IVUS Is A Mandatory in All PCI Patients!

Seeing Is Believing

Duk-Woo Park, MD, PhD

University of Ulsan College of Medicine
Asan Medical Center, *Seoul, Korea*

Angiography versus IVUS

ANGIOGRAPHY

2 dimensional

Planar

Shadow of lumen

Wall structures not imaged

Intermittent snapshots or repeat contrast injections necessary

QCA measurements prone to magnification errors

IVUS

360º view

Tomographic and sagittal

Visualization of shape and location

Visualization of inner wall structures and morphology

Continuous image

Precise measurements

Key Roles of IVUS in PCI

- **Pre-intervention Assessment**

  (1) plaque morphology and calcium

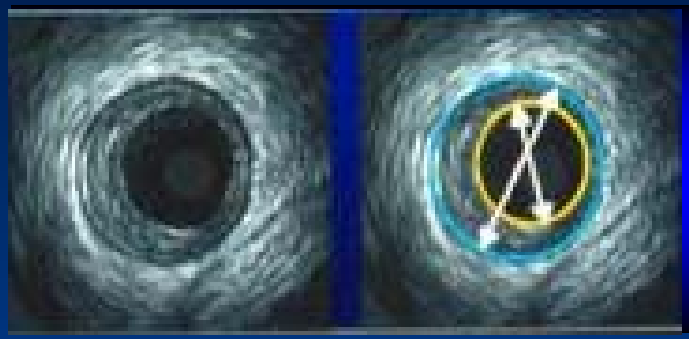
  (2) device selection

- **Post-intervention Assessment**

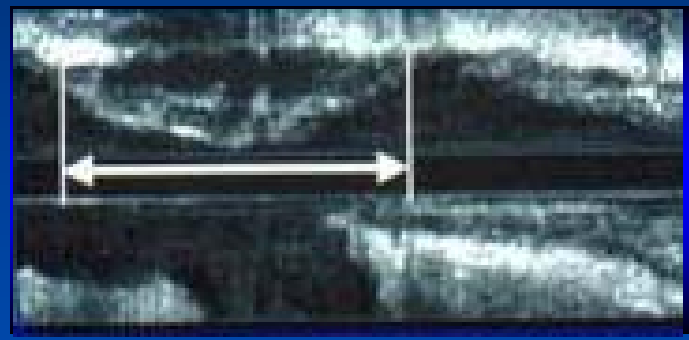
  (1) post-stent optimization

  (2) Immediate complications

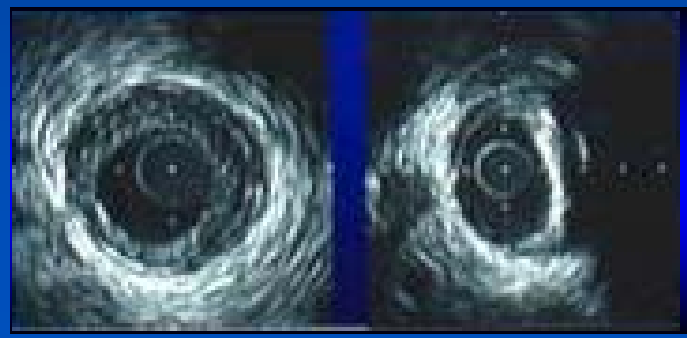
Pre-Stent Assessment



Size

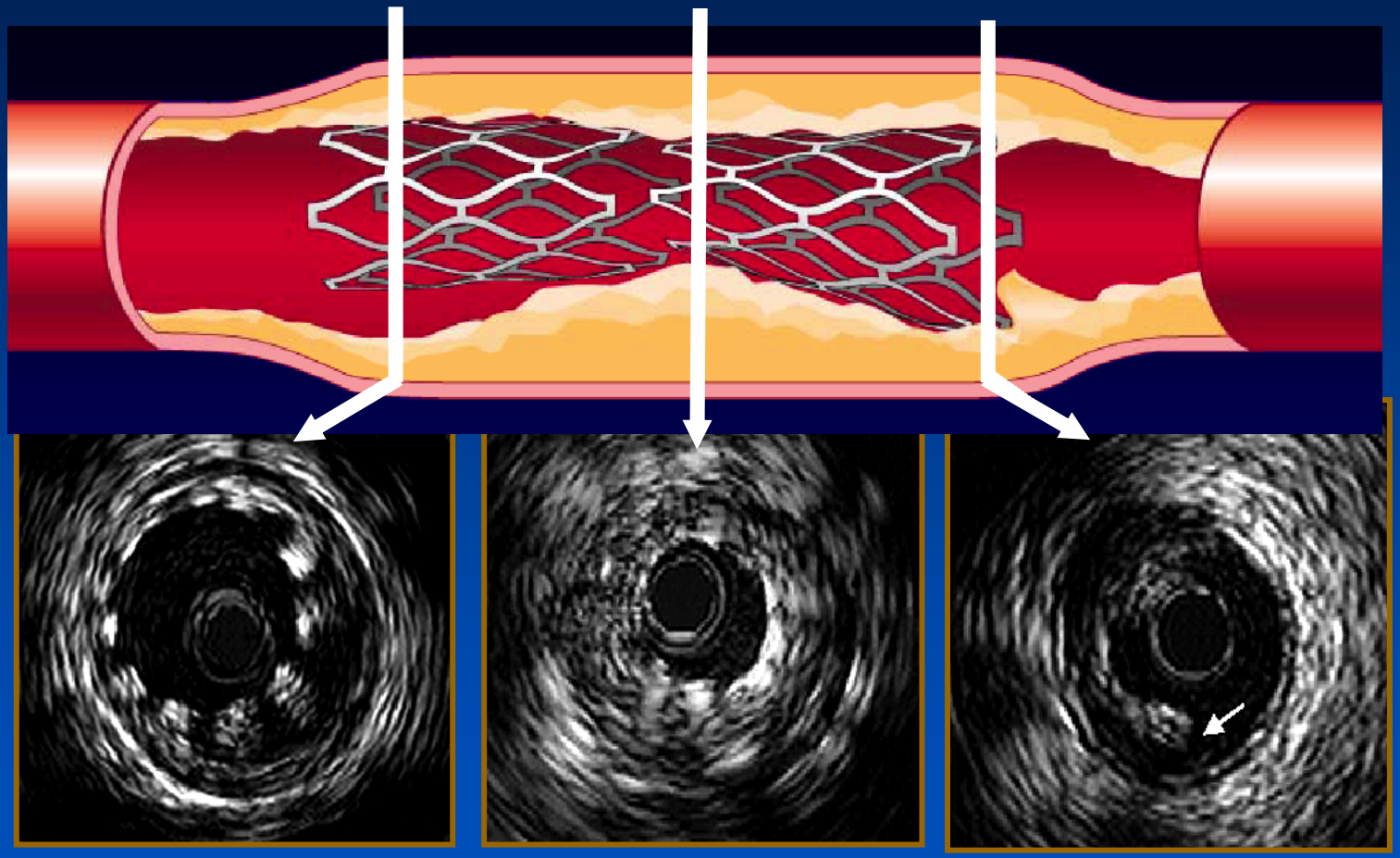


Plaque Length



Plaque Type

Post-Stent Assessment



In-Apposition Under-expansion Dissection

IVUS-guided PCI in the BMS Era

Study	Angio Better	IVUS Better
Choi et al (AHJ *2001;142:112-8)*		O
CENIC (*JACC* 2002;39:54A)		O
CRUISE (*Circulation 2000;102:523-30)*		O
SIPS (*Circulation* 2000;102:2497-502 and AJC 2003;91:143-7)		O
AVID (*Circulation* 1999;100:I-234)		O
Gaster et al (*Scan Cardiovasc J 2001;35:80-5 & Heart* 2003;89:1043-9)		O
RESIST (JACC 1998;32:320-8 & *Int J Cardiovasc Intervent* 2000;3:207-13)		O
TULIP (*Circulation 2003;107:62-7)*		O
BEST (*Circulation2003;107:545-551*)		O
OPTICUS (Circulation. 2001;104:1343-9)	O	
PRESTO (Am Heart J. 2004;148:501-6)	O	
DIPOL (Am Heart J. 2007;154:669-75)		O

Large RCT comparing IVUS- vs. CAG-guided PCI

A Randomized Controlled Trial of Angiography Versus Intravascular Ultrasound-Directed Bare-Metal Coronary Stent Placement (The AVID Trial)

