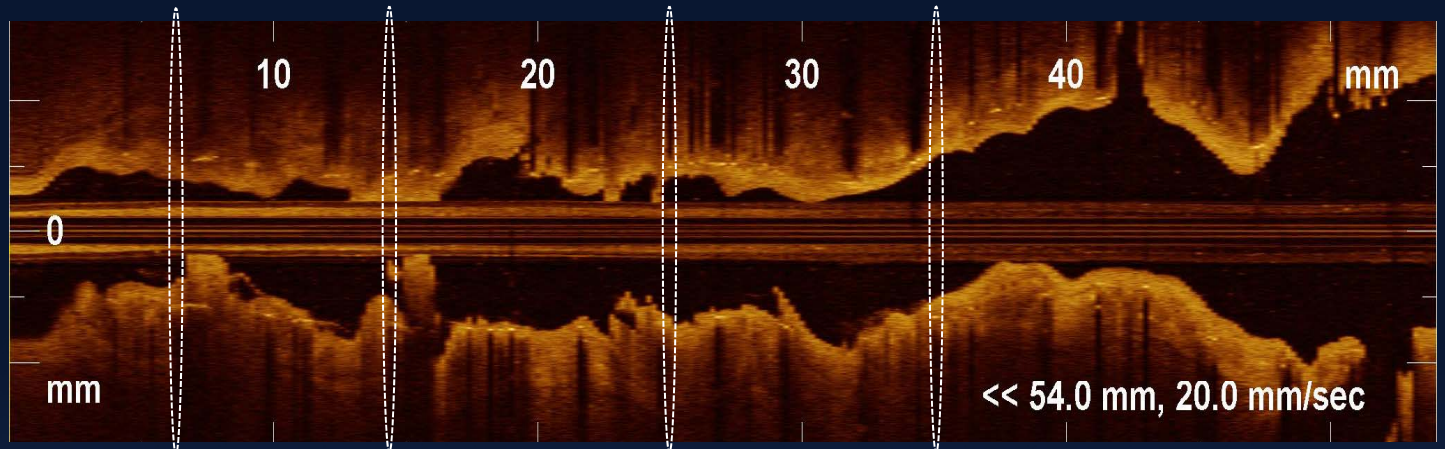
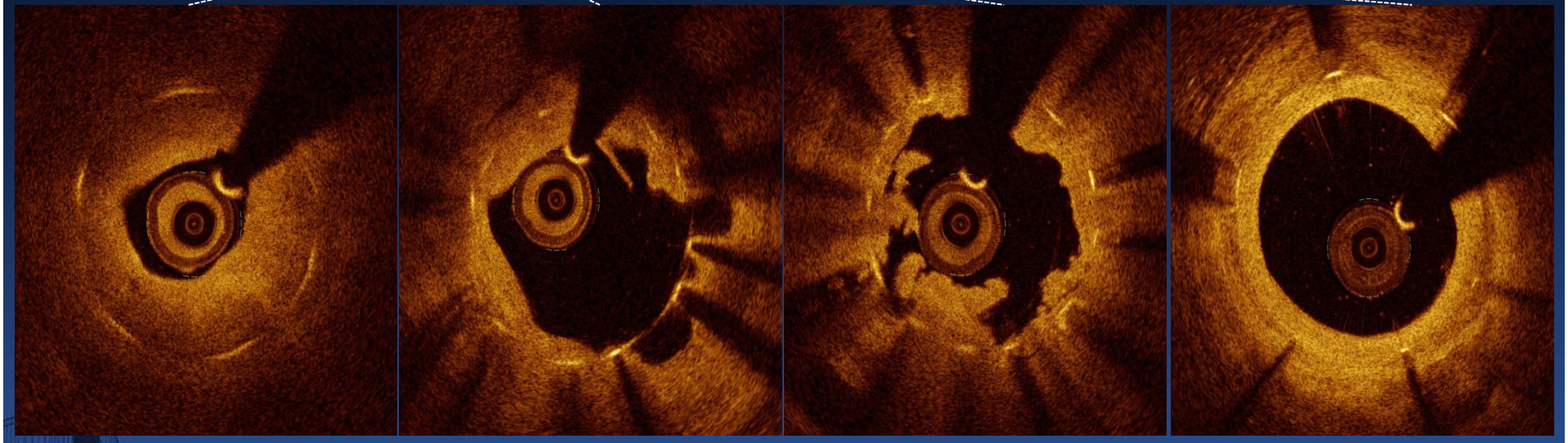




However, too much thrombus is the enemy of OCT

Cypher 2.5x28mm, 3.0x18mm, 3.0x13mm, and 3.5x8mm: VLST at 4 years





However, too much thrombus is the enemy of OCT

OCT and IVUS in DES and VLST

Median time to presentation 615 days (394, 1186)

	VLST	Controls*	P
Stents	18	36	
Cross-sections with uncovered struts (%)	33.3 (0, 43.7)	9 (0, 7.8)	0.003
Cross-sections with >30% uncovered struts (%)	21.6 (0, 43.7)	0 (0, 6.9)	0.002
Malapposed struts per patient (%)	5.9±6.3	1.8±1.5	0.001
Minimum stent CSA (mm^2)	5.7±1.4	5.9±1.4	1.0
Mean EEM CSA (mm^2)	19.4±5.8	15.1±4.6	0.003
"Remodeling index" (lesion/reference EEM CSA)	1.24 (1.06, 1.43)	0.99 (0.90, 1.11)	<0.001
Malapposition area (mm^2)	4.1±2.3	1.2±1.5	0.001

(Guagliumi et al, JACC Cardiovasc Interv, in press)

If I had to pick and choose. . .

	FFR	IVUS	IVUS+RF-IVUS	OCT	NIRS
Stenosis severity					
Non-LMCA	1				
LMCA	1	1			
Culprit lesion			2	1	
Embolization during stenting		2	1	2	1
Stent optimization		1			
Jailed sidebranch	1	2		2	
Vulnerable plaque			1	2	2
Stent thrombosis or restenosis		2		1	