Left Main Disease

Comparisons of PCI against CABG

10 years of advances

	Design	N (PCI/ CABG)	Endpoint	FU, yrs	Key findings
MAIN COMPARE (2008, 2010, 2018)	Multicenter registry	1102/1138	Death; death, Q-wave MI, or stroke; TVR	10	Similar rates of mortality and death, Q-wave MI, or stroke; higher rates of TVR with PCI
LE MANS (2008, 2016)	Multicenter RCT	52/53	Change in LVEF	10	Improvement in ejection fraction only with PCI, comparable rates of death, MI, stroke, or TVR
SYNTAX (2010, 2014)	Multicenter RCT	357/348	Death, MI, stroke, or RR	5	Comparable rates of death, MI, stroke, or repeat revascularization
Boudriot et al. (2011)	Multicenter RCT	100/101	Death, MI, or RR	1	PCI with sirolimus-eluting stent inferior to CABG
PRECOMBAT (2011, 2015, 2020)	Multicenter RCT	300/300	Death, MI, stroke, or ischemia-driven TVR	10	PCI non-inferior to CABG at 1, 5, and 10 year, comparable rates of death, MI, stroke, or ischemia-driven TVR
DELTA (2012)	Multicenter registry	1874/901	Death, MI, or stroke	3.5	Comparable rates of death, MI, or stroke. Higher TVR in PCI
NOBLE (2016)	Multicenter RCT	592/592	Death, MI, stroke, or any repeat revascularization	5	CABG superior to PCI (primary end points 28% in PCI group vs in 18% in CABG group)
EXCEL (2016, 2018)	Multicenter RCT	948/957	Death, MI, or stroke	4	Similar rates of primary endpoint of death, stroke, or MI at 4 years

TABLE 1 Summary of Randomized Clinical Trials of PCI With DES Vs CABG for LMCA Disease

	LEMANS[30,31]	Boudriot et al[32]	SYNTAX-LM[33-35]	PRECOMBAT[36,38]	EXCEL[39,40]	NOBLE[41,42]
Recruitment period	2001-2004	2003-2009	2005-2007	2004-2009	2010-2014	2008-2015
PCI/CABG, n/n	52/53	100/101	357/348	300/300	948/957	592/592
Follow-up, y	10	1	5 10 (for mortality)	10	5	5
Diabetes, %	18	36	25	32	29	15
Bifurcation, %	58	72	61	64	81	81
SYNTAX score, mean	Not reported	23	30	25	21	22
Stent	BMS and DES (35%)	DP-SES	DP-PES	DP-SES	DP-EES	BP-BES and DP-SES (7.7%)
IVUS	Recommend	Infrequent	Infrequent	At discretion, 91%	Recommended, 77%	Recommended, 74%
FFR guidance	Not reported	Not reported	Infrequent	Not reported	Recommended, 9.0%	Recommended
LIMA, %	72	99	97	94	99	96
Off pump, %	1.9	46	Not reported	64	29	16
Primary trial endpoint	Change in LVEF	Cardiac death, MI, or TVR	Death, MI, stroke, or repeat revascularization 10-y all-cause death	Death, MI, stroke, or TVR	Death, MI, or stroke	Death, nonprocedural MI, stroke, or repeat revascularization
Key finding	There was a trend toward higher LVEF at 10 y with PCI.	PCI was inferior to CABG at 1 y.	PCI was noninferior to CABG at 1 and 5 y in terms of death, MI, stroke, or repeat revascularization. No significant difference in 10-y all-cause death between PCI and CABG.	PCI was noninferior to CABG at 1, 5, and 10 y.	PCI was noninferior to CABG at 3 and 5 y.	PCI was inferior to CABG at 5 y.

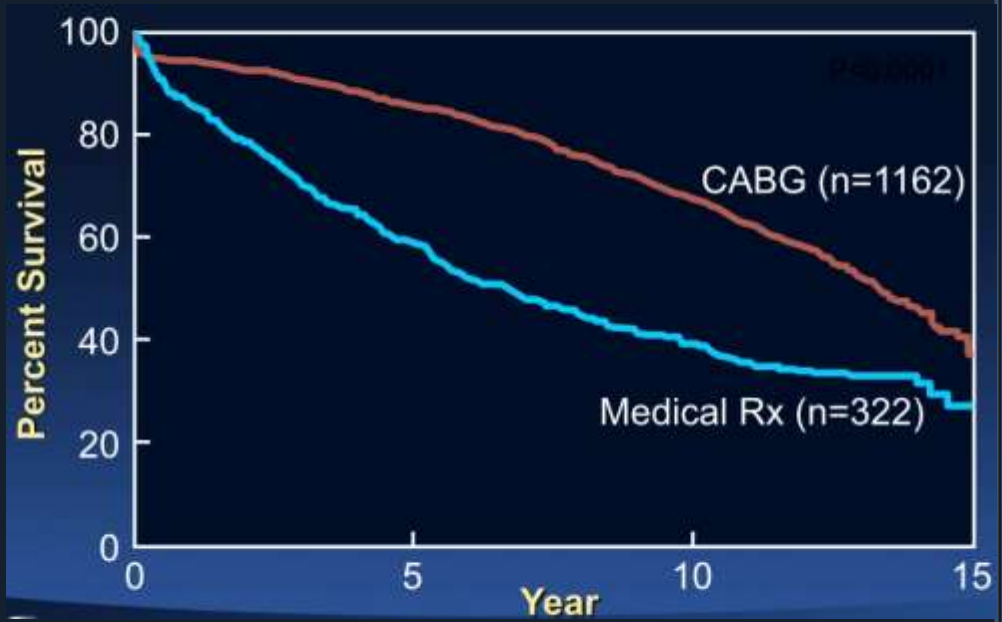
Park et al. JACC: Asia 2022

Data for Left Main
30 years ago

CABG vs. Medical Rx
(150 pts, VA and EU RCT)

Yusuf S et al. Lancet 1994; 344: 563-70

CABG vs. Medical Rx
(1484 pts, CASS Registry)



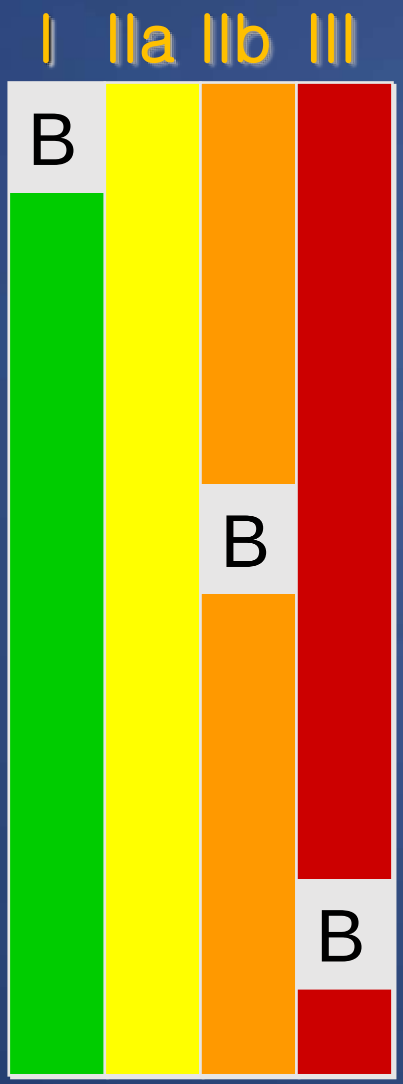
Yusuf S et al. Lancet 1994; 344: 563-70

PTCA was not considered as an Tx option

Guideline Changes for LMCA, 10 Years

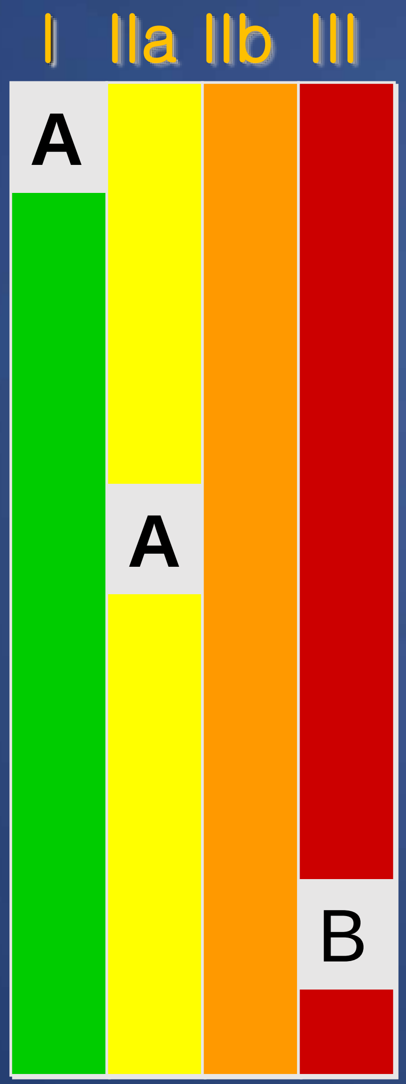
	Class of recommendation	LOE
2005 ACC/AHA/SCAI	**III—**PCI is not recommended in patients with unprotected LMCA disease and eligibility for CABG	C
2005 ESC/EACTS	**IIb—**Stenting for unprotected LMCA disease should only be considered in the absence of other revascularization options	C
. .	. .	
2011/2014 ACC/AHA/AATS/PCNA/SCAI/STS	**IIa**—For SIHD patients when both of the following are present: ● Anatomically low risk of PCI procedural complications & high likelihood of good long-term outcomes (e.g., a low SYNTAX score [≤22], ostial or trunk left main stenosis) Clinical characteristics that predict a significantly increased risk of adverse surgical outcomes (e.g., STS-predicted risk of operative mortality ≥5%)	B
	IIb—For SIHD patients when both of the following are present: ● Anatomically low-to-intermediate risk of PCI procedural complications & intermediate-to-high likelihood of good long-term outcome (e.g., low-intermediate SYNTAX score of <33, bifurcation left main stenosis) ● Clinically increased risk of adverse surgical outcomes	B
	III: HARM—SIHD patients with unfavorable anatomy for PCI & good candidates for CABG	B
2014 ESC/EACTS	**I**—Left main disease with a SYNTAX score ≤ 22. **IIb**—Left main disease with a SYNTAX score 23–32 **III**—Left main disease with a SYNTAX score ≥ 33	B
2018 ESC/EACTS	**I**—Left main disease with a SYNTAX score ≤ 22. **IIa**—Left main disease with a SYNTAX score 23–32	A
	III—Left main disease with a SYNTAX score ≥ 33	B
2021 ACC/AHA	**I**—In patients with SIHD and significant left main stenosis, CABG is recommended to improve survival.	B
	IIa—In selected patients with SIHD and significant left main stenosis for whom PCI can provide equivalent revascularization to that possible with CABG, PCI is reasonable to improve survival	B

Elective PCI for LM Stenosis
ESC/EACTS Guidelines 2014



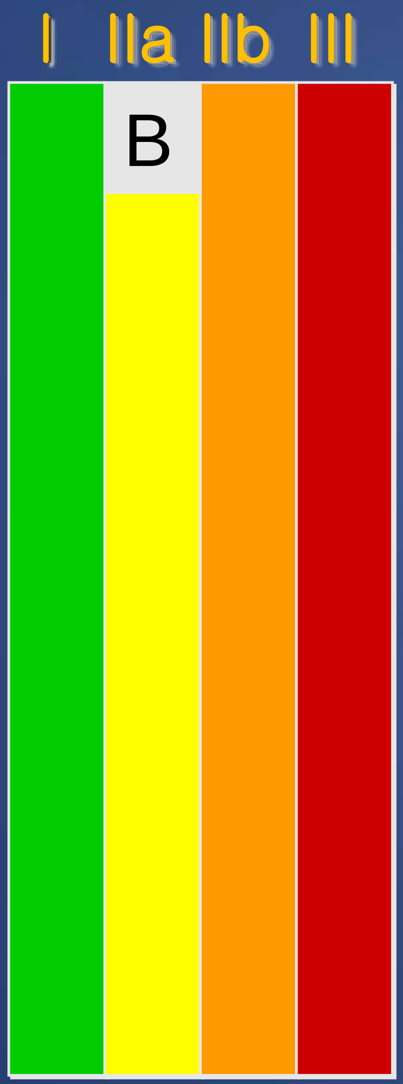
- *LM with*
  - SYNTAX score ≤22
- *LM with*
  - SYNTAX score 23-32
- *LM with*
  - SYNTAX score > 32

Elective PCI for LM Stenosis
ESC/EACTS Guidelines 2018



- *LM with*
  - SYNTAX score ≤22
- *LM with*
  - SYNTAX score 23-32
- *LM with*
  - SYNTAX score > 32

Elective PCI for LM Stenosis
ACC/AHA Guidelines 2021



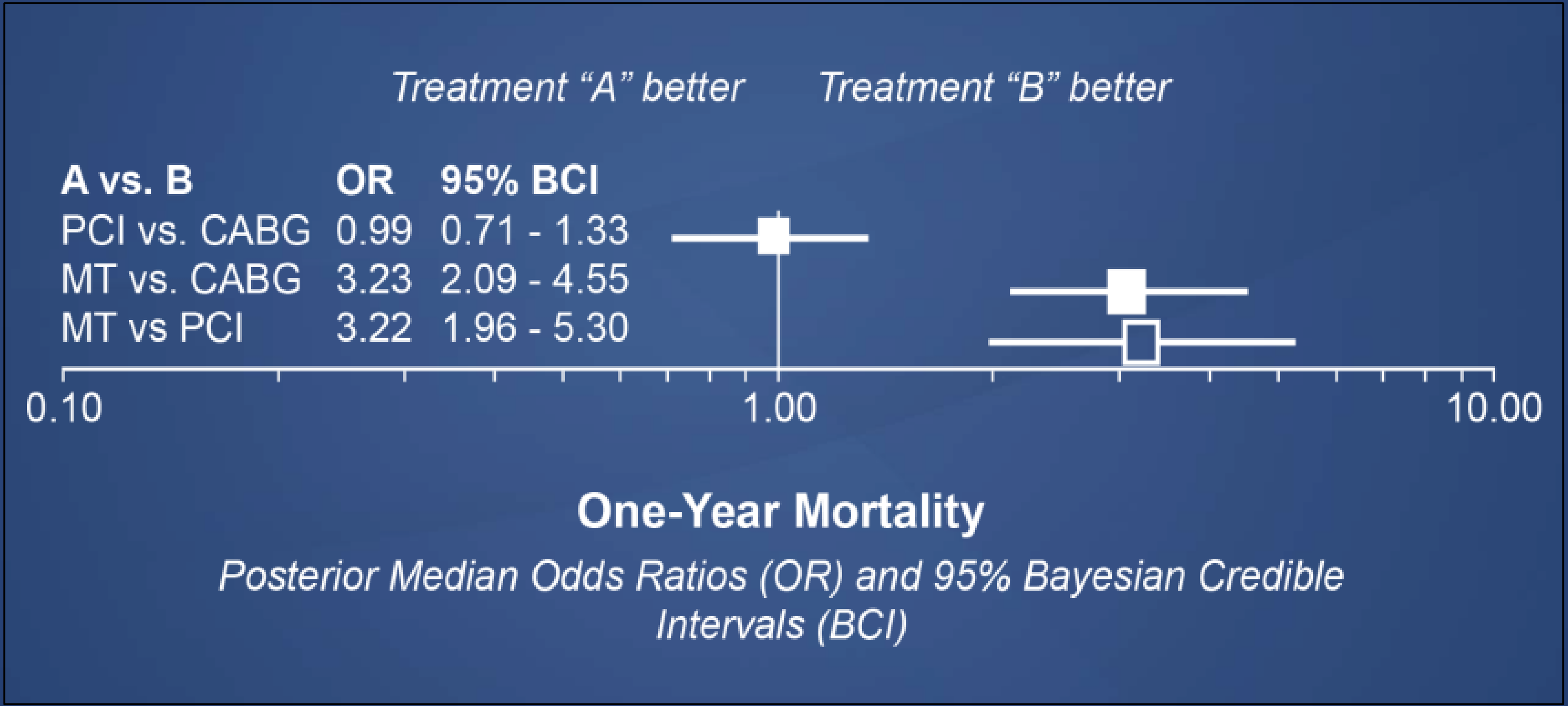
- *PCI and provide equivalent revascularization to that possible with CABG*

  - PCI is reasonable to improve survival

LM : PCI vs. CABG

PCI vs. Medical Treatment

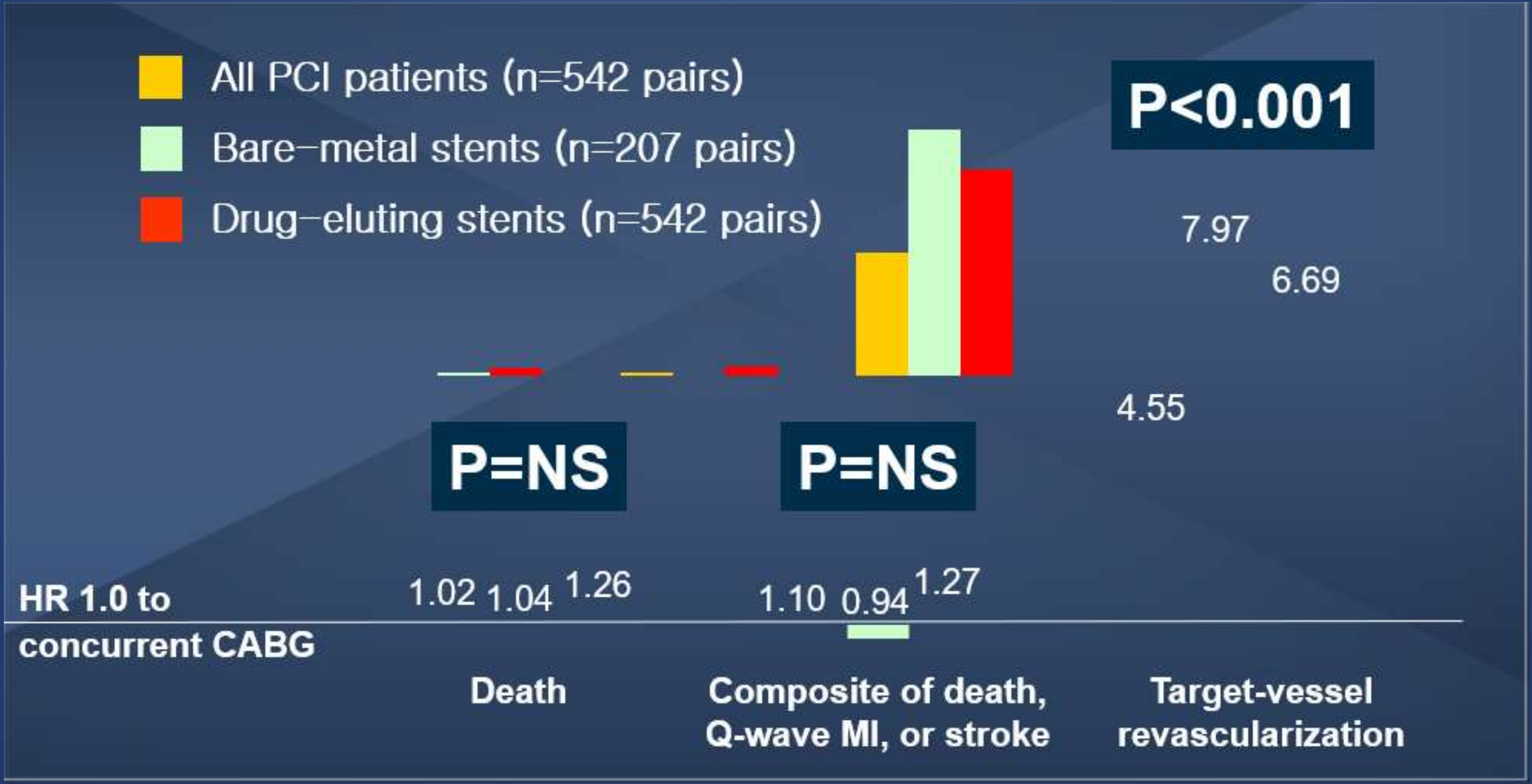
Bayesian network meta-analysis involving
12 (PCI vs. CABG), and 7 (CABG vs. Medication) studies



PCI is superior to medical treatment in the treatment of LM stenosis.

Bittl et al. Circulation, 2013

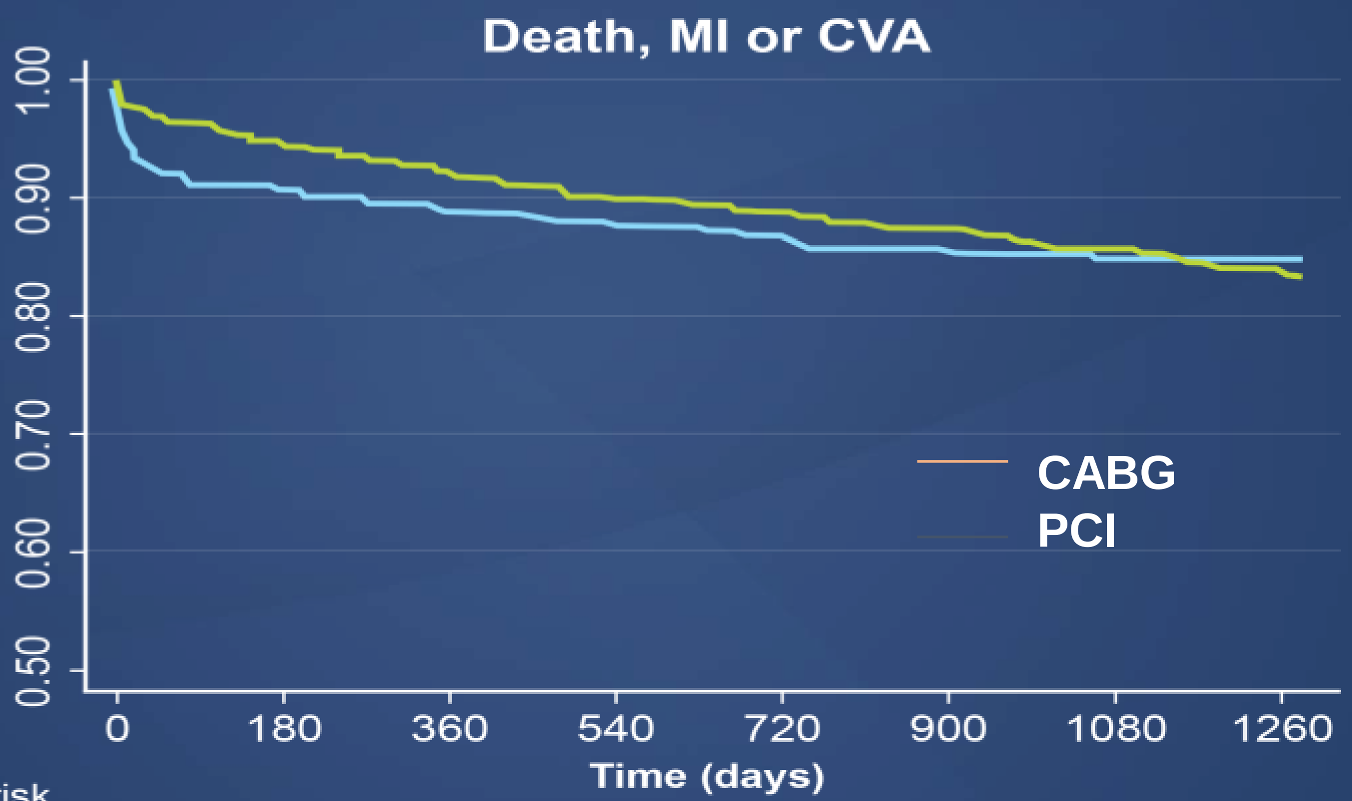
Hazard Ratios for Matched Cohort Outcomes
: Median 5-Year Outcomes



Park et al. *JACC*, 2010

The DELTA Registry
LM revascularization: PCI vs. CABG

Death, MI or CVA in Propensity Score-Matched Groups



Numbers at risk

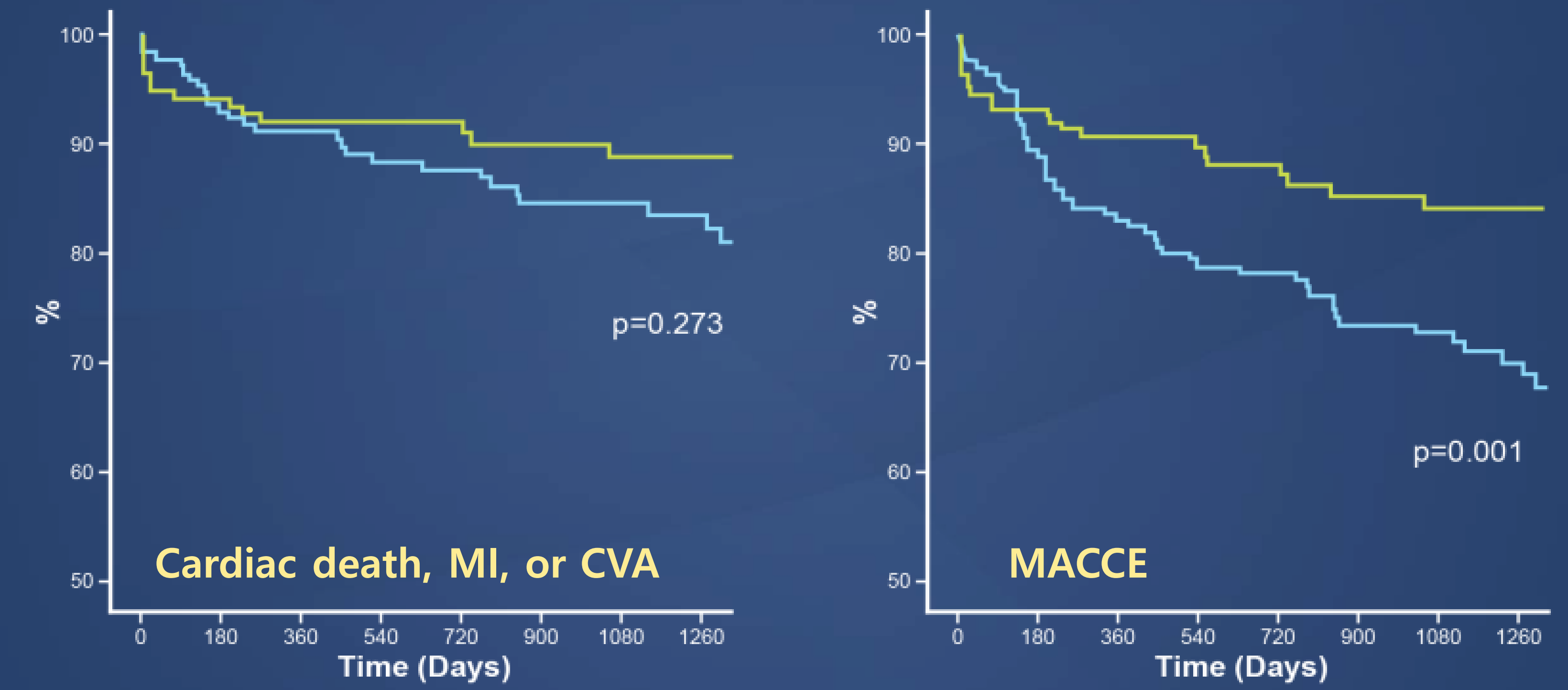
	0	180	360	540	720	900	1080	1260
CABG	599	502	481	454	430	401	382	357
PCI	594	551	527	492	471	448	410	275

Chieffo et al. JACC: Cardiovasc interv 2014

PCI vs. CABG in Females

Female subgroup of *DELTA* registry (PCI, 489; CABG, 328 patients)

The results of propensity score-matched groups



	0	180	360	540	720	900	1080	1260
CABG	174	139	130	114	95	80	74	67
PCI	174	153	141	127	12	106	98	68

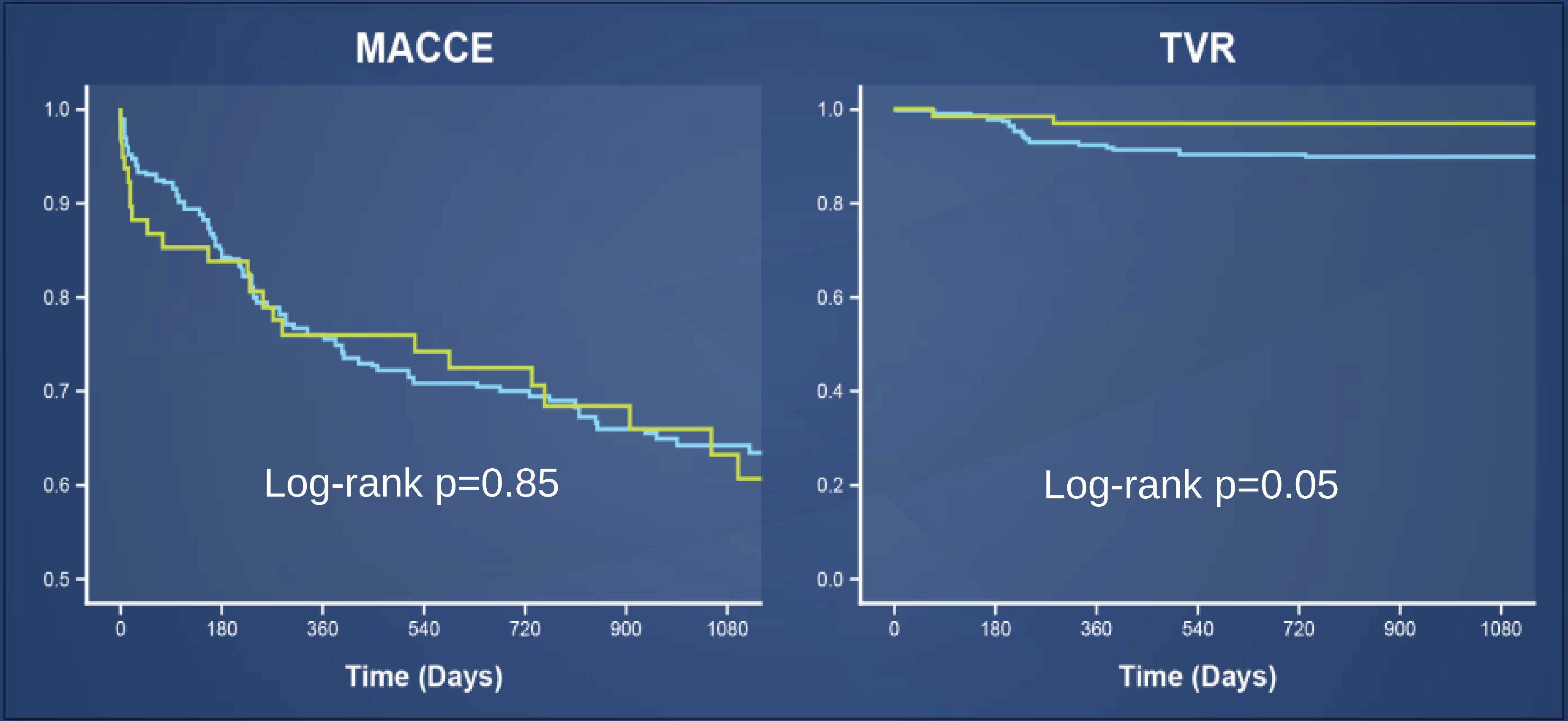
	0	180	360	540	720	900	1080	1260
CABG	174	139	130	114	95	80	74	67
PCI	174	153	141	127	12	106	98	68

There was no difference in the hard endpoints.

Buchanan et al. *Am J Cardiol*, 2014

PCI vs. CABG in Octogenarians

Octogenarian subgroup of *DELTA* registry (PCI, 218; CABG, 86)



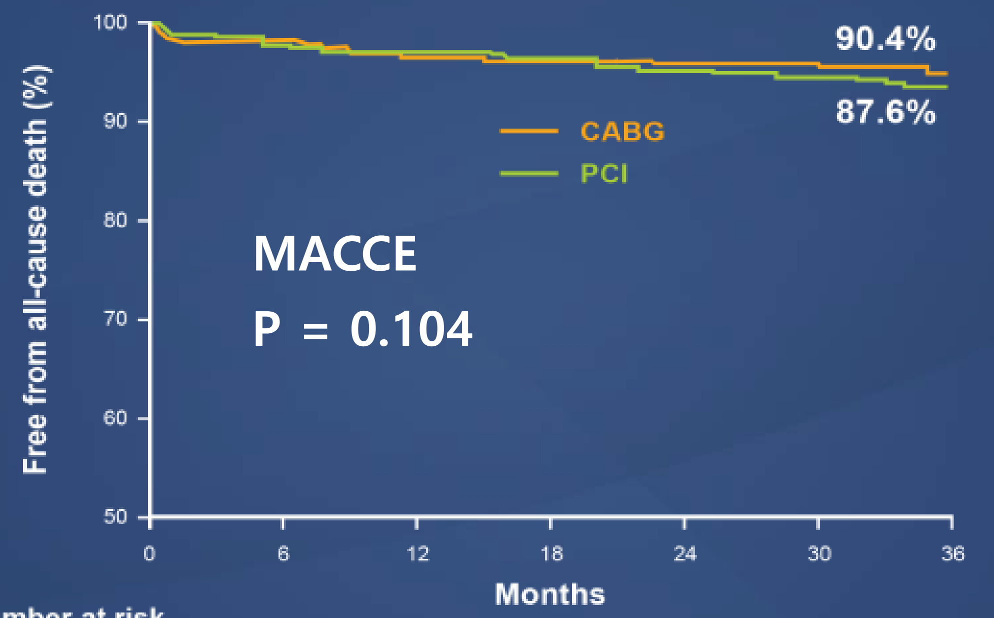
In octogenarians, no difference was observed in the occurrence of the hard endpoint after PCI or CABG.

Conrotto et al. Am J Cardiol, 2014

PCI vs. CABG for Ostial/Midshaft LM stenosis

A subgroup of *DELTA* registry (PCI, 482; CABG, 374 patients)

The results of propensity score-matched groups



Number at risk							
CABG	209	187	180	163	150	142	134
PCI	209	201	194	178	169	156	135

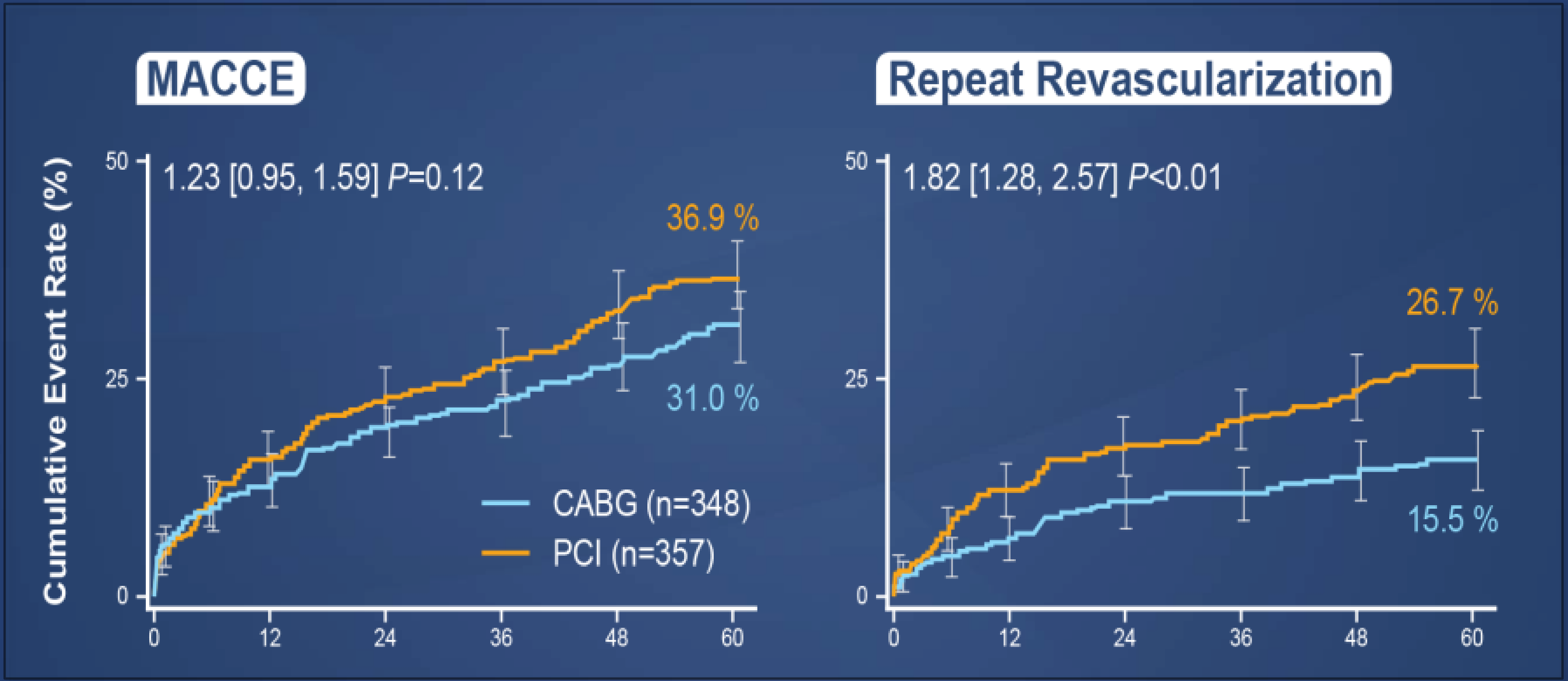
PCI for ostial/midshaft lesions was associated with clinical outcomes comparable to those observed with CABG

Naganuma et al. *JACC Cardiovasc Interv*, 2014

Long-term Outcomes of PCI vs. CABG

5-year outcomes of the LM subgroup of the *SYNTAX* trial

:PCI (N=357) vs. CABG (N=348)



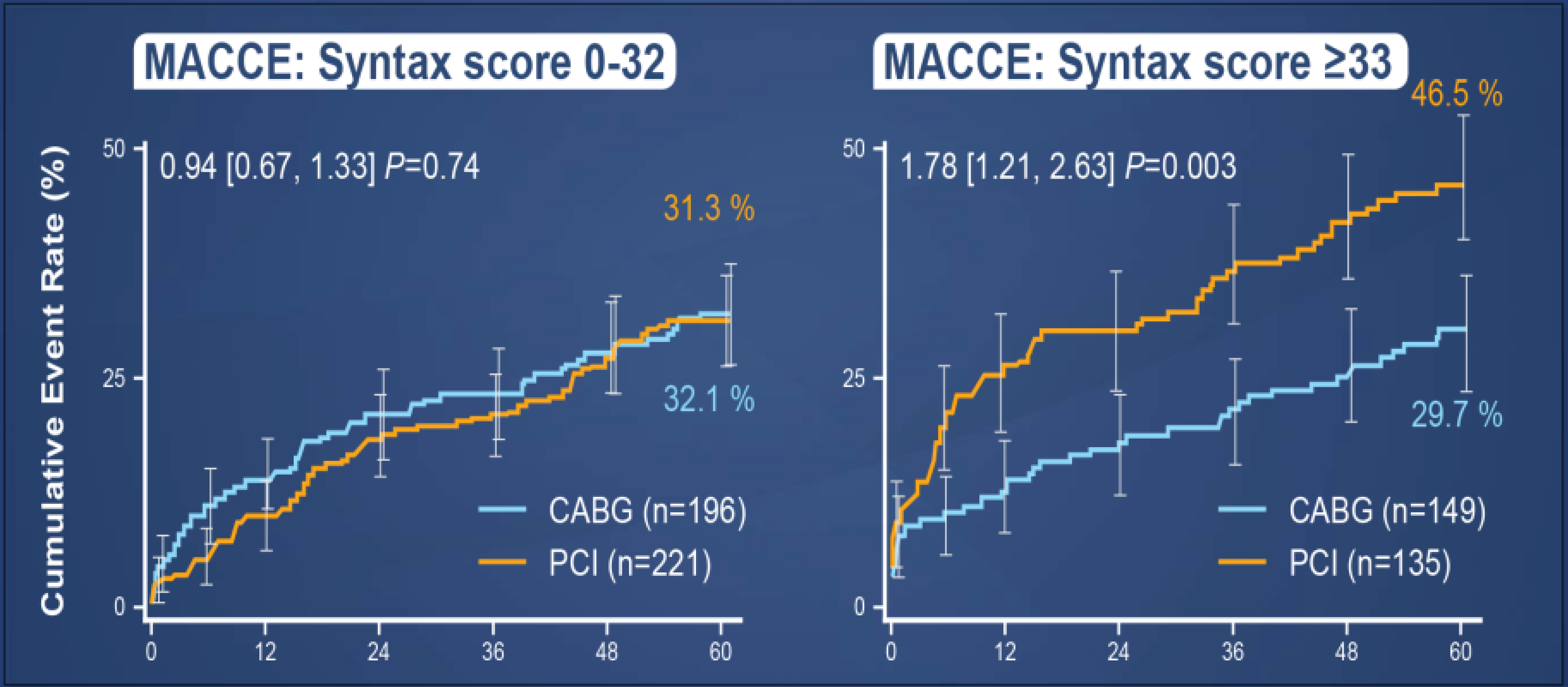
At 5 years, no difference in MACCE was found between PCI and CABG, but PCI was accompanied by a higher rate of repeat revascularization.

Morice et al. Circulation, 2014

Long-term Outcomes of PCI vs. CABG

5-year outcomes of the LM subgroup of the *SYNTAX* trial

:PCI (N=357) vs. CABG (N=348)



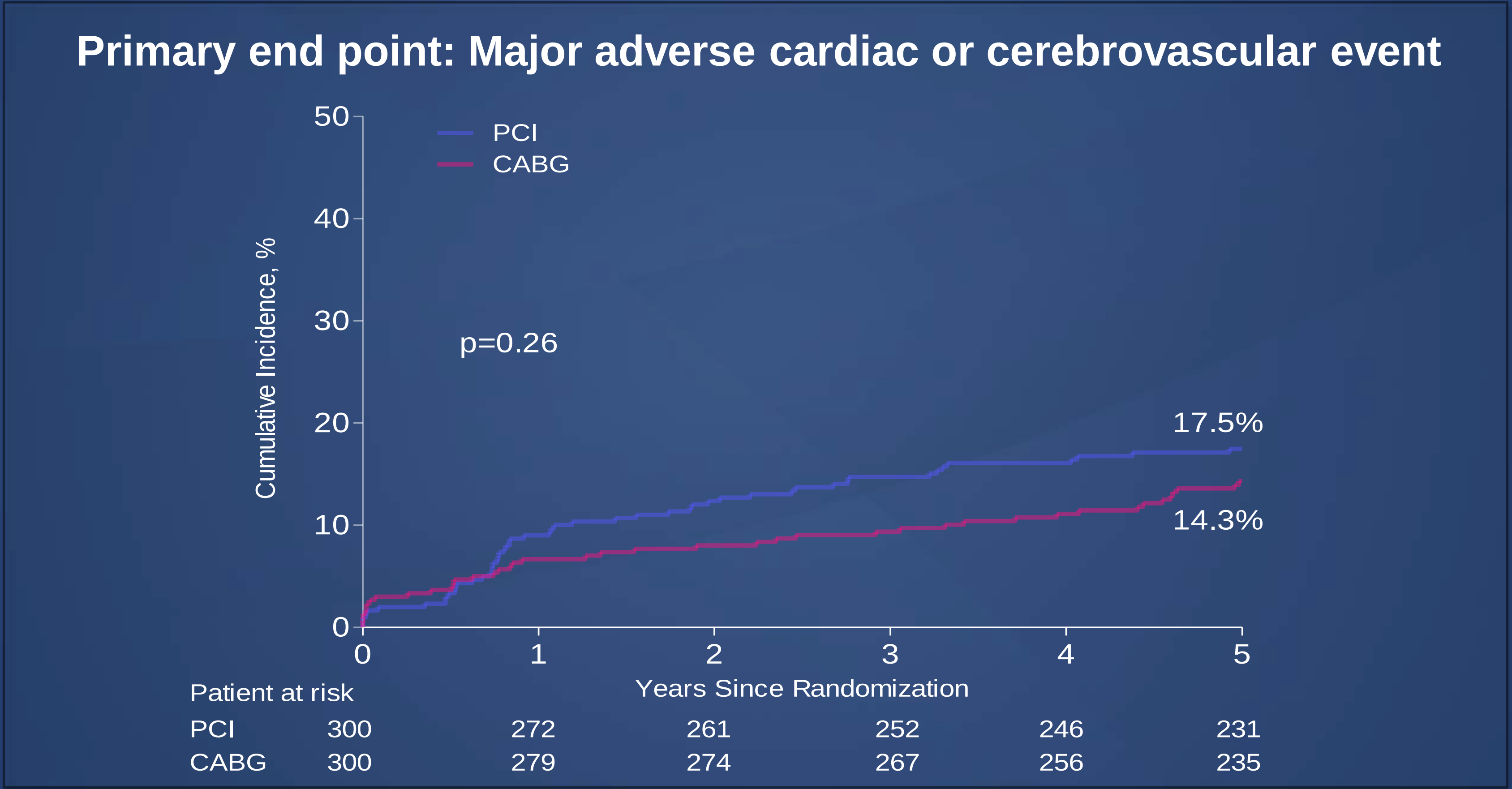
MACCE were similar between arms in patients with low/intermediate SYNTAX scores but significantly increased in patients with high scores.

Morice et al. *Circulation*, 2014

Long-term Outcomes of PCI vs. CABG

5-year outcomes of the randomized PRECOMBAT trial

:PCI (N=300) vs. CABG (N=300)



During 5 year follow-up, no significant difference in the rate of MACCE was observed between the PCI and CABG groups.

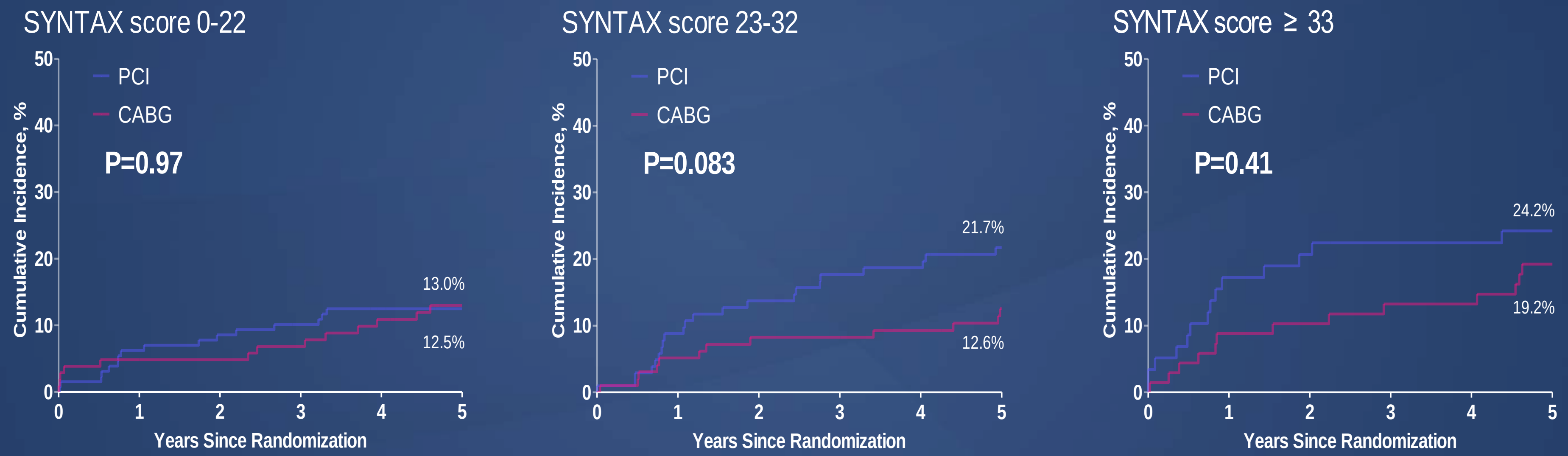
Ahn et al. JACC, 2015

Long-term Outcomes of PCI vs. CABG

5-year outcomes of the randomized PRECOMBAT trial

:PCI (N=300) vs. CABG (N=300)

Primary end point: Major adverse cardiac or cerebrovascular event



Patients at Risk (SYNTAX score 0-22)

	0	1	2	3	4	5
PCI	129	120	117	114	109	103
CABG	104	98	97	93	87	80

Patients at Risk (SYNTAX score 23-32)

	0	1	2	3	4	5
PCI	102	93	87	83	82	76
CABG	97	92	89	88	86	80

Patients at Risk (SYNTAX score ≥ 33)

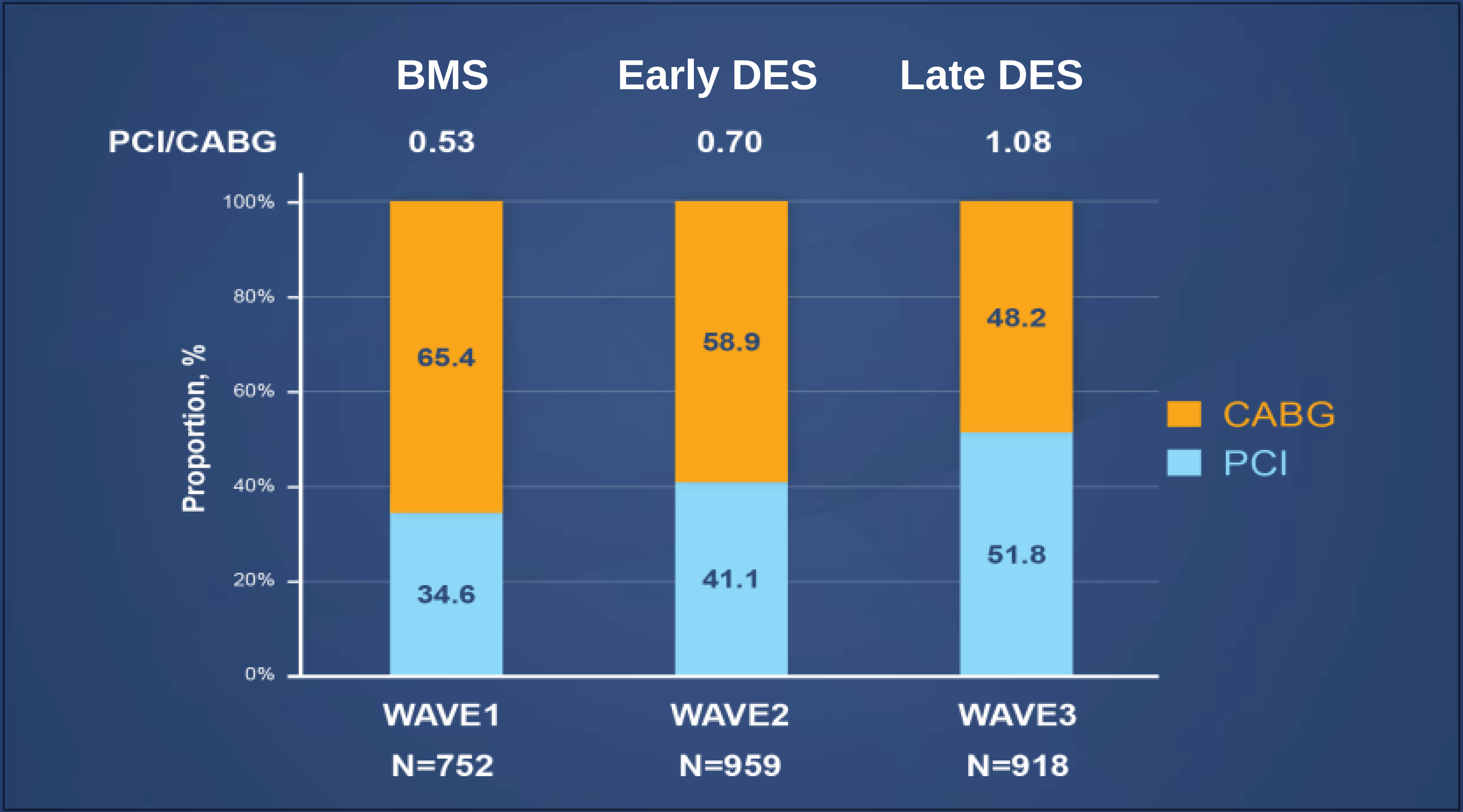
	0	1	2	3	4	5
PCI	58	48	46	44	44	41
CABG	68	62	61	59	58	53

During 5 year follow-up, no significant difference in the rate of MACCE was observed between the PCI and CABG groups.

Ahn et al. JACC, 2015

Temporal Trends

Data From the *Asan Medical Center*-LM Revascularization Registry

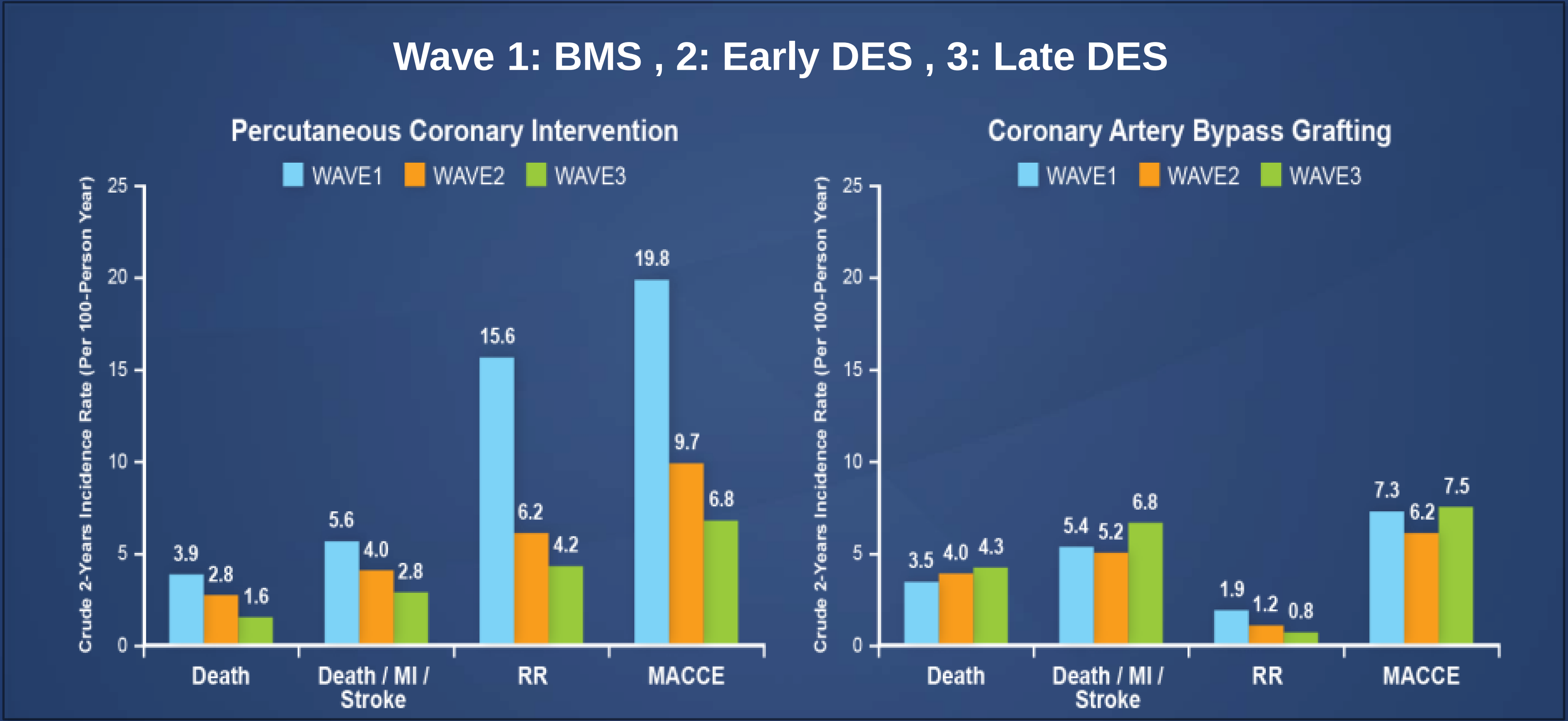


The proportion of PCI is significantly increasing.

Park et al. Circ Cardiovasc Interv, 2015

Temporal Trends

Data From the *Asan Medical Center*-LM Revascularization Registry

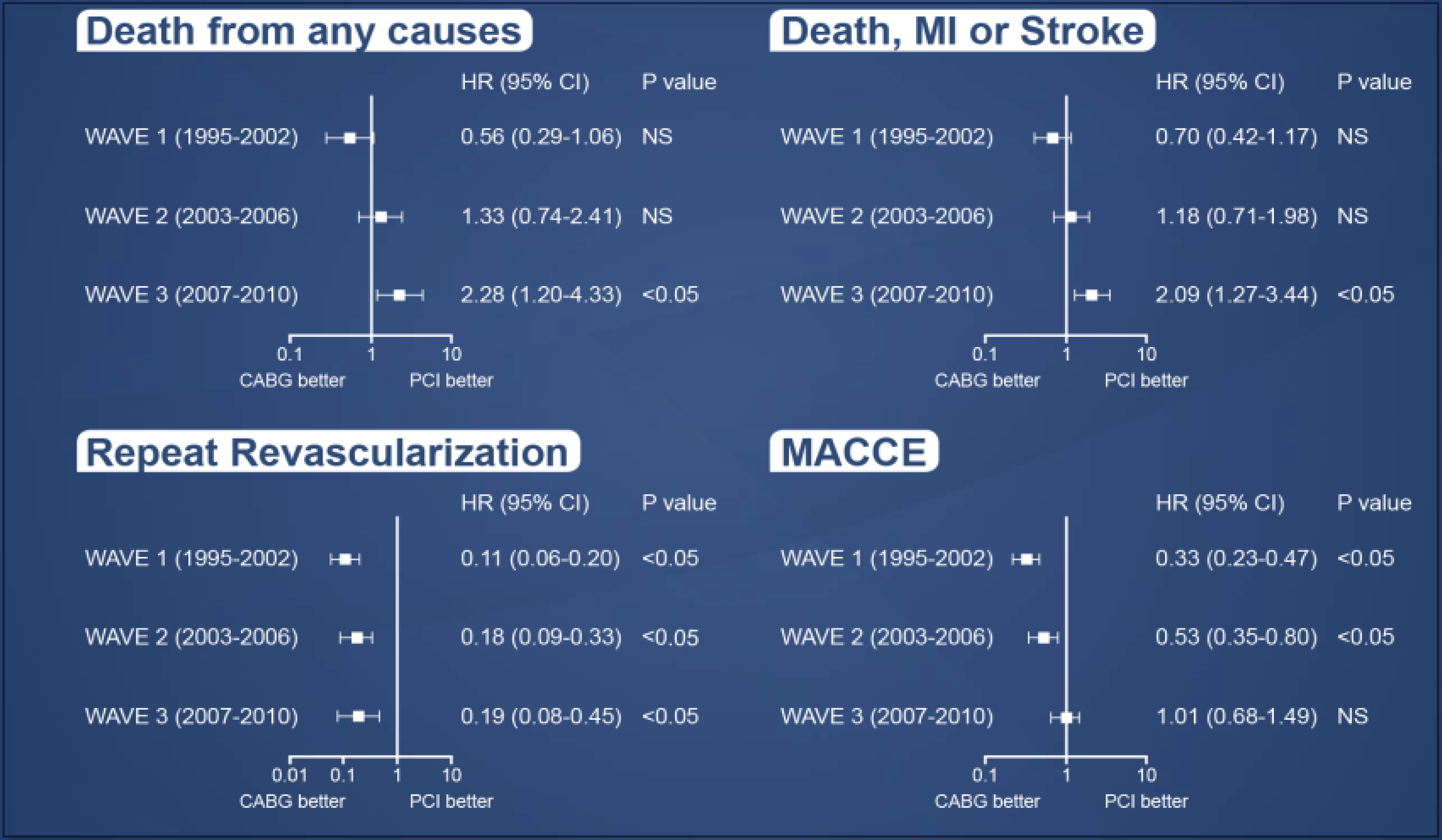


The incidence of adverse events is gradually decreasing with PCI, but the change has been insignificant with CABG.

Park et al. Circ Cardiovasc Interv, 2015

Temporal Trends

Data From the *Asan Medical Center*-LM Revascularization Registry

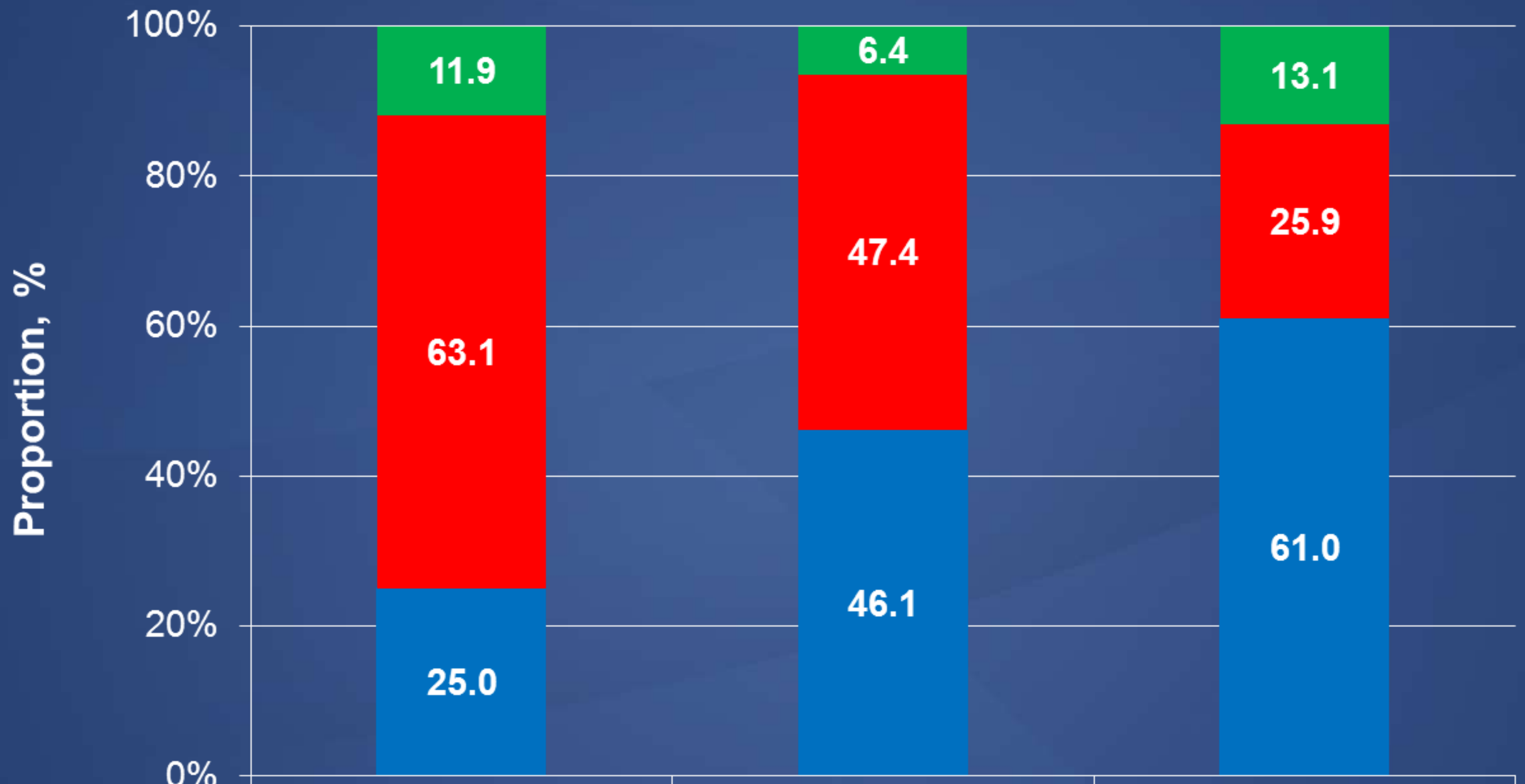


The trend favoring PCI was observed with the coronary stent evolving.

