IVUS-Guided PCI: Meta-analyses, patient selection, essential technique

Gary S. Mintz, MD

Cardiovascular Research Foundation

New York, NY

Disclosures

BostonScientific	Fellowship support, honoraria
Volcano	Grant support, honoraria
St Jude	Grant Support
ACIST	Honoraria

Clinical Data Regarding IVUS-guided DES Implantation

Randomized Trials

1) Jakabcin J, Spacek R, Bystron M, et al. Long-term health outcome and mortality evaluation after invasive coronary treatment using drug eluting stents with or without the IVUS guidance. Randomized control trial. HOME DES IVUS. Catheter Cardiovasc Interv 2010;75:578-583.
2) Chieffo A, Latib A, Caussin C, et al. A prospective, randomized trial of intravascular-ultrasound guided compared to angiography guided stent implantation in complex coronary lesions: the AVIO trial. Am Heart J 2013;165:65-72.
3) Kim JS, Kang TS, Mintz GS, et al. Randomized comparison of clinical outcomes between intravascular ultrasound and angiography-guided drug-eluting stent implantation for long coronary artery stenoses. JACC Cardiovasc Interv 2013;6:369-376.
4) Hong SJ, Kim BK, Shin DH, et al; IVUS-XPL Investigators. Effect of intravascular ultrasound-guided vs angiography-guided everolimus-eluting stent implantation: the IVUS-XPL randomized clinical trial. JAMA 2015;314:2155-63.
5) Tian NL, Gami SK, Ye F, et al. Angiographic and clinical comparisons of intravascular ultrasound- versus angiography-guided drug-eluting stent implantation for patients with chronic total occlusion lesions: two-year results from a randomised AIR-CTO study. EuroIntervention 2015;10:1409-17.
6) Kim BK, Shin DH, Hong MK, et al; CTO-IVUS Study Investigators. Clinical impact of intravascular ultrasound-guided chronic total occlusion intervention with zotarolimus-eluting versus biolimus-eluting stent implantation: randomized study. Circ Cardiovasc Interv 2015;8, e002592.
7) Tan Q, Wang Q, Liu D, et al. Intravascular ultrasound–guided unprotected left main coronary artery stenting in the elderly. Saudi Med J 2015;36:549-53.
8) Zhang JQ, Shi R, Pang W, et al. Application of intravascular ultrasound in stent implantation for small coronary arteries. J Clin Invasive Cardiol 2016;3:1-8.
9) Mariani J Jr, Guedes C, Soares P, et al. Intravascular ultrasound guidance to minimize the use of iodine contrast in percutaneous coronary intervention: the MOZART (Minimizing cOntrast utiliZation With IVUS Guidance in coRonary angioplasTy) randomized controlled trial. JACC Cardiovasc Interv. 2014;7:1287-93

Meta-analyses

1) Zhang Y, Farooq V, Garcia-Garcia HM, et al. Comparison of intravascular ultrasound versus angiography-guided drug-eluting stent implantation: a meta-analysis of one randomised trial and ten observational studies involving 19,619 patients. EuroIntervention. 2012;8:855-65.

2) Klersy C, Ferlini M, Raisaro A, et al. Use of IVUS guided coronary stenting with drug eluting stent: a systematic review and meta-analysis of randomized controlled clinical trials and high quality observational studies. Int J Cardiol. 2013;170:54-63.

3) Jang JS, Song YJ, Kang W, et al. Intravascular ultrasound-guided implantation of drug-eluting stents to improve outcome: a meta-analysis. JACC Cardiovasc Interv. 2014;7:233-43.

4) Ahn JM, Kang SJ, Yoon SH, et al. Meta-analysis of outcomes after intravascular ultrasound-guided versus angiography-guided drug-eluting stent implantation in 26,503 patients enrolled in three randomized trials and 14 observational studies. Am J Cardiol. 2014;113:1338-47

5) Zhang YJ, Pang S, Chen XY, et al. Comparison of intravascular ultrasound guided versus angiography guided drug eluting stent implantation: a systematic review and meta-analysis. BMC Cardiovasc Disord. 2015;15:153.

6) Alsidawi S, Effat M, Rahman S, Abdallah M, Leesar M. The role of vascular imaging in guiding routine percutaneous coronary interventions: A meta-analysis of bare Metal stent and drug-eluting stent trials. Cardiovasc Ther. 2015;33:360-6.

7) Nerlekar N, Cheshire CJ, Verma KP, et al. Intravascular ultrasound guidance improves clinical outcomes during implantation of both first and second-generation drug-eluting stents: a meta-analysis. EuroIntervention 2017;12:1632-42.

8) Steinvil A, Zhang YJ, Lee SY, et al. Intravascular ultrasound-guided drug-eluting stent implantation: An updated meta-analysis of randomized control trials and observational studies. Int J Cardiol. 2016;216:133-9.

9) Elgendy IY, Mahmoud AN, Elgendy AY, et al. Outcomes with intravascular ultrasound-guided stent implantation: A meta-analysis of randomized trials in the era of drug-eluting stents. Circ Cardiovasc Interv. 2016;9:e003700.

10) Shin DH, Hong SJ, Mintz GS, et al. Effects of intravascular ultrasound-guided versus angiography-guided new-generation drug-eluting stent implantation: Meta-Analysis With Individual Patient-Level Data From 2,345 Randomized Patients. JACC Cardiovasc Interv. 2016;9:2232-9.

11) Bavishi C, Sardar P, Chatterjee S, et al. Intravascular ultrasound–guided vs angiography-guided drug-eluting stent implantation in complex coronary lesions: Meta-analysis of randomized trials. Am Heart J. 2017 Mar;185:26-34.

Registries

1) Agostoni P, Valgimigli M, Van Mieghem CA, et al. Comparison of early outcome of percutaneous coronary intervention for unprotected left main coronary artery disease in the drug-eluting stent era with versus without intravascular ultrasonic guidance. Am J Cardiol 2005;95:644-647.

2) Roy P, Steinberg DH, Sushinsky SJ, et al. The potential clinical utility of intravascular ultrasound guidance in patients undergoing percutaneous coronary intervention with drug-eluting stents. Eur Heart J 2008;29:1851-7.

3) Fujimoto H, Tao S, Dohi T, et al. Primary and mid-term outcome of sirolimus-eluting stent implantation with angiographic guidance alone. J Cardiol. 2008;51:18-24 .

4) Park SJ, Kim YH, Park DW, et al; Investigators M-C. Impact of intravascular ultrasound guidance on long-term mortality in stenting for unprotected left main coronary artery stenosis. Circ Cardiovasc Interv 2009;2:167-177.

5) Kim SH, Kim YH, Kang SJ et al. Long-term outcomes of intravascular ultrasound-guided stenting in coronary bifurcation lesions. Am J Cardiol 2010;106:612-618.

6) Maluenda G, Lemesle G, Ben-Dor I, et al. Impact of intravascular ultrasound guidance in patients with acute myocardial infarction undergoing percutaneous coronary intervention. Catheter Cardiovasc Interv 2010;75:86-92.

7) Claessen BE, Mehran R, Mintz GS, et al. Impact of intravascular ultrasound imaging on early and late clinical outcomes following percutaneous coronary intervention with drug-eluting stents. JACC Cardiovasc Interv 2011;4:974-981.

8) Kim JS, Hong MK, Ko YG, et al. Impact of intravascular ultrasound guidance on long-term clinical outcomes in patients treated with drug-eluting stent for bifurcation lesions: data from a Korean multicenter bifurcation registry. Am Heart J 2011;161:180-187.

9) Youn YJ, Yoon J, Lee JW, et al. Intravascular ultrasound-guided primary percutaneous coronary intervention with drug-eluting stent implantation in patients with ST-segment elevation myocardial infarction. Clin Cardiol 2011;34:706-713.

10) Chen SL, Ye F, Zhang JJ, et al. Intravascular ultrasound-guided systematic two-stent techniques for coronary bifurcation lesions and reduced late stent thrombosis. Catheter Cardiovasc Interv 2013;81:456-463.

11) Hur SH, Kang SJ, Kim YH, et al. Impact of intravascular ultrasound-guided percutaneous coronary intervention on long-term clinical outcomes in a real world population. Catheter Cardiovasc Interv 2013;81:407-416.

12) Park KW, Kang SH, Yang HM, et al. Impact of intravascular ultrasound guidance in routine percutaneous coronary intervention for conventional lesions: data from the EXCELLENT trial. Int J Cardiol 2013;167:721-726.

13) Witzenbichler B, Maehara A, Weisz G, et al. Relationship between intravascular ultrasound guidance and clinical outcomes after drug-eluting stents: The ADAPT-DES Study. Circulation. 2014;129:463-70

14) Ahn SG, Yoon J, Sung JK, et al. Intravascular ultrasound-guided percutaneous coronary intervention improves the clinical outcome in patients undergoing multiple overlapping drug-eluting stents implantation. Korean Circ J 2013;43:231-8.

15) Ahn JM, Han S, Park YK, et al; RESET Investigators. Differential prognostic effect of intravascular ultrasound use according to implanted stent length. Am J Cardiol 2013;111:829-835.

16) Yoon YW, Shin S, Kim BK, et al; Investigators R. Usefulness of intravascular ultrasound to predict outcomes in short-length lesions treated with drug-eluting stents. Am J Cardiol 2013;112:642-646.

