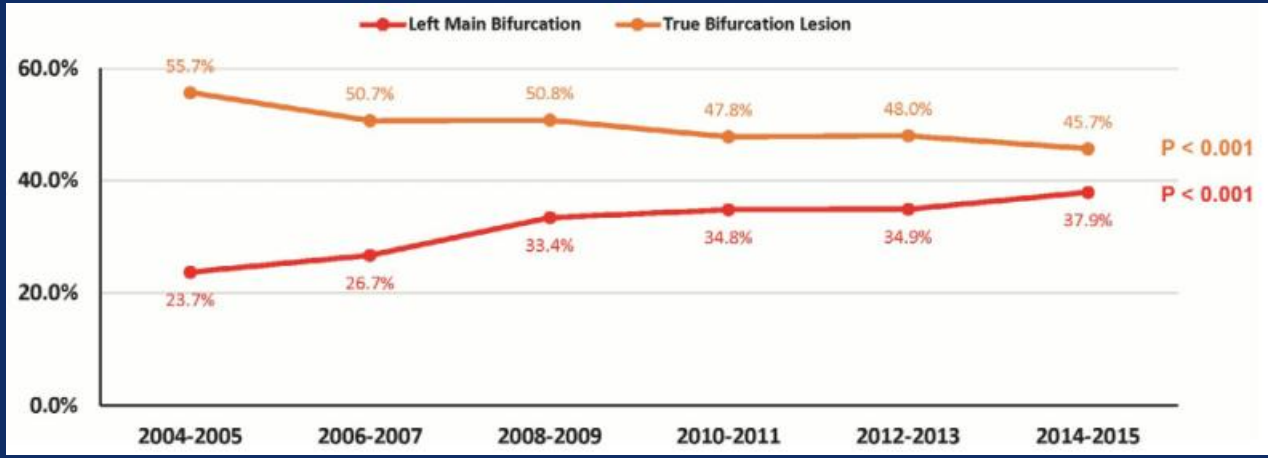
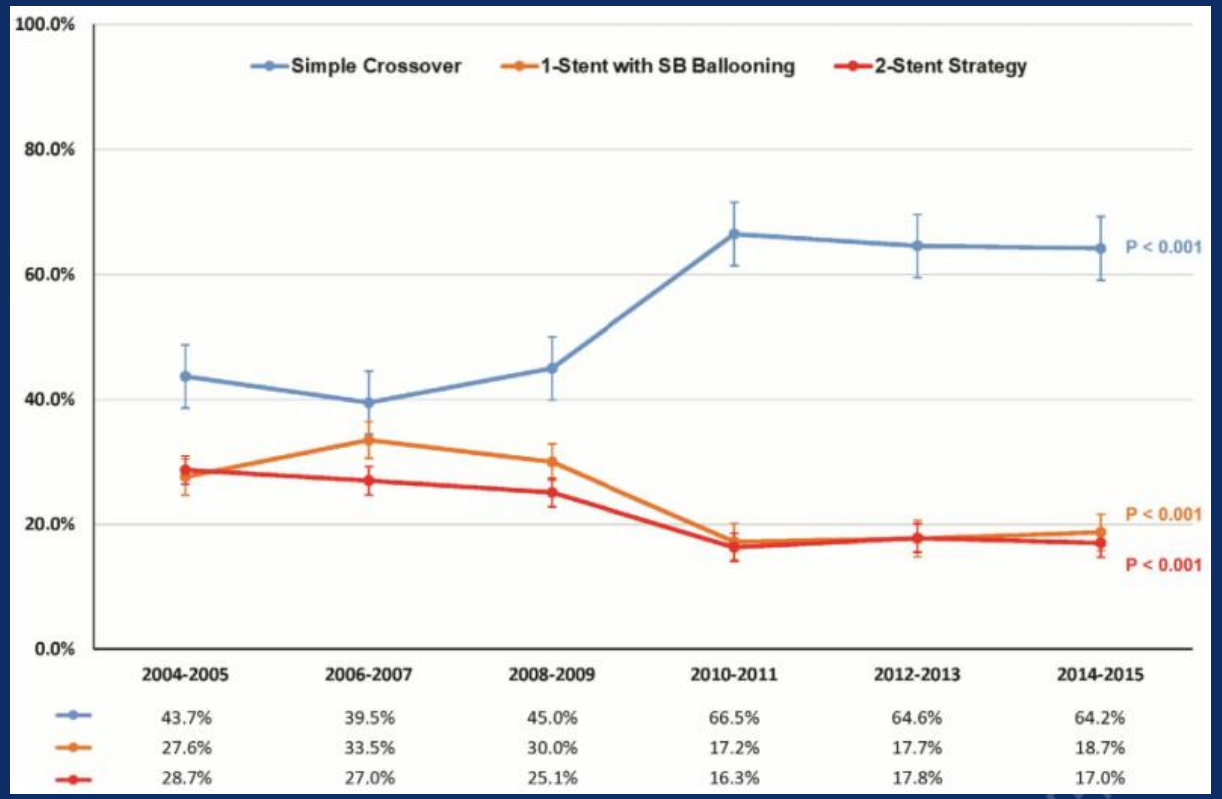
Coronary Bifurcation PCI

Ten-year trends in coronary bifurcation PCI

Changes in Lesion Characteristics



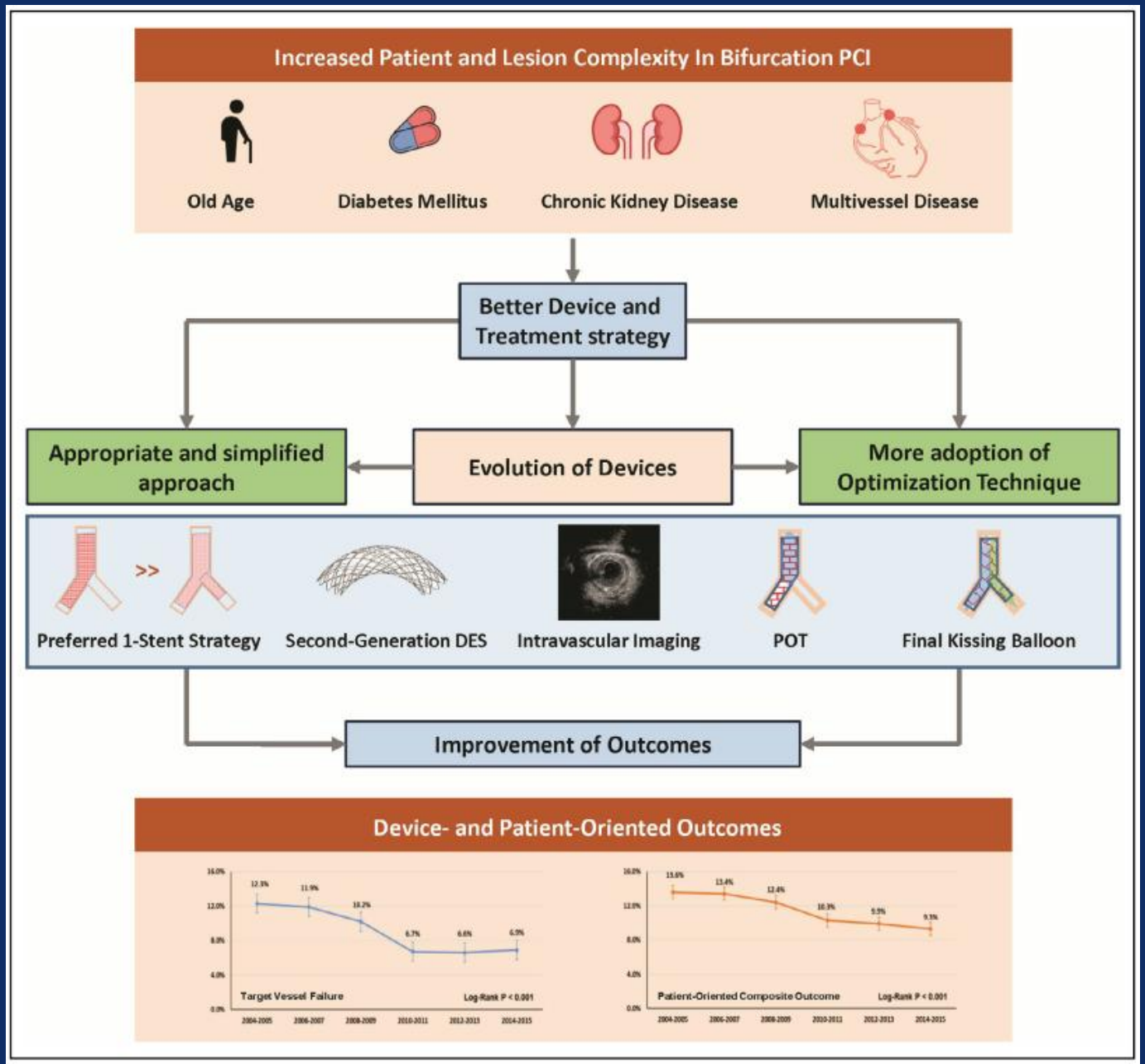
Changes in Treatment Strategy trends



CVRF

Lee et al, J Am Heart Assoc. 2021;10:e021632.

Ten-year trends in coronary bifurcation PCI



Lee et al, J Am Heart Assoc. 2021;10:e021632.

LM vs. Non-LM Bifurcation

Procedural Characteristics

Variables	Left Main Bifurcation (N=935)			Non-Left Main Bifurcation (N=1713)		
	1-Stent (N=682)	2-Stent (N=253)	*P* Value	1-Stent (N=1512)	2-Stent (N=201)	*P* Value
Treatment strategy			<0.001			<0.001
1-stent without side branch ballooning	489 (71.7%)	0 (0%)		1196 (79.1%)	0 (0%)	
1-stent with side branch ballooning	193 (28.3%)	0 (0%)		316 (20.9%)	0 (0%)	
Crush	0 (0%)	142 (56.1%)		0 (0%)	102 (50.7%)	
T-stenting or TAP	0 (0%)	60 (23.7%)		0 (0%)	65 (32.3%)	
Culottes	0 (0%)	16 (6.3%)		0 (0%)	15 (7.5%)	
Kissing or V stenting	0 (0%)	26 (10.3%)		0 (0%)	15 (7.5%)	
Others	0 (0%)	9 (3.6%)		0 (0%)	4 (2.0%)	
No. of used stent	1.7±0.9	2.6±1.0	<0.001	1.6±0.9	2.3±1.1	<0.001
Stent type			0.161			0.011
Everolimus-eluting stents	367 (53.8%)	131 (51.8%)				
Zotarolimus-eluting stents	164 (24.0%)	69 (27.3%)				
Biolimus-eluting stent	132 (19.4%)	40 (15.8%)		317 (21.0%)	25 (12.4%)	
Mixed or other stents	19 (2.8%)	13 (5.1%)		81 (5.4%)	9 (4.5%)	
IVUS guidance	427 (62.6%)	172 (68.0%)	0.148	389 (25.7%)	75 (37.3%)	0.001
Final kissing ballooning	163 (23.9%)	233 (92.1%)	<0.001	228 (15.1%)	165 (82.1%)	<0.001
POT(proximal optimization technique)	237 (34.8%)	56 (22.1%)	<0.001	394 (26.1%)	52 (25.9%)	>0.999
Re-POT	25 (3.7%)	48 (19.0%)	<0.001	23 (1.5%)	27 (13.4%)	<0.001
NC balloon use	162 (23.8%)	87 (34.4%)	0.001	228 (15.1%)	57 (28.4%)	<0.001

Choi et al, Circ Cardiovasc Interv. 2020;13:e008543.