Park et al. Circ Cardiovasc Interv, 2015

IRIS-MAIN registry

50 academic and community hospitals in Asia (*n=5883*)



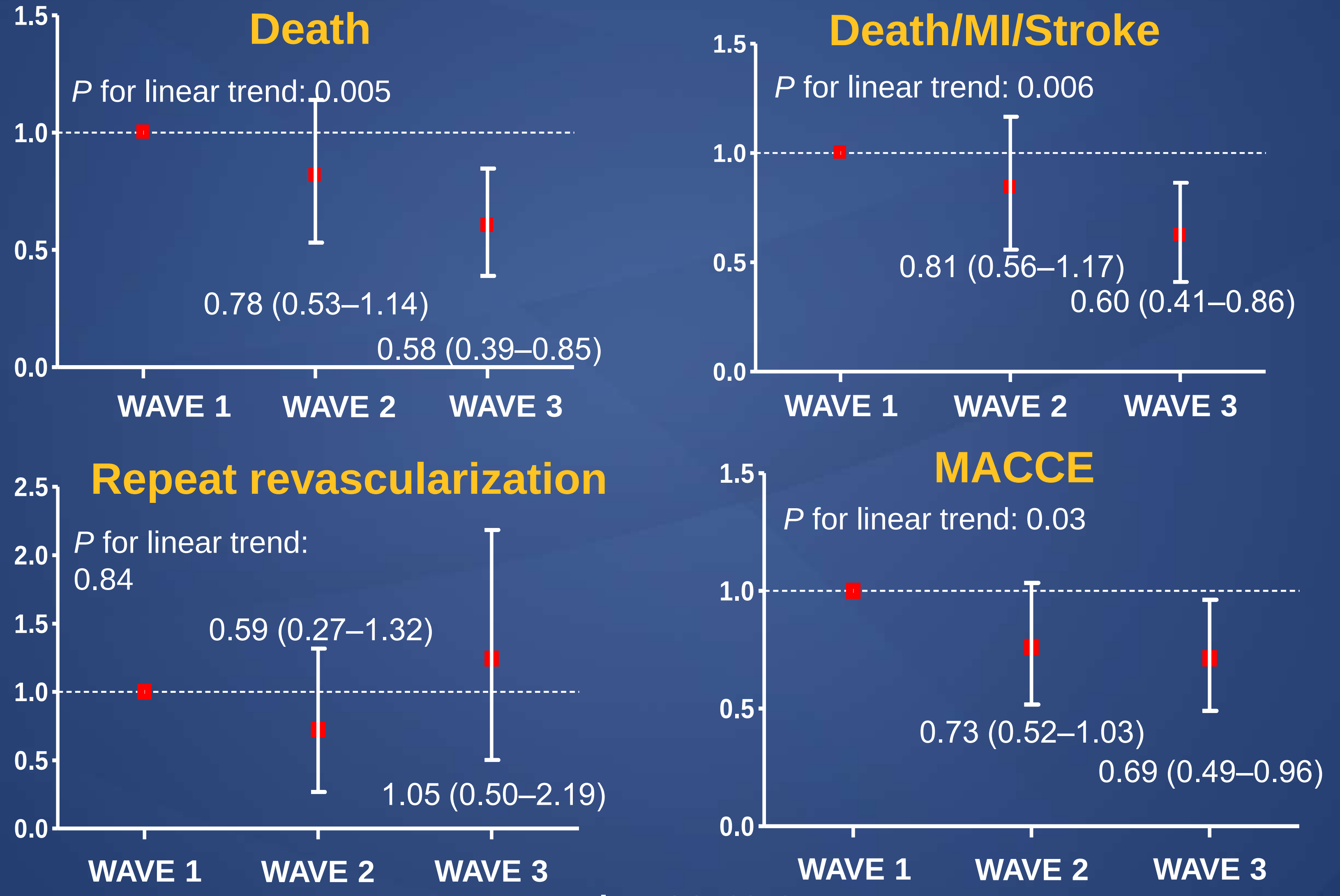
	WAVE1	WAVE2	WAVE3
Medical Tx	129	131	356
CABG	683	964	704
PCI	271	937	1658

Historical time periods: WAVE1: 1995 – 2002, WAVE2: 2003 – 2006, WAVE3: 2007 – 2013

Lee et al. JACC, 2016

IRIS-MAIN registry

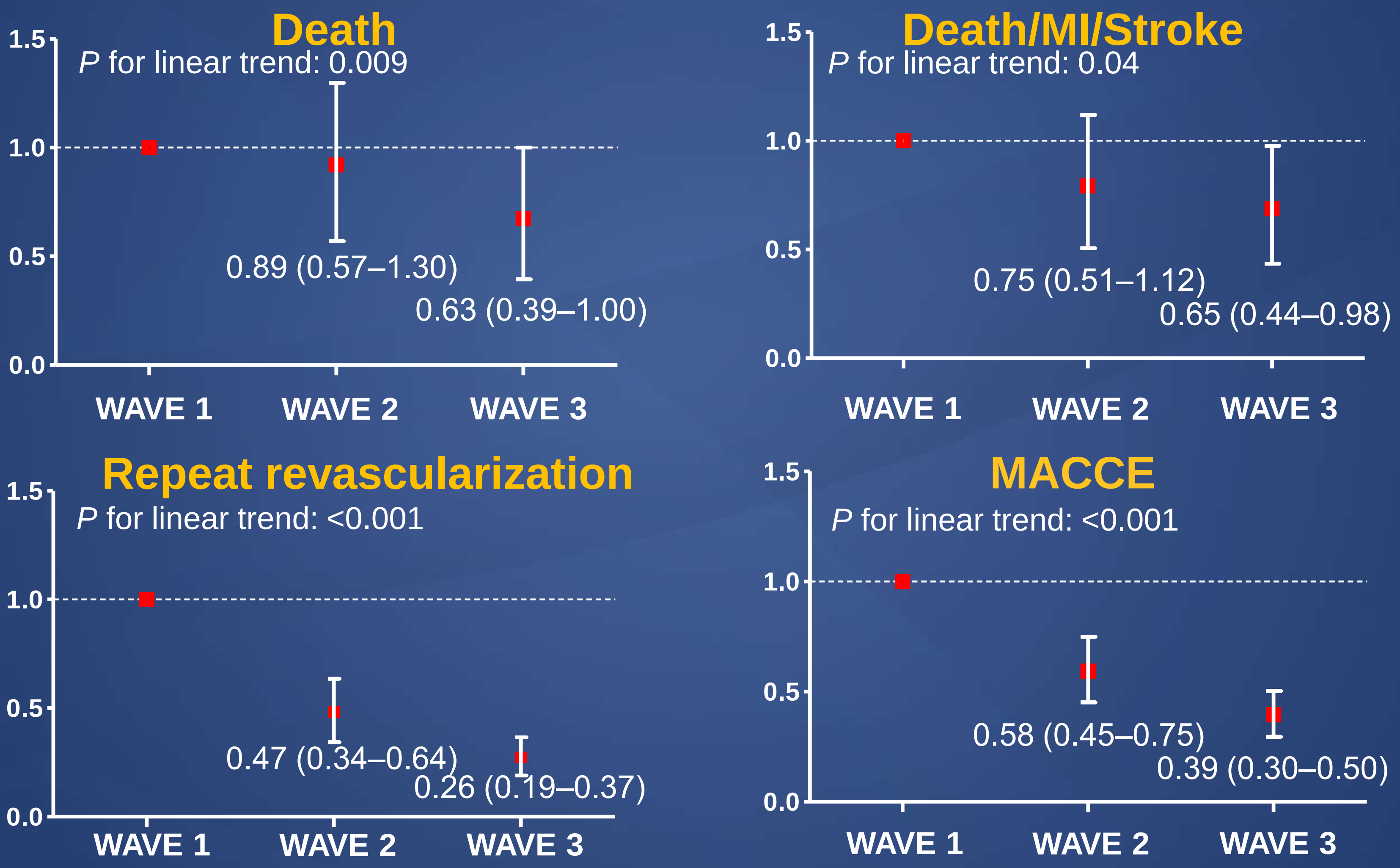
Medical Therapy Group



Lee et al. JACC, 2016

IRIS-MAIN registry

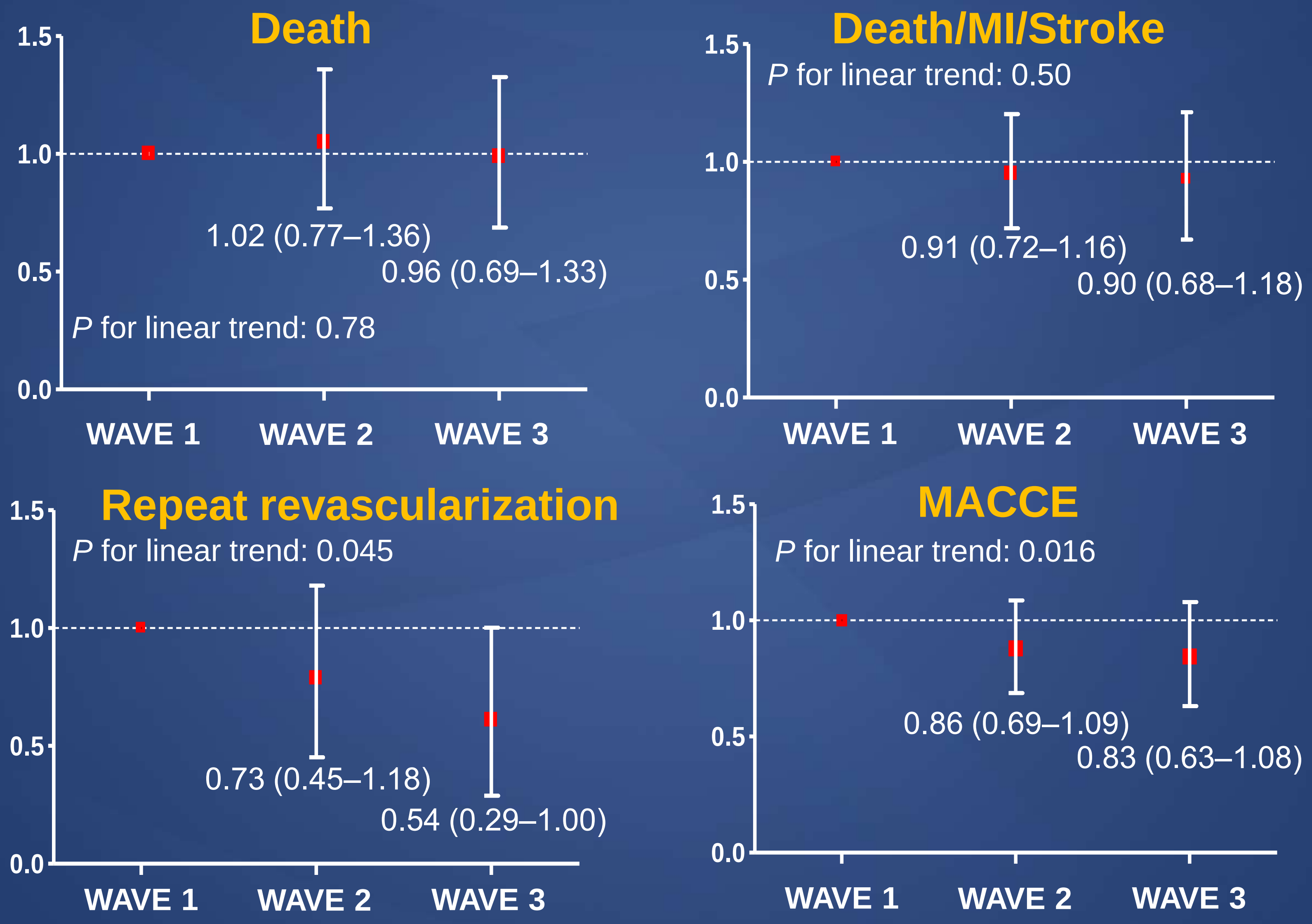
PCI Group



Lee et al. JACC, 2016

IRIS-MAIN registry

CABG Group



Lee et al. JACC, 2016

IRIS-MAIN registry

PCI versus Medical Tx

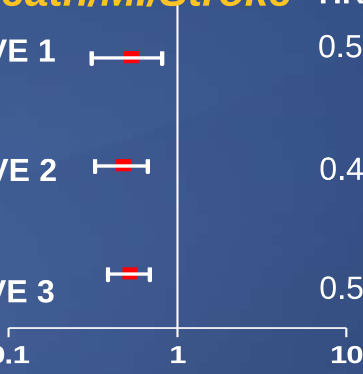
Death

	HR (95% CI)	*P* value
WAVE 1	0.42 (0.24–0.72)	0.002
WAVE 2	0.47 (0.32–0.68)	<0.001
WAVE 3	0.46 (0.34–0.63)	<0.001

PCI better   Medical Tx better

Death/MI/Stroke

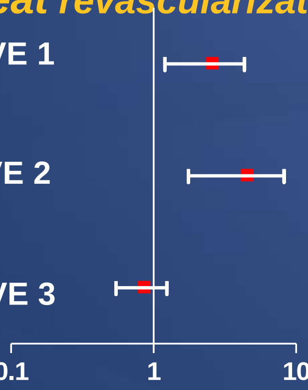
	HR (95% CI)	*P* value
WAVE 1	0.50 (0.31–0.81)	0.003
WAVE 2	0.47 (0.33–0.67)	<0.001
WAVE 3	0.52 (0.39–0.69)	<0.001



PCI better   Medical Tx better

Repeat revascularization

	HR (95% CI)	*P* value
WAVE 1	2.29 (1.20–4.35)	0.01
WAVE 2	3.81 (1.76–8.27)	0.001
WAVE 3	0.82 (0.55–1.24)	0.36



PCI better   Medical Tx better

MACCE

	HR (95% CI)	*P* value
WAVE 1	0.98 (0.67–1.41)	0.90
WAVE 2	0.97 (0.70–1.33)	0.83
WAVE 3	0.64 (0.50–0.81)	0.001

PCI better   Medical Tx better

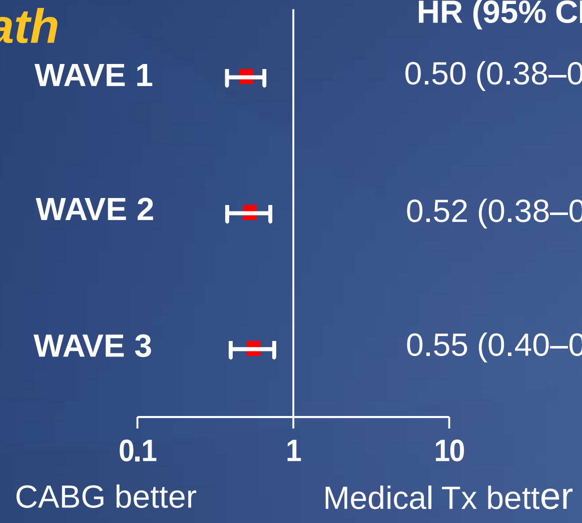
Lee et al. JACC, 2016

IRIS-MAIN registry

CABG versus Medical Tx

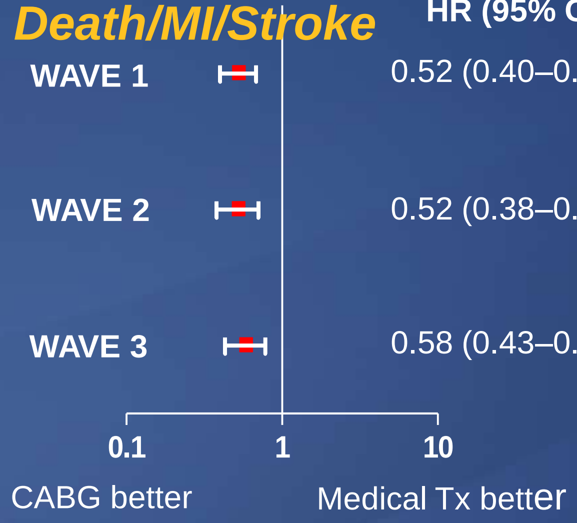
Death

	HR (95% CI)	*P* value
WAVE 1	0.50 (0.38–0.65)	<0.001
WAVE 2	0.52 (0.38–0.71)	<0.001
WAVE 3	0.55 (0.40–0.76)	<0.001



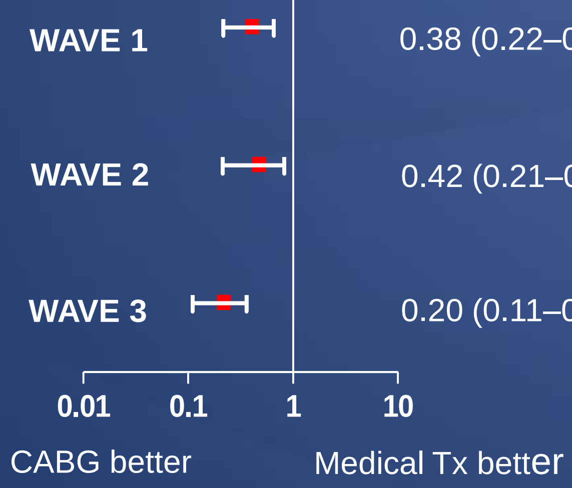
Death/MI/Stroke

	HR (95% CI)	*P* value
WAVE 1	0.52 (0.40–0.68)	<0.001
WAVE 2	0.52 (0.38–0.70)	<0.001
WAVE 3	0.58 (0.43–0.78)	<0.001



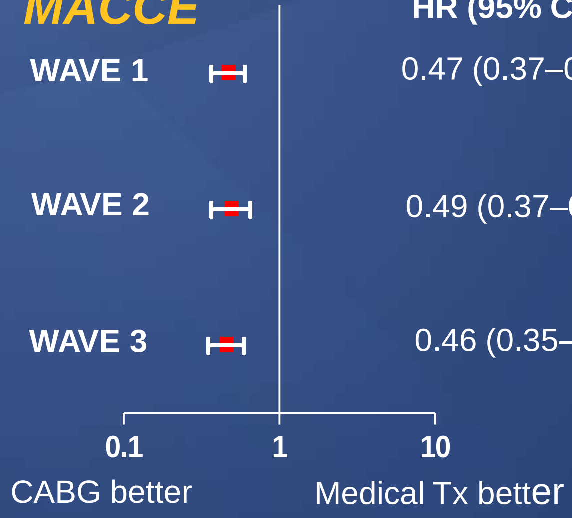
Repeat revascularization

	HR (95% CI)	*P* value
WAVE 1	0.38 (0.22–0.65)	0.001
WAVE 2	0.42 (0.21–0.83)	0.01
WAVE 3	0.20 (0.11–0.36)	<0.001



MACCE

	HR (95% CI)	*P* value
WAVE 1	0.47 (0.37–0.60)	<0.001
WAVE 2	0.49 (0.37–0.65)	<0.001
WAVE 3	0.46 (0.35–0.59)	0.001

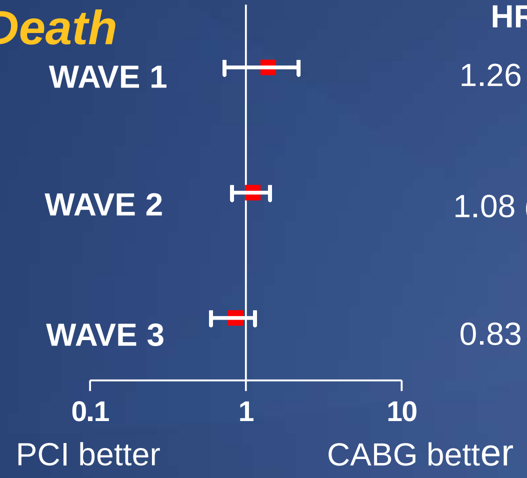


Lee et al. JACC, 2016

IRIS-MAIN registry

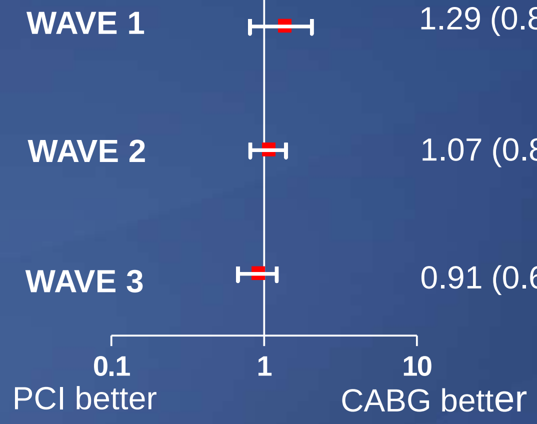
PCI versus CABG

Death



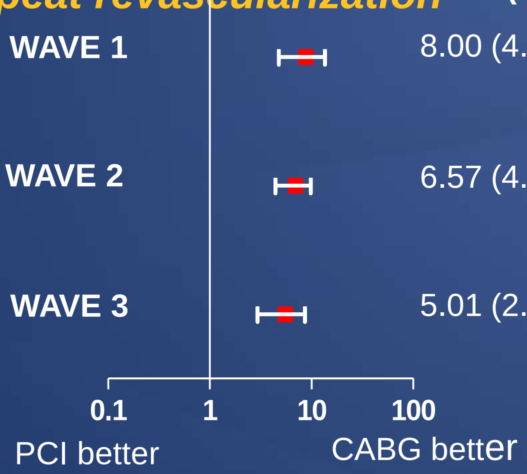
	HR (95% CI)	*P* value
WAVE 1	1.26 (0.73–2.18)	0.40
WAVE 2	1.08 (0.82–1.44)	0.58
WAVE 3	0.83 (0.60–1.15)	0.26

Death/MI/Stroke



	HR (95% CI)	*P* value
WAVE 1	1.29 (0.81–2.06)	0.28
WAVE 2	1.07 (0.82–1.40)	0.64
WAVE 3	0.91 (0.68–1.21)	0.50

Repeat revascularization



	HR (95% CI)	*P* value
WAVE 1	8.00 (4.75–13.49)	<0.001
WAVE 2	6.57 (4.41–9.80)	<0.001
WAVE 3	5.01 (2.93–8.58)	<0.001

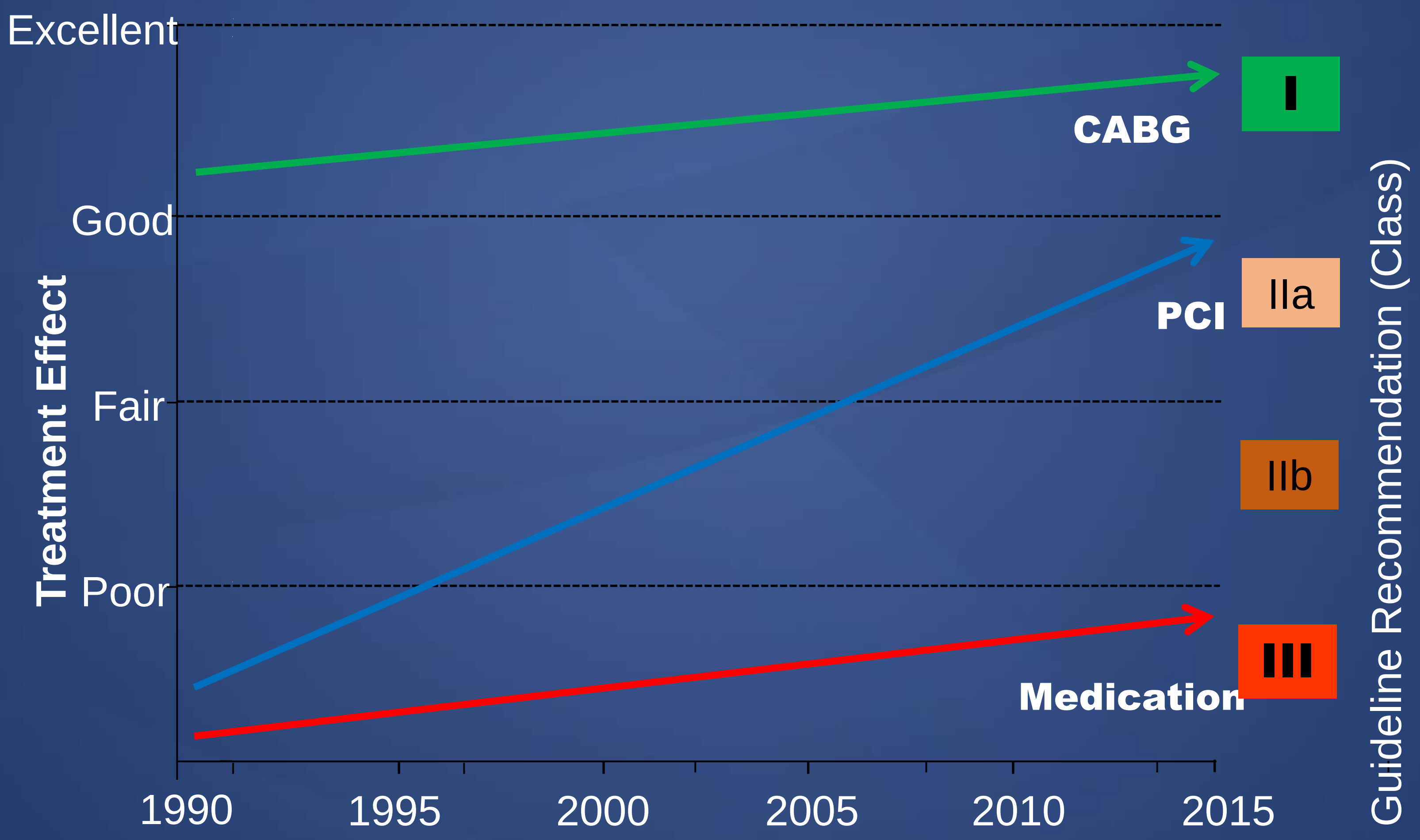
MACCE

	HR (95% CI)	*P* value
WAVE 1	2.97 (2.12–4.18)	<0.001
WAVE 2	2.14 (1.72–2.65)	<0.001
WAVE 3	1.50 (1.17–1.92)	0.001

Lee et al. JACC, 2016

IRIS-MAIN registry

Secular Changes of Treatment Effect
of Each Treatment Stratum



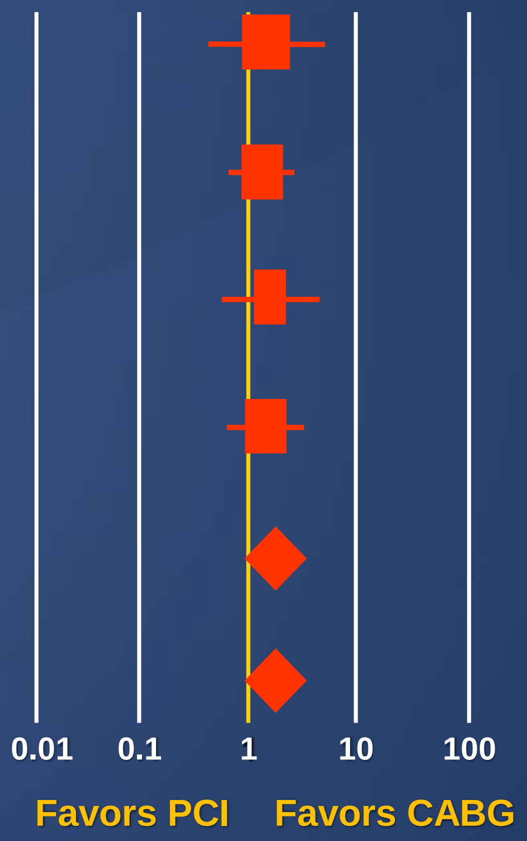
Lee et al. JACC, 2016

PCI vs. CABG for Left Main Disease
Meta-analysis of 4 RCTs, 1,611 Patients

1 Year MACCE

	PCI	CABG	OR (95%CI)	*p*-Value
LEMANS	16/52	13/53	1.37 (0.58-3.23)	0.48
SYNTAX left main	56/355	46/336	1.18 (0.77-1.80)	0.44
Boudriot et al.	19/100	14/101	1.46 (0.69-3.10)	0.33
PRECOMBAT	26/300	20/300	1.33 (0.73-2.44)	0.36
Fixed effects estiamate	14.5% (117/807)	11.8% (93/790)	1.28 (0.95-1.72)	0.11
Random effects estimate			1.28 (0.95-1.72)	0.11

OR (95%CI)



I^2=0%

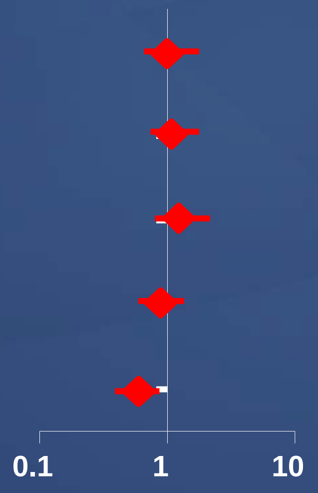
Capodanno et al, JACC, 2011

PCI vs. CABG for Left Main Disease

Meta-analysis of 24 studies, 14,203 patients

According to follow-up duration

Time Point	No. of Studies	Sample Size	Statistics: Odds ratio	Lower limit	Upper limit	p-Value
1 Year	10	4515	0.938	0.659	1.337	0.72
2 Year	9	4953	1.011	0.739	1.383	0.95
3 Year	5	3104	1.149	0.608	1.633	0.44
4 Year	4	5329	0.829	0.619	1.110	0.20
5 Year	5	3360	0.641	0.512	0.803	<0.001



* MACE = death, MI, or stroke

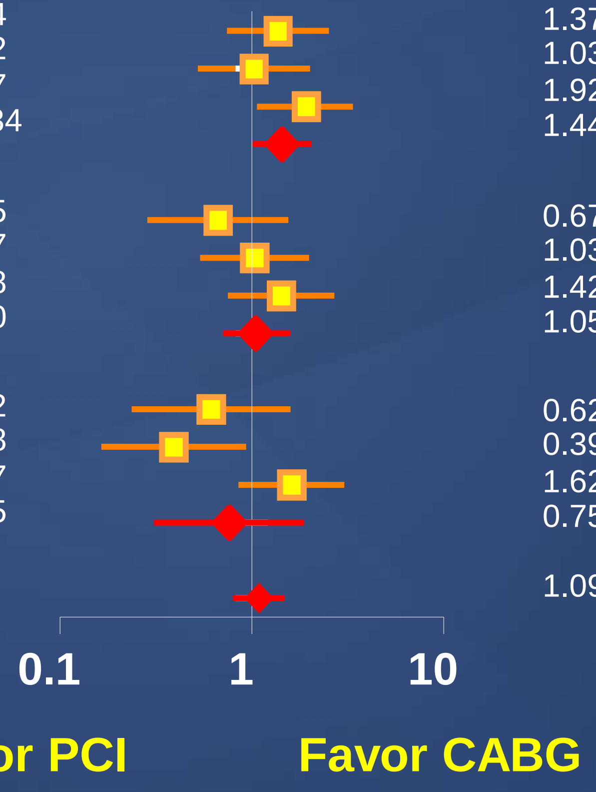
Athappan et al. JACC: Cardiovascular Interventions, 2013

PCI vs. CABG for Left Main Disease

Meta-analysis of 24 studies, 14,203 patients

According to SYNTAX score

		N	95% CI
High	SYNAX	284	1.37 (0.74, 2.53)
	MAIN-COMPARE	662	1.03 (0.52, 2.02)
	CREDO-Kyoto	347	1.92 (1.09, 3.38)
	Overall	1134	1.44 (1.01, 2.06)
Intermediate	SYNAX	195	0.67 (0.29, 1.55)
	MAIN-COMPARE	467	1.03 (0.54, 1.99)
	CREDO-Kyoto	308	1.42 (0.75, 2.70)
	Overall	970	1.05 (0.71, 1.59)
Low	SYNAX	222	0.62 (0.24, 1.59)
	MAIN-COMPARE	438	0.39 (0.17, 0.94)
	CREDO-Kyoto	277	1.62 (0.86, 3.05)
	Overall	935	0.75 (0.31, 1.88)
	Total Overall		1.09 (0.80, 1.48)



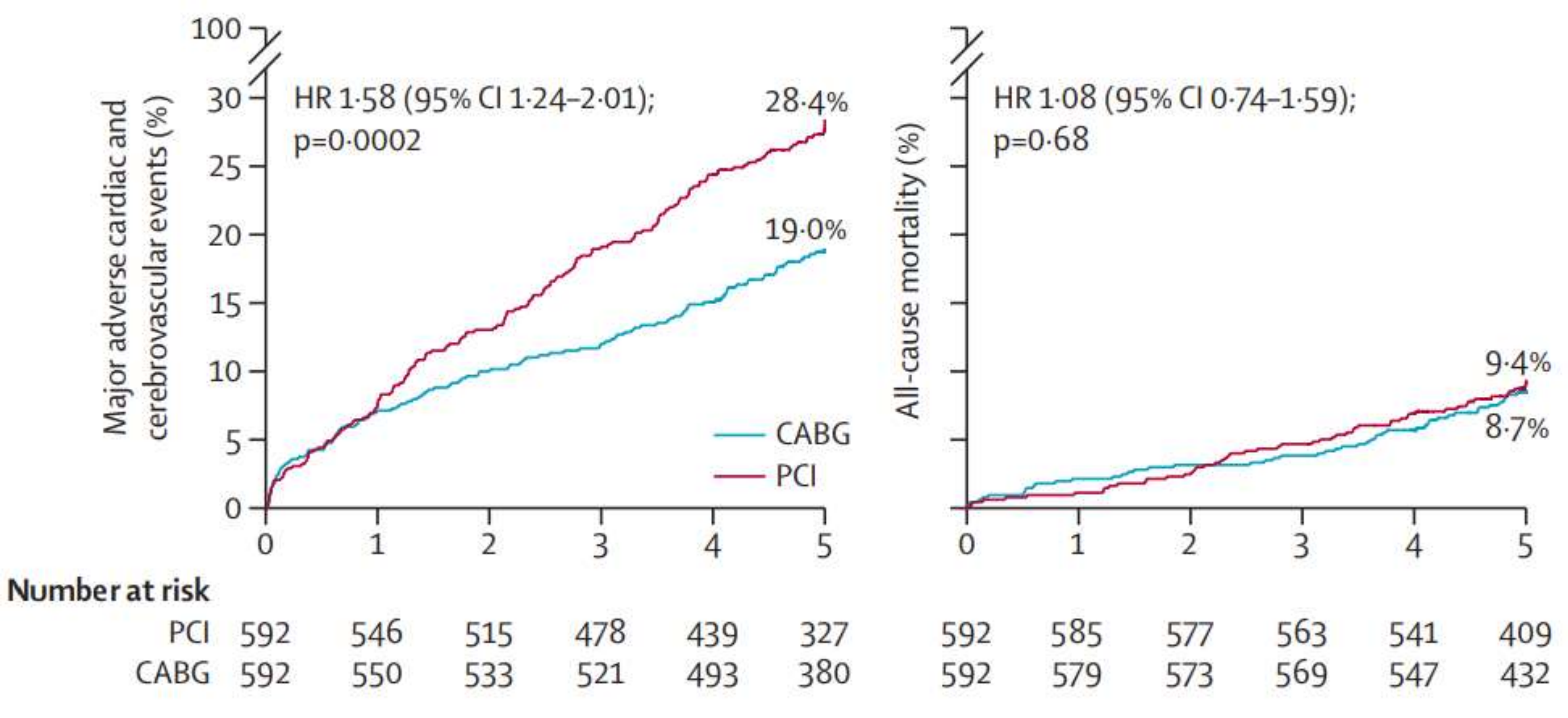
Athappan et al. JACC: Cardiovascular Interventions, 2013

PCI vs. CABG for Left Main Disease

5-year clinical outcomes of the randomized NOBLE trial

:PCI (N=592) vs. CABG (N=592)

Primary Endpoint: MACCE, All-cause mortality



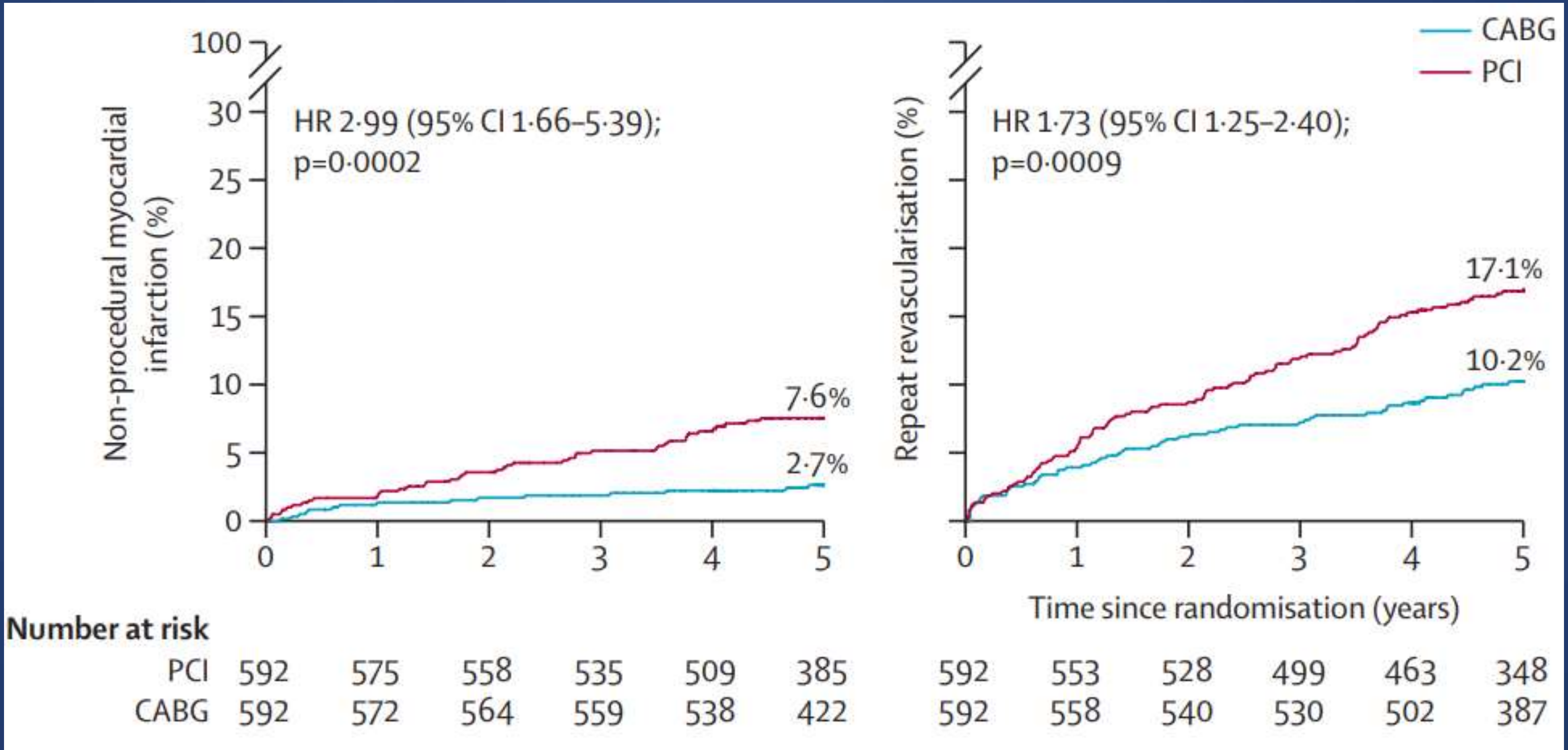
Holm NR et al. Lancet 2020.

PCI vs. CABG for Left Main Disease

5-year clinical outcomes of the randomized NOBLE trial

:PCI (N=592) vs. CABG (N=592)

Primary Endpoint: Non-procedural MI, Repeat revascularization



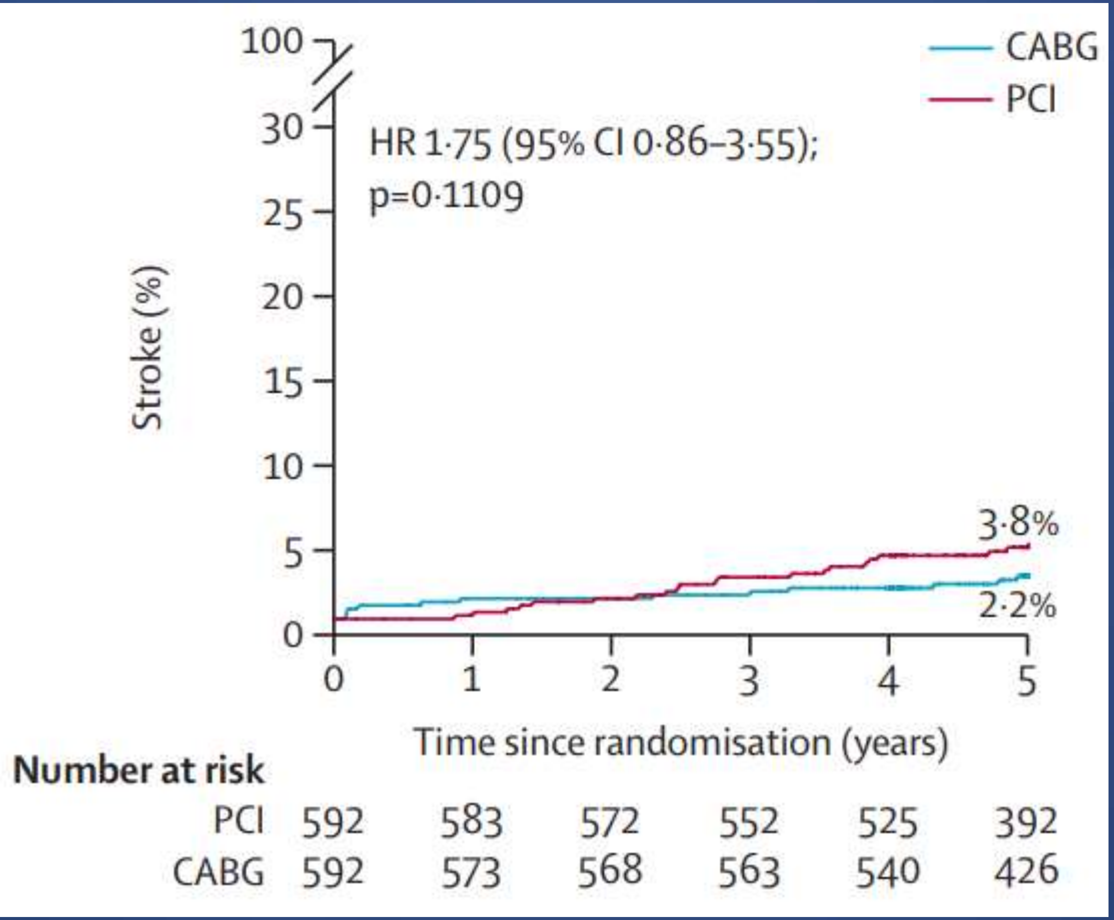
Holm NR et al. Lancet 2020.

PCI vs. CABG for Left Main Disease

5-year clinical outcomes of the randomized NOBLE trial

:PCI (N=592) vs. CABG (N=592)

Primary Endpoint: Stroke

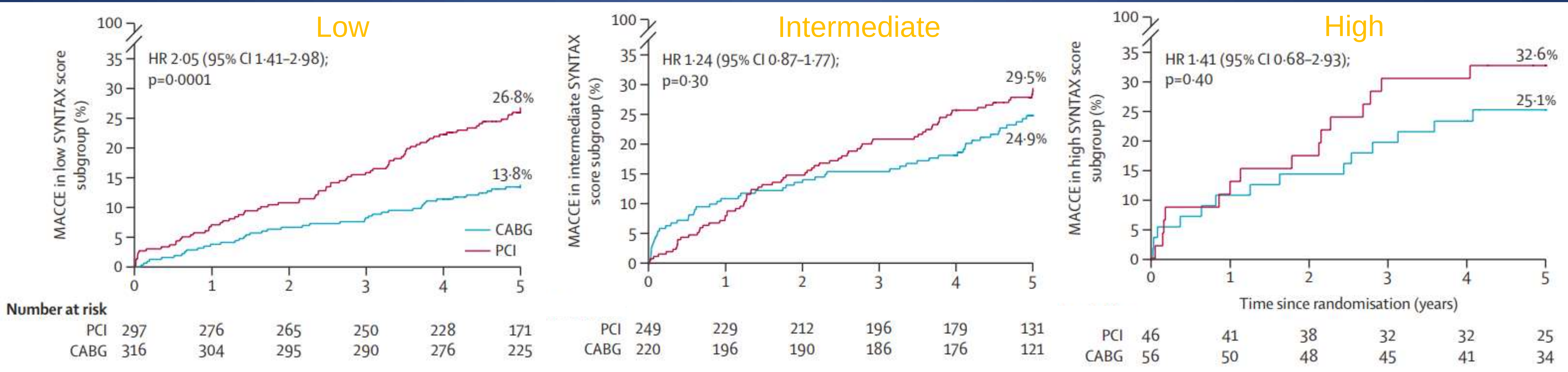


Holm NR et al. Lancet 2020.

PCI vs. CABG for Left Main Disease

5-year clinical outcomes of the randomized NOBLE trial
:PCI (N=592) vs. CABG (N=592)

Primary Endpoint(MACCE) by SYNTAX score subgroups



A low score is defined as 1–22; intermediate is 23–32; high is ≥33.

Holm NR et al. Lancet 2020.

PCI vs. CABG for Left Main Disease

5-year outcomes of the randomized EXCEL trial

:PCI (N=948) vs. CABG (N=957)

	PCI (n=948)	CABG (n=957)	Diff [95% CI]	OR [95%CI]
Primary endpoint				
Death, stroke or MI at 5 years	22.0%	19.2%	2.8 [-0.9 to 6.0]	1.19 (0.95-1.05)
Secondary endpoints				
Death from any cause	13.0%	9.9%	3.1 [0.2 to 6.1]	1.38 (1.03-1.85)
Death, stroke, MI or ischemia-driven revasc	31.3 %	24.9 %	6.2 [2.4-10.6]	1.39 (1.13-1.71)

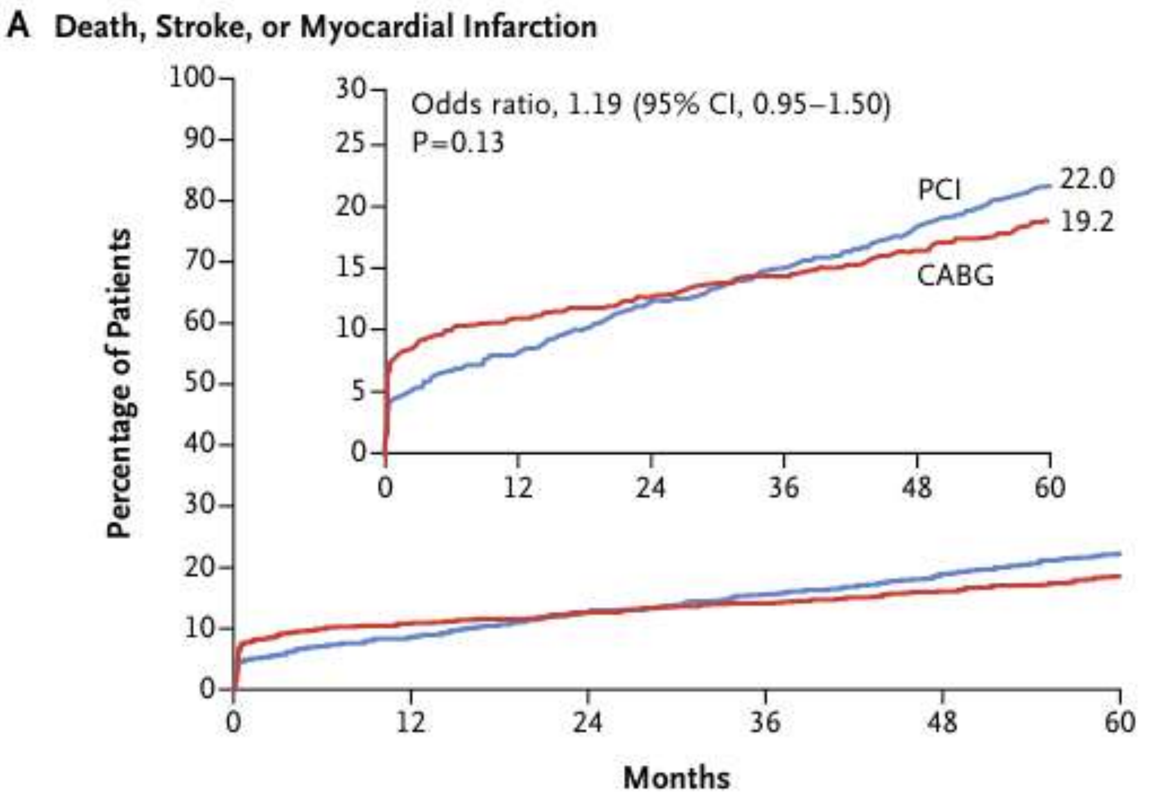
G.W. Stone et al. N Engl J Med 2019.

PCI vs. CABG for Left Main Disease

5-year outcomes of the randomized EXCEL trial

:PCI (N=948) vs. CABG (N=957)

Primary Endpoint: Death, Stroke or MI at 5 Years



No. at Risk	0	12	24	36	48	60
PCI	948	854	809	778	738	486
CABG	957	818	789	763	734	532

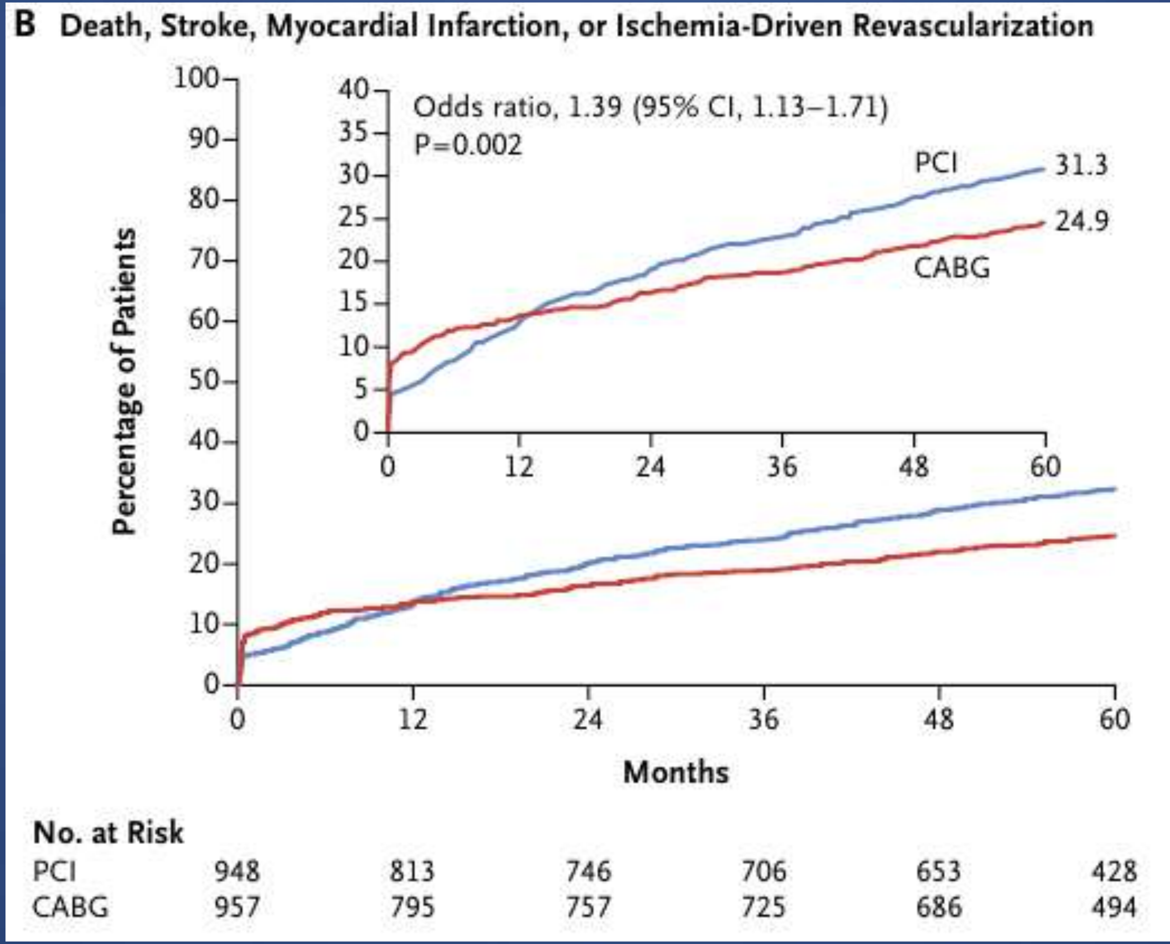
G.W. Stone et al. N Engl J Med 2019.

PCI vs. CABG for Left Main Disease

5-year outcomes of the randomized EXCEL trial

:PCI (N=948) vs. CABG (N=957)

Death, Stroke, MI or Ischemia-driven Revascularization at 5 Years



G.W. Stone et al. N Engl J Med 2019.

PCI vs. CABG for Left Main Disease

5-year outcomes of the randomized EXCEL trial

:PCI (N=948) vs. CABG (N=957)

Secondary Outcomes Analysis

Outcome	PCI (N=948) Events	PCI (N=948) Event Rate	CABG (N=957) Events	CABG (N=957) Event Rate	Difference in Event Rates (95% CI)	Odds Ratio (95% CI)
	no.	%	*no.*	%	*percentage points*	
Death from any cause	119	13.0	89	9.9	3.1 (0.2 to 6.1)	1.38 (1.03 to 1.85)
Cardiovascular	61	6.8	49	5.5	1.3 (−0.9 to 3.6)	1.26 (0.85 to 1.85)
Definite cardiovascular	45	5.0	40	4.5	0.5 (−1.4 to 2.5)	1.13 (0.73 to 1.74)
Undetermined cause	16	1.9	9	1.1	0.9 (−0.3 to 2.0)	1.78 (0.78 to 4.06)
Noncardiovascular	58	6.6	40	4.6	2.0 (−0.2 to 4.2)	1.47 (0.97 to 2.23)
Stroke	26	2.9	33	3.7	−0.8 (−2.4 to 0.9)	0.78 (0.46 to 1.31)
Myocardial infarction	95	10.6	84	9.1	1.4 (−1.3 to 4.2)	1.14 (0.84 to 1.55)
Periprocedural	37	3.9	57	6.1	−2.1 (−4.1 to −0.1)	0.63 (0.41 to 0.96)
Nonperiprocedural	59	6.8	31	3.5	3.2 (1.2 to 5.3)	1.96 (1.25 to 3.06)
Ischemia-driven revascularization	150	16.9	88	10.0	6.9 (3.7 to 10.0)	1.84 (1.39 to 2.44)
PCI	125	14.1	80	9.1	4.9 (1.9 to 7.9)	1.65 (1.22 to 2.22)
CABG	38	4.3	8	0.9	3.4 (1.9 to 4.9)	4.90 (2.27 to 10.56)

G.W. Stone et al. N Engl J Med 2019.

PCI vs. CABG for Left Main Disease

5-year outcomes of the randomized EXCEL trial

:PCI (N=948) vs. CABG (N=957)

Additional Outcomes Analysis

Outcome	PCI (N=948)		CABG (N=957)		Difference in Event Rates (95% CI)	Odds Ratio (95% CI)
	Events	Event Rate	Events	Event Rate		
	no.	%	*no.*	%	*percentage points*	
Additional outcomes						
Any revascularization	153	17.2	92	10.5	6.7 (3.5 to 9.9)	1.79 (1.36 to 2.36)
Stent thrombosis	16	1.8	0	0	—	—
Definite	10	1.1	0	0	—	—
Probable	6	0.7	0	0	—	—
Symptomatic graft stenosis or occlusion	0	0	58	6.5	—	—
Therapy failure†	10	1.1	58	6.5	−5.4 (−7.2 to −3.6)	0.16 (0.08 to 0.32)
Cerebrovascular events‡	29	3.3	46	5.2	−1.9 (−3.8 to 0)	0.61 (0.38 to 0.99)
Transient ischemic attack	3	0.3	14	1.6	−1.3 (−2.2 to −0.4)	0.21 (0.06 to 0.74)

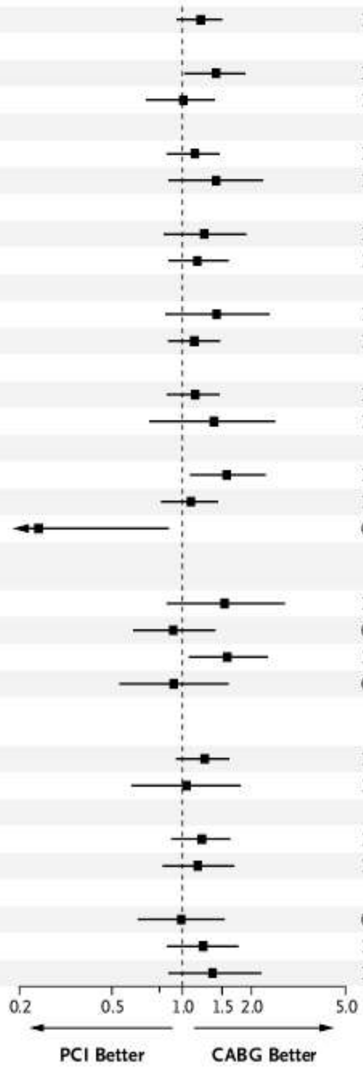
G.W. Stone et al. N Engl J Med 2019.

PCI vs. CABG for Left Main Disease

5-year outcomes of the randomized EXCEL trial:*PCI (N=948) vs. CABG (N=957)*

Subgroup analysis of Primary outcomes at 5 Years

Subgroup	PCI (N=948) Events/total patients no.	PCI Event rate %	CABG (N=957) Events/total patients no.	CABG Event rate %	Odds Ratio (95% CI)
All patients	203/948	22.0	176/957	19.2	1.19 (0.95–1.50)
Age (median cutoff)					
≥67 yr	123/466	27.2	98/472	21.8	1.39 (1.02–1.89)
<67 yr	80/482	16.9	78/485	16.6	1.00 (0.71–1.40)
Sex					
Male	145/722	20.6	134/742	18.7	1.12 (0.86–1.46)
Female	58/226	26.3	42/215	21.1	1.39 (0.88–2.20)
Diabetes mellitus, medically treated					
Yes	72/256	29.0	62/249	25.5	1.24 (0.83–1.86)
No	131/692	19.4	114/707	16.9	1.17 (0.89–1.55)
Chronic kidney disease					
Estimated GFR ≤60 ml/min	54/164	34.0	37/144	27.6	1.44 (0.86–2.39)
Estimated GFR >60 ml/min	147/770	19.5	135/791	17.6	1.13 (0.87–1.47)
Left ventricular ejection fraction					
≥50%	158/782	20.6	144/796	18.7	1.14 (0.88–1.46)
<50%	33/111	31.5	26/115	24.2	1.35 (0.73–2.49)
Geographic region					
North America	89/381	24.2	61/371	17.3	1.57 (1.09–2.26)
Europe	111/534	21.1	102/541	19.6	1.09 (0.81–1.48)
Other	3/33	9.6	13/45	29.6	0.24 (0.06–0.96)
Non–left main diseased coronary arteries (core laboratory assessment)					
0	33/163	20.7	23/167	14.3	1.55 (0.86–2.78)
1	60/292	21.2	61/292	21.9	0.94 (0.62–1.40)
2	79/325	25.0	50/295	17.8	1.58 (1.06–2.36)
3	31/162	19.2	37/182	20.7	0.93 (0.54–1.59)
Left main bifurcation or trifurcation stenosis ≥50% (core laboratory assessment)					
Yes	171/771	22.7	136/741	19.0	1.24 (0.96–1.60)
No	32/171	19.2	35/195	18.9	1.05 (0.62–1.79)
SYNTAX score (site reported)					
≤22	119/560	21.9	106/588	18.7	1.21 (0.90–1.62)
23–32	84/386	22.2	70/366	20.0	1.16 (0.81–1.67)
SYNTAX score (core laboratory assessment)					
≤22	49/294	17.2	58/364	16.7	0.99 (0.65–1.51)
23–32	91/392	23.7	69/346	20.7	1.22 (0.85–1.74)
≥33	56/228	25.0	42/216	20.0	1.36 (0.86–2.15)



G.W. Stone et al. N Engl J Med 2019.

Role of Left Main PCI After EXCEL and NOBLE

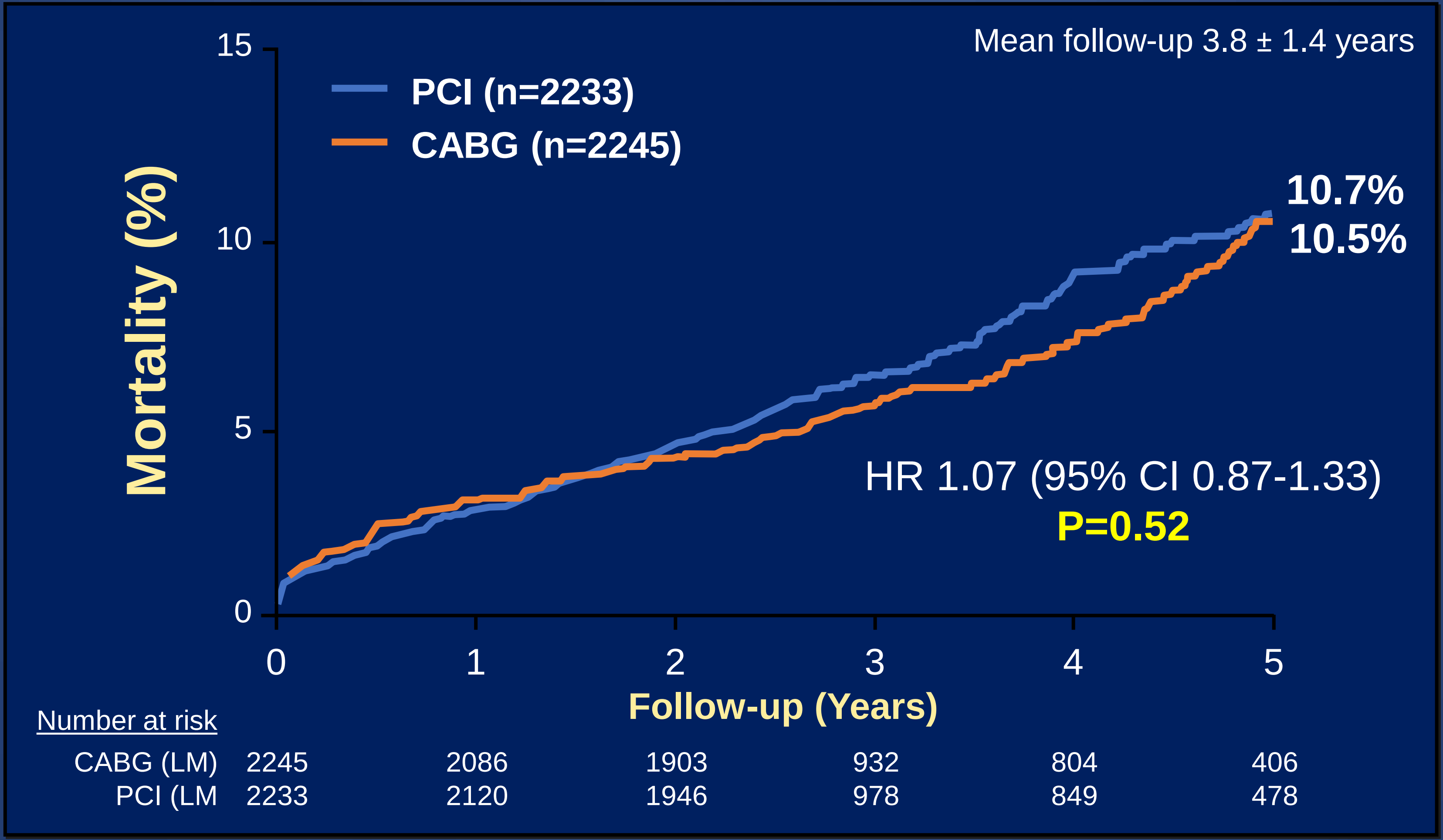
Variables	EXCEL	NOBLE
Patients (no.)	1,905	1,201
Median follow-up	5 year	4.9 year
HR (95% CI), CABG/PCI		
Primary endpoint	1.19 (0.95-1.05)	1.58 (1.24-2.01)
All-cause death	1.38 (1.03-1.85)	1.08 (0.74-1.59)
Cardiac death	1.3 (-0.9-3.6)	0.99 (0.57-1.73)
MI	1.4 (-1.3-4.2)	2.99 (1.66-5.39)
Stroke	-0.8 (-2.4-0.9)	1.75 (0.86-3.55)
Revascularization	6.9 (3.7-10.0)	1.73(1.25-2.40)

NOBLE: Stent thrombosis (2% NOBLE vs. 1.8% EXCEL),
non-procedural MI excluded (3% CABG vs. 8% PCI)

Individual-patient-data Analysis from 11 PCI vs. CABG Trials

11,518 randomized pts; 4,478 (38.9%) with left main ds.

All-cause Mortality (Left Main)



Head SJ et al. Lancet 2018;391:939-48

Individual-patient-data Analysis from 11 PCI vs. CABG Trials

11,518 randomized pts; 4,478 (38.9%) with left main ds.