17) de la Torre Hernandez JM, Baz Alonso JA, Gómez Hospital JA, et al; IVUS-TRONCO-ICP Spanish study. Clinical impact of intravascular ultrasound guidance in drug-eluting stent implantation for unprotected left main coronary disease: pooled analysis at the patient-level of 4 registries. JACC Cardiovasc Interv. 2014;7:244–54.

18) Hong SJ, Kim BK, Shin DH, et al; K-CTO Registry. Usefulness of intravascular ultrasound guidance in percutaneous coronary intervention with second-generation drug-eluting stents for chronic total occlusions (from the Multicenter Korean-Chronic Total Occlusion Registry). Am J Cardiol. 2014;114:534–40.

19) Gao XF, Kan J, Zhang YJ, et al. Comparison of one-year clinical outcomes between intravascular ultrasound-guided versus angiography-guided implantation of drug-eluting stents for left main lesions: a single-center analysis of a 1,016-patient cohort. Patient Prefer Adherence. 2014;8:1299–309.

20) Fröhlich GM, Redwood S, Rakhit R, et al. Long-term survival in patients undergoing percutaneous interventions with or without intracoronary pressure wire guidance or intracoronary ultrasonographic imaging: a large cohort study. JAMA Intern Med. 2014;174:1360-6.

21) Yazici HU, Agamaliyev M, Aydar Y, Goktekin O. The impact of intravascular ultrasound guidance during drug eluting stent implantation on angiographic outcomes. Eur Rev Med Pharmacol Sci. 2015;19:3012-7.

22) Singh V, Badheka AO, Arora S, et al. Comparison of inhospital mortality, length of hospitalization, costs, and vascular complications of percutaneous coronary interventions guided by ultrasound versus angiography. Am J Cardiol 2015;115:1357-66.

23) Magalhaes MA, Minha S, Torguson R, et al. The effect of complete percutaneous revascularisation with and without intravascular ultrasound guidance in the drug-eluting stent era. EuroIntervention 2015;11:625-33.

24) Nakatsuma K, Shiomi H, Morimoto T, et al; CREDO-Kyoto AMI investigators. Intravascular Ultrasound Guidance vs. Angiographic Guidance in Primary Percutaneous Coronary Intervention for ST Segment Elevation Myocardial Infarction - Long-Term Clinical Outcomes From the CREDO-Kyoto AMI Registry. Circ J 2016;80:477-84.

25) Patel Y, Depta JP, Patel JS, et al. Impact of intravascular ultrasound on the long-term clinical outcomes in the treatment of coronary ostial lesions. Catheter Cardiovasc Interv 2016;87:232-40.

26) Ahmed K, Jeong MH, Chakraborty R, et al. Role of intravascular ultrasound in patients with acute myocardial infarction undergoing percutaneous coronary intervention. Am J Cardiol. 2011;108:8-14.

27) Roy P, Torguson R, Okabe T, et al. Angiographic and procedural correlates of stent thrombosis after intracoronary implantation of drug-eluting stents. J Interv Cardiol 2007;20:307–13.

28) Gerber RT, Latib A, Ielasi A, et al. Defining a new standard for IVUS optimized drug eluting stent implantation: the PRAVIO study. Catheter Cardiovasc Interv 2009;74:348–56.

29) Biondi-Zoccai G, Sheiban I, Romagnoli E, et al. Is intravascular ultrasound beneficial for percutaneous coronary intervention of bifurcation lesions? Evidence from a 4314-patient registry. Clin Res Cardiol 2011;100:1021–8.

30) Wakabayashi K, Lindsay J, Laynez-Carnicero A, et al. Utility of intravascular ultrasound guidance in patients undergoing percutaneous coronary intervention for type C lesions. J Interv Cardiol 2012;25:452–9.

31) Patel Y, Depta JP, Novak E, et al. Long-term outcomes with use of intravascular ultrasound for the treatment of coronary bifurcation lesions. Am J Cardiol 2012;109:960–5.

32) De la Torre Hernandez JM, Alfonso F, Sanchez Recalde A, et al; ESTROFA-LM Study Group. Comparison of paclitaxel-eluting stents (Taxus) and everolimus-eluting stents (Xience) in left main coronary artery disease with 3 years follow-up (from the ESTROFA-LM registry). Am J Cardiol 2013;111:676-83.

33) Patel Y, Depta JP, Patel JS, Masrani SK, Novak E, Zajarias A, Kurz HI, Lasala JM, Bach RG, Singh J. Impact of intravascular ultrasound on the long-term clinical outcomes in the treatment of coronary ostial lesions. Catheter Cardiovasc Interv 2016;87:232-40.

Cardiovascular Research Foundation

Mintz. Coronary Artery Disease 2017, in press

Major meta-analyses of IVUS vs angio-guided DES

					HR (p-values)					
Reference	**Yr**	**RCT**	**Non-RCT**	**Pts**	**MACE**	**Death**	**MI**	**ST**	**TLR**	**TVR**
Zhang et al Eurointervention	2012	1	10	19,619	0.87 (p=0.008)	0.59 (p<0.001)	0.82 (p=0.13)	0.58 (p<0.001)	0.90 (p=0.3)	0.90 (p=0.2)
Propensity score matched groups				5,300	0.86 (p=0.06)	0.73 (p=0.04)	0.63 (p=0.01)	0.57 (p=0.004)	0.85 (p=0.3)	0.94 (p=0.6)
Klersy et al Int J Cardiol	2013	3	9	18,707	0.80 (p<0.001)	0.60 (p<0.001)	0.59 (p=0.001)	0.50 (p=0.007)	0.95 (p=0.8)	
Jang et al. JACC Cardiovasc Interv	2014	3	12	24,869	0.79 (p=0.001)	0.64 (p<0.001)	0.57 (p<0.001)	0.59 (p=0.002)	0.76 (p=0.01)	0.81 (p=0.01)
Propensity score matched groups				13,545	0.79 (p=0.01)	0.58 (p=0.01)	0.56 (p=0.04)	0.52 (p=0.004)	0.85 (p=0.3)	0.93 (p=0.3)
Ahn et al. Am J Cardiol	2014	3	14	26,503	0.74 (p<0.001)	0.61 (p<0.001)	0.57 (p<0.001)	0.59 (p<0.001)	0.81 (p=0.046)	0.82 (p=0.022)
Zhang et al. BMC Cardiovaasc Disorders	2015	3	17	29,068	0.77 (p<0.001)	0.62 (p<0.001)	0.64 (p<0.001)	0.59 (p<0.001)	0.81 P=0.005)	0.86 (p=0.012)
Complex lesions or ACS				6,393	0.69 (p<0.001)	0.52 (p<0.001)		0.64 (p<0.001)		
Steinvil et al. Int J Cardiol	2016	7	18	31,283	0.76 (p<0.001)	0.62 (p<0.001)	0.67 (p<0.001)	0.58 (p<0.001)	0.77 P=0.005)	0.85 (p<0.001)
Complex lesions					0.70 (p<0.001)	0.52 (p<0.001)	0.72 (p=0.008)	0.32 (p<0.001)	0.76 (p=0.062)	0.62 (p=0.002)
Nerlekar et al. EuroIntervention	2016	6	9	9,313	0.73 (P<0.001)	0.55 (p=0.005)	0.67 (p=0.01)	0.52 (p<0.001)	0.66 (p<0.001)	0.79 (p=0.04)
		11 – 1st generation		6156	0.79 (p=0.01)	0.64 (p=0.07)	0.63 (p=0.007)	0.56 (p<0.001)	0.70 (p=0.02)	0.88 (p=0.29)
		6 – 2nd generation		3157	0.73 (p<0.001)	0.33 (p=0.02)	0.82 (p=0.65)	0.32 (p=0.02)	0.61 (p=0.01)	0.47 (p=0.29)

Meta-analyses of Randomized Trials of IVUS vs Angiography-guided DES Implantation

Reference	Study Population	MACE	CV Mortality	MI	ST	TLR	TVR
Elgendy et al. Circ Cardiovasc Interv 2016;9:e003700	7 RCTs 3275 (IVUS: 1634 and Angiography: 1641)	0.59 (0.46-0.76)	0.46 (0.21-1.00)	0.58 (0.30-1.11)	0.49 (0.24-0.99)	0.60 (0.43-0.84)	0.61 (0.41-0.91)
Steinvil et al. Int J Cardiol 2016;216:133-9	7 RCTs 3192 (IVUS: 1593 and Angiography: 1599)	0.66 (0.52-0.84)	0.81 (0.44-1.47)	1.04 (0.68-1.59)	0.71 (0.28-1.78)	0.61 (0.43-0.87)	0.61 (0.41-0.90)
Bavishi et al. Am Heart J 2017;185:26-34	8 RCTs 3276 (IVUS: 1635 and Angiography: 1641)	0.64 (0.51-0.80)	0.51 (0.23-1.12)	0.90 (0.58-1.41)	0.57 (0.26-1.23)	0.62 (0.45-0.86)	0.60 (0.42-0.87)
Shin et al. JACC Cardiovasc Interv 2016;9:2232-9.*	3 RCTs 2345 (IVUS: 1170 and Angiography: 1175)	0.36 (0.13-0.99)	0.38 (0.10-1.42)	-	0.50 (0.13-2.01)	0.61 (0.40-0.93)	-