LM vs. Non-LM Bifurcation

Cumulative Incidence of Adverse Events at 5 Years

	All Patients (N=2648)			Left Main Bifurcation (N=935)			Non-Left Main Bifurcation (N=1713)		
	1-Stent (N=2194)	2-Stent (N=454)	*P* Value	1-Stent (N=682)	2-Stent (N=253)	*P* Value	1-Stent (N=1512)	2-Stent (N=201)	*P* Value
TLF*	137 (7.6%)	47 (12.1%)	<0.001	60 (10.6%)	37 (17.4%)	0.006	77 (6.3%)	10 (5.6%)	0.950
Cardiac death or MI	84 (4.5%)	14 (3.5%)	0.536	38 (6.6%)	10 (4.4%)	0.355	46 (3.6%)	4 (2.3%)	0.453
All-cause death	94 (5.1%)	20 (5.4%)	0.814	40 (7.1%)	11 (5.2%)	0.418	54 (4.2%)	9 (5.5%)	0.505
Cardiac death	55 (3.0%)	8 (2.0%)	0.416	25 (4.5%)	4 (1.8%)	0.119	30 (2.3%)	4 (2.2%)	0.927
MI	33 (1.7%)	7 (1.7%)	0.911	16 (2.7%)	6 (2.7%)	0.964	17 (1.3%)	1 (0.6%)	0.423
TLR	67 (3.9%)	38 (9.9%)	<0.001	30 (5.5%)	32 (15.3%)	<0.001	37 (3.2%)	6 (3.3%)	0.597

Values are n (%). Cumulative incidence of events was presented as Kaplan-Meier estimates. MI indicates myocardial infarction; TLF, target lesion failure; and TLR, target lesion revascularization.

*TLF was defined as a composite of cardiac death, MI, and TLR.

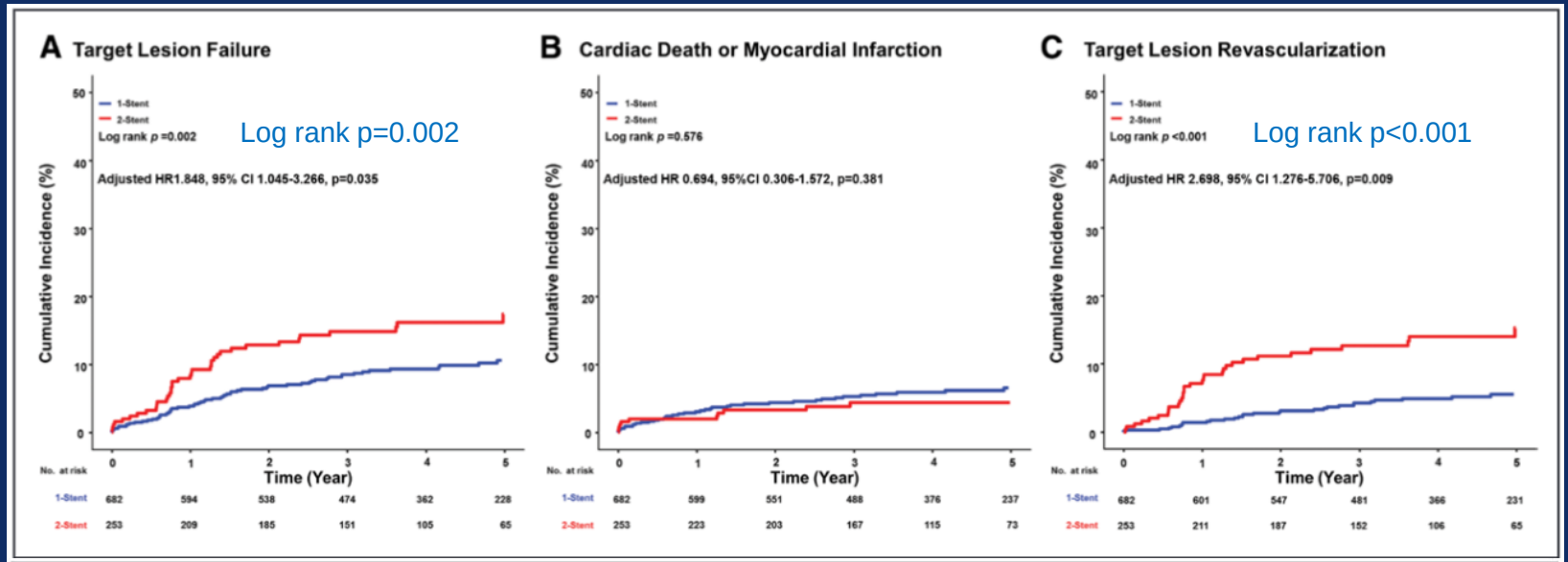
CVRF

Choi et al, Circ Cardiovasc Interv. 2020;13:e008543.

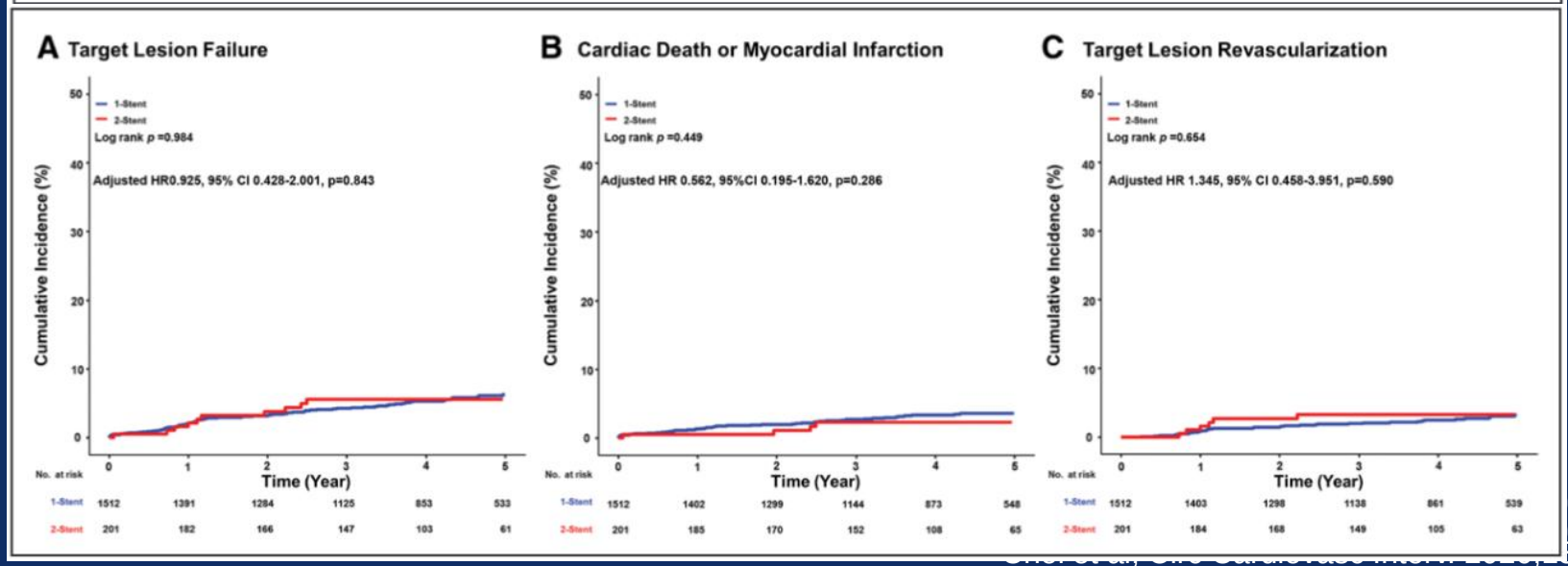
LM vs. Non-LM Bifurcation

Comparison of 5-yr clinical outcomes between 1-stent and 2-stent strategy

Left Main



Non-Left Main



Choi et al, Circ Cardiovasc Interv. 2020;13:e008543.

Clinical Outcomes Following Coronary Bifurcation PCI Techniques

- Systemic Review and Network Meta-Analysis (5,711 patients)

TABLE 2 Angiographic Characteristics

First Author/Trial/Ref. (#)	Interventions	Bifurcation Treated				True Bifurcation
		LMCA	LAD	LCX	RCA	
Pan et al. (8)	Pro vs. T ste	3 (6); 2 (5)	33 (71); 33 (75)	8 (17); 6 (13)	3 (6); 3 (7)	47 (100); 44 (100)
CACTUS (9)	Crush vs. Pro	0 (0); 0 (0)	131 (74); 121 (70)	34 (19); 43 (25)	12 (7); 9 (5)	328 (94) OA
Colombo et al. (10)	T ste vs. Pro	0 (0); 0 (0)	64 (74) OA	15 (17) OA	7 (8) OA	63 (100); 22 (100)
Lin et al. (3)*	Pro vs. DK	0 (0); 0 (0)	45 (83); 43 (80)	5 (9); 6 (11)	4 (7); 5 (9)	54 (100); 54 (100)
BBC ONE (4)*	Pro vs. Crush	0 (0); 0 (0)	201 (81); 209 (84)	35 (14); 28 (11)	9 (4); 12 (5)	202 (81); 209 (84)
EBC TWO (11)	Pro vs. Cul	0 (0); 0 (0)	80 (78); 75 (77)	16 (15); 18 (19)	6 (6); 4 (4)	103 (100); 97 (100)
DK-Crush V (6)	Pro vs. DK	242 (100); 240 (100)	0 (0); 0 (0)	0 (0); 0 (0)	0 (0); 0 (0)	242 (100); 240 (100)
Zheng et al. (12)	Crush vs. Cul	13 (9); 19 (13)	96 (64); 102 (68)	35 (23); 26 (17)	6 (4); 3 (2)	150 (100); 150 (100)
DK-Crush III (13)	DK vs. Cul	210 (100); 209 (100)	0 (0); 0 (0)	0 (0); 0 (0)	0 (0); 0 (0)	210 (100); 209 (100)
NSTS (14)	Crush vs. Cul	20 (10); 21 (10)	132 (63); 142 (66)	42 (20); 43 (20)	15 (7); 9 (4)	153 (73); 177 (82)
DK-Crush II (15)	DK vs. Pro	32 (17); 29 (16)	112 (61); 107 (59)	23 (12); 30 (16)	17 (9); 16 (9)	183 (100); 183 (100)
NBS (16)*	Pro vs. Crush	(2) OA	(73) OA	(18) OA	(7) OA	ND
BBK I (17)	Pro vs. T ste	0 (0); 0 (0)	76 (75); 74 (73)	16 (16); 21 (21)	9 (9); 6 (6)	69 (69); 69 (69)
PERFECT (18)	Crush vs. Pro	0 (0); 0 (0)	200 (94); 190 (92)	10 (5); 15 (7)	3 (1); 1 (0)	194 (91); 169 (82)
NBBSIV (19)*	Pro vs. Cul	(3); (1)	(74); (77)	(17); (18)	(6); (4)	(100); (100)
BBK II (20)	Cul vs. TAP	28 (19); 23 (15)	82 (55); 83 (55)	36 (24); 38 (25)	4 (3); 6 (4)	147 (98); 143 (95)
Zhang et al. (21)	Pro vs. Cul	16 (31); 14 (27)	33(63); 34 (65)	3 (6); 2 (4)	0 (0); 2 (4)	52 (100); 52 (100)
Ruiz et al. (22)	Pro vs. T ste	0 (0); 0 (0)	24 (71); 26 (72)	9 (26); 6 (17)	1 (3); 4 (11)	27 (79); 33 (92)
DK-Crush I (23)	Crush vs. DK	(16); (15)	(62); (66)	(14); (11)	(8); (8)	(100); (100)
Ye et al. 2010 (24)	Pro vs. DK	ND	ND	ND	ND	26 (100) 25 (100)
Ye et al. 2012 (25)	Pro vs. DK	0 (0) 0 (0)	(78) OA	(15) OA	(7) OA	37 (100) 38 (100)