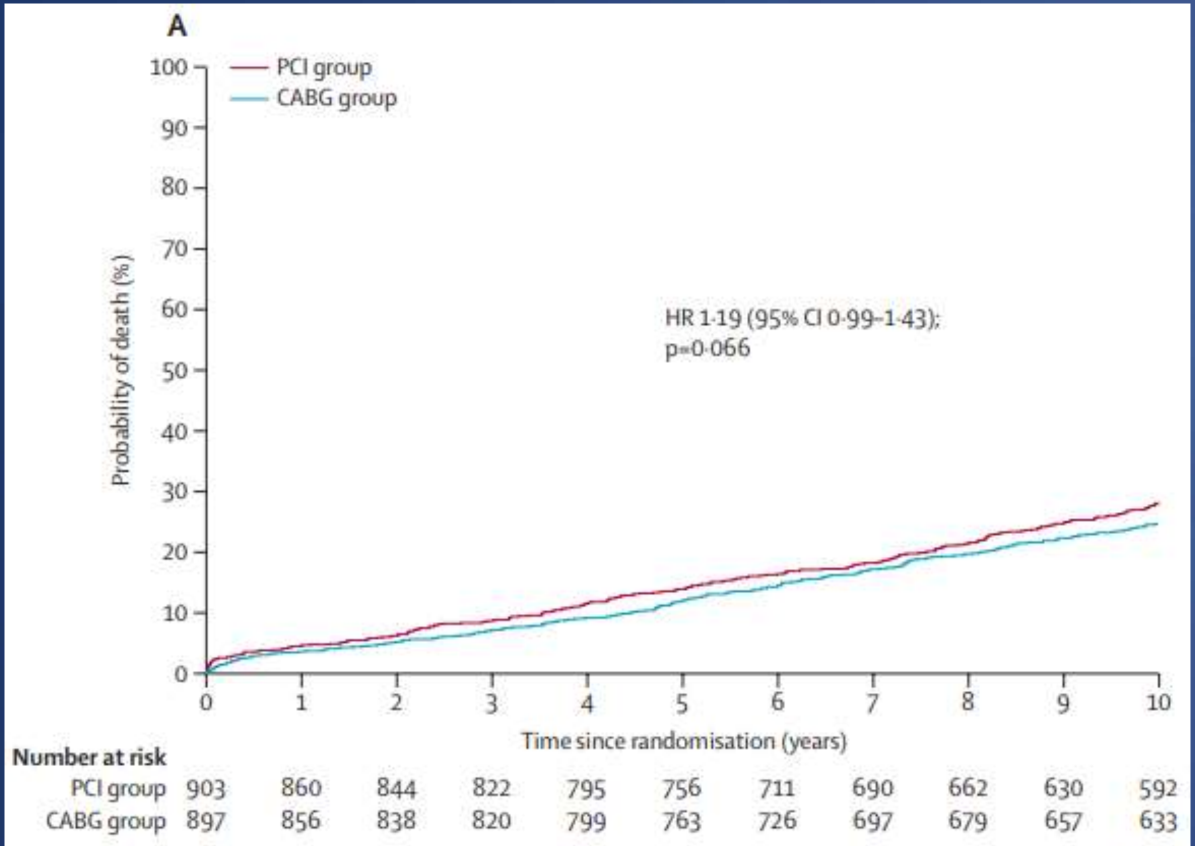
All-cause Mortality (LM patients)

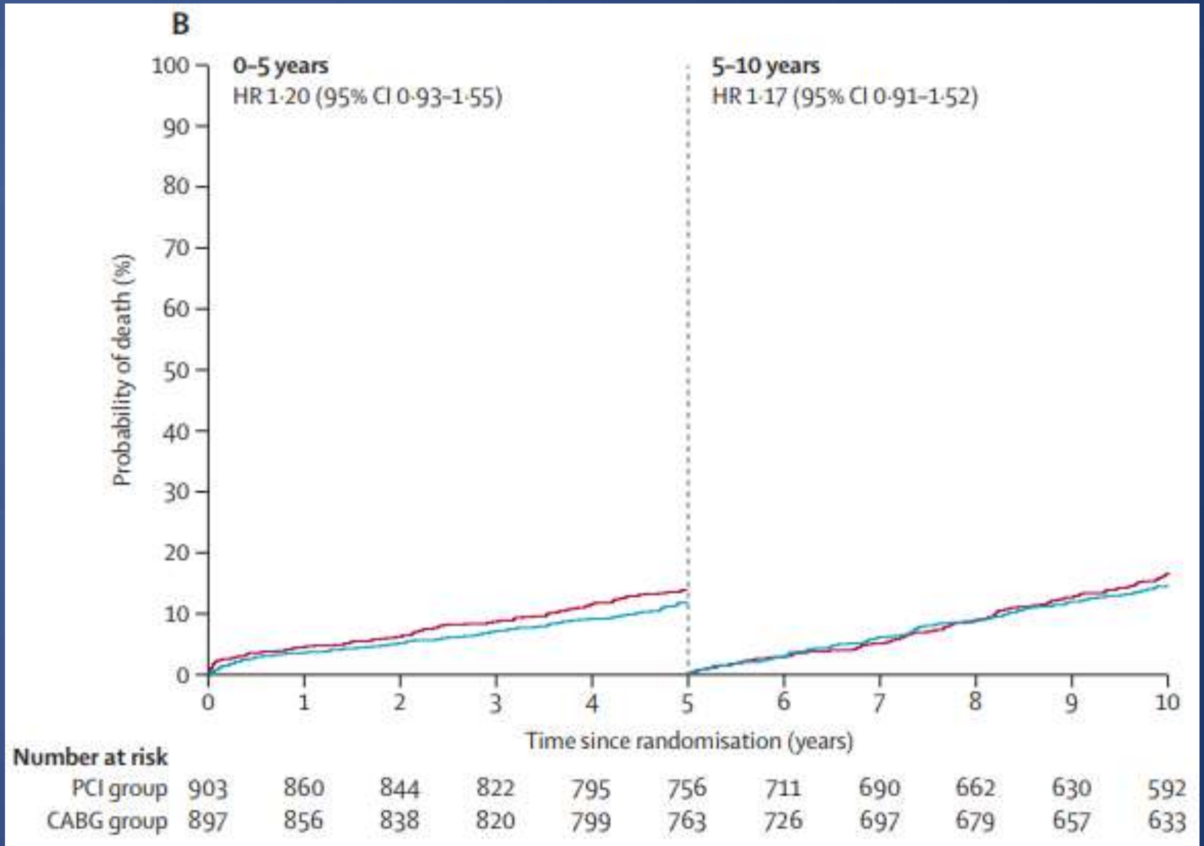
	PCI (n=2,233)	CABG (n=2,245)	HR (95%CI]	P value	P_{int}
Overall mortality	10.7% (174)	10.5% (158)	1.07 [0.87, 1.33]	**0.52**	
Diabetes	16.5% (71)	13.4% (51)	1.34 [0.93, 1.91]	0.11	**0.13**
No diabetes	8.8% (104)	9.6% (107)	0.94 [0.72, 1.23]	0.65	
SYNTAX score 0-22	8.1% (45)	8.3% (49)	0.91 [0.60, 1.36]	0.64	**0.38** (0.06 for trend)
SYNTAX score 23-32	10.8% (67)	12.7% (63)	0.92 [0.65, 1.30]	0.65	
SYNTAX score ≥33	15.0% (56)	12.4% (45)	1.39 [0.94, 2.06]	0.10	

Head SJ et al. Lancet 2018;391:939-48

PCI vs. CABG for Left Main Disease

10-year outcomes of the randomized SYNTAX Extended Survival (SYNTAXES) study: *PCI (N=357) vs. CABG (N=348)*





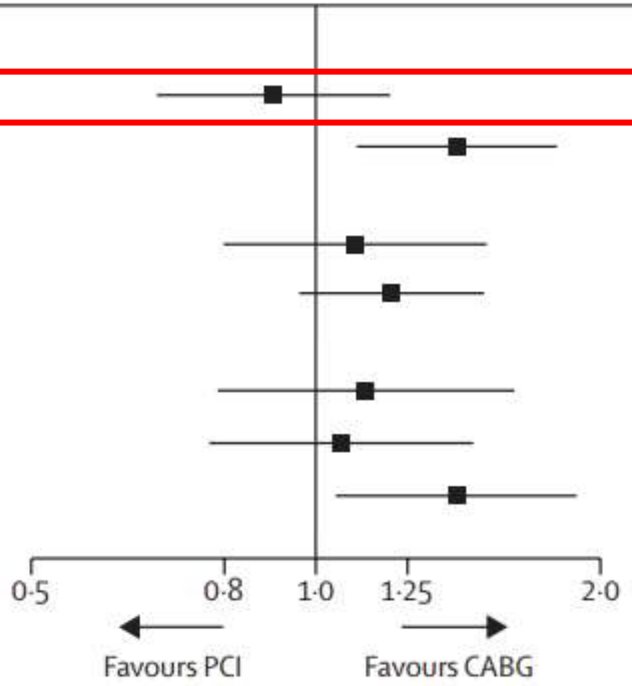
Thuijs DJFM et al., Lancet, 2019

PCI vs. CABG for Left Main Disease

10-year outcomes of the randomized SYNTAX Extended Survival (SYNTAXES) study: *PCI (N=357) vs. CABG (N=348)*

Prespecified Subgroup analysis of 10-year all-cause death

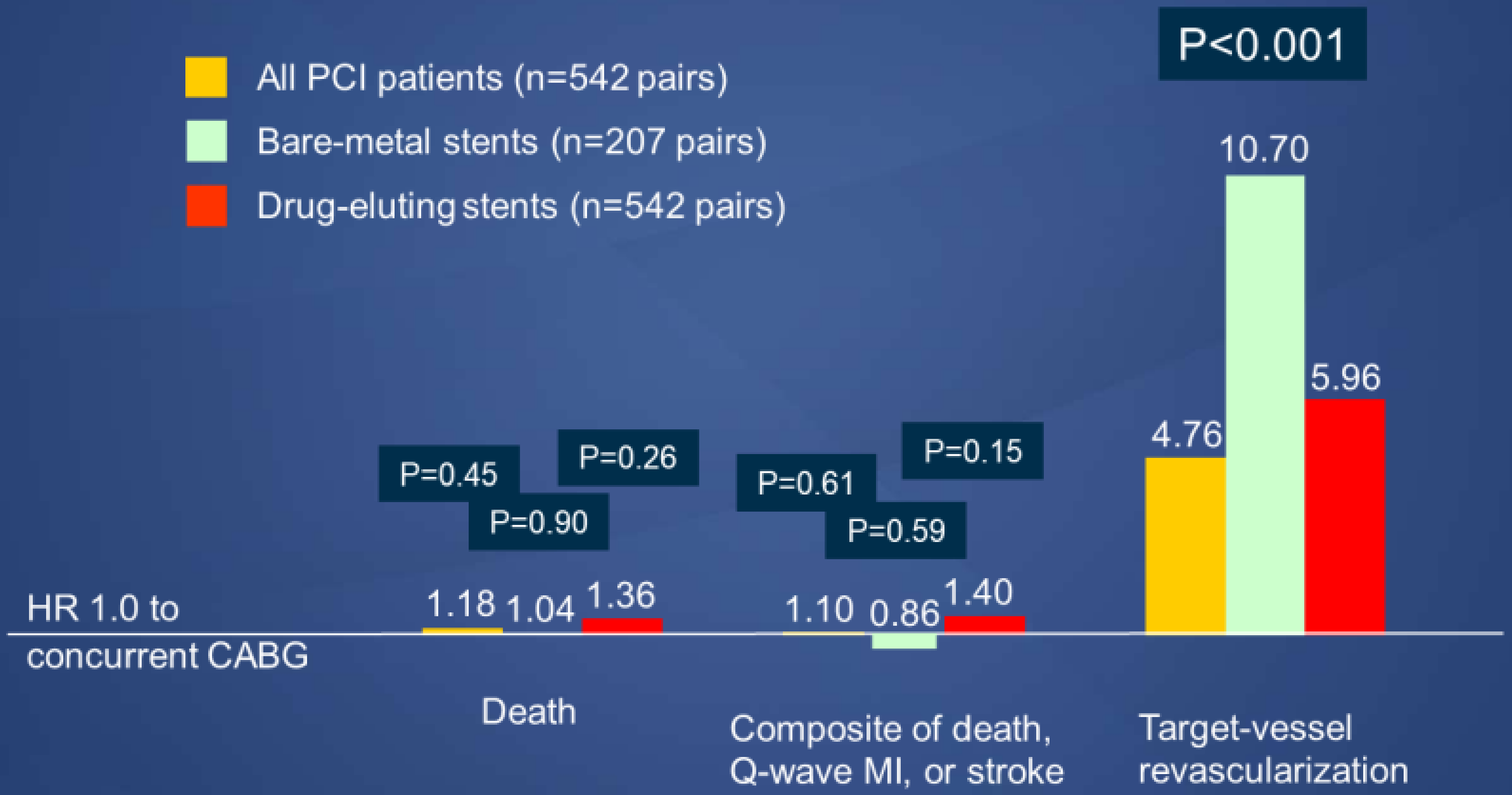
	PCI group	CABG group	HR (95% CI)	$P_{interaction}$
Type of coronary disease				
Left main coronary artery disease	95/357	98/348	0·92 (0·69–1·22)	0·023
Three-vessel disease*	153/546	114/549	1·42 (1·11–1·81)	
Medically treated diabetes				
Yes	80/231	72/221	1·10 (0·80–1·52)	0·60
No	168/672	140/676	1·23 (0·98–1·53)	
Coronary disease complexity				
SYNTAX score ≤22	65/299	53/275	1·11 (0·77–1·60)	0·20†
SYNTAX score 23–32	80/310	72/300	1·07 (0·78–1·47)	
SYNTAX score ≥33	101/290	82/315	1·47 (1·10–1·96)	



Thuijs DJFM et al., Lancet, 2019

MAIN COMPARE Registry, 3-Year

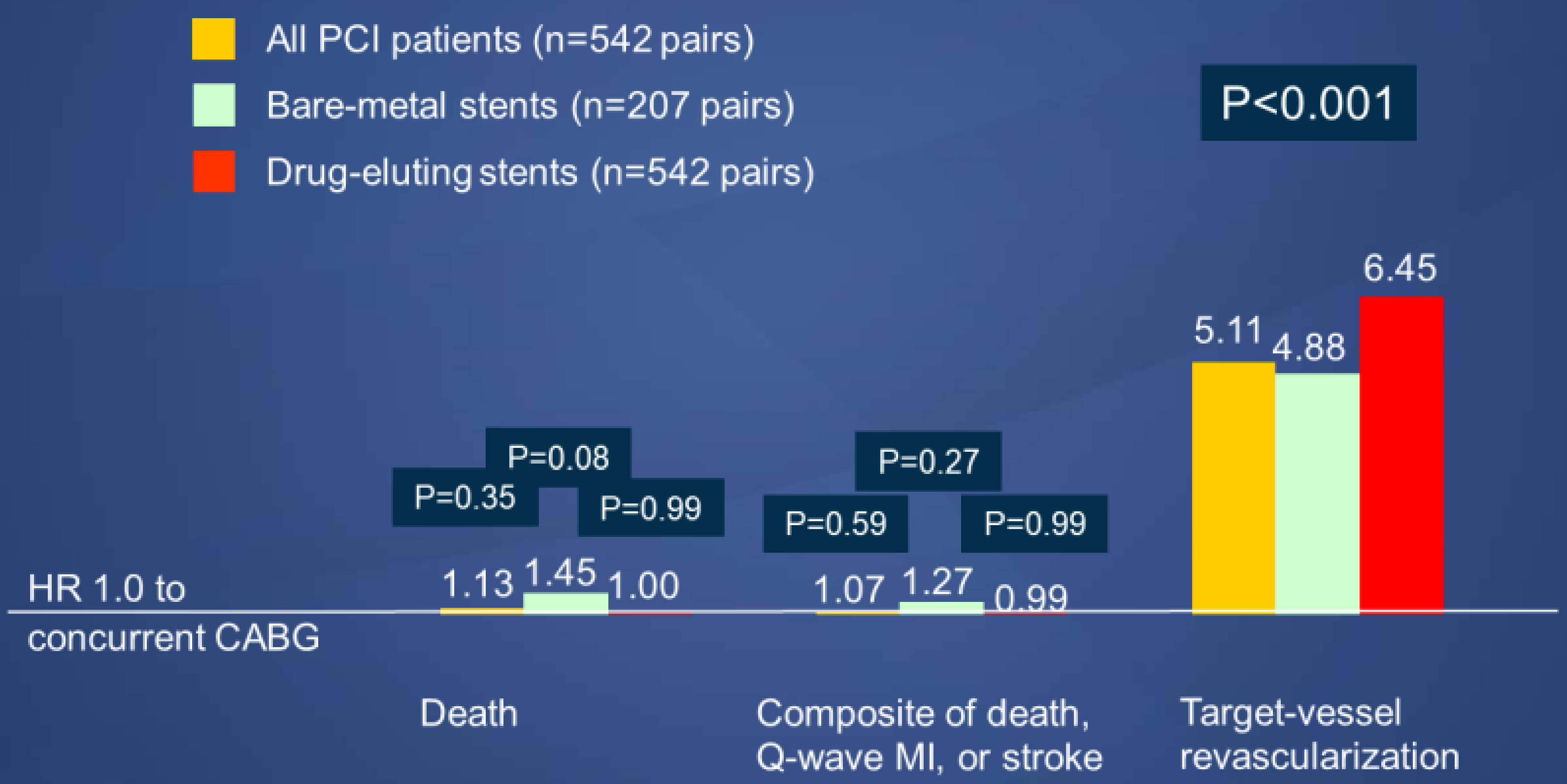
Adjusted HR by Use of PS Matching



Seung KB, Park DW, Park SJ, et al. N Engl J Med 2008;358:1781-92

MAIN COMPARE Registry, 5-Year

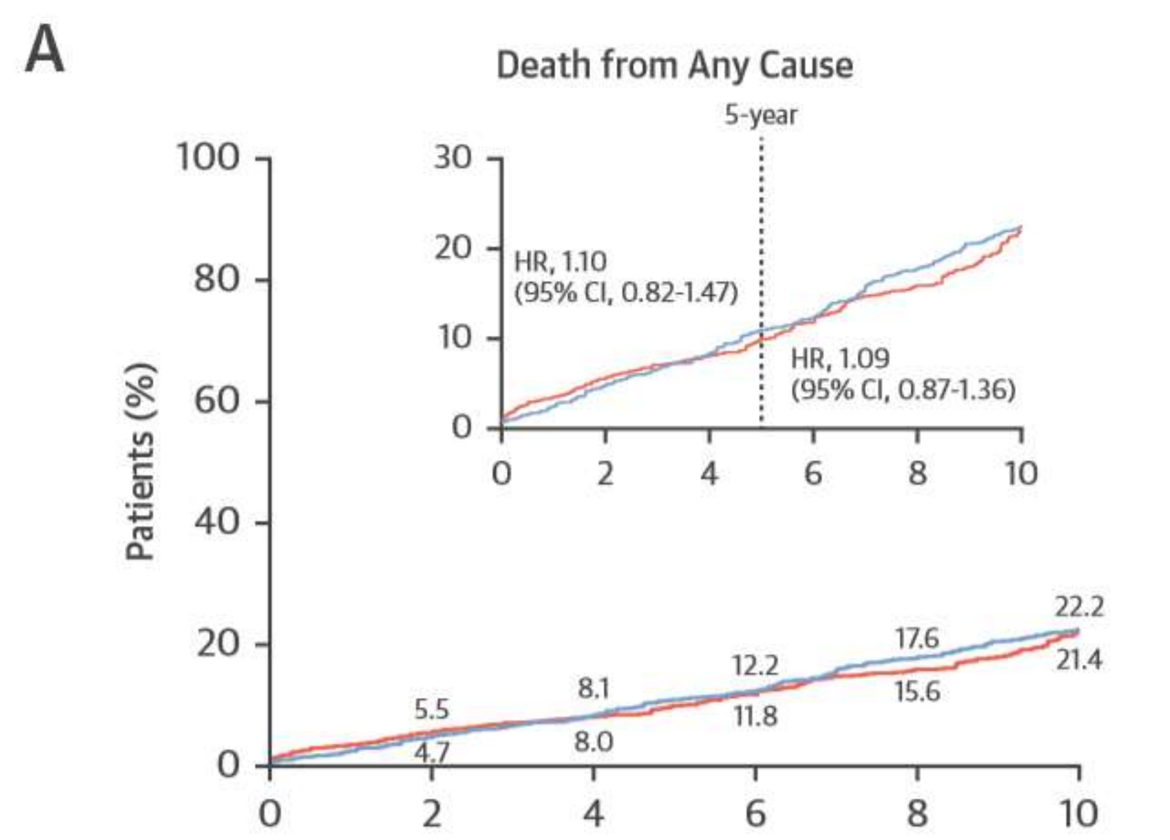
Adjusted HR by Use of IPTW Method



Park DW, Park SJ, et al. J Am Coll Cardiol. 2010;56:117-24.

PCI vs. CABG for Left Main Disease

10-year outcomes of the MAIN-COMPARE registry : All-cause death

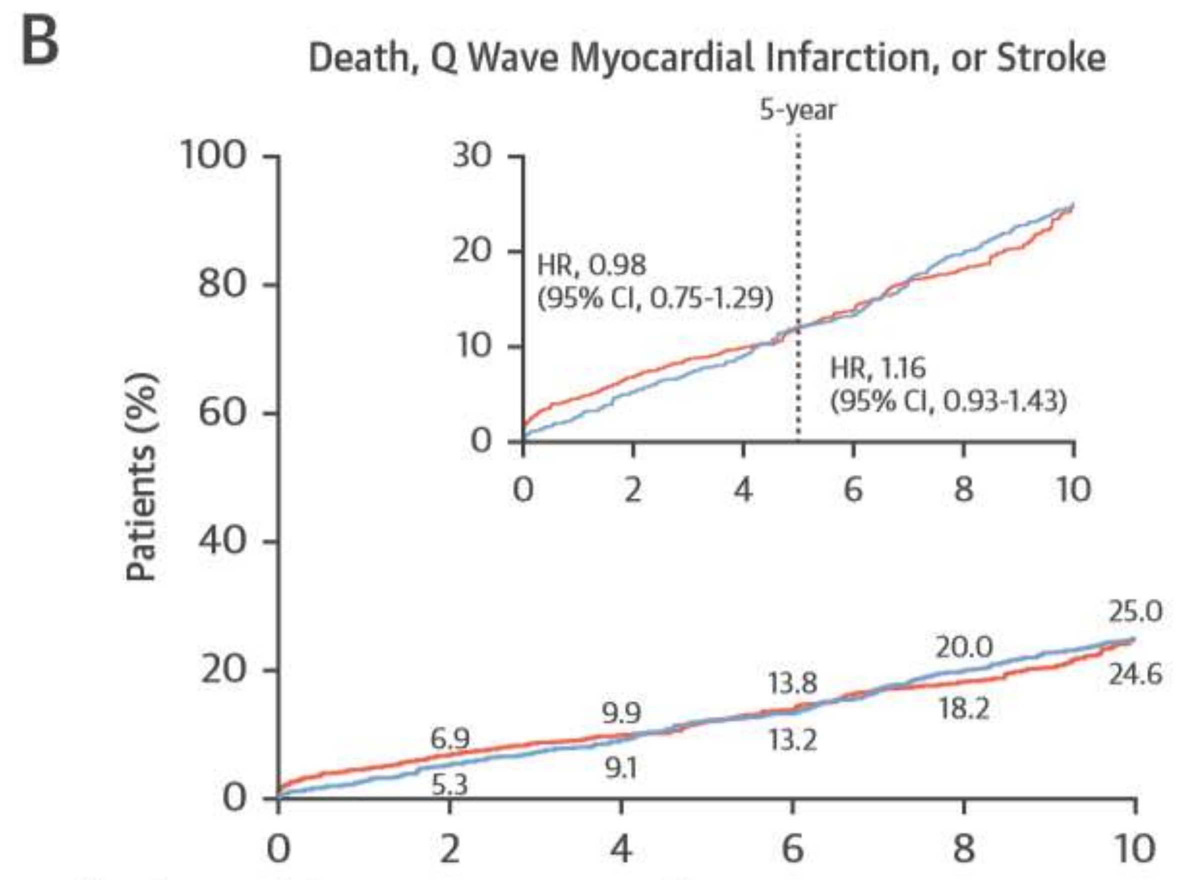


Number at risk						
PCI	1,102	1,049	1,010	966	906	854
CABG	1,138	1,074	1,046	1,003	957	887

Park et al. J Am Coll Cardiol. 2018;72:2813-22

PCI vs. CABG for Left Main Disease

10-year outcomes of the **MAIN-COMPARE** registry : Death, Q-wave MI, or stroke

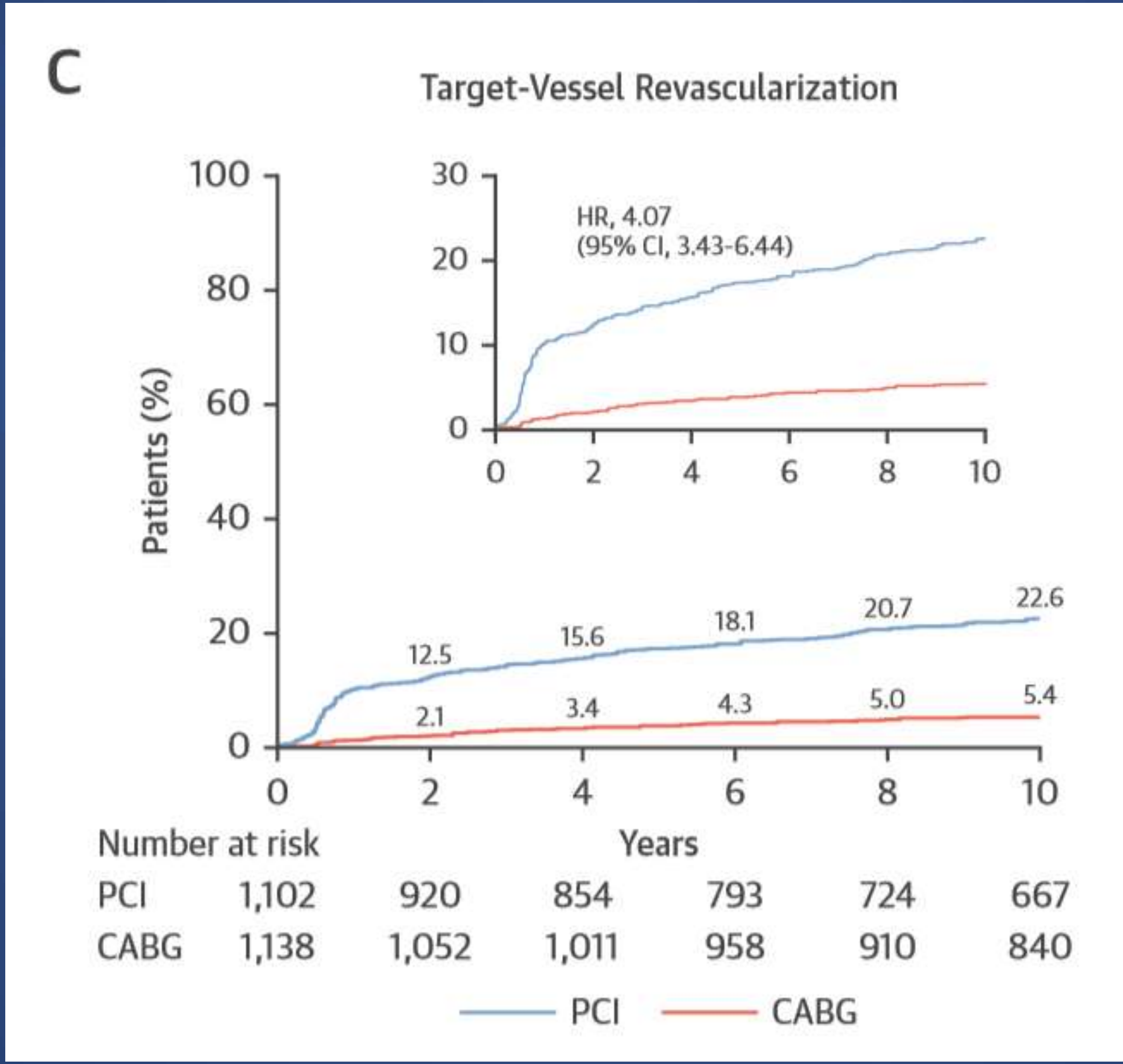


Number at risk						
PCI	1,102	1,044	1,002	956	882	827
CABG	1,138	1,060	1,026	981	931	857

Park et al. J Am Coll Cardiol. 2018;72:2813-22

PCI vs. CABG for Left Main Disease

10-year outcomes of the MAIN-COMPARE registry : Target-Vessel Revascularization



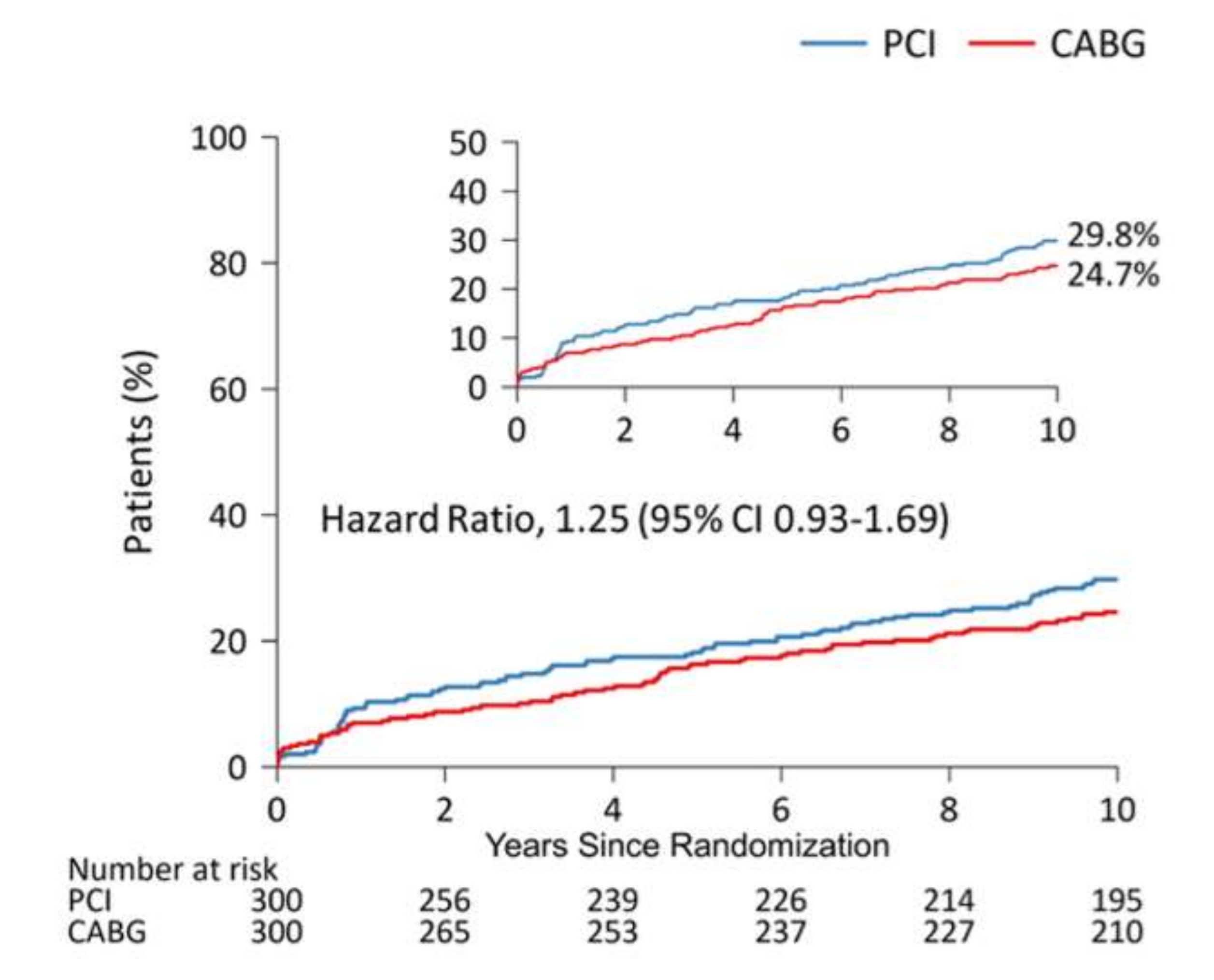
Park et al. J Am Coll Cardiol. 2018;72:2813-22

Hazard Ratios for Clinical Outcomes Before and After 5-Year of Follow-up

Outcome	Overall Cohort		Wave 1* (BMS)		Wave 2* (DES)	
	Hazard Ratio† (95% CI)	P value	Hazard Ratio† (95% CI)	P value	Hazard Ratio† (95% CI)	P value
Analyses with IPTW	N = 2240 patients (PCI 1102, CABG 1138)		N = 766 patients (BMS 318, CABG 448)		N = 1474 patients (DES 784, CABG 690)	
Death		0.64		0.05		0.15
0~5 years	1.10 (0.82–1.47)	0.53	1.65 (0.91–2.98)	0.10	1.02 (0.71–1.46)	0.91
>5 years	1.09 (0.87–1.36)	0.48	0.68 (0.46–1.02)	0.06	1.35 (1.00–1.81)	0.05
Composite outcome (death, Q-wave MI or stroke)		0.43		0.06		0.03
0~5 years	0.98 (0.75–1.29)	0.91	1.46 (0.84–2.53)	0.18	0.91 (0.66–1.27)	0.59
>5 years	1.16 (0.93–1.43)	0.19	0.67 (0.46–1.00)	0.05	1.46 (1.10–1.94)	0.009
TVR, All period	4.07 (3.43–6.44)	<0.001	4.45 (2.81–7.05)	<0.001	5.82 (3.77–9.01)	<0.001

PCI vs. CABG for Left Main Disease

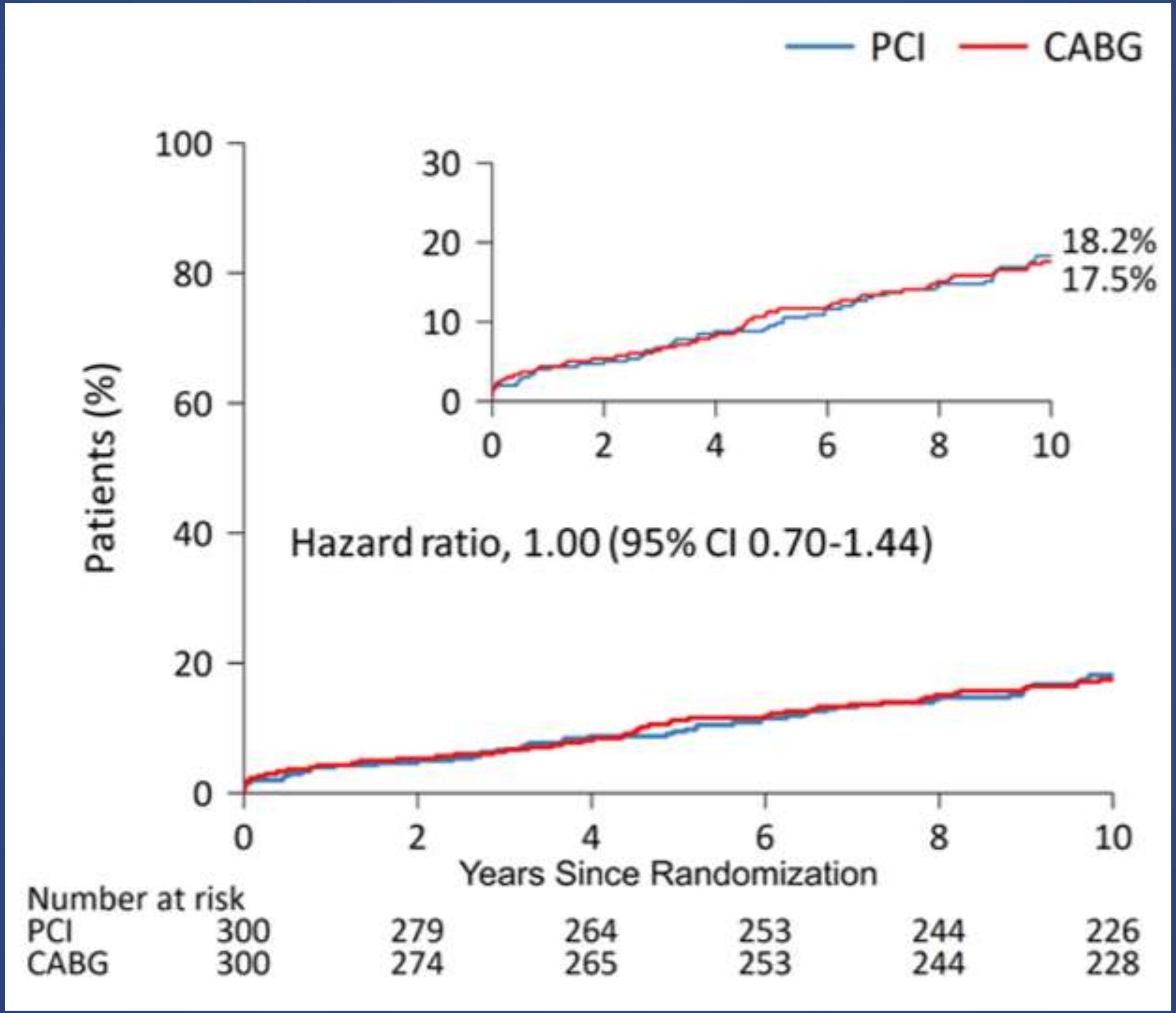
Extended Follow-Up of the **PRECOMBAT** trial : Primary composite outcome



DW Park et al. Circulation 2020;141:1437-1446

PCI vs. CABG for Left Main Disease

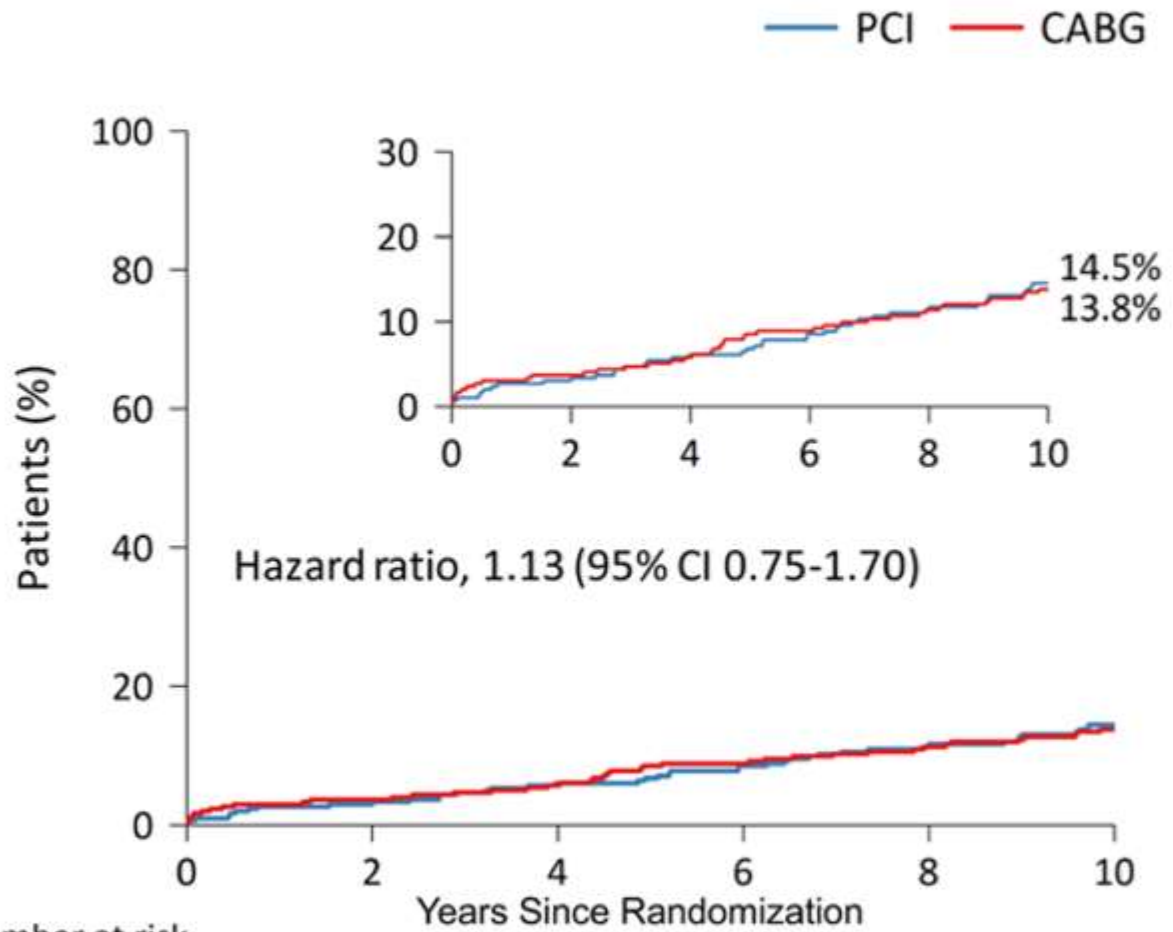
Extended Follow-Up of the **PRECOMBAT** trial : Death, MI, or Stroke



DW Park et al. Circulation 2020;141:1437-1446

PCI vs. CABG for Left Main Disease

Extended Follow-Up of the **PRECOMBAT** trial : All-cause Death

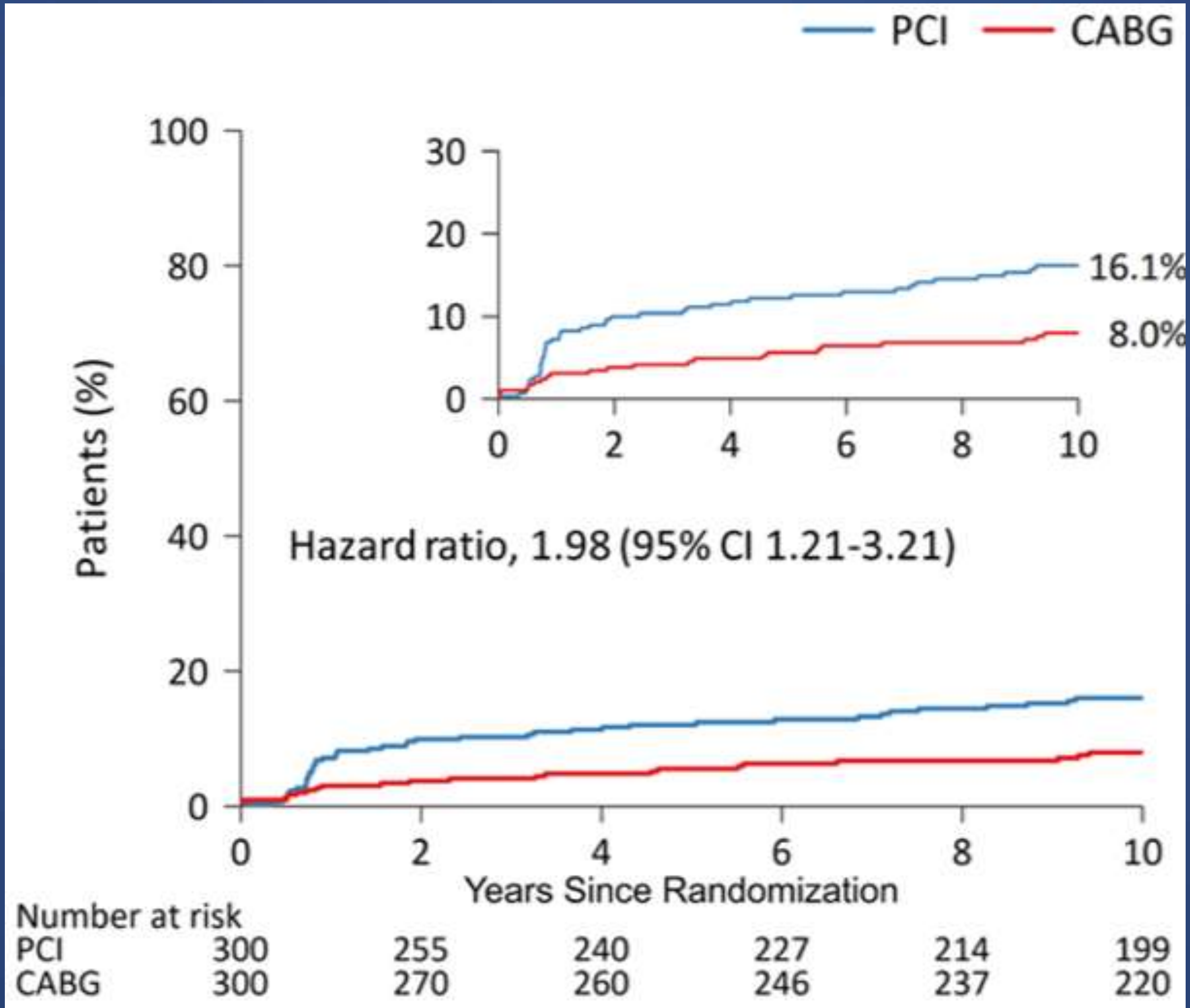


Number at risk						
PCI	300	284	272	262	253	237
CABG	300	279	272	262	254	238

DW Park et al. Circulation 2020;141:1437-1446

PCI vs. CABG for Left Main Disease

Extended Follow-Up of the **PRECOMBAT** trial : Target-Vessel revascularization

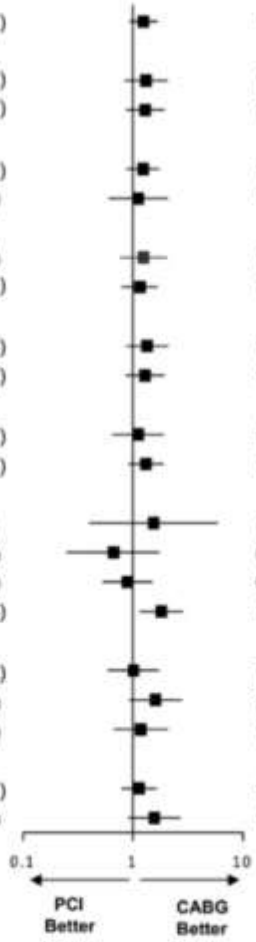


DW Park et al. Circulation 2020;141:1437-1446

PCI vs. CABG for Left Main Disease

Extended Follow-Up of the PRECOMBAT trial

Subgroup	PCI	CABG	Hazard Ratio (95% CI)	P value for Interaction
	no. /total no. (%)			
Overall	87/300 (29.8)	72/300 (24.7)	1.25 (0.93–1.69)	
Age				0.99
<65	42/171 (25.0)	27/151 (18.2)	1.32 (0.84–2.08)	
≥65	45/129 (36.3)	45/149 (31.4)	1.30 (0.87–1.95)	
Sex				0.95
Male	68/228 (30.6)	54/231 (24.0)	1.24 (0.87–1.75)	
Female	19/72 (27.1)	18/69 (26.9)	1.12 (0.60–2.09)	
Diabetes				0.70
Yes	37/102 (36.8)	24/90 (27.3)	1.25 (0.76–2.05)	
No	50/198 (26.1)	48/210 (25.6)	1.16 (0.79–1.69)	
Clinical presentation				0.89
Non-acute coronary syndrome	42/160 (26.7)	30/137 (22.8)	1.35 (0.87–2.11)	
Acute coronary syndrome	45/140 (33.4)	42/163 (26.2)	1.29 (0.86–1.95)	
Left main involvement				0.54
Ostium and shaft	23/99 (23.6)	23/111 (21.2)	1.12 (0.65–1.91)	
Distal bifurcation	64/200 (33.1)	48/183 (28.1)	1.32 (0.91–1.90)	
Extent of diseased vessel				0.048
Left main only	4/27 (15.1)	5/34 (14.9)	1.55 (0.40–5.95)	
Left main with 1-vessel disease	6/50 (13.4)	10/53 (19.8)	0.67 (0.25–1.76)	
Left main with 2-vessel disease	30/101 (30.1)	26/90 (29.9)	0.89 (0.53–1.51)	
Left main with 3-vessel disease	47/122 (40.0)	31/123 (25.6)	1.82 (1.16–2.86)	
Syntax score				0.63
≤22	27/131 (21.6)	23/109 (22.2)	1.01 (0.59–1.73)	
22-32	32/102 (31.8)	21/98 (22.2)	1.61 (0.92–2.81)	
≥33	26/58 (46.2)	24/68 (45.7)	1.18 (0.67–2.09)	
Complete revascularization				0.45
Yes	57/205 (28.3)	53/211 (25.7)	1.14 (0.79–1.65)	
No	30/95 (33.2)	19/89 (22.2)	1.57 (0.90–2.73)	

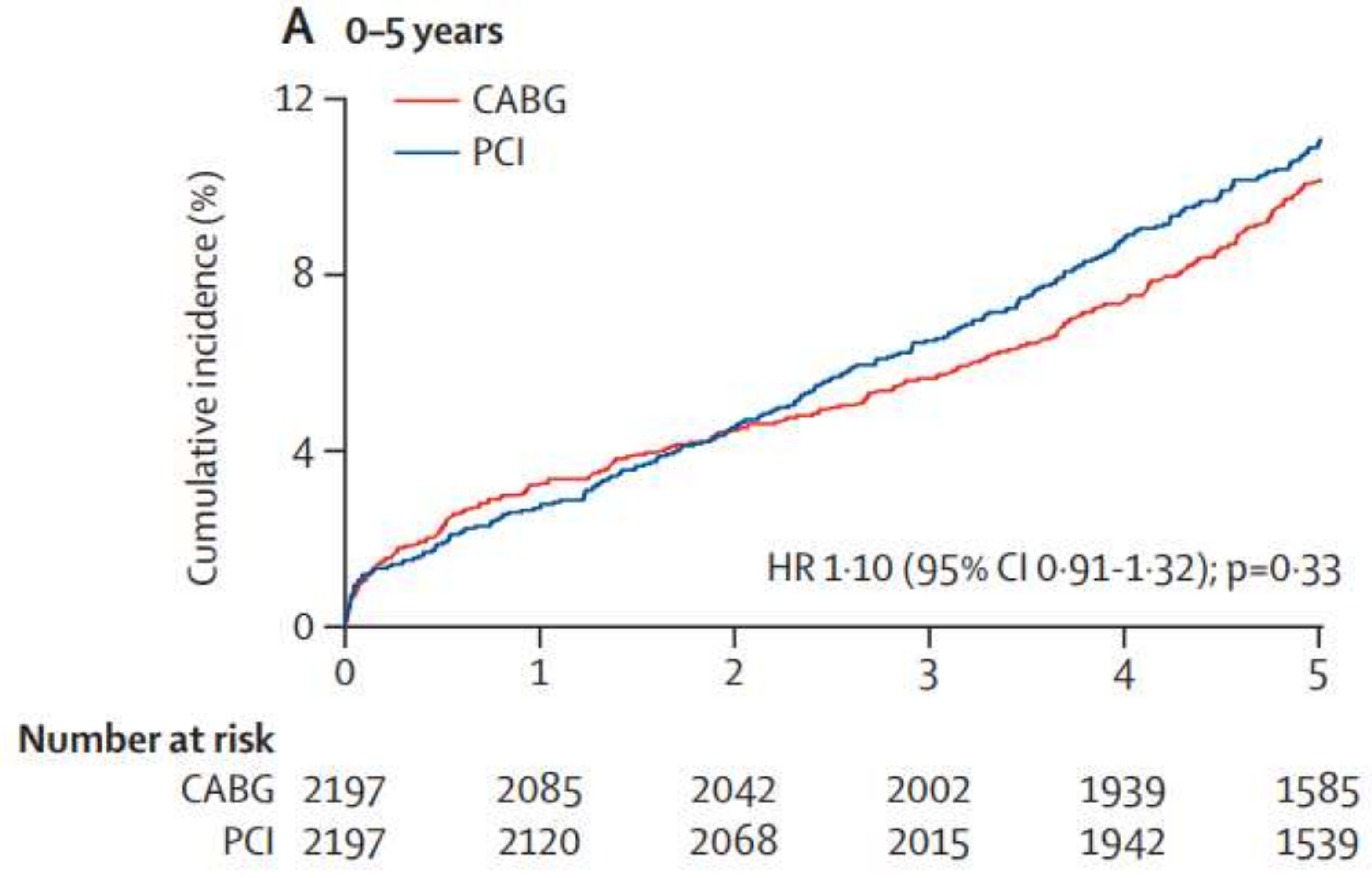


DW Park et al. Circulation 2020;141:1437-1446

PCI vs. CABG for Left Main Disease

Individual patient data meta-analysis : **SYNTAX, PRECOMBAT, NOBLE, EXCEL**

all-cause death (0-5Yr)

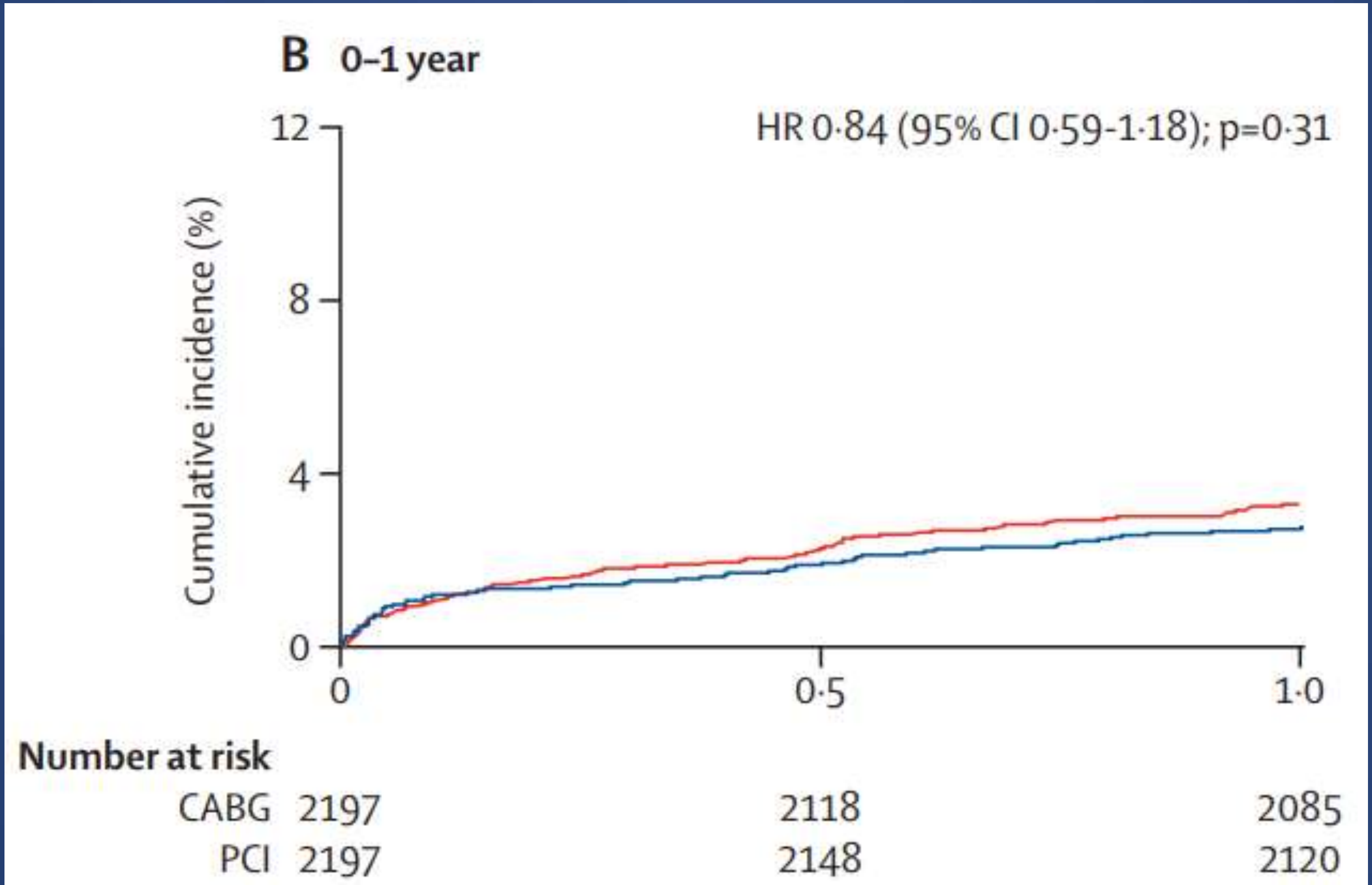


Sabatine et al. Lancet 2021;398:2247-57

PCI vs. CABG for Left Main Disease

Individual patient data meta-analysis : **SYNTAX, PRECOMBAT, NOBLE, EXCEL**

all-cause death (0-1Yr)

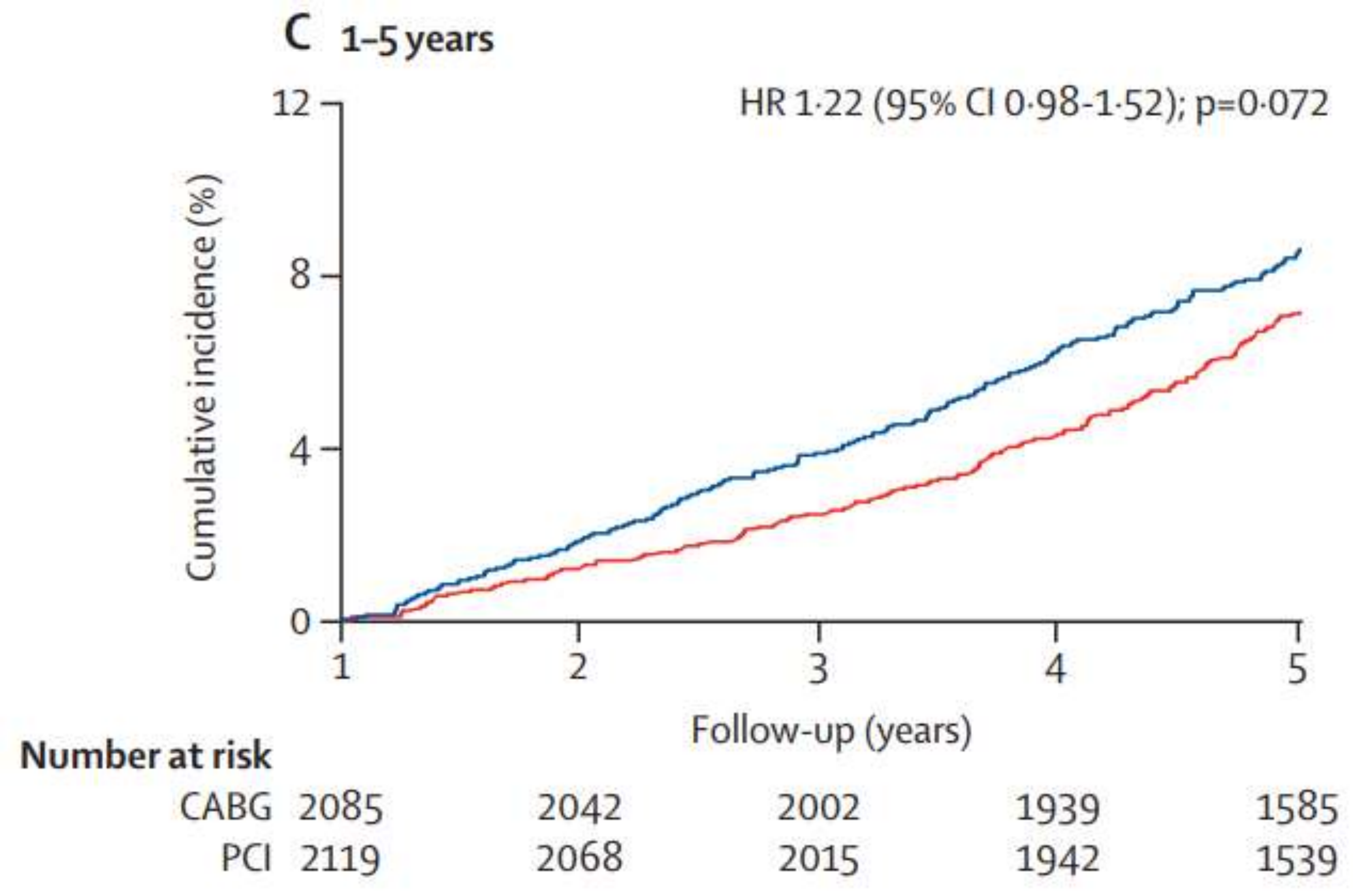


Sabatine et al. Lancet 2021;398:2247-57

PCI vs. CABG for Left Main Disease

Individual patient data meta-analysis : **SYNTAX, PRECOMBAT, NOBLE, EXCEL**

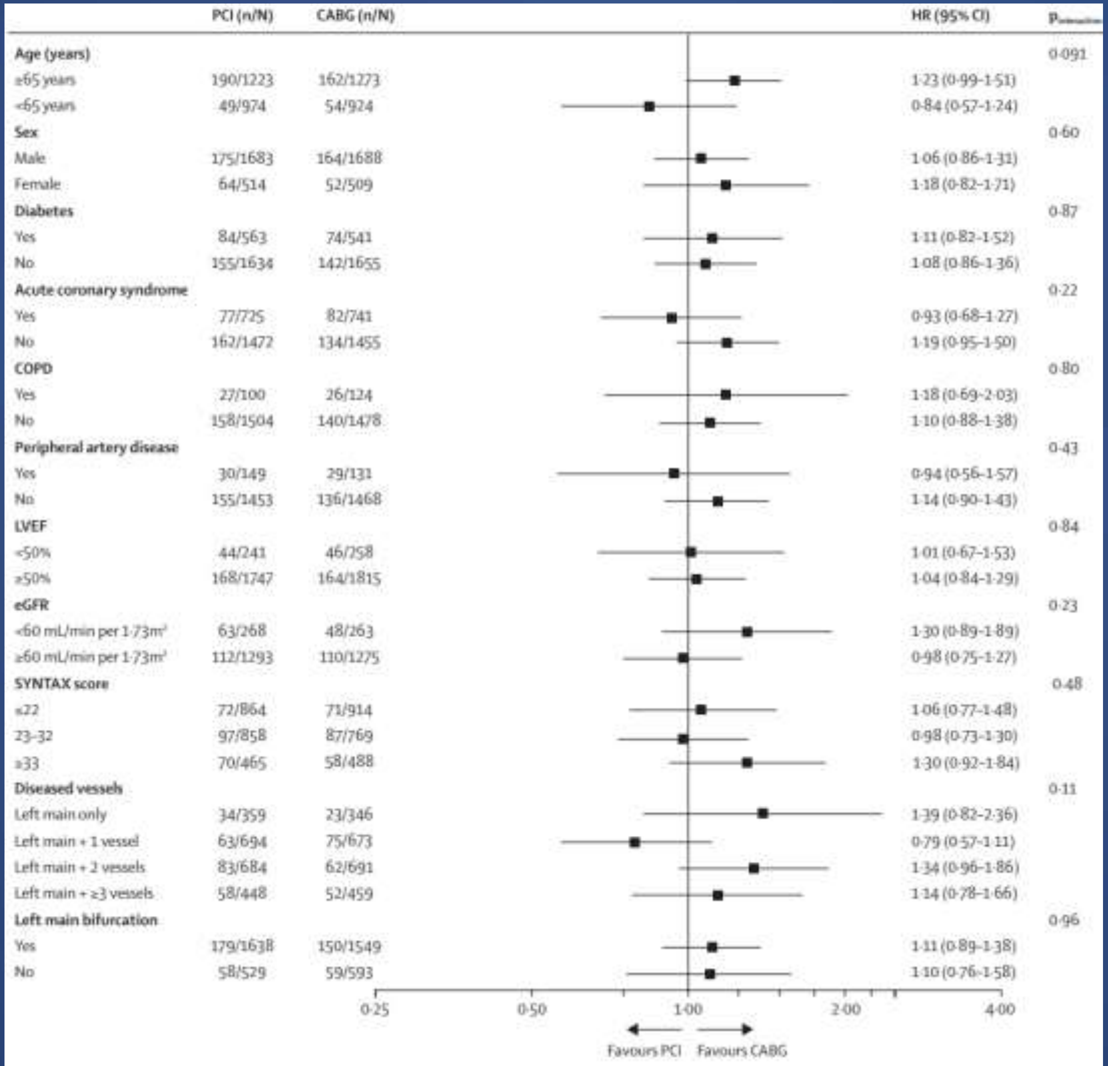
all-cause death (1-5Yr)



Sabatine et al. Lancet 2021;398:2247-57

PCI vs. CABG for Left Main Disease

Individual patient data meta-analysis : **SYNTAX, PRECOMBAT, NOBLE, EXCEL**

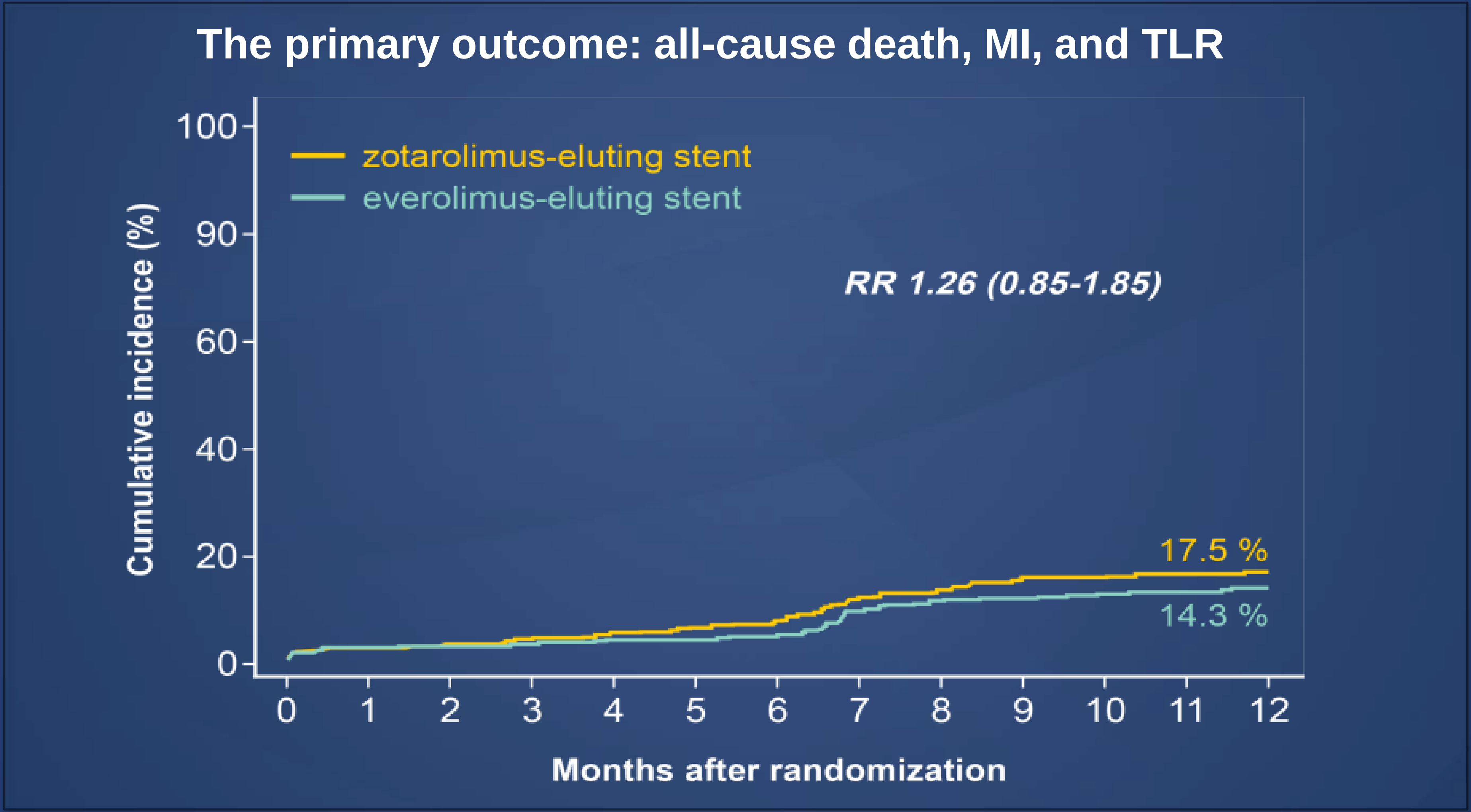


Sabatine et al. Lancet 2021;398:2247-57

LM : DES vs. DES

ISAR-LEFT MAIN 2

ZES vs. EES

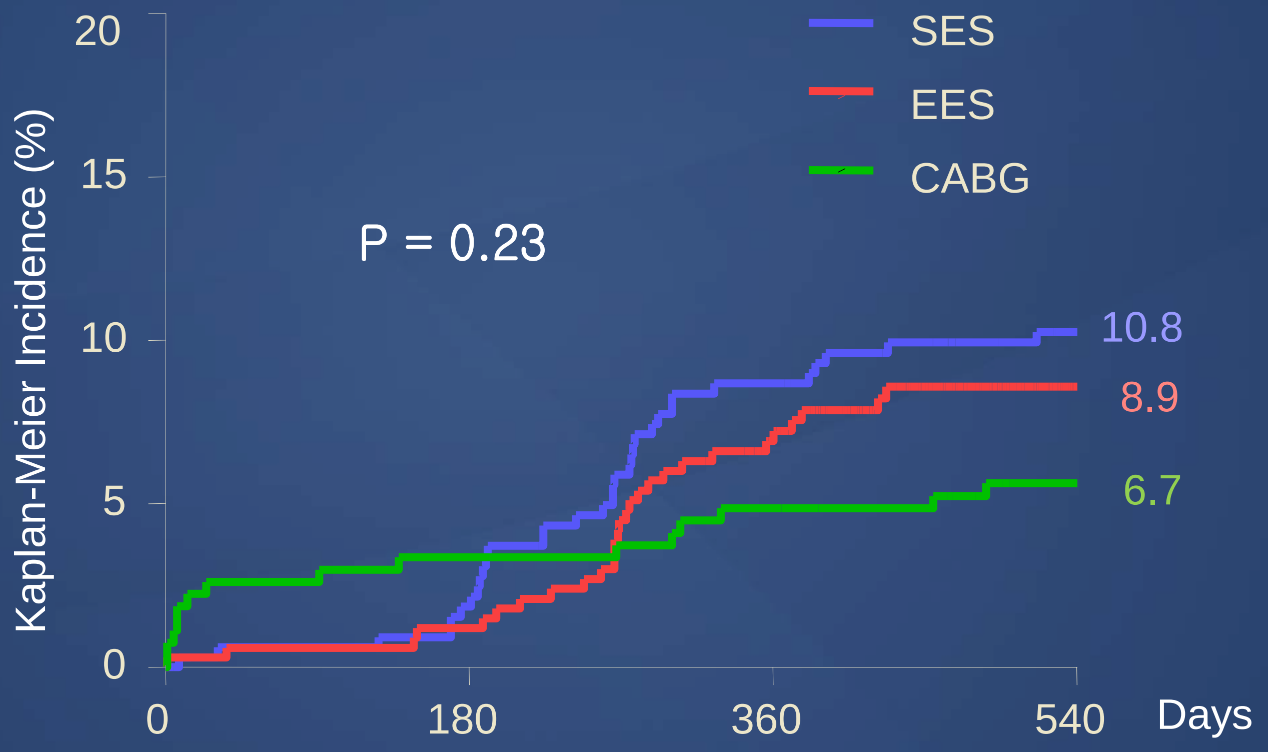


Mehilli et al. JACC, 2013

PRECOMBAT-2 Study

EES vs. SES

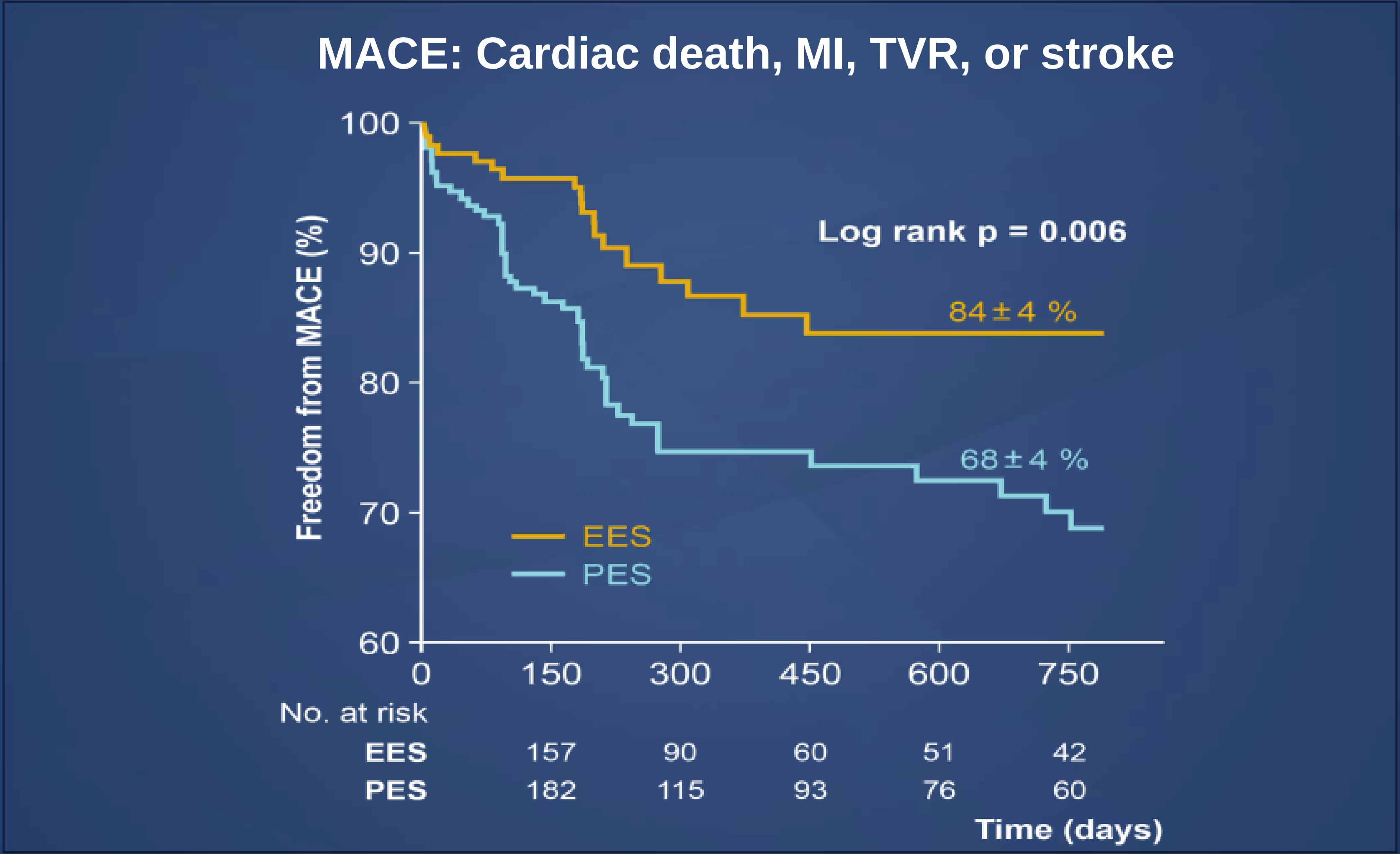
Primary end point: Major adverse cardiac or cerebrovascular event