Meta-analysis performed using patient-level data

Meta-analysis of MACE in 8 Randomized Trials

		IVUS-guided		Angio-guided		RR (95% CI)	RR (95% CI)
Study	Year	Events	Total	Events	Total		
AIR-CTO	2015	25	115	29	115	0.86 (0.54, 1.38)	
AVIO	2013	24	142	33	142	0.73 (0.45, 1.17)	
CTO-IVUS	2015	5	201	14	201	0.36 (0.13, 0.97)	
HOME DES IVUS	2013	11	105	12	105	0.92 (0.42, 1.98)	
IVUS-XPL	2015	19	700	39	700	0.49 (0.28, 0.83)	
RESET	2013	12	269	20	274	0.61 (0.30, 1.03)	
Tan et al	2015	8	61	17	62	0.48 (0.22, 1.03)	
Zhang et al	2016	3	42	9	42	0.33 (0.10, 1.15)	
Subtotal (95% CI)			1635		1641	0.64 (0.51, 0.80)	
Total events		107		173			IVUS better / Angio better

	IVUS events	Angio events	RR	95% CI	P-value
MACE	**6.5%**	**10.5%**	**0.64**	**0.51-0.80**	**0.0001**
CV mortality	0.5%	1.2%	0.51	0.23-1.12	0.09
MI	2.0%	2.4%	0.90	0.58-1.41	0.65
TLR	4.1%	6.6%	0.62	0.45-0.86	0.004
TVR	5.5%	9.2%	0.60	0.42-0.87	0.007
ST	0.6%	1.3%	0.57	0.26-1.23	0.15

Cardiovascular Research Foundation

Bavishi et al. Am Heart J 2017;185:26-34

Patient level meta-analysis of 3 randomized trials using only *second generation DES*

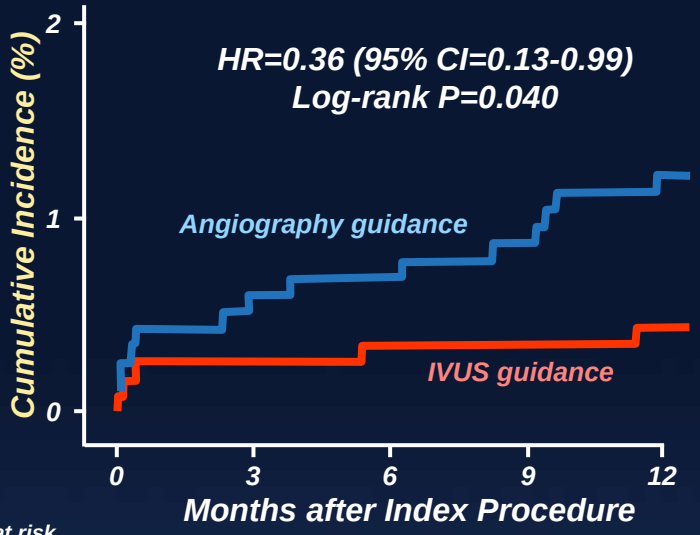
	IVUS events	Angio events	HR	95% CI	P-value
Intention-to-treat	n=1170	n=1175			
MACE*	0.4%	1.2%	0.36	0.13-0.99	0.04
CV mortality	0.3%	0.7%	0.38	0.10-1.42	0.134
MI	0%	0.4%			0.026
Stent Thrombosis	0.3%	0.5%	0.50	0.13-2.01	0.32
TLR	3.0%	5.0%	0.61	0.40-0.93	0.02
Per Protocol	n=1236	n=1109			
MACE*	0.4%	1.3%	0.32	0.12-0.89	0.021
CV mortality	0.2%	0.7%	0.34	0.09-1.27	0.09
MI	0	0.5%			0.018
Stent Thrombosis	0.2%	0.5%	0.45	0.11-1.79	0.243
TLR	2.9%	5.3%	0.54	0.36-0.82	0.004

MACE defined as a composite of CV death, MI, or stent thrombosis

Shin et al. JACC Cardiovasc Interv. 2016;9:2232-9

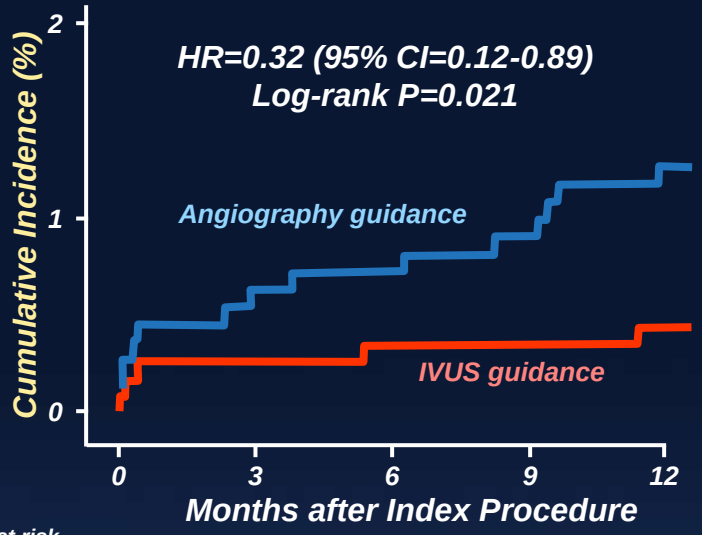
Composite of cardiac death, MI, or stent thrombosis

MACE* by intention-to-treat analysis



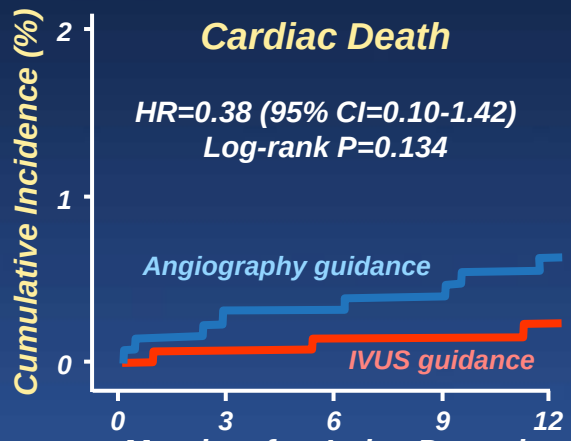
Number at risk					
Angio guidance	1175	1143	1133	1125	1076
IVUS guidance	1170	1137	1130	1120	1073

MACE* by per-protocol analysis

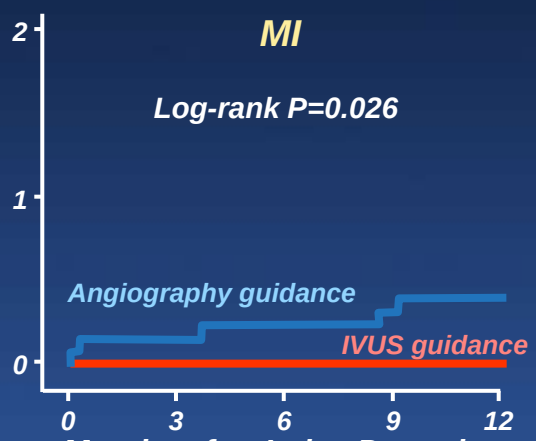


Number at risk					
Angio guidance	1109	1076	1067	1058	1018
IVUS guidance	1236	1204	1196	1187	1131

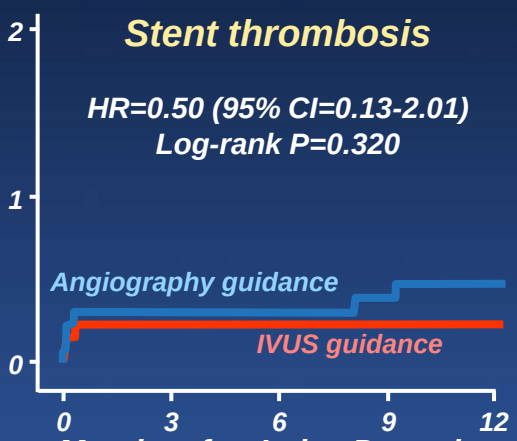
Cardiac Death



MI



Stent thrombosis



Number at risk					
Angio guidance	1175	1145	1136	1129	1180
IVUS guidance	1170	1138	1131	1121	1074