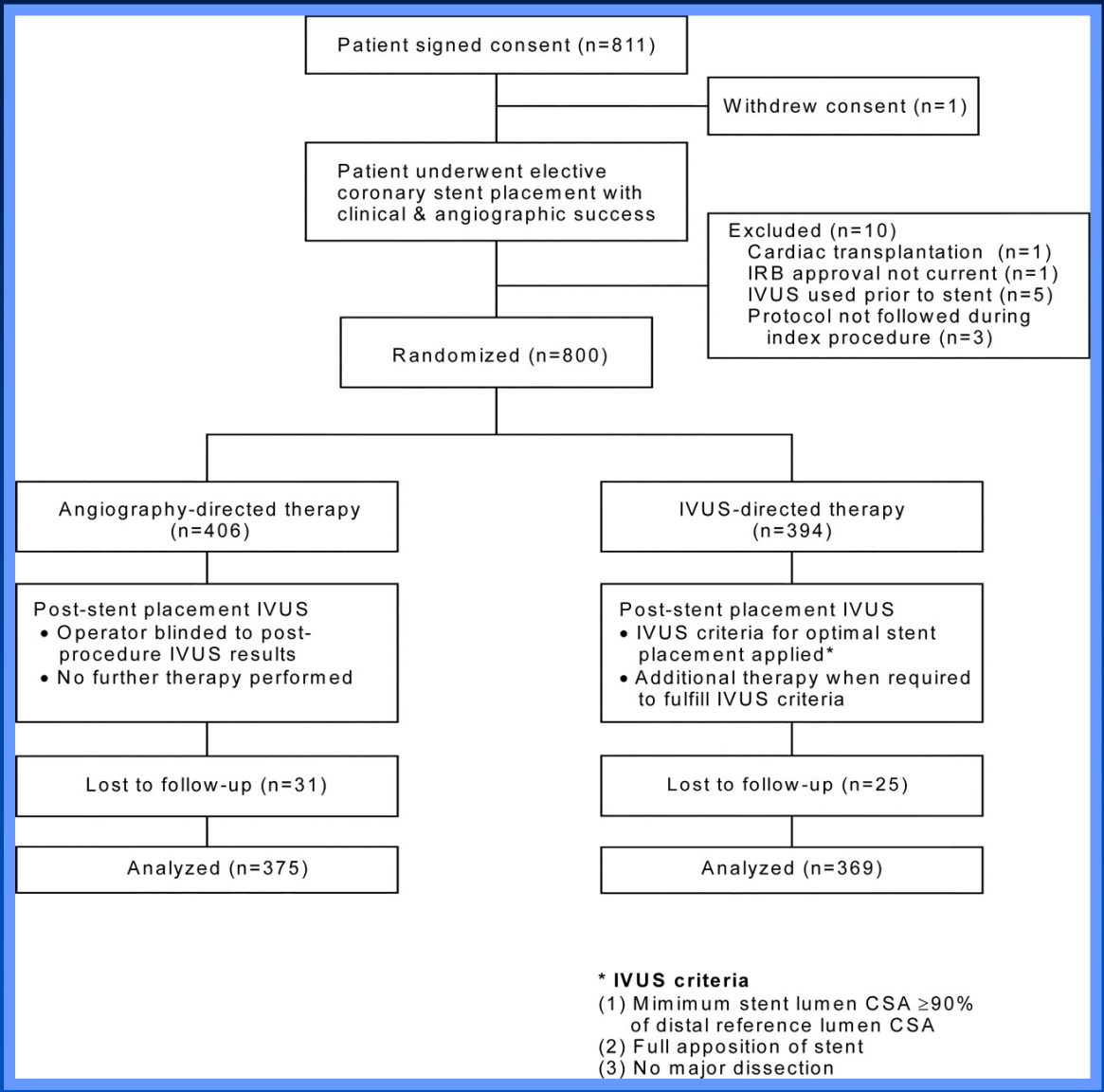
Robert J. Russo, MD, PhD; Patricia D. Silva, MS, MAS; Paul S. Teirstein, MD; Michael J. Attubato, MD; Charles J. Davidson, MD; Anthony C. DeFranco, MD; Peter J. Fitzgerald, MD, PhD; Steven L. Goldberg, MD; James B. Hermiller, MD; Martin B. Leon, MD; Frederick S. Ling, MD; Jennifer E. Lucisano, RN, BSN; Richard A. Schatz, MD; S. Chiu Wong, MD; Neil J. Weissman, MD; David M. Zientek, MD; for the AVID Investigators

Primary end-point: TLR at 1 year

Secondary end-point: death, MI, ST, CABG

Russo, R. J. et al. Circ Cardiovasc Intervent 2009;2:113-123

The AVID Trial



Russo, R. J. et al. Circ Cardiovasc Intervent 2009;2:113-123

The AVID Trial

Table 2. Summary Statistics for Angiographic and Intravascular Ultrasound Variables

Variable	Angiography-Directed Therapy (n=406)	IVUS-Directed Therapy (n=394)	*P*
Angiography core laboratory			
Poststent			
Balloon:artery ratio	1.29±0.26	1.38±0.29	<0.001
Stent minimum diameter, mm	2.87±0.48	2.93±0.55	0.11
Diameter expansion, %	97.1±14.9	97.9±16.5	0.52
Final			
Stent minimum diameter, mm	2.87±0.48	2.97±0.56	0.01
Intravascular ultrasound core laboratory			
Poststent			
Distal reference average lumen diameter, mm	3.22±0.66	3.22±0.64	0.97
Lumen diameter at minimum stent area, mm	2.89±0.51	2.95±0.49	0.15
Distal reference lumen area, mm^2	8.59±3.67	8.61±3.64	0.94
Minimum stent area, mm^2	6.88±2.43	7.17±2.45	0.11
Area expansion, %	84.4±20.8	86.6±20.0	0.14
Final			
Lumen diameter at minimum stent area, mm	2.90±0.52	3.02±0.54	0.001
Minimum stent area, mm^2	6.90±2.43	7.55±2.82	0.001
Area expansion, %	84.6±20.8	90.4±20.6	<0.001
Gain in minimum stent area, mm^2	NA	0.39±1.18	. . .

Russo, R. J. et al. Circ Cardiovasc Intervent 2009;2:113-123

The AVID Trial

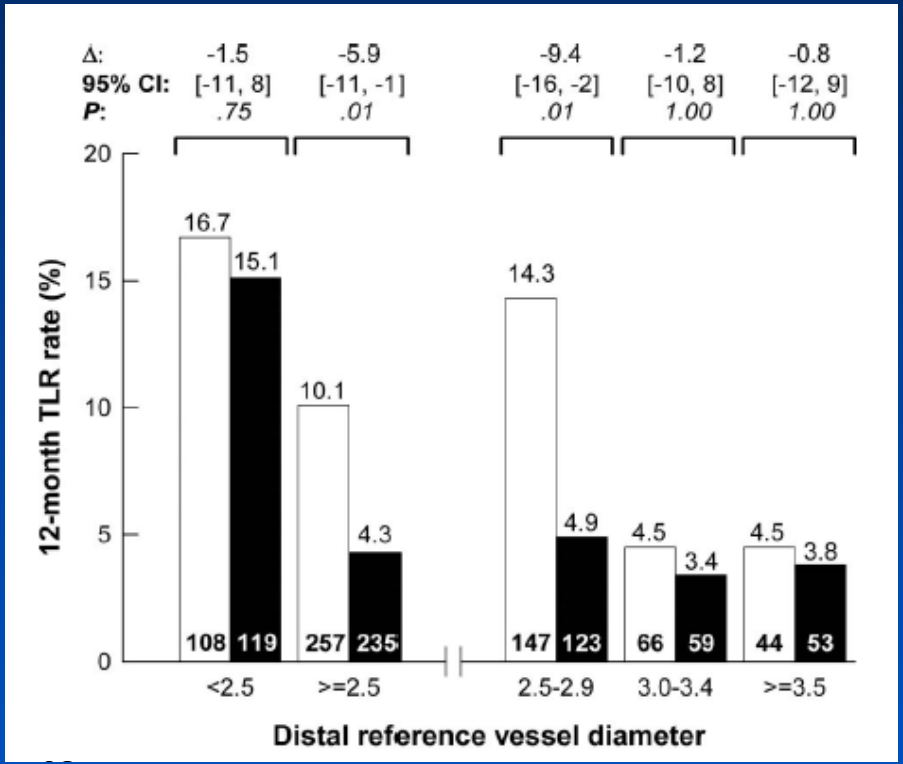
Table 4. Twelve-Month Clinical Event Rates Demonstrating the Improvement in Clinical Outcome in the IVUS-Directed Therapy Group