At risk			
SES	327	294	275
EES	334	297	176
CABG	272	253	241

Park SJ et al. JACC Cardiovasc Interv., 2012

The ULMD Florence registry
EES vs. PES

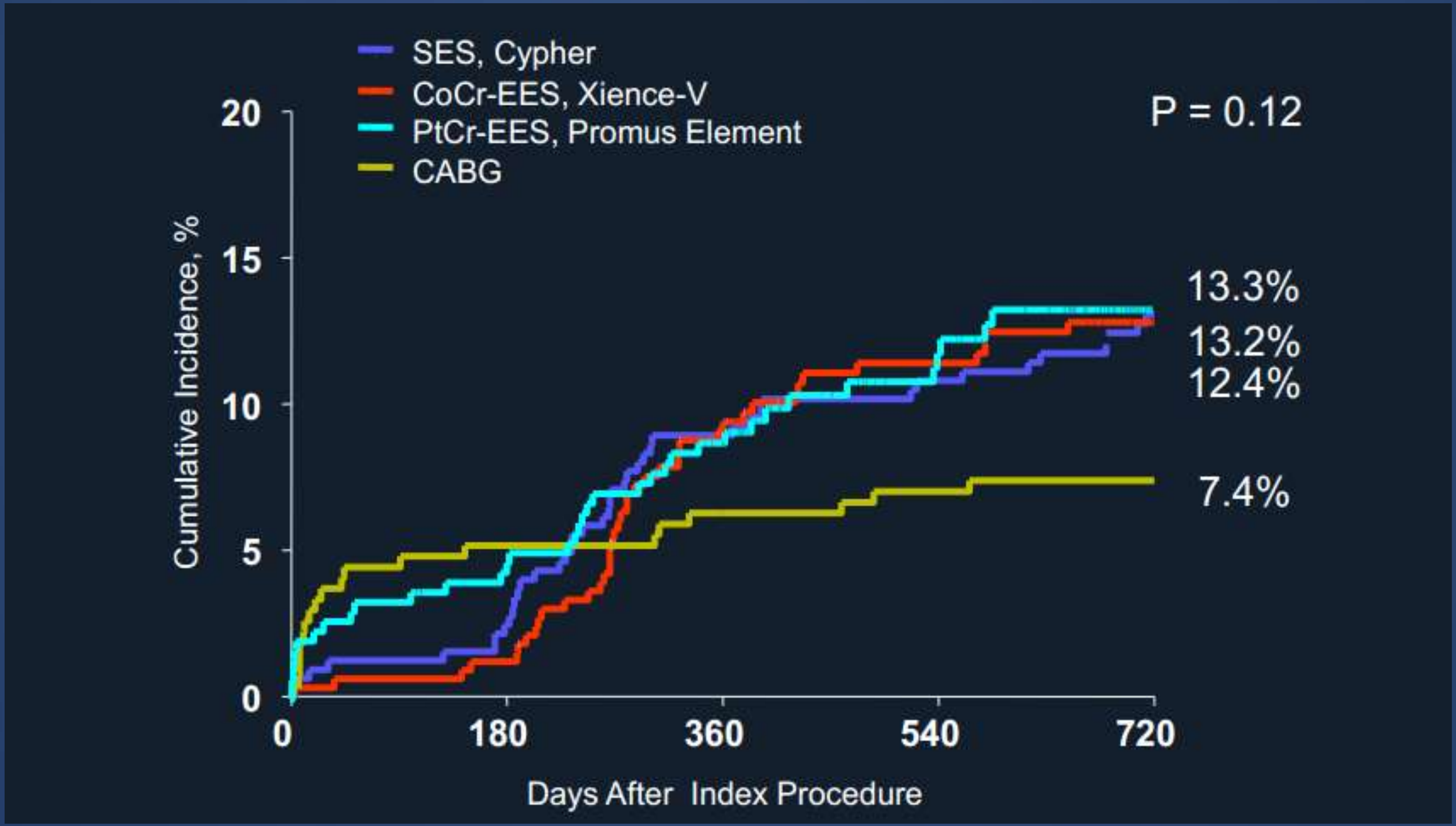


Valeni et al. JACC, 2012

PRECOMBAT-3, 2 Year

EEE vs. SES

Death, MI, Stroke or Ischemic TVR

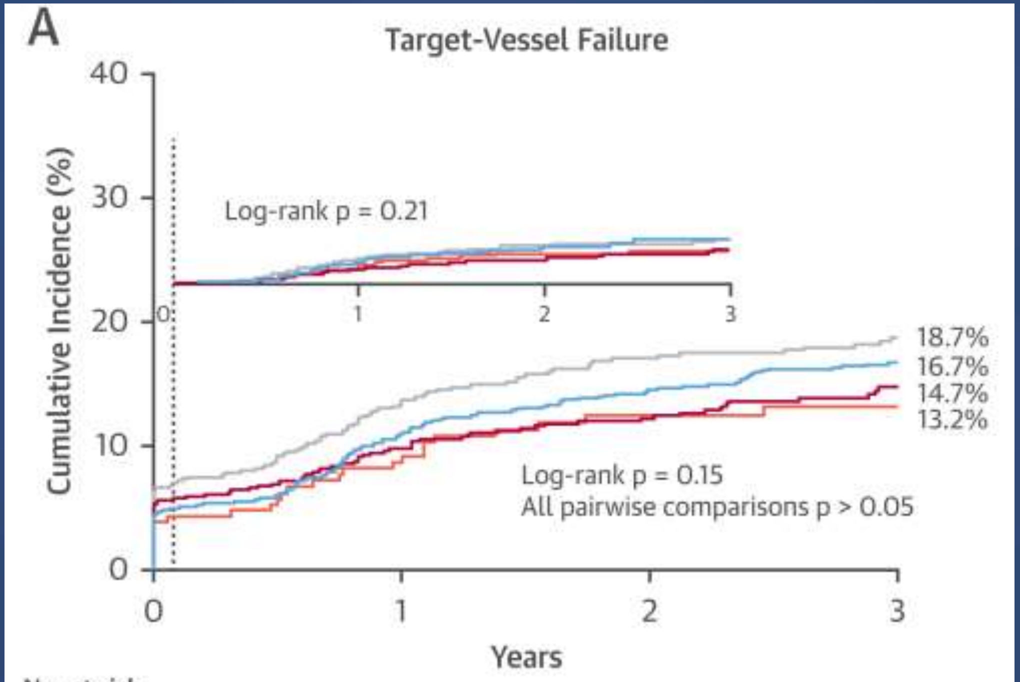


Unpublished Data. 2014

IRIS-MAIN Registry

Comparison of 2nd generation DES

Target vessel failure: Cardiac death, Target vessel MI, or TVR



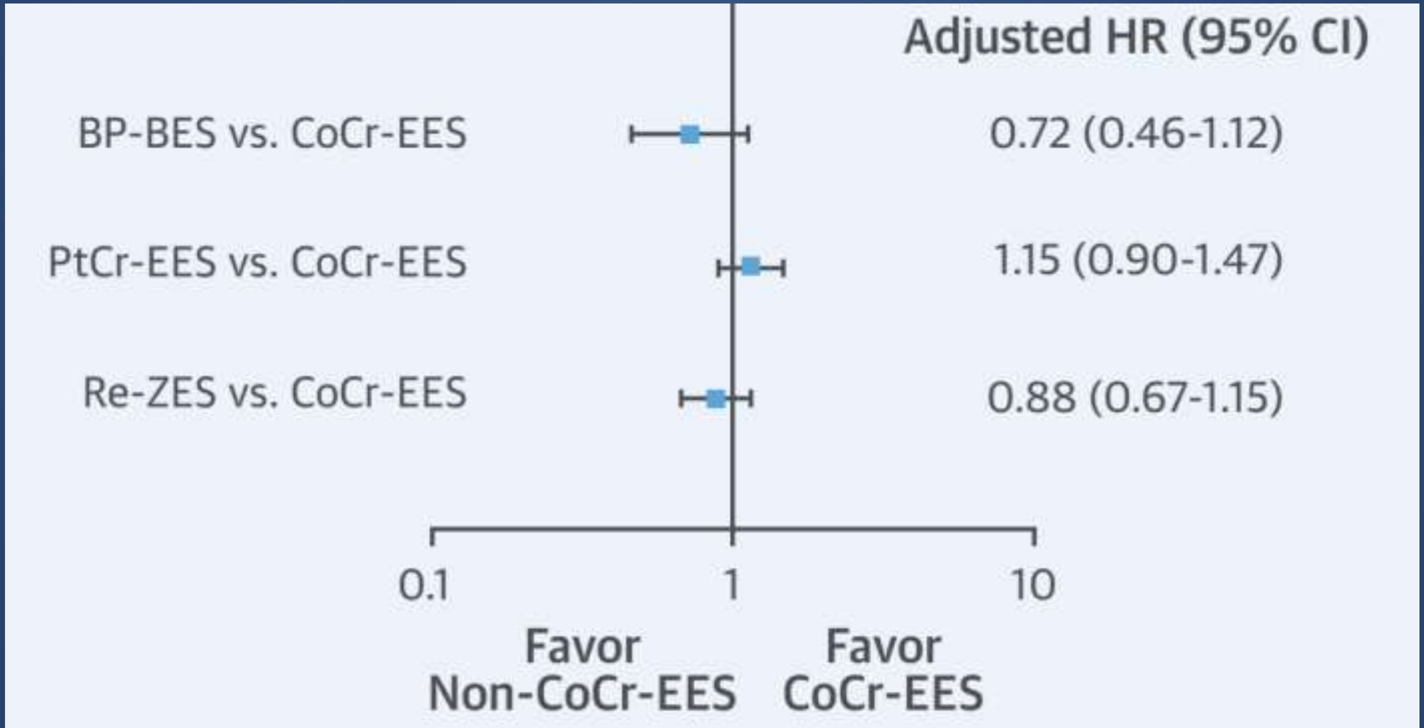
No. at risk	0	1	2	3
CoCr-EES	1254	919	758	586
BP-BES	232	175	147	91
PtCr-EES	616	456	388	308
Re-ZES	590	507	418	238

PH Lee et al. JACC 2018;71:832-41.

IRIS-MAIN Registry

Comparison of 2nd generation DES

Target vessel failure: Cardiac death, Target vessel MI, or TVR



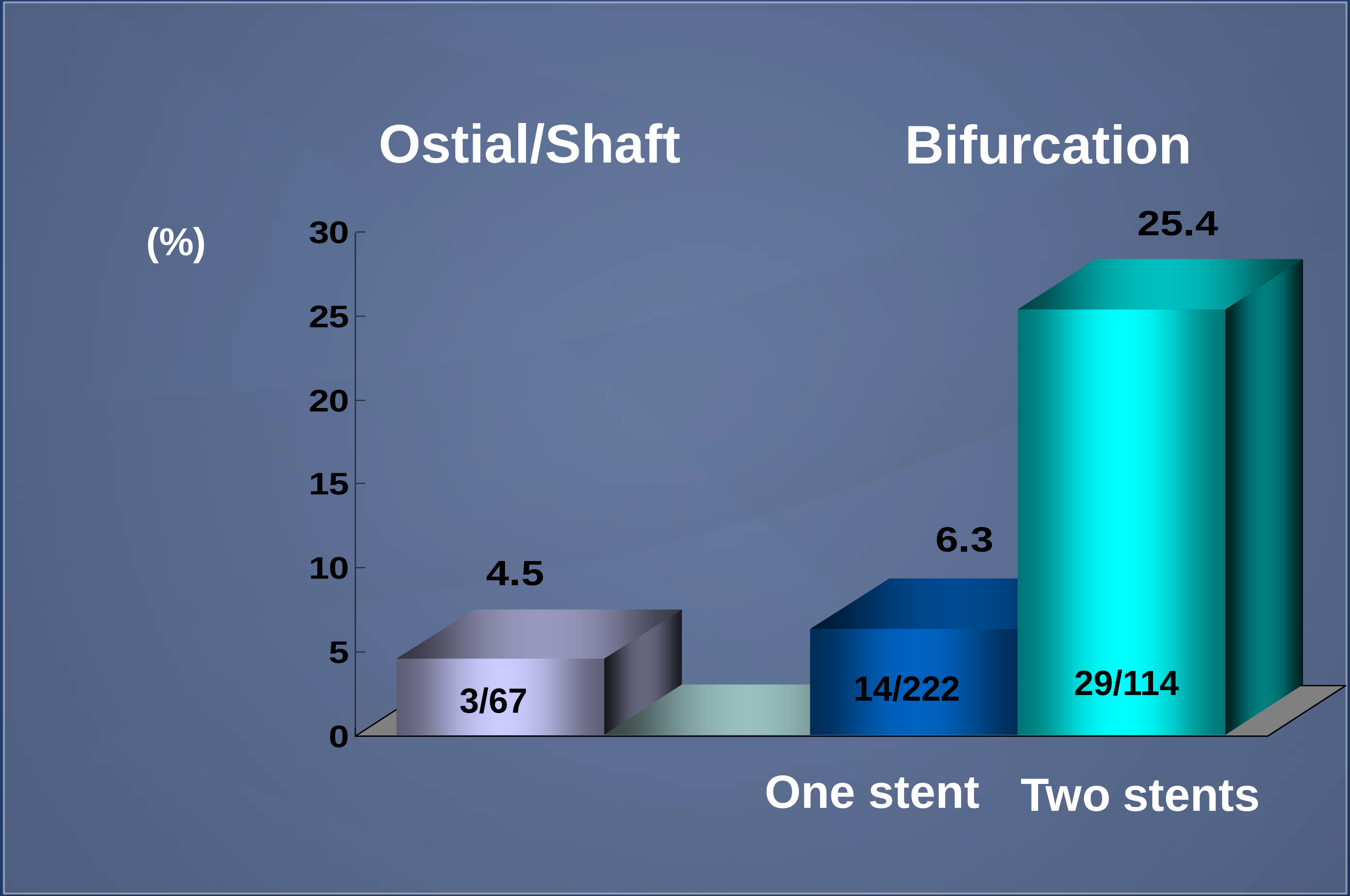
PH Lee et al. JACC 2018;71:832-41.

Distal bifurcation

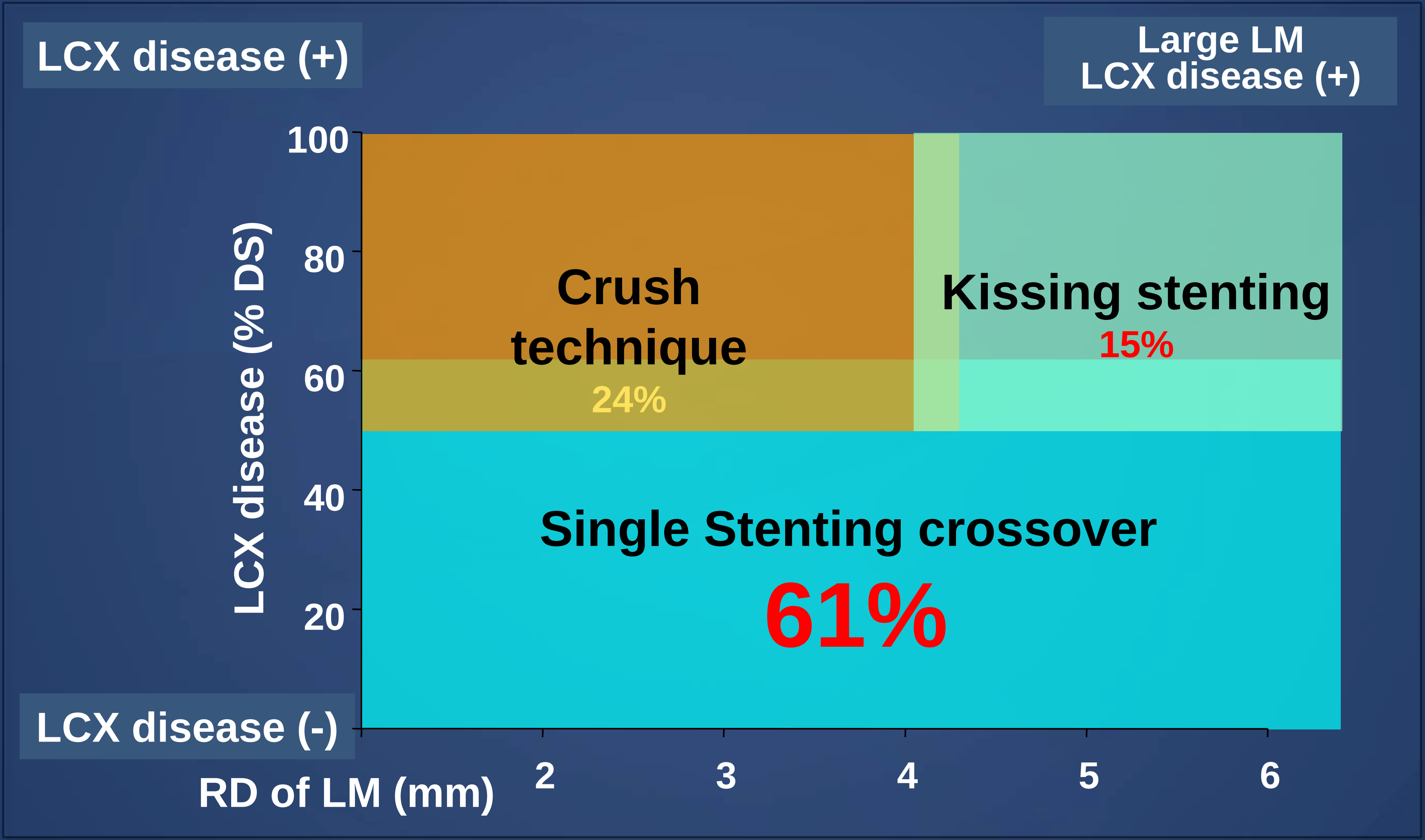
vs.

Ostial / Shaft lesion

Restenosis at 2 year



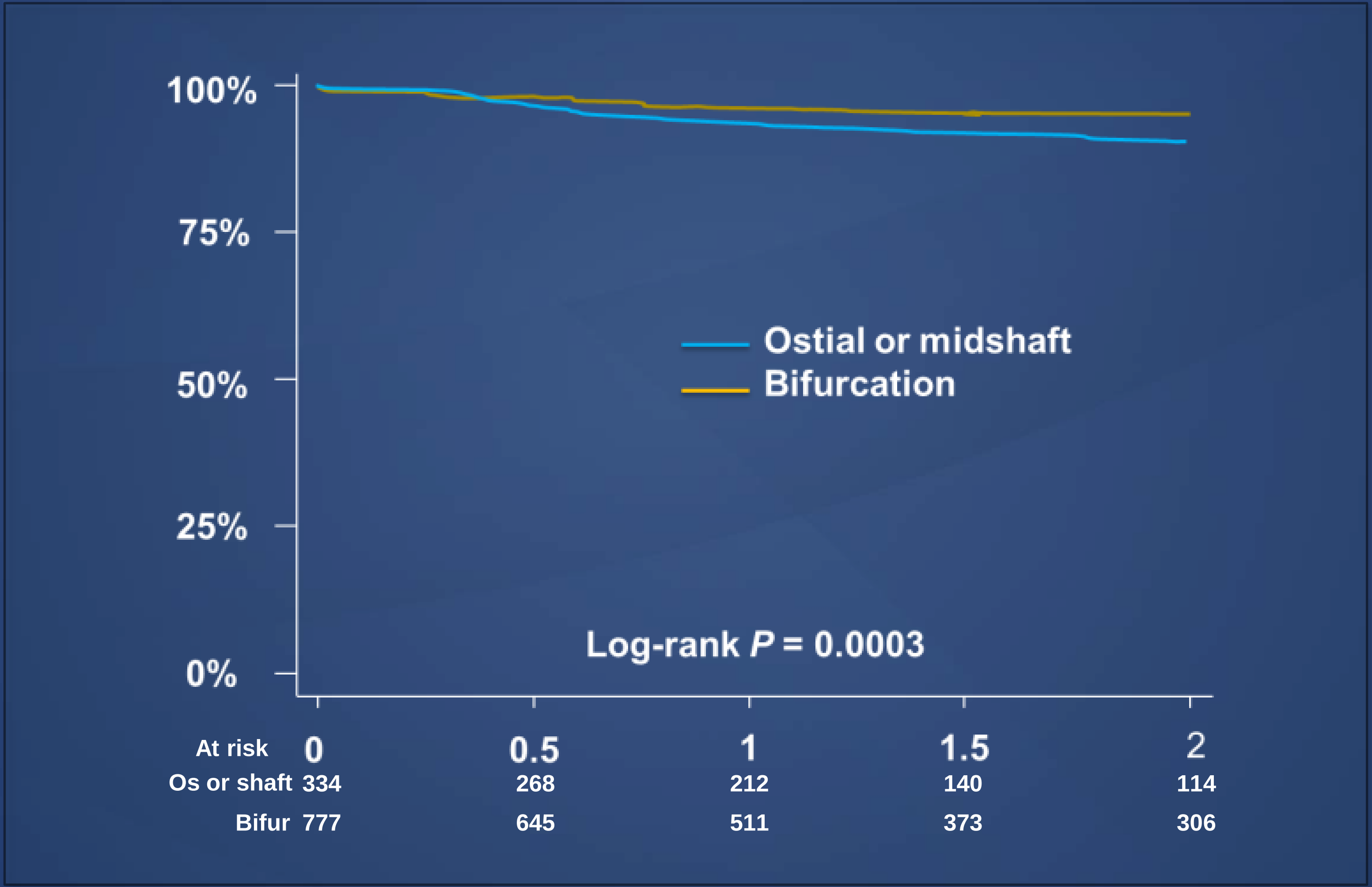
Lesion Specific Approach for LM Bifurcation



Data from MAIN-COMPARE Registry

Bifurcation vs. Ostial / midshaft lesions

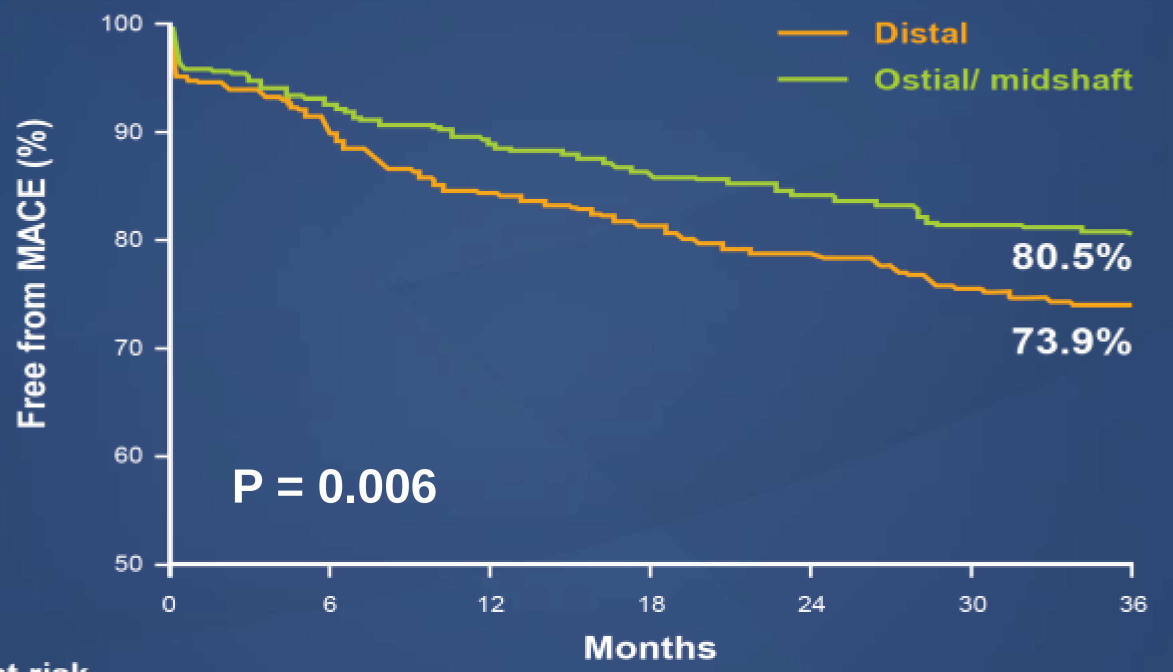
TLR :Treated with DES



T. Palmerini et al. EHJ, 2009

Distal bifurcation vs. Ostial/midshaft

A subgroup of *DELTA* registry - propensity score-matched groups
(Distal bifurcation N=1130, Ostial/mid-shaft N=482)



Number at risk

Distal	368	331	308	287	271	245	224
Ostial/ midshaft	368	339	323	295	285	264	248

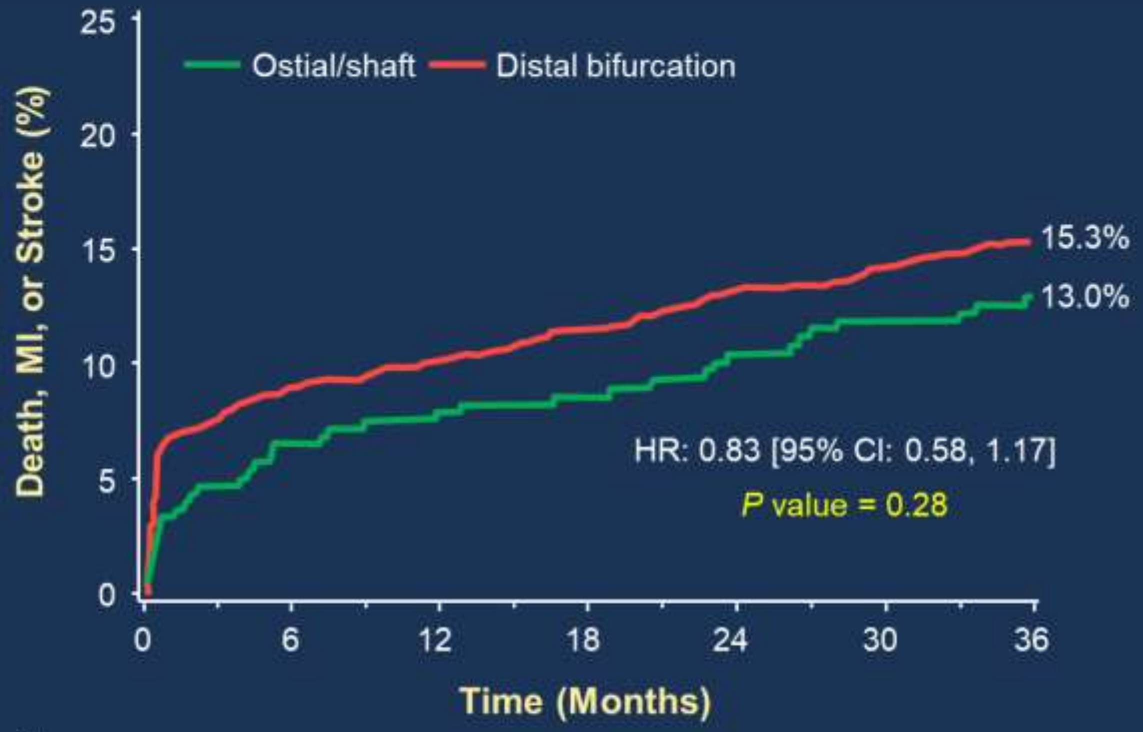
PCI for ostial/mid-shaft lesions was associated with better outcomes than distal bifurcation lesions in LM stenting.

Naganuma et al. JACC Cardiovasc Interv, 2013

Distal bifurcation vs. Ostial/midshaft

Post-hoc analysis of EXCEL Trial
(Distal bifurcation N=1559, Ostial/mid-shaft N=293)

Primary Endpoint: Death, MI or Stroke



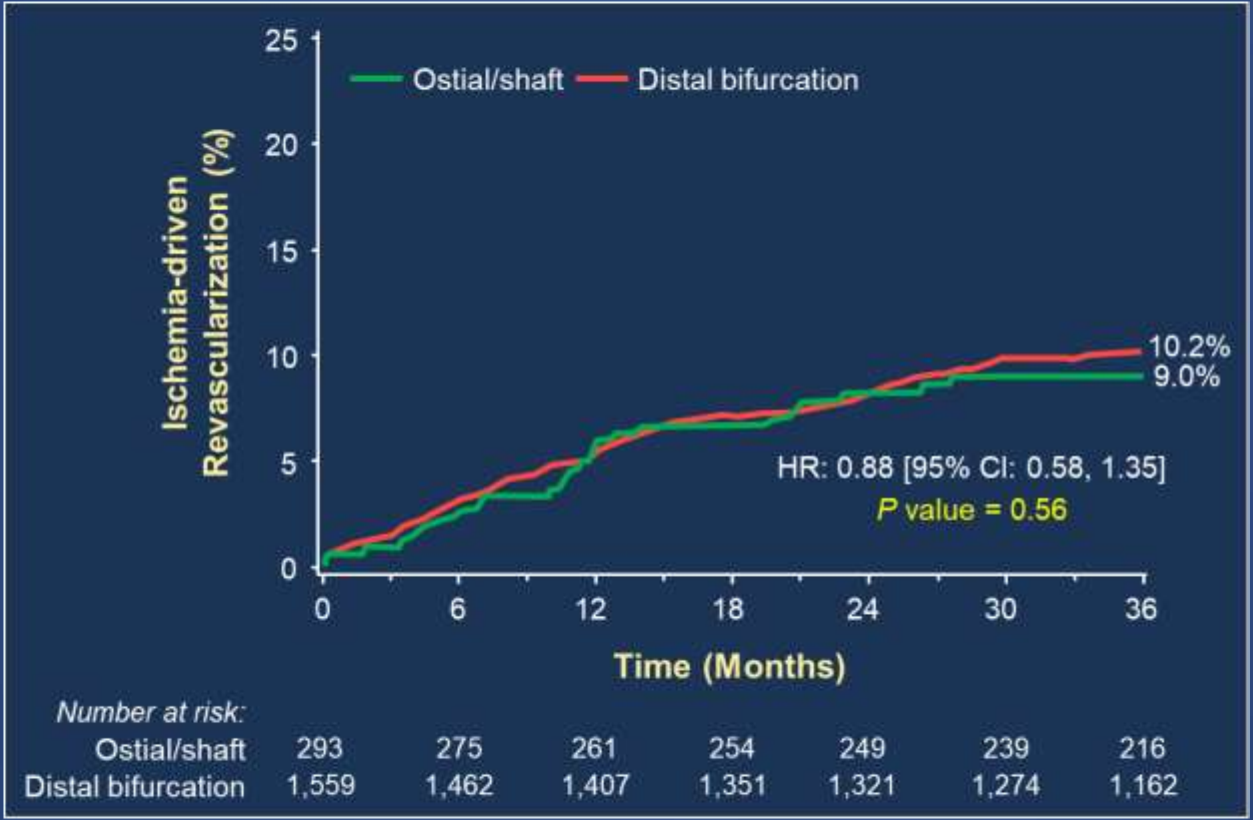
Number at risk:							
Ostial/shaft	293	269	262	258	253	244	219
Distal bifurcation	1,559	1,401	1,373	1,335	1,307	1,277	1,157

Gershlick AH et al., JACC Cardiovasc Interv, 2017

Distal bifurcation vs. Ostial/midshaft

Post-hoc analysis of EXCEL Trial
(Distal bifurcation N=1559, Ostial/mid-shaft N=293)

Ischemia-driven Revascularization

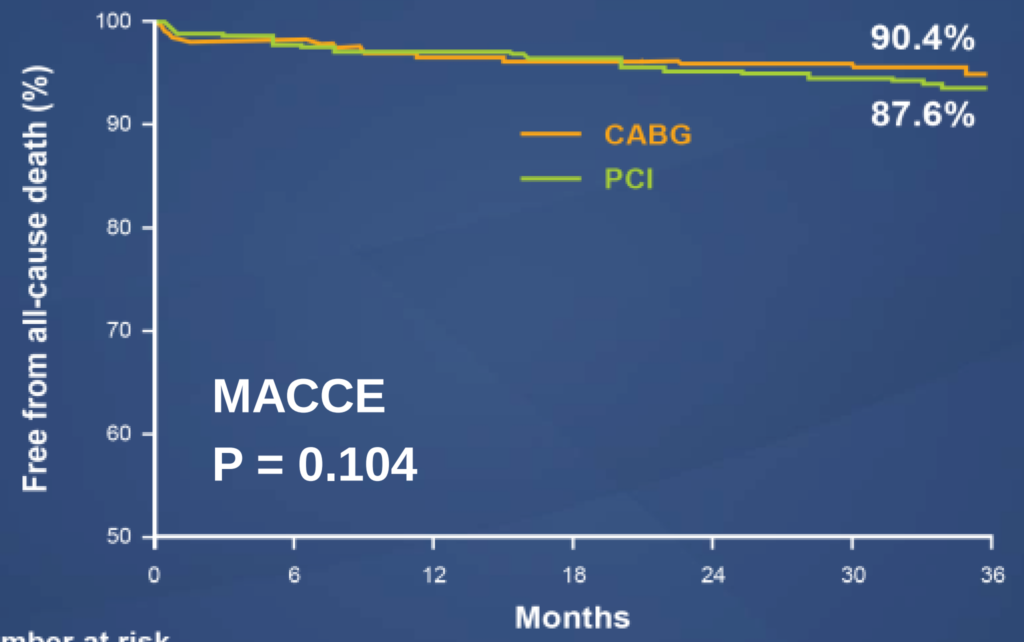


Gershlick AH et al., JACC Cardiovasc Interv, 2017

PCI vs. CABG for Ostial/Midshaft LM stenosis

A subgroup of *DELTA* registry (PCI, 482; CABG, 374 patients)

The results of propensity score-matched groups

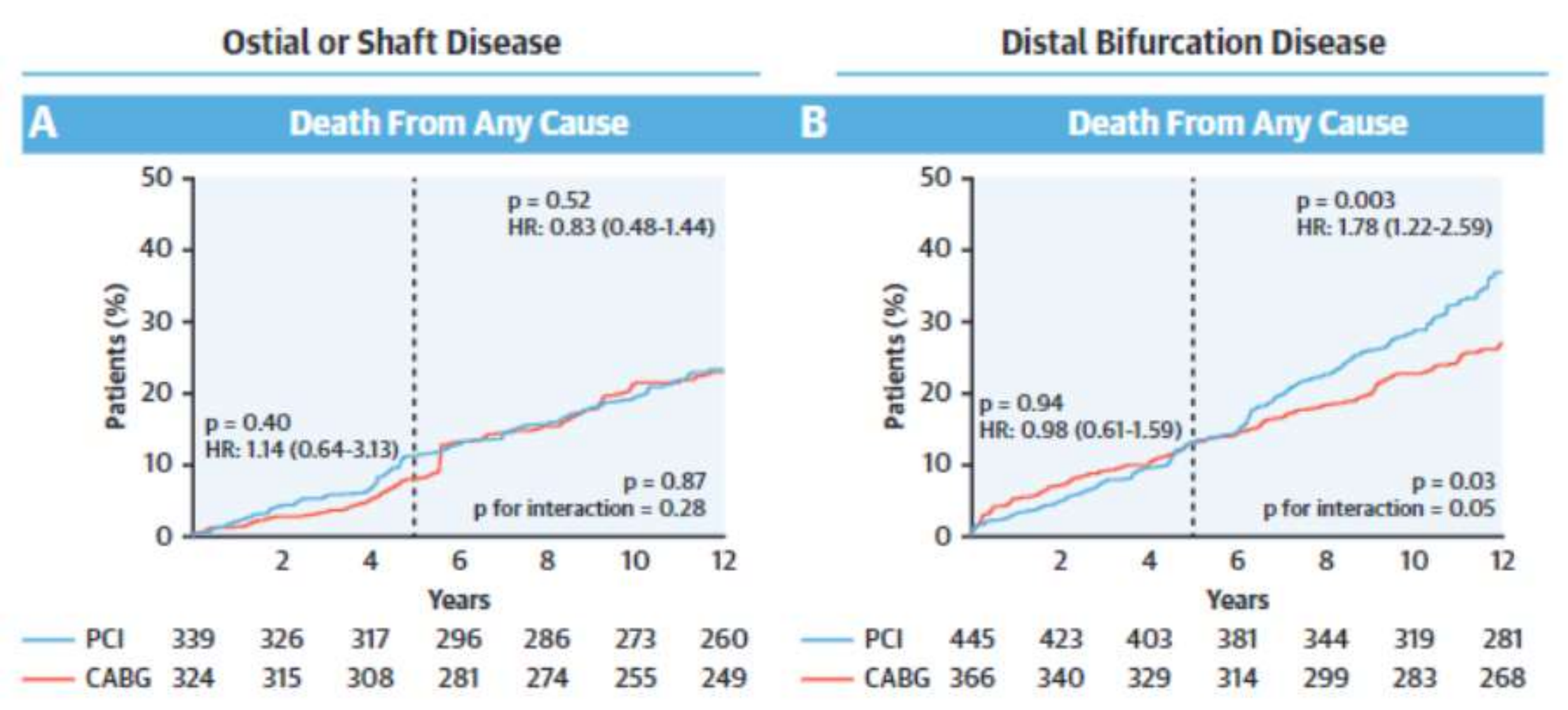


Number at risk							
CABG	209	187	180	163	150	142	134
PCI	209	201	194	178	169	156	135

PCI for ostial/midshaft lesions was associated with clinical outcomes comparable to those observed with CABG

Naganuma et al. JACC Cardiovasc Interv, 2014

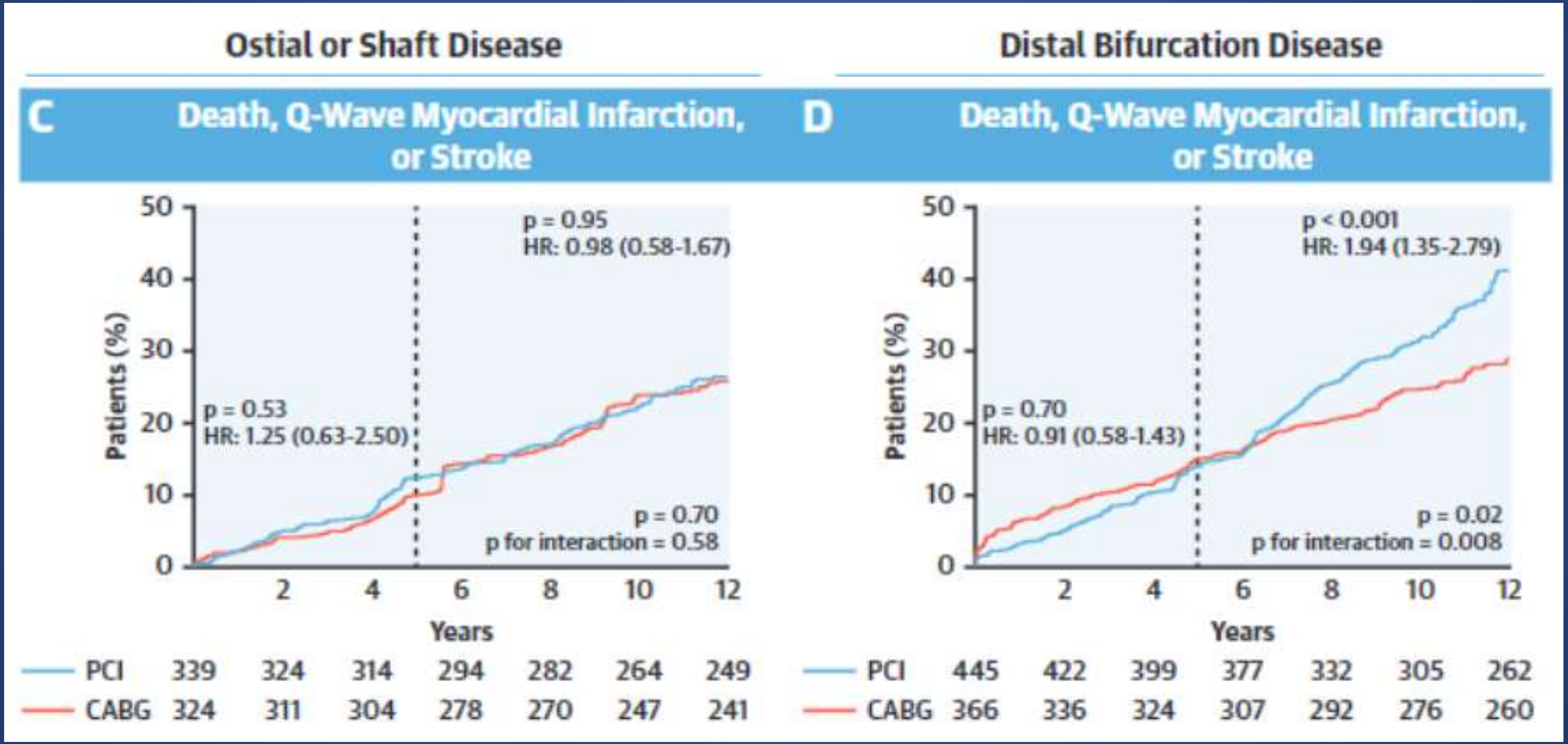
DES vs. CABG
for LM Ostial/Shaft & Bifurcation
MAIN-COMPARE registry



Hyun et al, JACC Intv, 2020

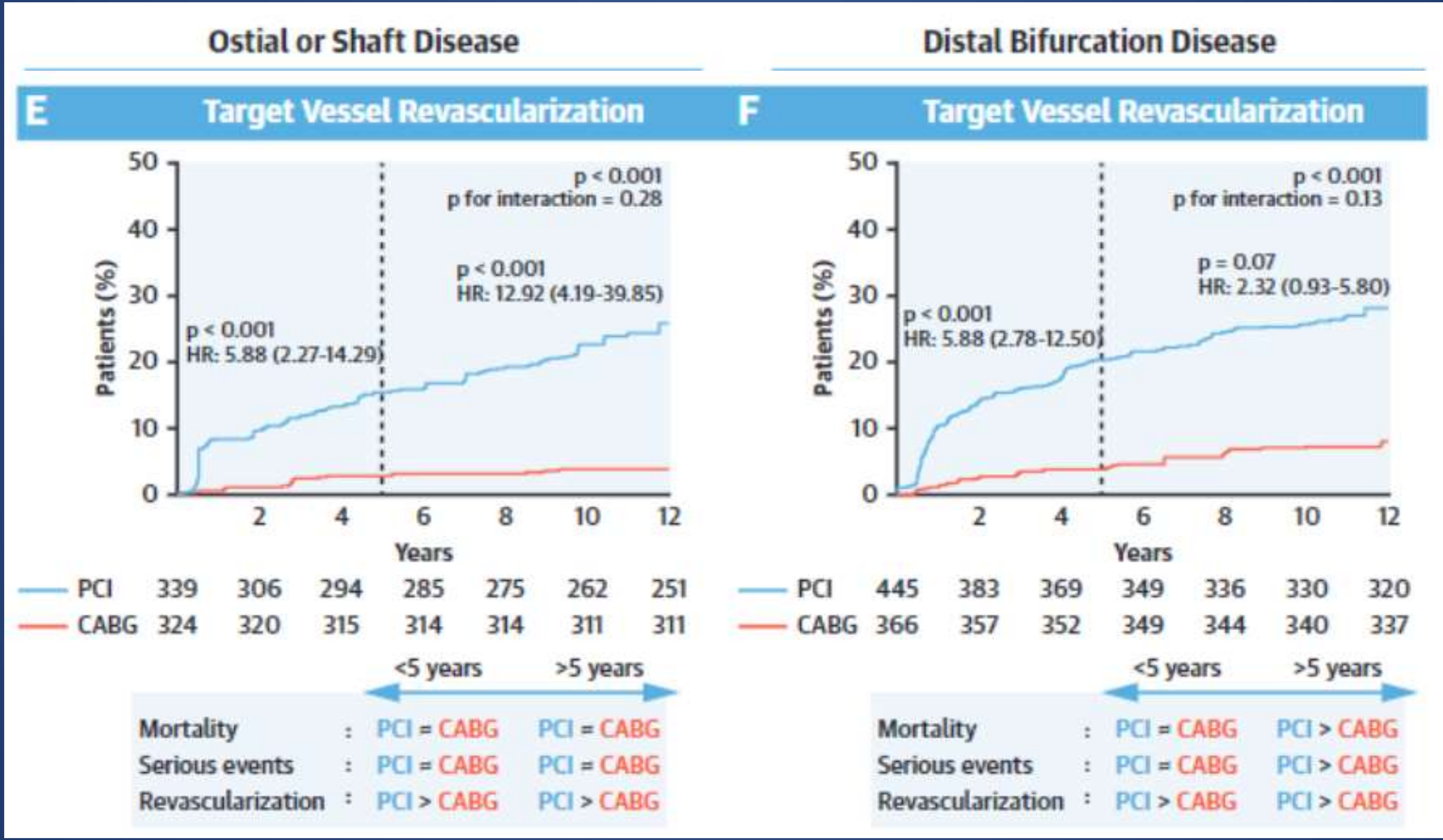
DES vs. CABG
for LM Ostial/Shaft & Bifurcation

MAIN-COMPARE registry



Hyun et al, JACC Intv, 2020

DES vs. CABG
for LM Ostial/Shaft & Bifurcation



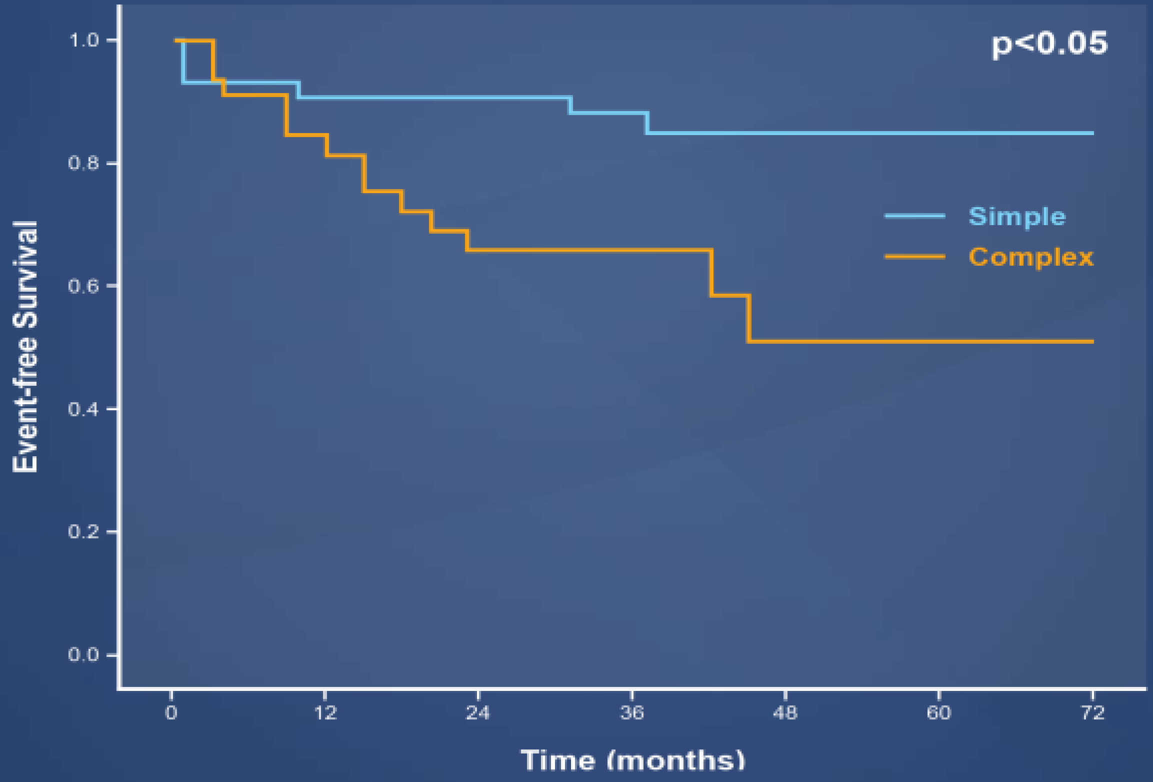
Hyun et al, JACC Intv, 2020

Distal LM Restenosis

UDLM-ISR subgroup of The *CORPAL* Registry (N=79)

Simple: POBA or in-stent implantation

Complex: 1 additional stent implantation or 2-stenting technique

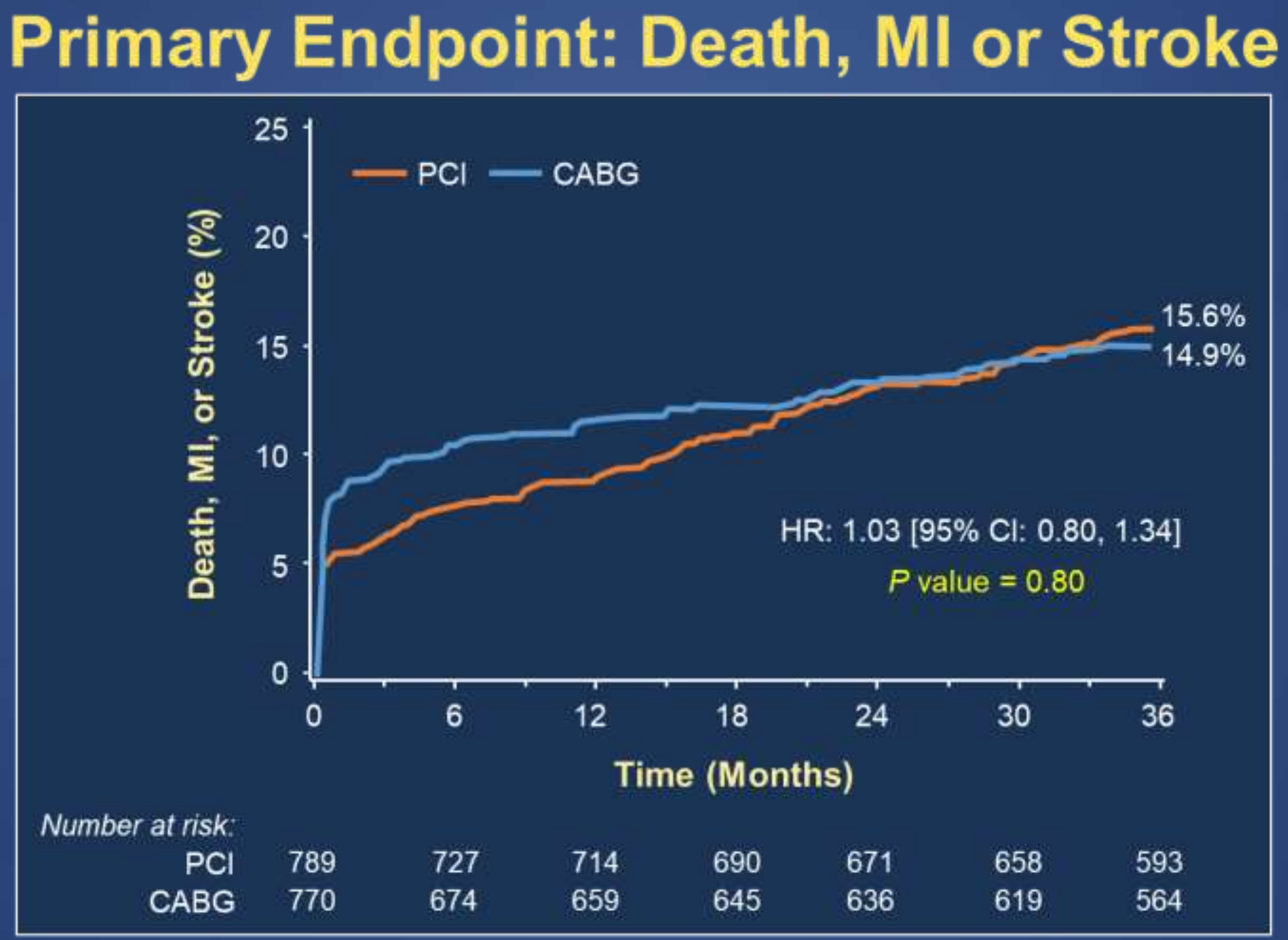


A simple strategy appeared to be a good treatment option, associated with a lower event rate at follow-up.

Ojeda et al. JACC Cardiovasc Interv, 2014

PCI vs. CABG for Distal Bifurcation LM stenosis

Post-hoc analysis of EXCEL Trial
(Distal bifurcation N=1559, Ostial/mid-shaft N=293)



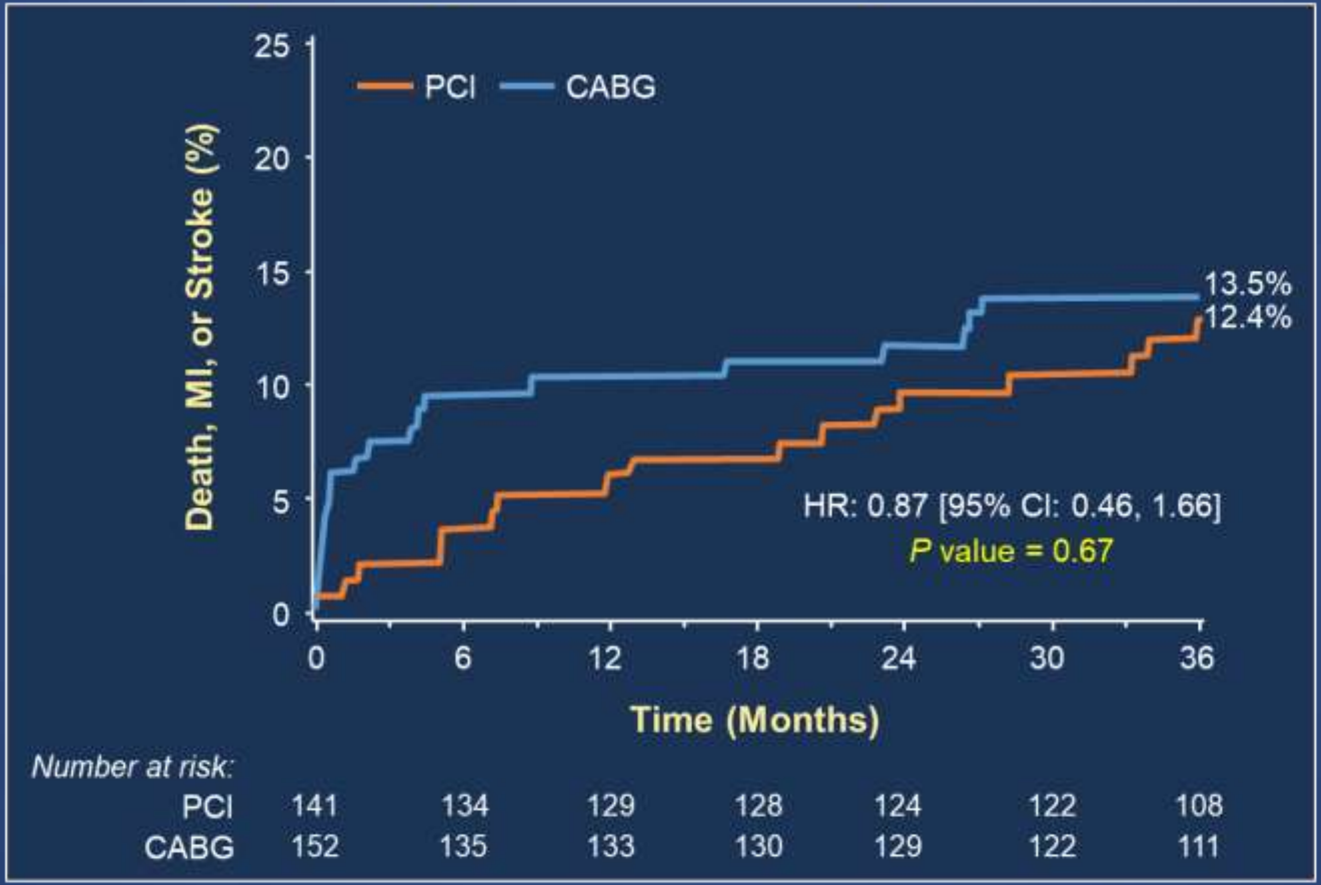
Gershlick AH et al., JACC Cardiovasc Interv, 2017

PCI vs. CABG for Ostial/Midshaft LM stenosis

Post-hoc analysis of EXCEL Trial

(Distal bifurcation N=1559, Ostial/mid-shaft N=293)

Primary Endpoint: Death, MI or Stroke



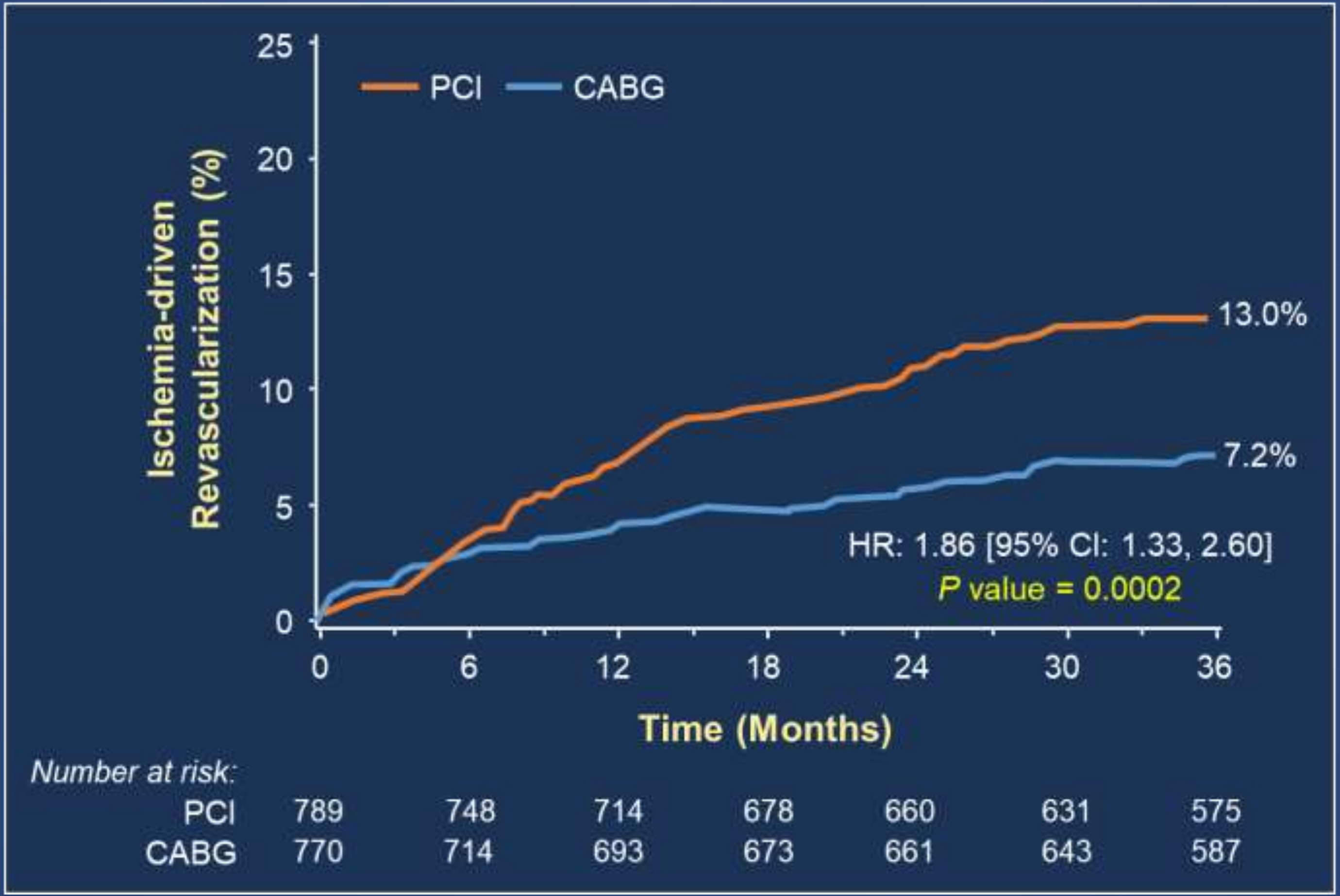
Gershlick AH et al., JACC Cardiovasc Interv, 2017

PCI vs. CABG for Distal Bifurcation LM stenosis

Post-hoc analysis of EXCEL Trial

(Distal bifurcation N=1559, Ostial/mid-shaft N=293)

Ischemia-driven Revascularization



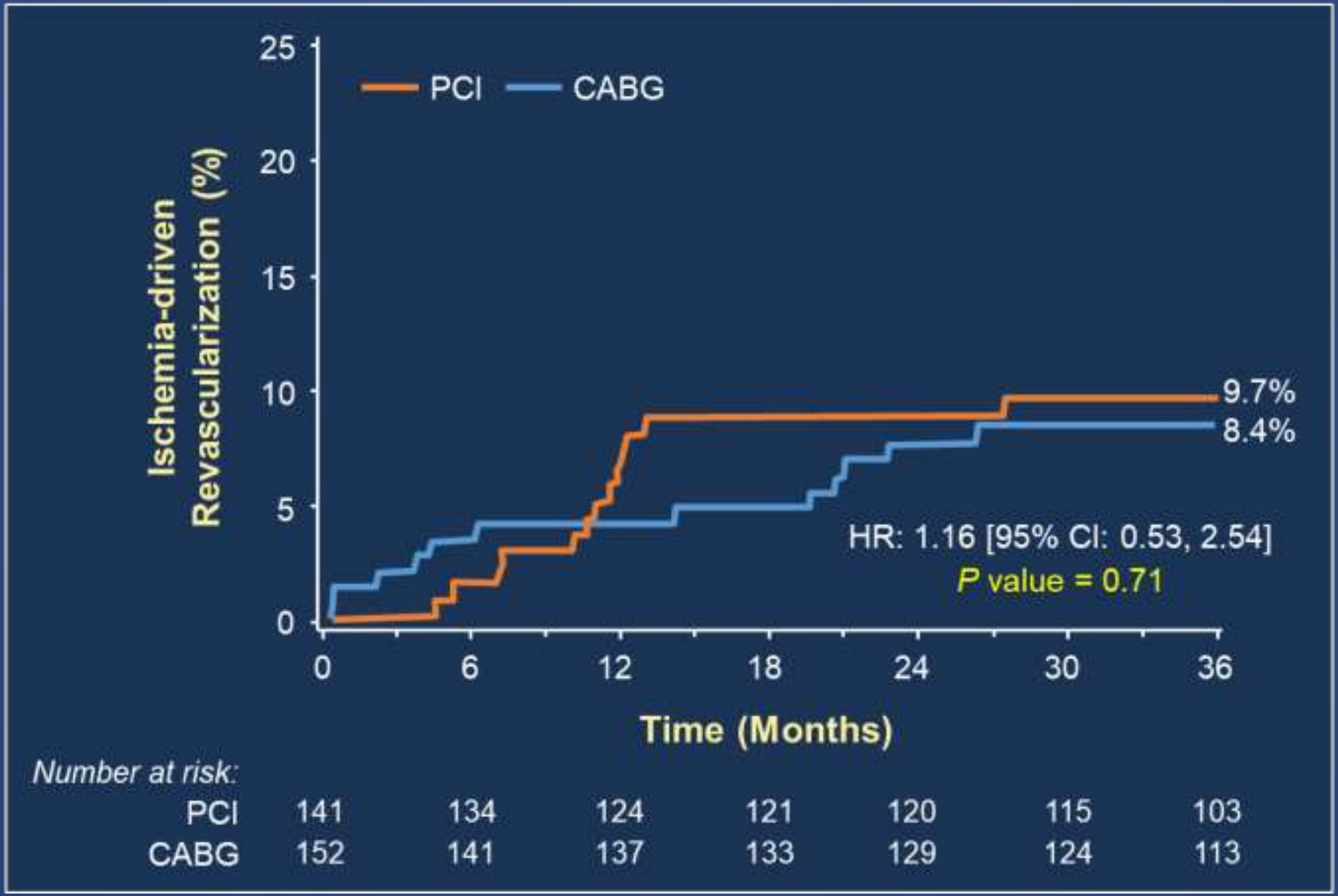
Gershlick AH et al., JACC Cardiovasc Interv, 2017

PCI vs. CABG for Ostial/Midshaft LM stenosis

Post-hoc analysis of EXCEL Trial

(Distal bifurcation N=1559, Ostial/mid-shaft N=293)

Ischemia-driven Revascularization



Gershlick AH et al., JACC Cardiovasc Interv, 2017

Mortality after LM reintervention

ISAR-LEFT-MAIN and ISAR-LEFT-MAIN2 registry

TABLE 2 Procedural Findings at the Index Procedure

	Alive (n = 119)	Dead (n = 47)	p Value
Location of left main lesion			0.88
Ostial	8.4 (10/119)	8.5 (4/47)	
Distal/bifurcation	81.5 (97/119)	78.7 (37/47)	
Body	10.1 (12/119)	12.8 (6/47)	
Occluded right coronary artery	9.2 (11/119)	14.9 (7/47)	0.29
Trifurcation morphology	14.3 (17/119)	10.6 (5/47)	0.53
Stenting technique			0.26
Single	45.4 (54/119)	57.4 (27/47)	
T-stenting	10.1 (12/119)	4.3 (2/47)	
Culotte stenting	44.5 (53/119)	38.3 (18/47)	
Kissing balloon technique	55.5 (66/119)	34.0 (16/47)	0.01
Coronary artery dominance			0.49
Left	8.4 (10/119)	10.6 (5/47)	
Right	82.4 (98/119)	74.5 (35/47)	
Balanced	9.2 (11/119)	14.9 (7/47)	
Stent type			0.02
Sirolimus-eluting stent	29.4 (35/119)	8.5 (4/47)	
Zotarolimus-eluting stent	27.7 (33/119)	44.7 (21/47)	
Paclitaxel-eluting stent	17.6 (21/119)	23.4 (11/47)	
Everolimus-eluting stent	25.2 (30/119)	23.4 (11/47)	

Values are % (n/N).