1175	1144	1134	1126	1076
1170	1138	1131	1121	1074

1175	1143	1134	1126	1077
1170	1137	1130	1120	1073

Cardiovascular Research Foundation

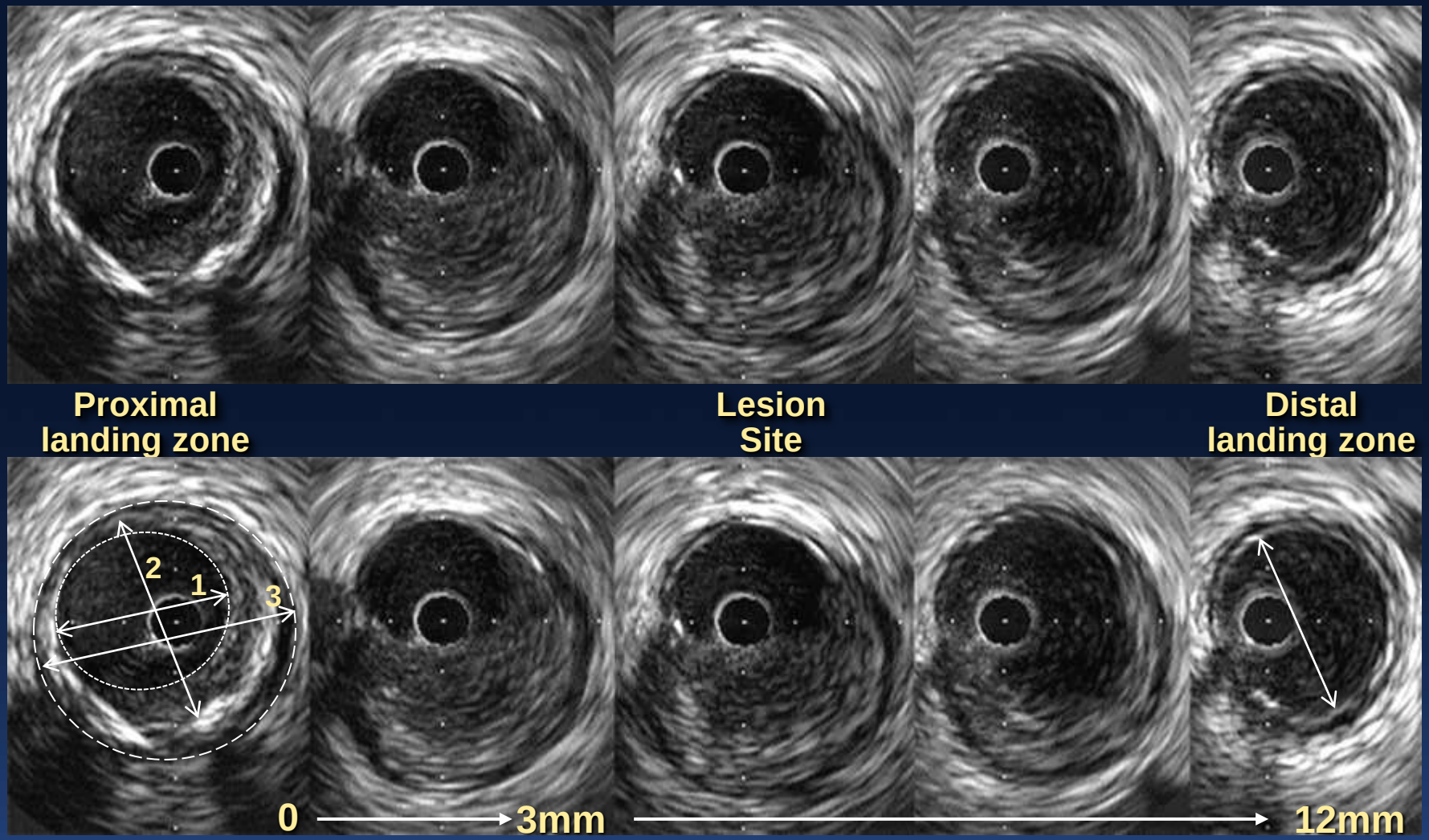
Shin et al. JACC Cardiovasc Interv. 2016;9:2232-9

- **Nerlekar et al. EuroIntervention 2017;12:1632-42**
  - Even though second generation DES were associated with fewer events compared to first generation DES in both the IVUS-guided and angiography-guided groups, there was a greater benefit to IVUS guidance when implanting second generation compared to first generation DES.
  - Beginning in 2012, there was a greater benefit of IVUS-guidance to reduce MACE (4,154 pts, odds ratio 0.60, $p<0.001$) compared to the period ending in 2011 (4,111 pts, odds ratio 0.83, $p=0.04$).
- **Zhang et al BMC Cardiovasc Disord. 2015;15:153**
  - The benefit of IVUS guidance was more pronounced in patients with ACS or complex lesions (LMCA, bifurcation, chronic total occlusions, or long lesions) compared to patients with “any” clinical presentation or “any” lesion.”

Incidence and predictors of coronary stent thrombosis: Evidence from an international collaborative meta-analysis including 30 studies, 221,066 patients, and 4276 thromboses

- *Most frequently and consistently reported predictors of definite/probable ST were*
  - Early antiplatelet therapy discontinuation
  - Extent of coronary artery disease
  - Stent number/ length
- *Significant, but less consistent predictors of ST were*
  - ACS at admission
  - Diabetes mellitus
  - Smoking status
  - Bifurcation/ostial disease
- *Predictors of ST with relative risk estimates > 5 in at least one study were*
  - Antiplatelet therapy discontinuation before 30 days
  - Residual dissection
  - Antiplatelet therapy discontinuation between 30 days and 180 days,
  - Stent undersizing
  - Prior brachytherapy
  - Left ventricular systolic dysfunction
  - Smoking status
  - Bifurcational/ostial lesion
  - ACS at admission
  - Small vessel coronary disease

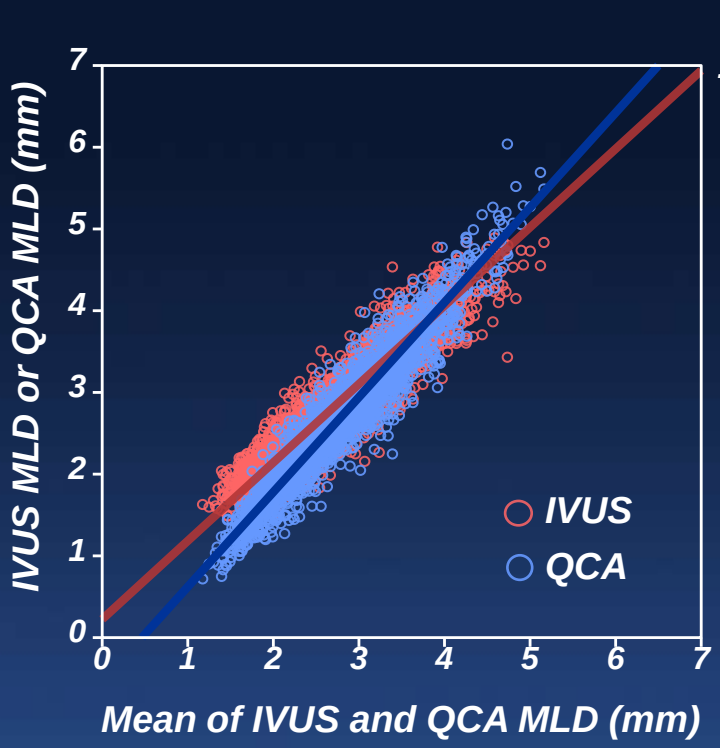
D'Ascenzo et al. Int J Cardiol 2013;167:575-84

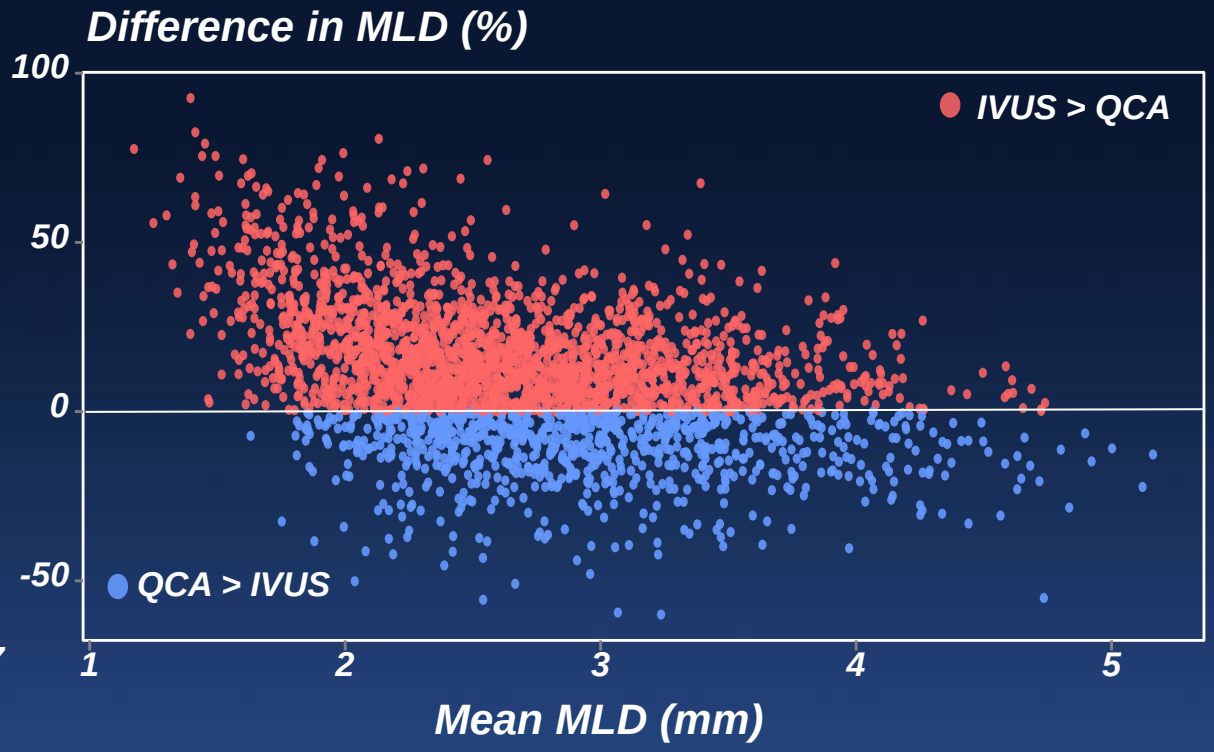


Increasingly aggressive

1) *Largest reference lumen whether proximal or distal*
2) *Midwall*
3) *Media-to-media (although this is often "discounted" by approximately 0.5mm)*