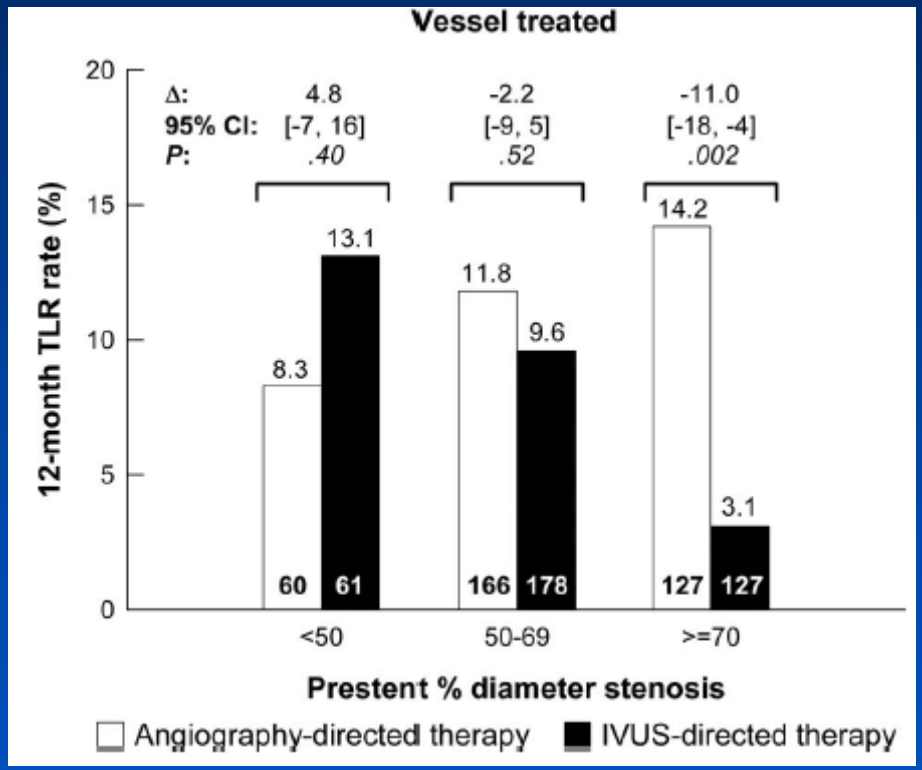
	Angiography-Directed Therapy	IVUS-Directed Therapy	Δ	95% Confidence Interval	*P*
Intention-to-treat analysis					
Subjects	375	369			
Clinical events, %					
TLR	12.0	8.1	−3.9	−8.3, 0.5	0.08
Death	1.9	3.3	1.4	−1.0, 3.9	0.23
Myocardial infarction	5.1	6.8	1.7	−1.7, 5.2	0.32
Stent thrombosis	1.1	1.4	0.3	−1.5, 2.2	0.75
CABG	2.7	2.7	0.0	−2.5, 2.6	0.97
Any MACE	18.7	18.4	−0.2	−5.8, 5.4	0.93
Subjects with an angiographic prestent distal reference diameter ≥2.5 mm					
Subjects	257	235			
Clinical events, %					
TLR	10.1	4.3	−5.9	−10.6, −1.2	0.01
Death	1.2	3.8	2.7	−0.2, 6.0	0.06
Myocardial infarction	5.1	5.5	0.5	−3.6, 4.7	0.81
Stent thrombosis	1.2	1.7	0.5	−1.9, 3.2	0.71
CABG	2.3	2.1	−0.2	−3.1, 2.8	0.88
Any MACE	15.6	14.5	−1.1	−7.4, 5.3	0.73

Russo, R. J. et al. Circ Cardiovasc Intervent 2009;2:113-123

The AVID Trial
: subgroup analysis

IVUS-guided
Angiography-guided





IVUS-guided PCI with BMS results in a significantly lower TLR rate for vessels > 2.5 mm and with high-grade (70%) DS

Routine IVUS guidance for Current PCI Practice with DES

IVUS Impact

(1) Restenosis ?

(2) Stent thrombosis ?

Predictors of DES Thrombosis & Restenosis

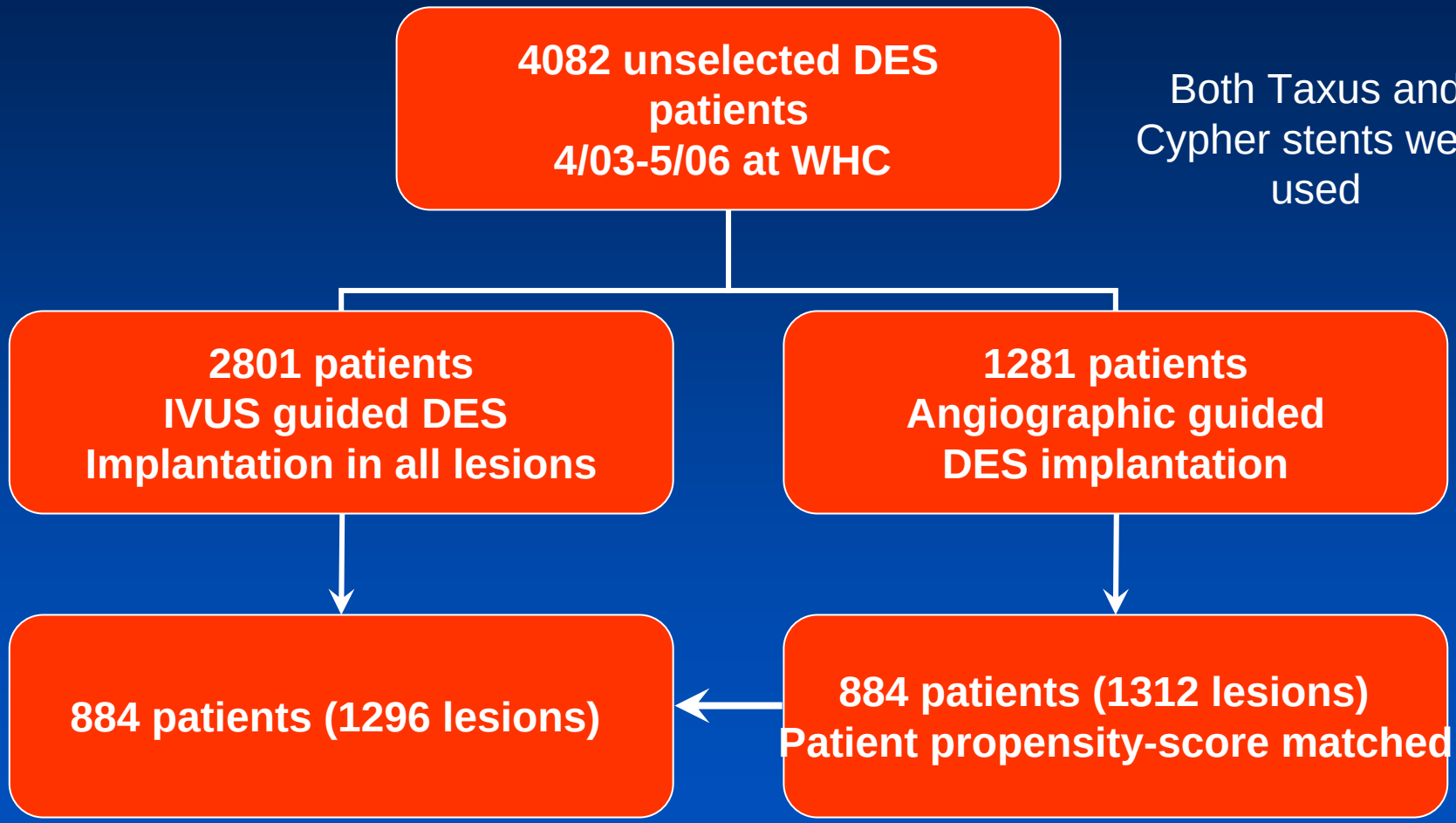
	Thrombosis	Restenosis
Underexpansion	• *Fujii et al. J Am Coll Cardiol 2005;45:995-8)* • *Okabe et al., Am J Cardiol. 2007;100:615-20*	• *Sonoda et al. J Am Coll Cardiol 2004;43:1959-63* • *Hong et al. Eur Heart J 2006;27:1305-10* • *TAXUS IV, V, VI meta-analysis* • *Fujii et al. Circulation 2004;109:1085-1088*
Peri-stent optimization **- remained lesions** **- geographic miss** **- large plaque burden…**	• *Fujii et al. J Am Coll Cardiol 2005;45:995-8)* • *Okabe et al., Am J Cardiol. 2007;100:615-20*	• *Sakurai et al. Am J Cardiol 2005;96:1251-3* • *Liu et al, Am J Cardiol, in press* • *Costa et al, Am J Cardiol, 2008;101:1704-11*

Rational for Routine IVUS Use In the DES Era

- Despite marked reduction of restenosis with DES compared to BMS, these stents are not free of restenosis and are limited by late stent thrombosis.
- Several IVUS studies have suggested that suboptimal stent deployment is the predominant etiology underlying both DES restenosis and thrombosis
- Given the importance of optimal stent deployment (**stent expansion and apposition to the vessel wall**) with DES, it is intuitive that IVUS guidance should yield clinical benefit.