Values are n, n (%), or mean ± SD. Data are presented for each arm. *When arm-specific data was not available, it is reported as Overall (OA).

Cul = Culotte; DK = DK-Crush; LAD = left anterior descending artery; LCX = left circumflex artery; LMCA = left main coronary artery; NBBSIV = Nordic-Baltic Bifurcation Study IV; NBS = Nordic Bifurcation Study; ND = not declared; NSTS = Nordic Stent Technique Strategy; Pro = Provisional stenting; RCA = right coronary artery; T ste = T stenting; TAP = T and protrusion.

Giuseppe Di Gioia et al, JACC Cardiovasc Interv. 2020 Jun 22;13(12):1432-1444.

The CACTUS study

; Crush vs. Provisional side-branch stenting

Table 3. Clinical Outcomes

	Crush Group (n=177)	Provisional-Stenting Group (n=173)	*P*
30-day MACE (days 0–30)			
Q-wave MI	3 (1.7)	2 (1.1)	1.00
Non–Q-wave MI	15 (8.5)	12 (6.9)	0.69
TLR	3 (1.7)	1 (0.5)	0.63
TVR (including TLR)	3 (1.7)	1 (0.5)	0.63
Death	0	0	...
6-month MACE (days 31–180)			
MI	1 (0.5)	1 (0.5)	1.00
TLR	10 (5.6)	10 (5.8)	1.00
TVR (including TLR)	11 (6.2)	12 (6.8)	0.83
Death	0	1* (0.5)	0.49
Cumulative MACE (days 0–180)			
MI	19 (10.7)	15 (8.6)	0.59
TLR	13 (7.3)	11 (6.3)	0.83
TVR (including TLR)	14 (7.9)	13 (7.5)	1.00
Death	0	1* (0.5)	0.49

TLR indicates target-lesion revascularization; TVR, target-vessel revascularization. Values are mean±SD or n (%).

*Noncardiac death (ischemic stroke confirmed by autopsy).

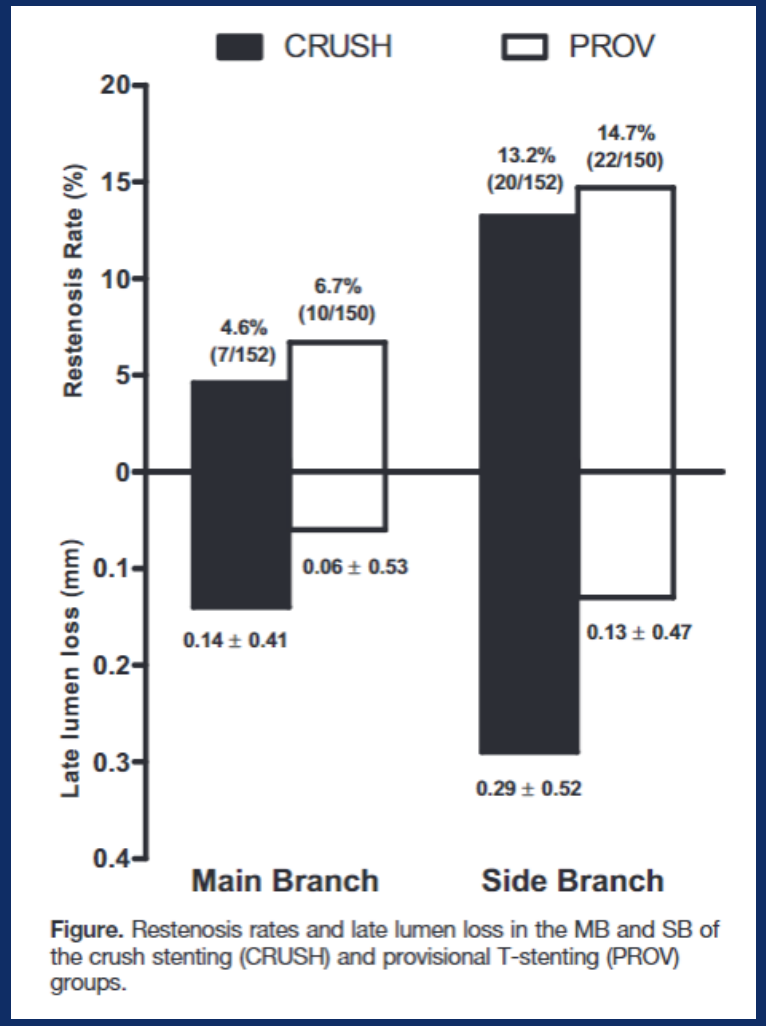


Figure. Restenosis rates and late lumen loss in the MB and SB of the crush stenting (CRUSH) and provisional T-stenting (PROV) groups.

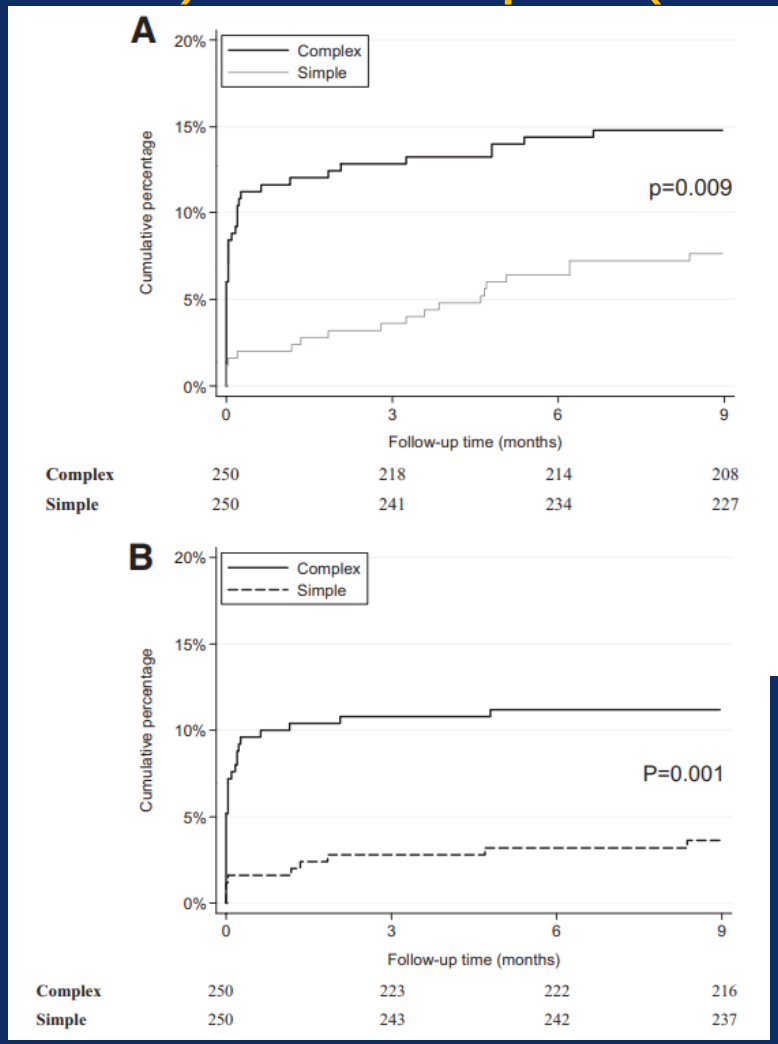
Colombo A et al, Circulation. 2009 Jan 6;119(1):71-8

BBC study
; Simple(Provisional) vs. Complex(Crush, Culotte)

Table 3. Trial End Points

	Simple	Complex	Hazard Ratio (95% CI)	*P*
Primary end point	n=250	n=250		
Death, MI, or target-vessel failure at 9 mo (%)	20 (8.0)	38 (15.2)	2.02 (1.17–3.47)	0.009
Secondary end points				
Death (%)	1 (0.4)	2 (0.8)		
Periprocedural (inpatient)	0	1		
Subsequent	1	1		
MI (%)	9 (3.6)	28 (11.2)	3.24 (1.53–6.86)	0.001
Periprocedural (inpatient)	4	17		
Subsequent	5	11		
CK data availability after PCI (%)	233 (94)	231 (93)		
Troponin availability after PCI (%)	233 (94)	222 (90)		
CK or troponin after PCI (%)	244 (98)	240 (97)		
Target-vessel failure (%)	14 (5.6)	18 (7.2)	1.32 (0.66–2.66)	0.43
Stent thrombosis (ARC definite)	1	5		
Restenosis of main vessel only	6	4		
Restenosis of side branch only	6	3		
Restenosis of both	1	6		
Treated with CABG	1	9		
Treated with re-PCI	13	8		
Repeat angiography (%)	32 (13)	43 (17)	1.44 (0.91–2.27)	0.12
In-hospital MACE (%)	5 (2.0)	20 (8.0)	4.00 (1.53–10.49)*	0.002
Death	0	1		
MI	5	18		
CABG	0	3		
Procedural end points	n=249	n=248		
Success in main vessel (%)†	244 (98)	242 (97)		
Success in side branch (%)‡	236 (94)	234 (94)		
Overall procedural success (%)§	235 (94)	234 (94)		
Stent implantation in main vessel (%)	245 (98)	239 (96)		
Stent implantation in side branch (%)	7 (3)	225 (91)		
Procedure time, min, mean (SE)	57 (1.6)	78 (1.9)		<0.001
Fluoroscopy time, min, mean (SE)	15 (0.7)	22 (0.8)		<0.001
Diamentor, cGy · cm^2, mean (SE)	6140 (300)	7900 (350)		<0.001
No. of guidewires used, mean (SE)	2.2 (0.1)	3.1 (0.1)		<0.001
No. of balloons used, mean (SE)	2.3 (0.1)	4.0 (0.1)		<0.001
No. of stents used, mean (SE)	1.2 (0.0)	2.2 (0.1)		<0.001

CI indicates confidence interval; MI, myocardial infarction; CABG, coronary artery bypass graft; and ARC, Academic Research Consortium.
*Risk ratio.
†Defined as TIMI 3 flow and <30% residual stenosis.
‡Defined as TIMI 3 flow.
§Defined as both of the above.