IVUS vs QCA lumen dimensions in PROSPECT





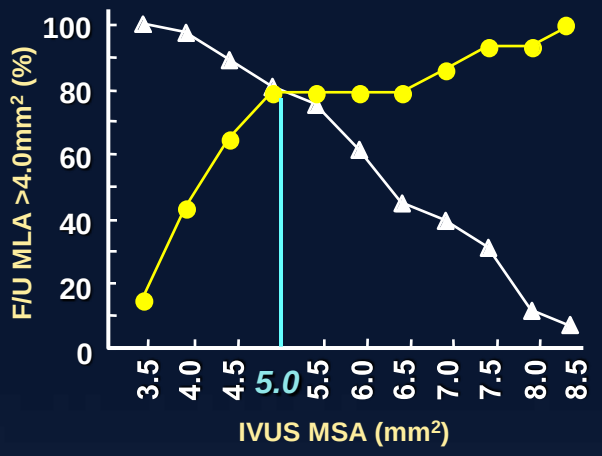
Cardiovascular Research Foundation

Goto et al. JACC Cardiovasc Imaging 2016;9:1011-3

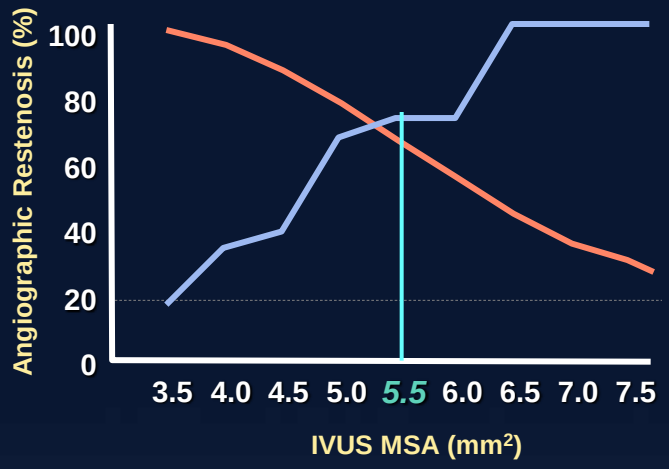
IVUS Predictors of DES Early Thrombosis & Restenosis

	Early Thrombosis	Restenosis/MACE
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*
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*
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*