Routine IVUS Impact on DES Outcomes:

Data from Washington Hospital Center



Both Taxus and Cypher stents were used

All patients completed 12 month clinical follow up

Roy et al. EHJ 2008:29;1851-57

Patient Characteristics

%	IVUS (n=884)	No IVUS (n=884)	p Value
Male gender	613 (69.3%)	619 (70.0%)	0.76
Age, yrs (mean ± SD)	66.0 ± 11.6	65.6 ± 11.8	0.54
Diabetes	317 (35.9%)	304 (34.4%)	0.52
Current smoker	186 (21.0%)	181(20.5%)	0.77
Hypertension	723 (81.8%)	721 (81.6%)	0.90
Dyslipidaemia	762 (86.2%)	770 (87.1%)	0.58
Chronic renal insufficiency	110 (12.4%)	112 (12.7%)	0.89
Prior myocardial infarction	380 (43.0%)	365 (41.3%)	0.47
Prior coronary bypass surgery	206 (23.3%)	198 (22.4%)	0.65
Prior percutaneous coronary intervention	240 (27.1%)	216 (24.4%)	0.19
Peripheral vascular disease	145 (16.4%)	142 (16.1%)	0.85

Clinical Presentation

	IVUS (n=884)	No IVUS (n=884)	p Value
Stable angina	**213 (24.1%)**	**222 (25.1%)**	**0.62**
Unstable angina	**397 (44.9%)**	**381 (43.1%)**	**0.44**
Acute myocardial infarction	**152 (17.2%)**	**157 (17.8%)**	**0.75**
Cardiogenic shock	**28 (3.2%)**	**27 (3.1%)**	**0.89**
Left ventricular ejection fraction (% ± SD)	**47 ± 15**	**48 ± 13**	**0.14**

Angiographic Details

	IVUS (n=884)	No IVUS (n=884)	P
Target vessel			**0.26**
Left main coronary artery, n (%)	**26 (2.0)**	**30 (2.3)**	
Left anterior descending artery, n (%)	**427 (32.9)**	**433 (33.0)**	
Left circumflex, n (%)	**320 (24.7)**	**305 (23.2)**	
Right coronary artery, n (%)	**446 (34.4)**	**450 (34.3)**	
Saphenous vein graft, n (%)	**75 (5.8)**	**84 (6.4)**	
Lesion location			**0.98**
Lesion Type (ACC/AHA classification)			**0.86**
In- stent restenosis, n (%)	**70 (5.4)**	**57 (4.3)**	**0.21**

Procedural Details

Procedural Details, n (%)	IVUS (n=884)	No IVUS (n=884)	p
Number of lesions treated (n ± SD)	1.70 ± 0.85	1.70 ± 1.1	1.0
Number of stents implanted (n ± SD)	1.48 ± 0.8	1.5 ± 0.9	0.43
Sirolimus-eluting stent	832 (64.2)	779 (59.4)	0.01
Paclitaxel-eluting stent	464 (35.8)	533 (40.6)	0.01
Stent diameter (mm ± SD)	3.05 ± 0.4	3.09 ± 1.8	0.47
Stent length (mm ± SD)	20.73 ± 6.4	20.1 ± 6.9	0.04
Direct stenting	370 (28.7%)	537 (41.1%)	<0.001
Post dilatation	343 (31.0%)	219 (17.7%)	<0.001
Emergent intra-aortic balloon pump	22 (2.5%)	32 (3.6%)	0.17
Rotational atherectomy	46 (3.5%)	20 (1.5%)	<0.001
Cutting balloon	95 (7.3%)	37 (2.8%)	<0.001
Glycoprotein IIb/IIIa Inhibitor use	157 (17.8%)	163 (18.4%)	0.71

30 Day Outcomes

	IVUS (n=884)	No IVUS (n=884)	p
Major adverse cardiac events	25 (2.8%)	46 (5.2%)	0.01
Death	15 (1.7%)	29 (3.3%)	0.03
Cardiac death	6 (0.7%)	14 (1.6%)	0.07
Q-wave myocardial infarction	6 (0.7%)	12 (1.4%)	0.15
Target vessel revascularization	10 (1.1%)	17 (2.0%)	0.17
Target lesion revascularization	6 (0.7%)	15 (1.7%)	0.045
Stent thrombosis	4 (0.5%)	12 (1.4%)	0.045

***MACE; death, Q-MI, TVR**

Roy et al. EHJ 2008:29;1851-57

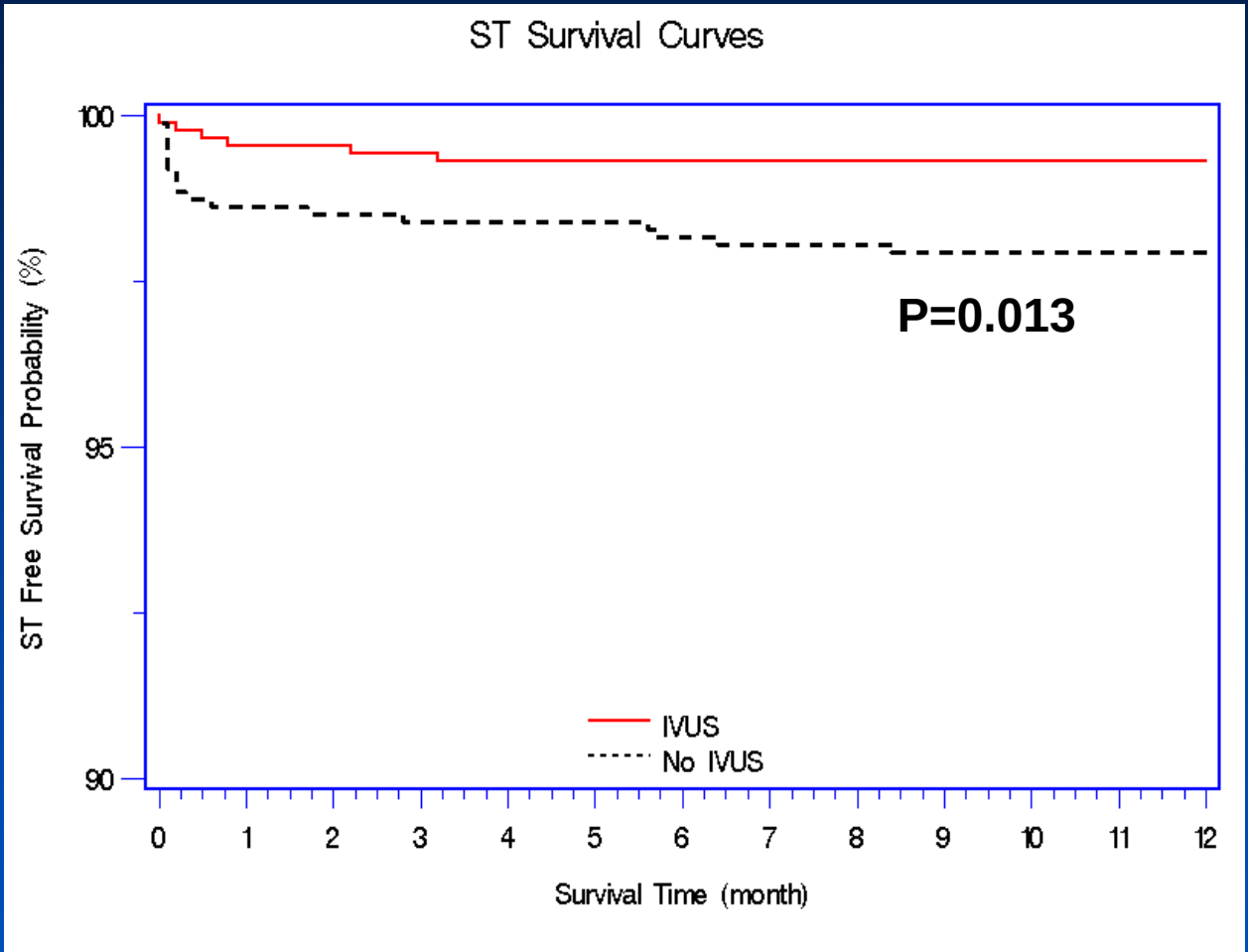
12 Months Outcomes

	IVUS (n=884)	No IVUS (n=884)	p
Major adverse cardiac events	128 (14.5%)	143 (16.2%)	0.32
Death	50 (5.7%)	62 (7.1%)	0.23
Cardiac death	16 (1.9%)	24 (2.8%)	0.18
Q-wave myocardial infarction	18 (2.1%)	26 (3.1%)	0.21
Target vessel revascularization	73 (8.5%)	77 (9.1%)	0.69
Target lesion revascularization	43 (5.1%)	61 (7.2%)	0.06
Definite stent thrombosis	6 (0.7%)	18 (2.0%)	0.014
Probable stent thrombosis	35 (4.0%)	51 (5.8%)	0.08
Late definite stent thrombosis	2 (0.2%)	6 (0.7%)	0.29

***MACE; death, Q-MI, TVR**

Roy et al. EHJ 2008:29;1851-57

Freedom from Definite Stent Thrombosis



No IVUS was a predictor of cumulative ST at 12 months independent of DES type. (No IVUS: HR 3.3, CI 1.25-10, p=0.01)

Summary

- IVUS-guided PCI with DES has the potential to influence treatment strategy and reduce both DES thrombosis and the need for repeat revascularization.
- IVUS guidance should be considered for routine use during DES implantation in patients at increased risk for these events.