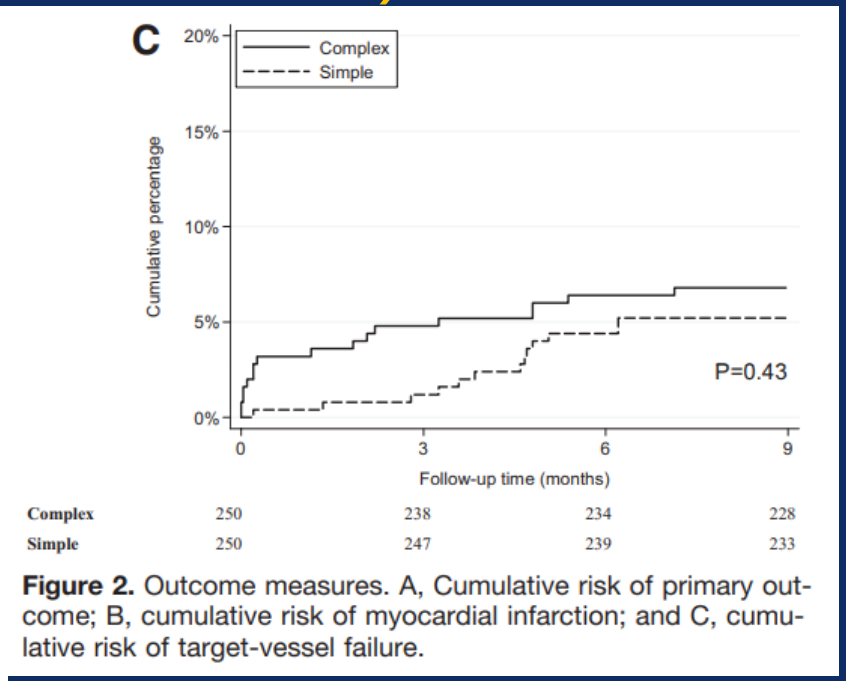


Figure 2. Outcome measures. A, Cumulative risk of primary outcome; B, cumulative risk of myocardial infarction; and C, cumulative risk of target-vessel failure.

Hildick-Smith D et al. Circulation 2010;121:1235-43.

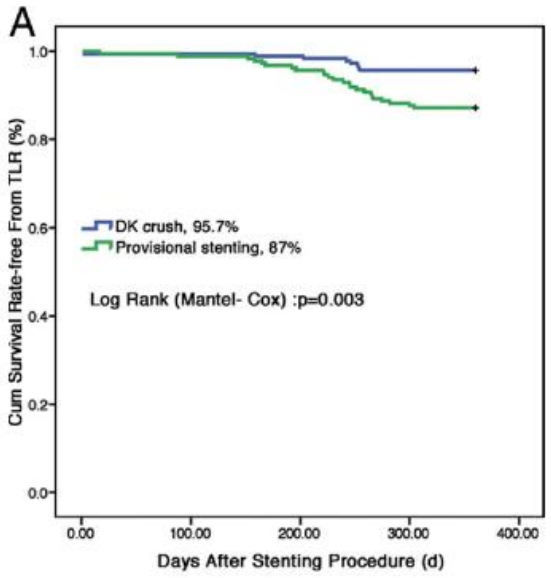
DKCRUSH-Ⅱ

; Double kissing crush *vs.* Provisional stenting

Table 6 Clinical Outcome

	DK Group (n = 185)	PS Group (n =185)	p Value
Intra-procedural			
Acute closure	0 (0)	3 (1.6)	0.248
Cardiac death	0 (0)	0 (0)	1.000
Emergent CABG	0 (0)	0 (0)	1.000
Needing IABP	0 (0)	0 (0)	1.000
MI	0 (0)	3 (1.6)	0.248
In-hospital			
Cardiac death	1 (0.5)	0 (0)	0.500
MI	6 (3.2)	4 (2.2)	0.751
CABG	0 (0)	0 (0)	1.000
TLR	1 (0.5)	1 (0.5)	1.000
TVR	1 (0.5)	1 (0.5)	1.000
MACE	6 (3.2)	4 (2.2)	0.751
Stent thrombosis definite	4 (2.2)	1 (0.5)	0.372
Procedural success	179 (96.8)	173 (93.5)	0.217
At 6-month			
Cardiac death	1 (0.5)	2 (1.1)	1.000
MI	6 (3.2)	4 (2.2)	0.751
CABG	0 (0)	1 (0.5)	0.500
TLR	2 (1.1)	6 (3.2)	0.284
TVR	3 (1.6)	8 (4.3)	0.220
MACE	6 (3.2)	11 (5.9)	0.321
Stent thrombosis definite	4 (2.2)	1 (0.5)	0.372
At 12-month			
Cardiac death	2 (1.1)	2 (1.1)	1.000
MI	6 (3.2)	4 (2.2)	0.751
CABG	0 (0)	1 (0.5)	0.500
TLR	8 (4.3)	24 (13.0)	0.005
TVR	12 (6.5)	27 (14.6)	0.017
MACE	19 (10.3)	32 (17.3)	0.070
Stent thrombosis	5 (2.7)	2 (1.1)	0.449
Definite	4 (2.2)	1 (0.5)	0.372
Possible	1 (0.5)	1 (0.5)	1.000

Values are n (%).
IABP = intra-aortic balloon pumping; MACE = major adverse cardiac event(s); TLR = target lesion revascularization; TVR = target vessel revascularization; other abbreviations as in Table 1.



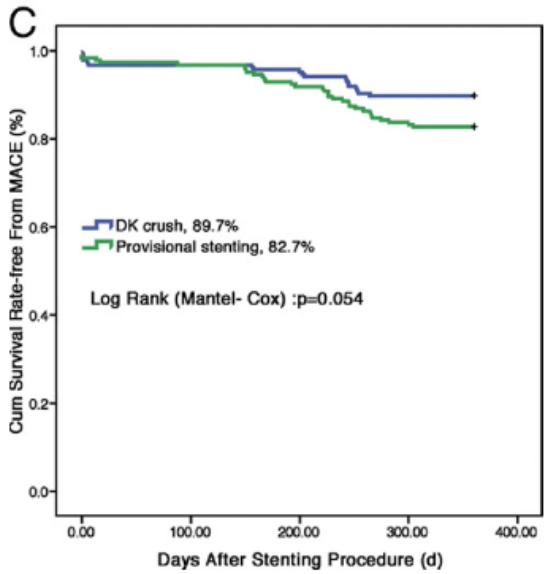
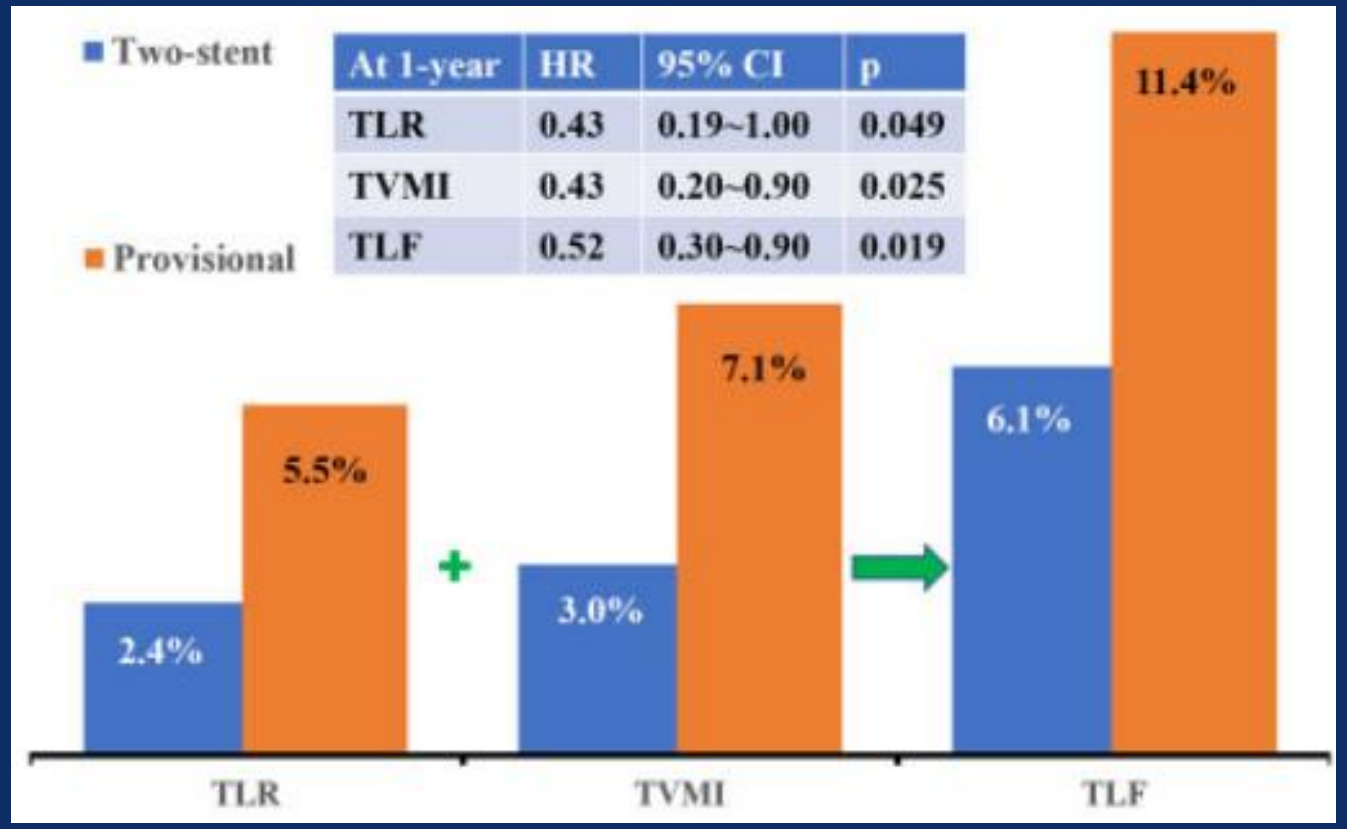


Figure 1 Comparison of Survival Rate Free From TLR, TVR, and MACE Between DK Crush and PS Groups

(A) Target lesion revascularization (TLR), **(B)** target vessel revascularization (TVR), and **(C)** major adverse cardiac events (MACE). PS = provisional stenting.