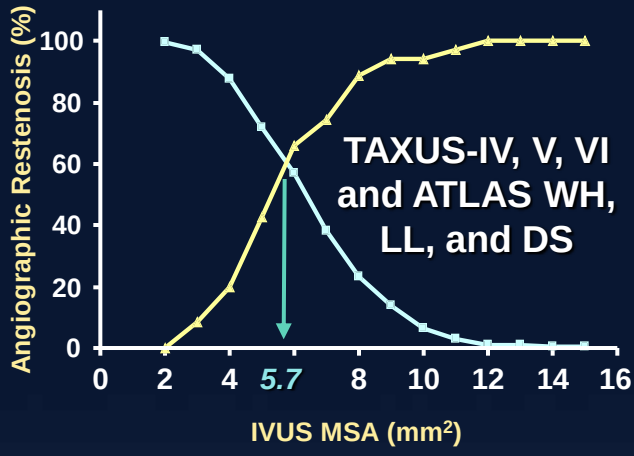
SES in SIRIUS



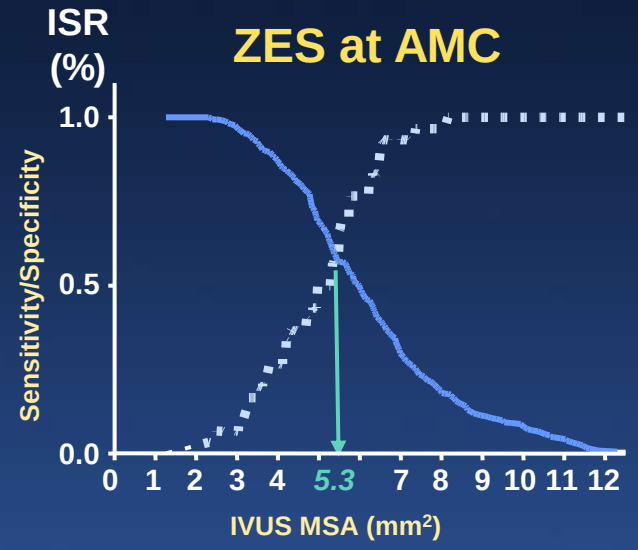
SES at AMC



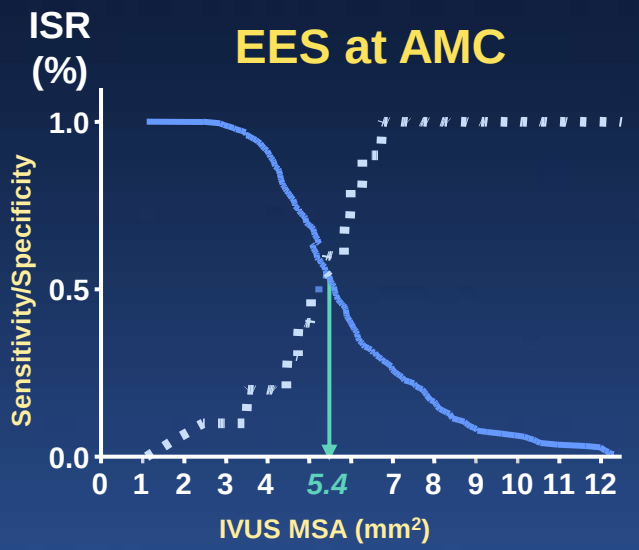
PES



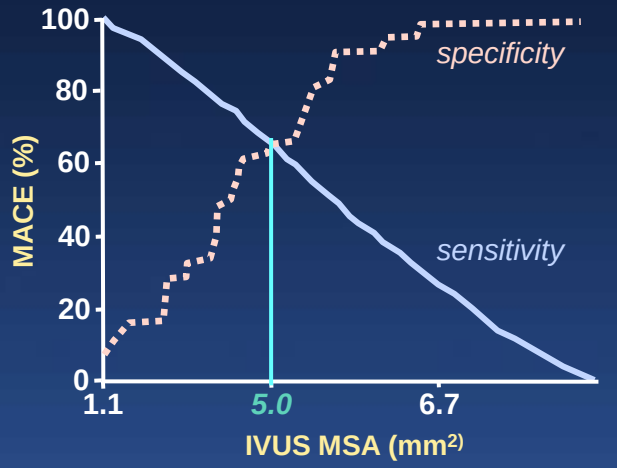
ZES at AMC



EES at AMC

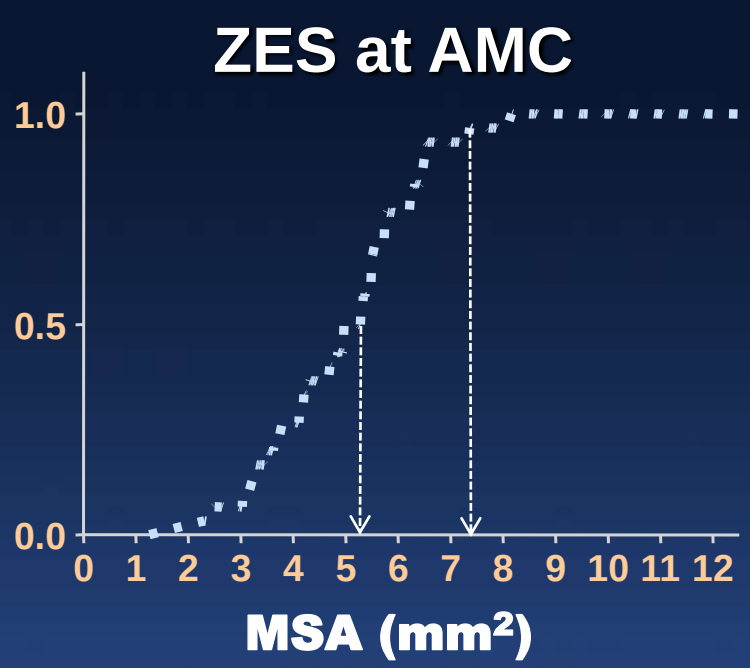


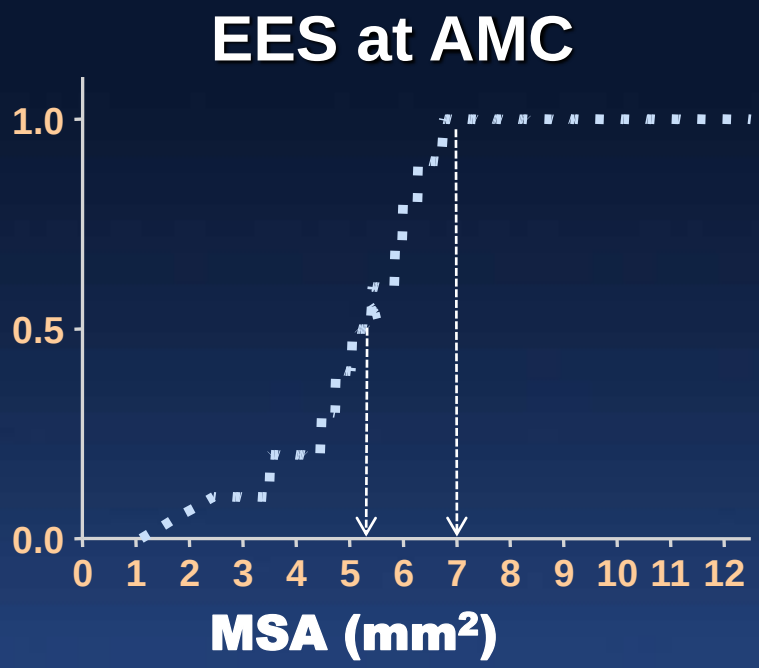
EES in IVUS-XPL/RESET



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
Song et al. Cathet Cardiovasc Interv 2014;83:873-8
Lee et al. Rev Esp Cardiol 2017;70:88-95

Predicting Freedom From Angiographic Restenosis with Second Generation DES



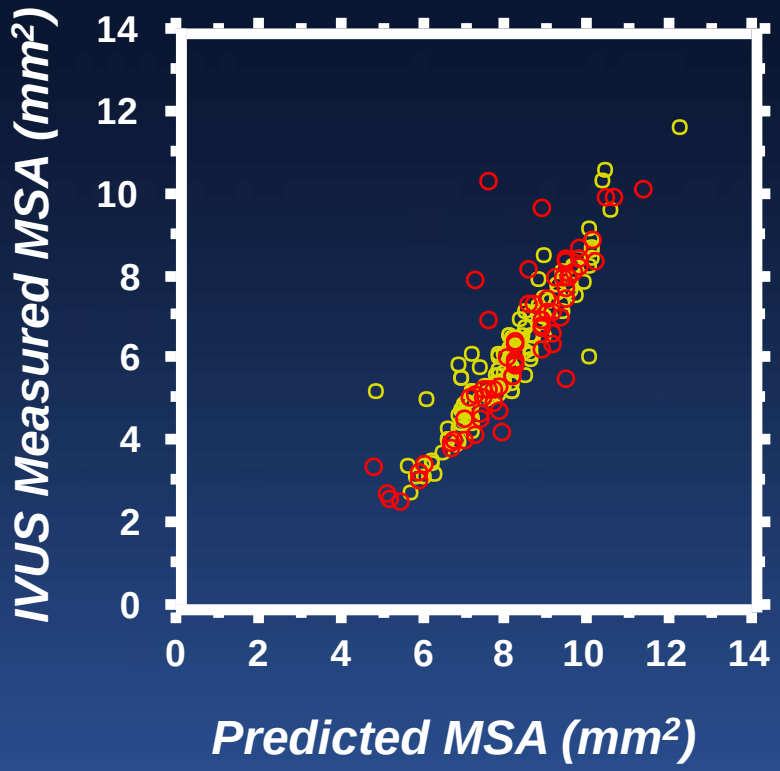


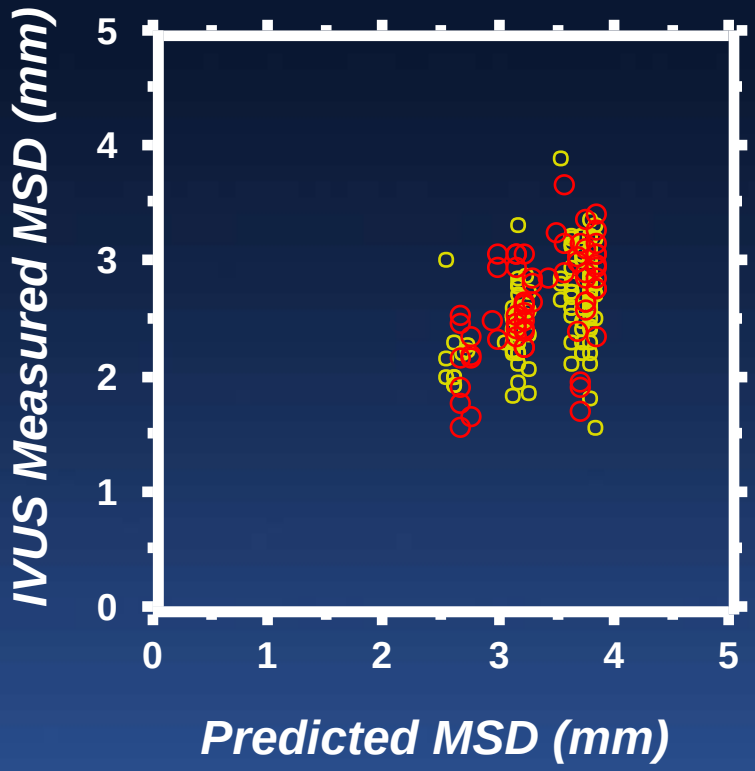
Cardiovascular Research Foundation

Song et al. Cathet Cardiovasc Interv 2014;83:873-8

Manufacturer's Compliance Charts Cannot Be Used to Guarantee Adequate Stent Expansion

Comparison of IVUS-measured minimum stent diameter (MSD) and minimum stent area (MSA) with the predicted measurements from Cypher in yellow, n=133) and Taxus in red, n=67). DES achieve an average of only 75% of the predicted MSD (66% of MSA)

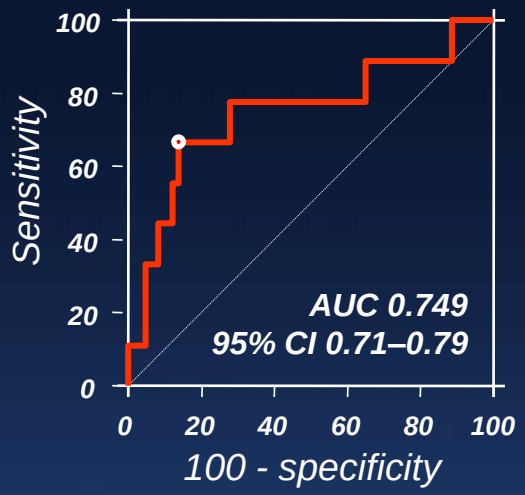




de Rebamar Costa et al, Am J Cardiol 2005;96:74-8
de Rebamar Costa et al, Am Heart J 2007;153:297-303
He et al. Am J Cardiol 2010;105:1272-5

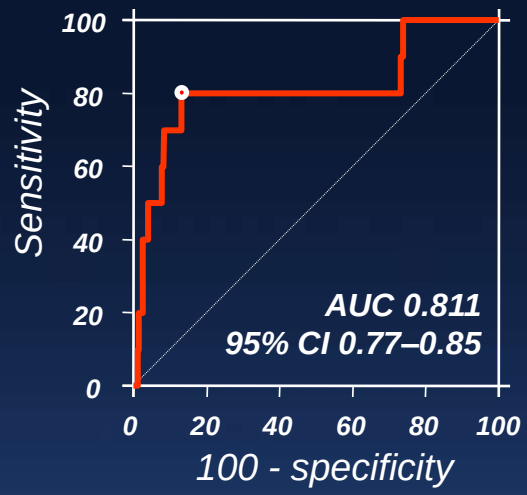
IVUS Predictors of Edge Restenosis after Second Generation DES

433 E-ZES



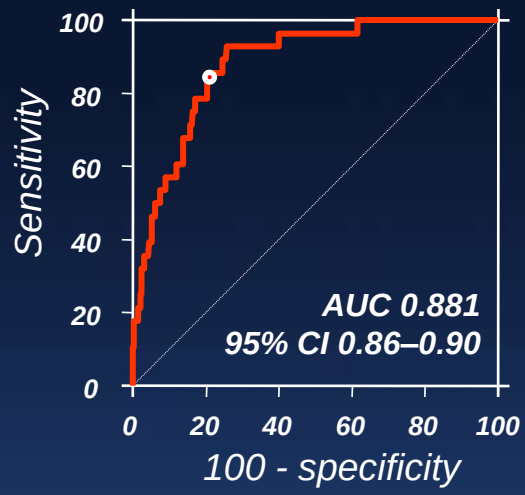
Plaque burden=56.3%
Sensitivity 67%
Specificity 86%