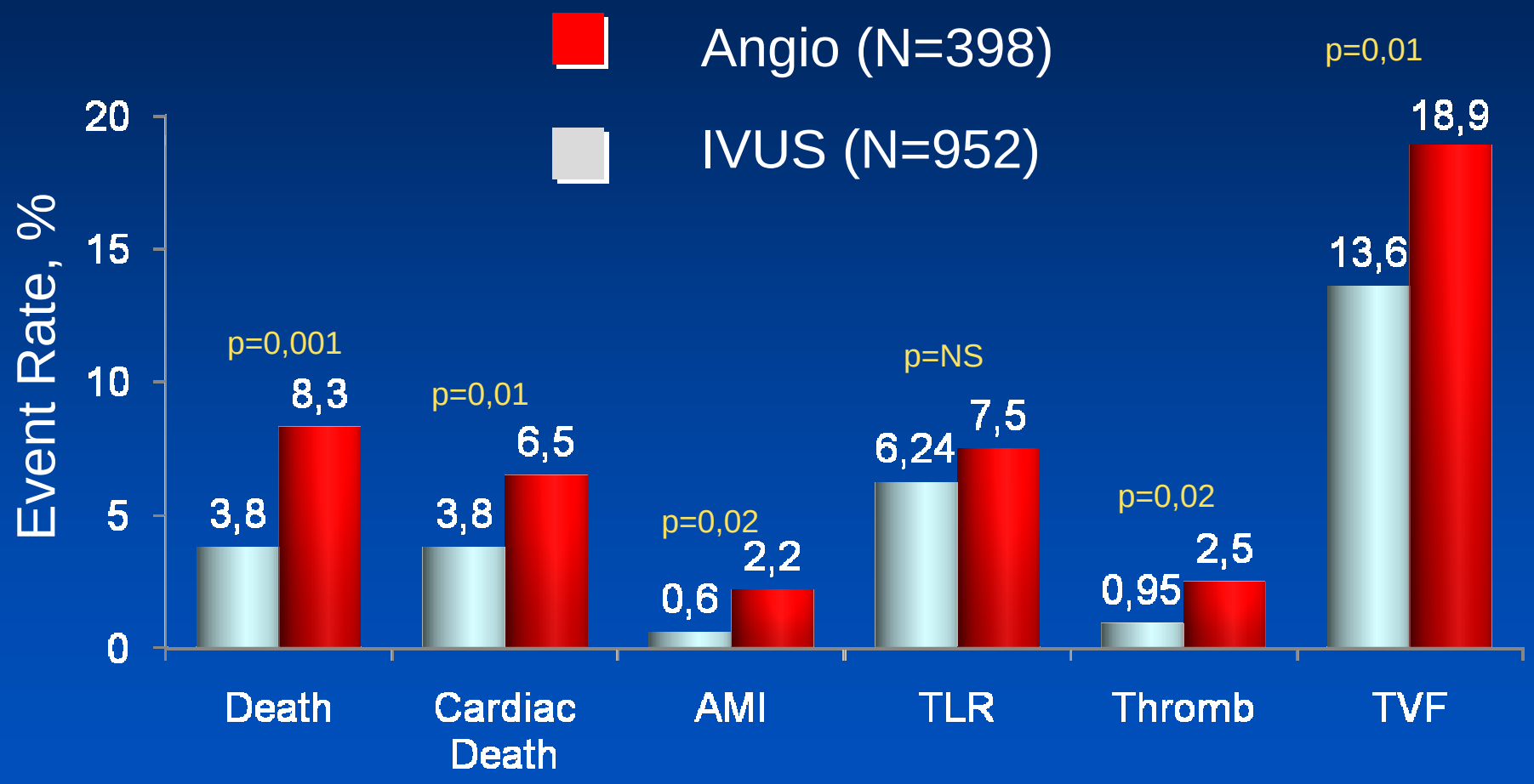
952 IVUS-guided vs 398 angio-guided among 1350 patients treated with DES

	IVUS-guided (N=952)	Angio-guided (N=398)	p
Age	63.4±0.36 yrs	63.5±0.42 yrs	
Diabetes	27%	35%	0.007
ACS	26%	27%	NS
Multivessel disease	54%	45%	0.001
LAD	46%	15%	<0.001
Stents/lesion	1.01	1.04	NS
%DES	93%	81%	<0.01
Stent diameter (mm)	3.0±0.4	2.9±0.5	<0.001
Stent length (mm)	24.0±7.4	22.9±7.8	<0.0001
Post-dilation	14%		

(Costantini et al. TCT 2008)

Long Term Outcome

(Mean Follow Up Time: 31.9± 15.3 Months)

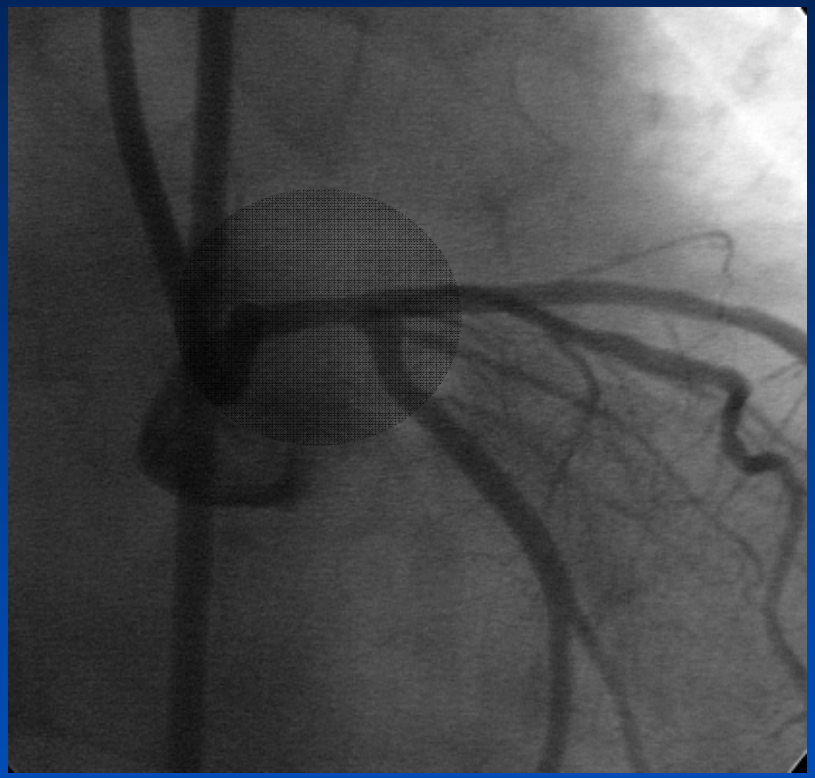


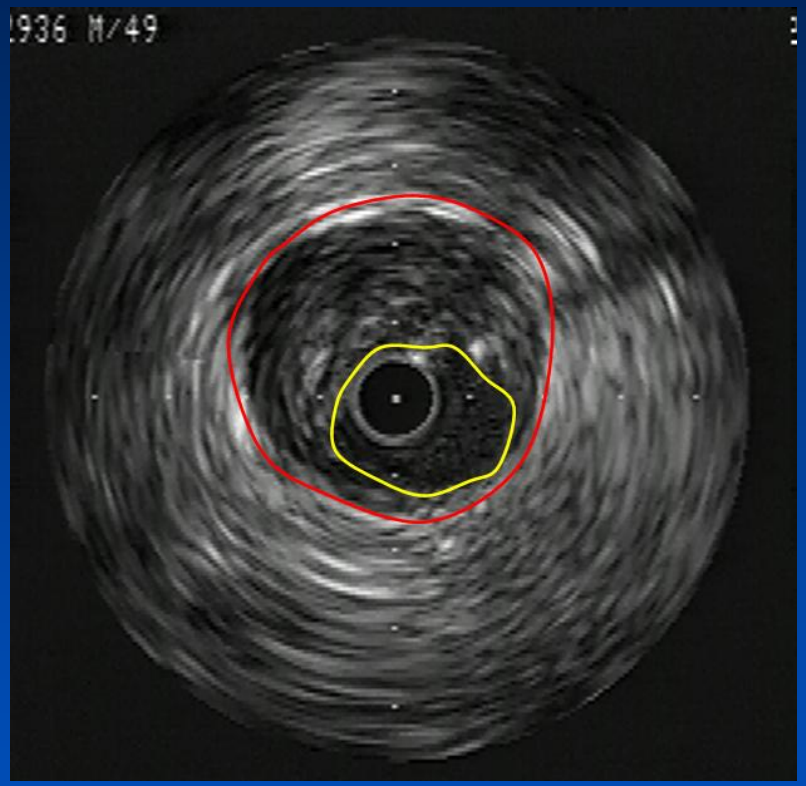
(Costantini et al. TCT 2008)

IVUS guidance is more important in Complex Stenting (LM Intervention) !!