Chen et al, JACC. 2011 Feb 22;57(8):914-20.

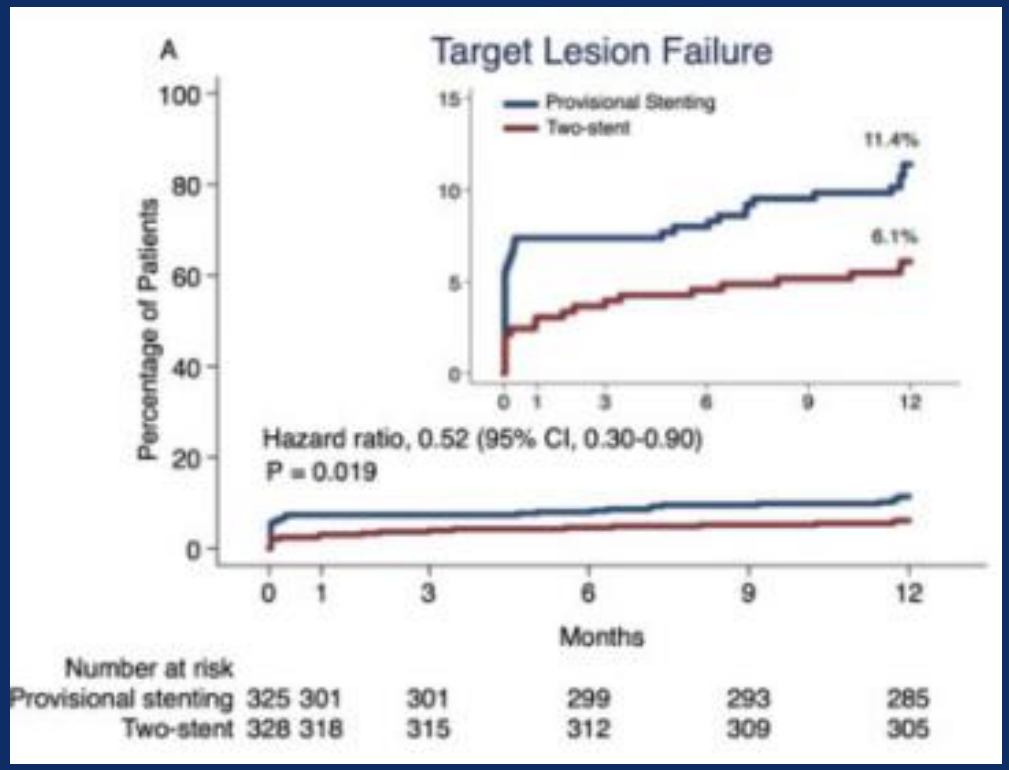
DEFINITION II trial
; Provisional vs 2-stent technique



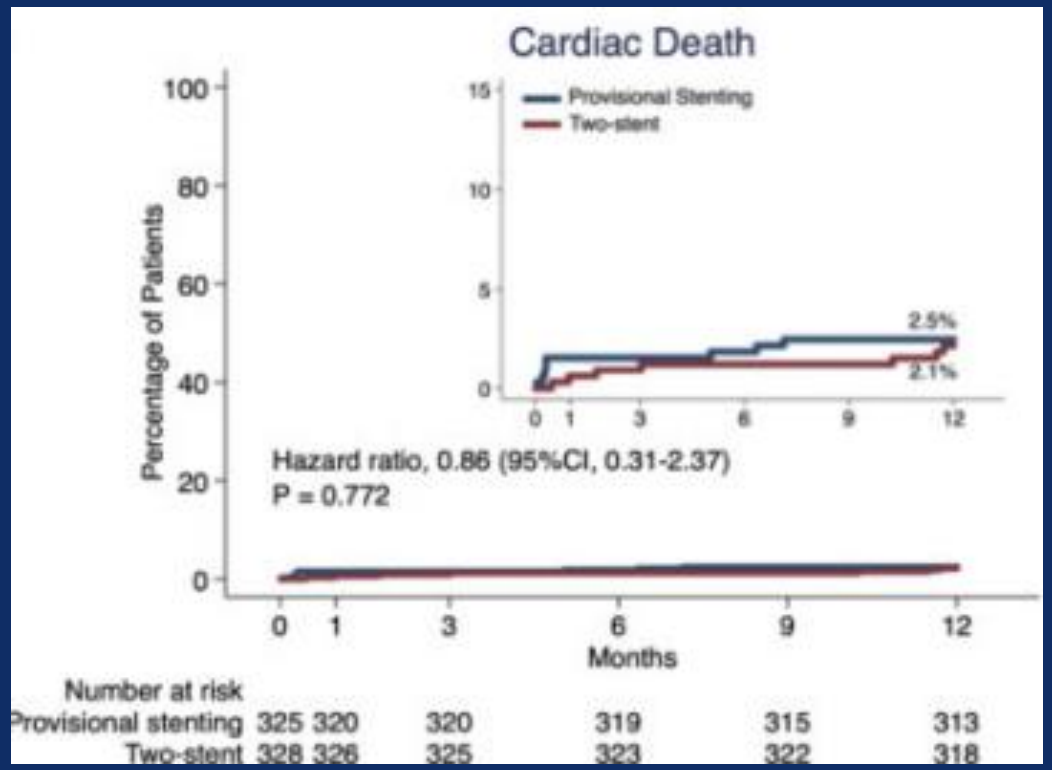
Zhang et al, EHJ. 2020 Jul 14;41(27):2523-2536.

DEFINITION II trial
; Provisional vs 2-stent technique

A) Target Lesion Failure (TLF)



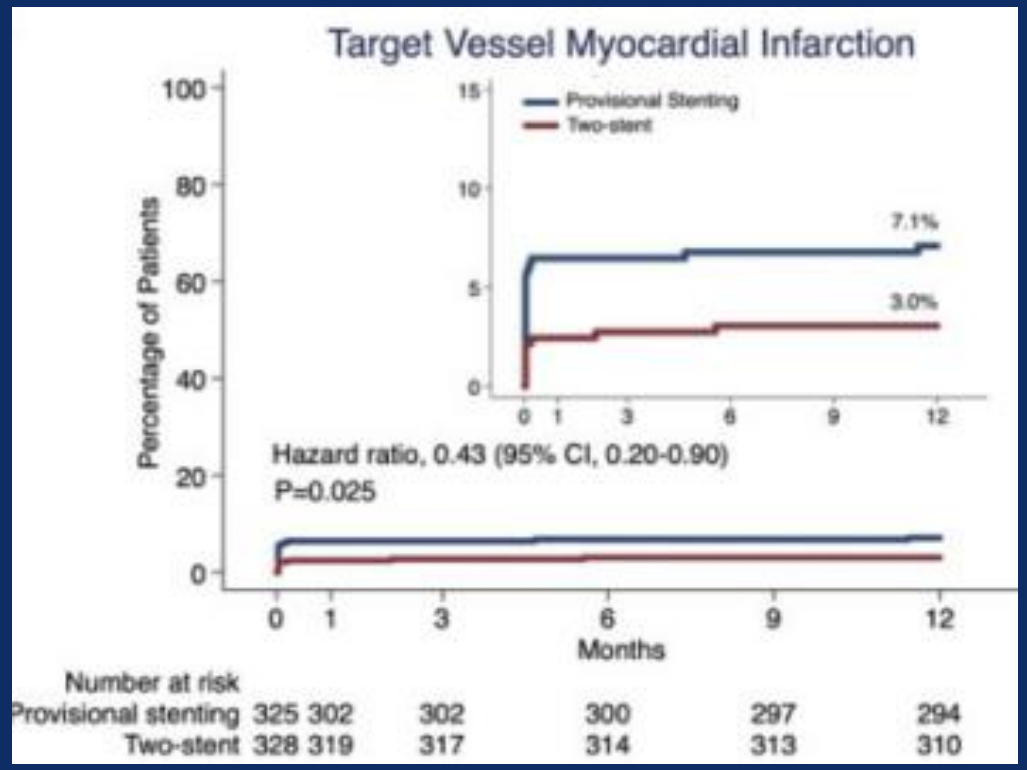
B) Cardiac Death



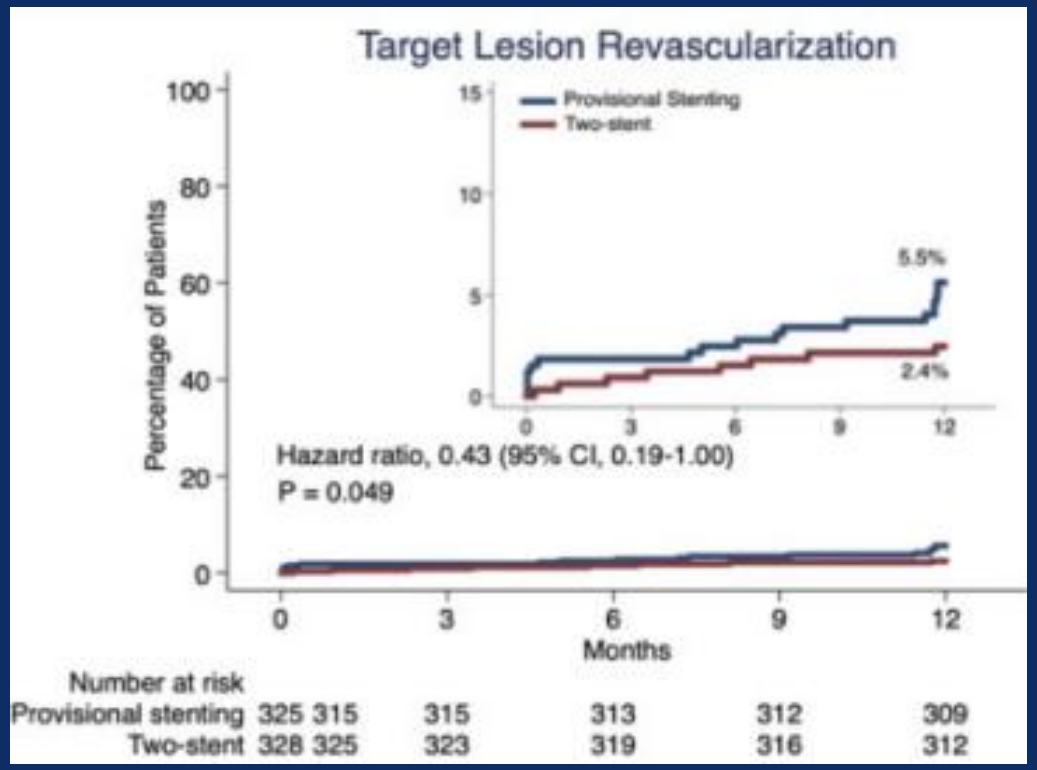
Zhang et al, EHJ. 2020 Jul 14;41(27):2523-2536.