422 R-ZES



Plaque burden=57.3%
Sensitivity 80%
Specificity 87%

813 EES

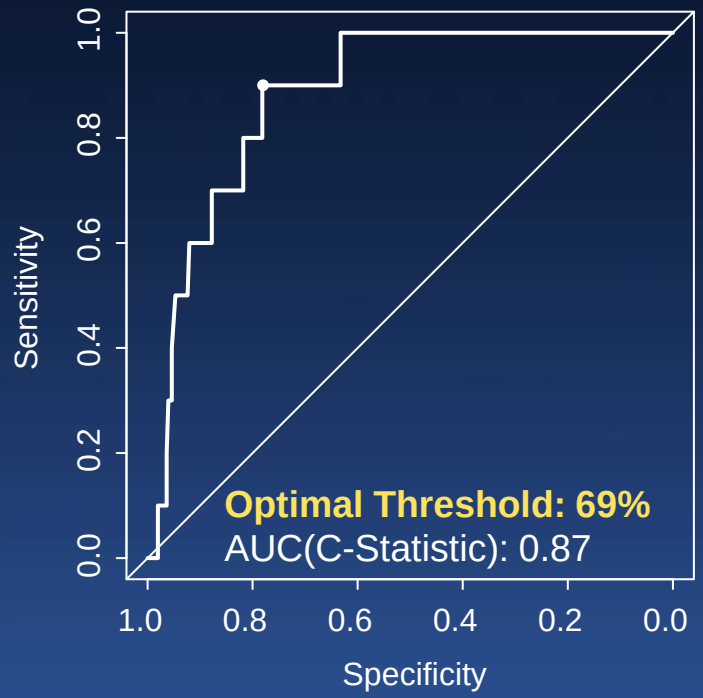


Plaque Burden=54.2%
Sensitivity 86%
Specificity 80%

Cardiovascular Research Foundation

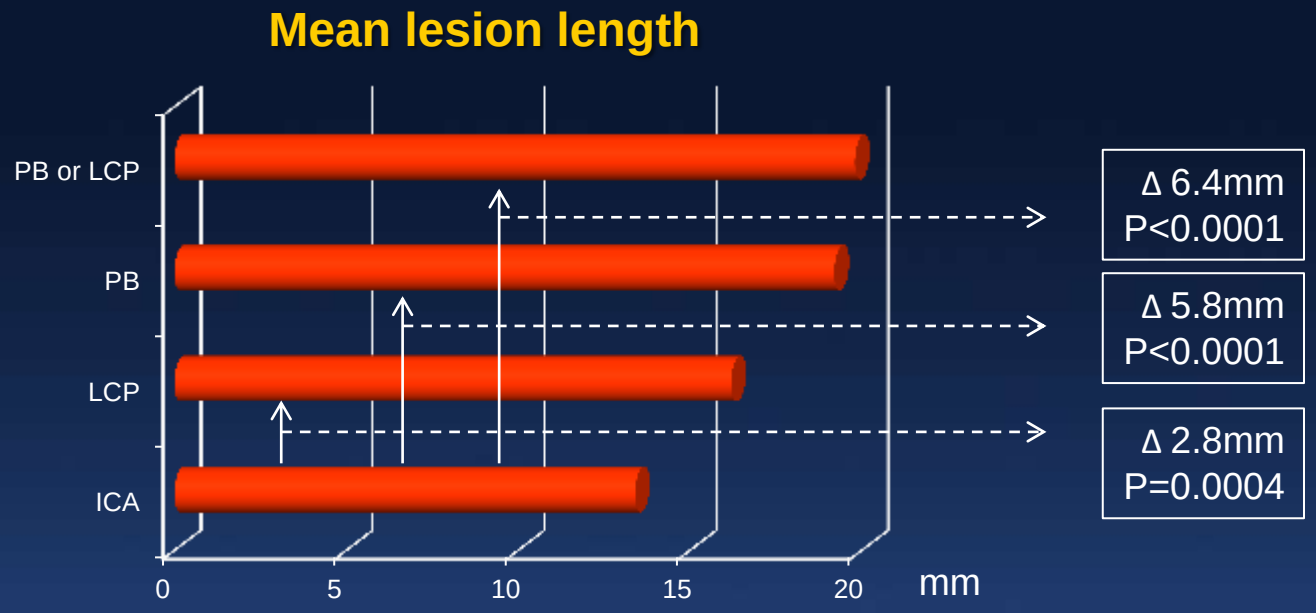
Kang et al. Am J Cardiol 2013;111:1408-14

Plaque burden predictor of TCFA in 271 atherosclerotic lesions from 106 fresh coronary arteries in 54 patients at necropsy.



Inaba et al. Am J Cardiol 2017;119:372-8

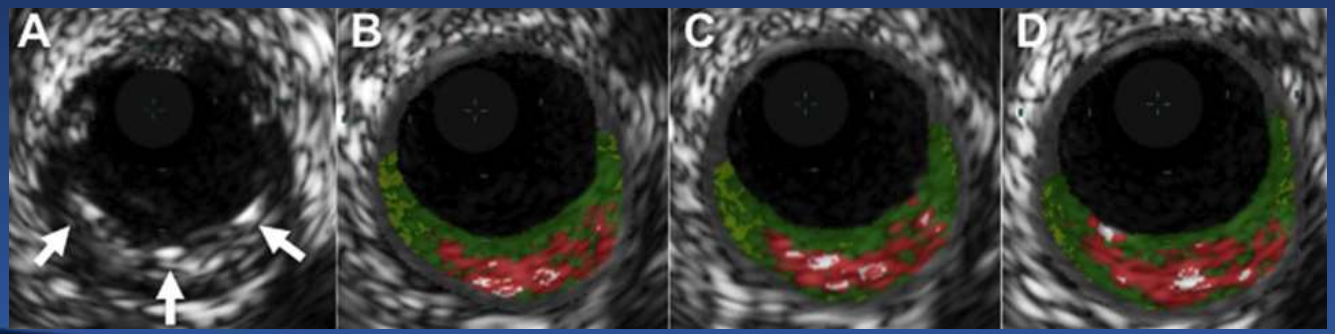
In 58 pts lesion length was measured by invasive coronary angiography (ICA) and NIRS-IVUS



Hansen ID et al. Coron Artery Dis 2015:26;484-9.

Three geographic miss studies using VH-IVUS

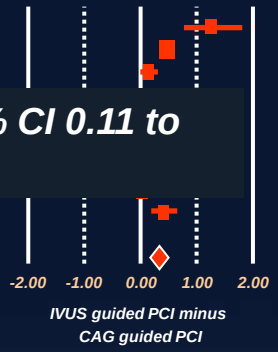
- Legutko et al. Am J Cadiol 2012;109:1405-10
  - 20 STEMI pts underwent primary PCI with restoration of TIMI grade 3 flow by angiographically guided direct stenting. Plaque rupture sites were incompletely covered in 60% and maximum necrotic core sites were incompletely covered in 50%.
- Legutko et al. Am J Cadiol 2013;112:1854-9
  - 20 NSTEMI pts with TIMI grade 3 flow underwent PCI angiographically guided stenting. Although the plaque rupture site was fully covered with the stent in all lesions, an uncovered VH-TCFA was found in 35%.
- Calvert et al. Cathet Cardiovasc Interv 2016;88:340-7
  - In 170 pts (100 stable angina; 70 MI) with 245 lesions stented, geographical miss with larger necrotic cores was seen in 33% and was associated with increased MACE in pts with MI, but not in pts with stable angina.



Implanted Stent Number

Means and 95% CI

	Std diff in means	Standard error	Vari-ance	Lower limit	Upper limit	Z-value	P value
Ahn SG et al. (2013)	1.200	0.238	0.057	0.733	1.667	5.041	0.000
Ahn JM et al. (2013)	0.477	0.036	0.001	0.408	0.547	13.407	0.000
Chen SL et al. (2012)	0.134	0.080	0.006	-0.022	0.291	1.681	0.093
Youn YJ et al. (2011)	0.371	0.113	0.013	0.149	0.593	3.277	0.001
Random Effect Model	0.269	0.080	0.006	0.112	0.426	3.360	0.001



0.27 more stents per lesion (95% CI 0.11 to 0.43, P<0.001)

Implanted Stent Length

Means and 95% CI

	Std diff in means	Standard error	Vari-ance	Lower limit	Upper limit	Z-value	P value
Ahn SG et al. (2013)	0.500	0.036	0.001	0.430	0.570	14.016	0.000
Chen SL et al. (2012)	0.167	0.080	0.006	0.010	0.324	2.088	0.037
Chieffo A et al. (2013)	0.106	0.105	0.011	-0.100	0.311	1.007	0.314
Park KW et al. (2012)	0.278	0.057	0.003	0.167	0.390	4.889	0.000
Roy P et al. (2008)	0.095	0.048	0.002	0.001	0.188	1.989	0.047
Witzenbichler B et al. (2012)	0.085	0.022	0.000	0.042	0.128	3.844	0.000
Yoon YW et al. (2013)	0.047	0.047	0.002	-0.045	0.140	1.005	0.315
Youn YJ et al. (2011)	0.521	0.114	0.013	0.298	0.745	4.569	0.000
Random Effect Model	0.175	0.048	0.002	0.080	0.271	3.618	<0.001

Mean difference in stent length of 0.18 mm (95% CI 0.08 to 0.27, P<0.001)

Mean Stent Diameter

Means and 95% CI

	Std diff in means	Standard error	Vari-ance	Lower limit	Upper limit	Z-value	P value
Ahn SG et al. (2013)	0.484	0.223	0.050	0.048	0.920	2.174	0.030
Ahn JM et al. (2013)	0.467	0.036	0.001	0.398	0.537	13.134	0.000
Chen SL et al. (2012)	0.195	0.080	0.006	0.038	0.352	2.439	0.015
Witzenbichler B et al. (2012)	0.553	0.023	0.001	0.509	0.597	24.557	0.000
Youn YJ et al. (2011)	0.343	0.113	0.013	0.122	0.565	3.034	0.002
Chieffo A et al. (2013)	0.243	0.105	0.011	0.037	0.449	2.311	0.021
Random Effect Model	0.328	0.054	0.003	0.221	0.435	6.015	<0.001