-Angiographic limitations
-Intermediate lesion :
How to decide to treat ?
-How to optimize

Angiographic limitations for assessing LMCA Disease





EEM : 14.04mm^2
Lumen : 4.0mm^2
Area stenosis : 71.5%

Limitation of Angiography at LM Stenting

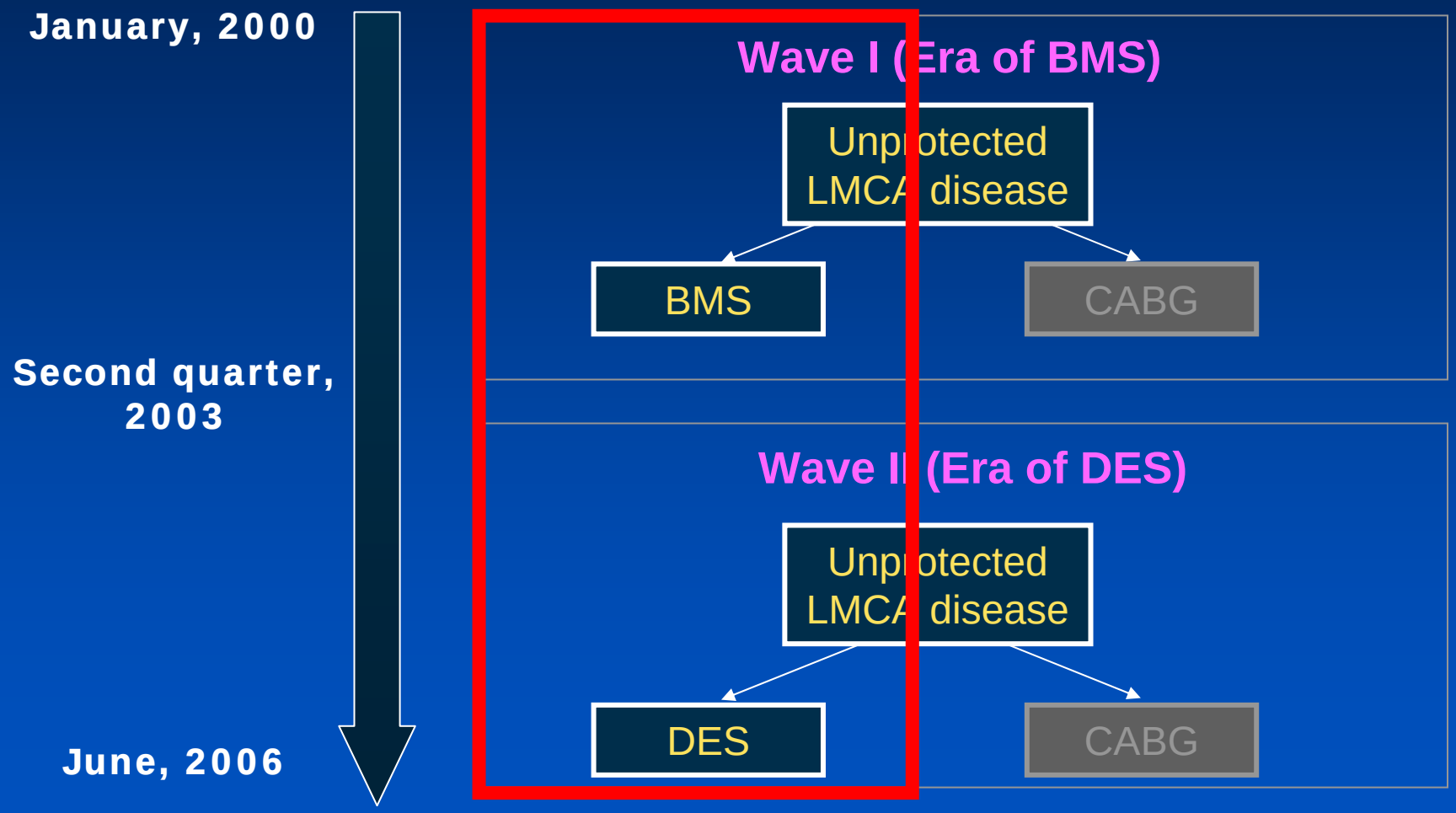
- Angiographic limitation due to has limitations in assessing the lesion morphology and true luminal size of LMCA because of aortic cusp opacification, streaming of contrast agent, short length of vessel, and lack of normal reference segment.

- Therefore, IVUS assessment provides very useful information in detecting significant stenosis, selecting appropriate diameter and length of stent and optimally expanding stent .

MAIN-COMPARE Registry

Stenting (BMS vs. DES) vs. CABG

Revascularization for Unprotected Left ***MAIN*** Coronary Artery Stenosis: *COM*parison of *P*ercutaneous Coronary *A*ngioplasty versus Surgical *RE*vascularization from Multi-Center Registry



12 major academic institutions in Korea

Patients

- In the MAIN-COMPARE registry, patients were divided into: (1) IVUS-guided PCI group and (2) angiography-guided PCI group

- The procedure was considered as IVUS-guided stenting when IVUS examination was performed during the procedure for guidance of optimal stenting.

- Patients who had prior open heart surgery, or presented with cardiogenic shock or MI were excluded.

Circ Cardiovasc Interv 2009

Baseline Clinical Characteristics

Variable	IVUS (n=756)	Angiography (n=219)	*P*
Age (years)	59.7±11.5	65.4±11.1	<0.001
Male gender	522 (69.0)	159 (72.6)	0.31
Diabetes			
Any type	204 (27.0)	72 (32.9)	0.09
Insulin-treated	39 (5.2)	21 (9.6)	0.02
Hypertension	360 (47.6)	120 (54.8)	0.06
Hyperlipidemia	229 (30.3)	59 (26.9)	0.34
Current smoker	191 (25.3)	49 (22.4)	0.38
Family history of CAD	58 (7.7)	11 (5.0)	0.18
Previous myocardial infarction	56 (7.4)	16 (7.3)	0.96
Previous PCI	130 (17.2)	52 (23.7)	0.03
Previous congestive heart failure	6 (0.8)	7 (3.2)	0.006

Baseline Clinical Characteristics

Variable	IVUS (n=756)	Angiography (n=219)	*P*
Cerebrovascular disease	50 (6.6)	22 (10.0)	0.09
Peripheral vascular disease	9 (1.2)	7 (3.2)	0.04
Chronic lung disease	15 (2.0)	4 (1.8)	0.88
Renal failure	14 (1.9)	9 (4.1)	0.05
Atrial fibrillation	9 (1.2)	6 (2.7)	0.10
Unstable angina	466 (61.6)	133 (60.7)	0.81
Ejection fraction (%)	62.7±8.5	59.4±12.2	0.001
Euro SCORE			
Mean	3.4±2.2	4.4±2.4	<0.001
High score ≥ 6	124 (16.4)	71 (32.4)	<0.001

Angiographic Characteristics

Variable	IVUS (n=756)	Angiography (n=219)	*P*
Lesion location			**0.26**
Ostium or shaft	**392 (51.9)**	**104 (47.5)**	
Bifurcation	**364 (48.1)**	**115 (52.5)**	
Extent of diseased vessel			<0.001
LM only	**227 (30.0)**	**31 (14.2)**	
LM plus 1 VD	**184 (24.3)**	**47 (21.5)**	
LM plus 2 VD	**187 (24.7)**	**67 (30.6)**	
LM plus 3 VD	**158 (20.9)**	**74 (33.7)**	
Right coronary artery disease	**239 (31.6)**	**101 (46.1)**	<0.001
Restenotic lesion	**24 (3.2)**	**5 (2.3)**	**0.49**

Procedural Findings

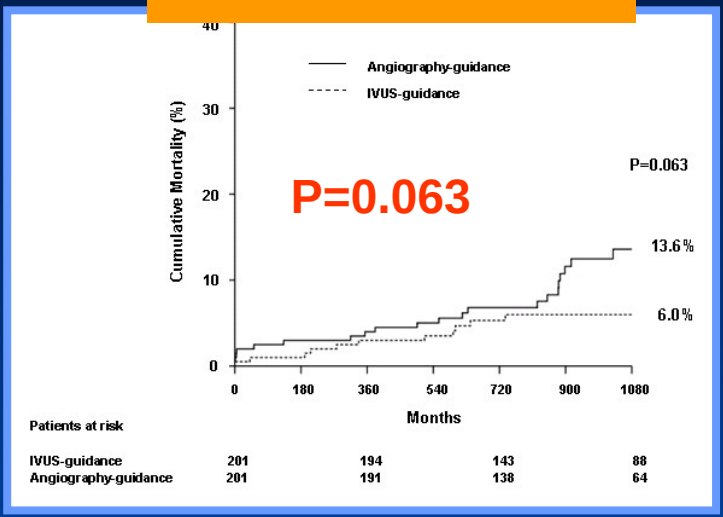
Variable	IVUS (n=756)	Angiography (n=219)	*P*
Use of GP IIb/IIIa inhibitors	47 (6.2)	9 (4.1)	0.24
Use of intra-aortic balloon pump	28 (3.7)	4 (1.8)	0.17
Direct stenting	155 (20.5)	36 (16.4)	0.18
Number of stents at LM site	1.2±0.4	1.2±0.5	0.66
Total stent length at LM site	27.3±20.9	30.1±20.7	0.08
Average stent diameter at LM site	3.6±0.5	3.4±0.4	0.002
Bifurcation treatment			0.95
Single stenting	226 (62.1)	71 (61.7)	
Complex stenting (≥ 2 stents)	138 (37.9)	44 (38.3)	