DEFINITION II trial
; Provisional vs 2-stent technique

C) Target Vessel MI



D) Target Lesion Revascularization

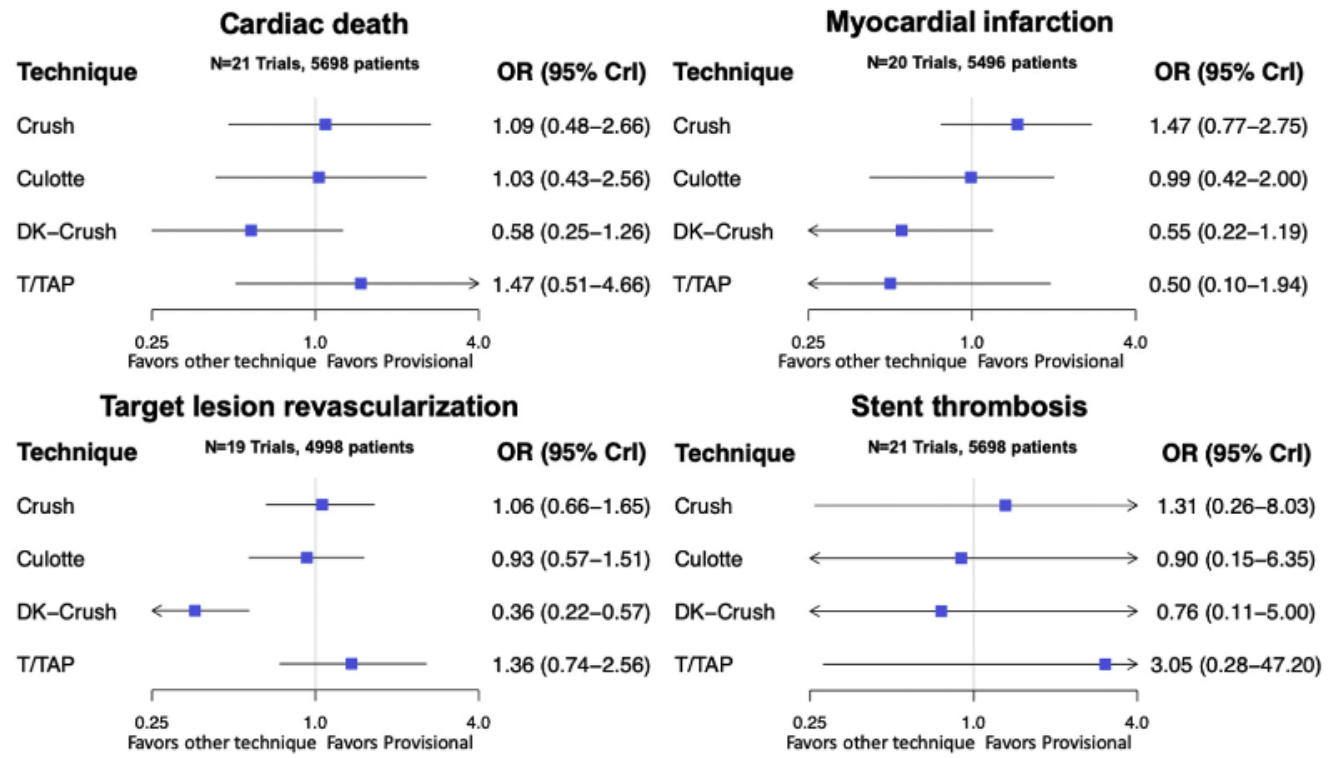


Zhang et al, EHJ. 2020 Jul 14;41(27):2523-2536.

Clinical Outcomes Following Coronary Bifurcation PCI Techniques

- Systemic Review and Network Meta-Analysis (5,711 patients)

FIGURE 2 Network Meta-Analysis Forest Plots for the Secondary Outcomes of Interest



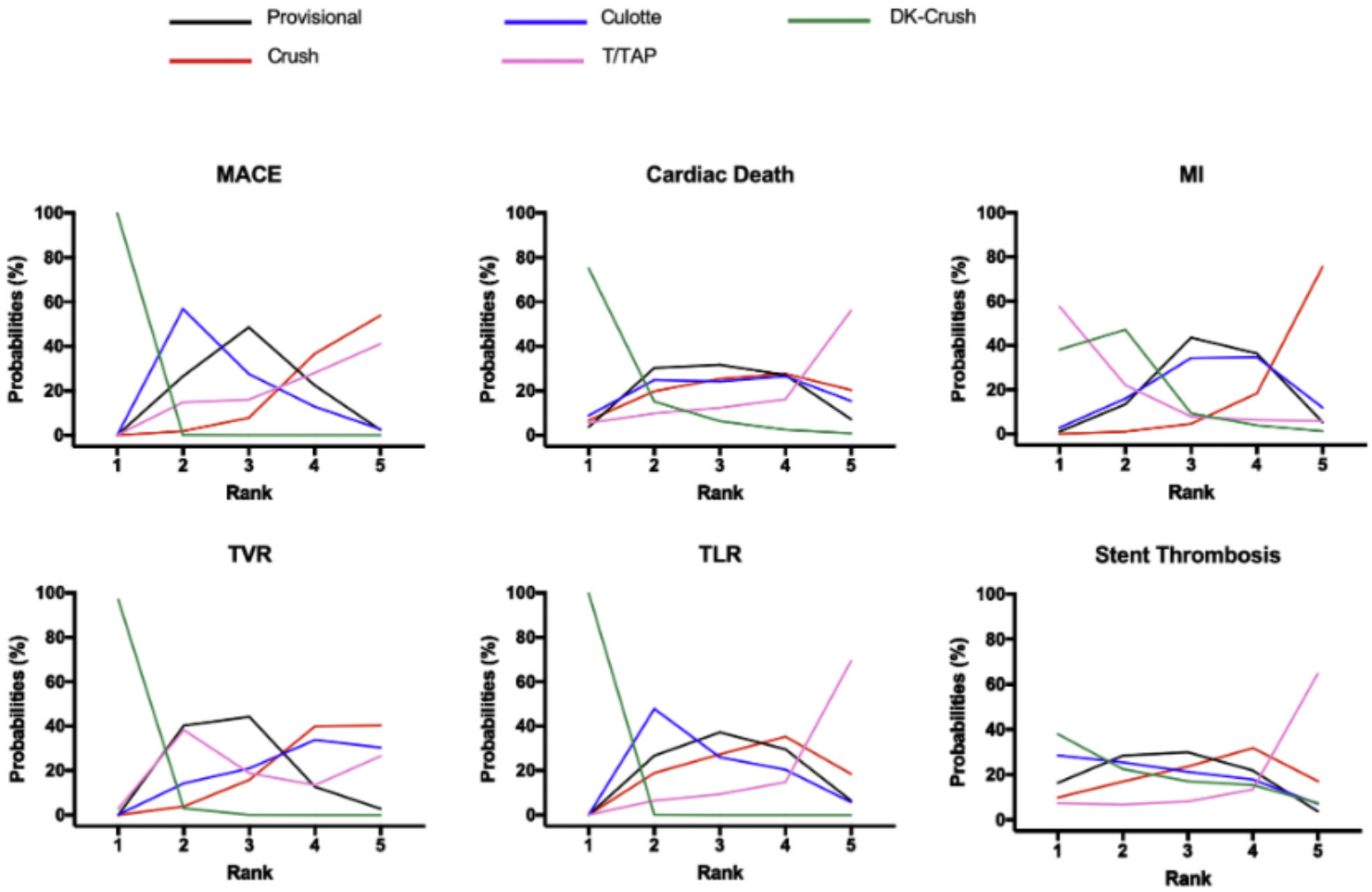
CrI — credible interval; DK-crush — double-kissing crush; MACE — major adverse cardiovascular events; OR — odds ratio; T/TAP — T stenting/T and protrusion.

Giuseppe Di Gioia et al, JACC Cardiovasc Interv. 2020 Jun 22;13(12):1432-1444.

Clinical Outcomes Following Coronary Bifurcation PCI Techniques

- Systemic Review and Network Meta-Analysis (5,711 patients)

FIGURE 3 Rank Probability Analysis for All Outcomes of Interest



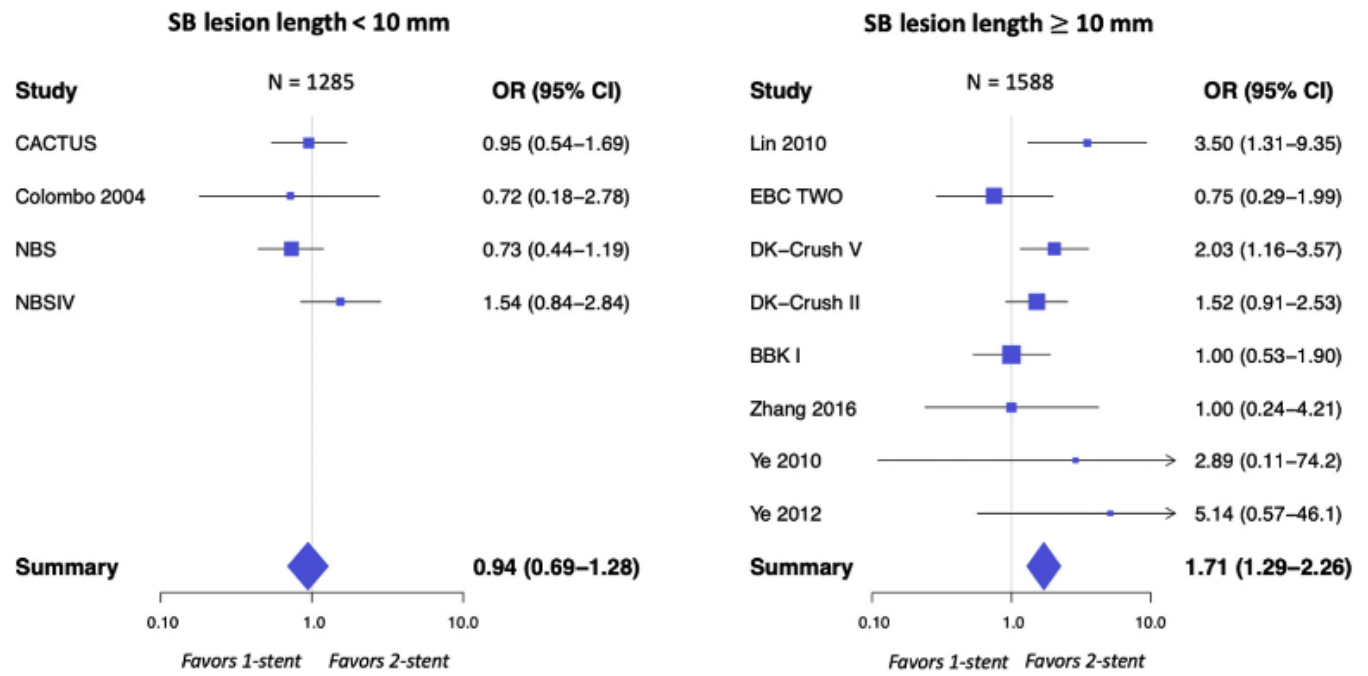
For every endpoint, each treatment is represented by a **line**, indicating the probability to be the best, second, third, fourth, or fifth best treatment. MI = myocardial infarction; TLR = target lesion revascularization; TVR = target vessel revascularization; other abbreviations as in Figure 2.