Mean difference in stent size of 0.33 mm (95% CI 0.22 to 0.44mm, P<0.001)

Minimal Lumen Diameter

Means and 95% CI

	Std diff in means	Standard error	Vari-ance	Lower limit	Upper limit	Z-value	P value
Agostoni et al. (2005)	0.208	0.267	0.071	-0.316	0.732	0.779	0.436
Ahn SG et al. (2013)	0.667	0.225	0.051	0.225	1.108	2.958	0.003
Chen SL et al. (2012)	0.369	0.081	0.006	0.211	0.527	4.582	0.000
Youn YJ et al. (2011)	0.270	0.113	0.013	0.048	0.491	2.389	0.017
Random Effect Model	0.335	0.034	0.001	0.269	0.400	9.981	<0.001

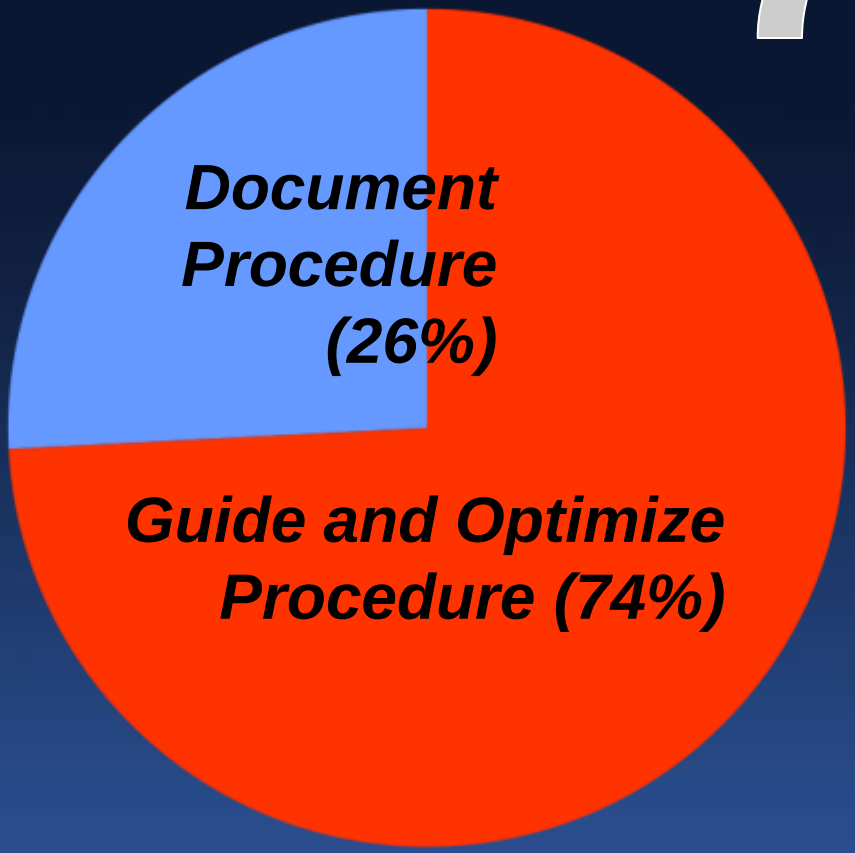
Mean difference in post-procedural MLD of 0.34 mm (95% CI 0.27 to 0.40, P<0.001)

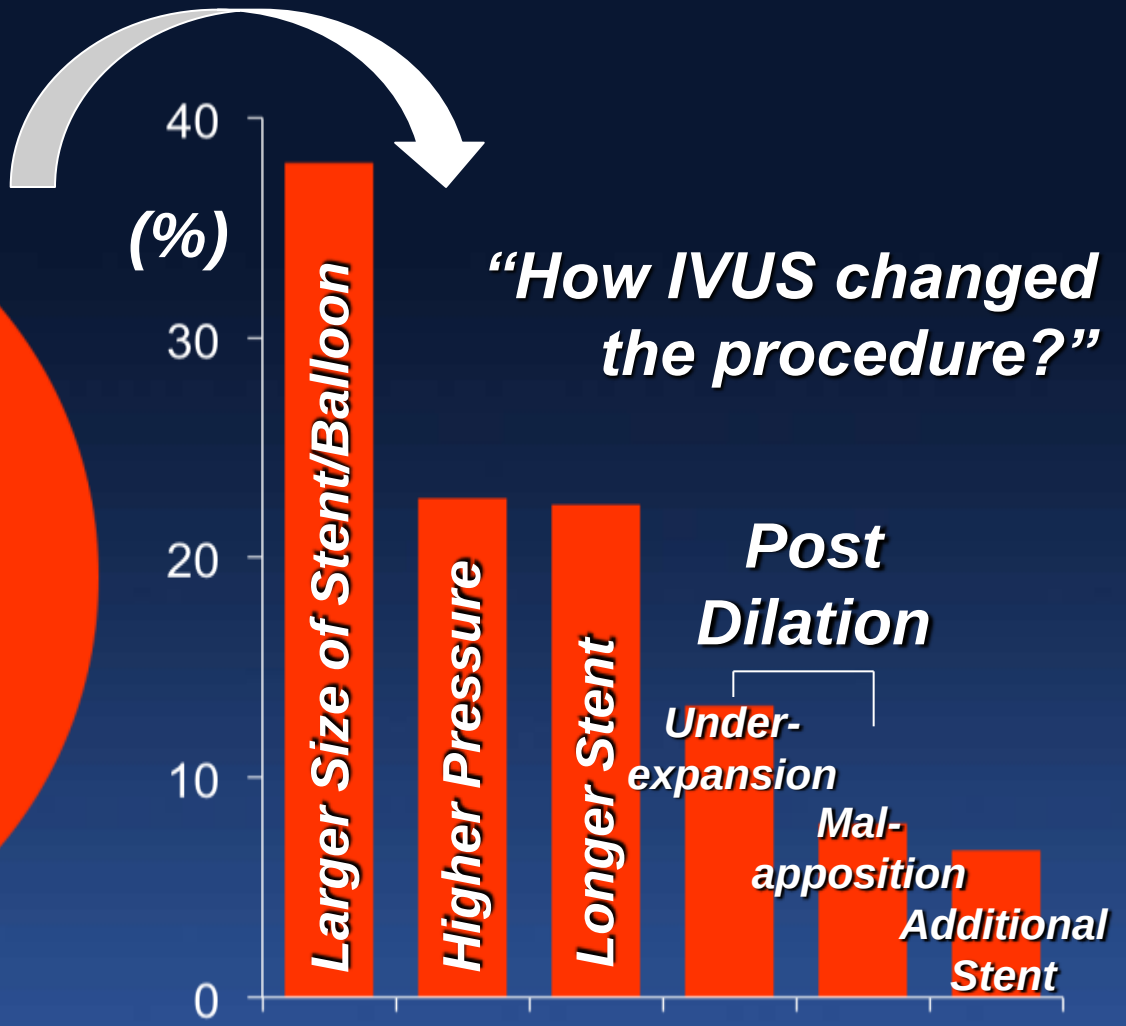
Cardiovascular Research Foundation

Ahn et al. Am J Cardiol 2014;113:1338-47

ADAPT-DES: The best single registry to date

How was IVUS used?





"How IVUS changed the procedure?"

Cardiovascular Research Foundation

Witzenbichler et al. Circulation 2014;129:463-70

IVUS Guidance to Minimize the Use of Iodine Contrast in PCI

- MOZART - Mariani et al. JACC Cardiovasc Interv 2014;7:1287-93
  - 83 pts randomized to IVUS vs angiographic guidance with a pre-specified PCI strategy designed to reduce contrast usage in both groups
  - **Reduction in contrast use (primary endpoint) from 64.5ml (IQR 42.8-97ml, range 19-170ml) to 20.0ml (IQR 12.5-30.0ml, range 3-54ml): p<0.0001**
  - No difference in 4-month outcomes although there was a trend toward a less common increase in serum Cr >0.5mg/dl (7.3% vs 19.0%, p=0.2)
- Ali et al. Eur Heart J. 2016;37:3090-3095
  - 31 pts with median creatinine of 4.2mg/dL (IQR 3.1-4.8)
  - Successful **zero contrast PCI** was performed at least 1 week after diagnostic angiography using real-time IVUS guidance and pre- and post-PCI FFR and CRF to confirm physiologic improvement
  - No MACE and preservation of renal function in all pts at a median follow-up of 79 days (IQR 33-107).

Conclusions

- **IVUS predictors of early thrombosis and restenosis after DES implantation are primarily underexpansion (or a small lumen area in ACS patients) and geographic miss**
- **In 33 published registry studies, 9 randomized clinical trials, and 11 meta-analyses, IVUS guidance reduced events compared to angiographic guidance by improving acute results especially in**
  - **Second generation DES**
  - **Complex patients**
  - **Complex lesions (LMCA, CTO, long lesions, bifurcations).**