Propensity Matched-Pairs in Overall PCI Population

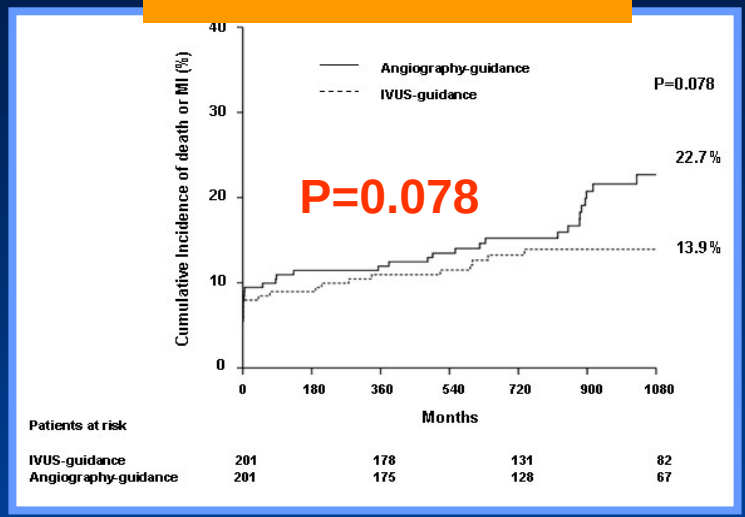
201 pairs in IVUS-guided vs. Angiography-guided