Giuseppe Di Gioia et al, JACC Cardiovasc Interv. 2020 Jun 22;13(12):1432-1444.

Clinical Outcomes Following Coronary Bifurcation PCI Techniques

- Systemic Review and Network Meta-Analysis (5,711 patients)

FIGURE 4 Pairwise Meta-Analysis of the Outcome of MACE Between 1- and 2-Stent Bifurcation PCI Strategies Stratified According to SB Lesion Length



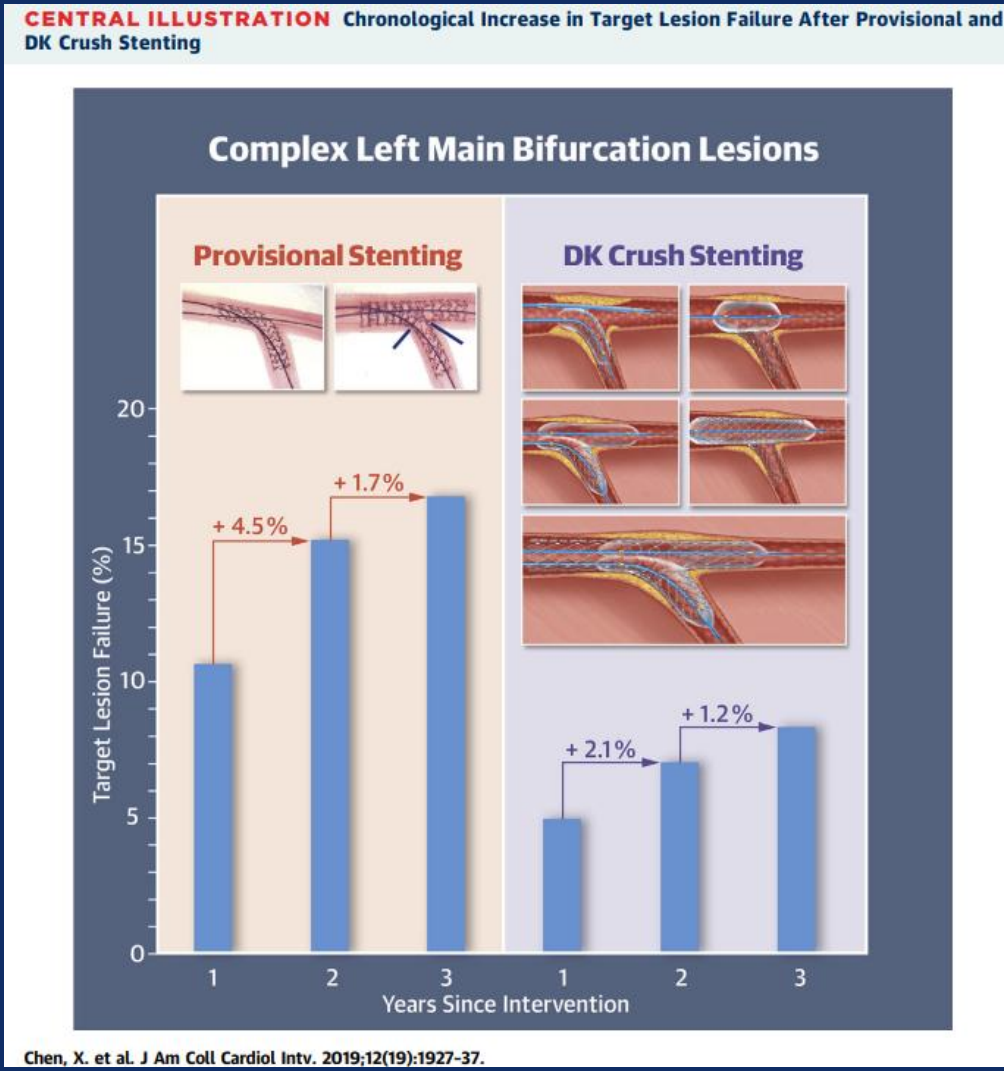
(Left) Forest plot with studies reporting side branch (SB) lesion length <10 mm. The summary estimate shows no difference between 1- and 2-stent bifurcation percutaneous coronary intervention (PCI) strategies. **(Right)** Forest plot with studies reporting SB lesion length ≥10 mm. The summary estimate favors 2-stent bifurcation PCI techniques. BBK I — Bifurcations Bad Krozingen I; CACTUS — Coronary Bifurcations: Application of the Crushing Technique Using Sirolimus-Eluting Stents; CI — confidence interval; EBC TWO — European Bifurcation Coronary Two; NBS — Nordic Bifurcation Study; NBBSIV — Nordic-Baltic Bifurcation Study IV; other abbreviations as in Figure 2.

Giuseppe Di Gioia et al, JACC Cardiovasc Interv. 2020 Jun 22;13(12):1432-1444.

LM bifurcation

DKCRUSH-V

; Double kissing crush *vs.* Provisional stenting in unprotected LM bifurcation lesions

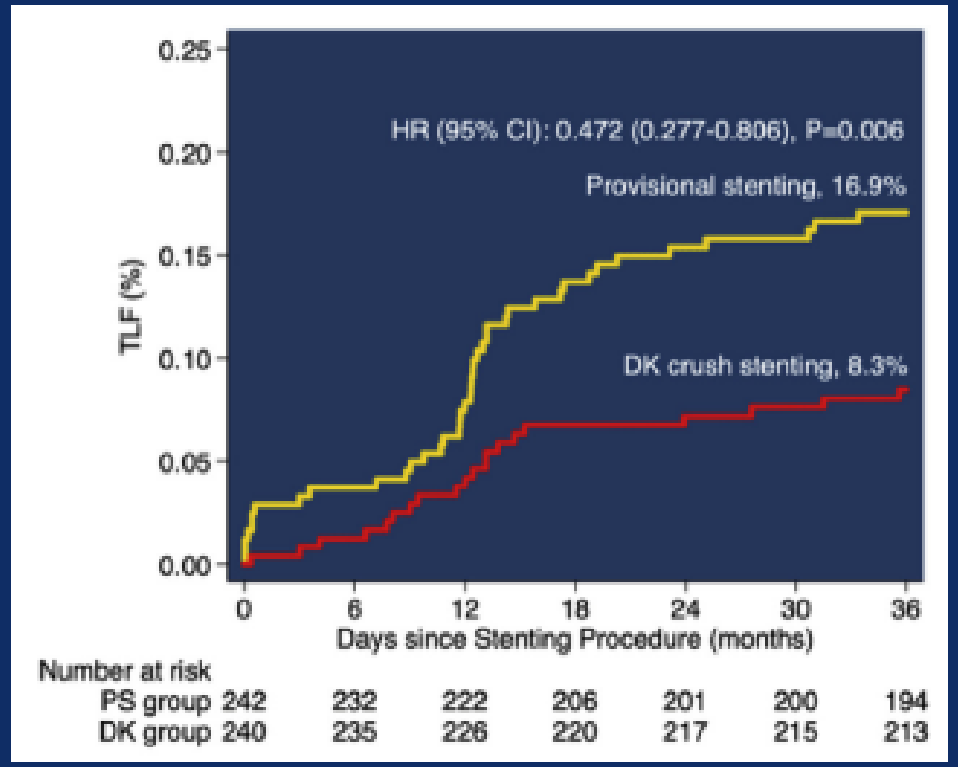


Chen et al, JACC: Cardiovascular Interventions. 2019 Oct 14;12(19):1927-1937.

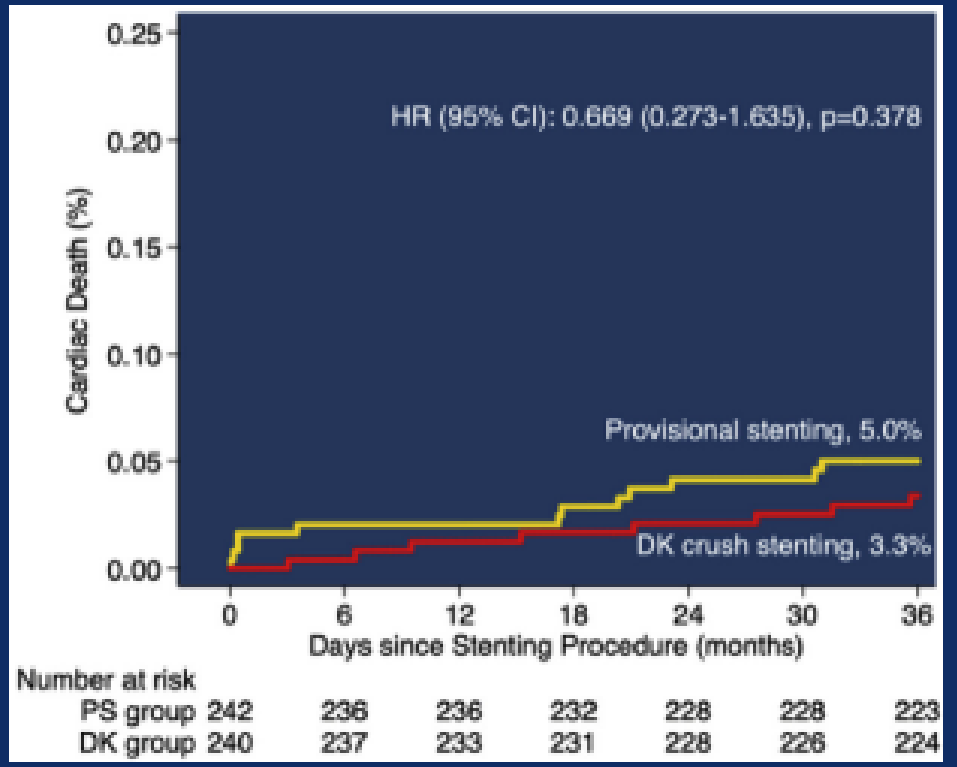
DKCRUSH-V

; Double kissing crush *vs.* Provisional stenting in unprotected LM bifurcation lesions

A) Target Lesion Failure (TLF)