TABLE 3 Mortality After Target Lesion Revascularization According to Lesion Location and Revascularization Strategy

	Mortality at 3 Years	Mortality at 5 Years	p Value
Lesion location			0.90
Ostial	14.3 (2)	31.8 (4)	
Distal/bifurcation	20.6 (27)	29.3 (37)	
Body	23.7 (4)	36.4 (6)	
Underlying stenting technique			0.30
Single	20.3 (16)	35.5 (27)	
T-stenting	14.9 (2)	14.9 (2)	
Culotte	21.5 (15)	26.9 (18)	
Revascularization type			0.90
CABG	18.1 (3)	24.4 (4)	
PTCA	24.1 (19)	31.5 (24)	
Stenting	16.5 (11)	29.9 (19)	

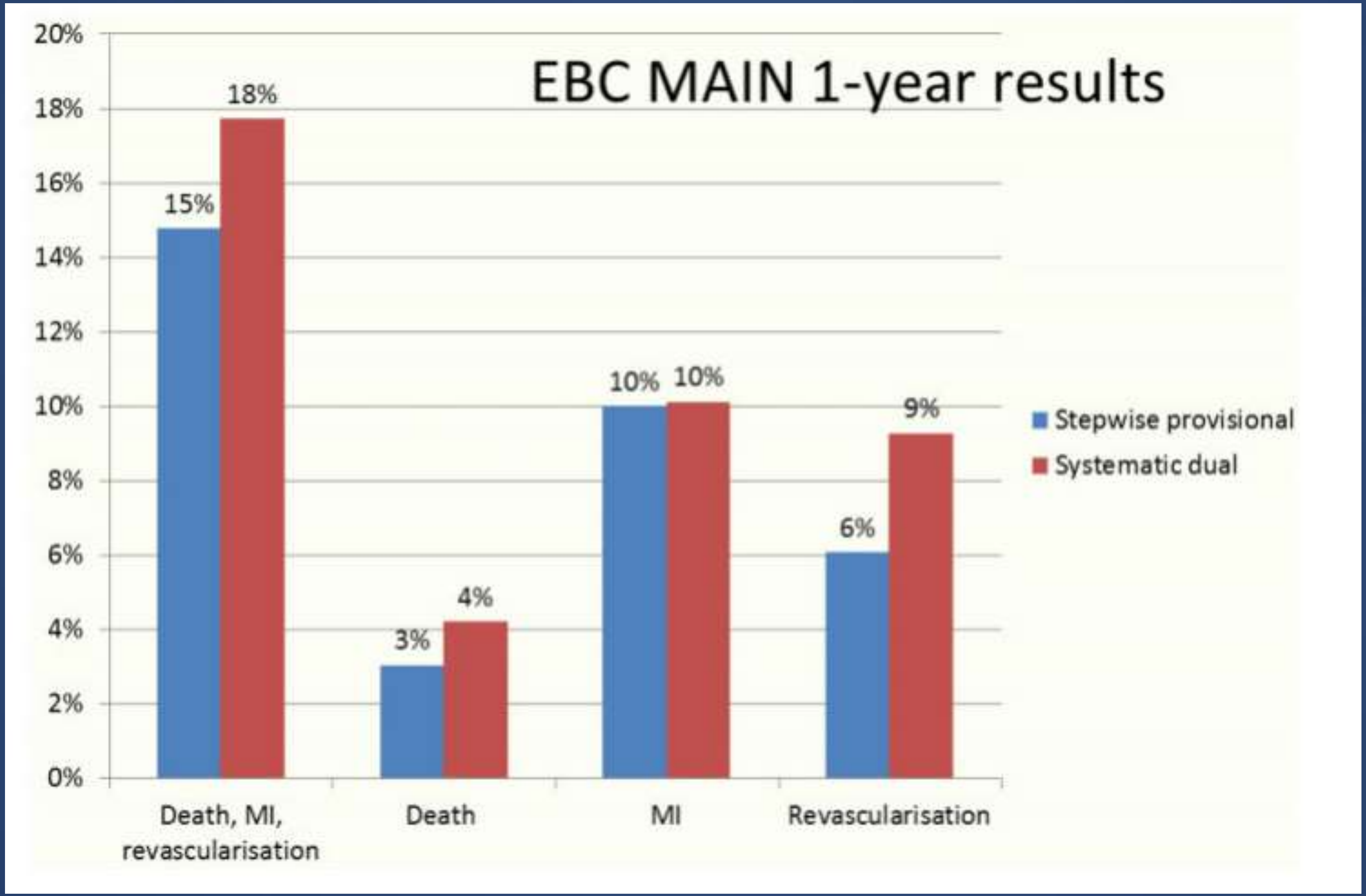
Values are % by Kaplan-Meier estimate (n).

Wiebe et al., JACC Cardiovasc Interv, 2020

Simple cross
vs.
Two-stent technique

EBC MAIN trial

LM bifurcation: 1 vs. 2 stent tech.

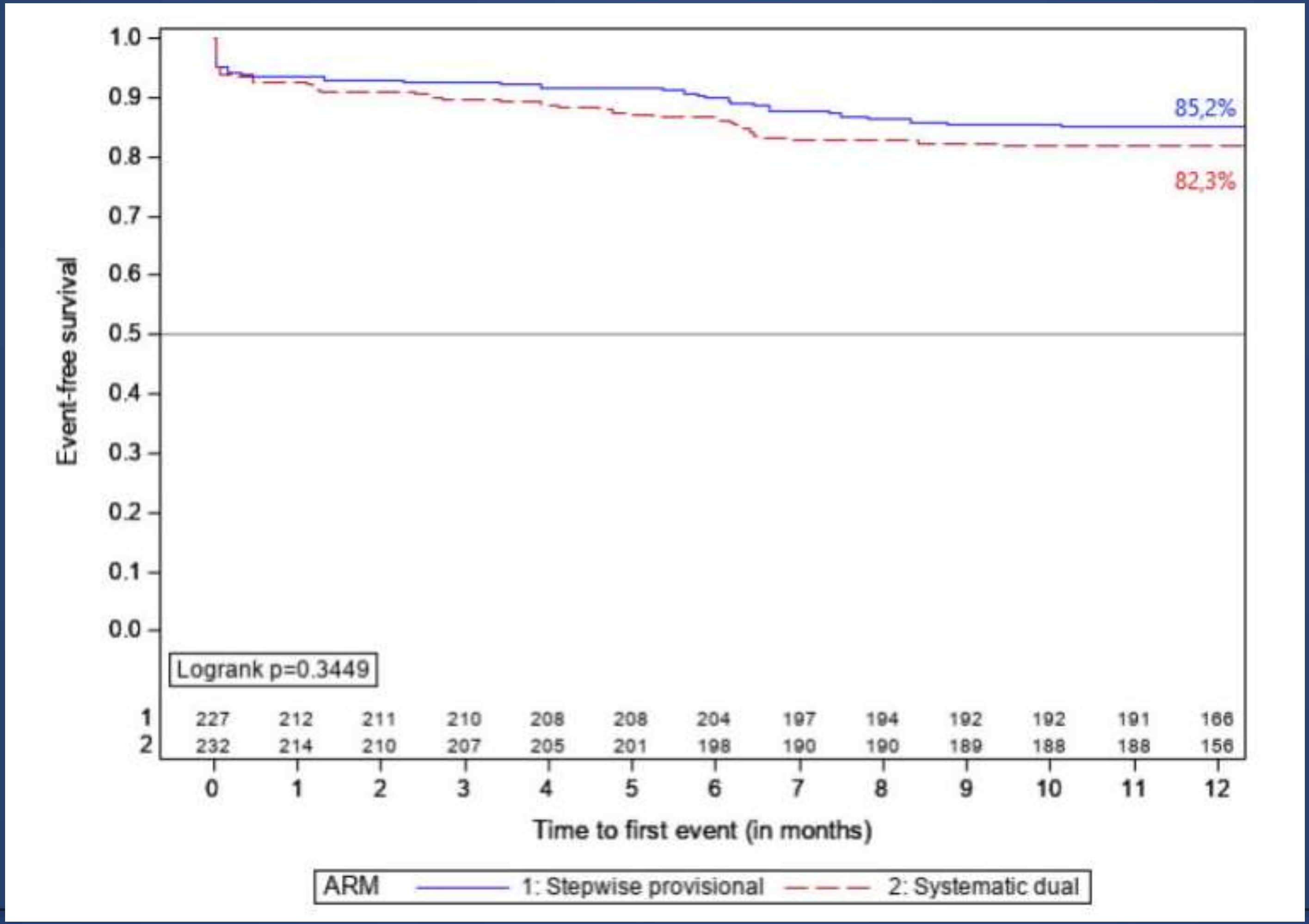


D. Hildick-Smith et al. EHJ, 2021, 24 ; 3829-3839

EBC MAIN trial

LM bifurcation: 1 vs. 2 stent tech.

Primary Endpoint : a composite of death, myocardial infarction, and target lesion revascularization at 12month

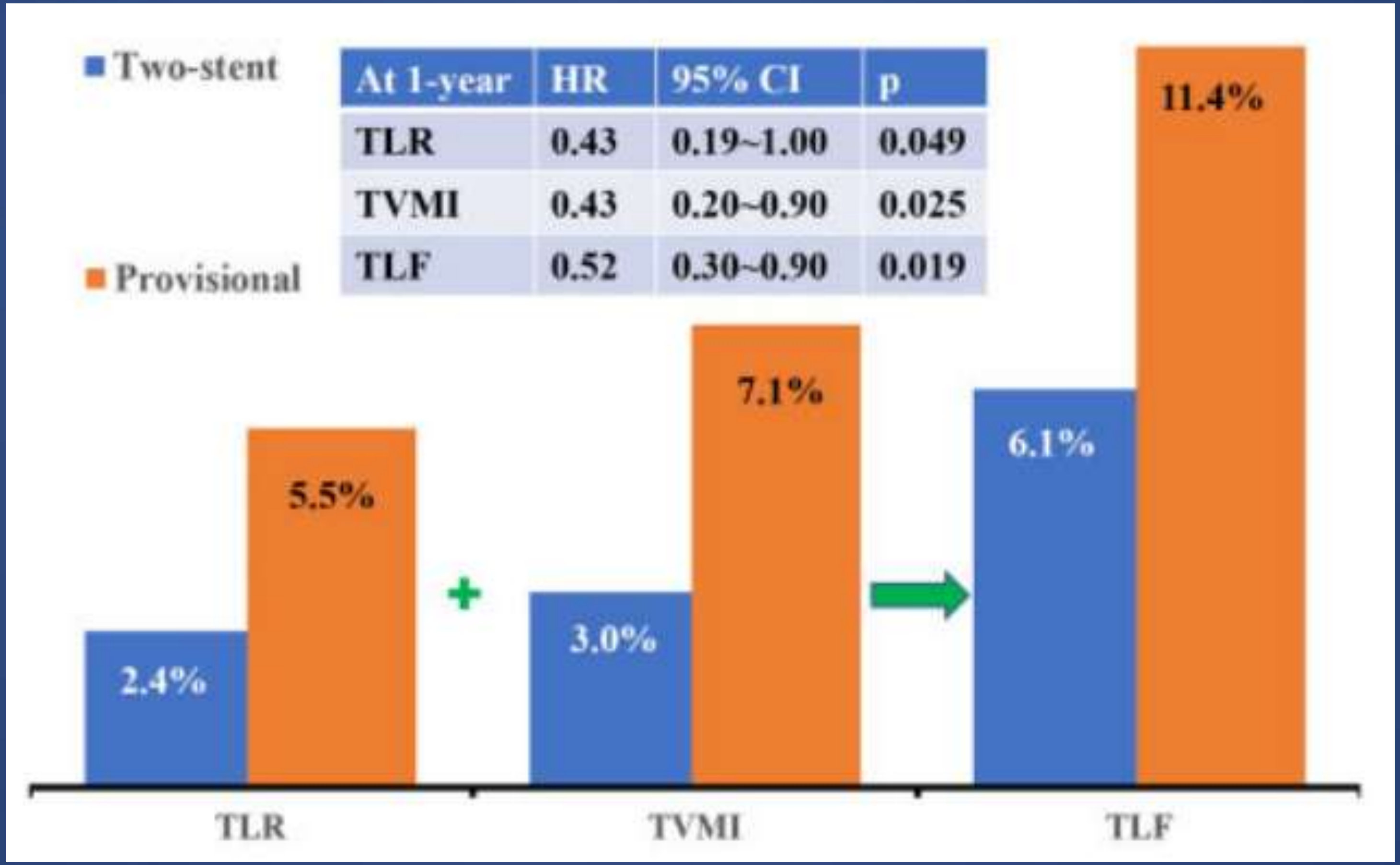


D. Hildick-Smith et al. EHJ, 2021, 24 ; 3829-3839

DEFINITION II trial

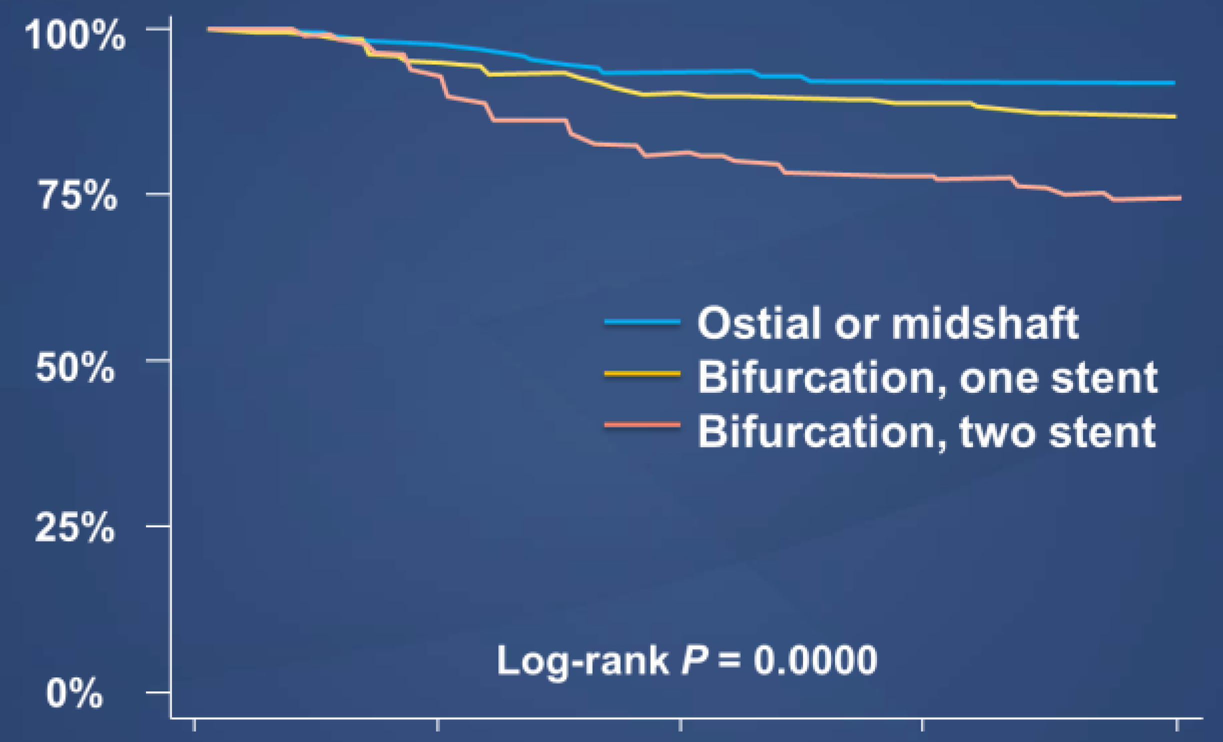
LM bifurcation: Two stent vs. provisional stenting

Primary Endpoint : target lesion failure, target lesion revascularization, target vessel myocardial infarction



Jun-Jie Zhang et al. EHJ, 2020, 41 ; 2523-2536

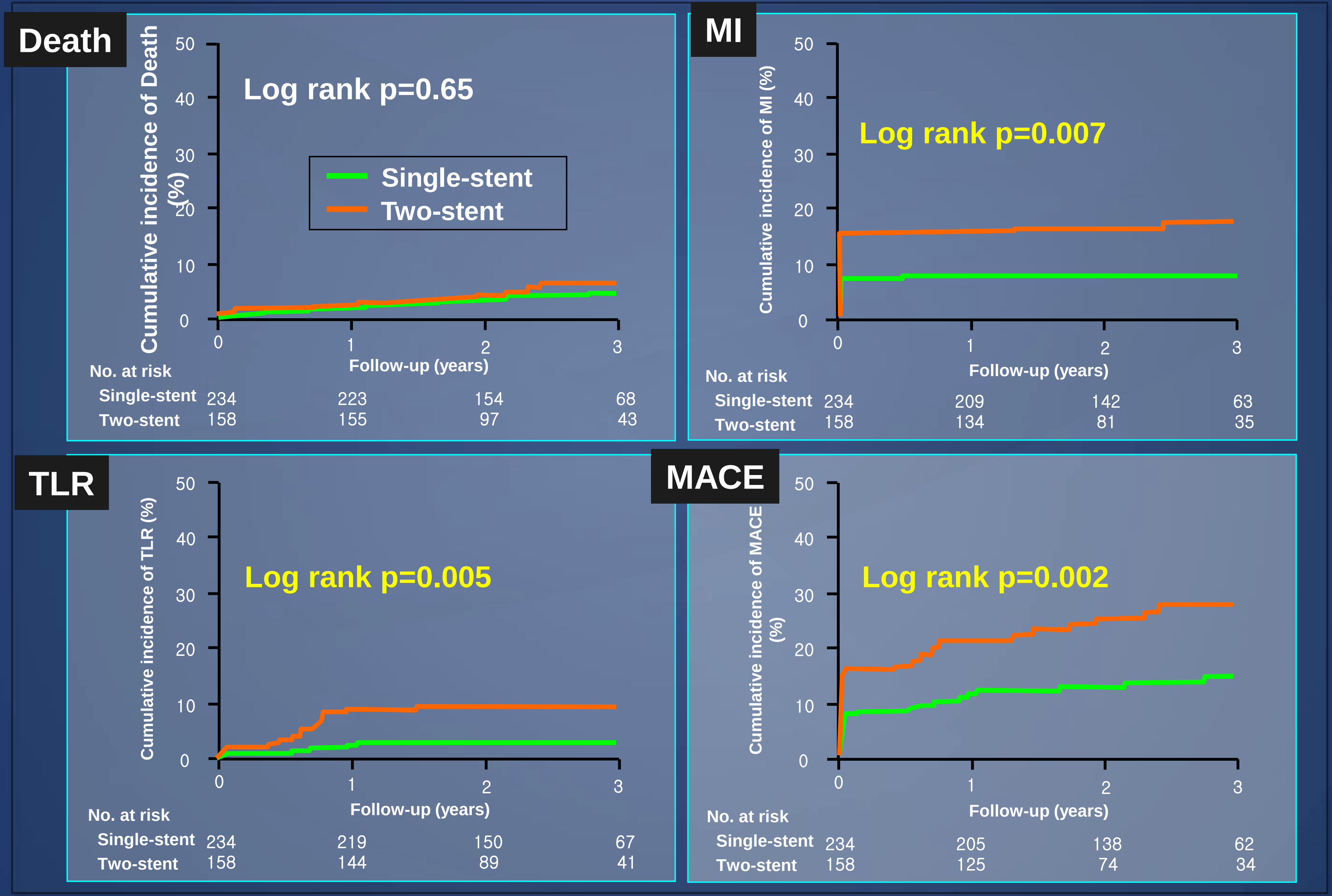
Ostial vs. 1 stent vs. 2 stent
TLR :Treated with DES



At risk	0	0.5	1	1.5	2
Os or shaft	334	268	212	140	114
1 stent	456	384	301	210	164
2 stent	317	257	207	162	141

T. Palmerini et al. EHJ, 2009

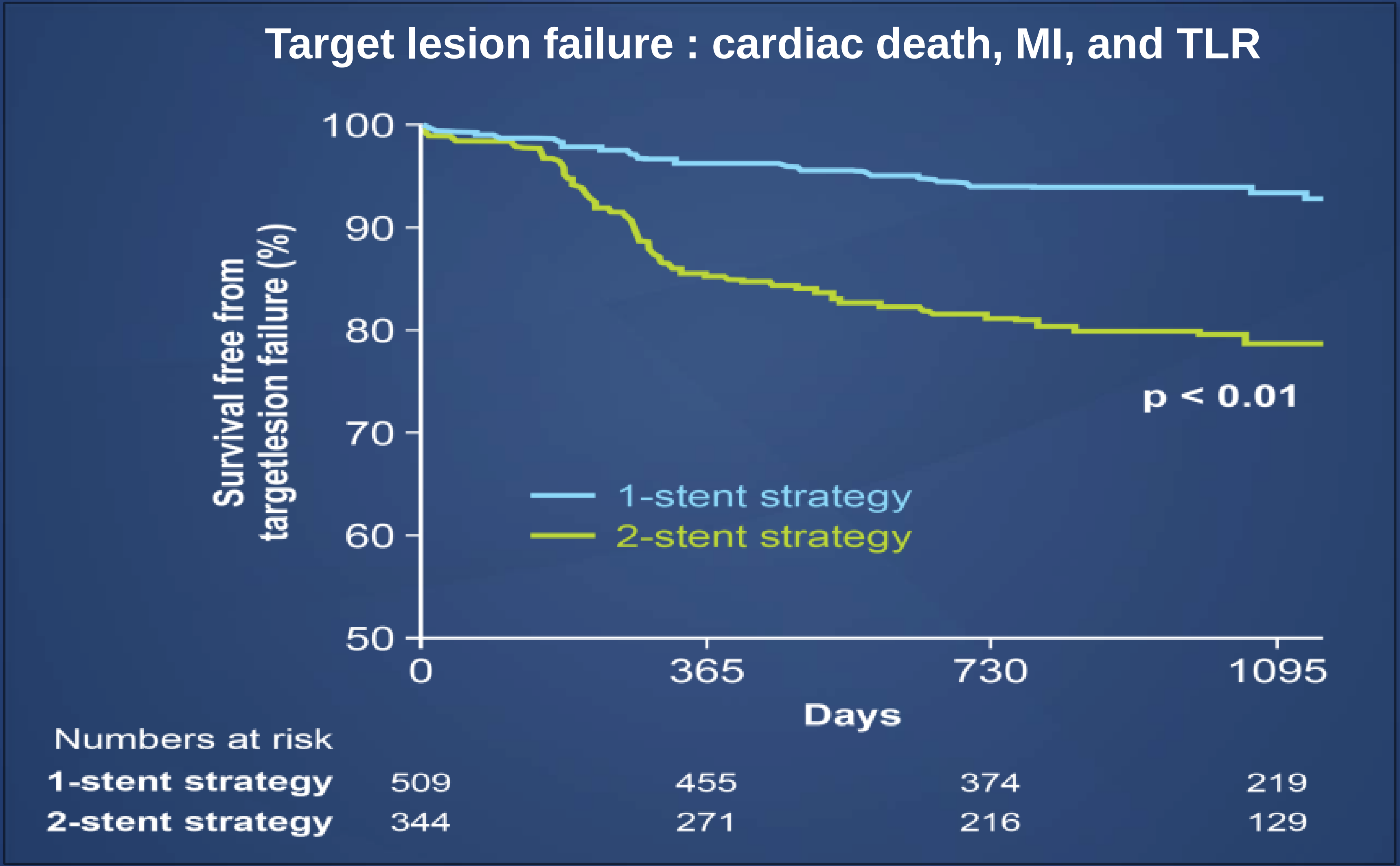
Single- vs. Two-Stent Strategy from MAINCOMPARE



Catheter Cardiovasc Interv., 2011

COBIS Registry II

LM bifurcation: 1 vs. 2 stent tech.



Song YB et al. JACC: Cardiovasc interv, 2014

IVUS-guided, Lesion-specific

Single stent	• Normal ostial LCX with MEDINA 1.1.0. or 1.0.0. • Small LCX with < 2.5 mm in diameter • Diminutive LCX • Normal or focal disease in distal LCX
Two stent	• Diseased LCX with MEDINA 1.1.1., 1.0.1., or 0.1.1 • Large LCX with ≥ 2.5 mm in diameter • Diseased left dominant coronary system • Concomitant diffuse disease in distal LCX

Park SJ, Kim YH. Colombo A, Issam D. Moussa et al. Textbook of Bifurcation Stenting

Provisional vs. 2-stent technique for Simple and Complex Bifurcation Lesions - The DEFINITION Study

Adjusted HR with 2-stent technique

	Simple	Complex
In-hospital		
MI	0.76 (0.45–1.28)	**0.58 (0.35–0.94)**
Cardiac death	—	0.53 (0.13–2.12)
TLR	1.66 (0.41–1.66)	—
MACE	0.68 (0.40–1.13)	**0.58 (0.35–0.94)**
Stent thrombosis	**6.68 (1.67–26.80)**	—
At 1 year		
MI	0.68 (0.40–1.13)	0.64 (0.40–1.03)
Cardiac death	0.95 (0.38–2.34)	**0.52 (0.28–0.97)**
TLR	**1.78 (1.16–2.74)**	1.07 (0.65–1.75)
MACE	1.03 (0.75–1.42)	0.79 (0.57–1.08)
Stent thrombosis	1.66 (0.62–4.45)	1.06 (0.42–1.69)

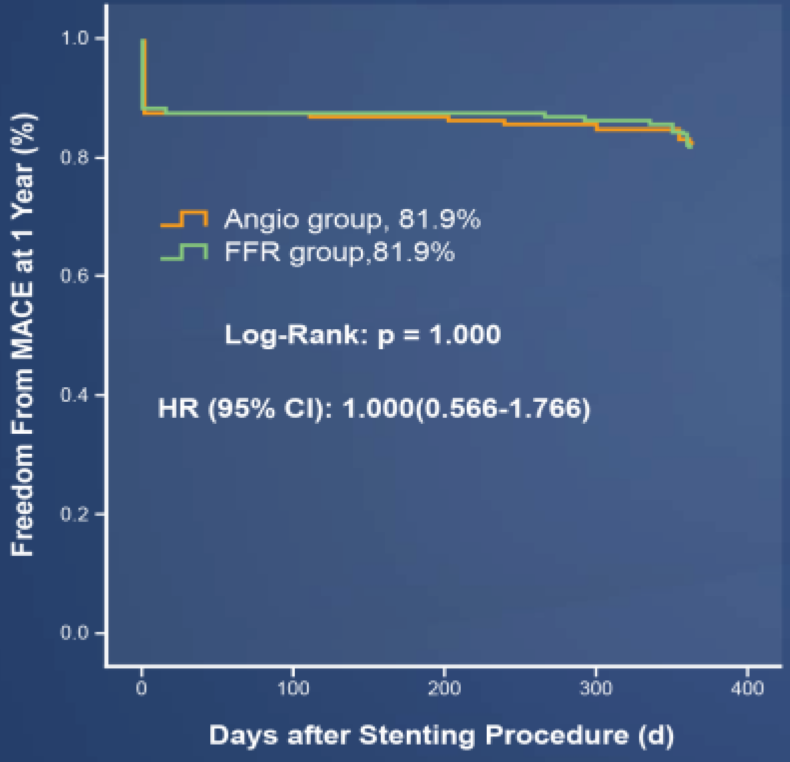
2-stent technique is still needed for complex bifurcation lesions

Chen et al. JACC: Cardiovasc Interv, 2014

FFR- vs. Angio-guided Provisional Stenting

The Randomized DKCRUSH-VI Trial

(160 patients with true bifurcation lesion in each group)



Variables	Angio	FFR	P
Stenting of SB	51 (31.9)	22 (13.8)	0.01
No. of SB stents	0.97 ± 0.31	0.13 ± 0.34	< 0.001
Length of SB stents	18.33 ± 9.67	2.92 ± 7.97	< 0.001

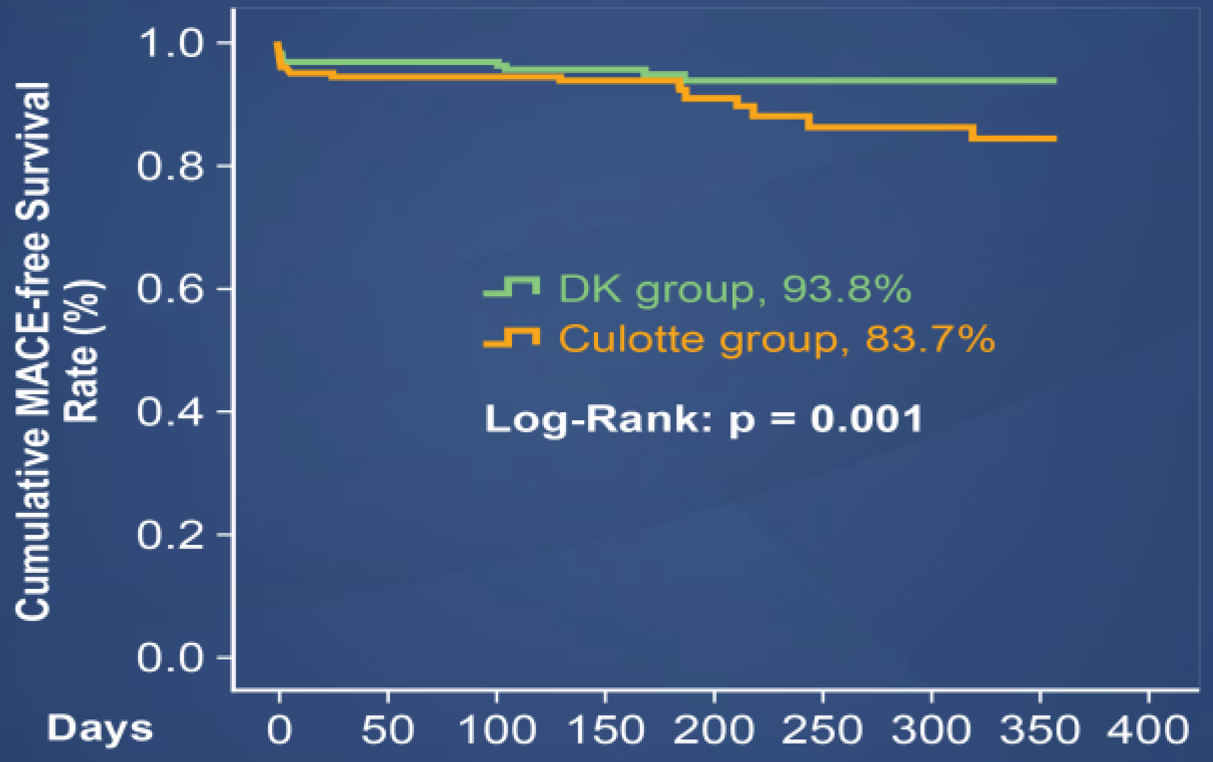
FFR-guided provisional stenting showed the similar outcomes with fewer stents

Chen et al. JACC Cardiovasc Interv, 2014

DKCRUSH III

DKCRUSH vs. Culotte for LM-bifurcation

MACE: MI, cardiac death, or TVR



Patients at risk (n)

DK	210	203	203	201	197	197	197	197	197
Culotte	209	197	197	196	190	180	180	177	175

Shao-Liang Chen et al. *JACC*, 2013

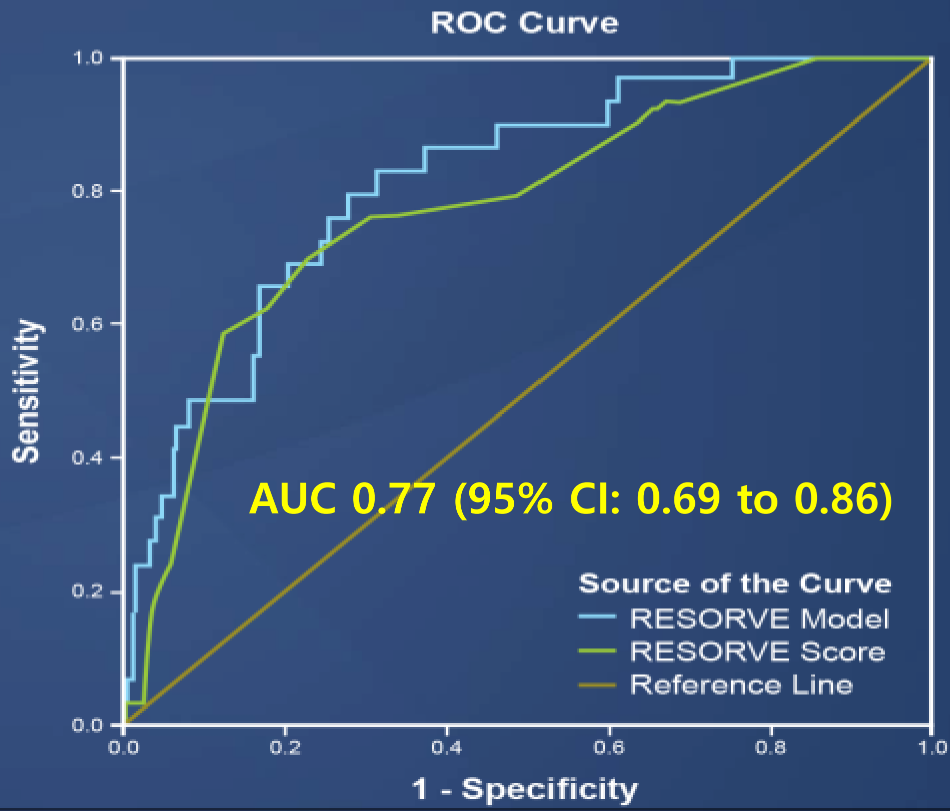
Risk Prediction of SB Occlusion

The RESOLVE Score System

: a model built from 1545 Chinese patients with bifurcation

Scores Attributed to Each Variable

Risk Factor	Level	Point
Plaque distribution	At the opposite side of SB	0
	At the same side of SB	1
MV TIMI flow grade before stenting	TIMI 3	0
	TIMI 2	6
	TIMI 1	11
	TIMI 0	17
Pre-procedural diameter stenosis of bifurcation core (%)	<50	0
	50–<70	2
	≥70	3
Bifurcation angle (°)	<70	0
	70–<90	4
	≥90	6
Diameter ratio between MV/SB	<1.0	0
	1.0–<1.5	2
	1.5–<2.0	6
	≥2.0	9
Diameter stenosis of SB before MV stenting (%)	<50	0
	50–<70	4
	70–<90	6
	≥90	7

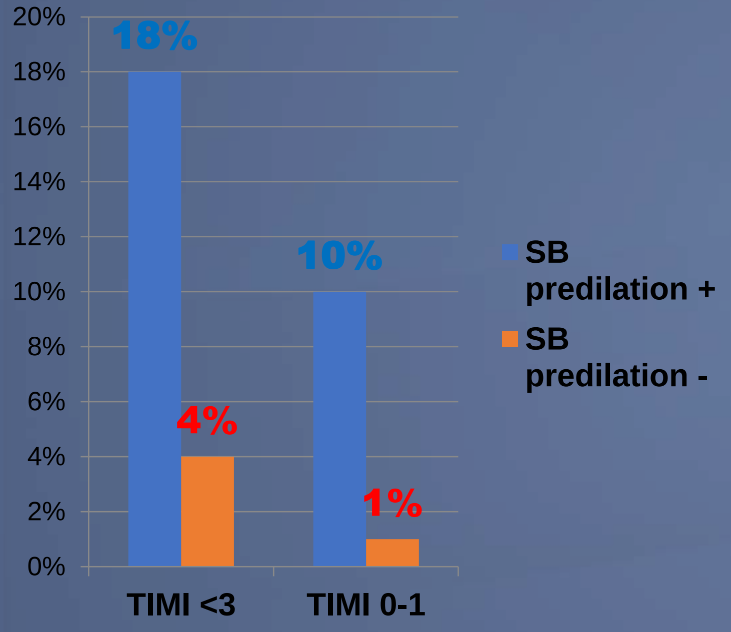


The RESOLVE score system can help identify patients at risk for SB occlusion during bifurcation stenting.

Dou et al. JACC Cardiovasc Interv, 2015

Effect of SB Predilation Before Provisional Stenting

A randomized study enrolling 372 patients with true bifurcation
(SB predilation + vs. SB predilation -)



	SB predilation + (n = 187)	SB predilation - (n = 185)	P
Impossibility to recross	2 (1.5%)	2 (1%)	0.62
Time of rewiring (min)	2.2 ± 6	3.2 ± 7	0.2
No. of wires used in the rewiring	1.1 ± 0.4	1.3 ± 0.6	0.023
Final % of stenosis at SB	16 ± 17	15 ± 16	0.59
Troponin postprocedure	2.9 ± 7.2	2.8 ± 6.2	0.87

Predilation of the SB resulted in improved TIMI flow after MB stenting, not hindering SB rewiring.

Pan et al. Am Heart J, 2014

With vs. Without
Routine Kissing Balloon Inflation (FKB)

ASAN-MAIN Registry
From 2003 to 2012
N = 2455

→ CABG (N=1086)
Medication (N=320)

PCI (DES)
N = 1049

→ Ostial/Shaft stenting (N=197)
Bifurcation stenting (N=274)
Others (N=138)
STEMI (N=27)

Stent Crossover
N = 413

FKB
N = 95

No-FKB
N = 318

AMC Data, 2014

With vs. Without Routine Kissing Balloon Inflation (FKB)

2- year Clinical Outcomes

	FKB (N=95)	Non-FKB (N=318)	Adjusted HR (95% CI)	P value
Death	4 (4.6%)*	12 (3.9%)	1.03 (0.28-3.82)	0.97
Death or MI	4 (4.6%)	13 (4.2%)	0.95 (0.26-3.51)	0.96
TVR	7 (8.1%)	14 (4.8%)	1.12 (0.40-3.11)	0.83
LM-TLR	7 (8.1%)	13 (4.4%)	1.32 (0.46-3.75)	0.60
Definite ST	0	0	NA	NA
MACE#	11 (12.5%)	26 (8.5%)	1.10 (0.49-2.49)	0.82

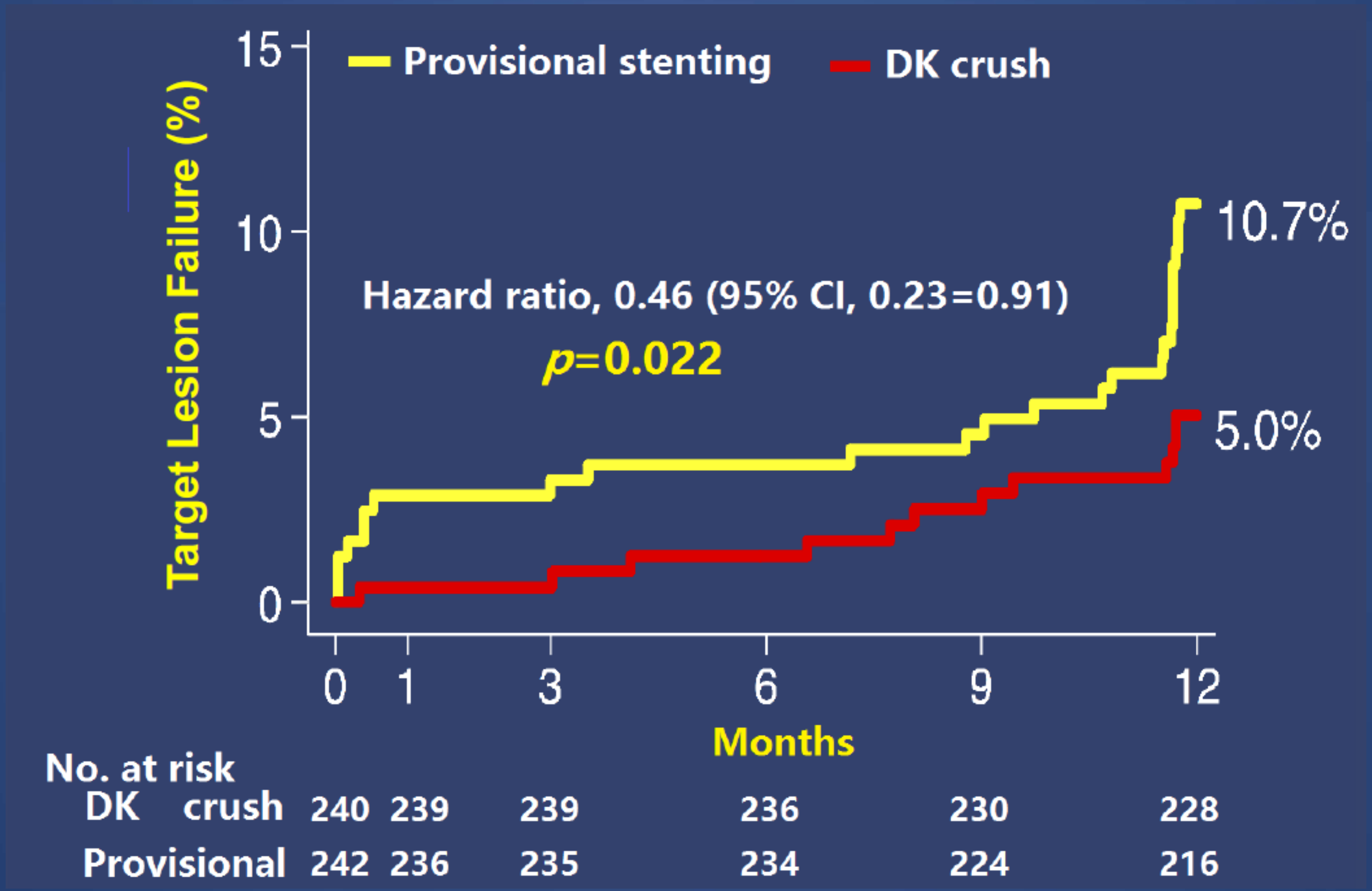
adjusted for age, DM, clinical presentation, stent No., pre- and post-stenting LCX DS
** derived from Kaplan-Meier estimate*
 # composite of death, MI, or LM TLR

AMC Data, 2014

DKCRUSH-V Randomized Trial

DKCRUSH vs. Provisional stenting for LM distal bifurcation

Primary Endpoint: TLF (Cardiac death, TVMI, or TLR)



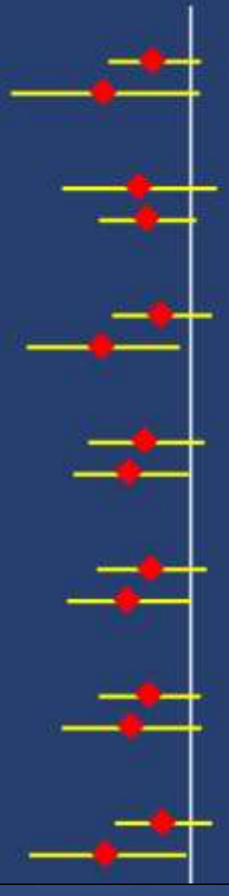
Shao-Liang Chen et al. *JACC*, 2017

DKCRUSH-V Randomized Trial

DKCRUSH vs. Provisional stenting for LM distal bifurcation

Target Lesion Failure at 1-Year Subgroup analysis

Subgroup	DK crush (N=240) Events / total patients no.	%	Provisional Stenting (N=242) Events / total patients no.	%	Hazard Ratio (95%)	P Value for Interaction
Age (years)						
<70	10/164	6.1	18/165	10.9	0.56 (0.27, 1.17)	0.375
≥70	2/76	1.4	8/77	10.4	0.25 (0.06, 1.15)	
Gender						
Female	3/41	7.3	9/54	16.7	0.44 (0.13, 1.52)	0.858
Male	9/199	4.5	17/188	9.0	0.50 (0.23, 1.09)	
Diabetes						
No	9/171	5.3	15/180	8.3	0.63 (0.28, 1.40)	0.372
Yes	3/69	4.3	11/62	17.7	0.25 (0.07, 0.84)	
Complex bifurcation lesions						
No	6/154	3.9	14/176	8.0	0.49 (0.19, 1.24)	0.652
Yes	6/86	7.0	12/66	18.2	0.38 (0.15, 0.97)	
Distal angle						
<70	7/158	4.4	14/169	8.3	0.53 (0.22, 1.29)	0.596
≥70	5/82	6.1	12/73	16.4	0.37 (0.14, 1.00)	
SYNTAX score						
≤32	8/149	5.4	16/154	10.4	0.52 (0.23, 1.17)	0.697
>32	4/91	4.4	10/88	11.4	0.39 (0.13, 1.19)	
NERS score						
<19	9/125	7.2	16/141	11.3	0.64 (0.30, 1.41)	0.264
≥19	3/115	2.6	10/101	9.9	0.26 (0.07, 0.93)	



Favors DK crush **Favors Provisional stenting**

Bifurcation technique

Bifurcation Coronary Disease

- **15~20% of PCI patients**
- **DES enhanced success rate, but have not resolved completely**
- **Dependable strategy – not established**

  - Rare studies evaluating anatomical intricacies

  - Lack of large randomized trials

  - Many anatomical variants

  → Single technique can't fit all

Difficulties of Bifurcation PCI

- **Risk of periprocedural complication**
- **Relatively high restenosis**
- **Not all lesions are the same**

  - Size of vessels (Meaningful SB size ≥2.25mm)

  - Variable plaque distribution

  - Extent of SB disease

  - Variable angulation
- **Higher risk of stent thrombosis**

PCI techniques are mainly based on personal experiences from skilled operators

Factors to be considered for PCI strategy

- **Anatomical factors**

  - LMCA bifurcation
  - Location of plaque (Anatomical classification)
  - Plaque or carina shift
  - Angle btw SB and MB
  - Dynamic change in bifurcation anatomy

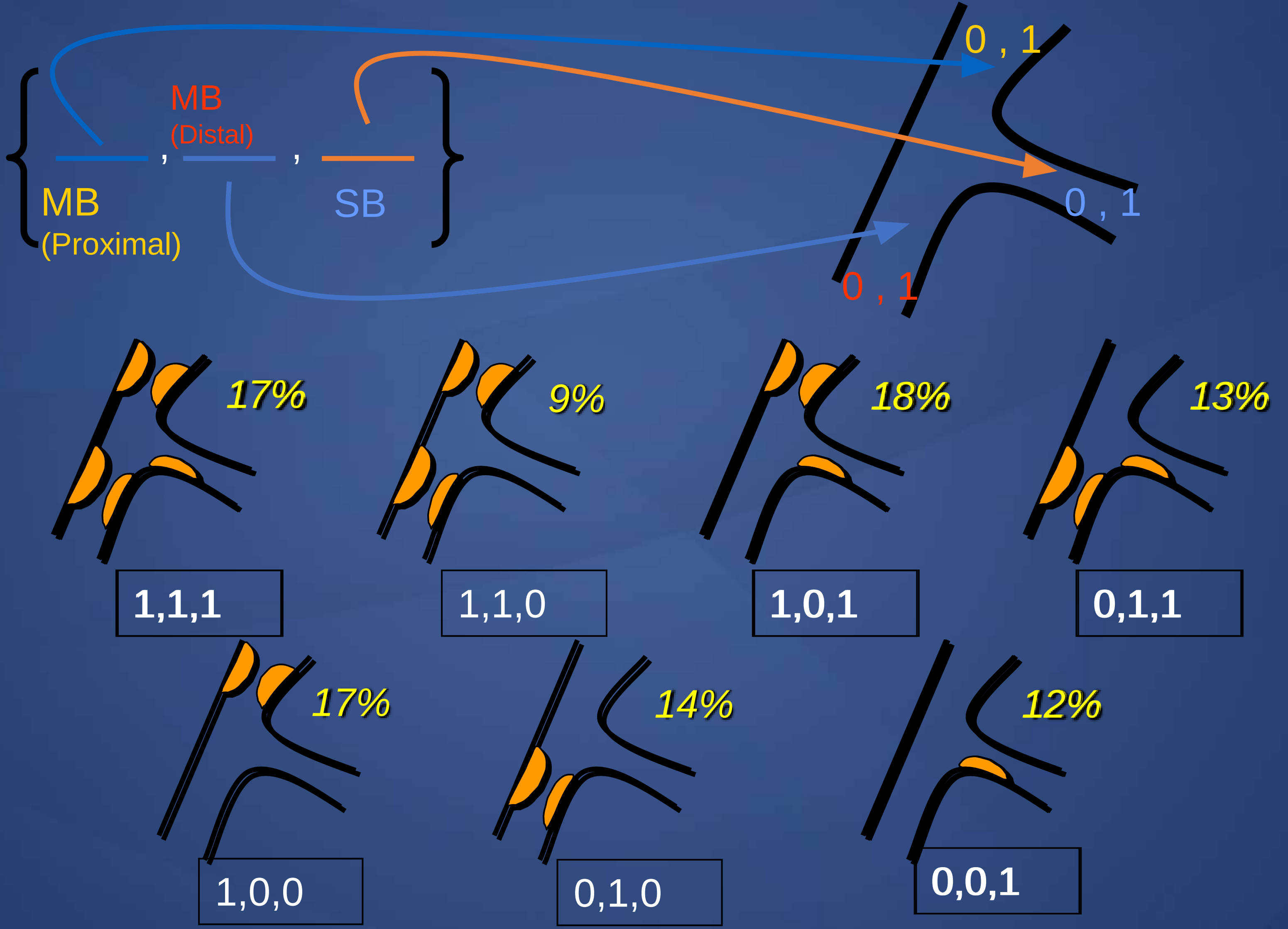
- **Modalities for objective anatomical evaluation**

  - QCA, IVUS, FFR

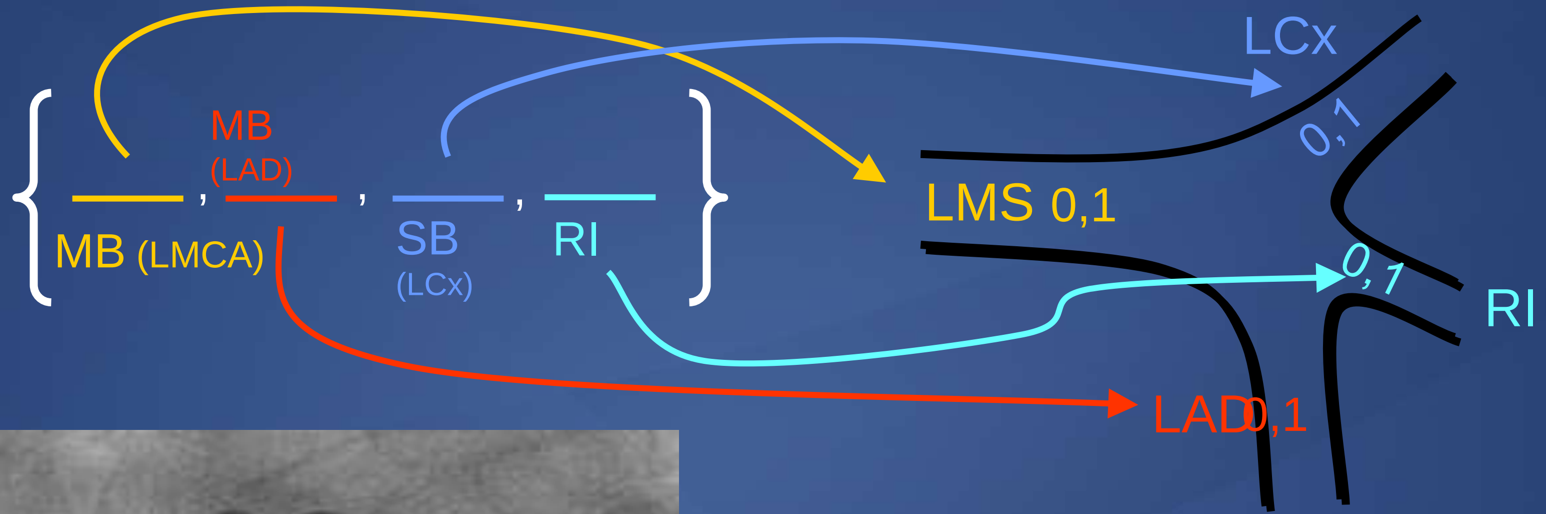
- **Selection of devices and strategies**

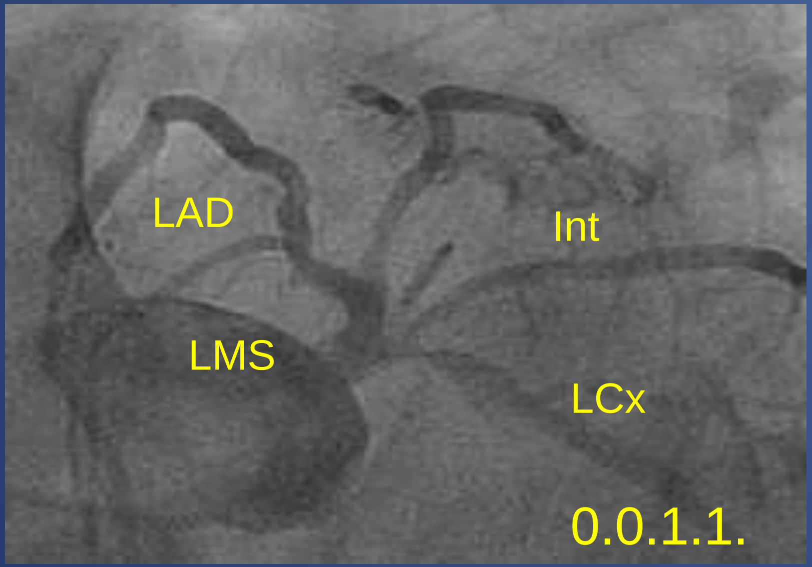
  - DES vs. BMS
  - Single vs. Double stent techniques
  - Kissing balloon or not
  - Dedicated bifurcation stents

Medina Classification



Trifurcation



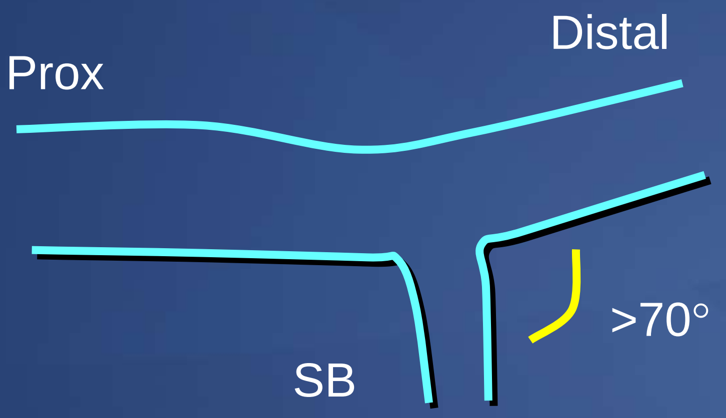


- If, RI size > LCx

→ LM, LAD, RI, LCx

Angulation

T-shape



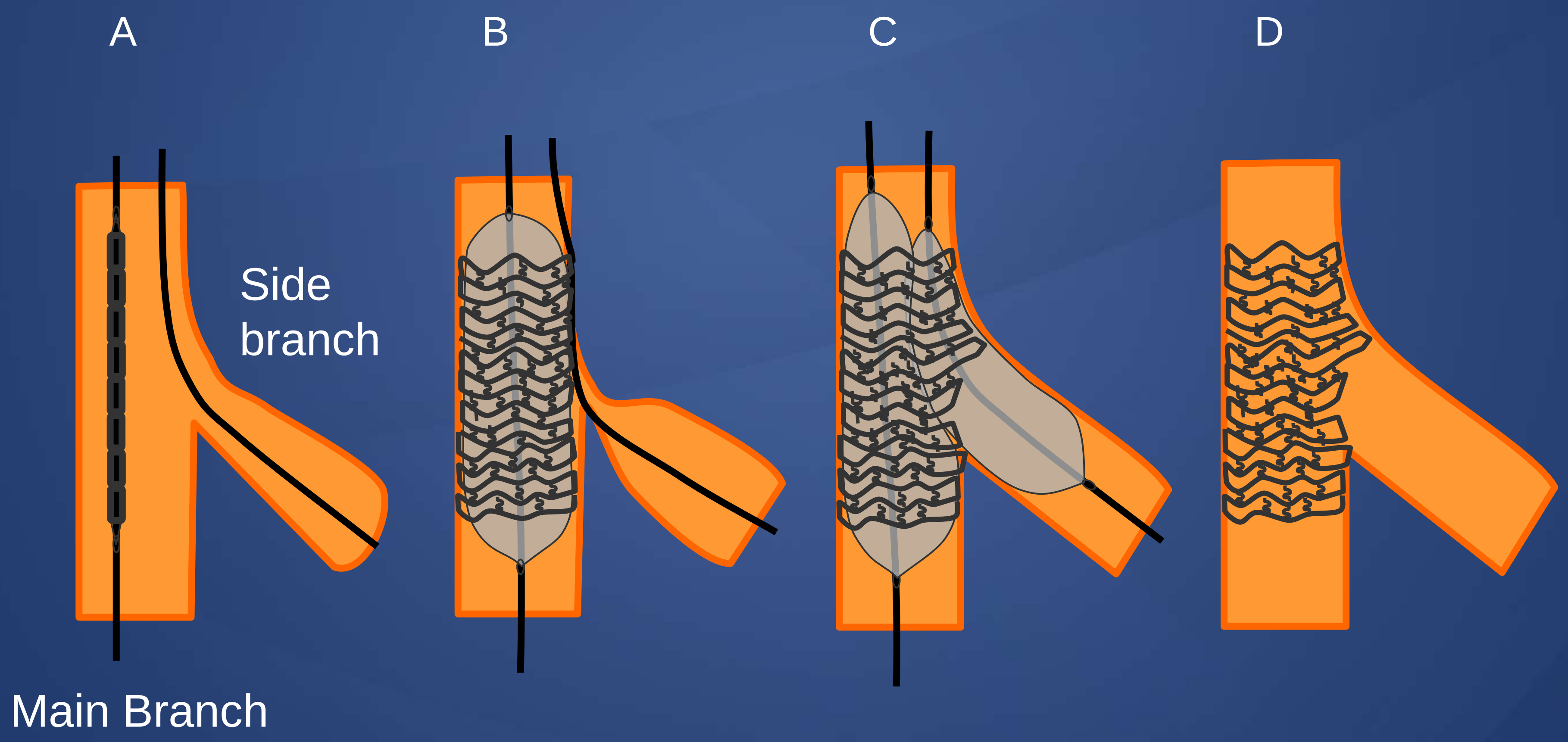
Y-shape

- **Difficult SB access**
- **Less plaque shifting**
- **T-stenting better**

- **Easier SB access**
- **More plaque shifting**
- **Cullotte or Crush better**

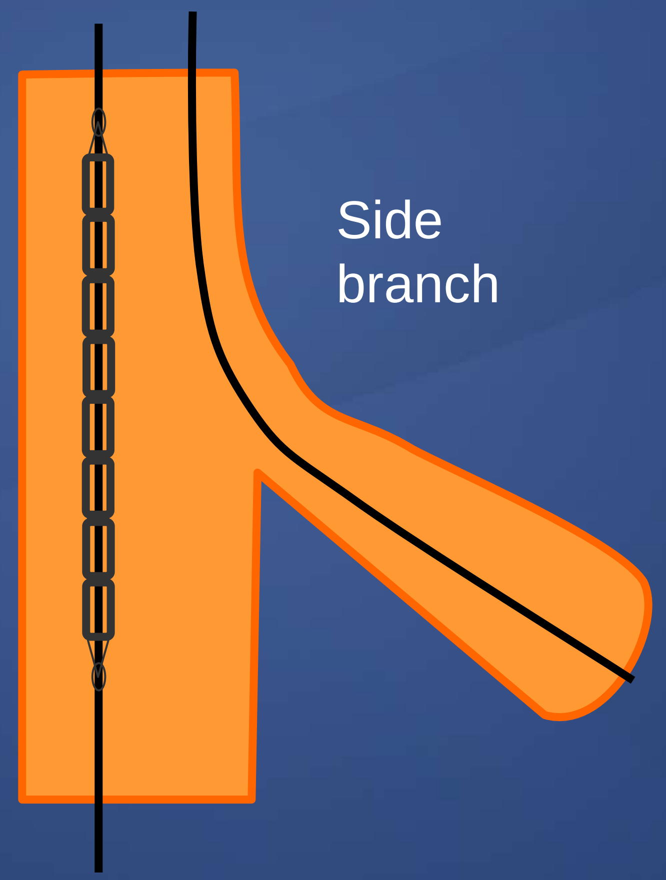
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

Normal or diminutive side branch ostium



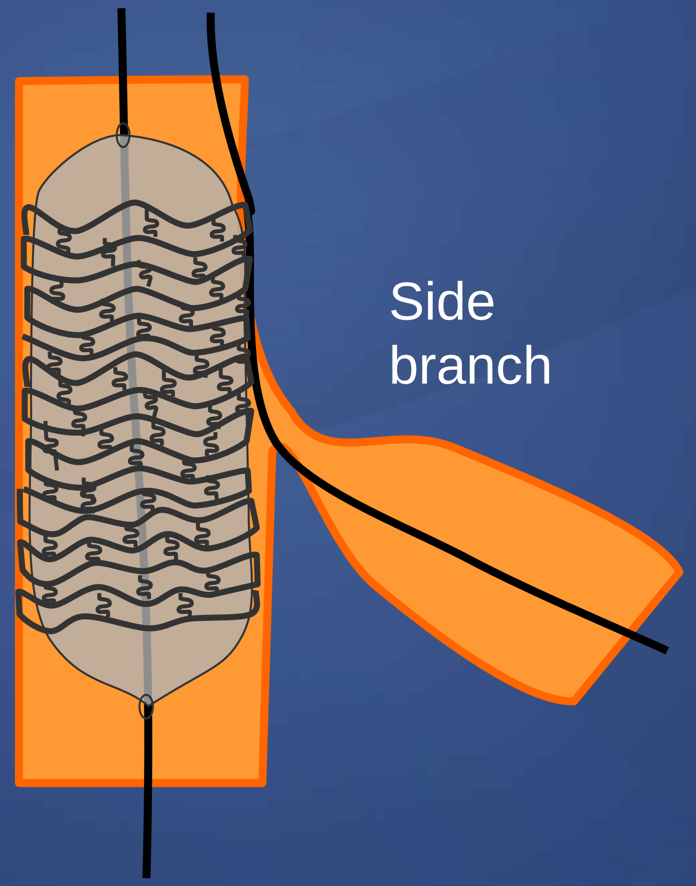
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

A. Wire both branches and predilate if needed



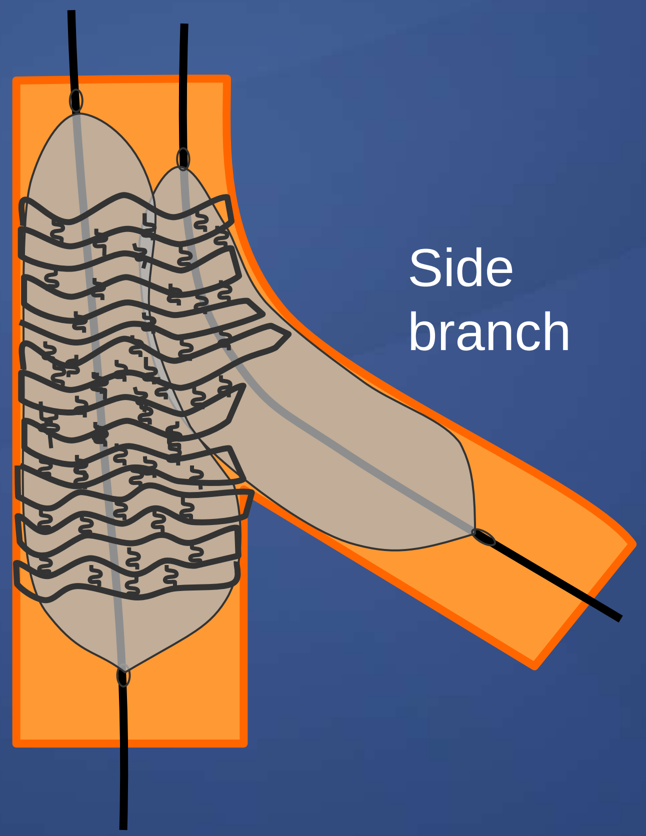
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

B. Stent the MB leaving a wire in the SB



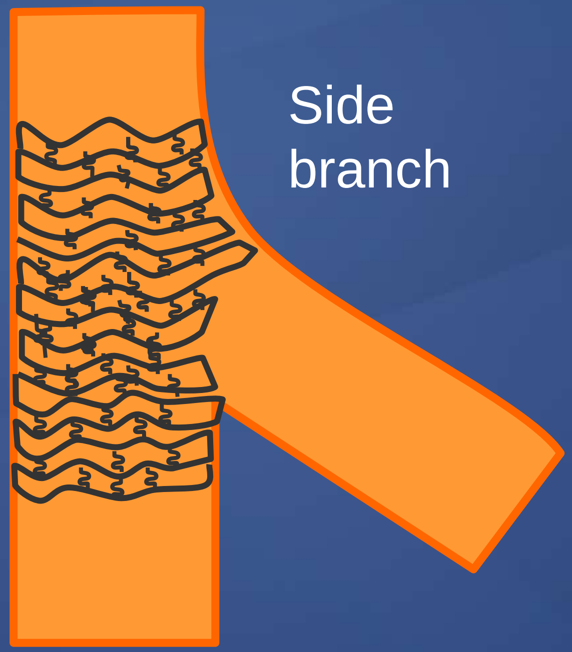
Stenting Crossing Side Branch
With Optional Kissing Balloon Inflation

C. Rewire the SB passing through the strut of the MB stent, remove the jailed wire, dilate toward SB, and perform FKB inflation



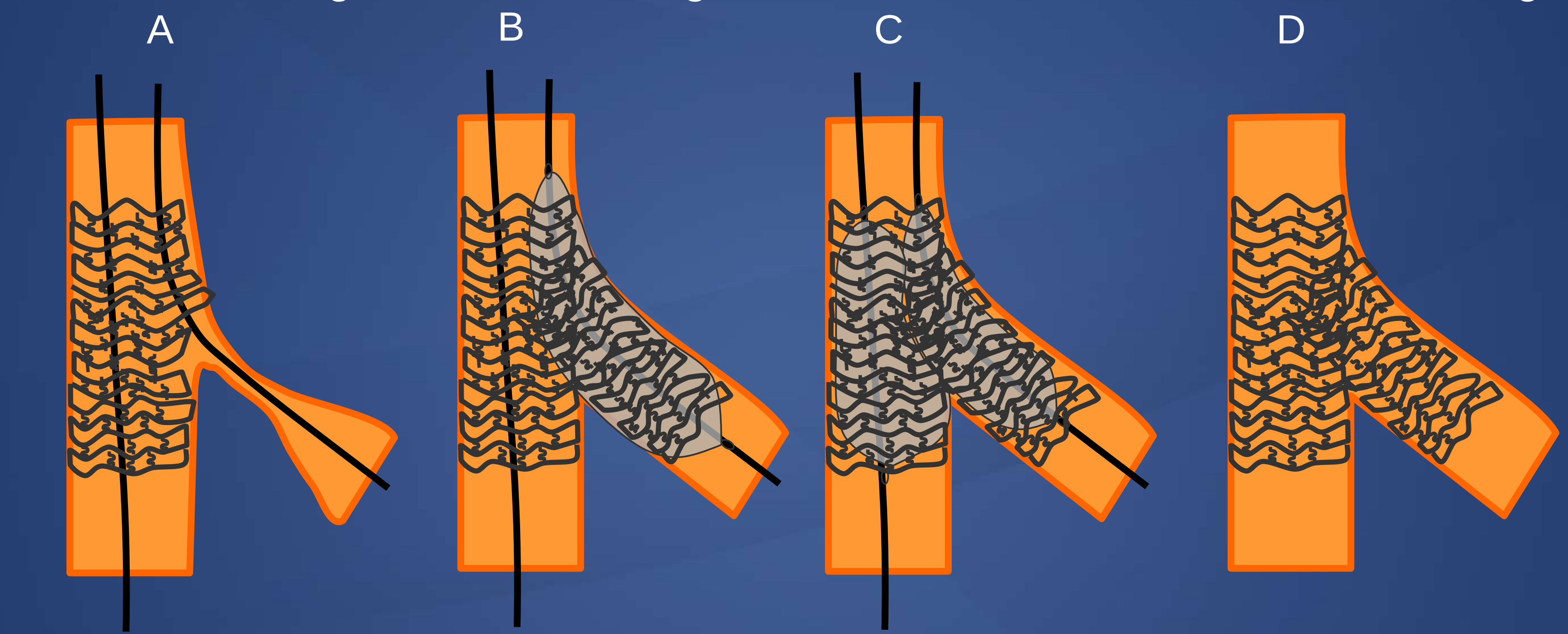
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

D. Final result



Provisional T Stenting

In cases with significant narrowing of side branch after main branch stenting



Jailed SB after MB stenting	SB stenting with minimal protrusion	Final kissing is necessary	Slightly protruded stent strut to MB

Advantages	Disadvantages
Good SB scaffolding with angles >70°	Potential gap at SB ostium Protrusion of SB stent into the MB