Clinical Outcomes

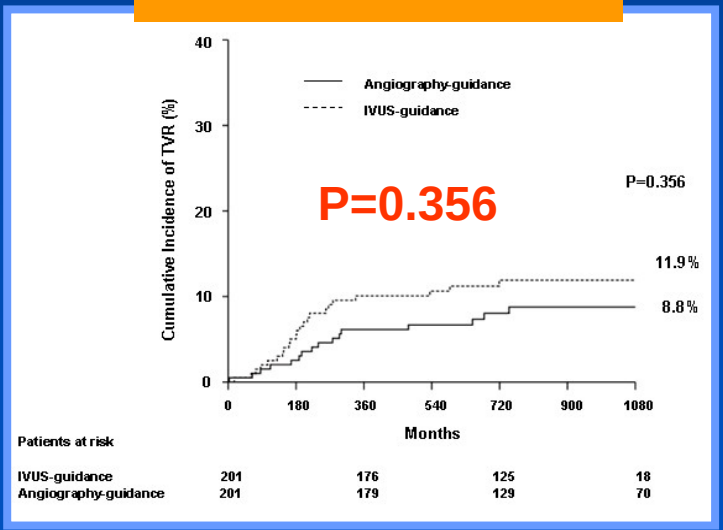
Death



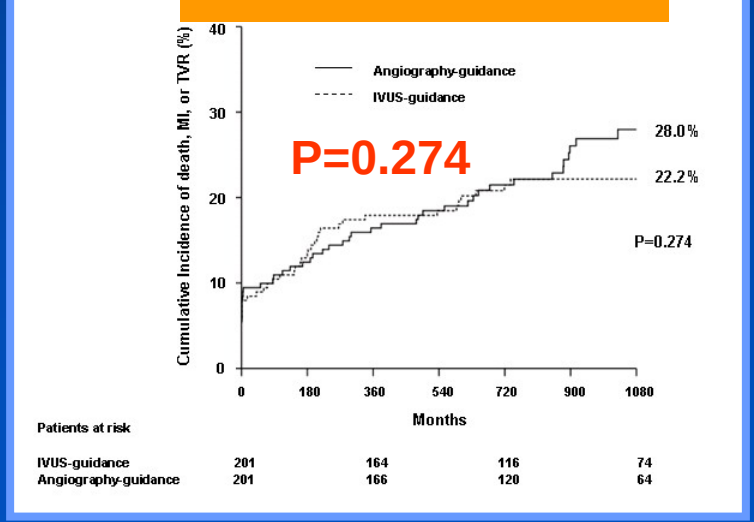
Death or MI



TVR



Death/MI/TVR

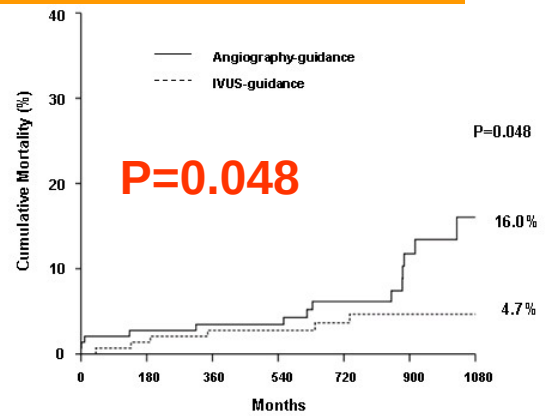


Propensity Matched-Pairs in DES Patients

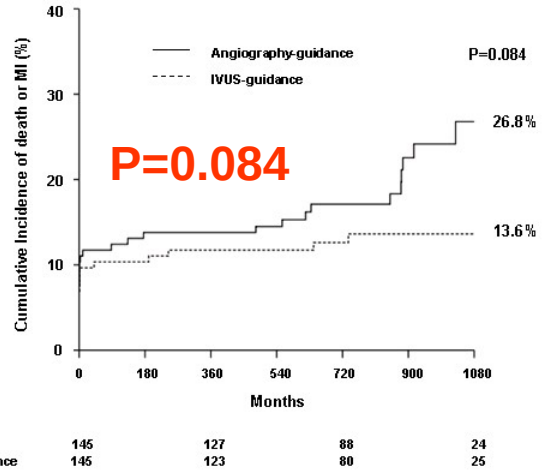
145 pairs in IVUS vs. Angiography

Clinical Outcomes

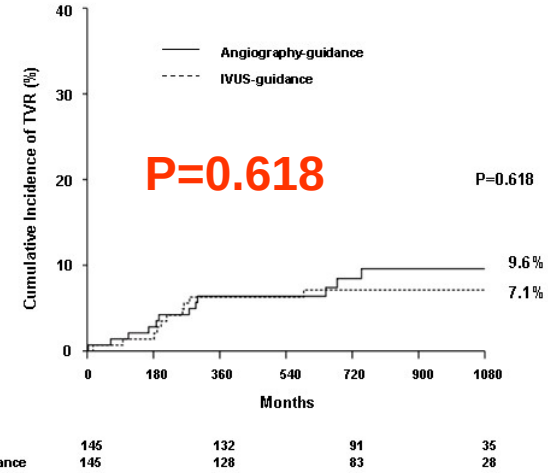
Death



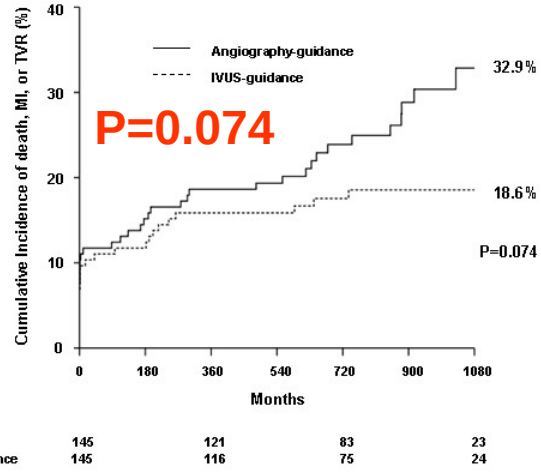
Death or MI



TVR



Death/MI/TVR

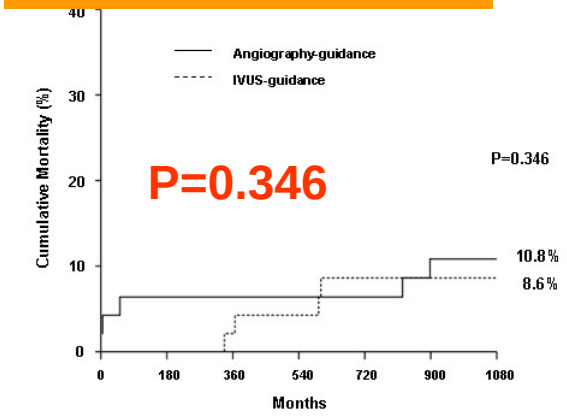


Propensity Matched-Pairs in BMS Patients

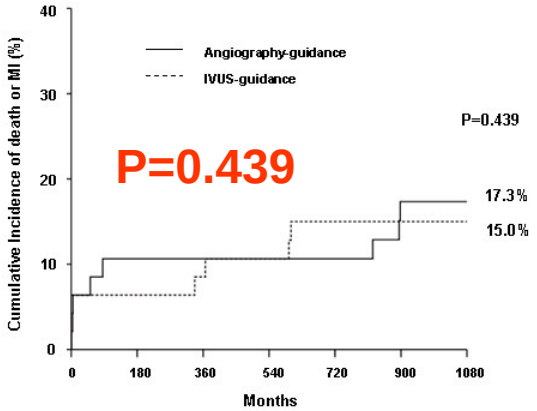
47 pairs in IVUS vs. Angiography

Clinical Outcomes

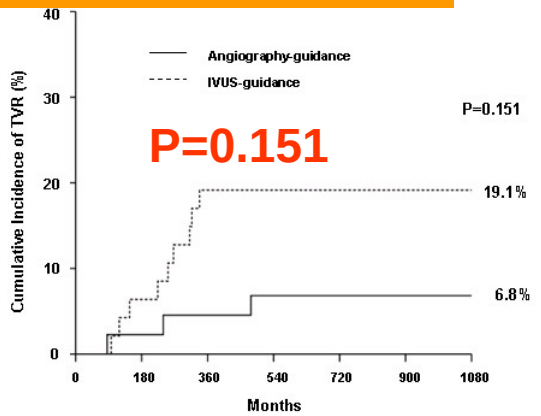
Death



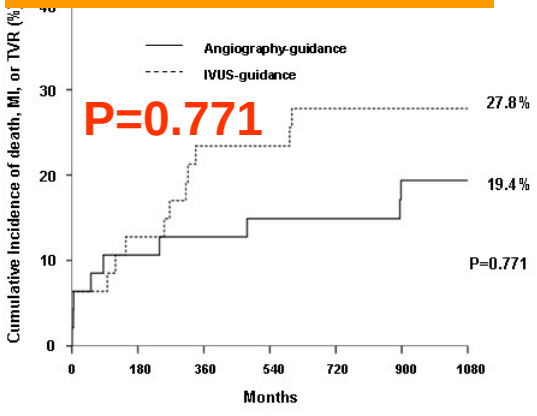
Death or MI



TVR



Death/MI/TVR



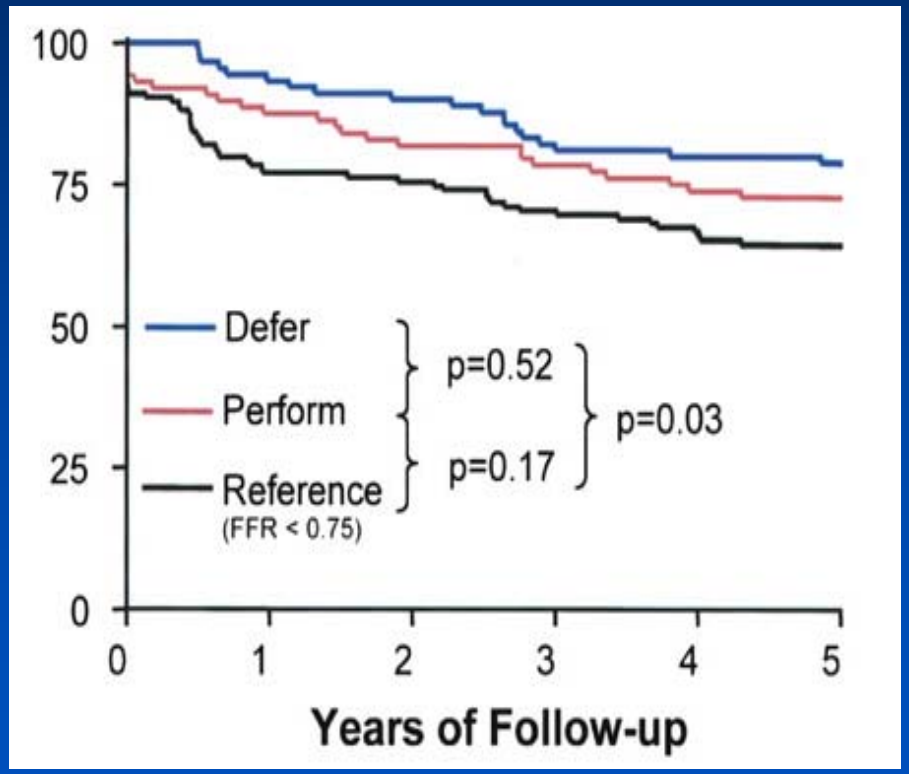
Summary

- IVUS-guided stenting reduced long-term mortality as compared with angiography-guided stenting after DES for unprotected LMCA stenosis.
- The differential survival rate between IVUS- versus angiography-guidance progressively diverged after 1 year in DES placement.
- Therefore, the reduction of the risk of very late stent thrombosis by IVUS-guidance might play a role in improving survival after DES placement.

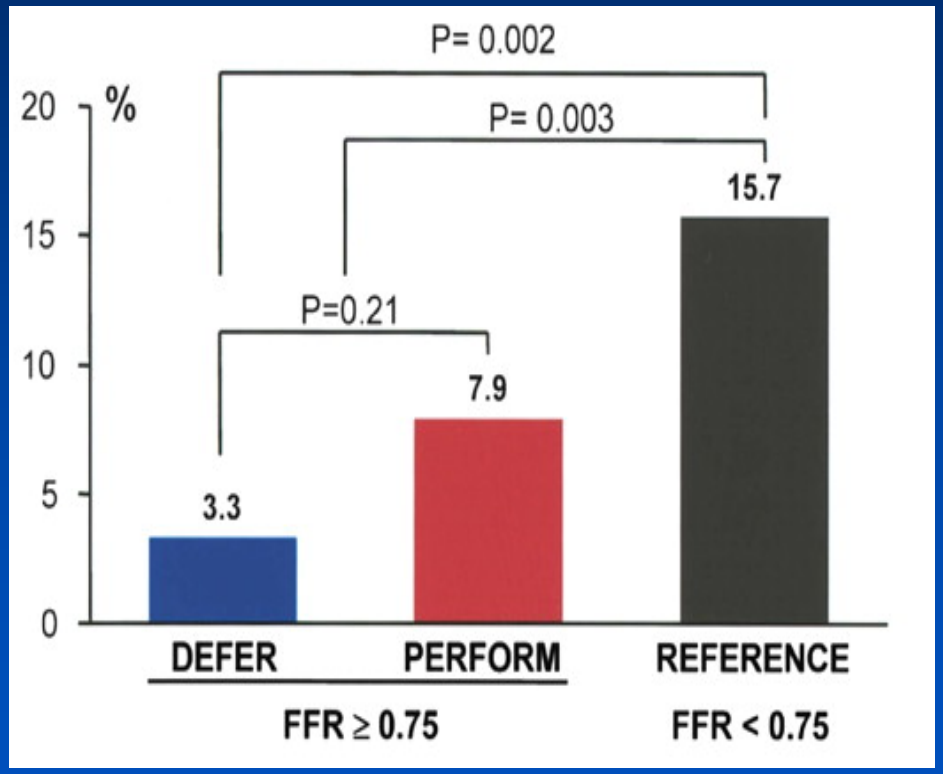
FFR vs. IVUS: very limited data…

DEFER 5 Year Results

Event Free Survival



Cardiac Death and MI



Pijls et al. J Am Coll Cardiol 2007;49:2105-11

FRACTIONAL FLOW RESERVE *versus* ANGIOGRAPHY FOR GUIDING PCI IN PATIENTS WITH MULTIVESSEL CORONARY ARTERY DISEASE

Fractional Flow Reserve *versus* Angiography for Multivessel Evaluation

Nico H.J.Pijls, MD, PhD
Catharina Hospital, Eindhoven
The Netherlands,
on behalf of the ***FAME investigators***

Adverse Events at 1 year

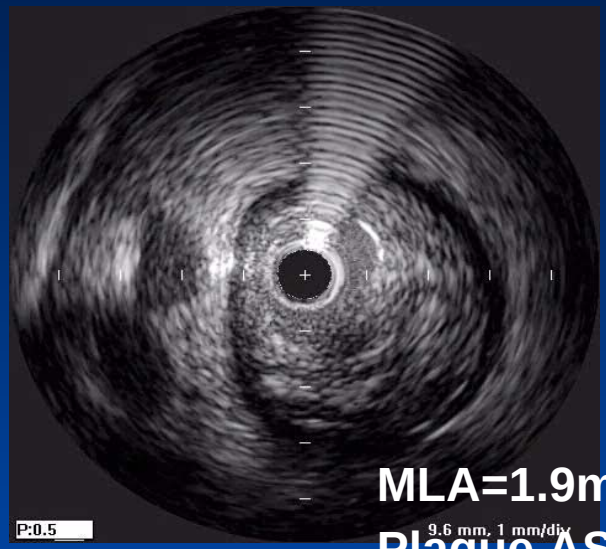
	ANGIO-group N=496	FFR-group N=509	P-value
Events at 1 year, No (%)			
Death, MI, CABG, or repeat-PCI	**91 (18.4)**	**67 (13.2)**	**0.02**
Death	**15 (3.0)**	**9 (1.8)**	0.19
Death or myocardial infarction	**55 (11.1)**	**37 (7.3)**	0.04
CABG or repeat PCI	**47 (9.5)**	**33 (6.5)**	0.08
Total no. of MACE	**113**	**76**	0.02
Myocardial infarction, specified			
All myocardial infarctions	**43 (8.7)**	**29 (5.7)**	0.07
Small periprocedural CK-MB 3-5 x N	**16**	**12**	
Other infarctions (“late or large”)	**27**	**17**	

IVUS vs. FFR Debate…
Conventional Wisdom….

"If you want to treat a lesion aggressively, use IVUS; if you want to treat it minimally, use FFR."

LAD Lesions, Stable Angina

IVUS-guided vs. FFR-guided



MLA=1.9mm²

Plaque AS=85%

FFR=0.94

The Ideal and

Actual is different !!

Thank You !!

summitMD.com