Provisional T Stenting

In cases with significant narrowing of side branch after main branch stenting

A. Jailed SB after MB stenting

Provisional T Stenting

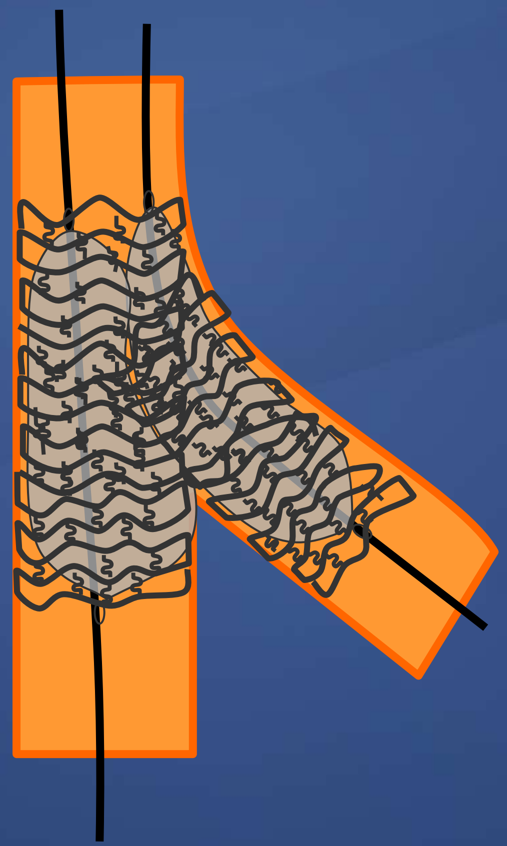
In cases with significant narrowing of side branch after main branch stenting

B. SB stenting with minimal protrusion

Provisional T Stenting

In cases with significant narrowing of side branch after main branch stenting

C. Final kissing is necessary



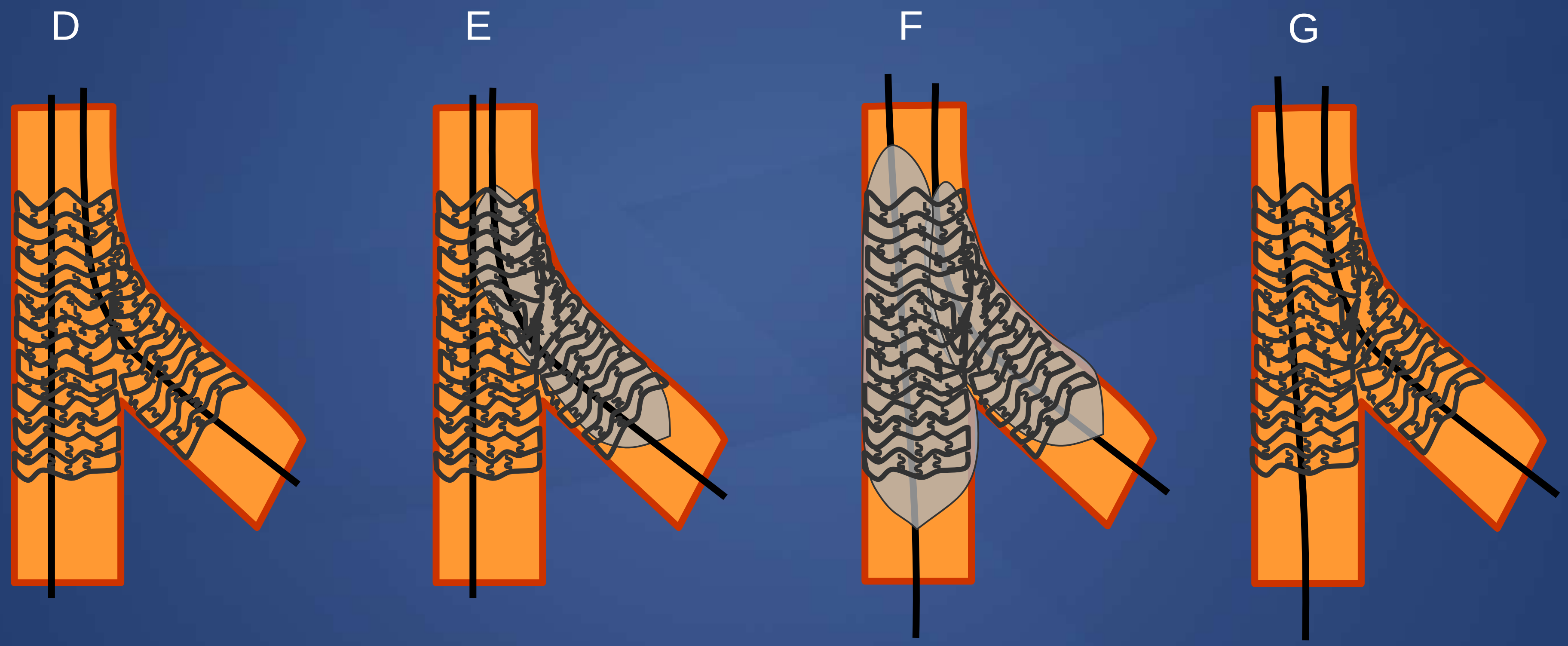
Provisional T Stenting

In cases with significant narrowing of side branch after main branch stenting

D. Slightly protruded stent strut to MB

"Internal" or "Reverse" Crush

Final kissing balloon dilatation is mandatory



Re-advancement of wire into the side branch

Opening of the side branch ostium

Final kissing balloon inflation

“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

A. Jailed SB after MB stenting

"Internal" or "Reverse" Crush

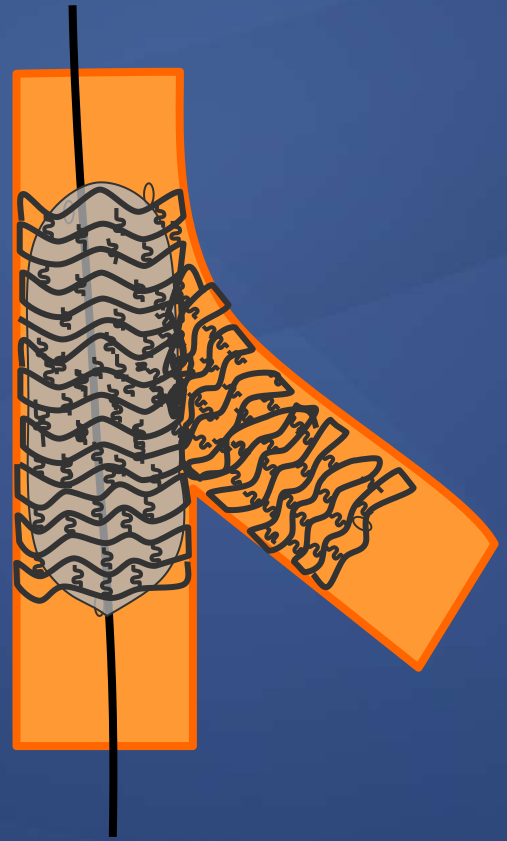
Final kissing balloon dilatation is mandatory

B. SB stenting with minimal protrusion

“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

C. Remove SB balloon & wire,
and inflate MB at high pressure to crush SB stent



“Internal” or “Reverse” Crush

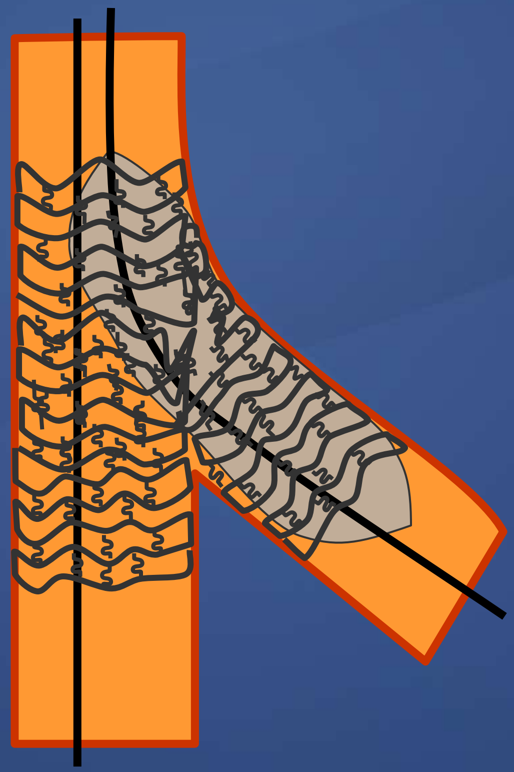
Final kissing balloon dilatation is mandatory

D. Re-advancement of wire into the side branch

"Internal" or "Reverse" Crush

Final kissing balloon dilatation is mandatory

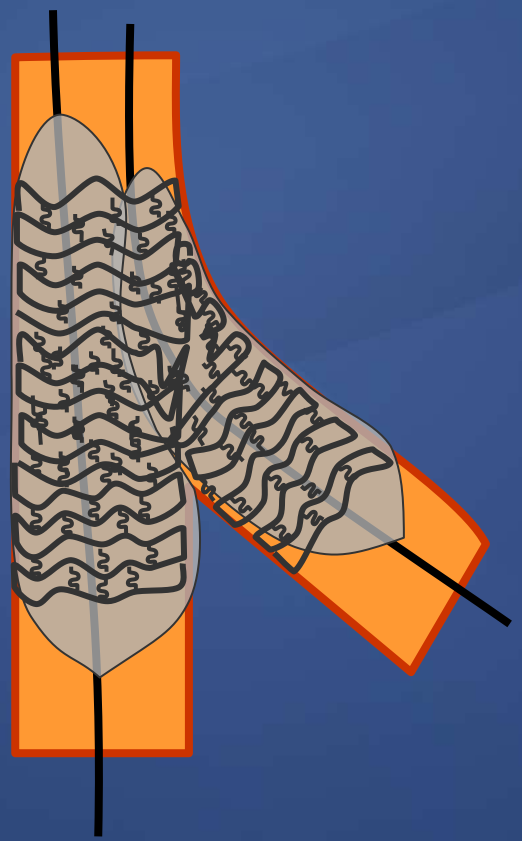
E. Opening of the side branch ostium



"Internal" or "Reverse" Crush

Final kissing balloon dilatation is mandatory

F. Final kissing balloon inflation

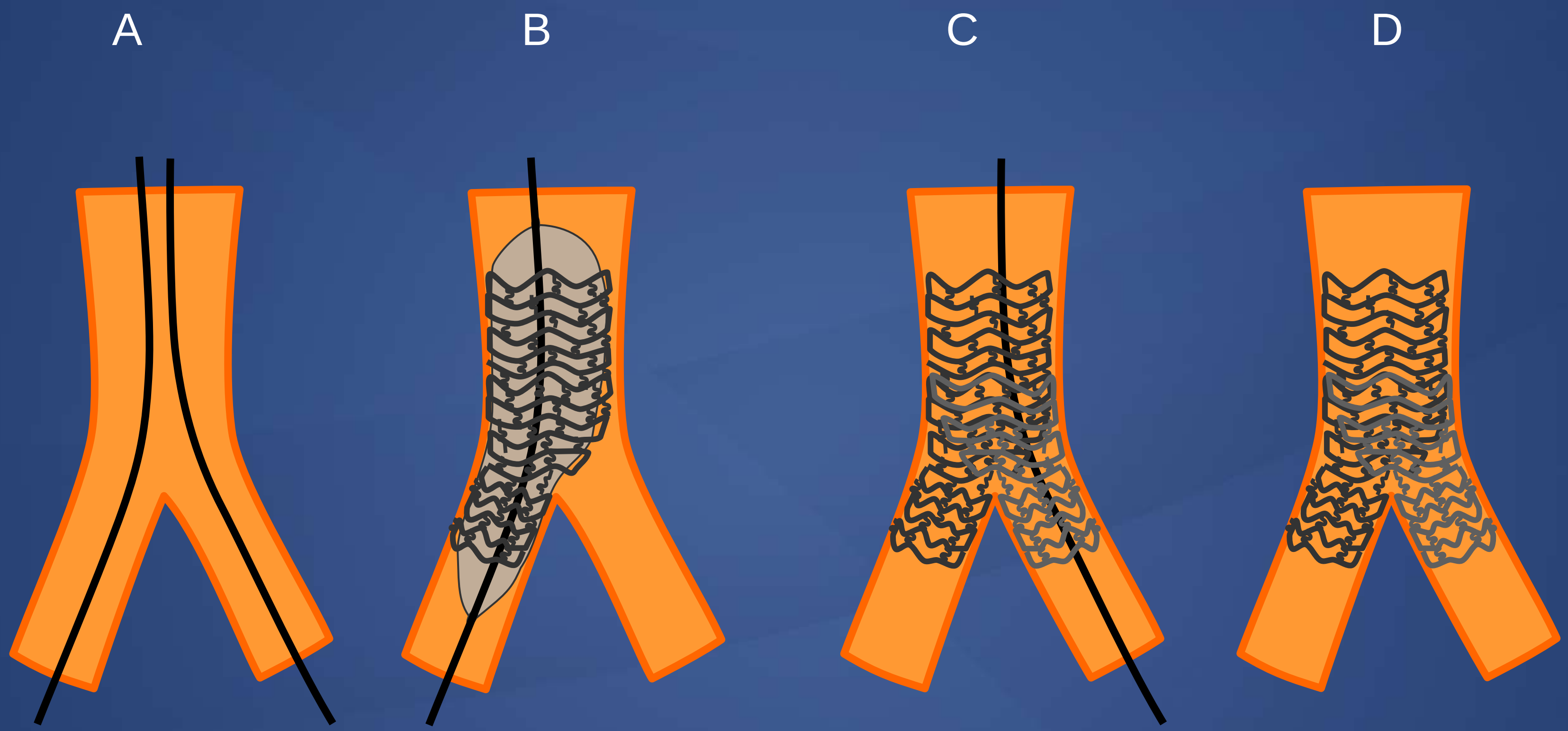


“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

G. Final result

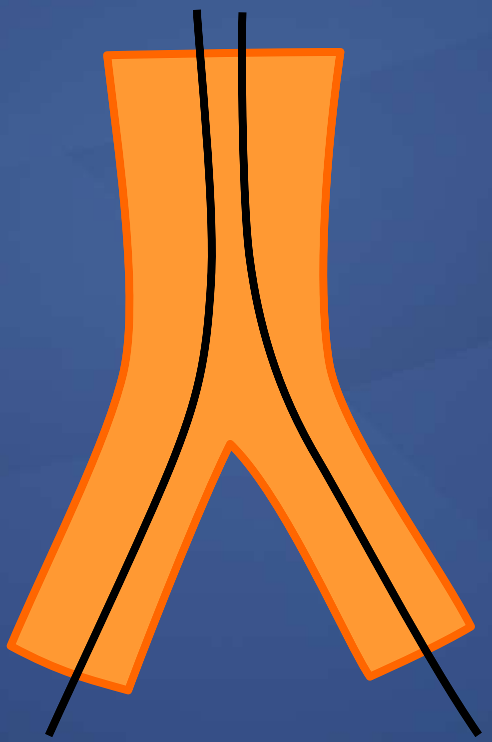
Y (Culotte) Stenting



Advantages	Disadvantages
Compatible with 6-Fr guider	Leaves multiple layers of strut
Independent of bifurcation angle	Potential acute closure of MB
Predictable scaffolding	

Y (Culotte) Stenting

A. Wire both branches and predilate if needed



Y (Culotte) Stenting

B. Deploy a stent in the more angulated branch (SB)

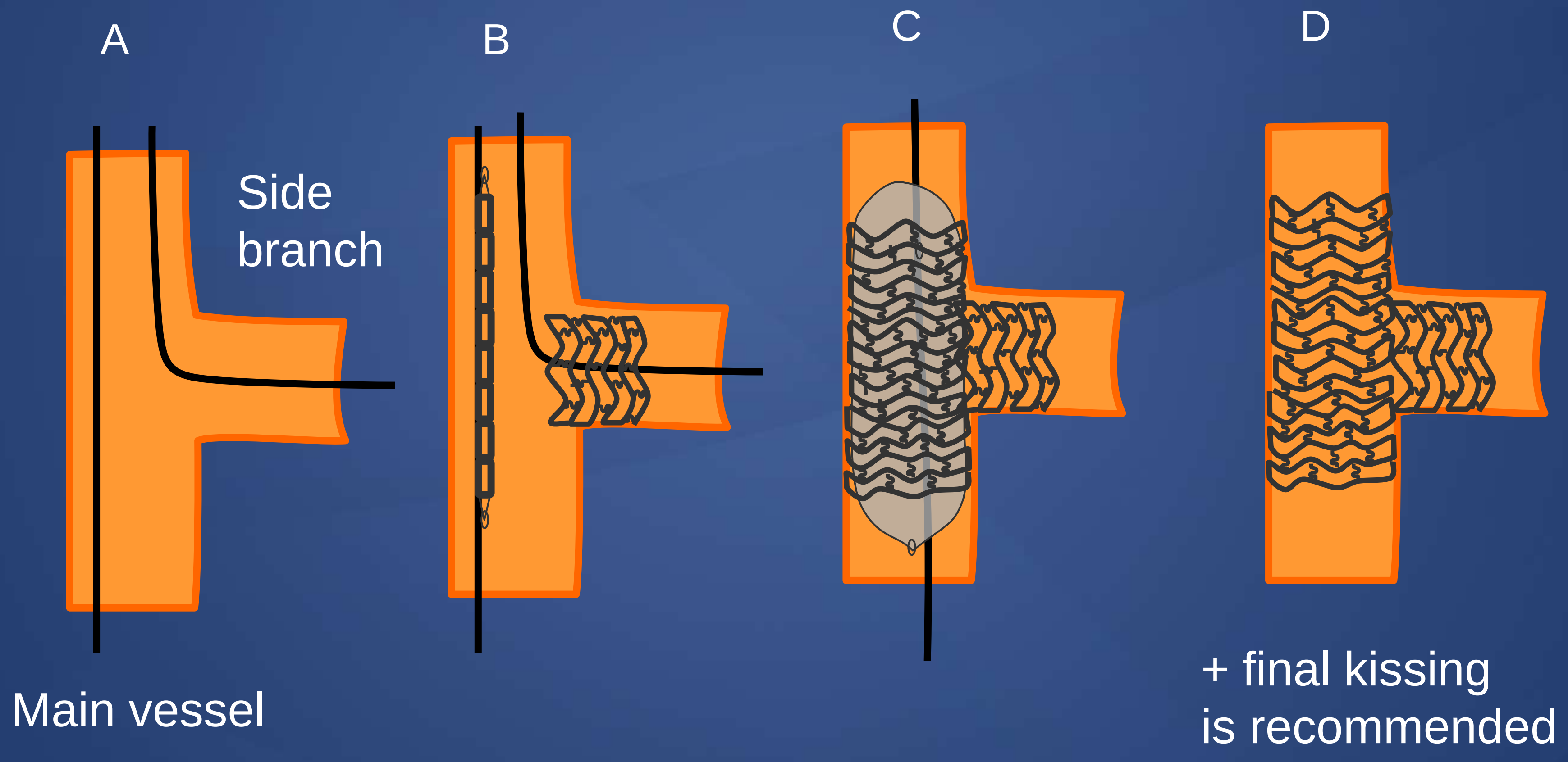
Y (Culotte) Stenting

C. Rewire unstented branch, dilate the stent to unjail the MB, and expand a second stent into the unstented MB

Y (Culotte) Stenting

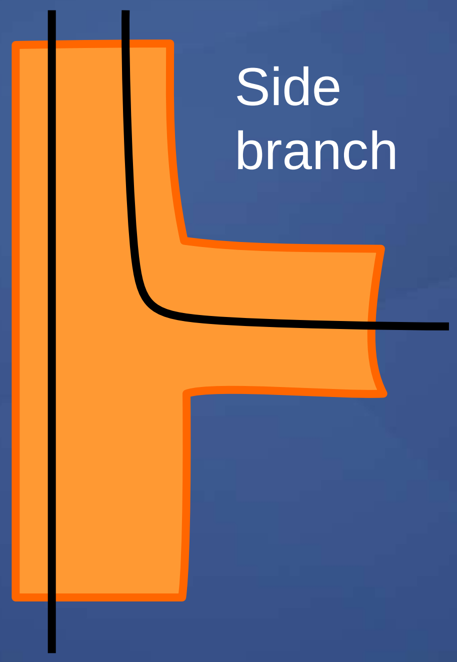
D. Final result after final kissing balloon

Modified T-Stenting



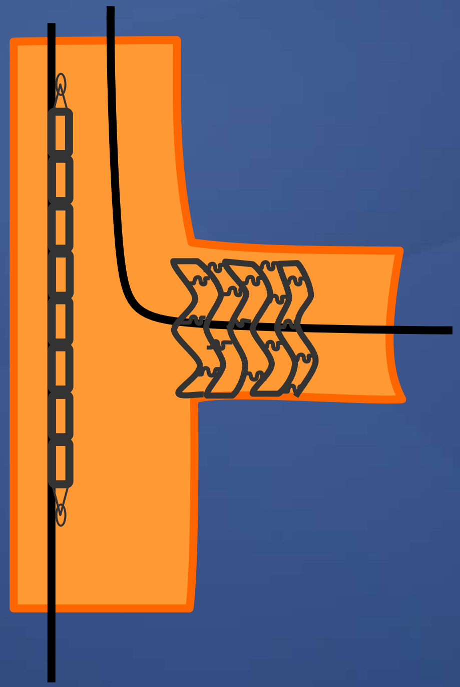
Modified T-Stenting

A. Wire both branches and predilate if needed



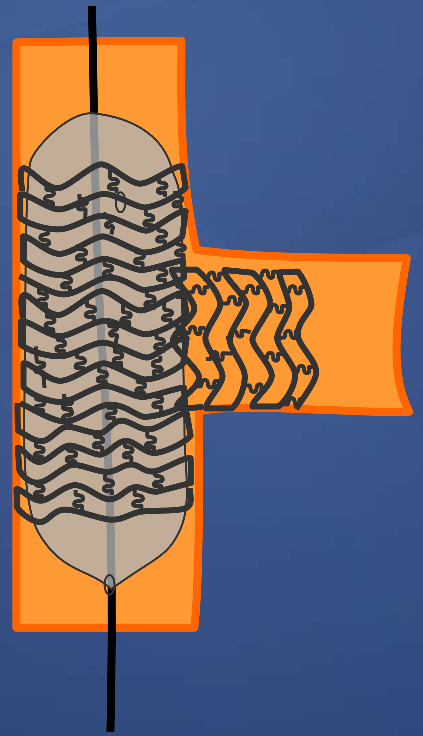
Modified T-Stenting

B. SB stent deployed at nominal pressure



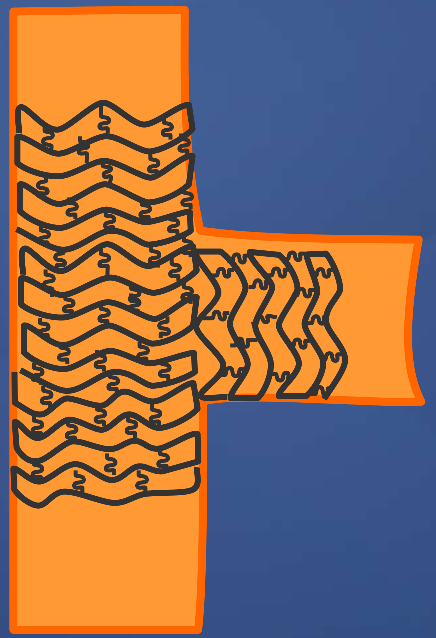
Modified T-Stenting

C. Remove balloon and wire from SB,
And deploy the MB stent at high pressure



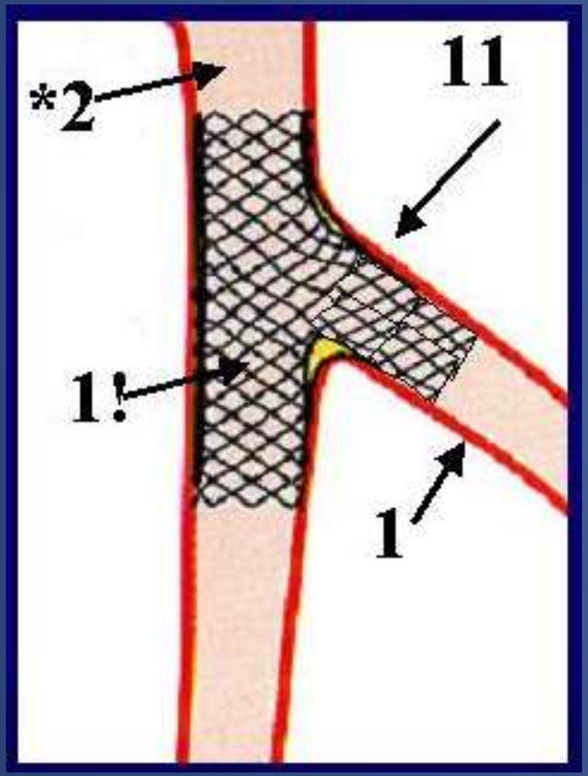
Modified T-Stenting

D. Rewire the SB and high-pressure dilatation, then final kissing inflation is recommended

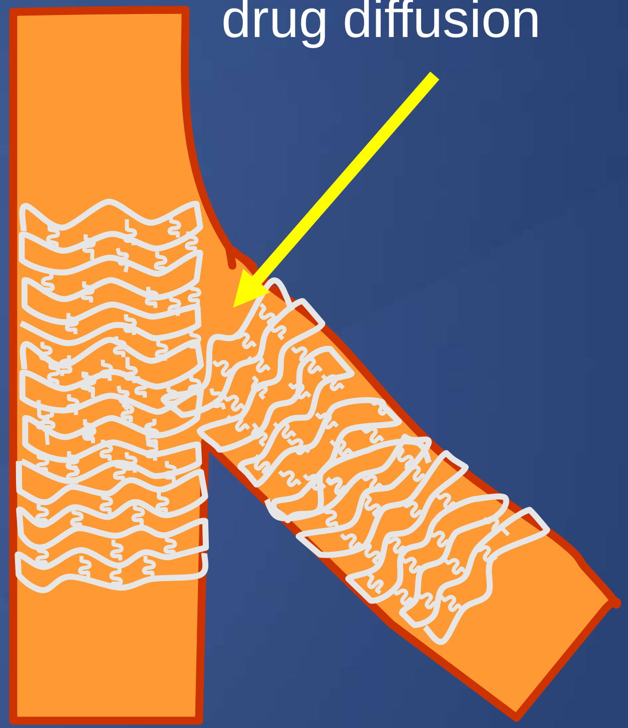


Limitation of Modified T Stenting

Restenosis site of T stenting in SIRIUS bifurcation



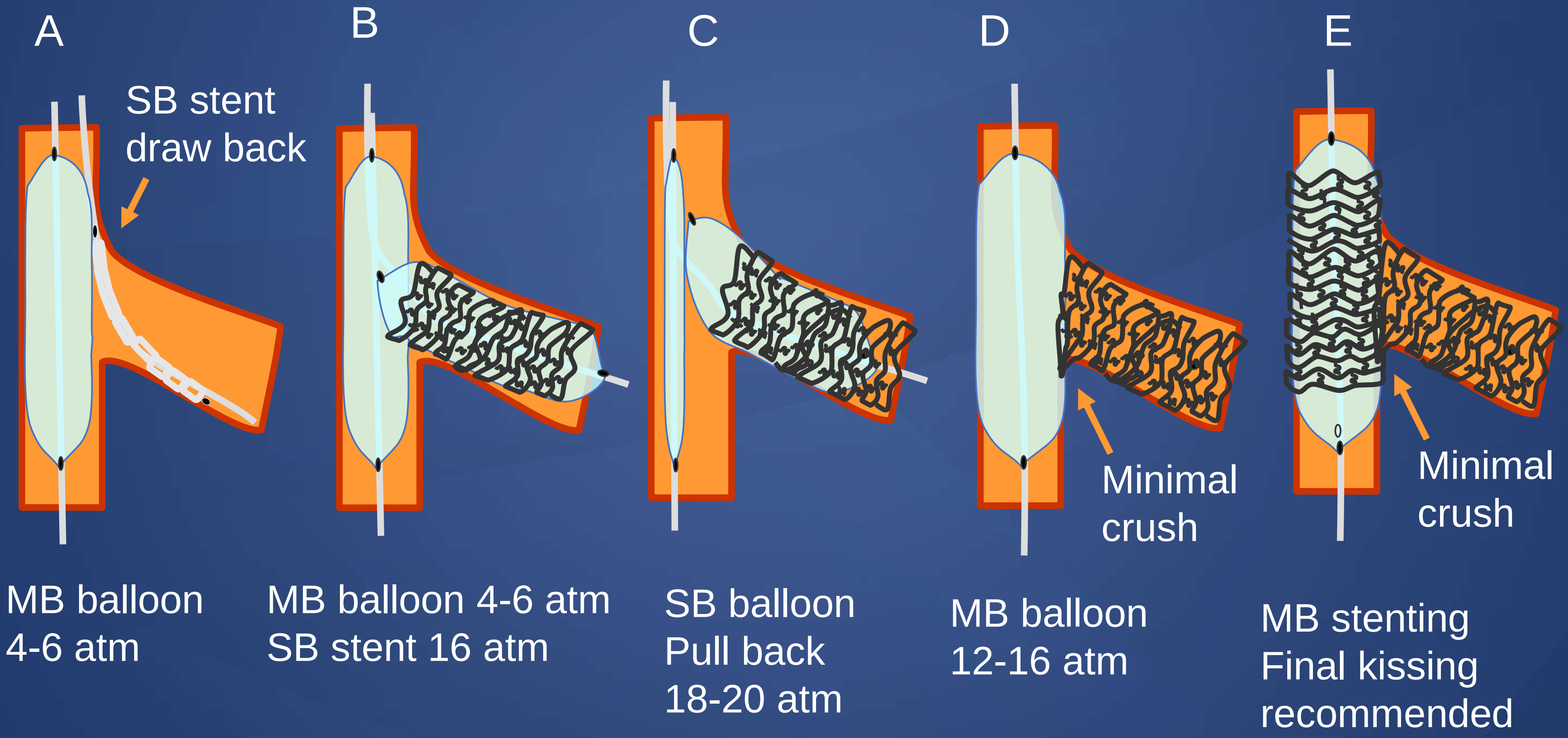
Potential gap without enough drug diffusion



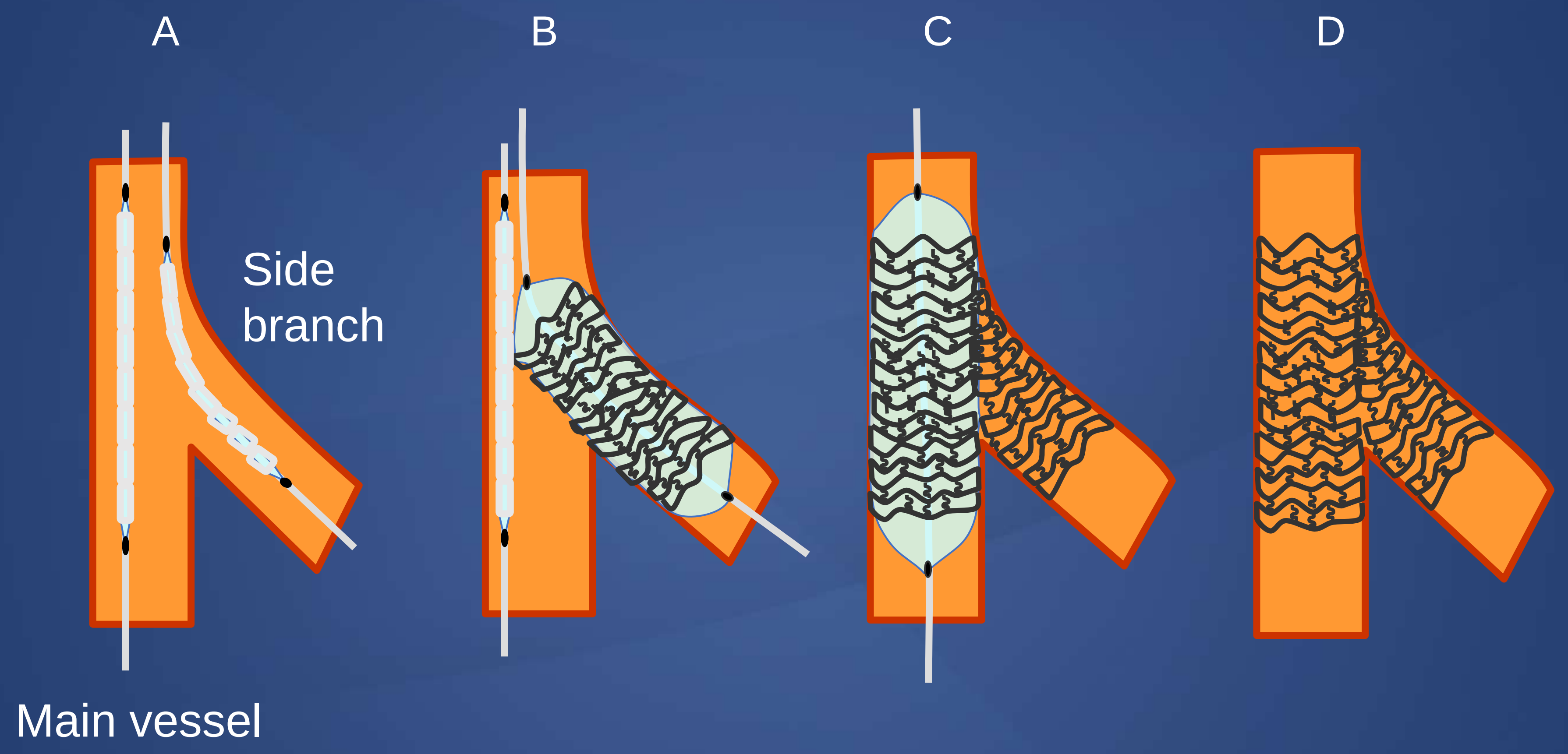
To prevent potential gap at the ostial side branch, the first stent should cover the entire surface of the side branch.

Modified T-Stenting

For Proper Ostial positioning



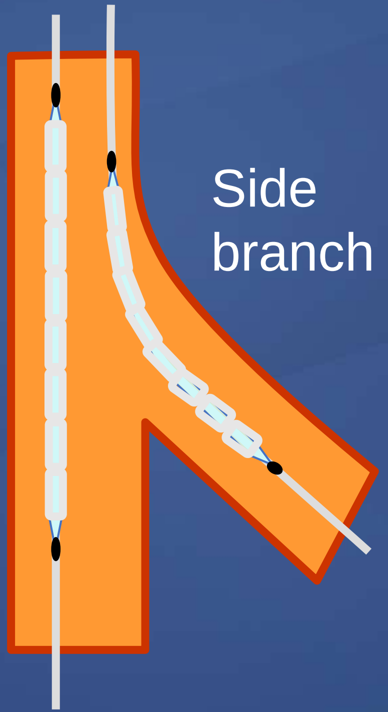
Crush Technique



Advantages	Disadvantages
Relatively simple	Difficult FKI
Low risk of SB occlusion	Requires 7 or 8-Fr guider
Good coverage of SB ostium	Leaves multiple layers of strut

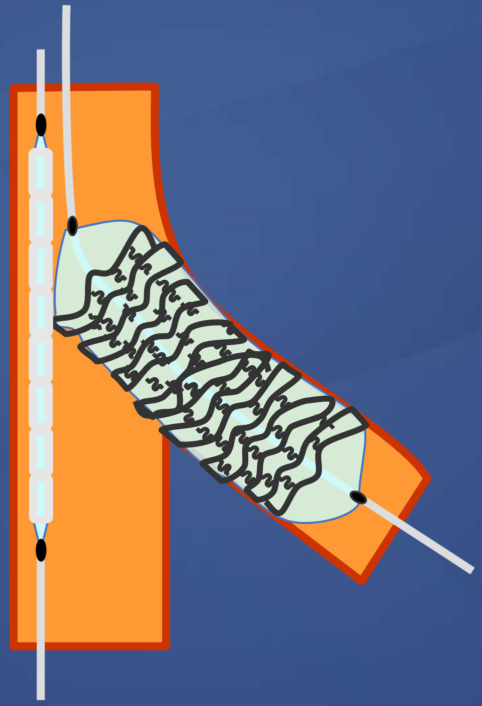
Crush Technique

A. Advance 2 stents



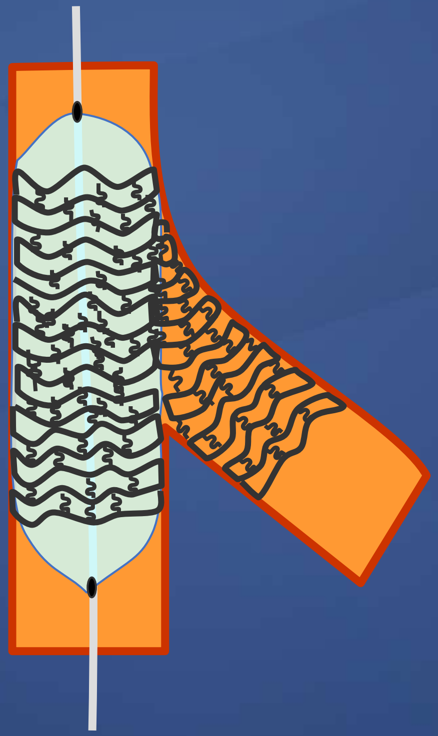
Crush Technique

B. Deploy the SB stent



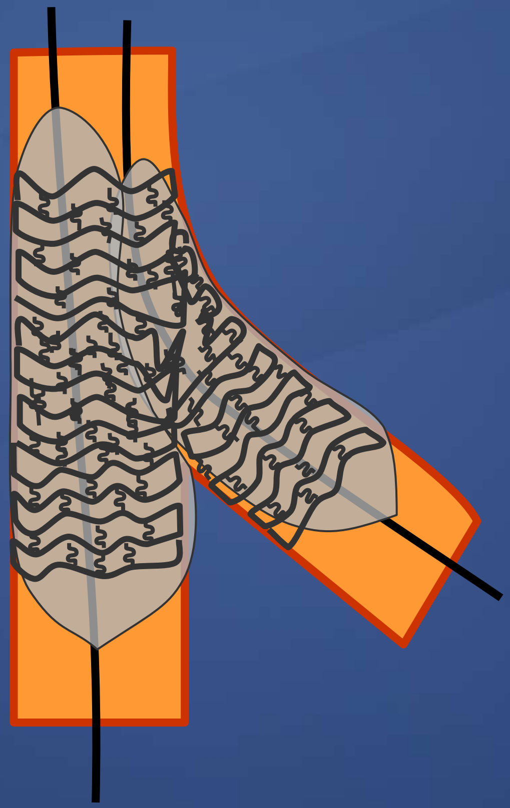
Crush Technique

C. Deploy the main stent,
then rewire SB and perform high-pressure dilatation



Crush Technique

D. Perform final kissing inflation

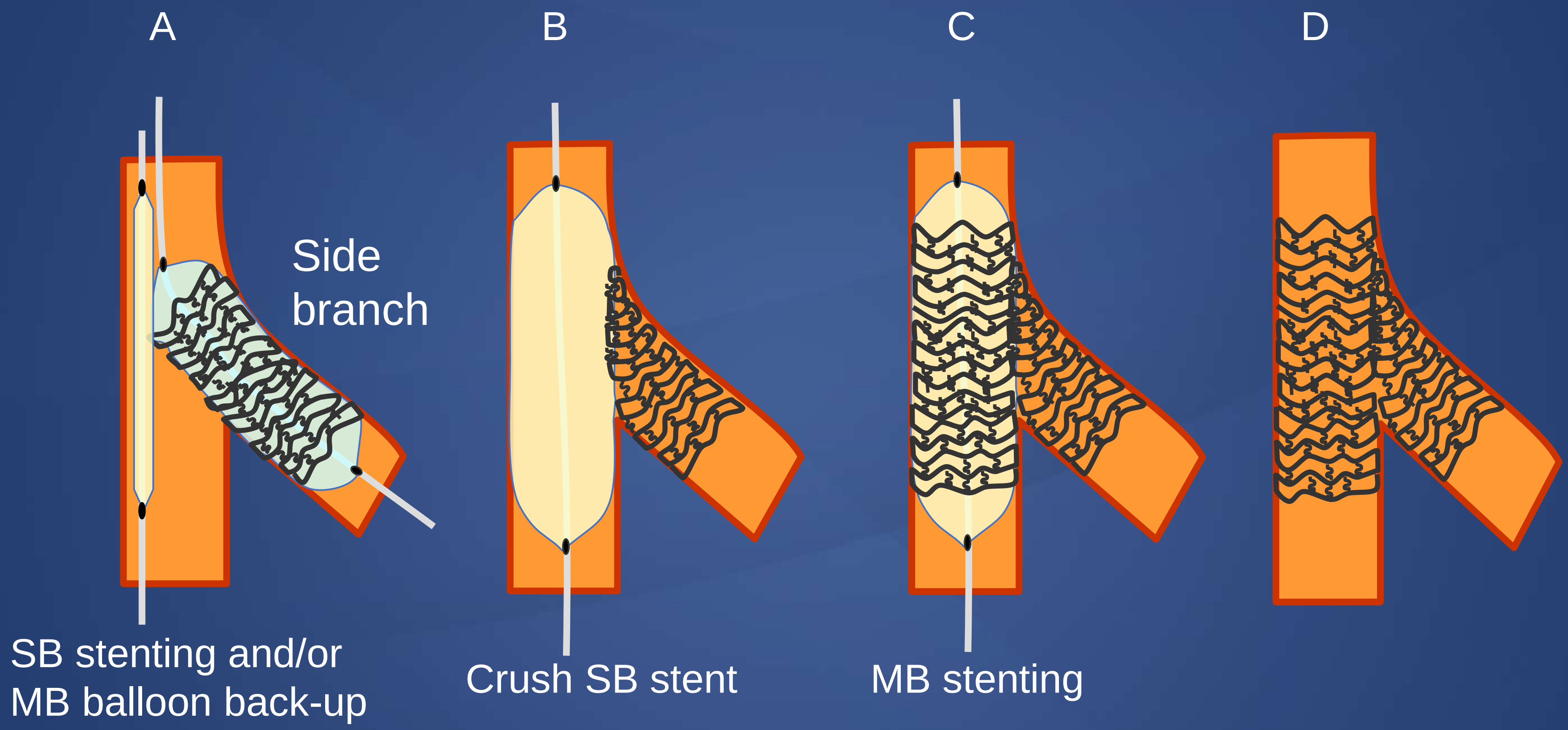


Crush Technique

D. Final result

Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

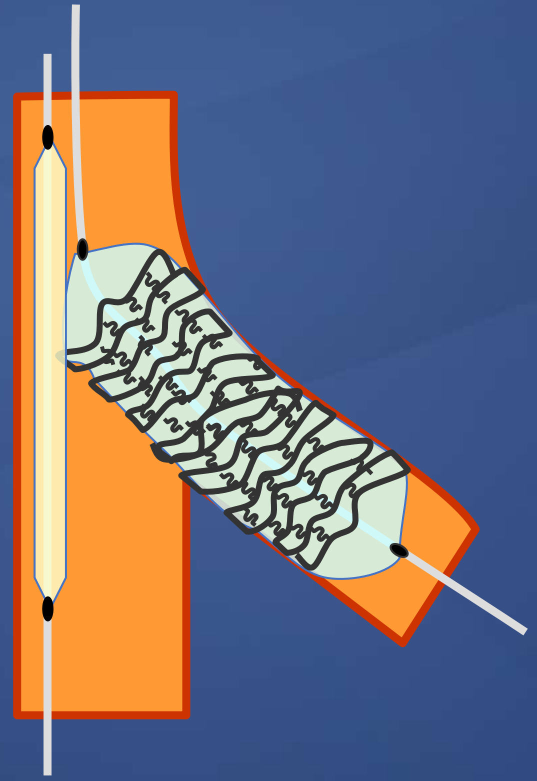


Advantages	Disadvantages
Minimizes multi-layers of struts	Still leaves multiple layers of strut
Good scaffolding at SB ostium	
Facilitates FKI	
Compatible with 6-Fr guider	

Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

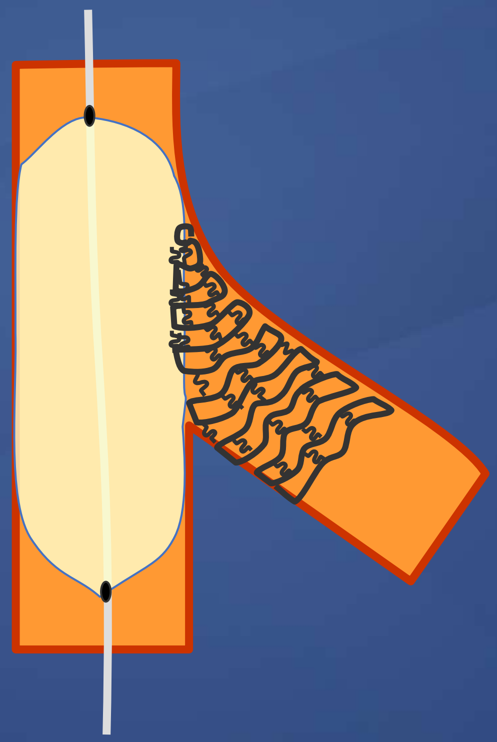
A. Deploy the SB stent ± MB balloon backup



Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

B. Crush SB stent



Mini-Crush with balloon

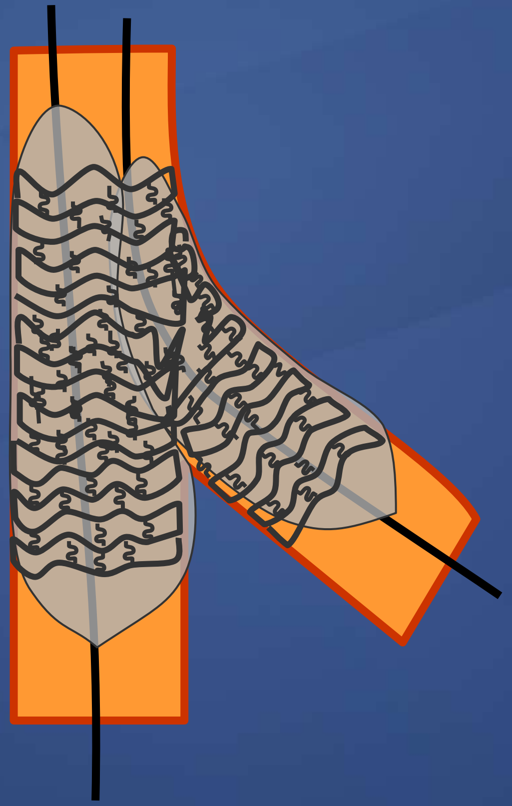
Performed with 6~7Fr guiding catheter

C. Deploy stent in MB,
then rewire SB and perform high-pressure dilatation

Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

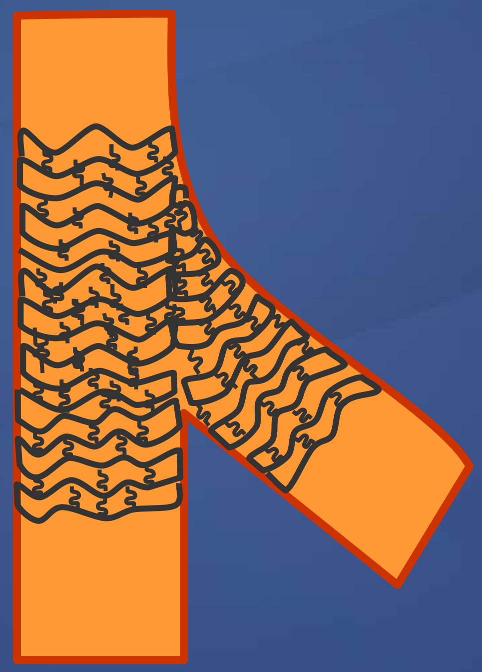
E. Perform final kissing inflation



Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

F. Final result



V Stenting

- Bifurcation without stenosis proximal to the bifurcation
- Short LM
- Less angle

V Stenting

A. Position 2 parallel stents covering both branches with a slight protrusion into the proximal MB

V Stenting

B. Deploy 2 stents individually (or simultaneously)

V Stenting

C. Perform high-pressure sequential single stent postdilation,
Then medium pressure final kissing inflation

Simultaneous Kissing Stenting

- Large proximal reference
- Bifurcation with stenosis proximal to the bifurcation

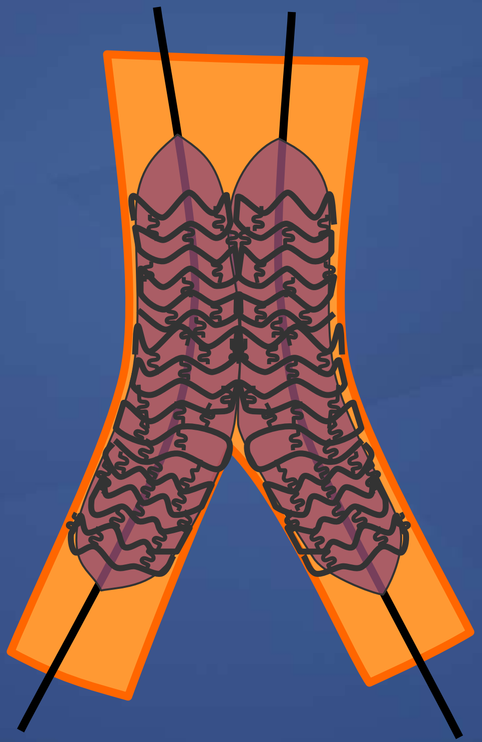
Advantages	Disadvantages
No risk of occlusion for both branches	Requires 7- or 8-Fr guider
No need to re-cross any stent	Leaves long metallic carina
Technically easy and quick	Over-dilatation in proximal MB
	Diaphragmatic membrane formation
	Difficulty in repeat revascularization

Simultaneous Kissing Stenting

A. Position 2 parallel stents covering both branches with a long double barrel protrusion into the proximal MB

Simultaneous Kissing Stenting

B. Deploy 2 stents



Simultaneous Kissing Stenting

C. Perform final kissing inflation resulting a new metallic carina

IVUS in LM disease

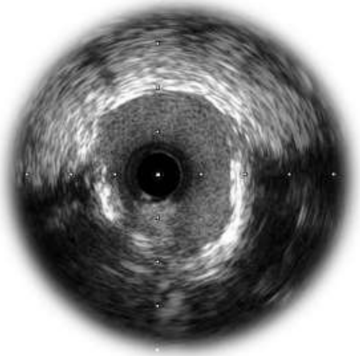
IVUS Use was Associated with Better 10-yr Outcomes after LM PCI

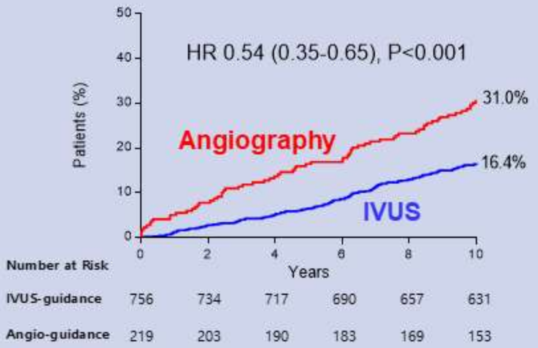
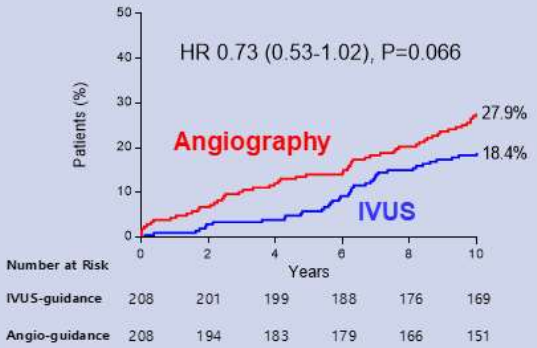
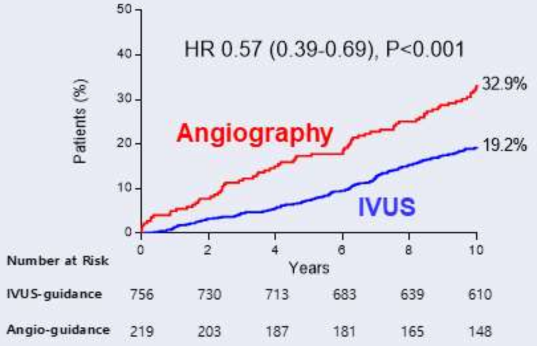
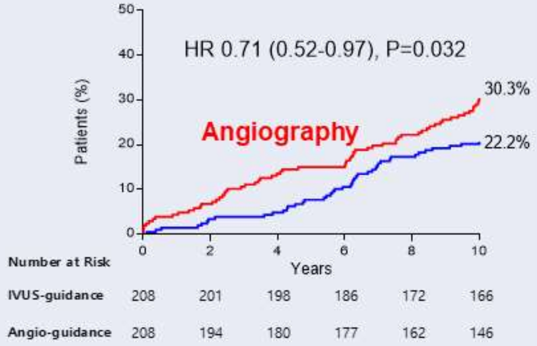
MAIN-COMPARE Registry

Left Main Disease

10-Year Follow-up

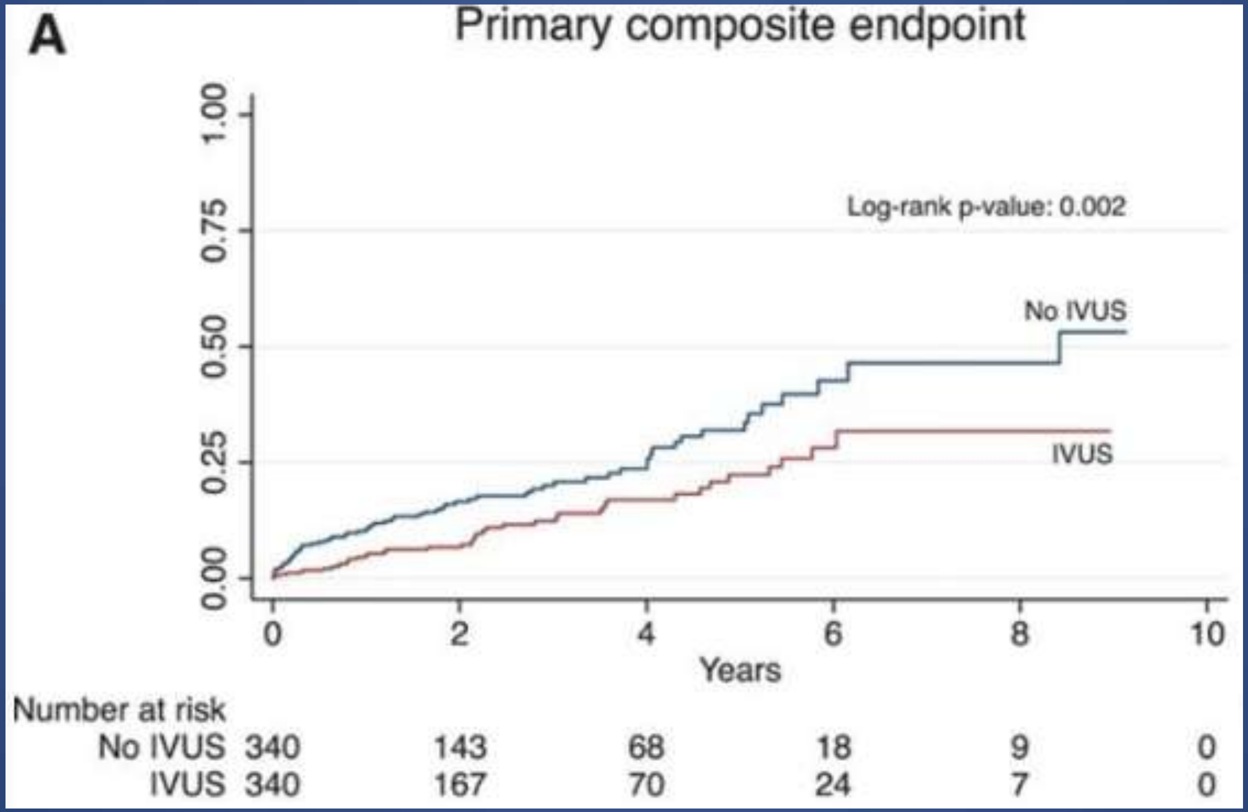
IVUS-guided PCI



	Overall Population	After Propensity-score Matching
All-cause death		
Composite of all-cause death, Q-wave MI, or stroke		

IVUS guidance associated with better outcome in LMCA stenting compared with angiography guidance alone

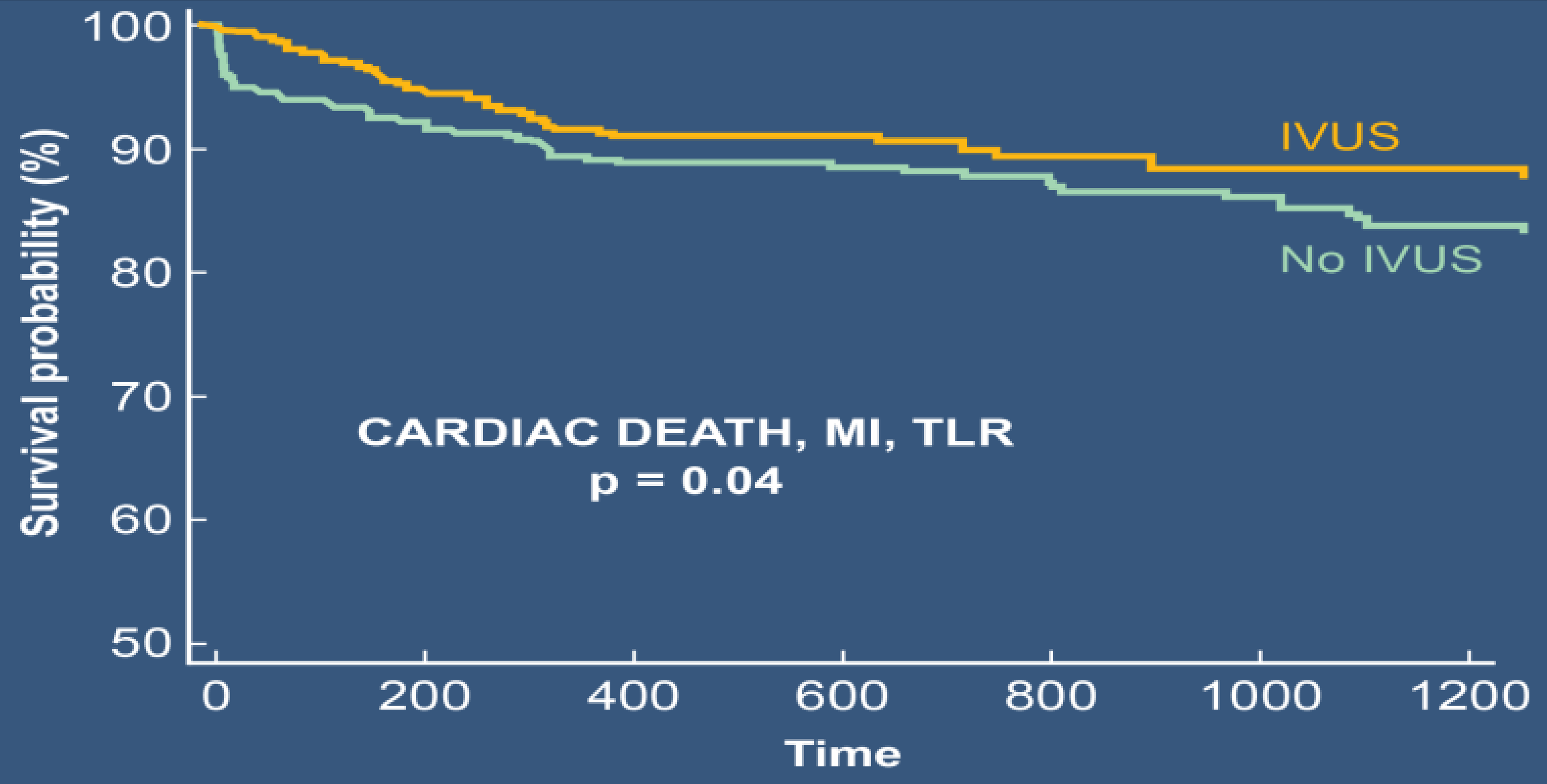
SCAAR Registry



Pontus Andell et al, Circ Cardiovasc Interv. 2017;10;e004813

Pooled analysis
:ESTROFA-LM, RENACIMIENTO, Bellvitge, Valdecilla

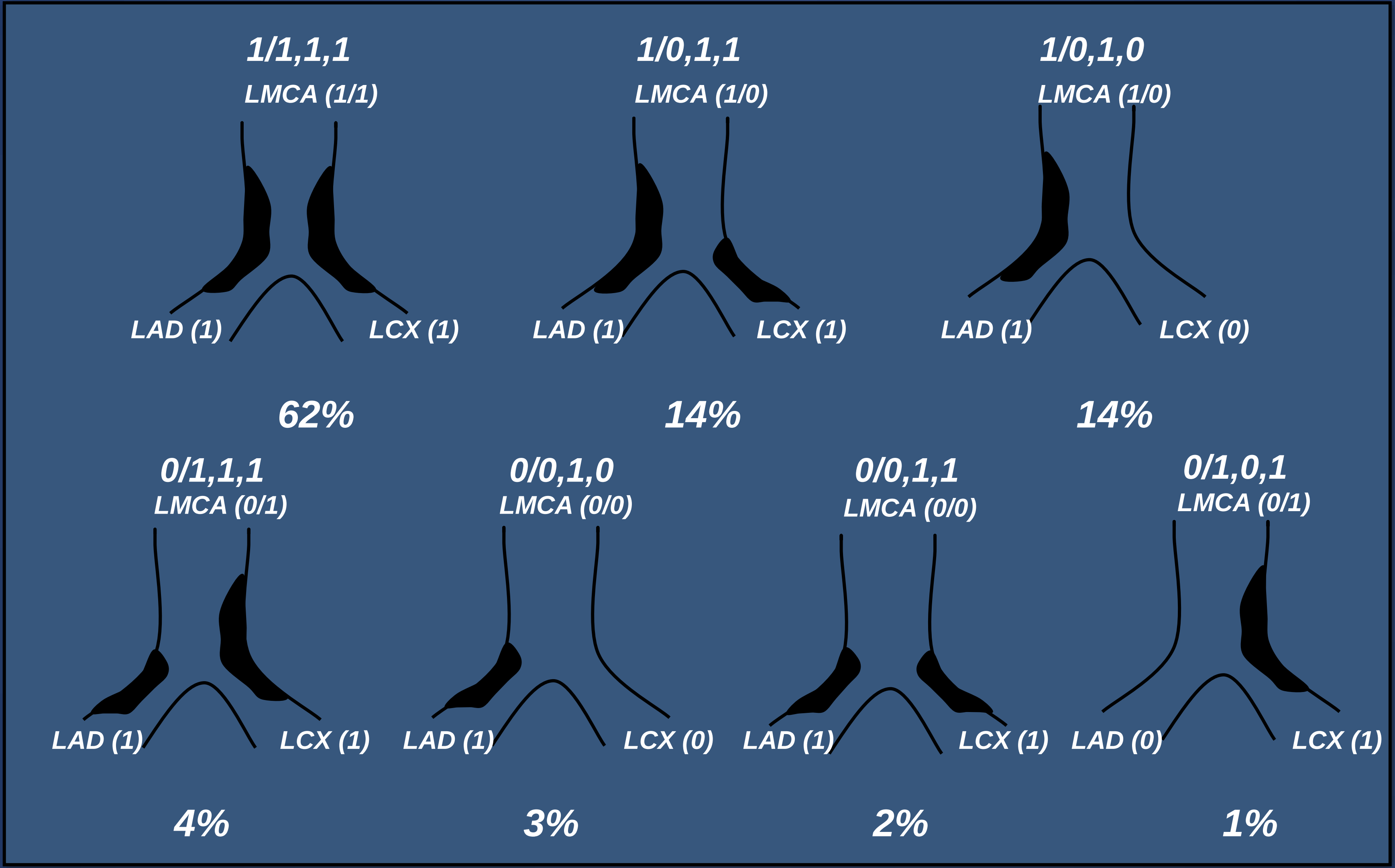
Effectiveness of IVUS on LM PCI



Pts. at risk	365 days	730 days	1095 days
IVUS	485	286	203
No IVUS	470	275	201

De la Torre Hernandez et al. *JACC: cardiovasc interv* 2014;7:244-54

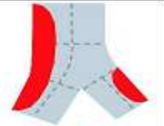
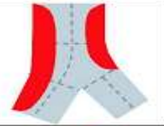
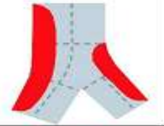
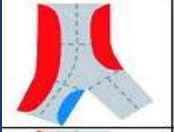
Plaque Distribution by IVUS (n=140)



In 90% plaque extends from LMCA-LAD

Oviedo C et al. Circ Cardiovasc Interv 2010;3:105-12.

Plaque Distribution by IVUS (n=82)

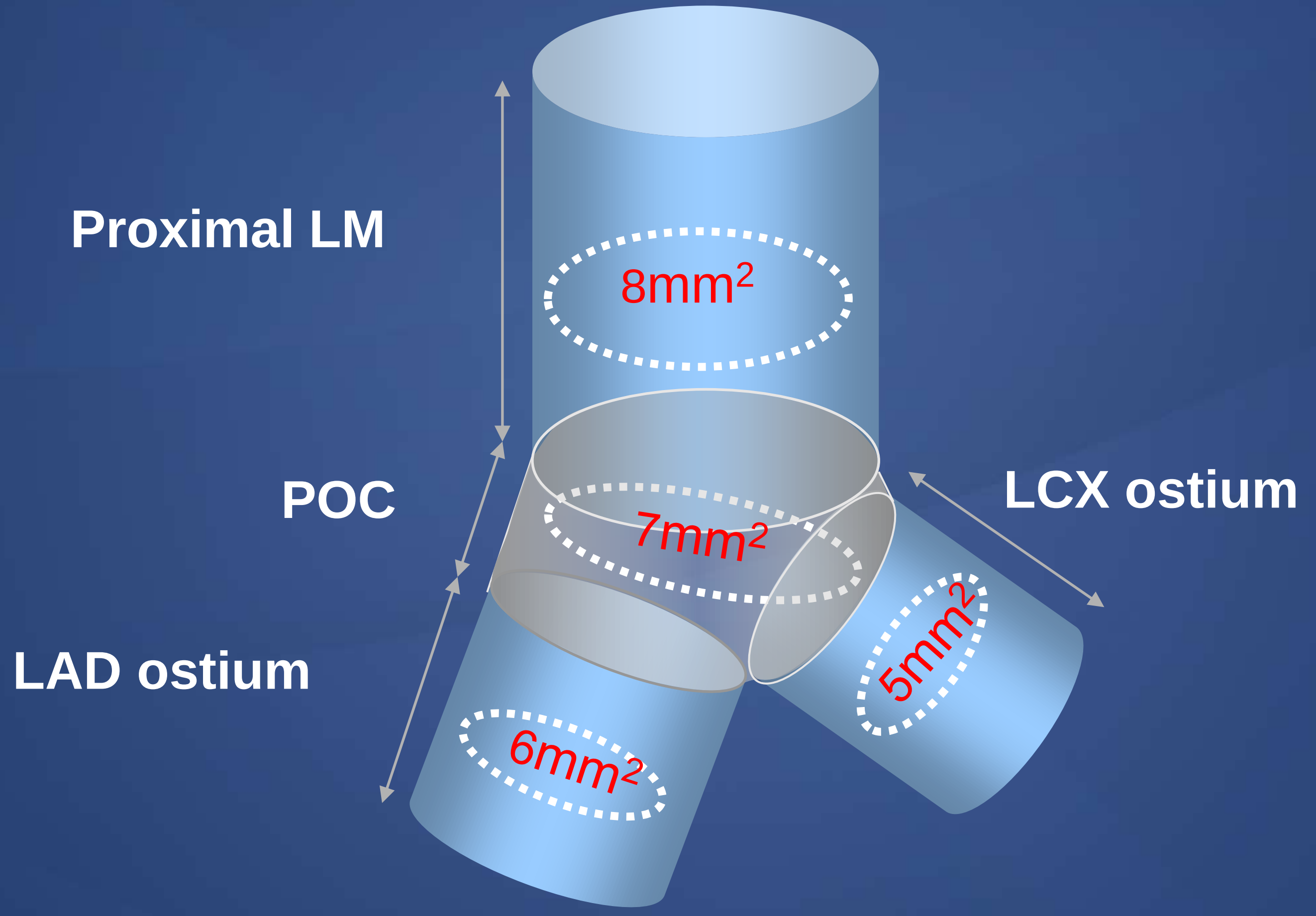
	N. (%)	LAD ostium, MLA (mm²)	POC, MLA (mm²)	DLM, MLA (mm²)	LCX ostium, MLA (mm²)
	5 (6%)	4.4±2.0	9.6±4.4	8.1±4.7	3.4±1.6
	26 (32%)	4.2±2.8	5.3±2.6	4.6±1.5	3.9±2.1
	12 (15%)	2.6±1.3	4.5±1.6	4.5±2.1	3.3±2.0
	9 (11%)	4.3±2.5	5.6±3.3	5.7±3.8	7.6±3.6
	9 (11%)	3.2±1.4	6.1±2.0	4.8±2.5	3.9±1.4
	4 (5%)	3.4±1.9	5.2±1.9	5.8±4.7	3.9±2.0
	4 (5%)	2.8±0.7	5.1±2.1	5.1±2.2	6.6±1.7
	5 (6%)	3.4±1.9	5.2±2.6	5.1±3.8	4.6±2.1

In all cases, the LM disease extended into LAD and LCX continuously.

Kang et al, Catheterization and Cardiovascular Interventions. 2011.

Optimal MSA

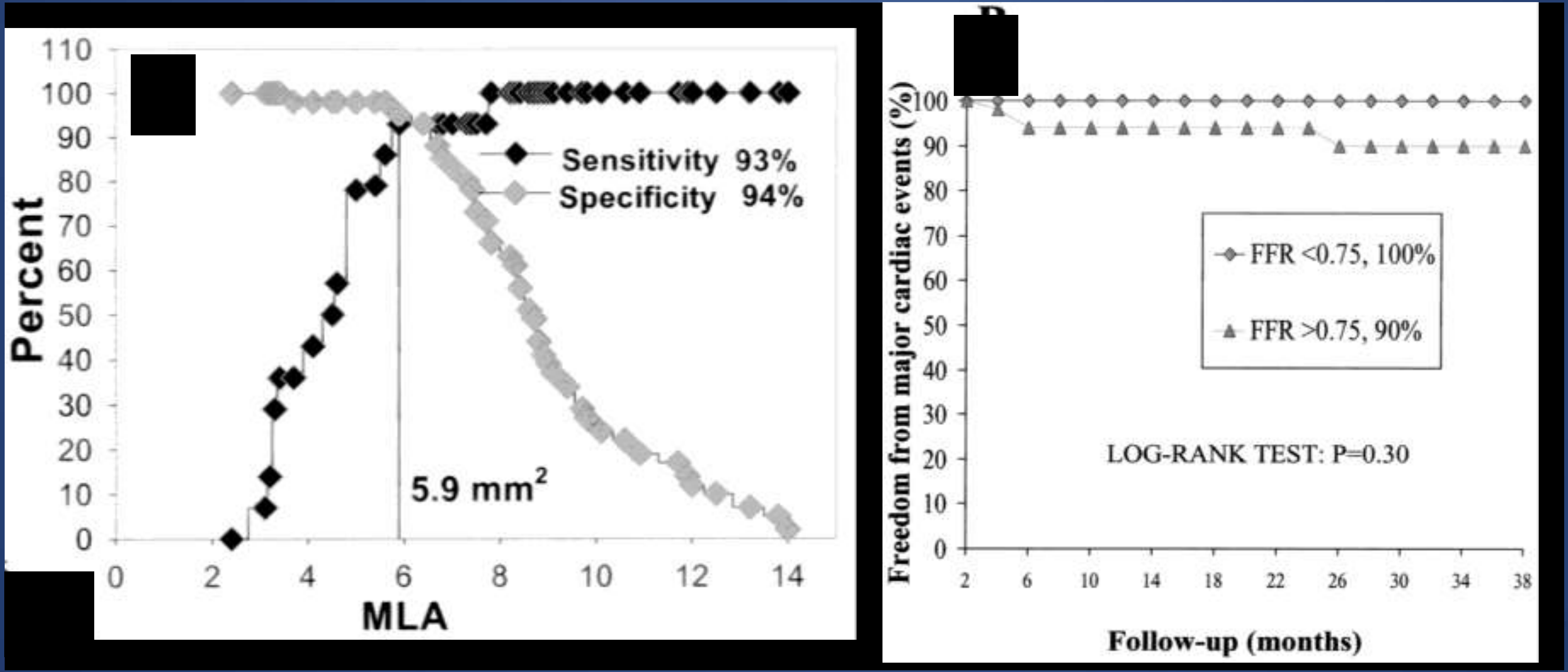
on a segmental basis



Kang et al. Circ Cardiovasc Interv 2011 2011;4:1168-74

Cut-off for Predicting LM FFR<0.75 : LM MLA 6.0mm²

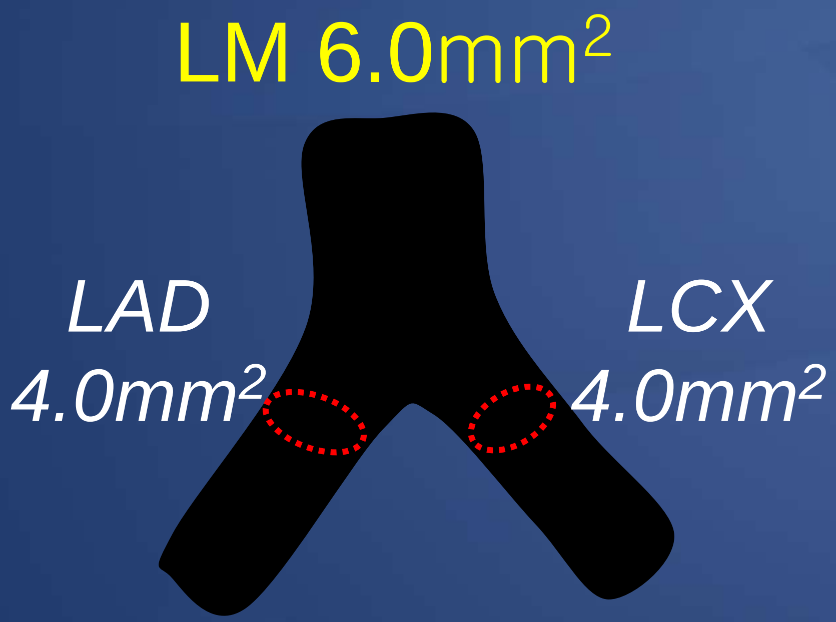
- Sum of lumen areas of two daughter vessels (Each of LAD and LCx should be 4.0mm²) = 150% of the parent LM
- **Murray's Law (*LM* r³ = *LAD* r³ + *LCx* r³)**



Jasti et al. Circulation 2004;110:2831–6

Geometric Abstraction

Old MLA cut-off 6.0mm^2 was obtained from *Murray's law* considering an MLA 4.0mm^2 as ischemic threshold of both LAD and LCX



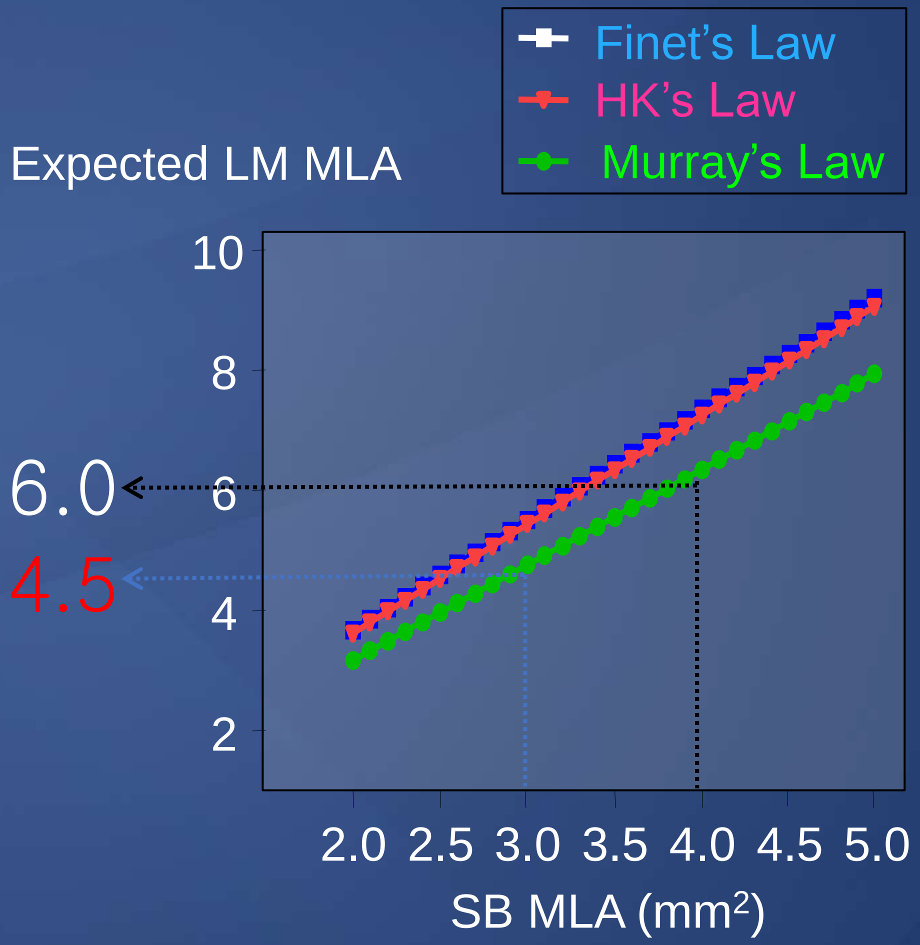
LAD	LCX	LM (Murray's)
4.0	**4.0**	**6.35**
4.0	3.9	6.27
4.0	3.8	6.19
4.0	3.7	6.11
4.0	3.6	6.04
4.0	3.5	5.96

De La Torre Hernandez et al. JACC 2011;58:351-8

Jasti et al. Circulation 2004;110:2831-6

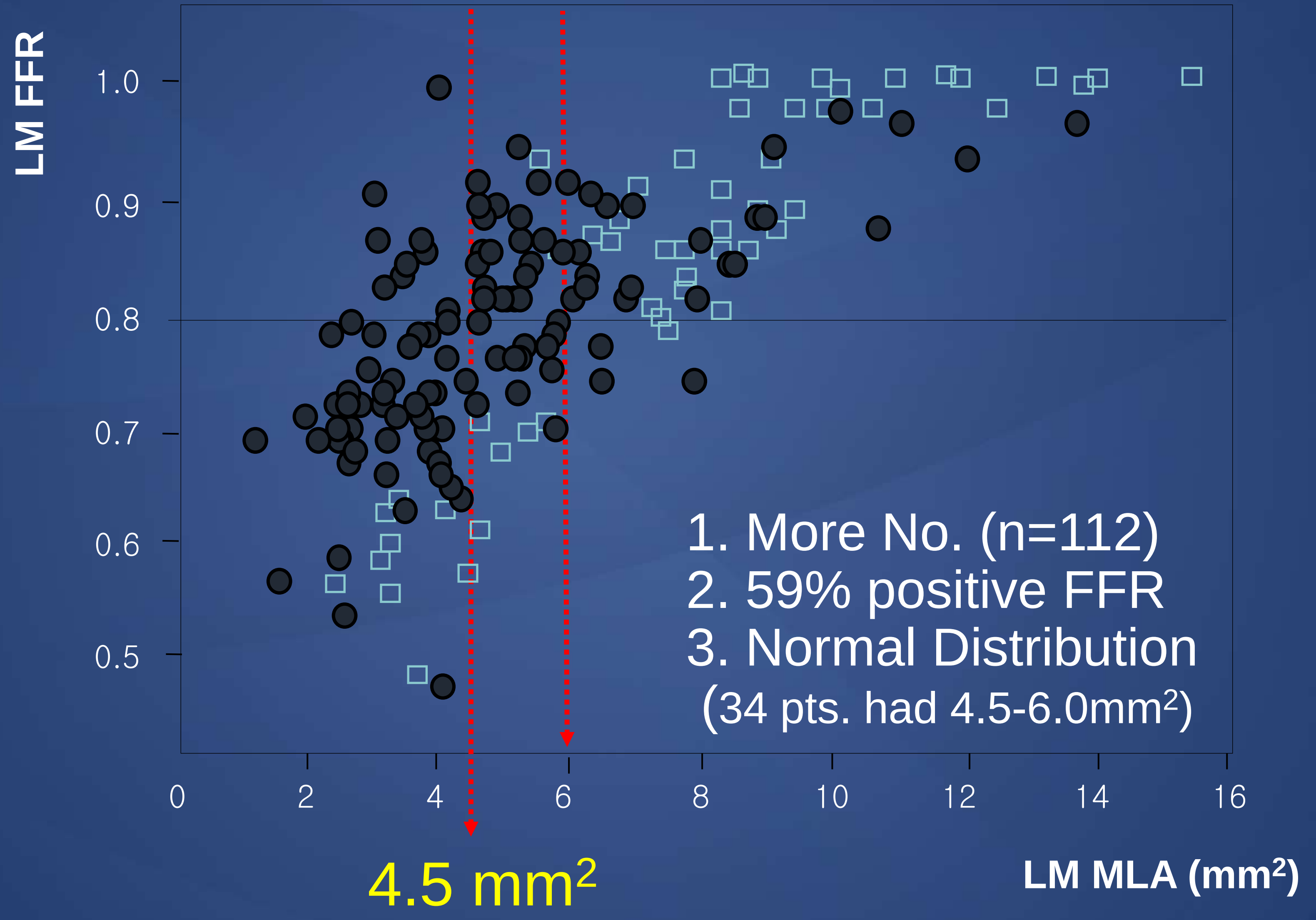
False Assumption…
The used cut-off 4.0mm² is too Big!

LAD	LCX	LM (Murray's)
3.0	3.0	4.76
3.0	2.9	4.68
3.0	2.8	4.60
3.0	**2.7**	**4.53**
3.0	2.6	4.45
3.0	2.5	4.37



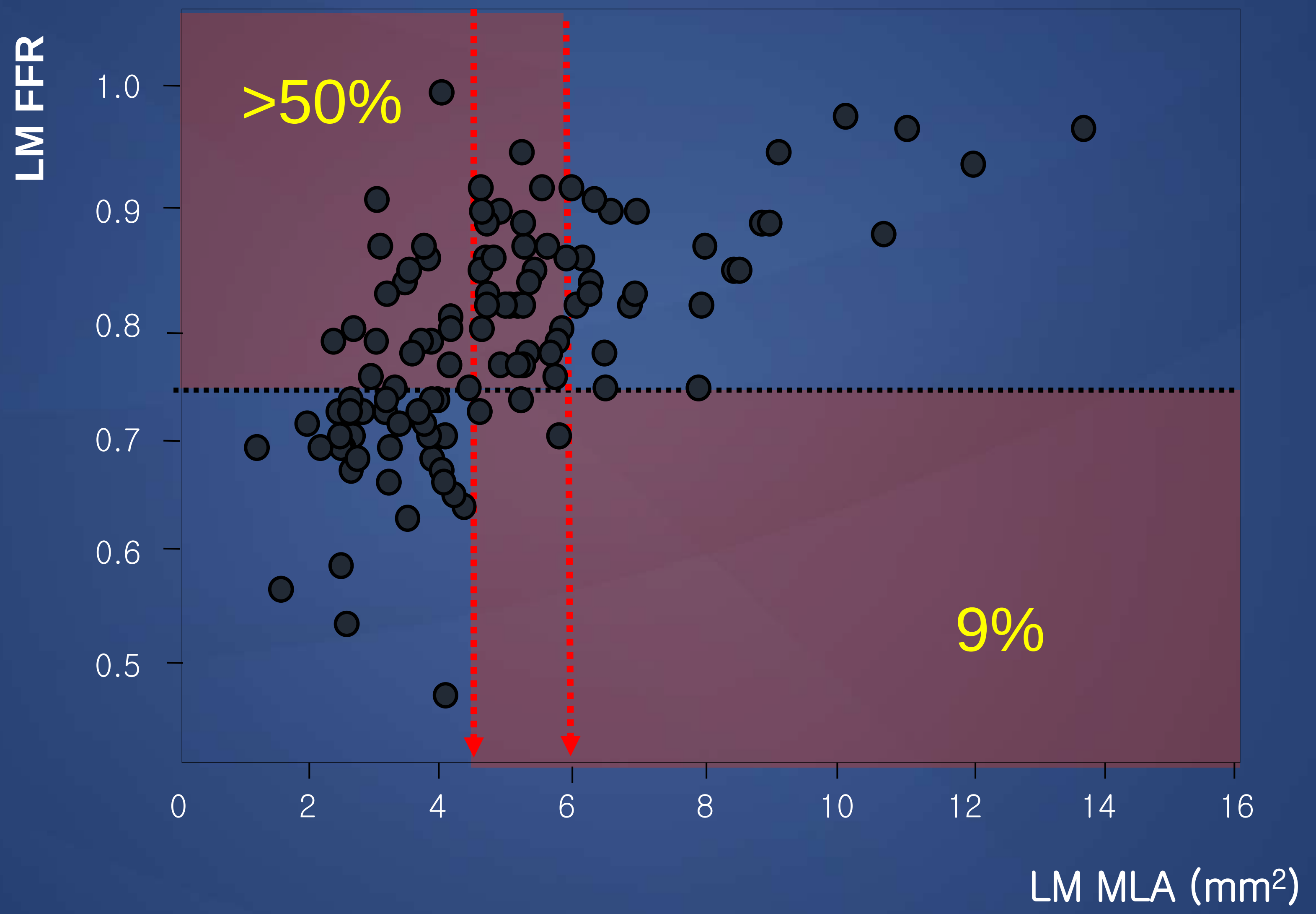
Huo et al. Eurointervention 2012;7:1310-6

AMC Data (n=112)



Park SJ et al. JACC Interv 2014;7:868–74

AMC Data (n=112)



Park SJ et al. JACC Interv 2014;7:868–74

- Old data (MLA 6.0mm^2) included downstream SB disease, and 32 of 55 (58%) were distal LM lesions that usually extend to the SB ostia
- Recent data (MLA 4.5mm^2) evaluated only pure LM lesions, which more reliably assessed the impact of LM-MLA on functional significance

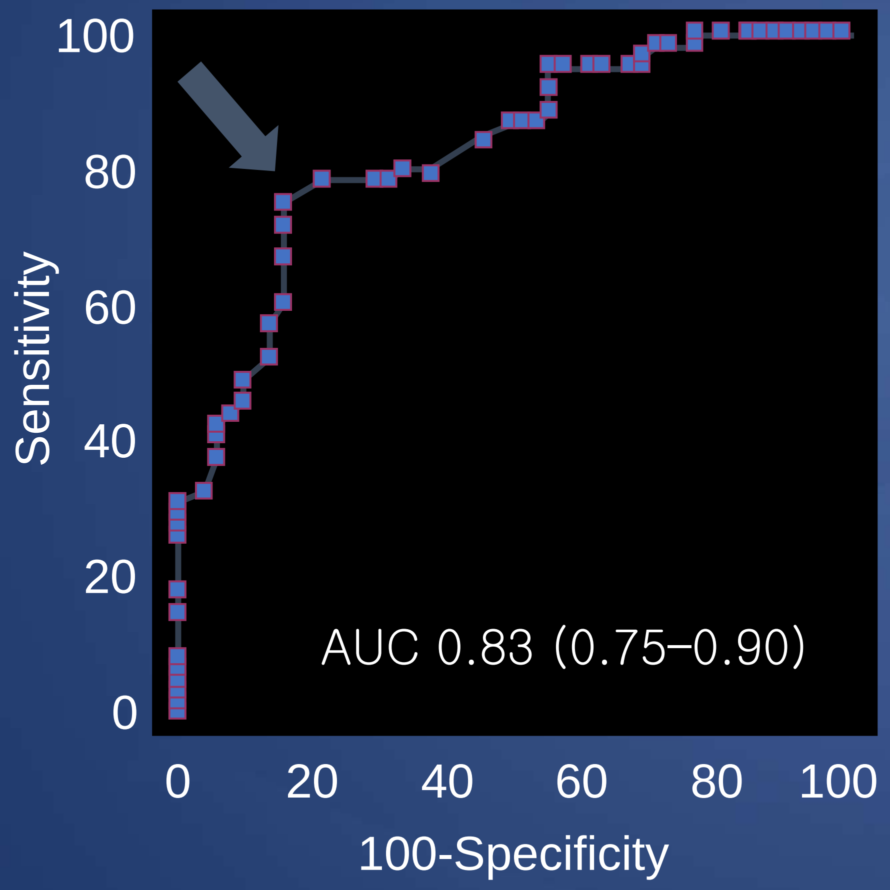
TABLE 1. Baseline Clinical, Angiographic, and IVUS Characteristics of Patients (n=55)

Age, y	62±11
Diabetes mellitus, n	20
Hypertension, n	50
Smoking, n	39
Prior bypass surgery, n	13
Ostial LM stenosis, n	20
Mid-LM stenosis, n	3
Distal LM stenosis, n	32

Jasti et al. Circulation 2004;110:2831-6

New LM MLA 4.5mm²

Matched with FFR <0.80
Ostial and Shaft LM Disease (N=112)

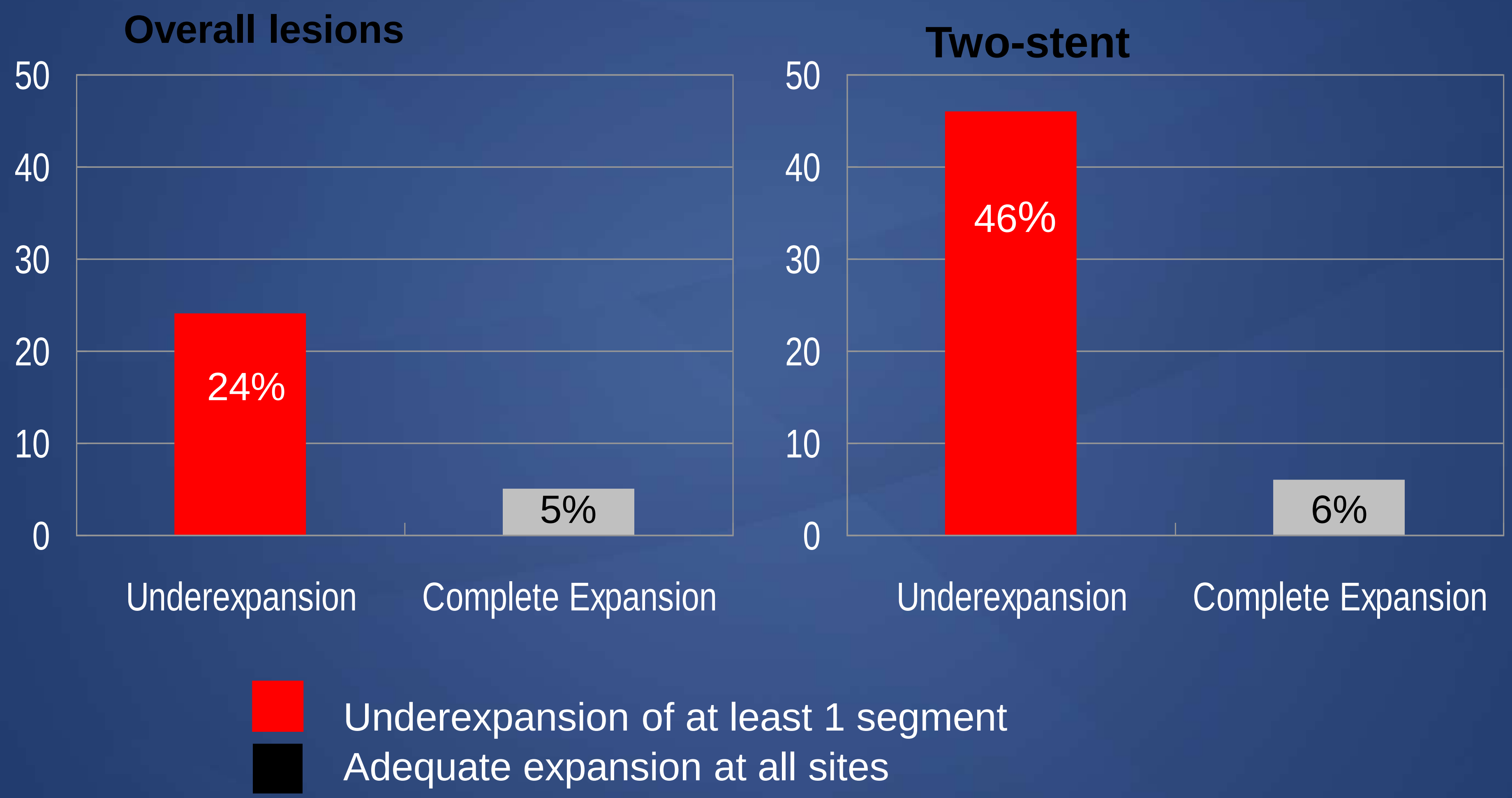


Sensitivity	79%
Specificity	80%
PPV	83%
NPV	76%

Park SJ et al. JACC Interv 2014;7:868–74

Frequency of ISR in LM Lesions

with vs. without Underexpansion

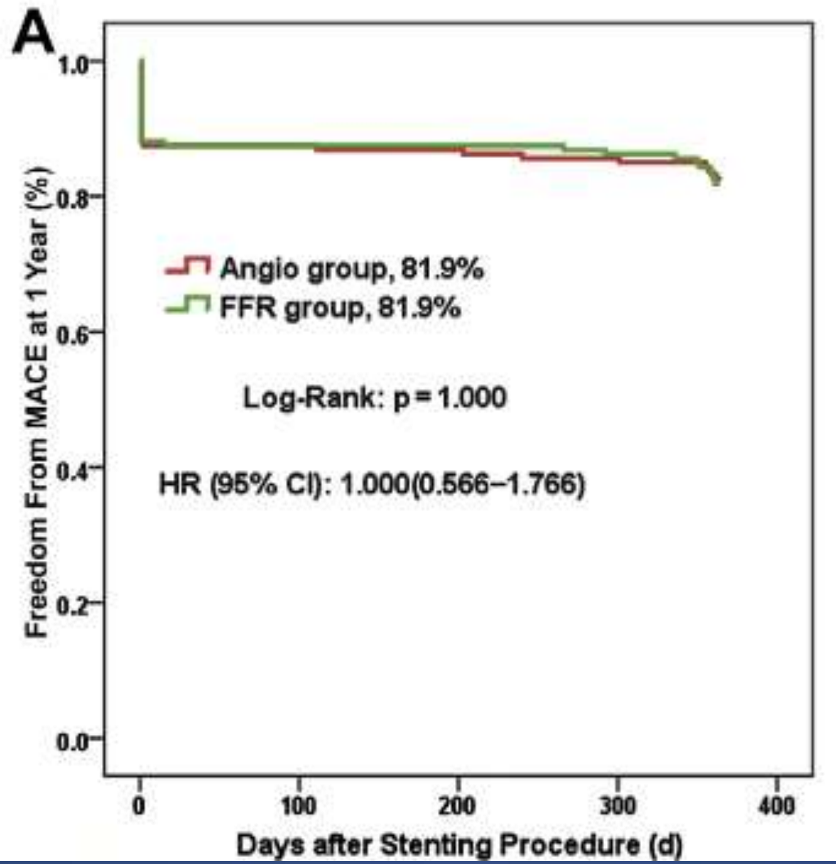


Kang et al. Circ Cardiovasc Interv 2011 2011;4:1168-74

FFR in LM disease

FFR guided and angio guided provisional stenting of LM DKCRUSH-VI trial

- primary endpoint : 1 yr composite of MACE

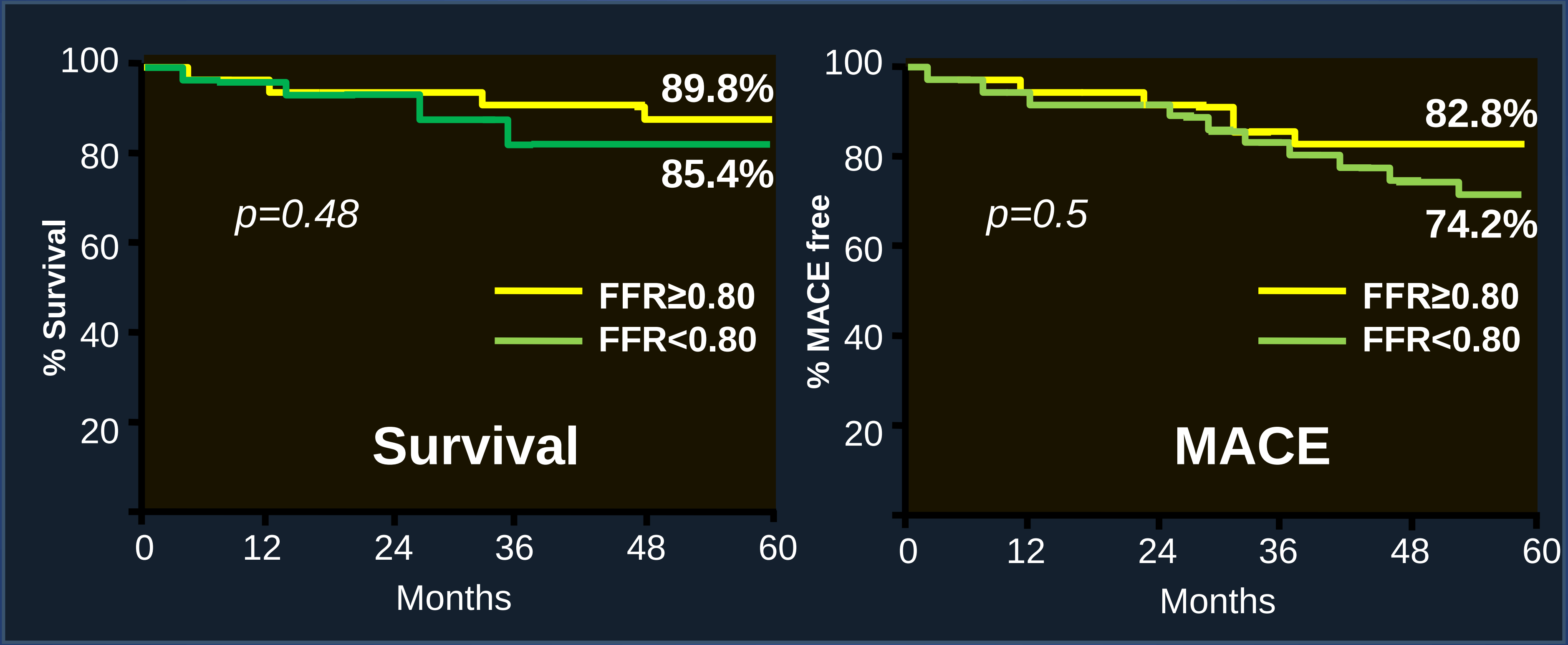


Angiographic and FFR guidance of provisional SB stenting of LM bifurcation lesions provided similar 1-year clinical outcome.

J Am Coll Cardiol Intv 2015;8:536–46

FFR guided PCI in Equivocal LMCA

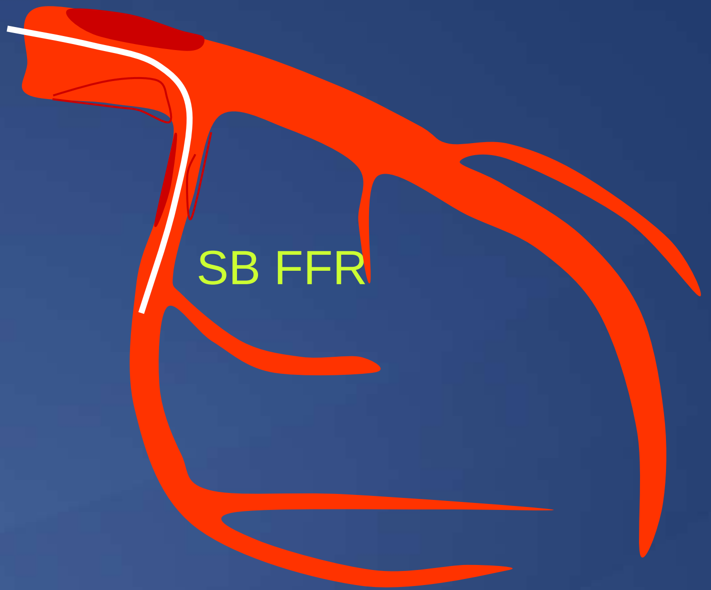
- In 213 patients with an equivocal LMCA stenosis
- FFR ≥0.80: Medication (n=138) vs. FFR<0.80: CABG (n=75)



An FFR-guided strategy showed the favorable outcome.

Circulation. 2009;120:1505-1512

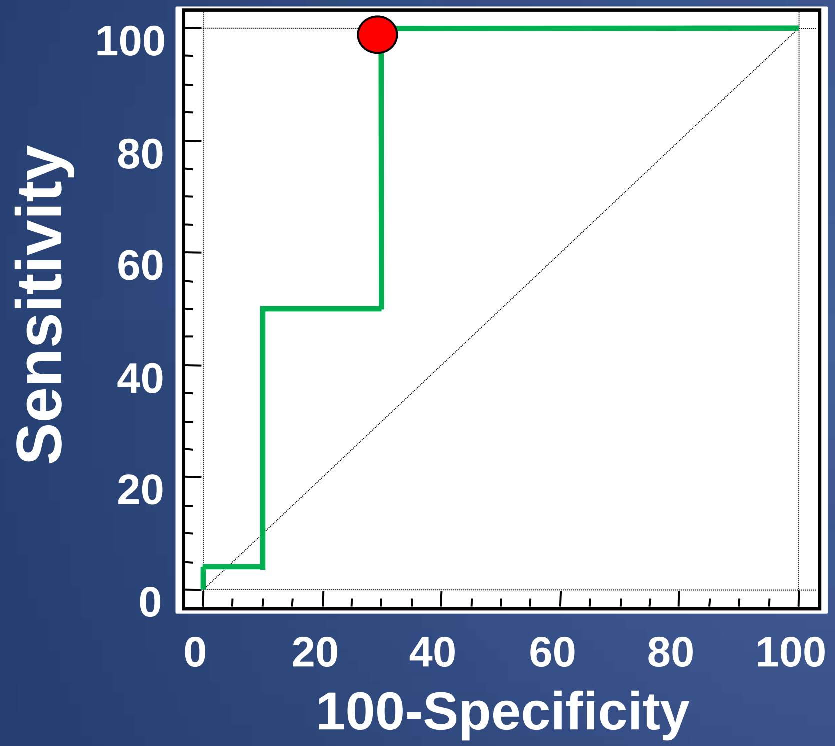
Use of IVUS vs. FFR in SB Assessment After LM Cross-over

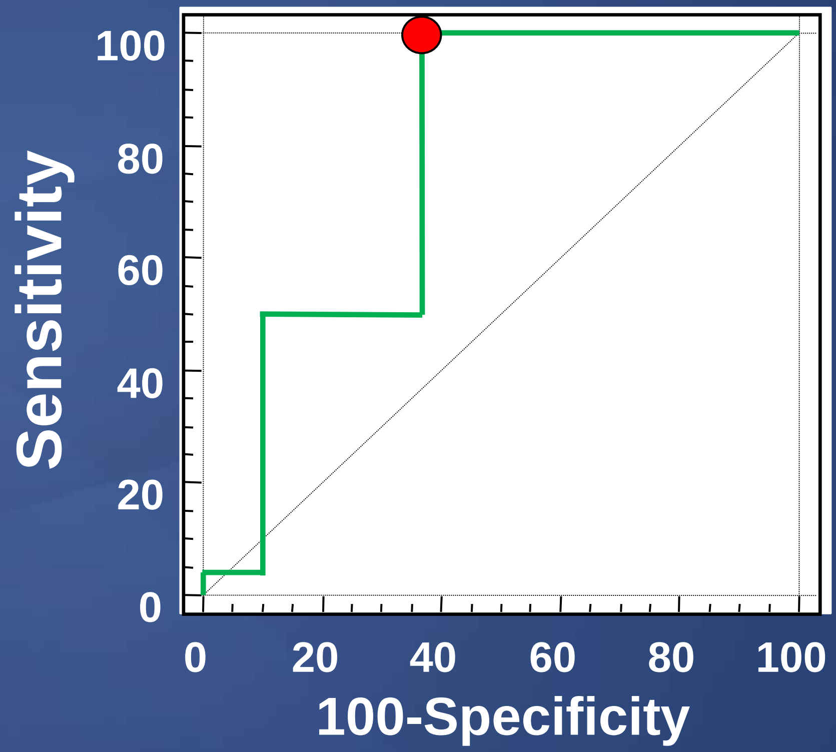


	SB-pullback IVUS	SB FFR
Advantage	▪ Confirm the anatomical compromise and MLA loss ▪ Mechanism of SB jailing	▪ Confirm the functional SB compromise
Pitfalls	▪ MLA-FFR mismatch ▪ No MLA criteria ▪ Low feasibility	▪ Minority - not feasible

Functional Compromise of LCX after LM Cross-Over Stenting

Preporcedural MLA and plaque burden of poststenting LCX FFR < 0.80





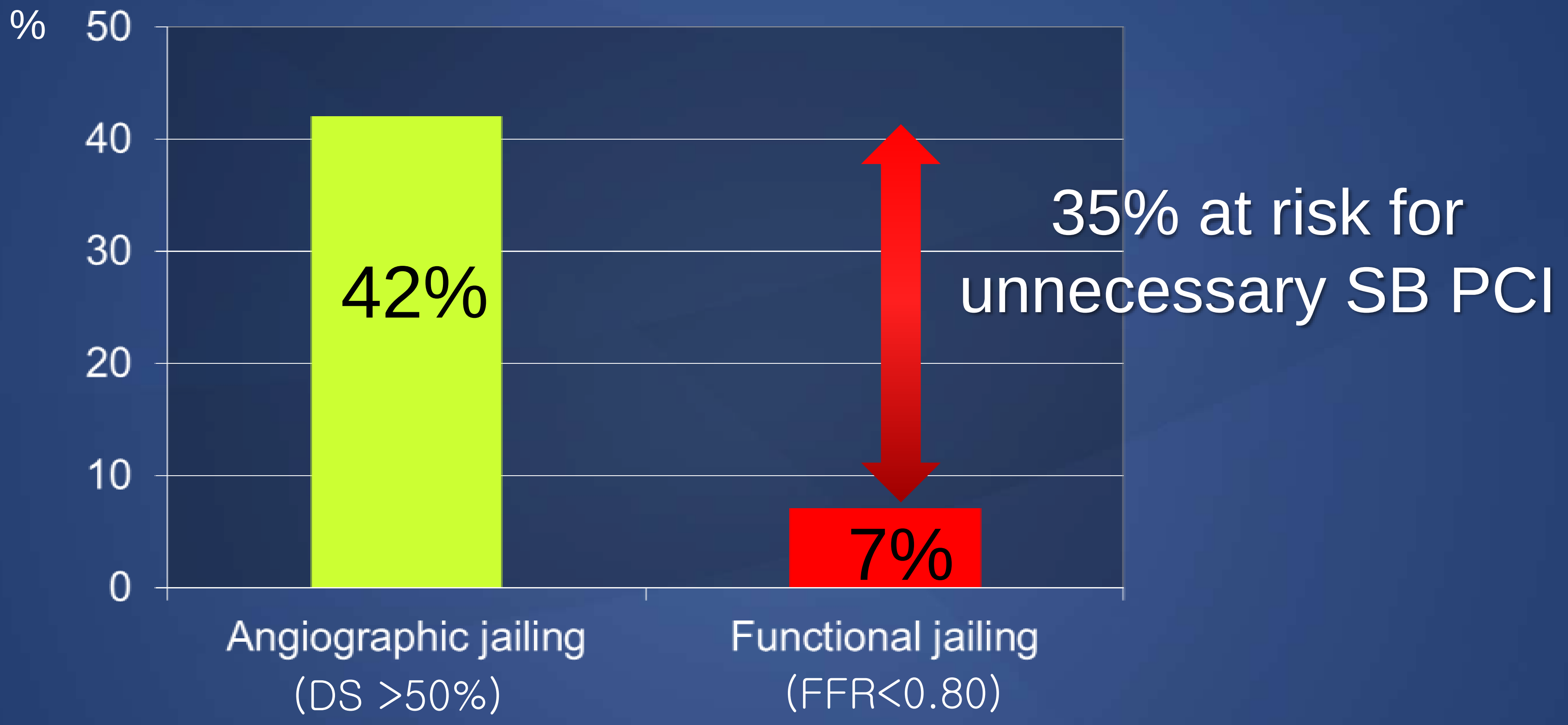
MLA 3.7 mm²

Plaque burden 56%

Kang SJ et al. Catheter Cardiovasc Interv. 2014;83:545-552

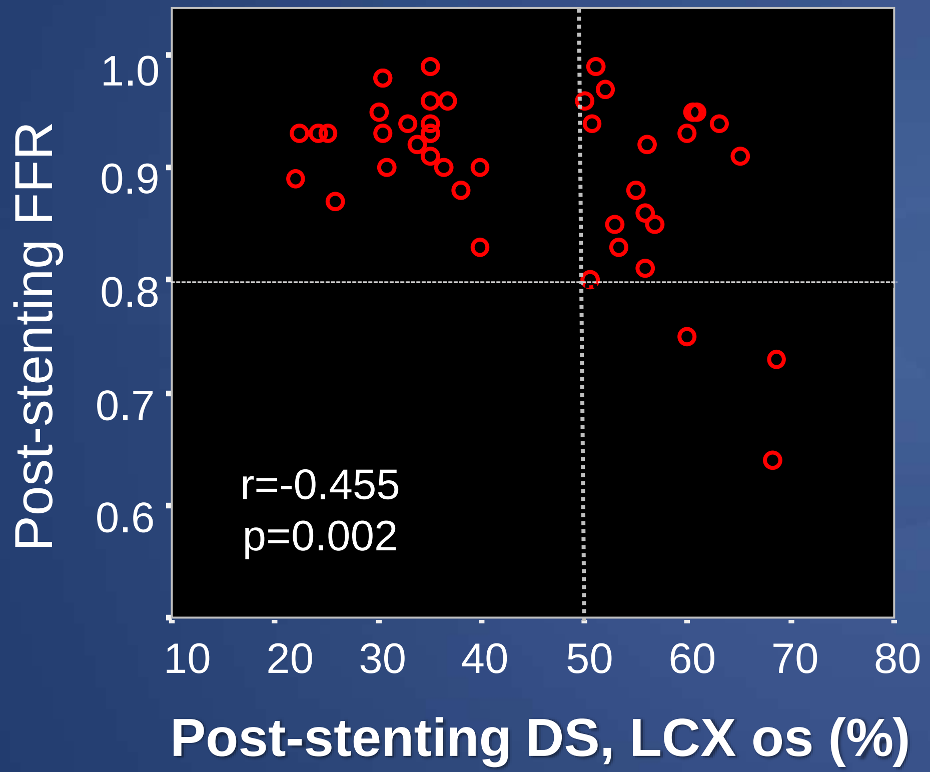
Functional LCX Compromise

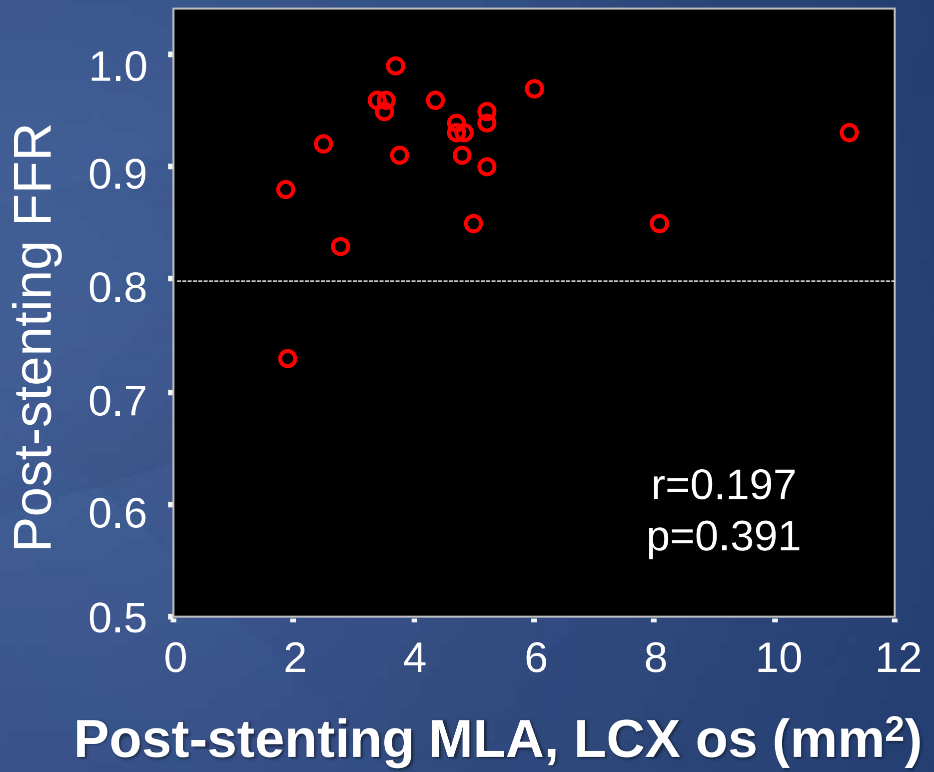
In LMCA Bifurcations (LCX ostial DS<50%)



When Pre-PCI LCX Ostial DS<50%, Just Do Single Stent!

LMCA Bifurcation
Post-stenting LCX Stenosis

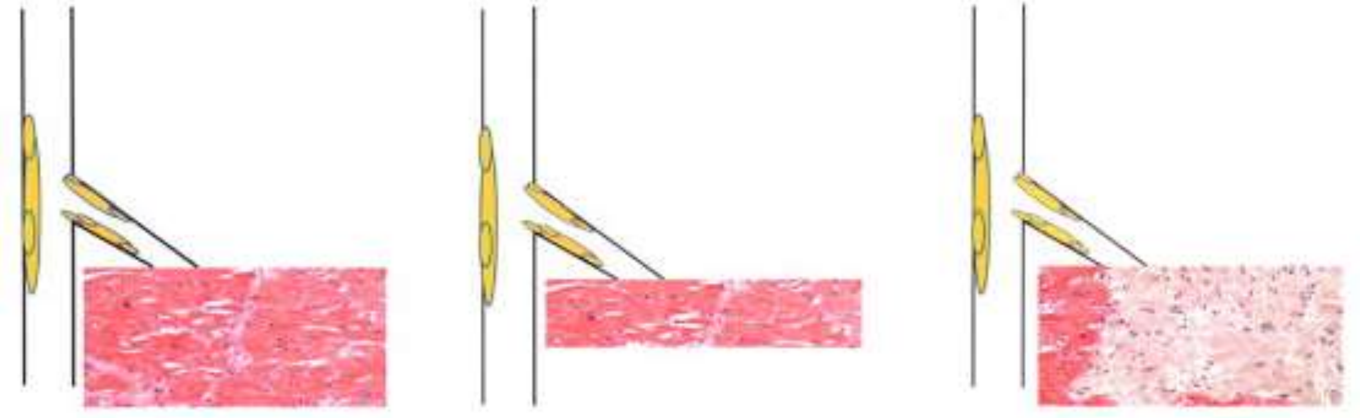




Kang et al. Catheter Cardiovasc Interv 2014;83:542-52

Why Mismatch?

- Lesion eccentricity of SB
- Negative remodeling of ostium
- Various size of myocardium
- Strut artifacts
- Focal carina shift



Ischemia (FFR= <0.80)
Large myocardial territory

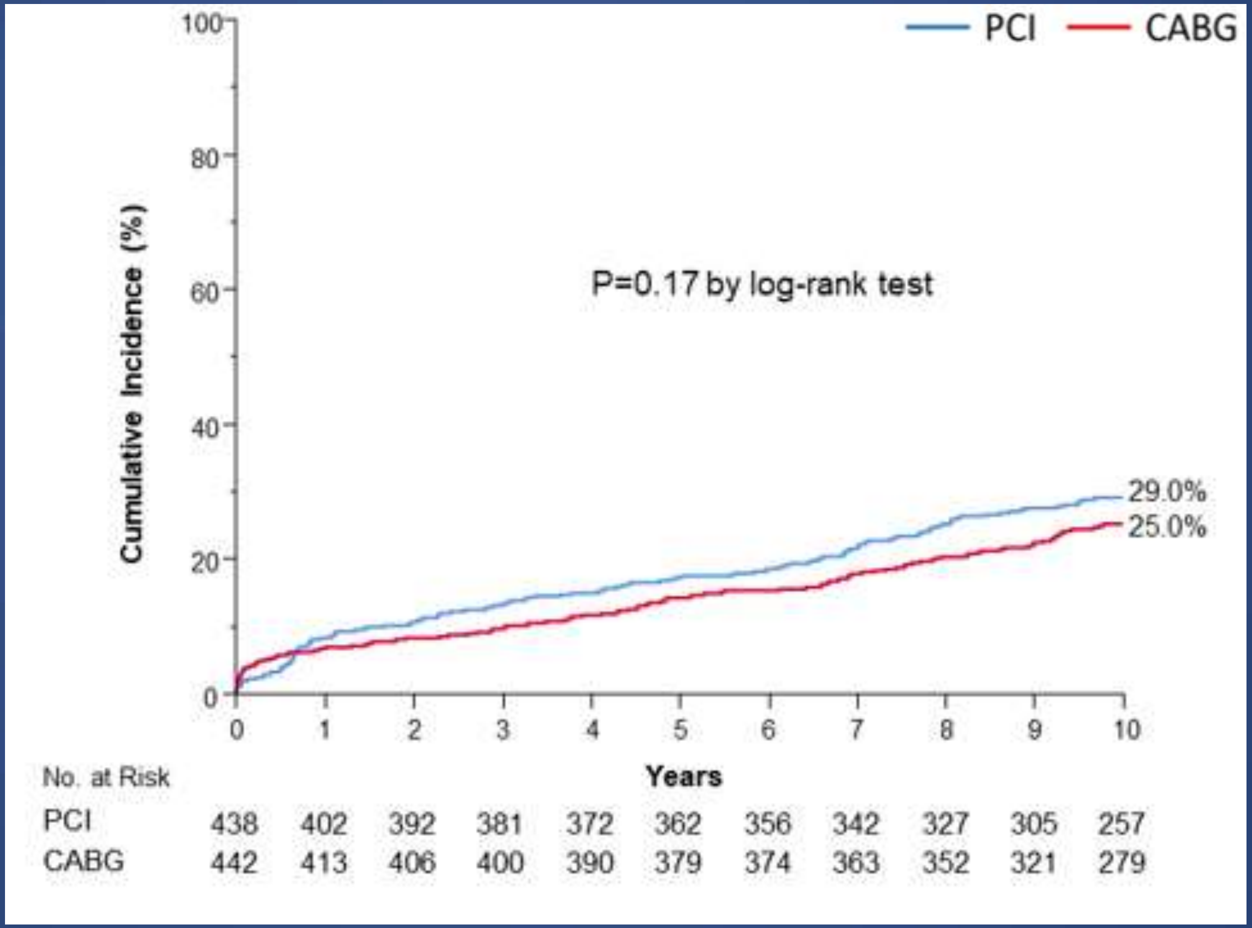
No ischemia (FFR= >0.80)
Small myocardial territory

No ischemia (FFR= >0.80)
Large myocardial infarct/ large territory

Sachdeva et al. Am J Cardiol 2011;107:1794-5

PCI vs. CABG for Left Main Disease

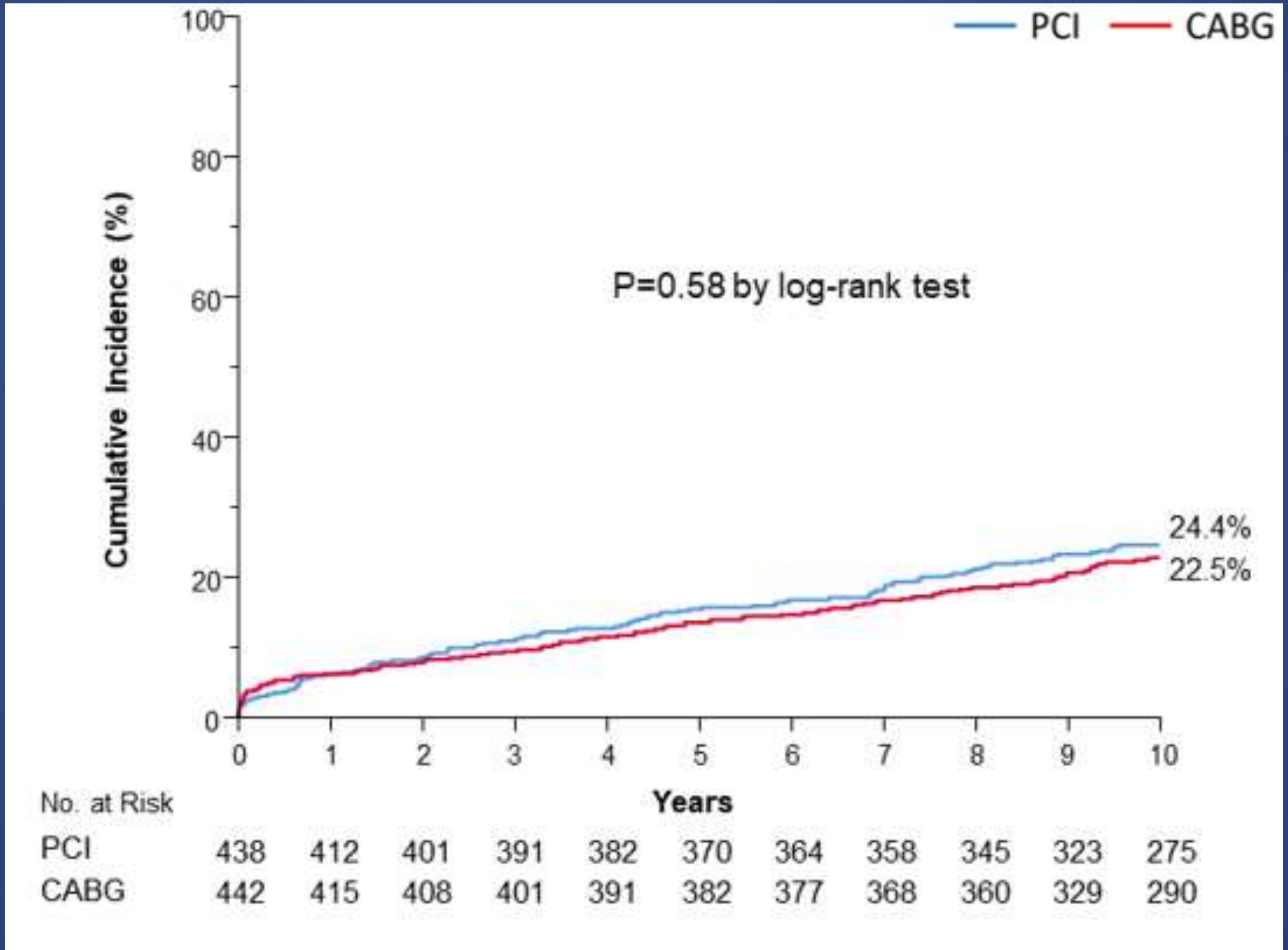
Extended Follow-Up of the **BEST** trial : Primary Composite Endpoint



JM Ahn et al. Circulation 2022 sep 19

PCI vs. CABG for Left Main Disease

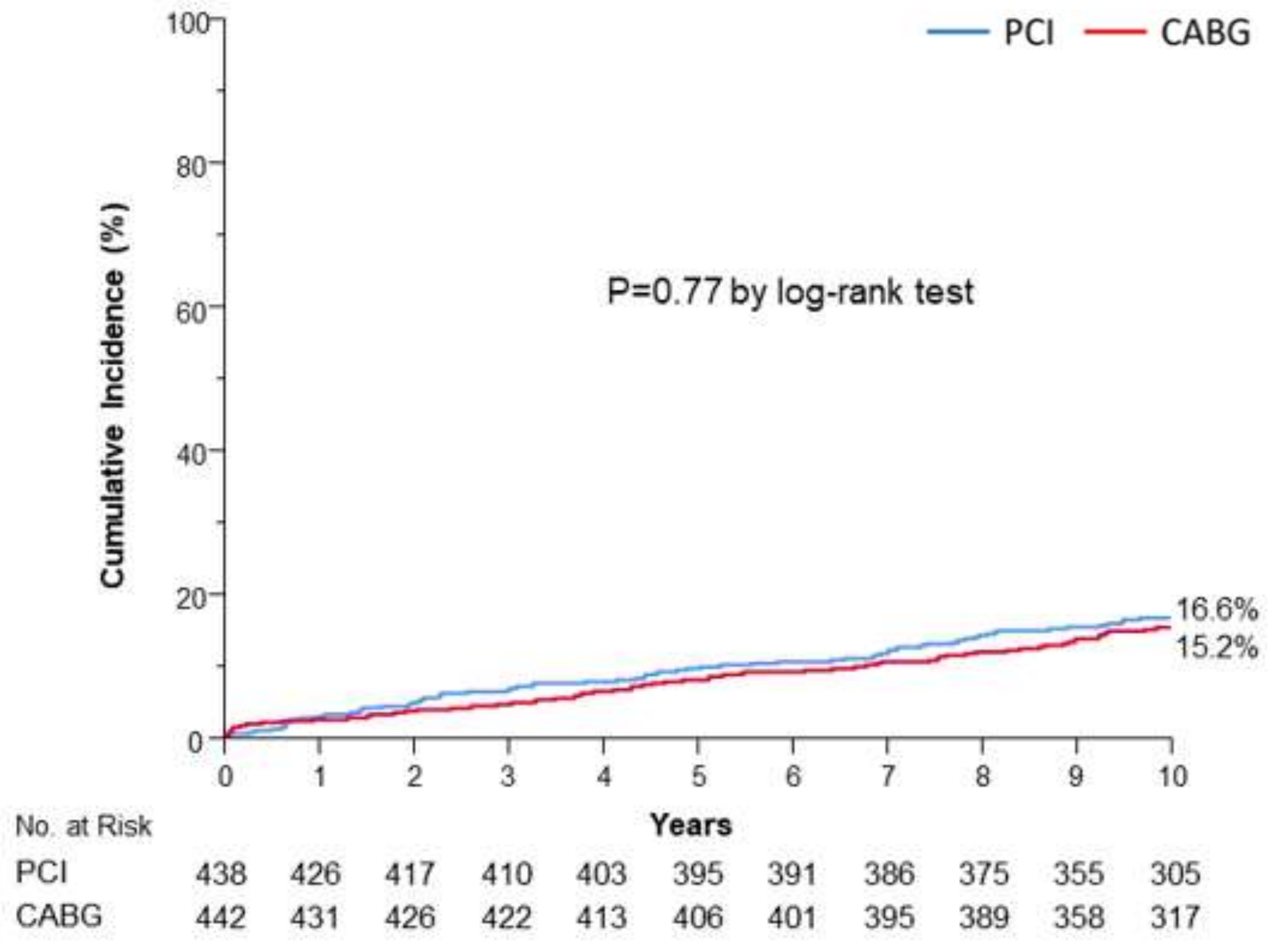
Extended Follow-Up of the **BEST** trial : Death, Stroke, or MI



JM Ahn et al. Circulation 2022 sep 19

PCI vs. CABG for Left Main Disease

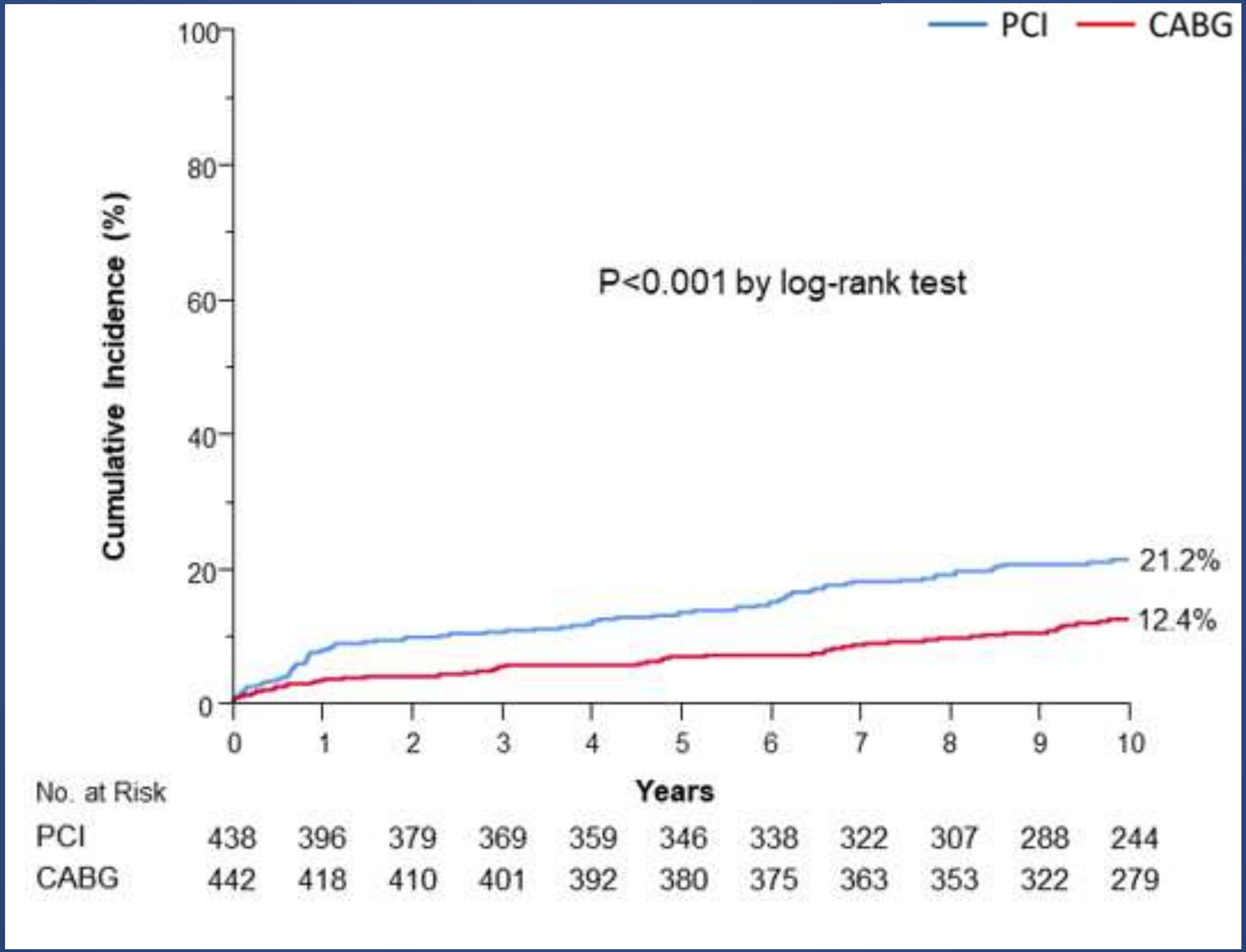
Extended Follow-Up of the **BEST** trial : All-cause death



JM Ahn et al. Circulation 2022 sep 19

PCI vs. CABG for Left Main Disease

Extended Follow-Up of the **BEST** trial : Repeat Revascularization

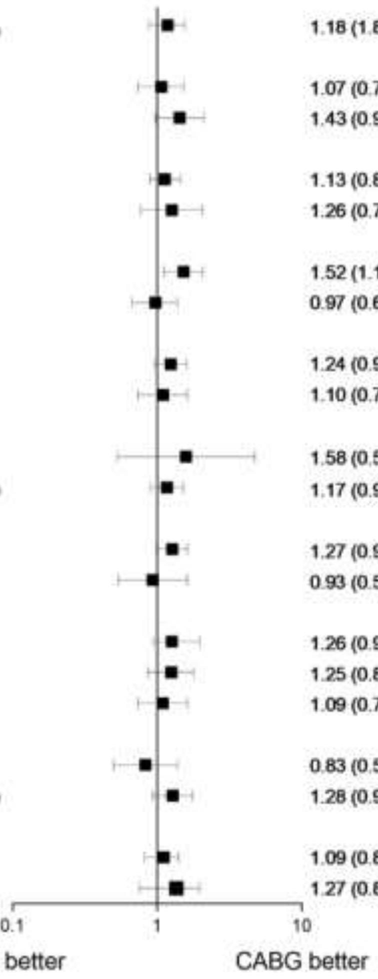


JM Ahn et al. Circulation 2022 sep 19

PCI vs. CABG for Left Main Disease

Extended Follow-Up of the BEST trial : Repeat Revascularization

Subgroup	Primary Outcome PCI *n / total n. (%)*	Primary Outcome CABG *n / total n. (%)*	Hazard Ratio (95% CI)	P value for Interaction
Overall	151/438 (34.5)	134/442 (30.3)	1.18 (1.88-1.56)	-
Age				0.18
≥65 yr	88/229 (38.4)	91/252 (36.1)	1.07 (0.74-1.53)	
<65 yr	63/209 (30.1)	43/190 (22.6)	1.43 (0.97-2.10)	
Sex				0.59
Male	101/304 (33.2)	98/325 (30.2)	1.13 (0.89-1.45)	
Female	50/134 (37.3)	36/117 (30.8)	1.26 (0.77-2.06)	
Diabetes				0.009
Yes	76/177 (42.9)	59/186 (31.7)	1.52 (1.12-2.07)	
No	75/261 (28.7)	75/256 (29.3)	0.97 (0.67-1.39)	
ACS				0.47
Yes	87/228 (38.2)	76/238 (31.9)	1.24 (0.96-1.60)	
No	64/210 (30.5)	58/204 (28.4)	1.10 (0.74-1.62)	
Ejection fraction				0.68
≤40%	13/17 (76.5)	11/17 (64.7)	1.58 (0.53-4.74)	
>40%	138/421 (32.8)	123/425 (28.9)	1.17 (0.90-1.51)	
Vascular extent				0.22
3VD	126/330 (38.2)	111/349 (31.8)	1.27 (0.99-1.62)	
2VD	25/108 (23.1)	23/93 (24.7)	0.93 (0.54-1.61)	
SYNTAX score				0.42
Score ≥33	27/66 (40.9)	27/79 (34.2)	1.26 (0.94-1.69)	
Score 23-32	66/187 (35.3)	54/177 (30.5)	1.25 (0.87-1.79)	
Score ≤22	58/185 (31.4)	53/186 (28.5)	1.09 (0.74-1.62)	
EuroSCORE				0.038
≥6	22/51 (43.1)	29/59 (49.2)	0.83 (0.50-1.39)	
<6	129/387 (33.3)	105/383 (27.4)	1.28 (0.93-1.76)	
Complete Revascularization				0.43
Yes	70/215 (32.6)	86/295 (29.2)	1.09 (0.83-1.42)	
No	79/215 (36.7)	39/122 (32.0)	1.27 (0.80-2.00)	



JM Ahn et al. Circulation 2022 sep 19

ISR

Boston Scientific
Advancing science for life™

WOLVERINE™

Cutting Balloon™ Dilatation Device

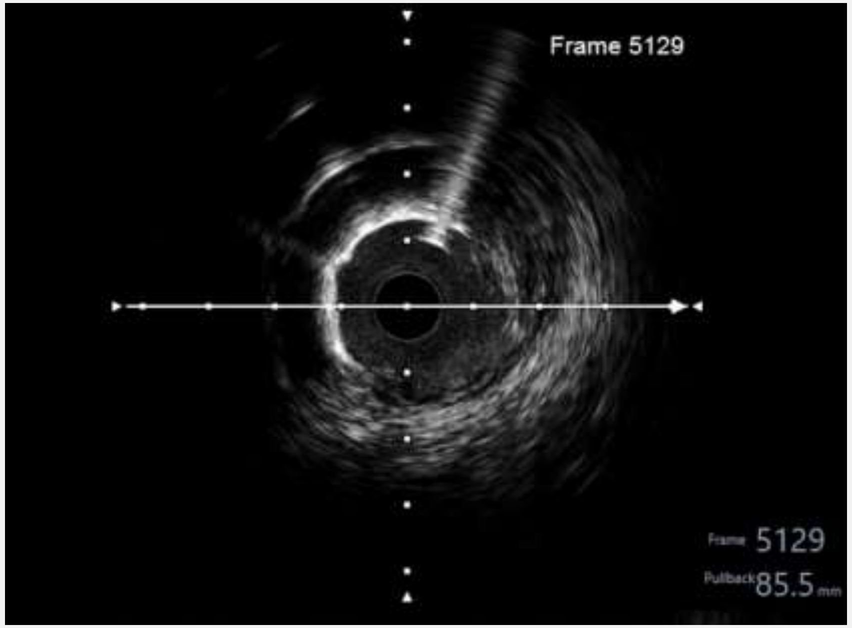
In-Service Presentation

Indications and Intended Use

The WOLVERINE™ Cutting Balloon Device is indicated for use in patients with coronary vessel disease who are acceptable candidates for coronary artery bypass graft surgery, should it be urgently needed, for the purpose of improving myocardial perfusion.

In addition, the target lesion should possess the following characteristics:

- **Discrete (< 15 mm in length), or tubular (10 mm to 20 mm in length)**
- **Reference vessel diameter (RVD) of 2.00 mm to 4.00 mm**
- **Readily accessible to the device**
- **Light to moderate tortuosity of proximal vessel segment**
- **Nonangulated lesion segment (< 45°)**
- **Smooth angiographic contour**
- **Absence of angiographically visible thrombus**



WOLVERINE™ FDA US IFU Updates

November 2021

Boston Scientific

INTENDED USE/INDICATIONS FOR USE

The Wolverine Cutting Balloon Device is indicated for dilatation of stenoses in coronary arteries for the purpose of improving myocardial perfusion in those circumstances where a high pressure balloon resistant lesion is encountered. In addition, the target lesion should possess the following characteristics:

- Discrete (< 15 mm in length), or tubular (10 mm to 20 mm in length)
- Reference vessel diameter (RVD) of 2.00 mm to 4.00 mm
- Readily accessible to the device
- Light to moderate tortuosity of proximal vessel segment
- Nonangulated lesion segment (< 45°)
- Smooth angiographic contour
- Absence of angiographically visible thrombus and/or calcification

Changes

- Removed "and/or calcification" in target lesion characteristics bullet points
- Emergency surgical backup now a clinical consideration
- Additional cleanup and formatting for clarity

Rationale

- Align Instruction for Use with modern product usage
    - Cutting Balloon was first introduced before stents were approved for coronary use
    - Modern use of cutting balloon has since changed
- Supported by extensive literature, clinical data and real-world experience
- FDA approved changes in Nov 2021

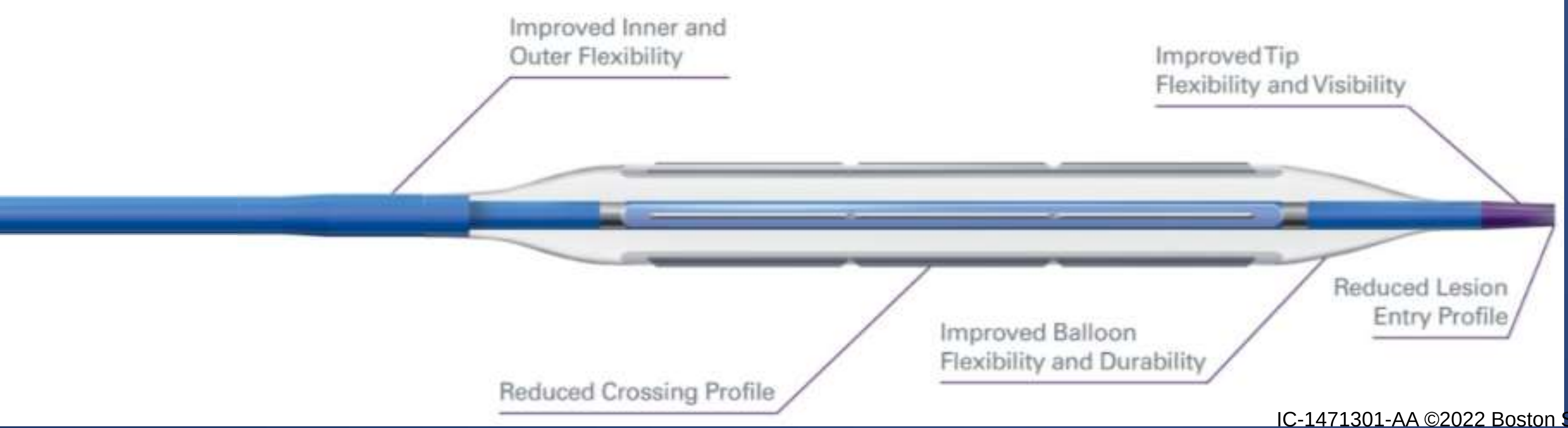
Product Design

Traditional balloon angioplasty can result in complications like:

VESSEL DISSECTION	POOR LUMINAL GAIN	LESION RECOIL	BALLOON SLIPPAGE	POOR STENT APPOSITION

The WOLVERINE™ Advantage

The unique design of the WOLVERINE Cutting Balloon is designed with **proprietary atherotomes** on a **low pressure non-compliant balloon** to directly address each of these complications



NC EMERGE™ Balloon Platform

Balloon Matrix and Inflation Pressures

Monorail Balloon Catheter with working lengths of 6, 10 and 15 mm

For vessels with reference diameter of 2.0 – 4.0 mm

BALLOON DIAMETER (mm)		BALLOON BODY LENGTH 6 mm	10 mm	15 mm
2.00	3 Atherotomes	5F Compatible GUIDEZILLA II 6F		
2.25				
2.50				
2.75				
3.00				
3.25				
3.50	4 Atherotomes	6F Compatible GUIDEZILLA II 7F		
3.75				
4.00				

INFLATION PRESSURE RATING

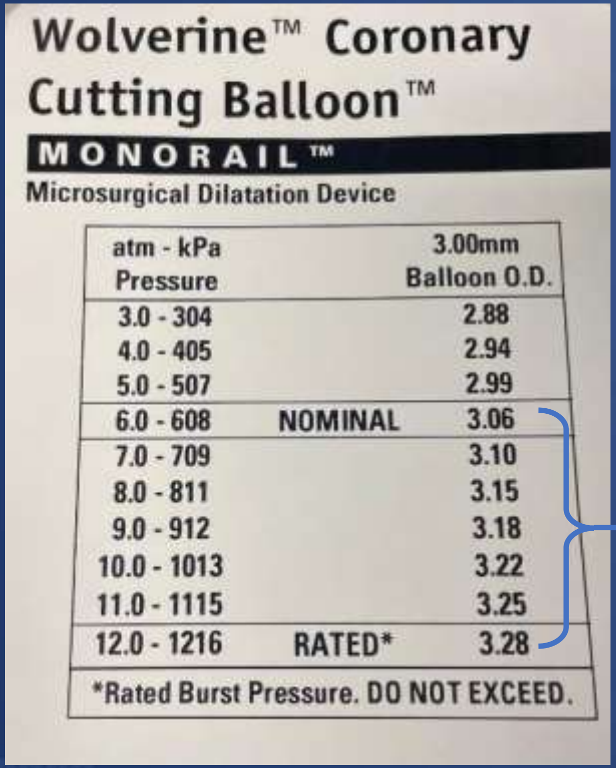
Nominal = 6 ATM

Rated Burst = 12 ATM

Sizing Considerations

WOLVERINE™ utilizes the NC EMERGE™ Catheter Platform, yet the balloon was designed to have a lower nominal pressure resulting in a different compliance

Growth Chart Example (3.0 mm)



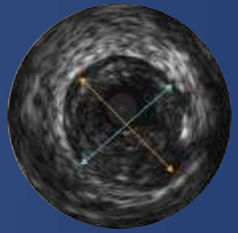
atm - kPa Pressure		3.00mm Balloon O.D.
3.0 - 304		2.88
4.0 - 405		2.94
5.0 - 507		2.99
6.0 - 608	NOMINAL	3.06
7.0 - 709		3.10
8.0 - 811		3.15
9.0 - 912		3.18
10.0 - 1013		3.22
11.0 - 1115		3.25
12.0 - 1216	RATED*	3.28

*Rated Burst Pressure. DO NOT EXCEED.

Sizing Considerations:

WOLVERINE grows roughly a quarter size when going from nominal (6 ATM) to rated burst pressure (12 ATM)

Physician consensus is to measure the normal distal reference with IVUS and then downsize WOLVERINE a half size from that measurement



Oversizing at nominal pressure will cause atherotomes to be “pillowed” by the balloon and may not provide adequate forces to modify calcium

Oversizing Example
Blue = Balloon
Red = Vessel

Oversizing at rated burst pressure may lead to vessel stretching and trauma due to balloon growth (not atherotomes)

WOLVERINE™
Cutting Balloon™ Dilatation Device

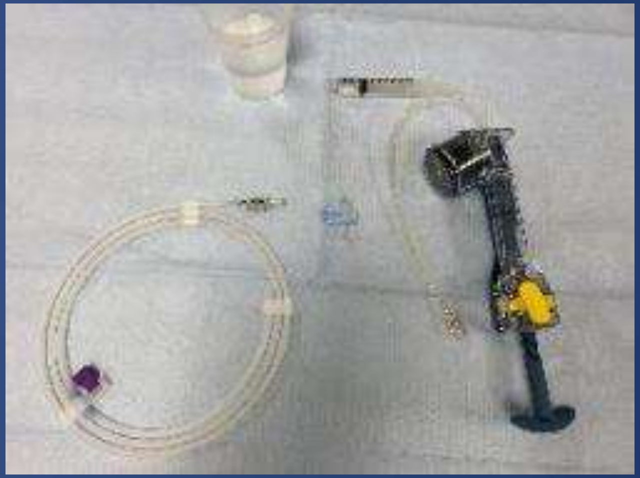
Device Preparation and Use Instructions

Device Preparation

Important: WOLVERINE™ preparation uses a wet negative prep procedure. Customary balloon preparation methods do not apply!

1

Sizing
- The Wolverine IFU states that the inflated diameter of the device should approximate a ratio of 1.1:1 in relation to the average diameter of the reference vessel. Oversizing increases risk of perforation. **As stated earlier, sizing a quarter to half size down may be needed if using higher inflation pressures.**



2

Unpacking
- Using sterile technique, remove the device in its protective hoop from its package and place onto a sterile field.
    - Do not remove the device from its protective hoop.
    - Do not remove the balloon protector from the device tip.

3

Attach Stopcock & Prepare Inflation Device
- Connect a three-way stopcock to the balloon port.
    - Turn stopcock lever OFF to the balloon.
    - Prepare an inflation device with 5 cc of contrast solution (mixture must be at least 50:50 contrast medium and sterile saline).

Device Preparation

4

Attach Inflation Device & Purge

- Attach the inflation device to stopcock.
  - Assure luer connections are properly aligned to avoid stripping the luer thread causing subsequent leakage and use care when connecting the device to avoid damage (e.g., shaft kink).
  - Purge stopcock by flushing 1-2 cc of contrast medium through the middle port.

5

Pull Full Negative

- Turn the stopcock lever towards the middle port or open to the balloon and immediately withdraw inflation device plunger to full negative and place the inflation device in a locked position. This will maintain a constant vacuum on the device.

6

Remove Device from Hoop

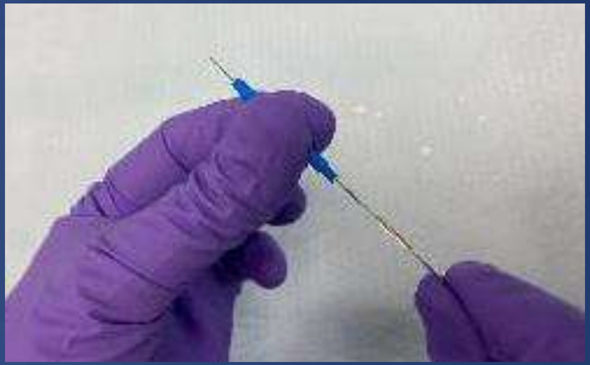
- When the device is ready to be inserted into the body, remove the device from its protective hoop. Use care when removing the device to avoid damage (e.g., shaft kink).

Device Preparation

7

Remove Balloon Protector

- Using straight force (not a twisting motion), pull the balloon protector distally from the device tip. For WOLVERINE MR Cutting Balloon Devices, remove the mandrel distally after removing the balloon protector.
    - Caution: If unusual resistance is felt during removal of the balloon protector or mandrel, do not use the device and replace with another.



8

Coiling & Securing with CLIPIT Clip

- The WOLVERINE MR Cutting Balloon Device may be coiled once and secured using the CLIPIT Clip provided in the device package.
    - Only the proximal shaft should be inserted into the CLIPIT Clip; the clip is not intended for the distal end of the device.
    - Remove the CLIPIT Clip prior to inserting the device into the patient’s body.

9

Flush Guidewire Lumen

- Flush the guidewire lumen of the device with heparinized saline. For WOLVERINE MR Cutting Balloon Device flush through the distal tip of the device.

10

Sterility

- Maintain device on a sterile table until ready to use.

Inflation & Removal Instructions

Inflation

1 **Go Slow**
- Under fluoroscopy, slowly inflate the device (1 ATM/5 sec) to 6 ATM (nominal size).
    - Do not inflate the device above 12 ATM (rated burst pressure).
    - If difficulty is experienced during balloon inflation, do not continue inflation; deflate and remove the device.

2 **Treat Distal then Proximal**
- When using the device on long lesion segments, treat distal portion first and then proximal lesion segment second. Repeat coronary arteriography after each use to evaluate results.

Tips and Tricks

Prior to advancing the catheter, it may help to increase pressure to 1 atm and then pull negative to aid in loosening the packaged balloon crimp and provide added flexibility

Removal

1 **Deflate & Pull Negative**
- Deflate the device by dialing down on the inflation/deflation device, then pull a negative vacuum. Maintain vacuum on the device and verify full deflation under fluoroscopy.

2 **Confirm Successful Result**
- Repeat coronary arteriography to confirm successful result.

3 **Withdraw**
- Withdraw the device into the guiding catheter. While withdrawing the deflated device and guidewire from the guide catheter through the hemostasis valve, tighten the hemostasis valve.

Tips and Tricks

Deflating slowly by dialing down pressure methodically to optimize balloon re-wrap

WOLVERINE™
Cutting Balloon™ Dilatation Device

Clinical Use Scenarios

WOLVERINE™

The right tool for vessel preparation device

Proper Solution to Help Prepare Lesions Prior to Stenting

WOLVERINE is right tool at helping treat a wide range of lesions:

- Cuts fibrotic plaque to limit recoil
- Cracks thin concentric and eccentric calcium
- Prepare small vessels prior to Drug Coated Balloon
- Address In-Stent Restenosis
- Limit balloon slippage in coronary ostium and bifurcation lesions

Cutting balloon angioplasty device designed with improved crossability and deliverability, to deliver precise and controlled cutting action

Clinical Use Scenarios

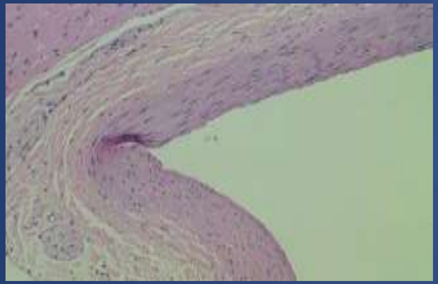
	Small Vessel Lesions REDUCE RESTENOSIS	Ostial and Bifurcation Lesions AVOID PLAQUE SHIFT	Fibrotic Lesions CHANGE LESION COMPLIANCE	Calcified Lesions CRACK CALCIUM TO ALLOW EXPANSION
LESION CHALLENGES	• High rates of restenosis • Tendency to dissect • Abrupt closure[1]	• Recoil • Plaque Shift • Side Branch Compromise	• High concentration of elastin and muscle fibers • High risk of vessel recoil	• Calcium deposits in plaque that prevent lumen gain • Varying degrees of burden and arcs
CUTTING BALLOON OBJECTIVES	• Use as stand-alone therapy • DCB or Stent?	• Dilates while reducing elastic recoil[2] • More plaque compression • Minimal plaque shift • Less vessel stretching[3]	• Atherotomes score through fibrotic plaque[4] • Reduce hoop strain and limit recoil • Lumen Gain	• Use as stand-alone therapy in eccentric and thin concentric calcium • Possible additive therapy with atherectomy • Lumen Gain

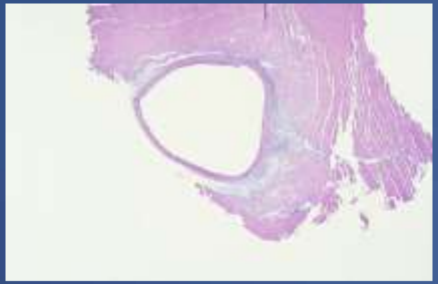
WOLVERINE™ Mechanism of Action

Porcine Artery Models

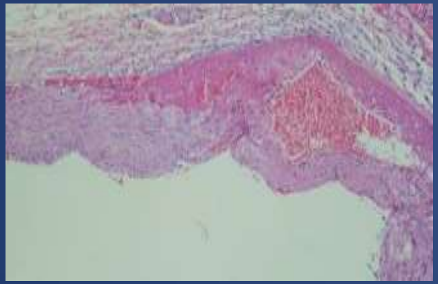
ACUTE | 14-DAY

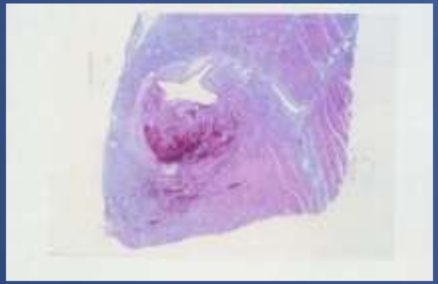
CUTTING BALLOON





POBA





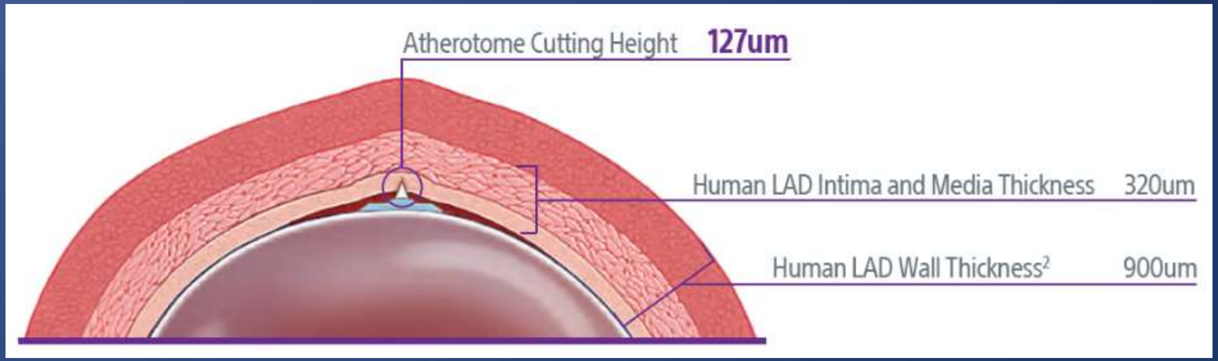
Acutely there is **over stretch*** and visible trauma to the vessel wall with POBA

At 14-days the vessel has **recoiled with POBA** and stayed open with cutting balloon

*This level of over-stretch was done for investigational purposes only

Reliable Option

- **25+ Year Track Record:** WOLVERINE has been used for over 25 years, and has a long track record of safety with real-world patients and clinical trials
- **Atherotome Height:** Approximately the same height as 1st generation stents or a human hair
- **Penetration Depth:** Even when placed in healthy tissue, WOLVERINE's atherotomes typically only penetrate partially into the media



Data on file. Photos taken by Boston Scientific. Results of pre-clinical studies are not predictive of clinical performance. Clinical results may vary.

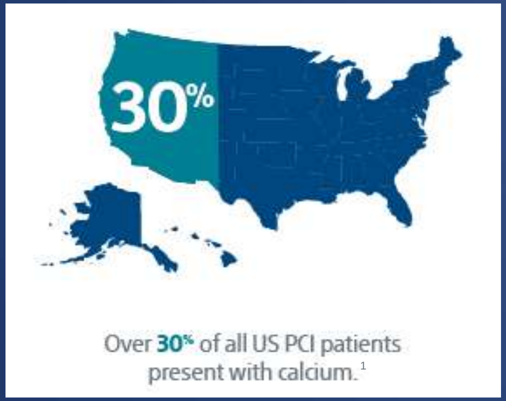
WOLVERINE™
Cutting Balloon™ Dilatation Device

Calcium Modification

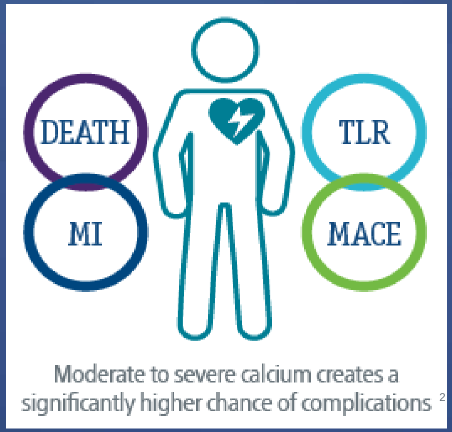
Calcium Needs to be Properly Treated

Calcium is a growing problem that can negatively impact PCIs if left untreated

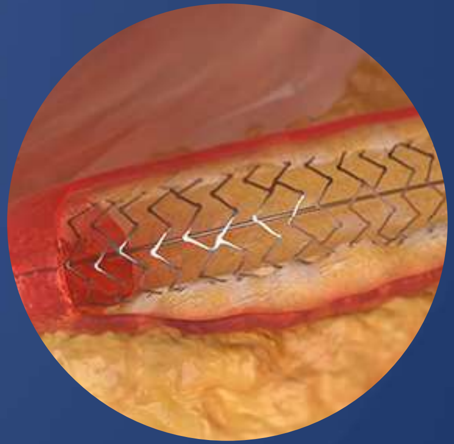
Calcium is prevalent in patients undergoing PCI



Calcium leads to worse clinical outcomes



Calcium can inhibit optimal stenting

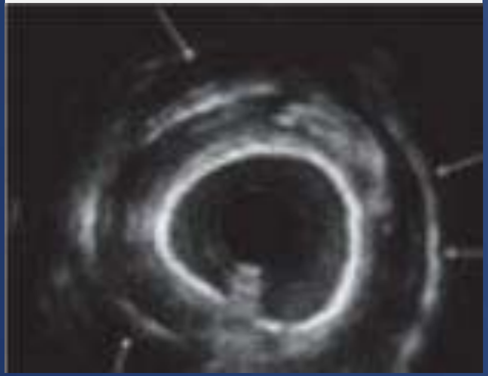


1. As reported to NHLBI Dynamic Registry. Bortnick, et. al. Am J Cardiol 2 014;113:573-579
2. Généreux, P. et al. J Am Coll Cardiol 2014 May;63(18):1845-1854

Calcium Morphology

CONCENTRIC

360˚Calcium Arc
Smooth Surface



ECCENTRIC

180 – 270˚ Calcium Arc
Irregular Surface

NODULE

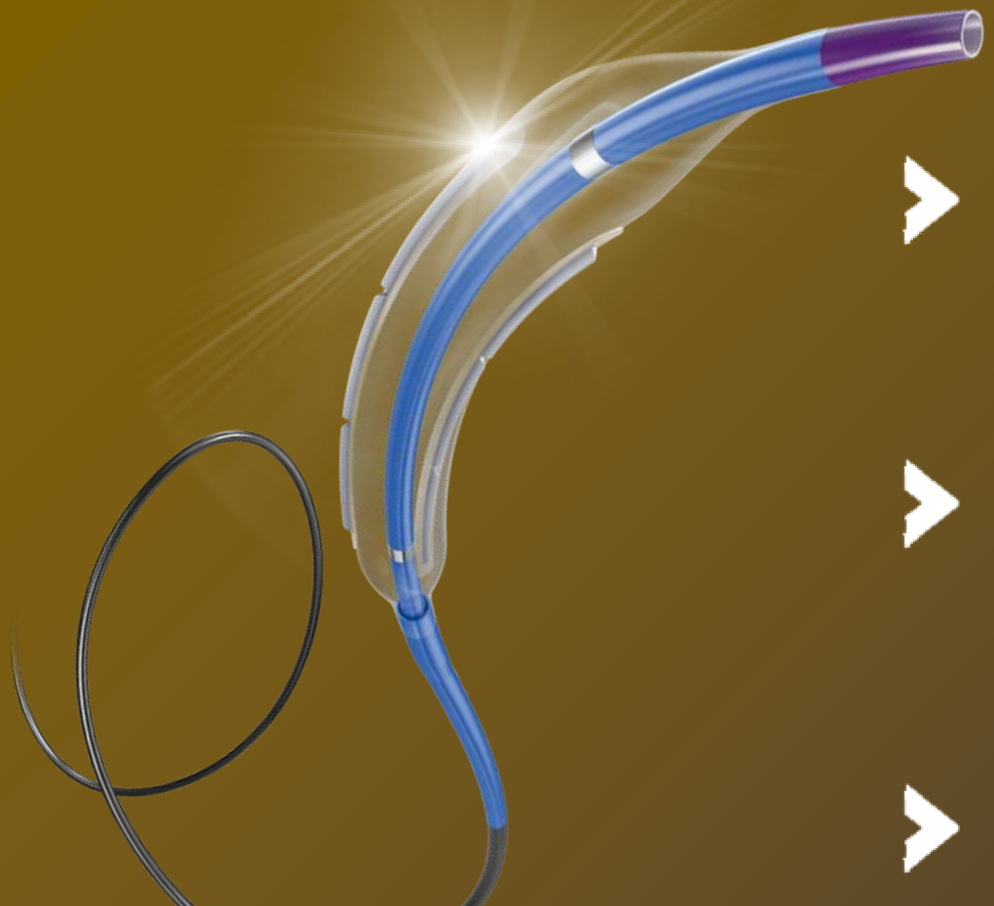
90 – 180˚ Calcium Arc
Luminal protrusion and
irregular leading edge

PSEUDO-NODULE

Extra-plaque
during CTO-PCI

Adapted from Dr. Anja Oksnes, School of Rock#5 Boston Scientific, Dec 14th 2021
Oksnes et al. J Intv Cardiol. 2021; 1, Article ID 9958035, 6 pages

The Right Tools Make a Difference



WOLVERINE™
Cutting Balloon™ Dilatation Device

Controlled Mechanism of Action

Atherotomes anchor to calcium and produce controlled, longitudinal fractures

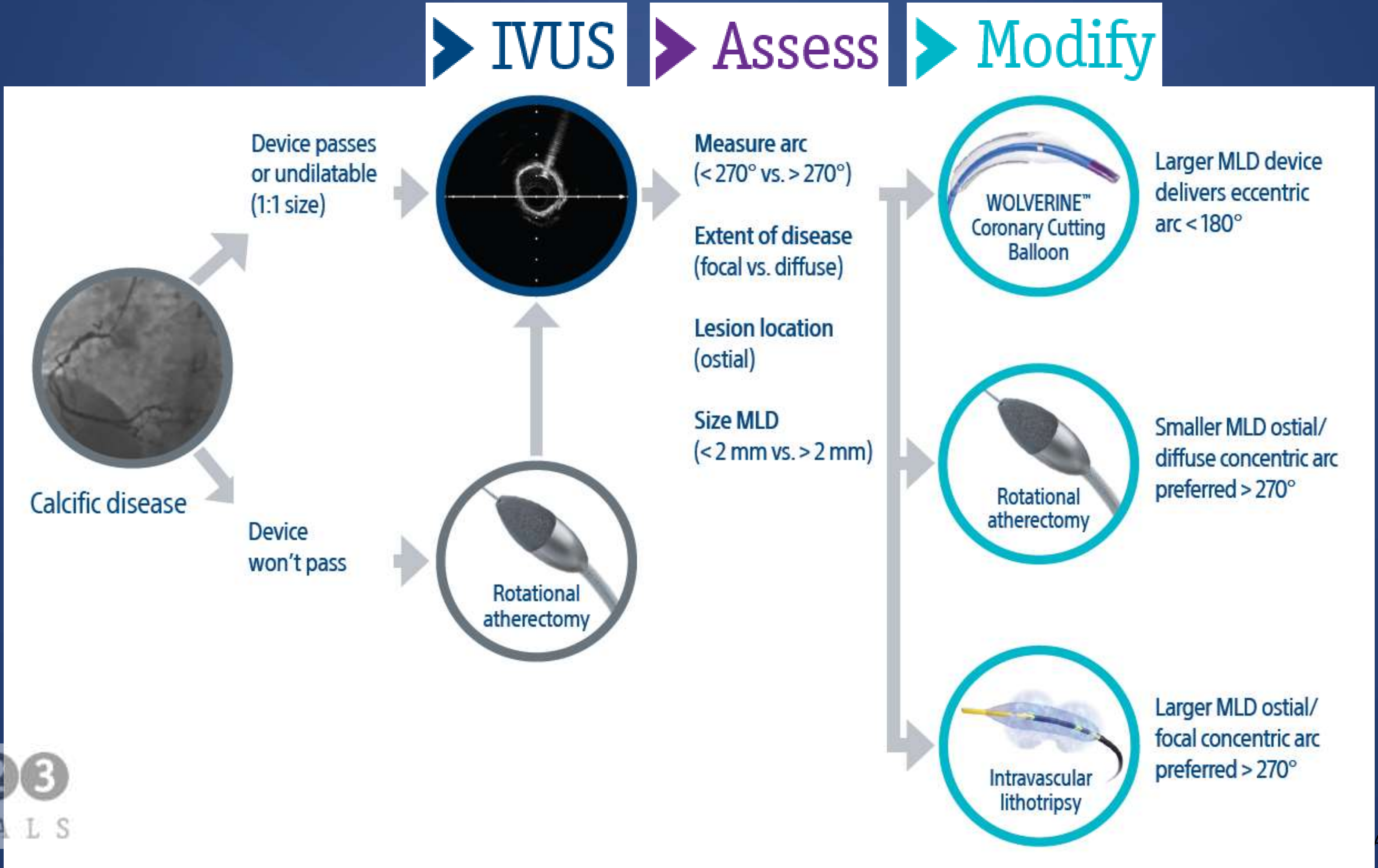
Strategic Atherotome Placement

Enables up to 4 points of contact with calcium, improving the probability of modification with a single balloon

Focused Force to Amplify Impact

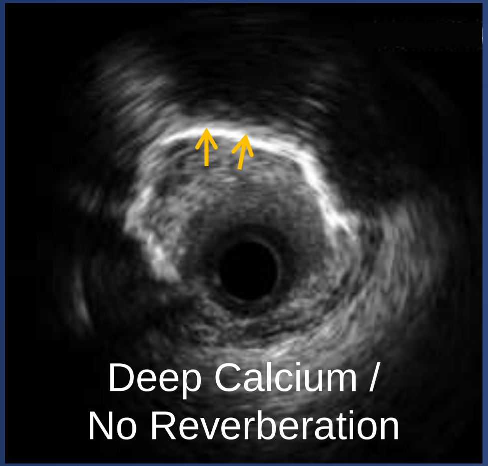
Pressure at atherotomes amplified to precisely fracture calcium at lower balloon inflation pressures

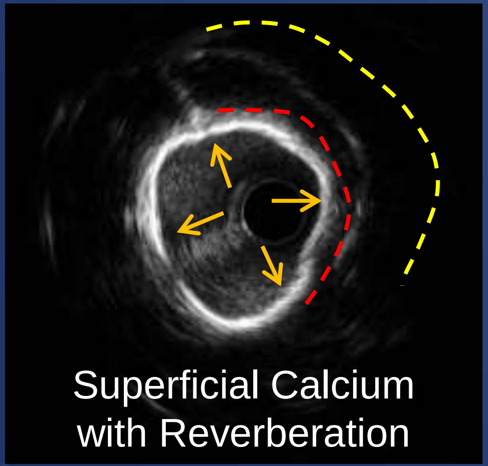
Calcific Lesion Modification Strategy



Assess Calcium FIRST with IVUS

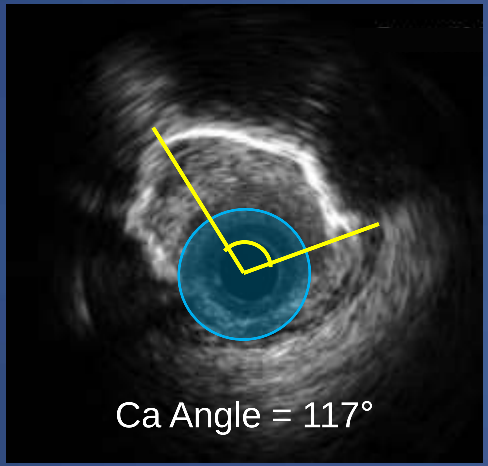
Thickness





Reverberation
Surface of calcium

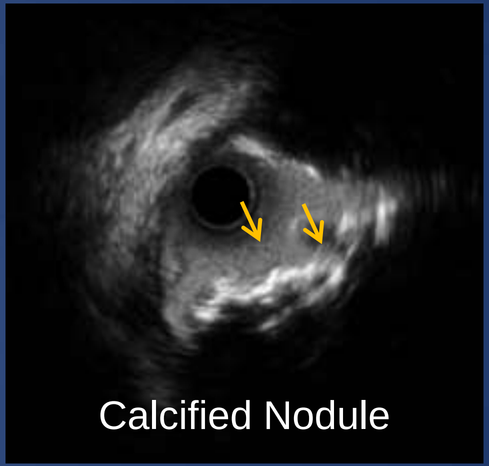
Angle

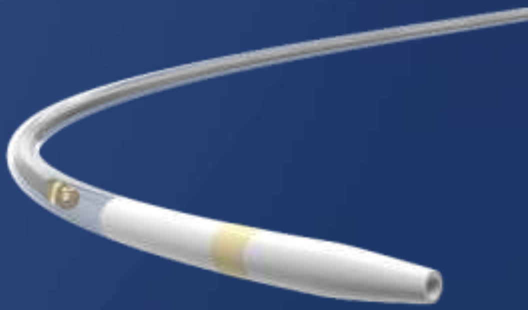


Length

LONGITUDINAL
VIEW

Nodule





Adapted from A. Mahaera TCT 2020

Proven Mechanism of Action

Effective. Safe. Versatile.

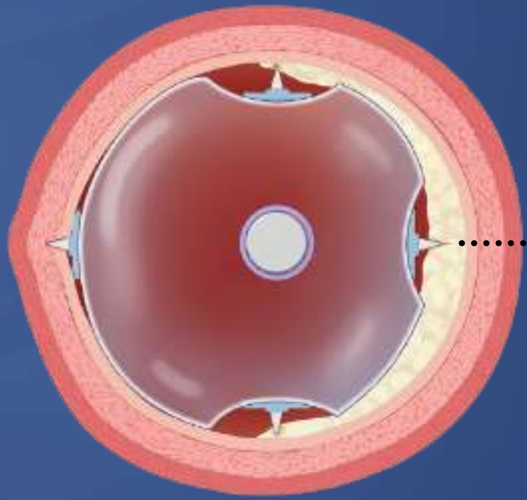
Wolverine's innovative design safely and efficiently cracks calcium[3]

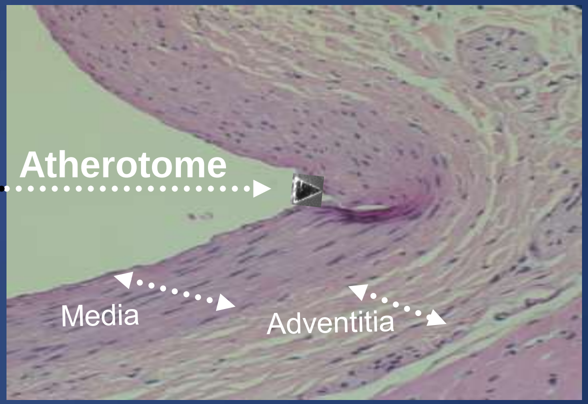
1 **Atherotome Amplified Force.**[1]

The atherotomes anchor into the plaque and amplify pressures generated by the balloon. This creates controlled, longitudinal cracks in the calcium.[1]

2 **Safely Cracks Calcium.**

Due to its unique design, Wolverine can modify calcium at lower pressures than POBA.[3] Atherotomes penetrate a small distance into the vessel wall, even in healthy tissue.[4]





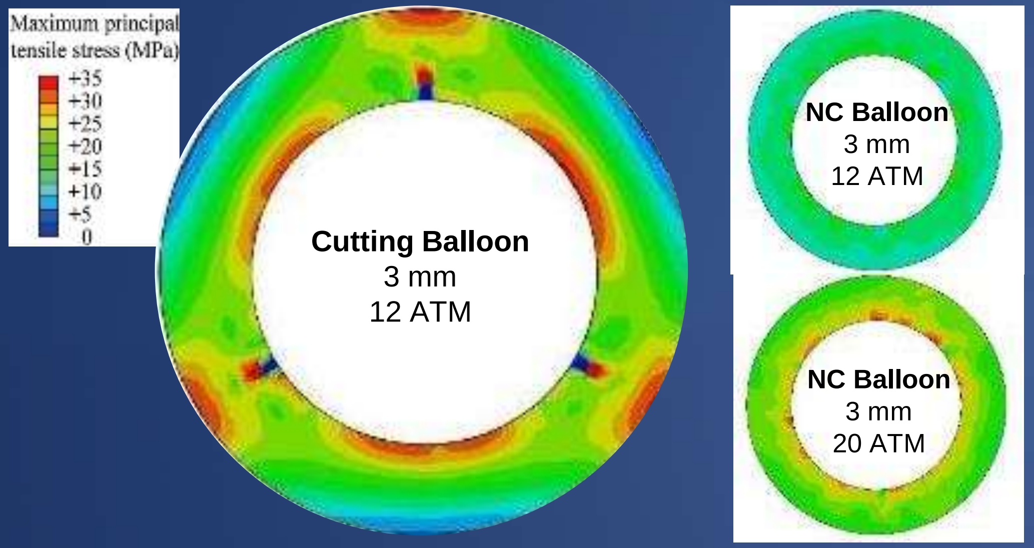
Pre-clinical Swine Coronary artery post Cutting Balloon[1]

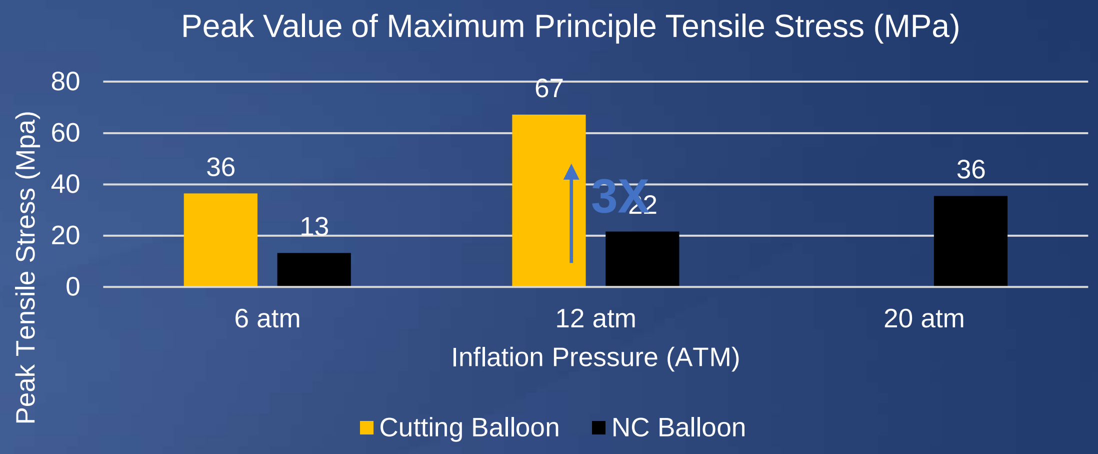
Atherotome Cutting Height	**127 µm**
Human LAD Media Thickness[2]	**320 µm**
Human LAD Wall Thickness[2]	**900 µm**

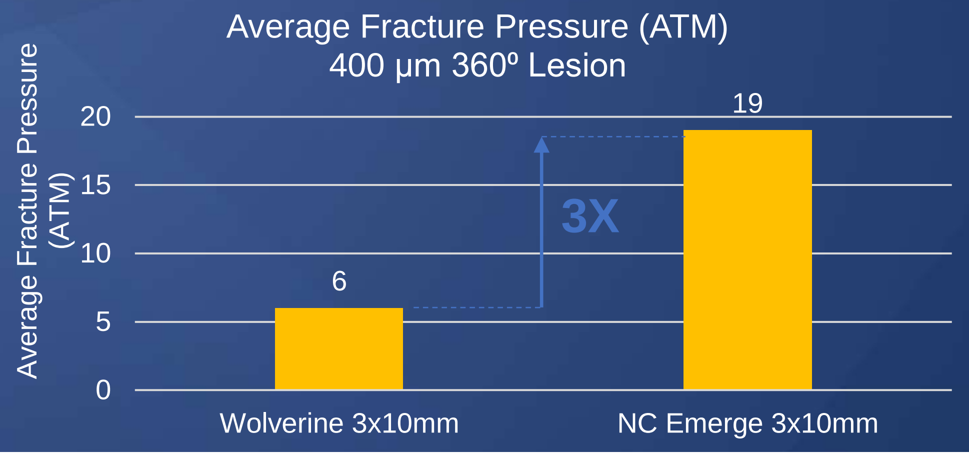
1 Xiaodong Zhu et al.;Circ Rep 2021; 3: 1 – 8 doi: 10.1253/circrep.CR-20-0070. Results of computer models are not predictive of clinical performance. Clinical results may vary.
2 Bonan, J InvasivCardiol, 1999; 11: 230
3 Mangieri, A. Cutting Balloon to Optimize Predilatation for Stent Implantation: The COPS Randomized Trial, TCT 2022
4 Data on file. Photos taken by Boston Scientific. Results of internal bench studies are not representative of clinical performance. Clinical results may vary.

Treating Calcium with WOLVERINE™

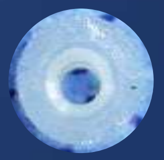
Calcification Model Stress Distributions







360º Calcification Model



- WOLVERINE™ atherotomes **amplified balloon peak tensile strength 3X** vs NC Balloon
- Force is focused at atherotomes for controlled even calcium cracking
- **Balloon dilation force is enhanced** between the anchored atherotomes

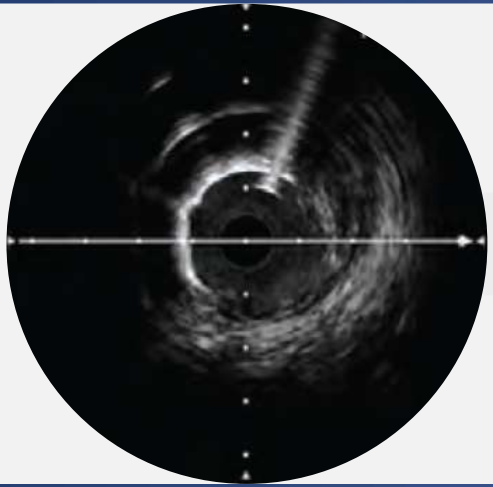
Kiyotaka IWASAKI. Euro PCR 2019; Influences of thickness and circumferential angles of calcification on the capability of fracturing calcification of the cutting balloon: an experimental investigation. Inflated up to 20 ATM until calcification model cracked in 37C water bath.
Results of bench models are not predictive of clinical performance. Clinical results may vary.

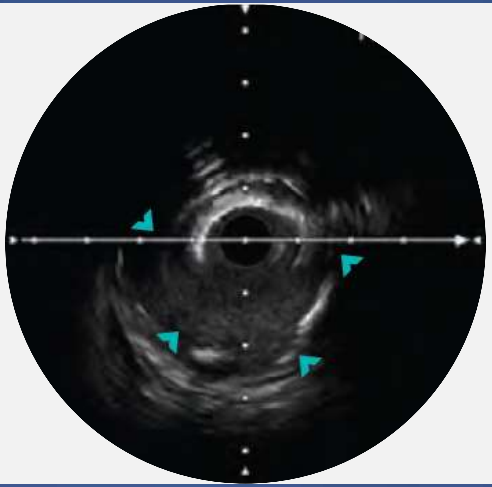
Xiaodong Zhu et al.;Circ Rep 2021; 3: 1 – 8 doi: 10.1253/circrep.CR-20-0070.
Results of computer models are not predictive of clinical performance. Clinical results may vary.

Demonstrated Efficacy in both Concentric and Eccentric Calcium

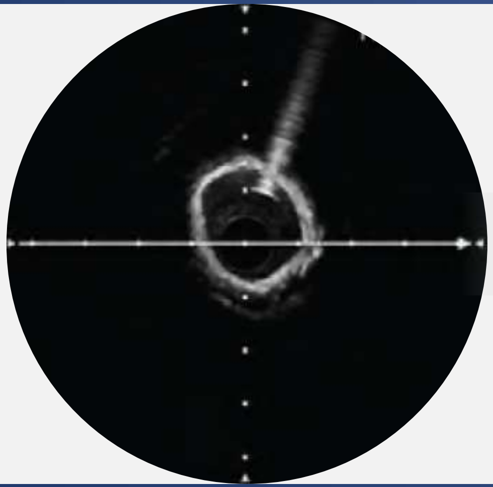
BEFORE **AFTER**

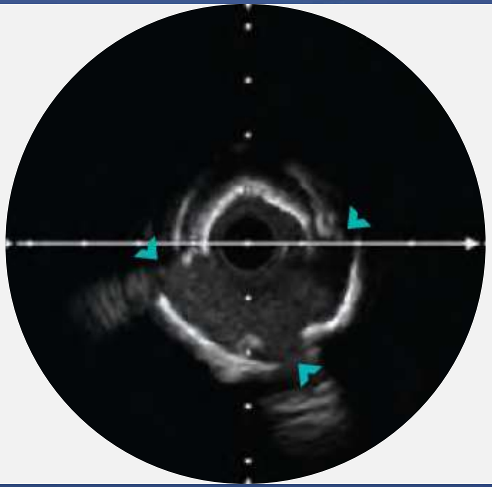
ECCENTRIC LESION





CONCENTRIC LESION





WOLVERINE™ has clinically demonstrated effectiveness in calcium ranging from 0° to 360° with a proven mechanism of action.[1]

Images courtesy of Dr. Simon Walsh, Royal Victoria Hospital, Belfast, Ireland; AUG 2020.

1. Ishihara et al.; Cardio. Intervention and Therapeutics (2021) 36:198-207

WOLVERINE™ Cracking Power in Action!

360˚ Calcium Simulated Lesion – Performed by Boston Scientific Research & Development

The COPS Trial
Cutting balloon to Optimize Predilatation for Stenting

Primary Investigators

Dr. Antonio Mangieri, Dr. Antonio Columbo

Three hospitals in Italy

Maria Cecilia Hospital, Humanitas Rozzano, Clinica Mediterranea

Study Design

- Prospective, randomized, multicenter open-label trial which enrolled 100 patients with significant calcified lesions evaluated at IVUS

Randomization 1:1

- **High Pressure Cutting Balloon n=50**
- **Non-Compliant Balloon n=50**

Primary Endpoint

- Minimal Stent Area (MSA) at Calcium Site

Secondary Endpoint

- Eccentricity Index : (LD max – LD min) / LD max
- MSA
- Device Failure
- Safety: Procedural Complications & One-Year MACE

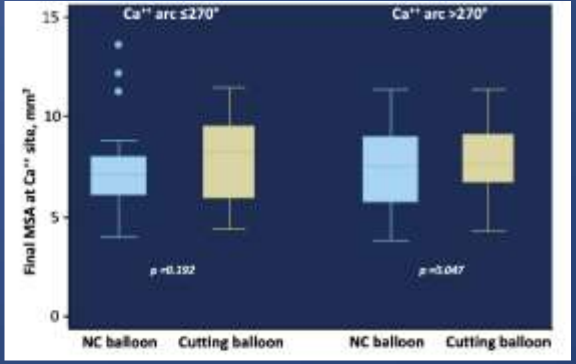
The COPS Trial: Results

Study contained a range calcium 100 – 360° and 29.4% avg of deep calcium

	Overall	CB (n=44)	NCB (n=43)	P value
Lesion Type				
Type B1	25 (28.7)	14 (32.5)	11 (25)	
Type B2/C	62 (71.2)	29 (67.4)	33 (75)	
Calcium distribution				0.482
Mixed Calcium	34 (40)	15 (34.8)	19 (45.2)	
Deep Calcium	25 (29.4)	15 (34.8)	10 (23.8)	
Superficial Calcium	26 (30.5)	13 (30.2)	13 (30.9)	
Arch of calcium (degrees)	266±84	274±84	258±85	0.373
Calcium length (mm)	12±6.6	11.9±7.3	12.5±6	0.667
Lesion length (mm)	24.3±9.7	23.5±9.6	25.1±9.8	0.442
Minimal lumen area (mm²)	3.2±0.9	3.4±1.1	3±0.7	0.02
QCA evaluation				
Reference vessel diameter (mm)	3.4±0.4	3.51±0.3	3.39±0.4	0.112
Percentage of stenosis (%)	81.2±8.1	79.4±7.6	82.7±8.3	0.97

WOLVERINE is clinically proven to provide superior MSA at the calcium site compared to POBA

	CB (n=44)	NCB (n=43)	P value
Final MSA (mm²)	7.1±1.7	6.5±2.1	0.116
Minimal Stent Diameter	2.7±0.4	2.5±0.4	0.064
Maximal Stent Diameter	3.2±0.4	3.1±0.4	0.189
Final MSA at calcium site	8.1±2	7.3±2.1	0.035
Minimal stent diameter at calcium site	2.9±0.7	2.7±0.4	0.016
Maximal stent diameter at calcium site	3.5±0.5	3.3±0.4	0.132
Eccentricity index at calcium site	0.84±0.7	0.8±0.8	0.013



The benefit was magnified in presence of severe calcifications

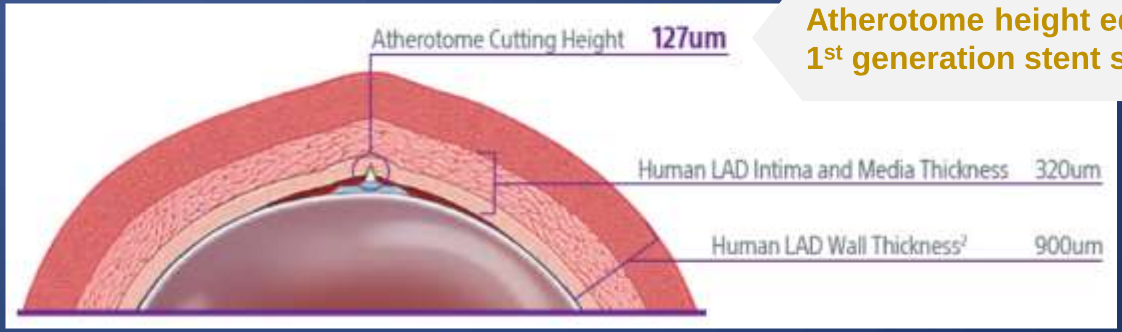
The COPS Trial: Safety

WOLVERINE™ use in calcium is safe, with no significant differences in procedural complications and 1-year MACE

	Overall	CB (n=44)	NCB (n=43)	P value
Device failure	3 (3.4)	3 (6.8)	0 (0)	0.517
Additional use of rotational atherectomy	1 (1.1)	1 (2.2)	0 (0)	0.79
Ellis type 1 vessel rupture	2 (2.2)	2 (4.4)	0 (0)	0.189
Implantation of a covered stent	1 (1.1)	1 (2.2)	0 (0)	0.65
Final TIMI flow >3	87 (100)	44 (100)	43 (100)	0.854
One year Follow-up				
Deaths	3 (3.4)	1 (1.1)	2 (4.6)	0.342
Cardiac deaths	1 (1.1)	0 (0)	1 (2.3)	0.887
Stroke	0 (0)	0 (0)	0 (0)	0.91
MI	0 (0)	0 (0)	0 (0)	0.96
TLR	3 (3.4)	1 (1.1)	2 (4.6)	0.49

WOLVERINE provided excellent procedural success with limited need for atherectomy (n=1) despite a high rate of severe calcium in the study

WOLVERINE is both a safe and effective option for modifying severely calcified lesions



Atherotome height equivalent to 1st generation stent strut thickness

The COPS Trial: Key Learnings

WOLVERINE™ resulted in a **significantly larger minimal stent area** at the calcified segment.

This difference was especially apparent in cases with **severe calcification**.

Stents had significantly **more uniform expansion** after vessel preparation with WOLVERINE.

WOLVERINE is safe for calcium treatment, even when inflated past rated burst pressure.

WOLVERINE™
Cutting Balloon™ Dilatation Device

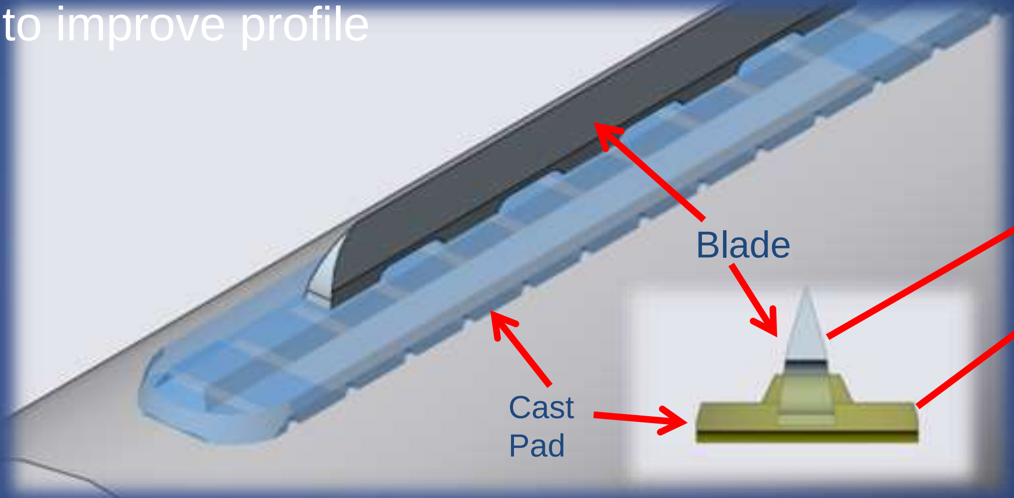
Competitive Product Comparisons

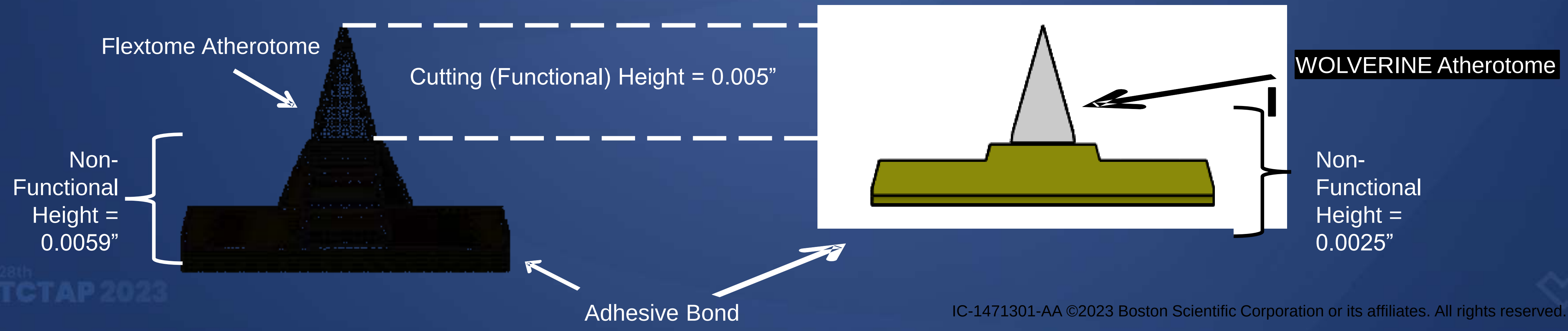
WOLVERINE vs FLEXTOME

	WOLVERINE™	FLEXTOME™
Manufacturer	Boston Scientific	Boston Scientific
Guide Cath Compatibility	**5F, 6F**	**5F, 6F**
Size Matrix: Diameter (mm)	2, 2.25, 2.5, 2.75, 3, 3.25, 3.5, 3.75, 4	2, 2.25, 2.5, 2.75, 3, 3.25, 3.5, 3.75, 4
Size Matrix: Length (mm)	6, 10, 15	6, 10, 15
Pressures (ATM)	NOM: **6** RBP: **12**	NOM: **6** RBP: **12**
Catheter Length (cm)	143	142
Balloon Compliance	Non-Compliant	Non-Compliant
Balloon Platform	NC EMERGE	NC Quantum MAVERICK
Tip Entry Profile	0.017”	0.020”
Proximal shaft Distal shaft	1.8Fr / 0.59mm 2.6Fr / 0.86mm	2.0Fr / 0.67mm 2.7Fr / 0.90mm
Plaque Mod Method	**3 or 4** evenly spaced atherotomes	**3 or 4** evenly spaced atherotomes

Atherotome Changes

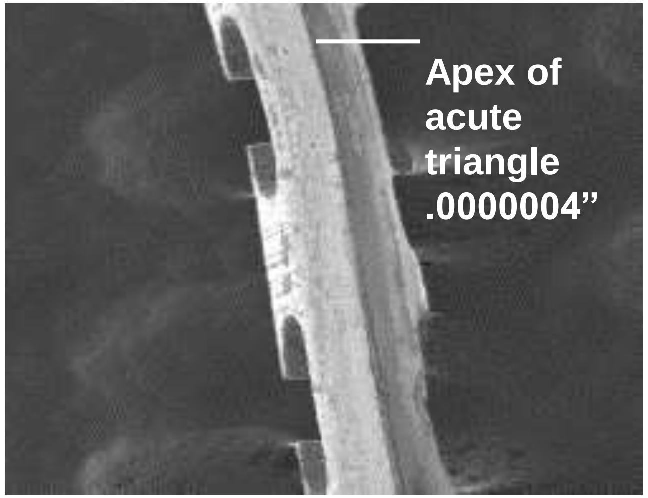
- Reduce non-functional blade height (portion in the cast pad) to improve profile
- Reduce cast pad height and width to improve profile





The Atherotome Advantage

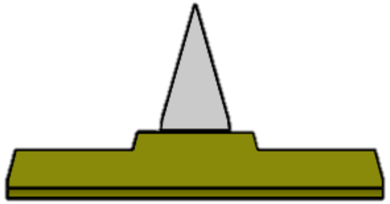
WOLVERINE™ Cutting Balloon™ Device
Atherotome



WOLVERINE Atherotome Advantage:

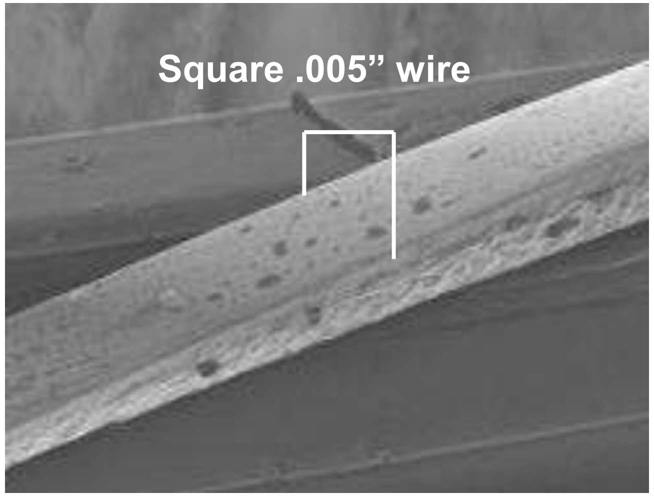
- Amplify balloon inflation pressures in calcium
- Create microsurgical incisions in fibrotic plaque

These two applications help to prepare vessels and limit recoil.



CUTTING BALLOON
CROSS SECTION

Product A
Nitinol Wire



Scoring Balloon Design:

- Flat scoring design provides a blunt force spread over a greater area.
- May explain why published data shows other scoring balloons to not generate as high of acute gain than cutting balloon.

Matsukawa, et al, Cardiovascular Intervention and Therapeutics (2019) 34:325 - 334

SCORING BALLOON
CROSS SECTION

Photographs taken by Boston Scientific at 100X magnification

Competitive Specifications

WOLVERINE™ is compatible with smaller guide catheter and offer the broad size matrix to treat according to the type of lesions

	WOLVERINE™	Product A	Product B	Product C
Guide Cath Compatibility	**5F, 6F**	**6F**	**6F**	**5F**
Size Matrix: Diameter (mm)	2, 2.25, 2.5, 2.75, 3, 3.25, 3.5, 3.75, 4	2, 2.5, 3, 3.5	2, 2.25, 2.5, 2.75, 3, 3.25, 3.5, 4	2, 2.5, 3, 3.5, 4
Size Matrix: Length (mm)	6, 10, 15	6, 10, 15	13	10, 15, 20
Pressures (ATM)	NOM: **6** RBP: **12**	NOM: **8** RBP: **16-20**	NOM: **6** RBP: **14**	NOM: **12** RBP: **20**
Catheter Length (cm)	143	137	142	139
Balloon Compliance	Non-Compliant	Semi-Compliant	Semi-Compliant	Non-Compliant
Plaque Mod Method	**3 or 4** evenly spaced atherotomes	Wire wrapped balloon	3 scoring elements	Single scoring wire

Clinical Study: Cutting Balloon vs. Scoring Balloon in Severely Calcified Patients

Plaque modification using a cutting balloon is more effective for stenting of heavily calcified lesion than other scoring balloons

Primary Investigator

- Ryuichi Matsukawa, Fukuoka Red Cross Hospital, Fukuoka, Japan

Study Design

- Retrospective analysis of 156 patients treated for calcified coronary artery disease with either Cutting Balloon (n=30), NSE Scoring Balloon (n=39) or Scoreflex Scoring Balloon (n=87) from April 2015 – December 2017

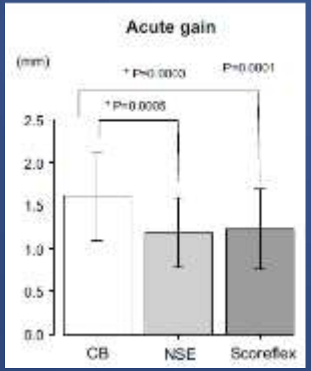
Notable Patient Characteristics

- Patients in all groups had similar characteristics including age, gender, lesion location, Minimum Lumen Diameter, reference vessel diameter and balloon to artery ratio
- However, the cutting balloon patients had a significantly higher rate of severe calcification (83.3%) than NSE (59%) or Scoreflex (44.8%)

Summary of Key Results

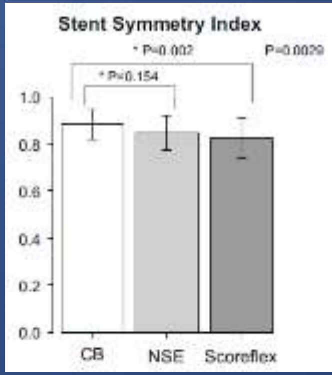
30% HIGHER ACUTE GAIN

Despite a significantly higher percentage of severe calcium, cutting balloon resulted in a statistically significant higher acute gain than scoring balloon.



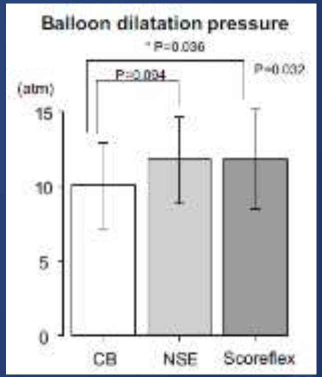
BETTER LUMEN SYMMETRY

Cutting balloon also had a superior effect on stent symmetry index, meaning that the stent lumen was more symmetrical than with scoring balloon.



ACHIEVED AT LOWER PRESSURES

This 30% higher acute gain was achieved with cutting balloon despite using a statistically significant lower inflation pressure than scoring balloon.



Matsukawa, et al, Cardiovascular Intervention and Therapeutics (2019) 34:325 - 334

WOLVERINE™
Cutting Balloon™ Dilatation Device

Brief Summary

WOLVERINE™ Brief Summary

PRECAUTIONS

The device should be used only by physicians trained in the performance of PTCA.
If difficulty is experienced during balloon inflation, do not continue; remove the device and do not attempt to use it.
Infusion of any medium through the guidewire lumen other than heparinized saline may compromise device performance.
Do not attempt to reposition a partially inflated balloon.
Do not use a guidewire having a diameter greater than 0.014 in (0.36 mm).
Potential ADVERSE EVENTS

Potential adverse events include, but are not limited to, the following:

- Abrupt closure
- Acute myocardial infarction
- Angina or unstable angina
- Arrhythmias, including ventricular fibrillation
- Arteriovenous fistula
- Cardiac tamponade/pericardial effusion
- Cardiogenic shock
- Cerebrovascular accident/stroke
- Coronary aneurysm
- Coronary artery bypass graft surgery
- Coronary artery spasm
- Coronary vessel dissection, perforation, rupture, or injury, possibly requiring surgical repair or intervention
- Death
- Drug reactions, including allergic reaction to contrast medium
- Embolism
- Hemodynamic compromise
- Hemorrhage or hematoma
- Hypo/hypertension
- Infection
- Minor vessel trauma
- Myocardial ischemia
- Percutaneous re-intervention
- Pseudoaneurysm (at vascular access site)
- Pyrogenic reaction
- Renal failure
- Respiratory insufficiency
- Restenosis of the dilated vessel
- Side branch occlusion
- Slow flow/no reflow
- Thrombosis
- Total occlusion of the coronary artery or bypass graft
- Transient ischemic attack
- Vasovagal reaction
- Ventricular irritability/dysfunction
- Vessel trauma requiring surgical repair or intervention
- Volume overload

91167617 AA

WOLVERINE™ Brief Summary

CAUTION: Rx only. Prior to use, please see the complete “Directions for Use” for more information on Indications, Contraindications, Warnings, Precautions, Adverse Events, and Operator’s Instructions.

INTENDED USE / INDICATIONS FOR USE

The Wolverine Cutting Balloon Device is indicated for use in patients with coronary vessel disease who are acceptable candidates for coronary artery bypass graft surgery, should it be urgently needed, for the purpose of improving myocardial perfusion. In addition, the target lesion should possess the following characteristics:

- Discrete (< 15 mm in length), or tubular (10 mm to 20 mm in length)
- Reference vessel diameter (RVD) of 2.00 mm to 4.00 mm
- Readily accessible to the device
- Light to moderate tortuosity of proximal vessel segment
- Nonangulated lesion segment (< 45°)
- Smooth angiographic contour
- Absence of angiographically visible thrombus

CONTRAINDICATIONS

The WOLVERINE Cutting Balloon Device is contraindicated for use in:

Delivery through the side cell of a previously placed stent as the deflated Cutting Balloon could become entangled in the stent.
Coronary artery spasm in the absence of a significant stenosis.

WARNINGS

- Exercise extreme care when treating a lesion distal to a stent. When treating lesions at a bifurcation, the device can be used prior to placing a stent, but should not be taken through the side cell of a stent to treat the side branch of a lesion at a bifurcation.
- The atherotomy process, because of its mechanism of action, may pose a greater risk of perforation than that observed with conventional Percutaneous Transluminal Coronary Angioplasty (PTCA). To reduce the potential for vessel damage, the inflated diameter of the device should approximate a 1.1:1 ratio of the diameter of the vessel just proximal and distal to the stenosis.
- The atherotomy process in patients who are not acceptable candidates for coronary artery bypass surgery requires careful consideration, including possible hemodynamic support during the atherotomy process, as treatment of this patient population carries special risk.
- Balloon pressure should not exceed the rated burst pressure.
- When performing percutaneous atherotomy, the availability of on-site surgical backup should be included as a clinical consideration.