B) Cardiac death

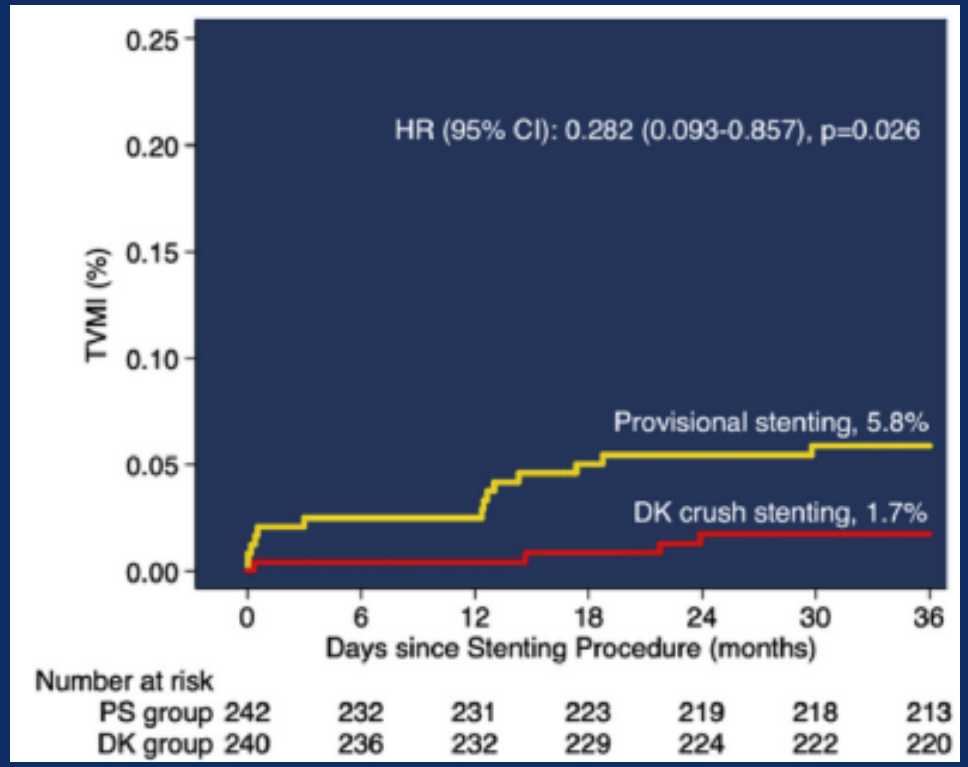


Chen et al, JACC: Cardiovascular Interventions. 2019 Oct 14;12(19):1927-1937.

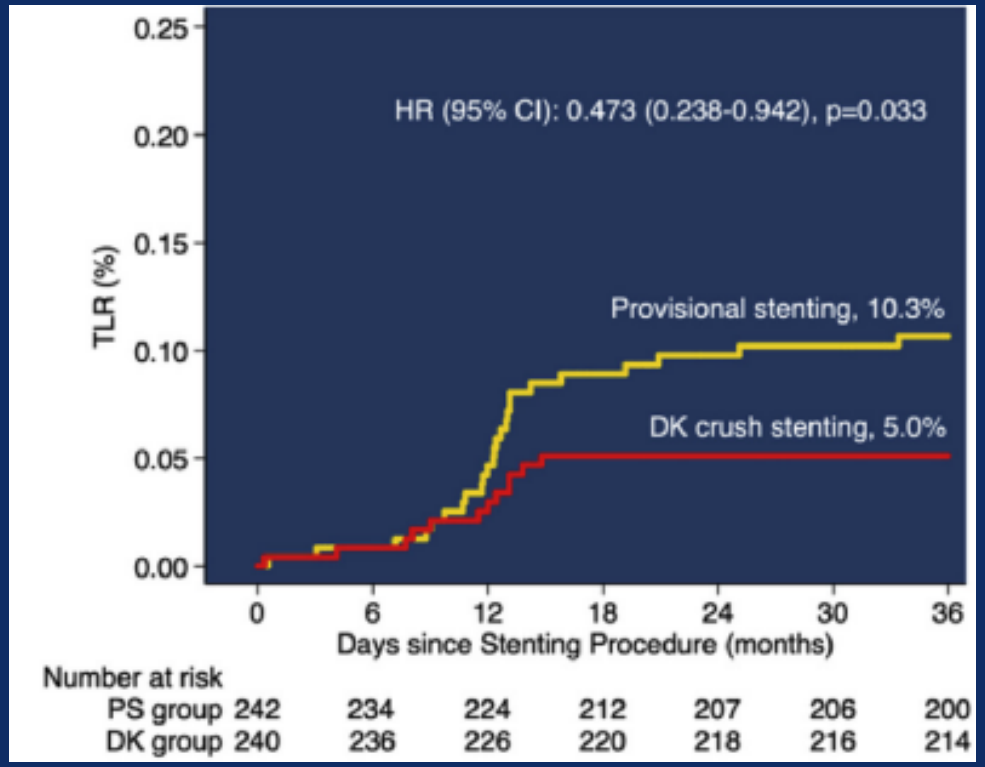
DKCRUSH-V

; Double kissing crush *vs.* Provisional stenting in unprotected LM bifurcation lesions

C) Target Vessel MI



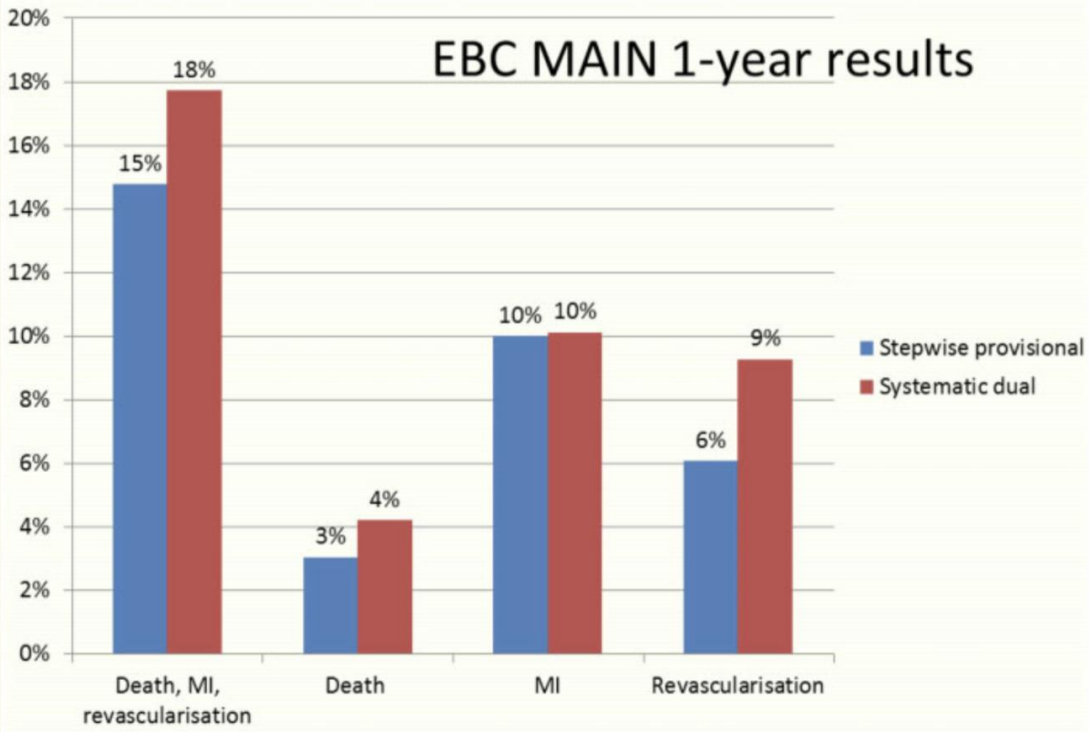
D) Target Lesion Revascularization



Chen et al, JACC: Cardiovascular Interventions. 2019 Oct 14;12(19):1927-1937.

EBC MAIN

; Provisional stenting *vs.* systemic 2-stent in unprotected LM bifurcation lesions



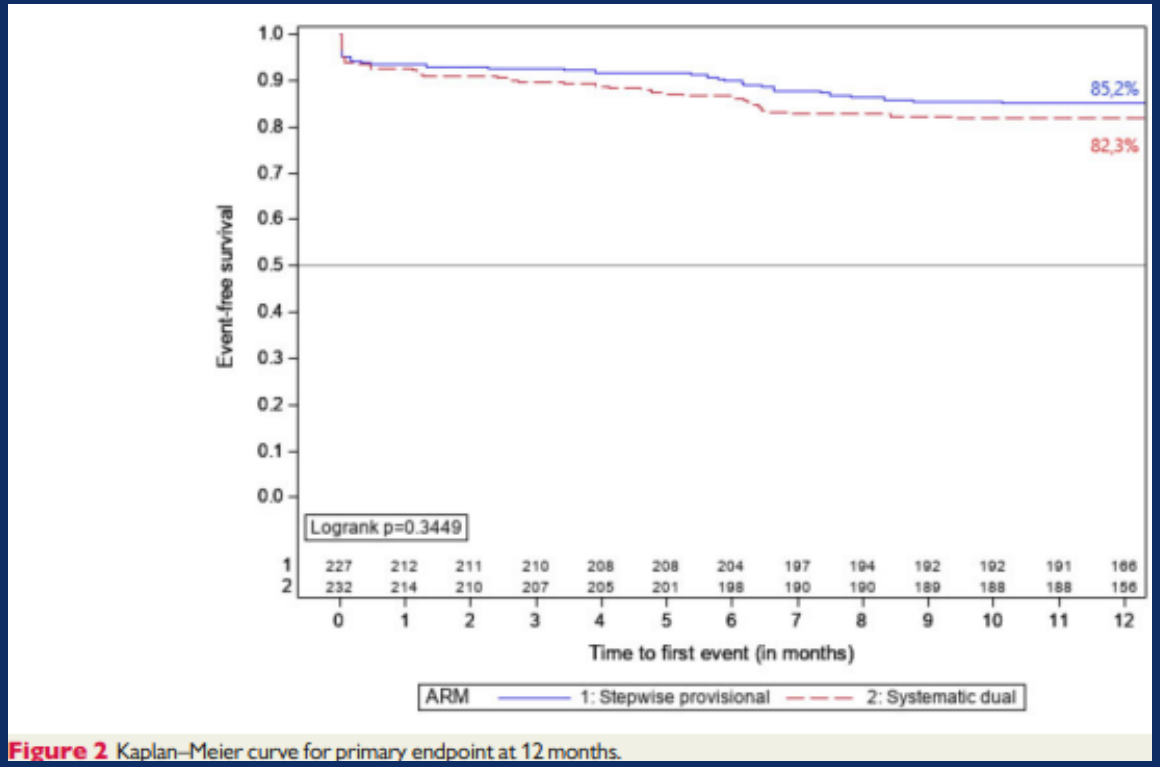


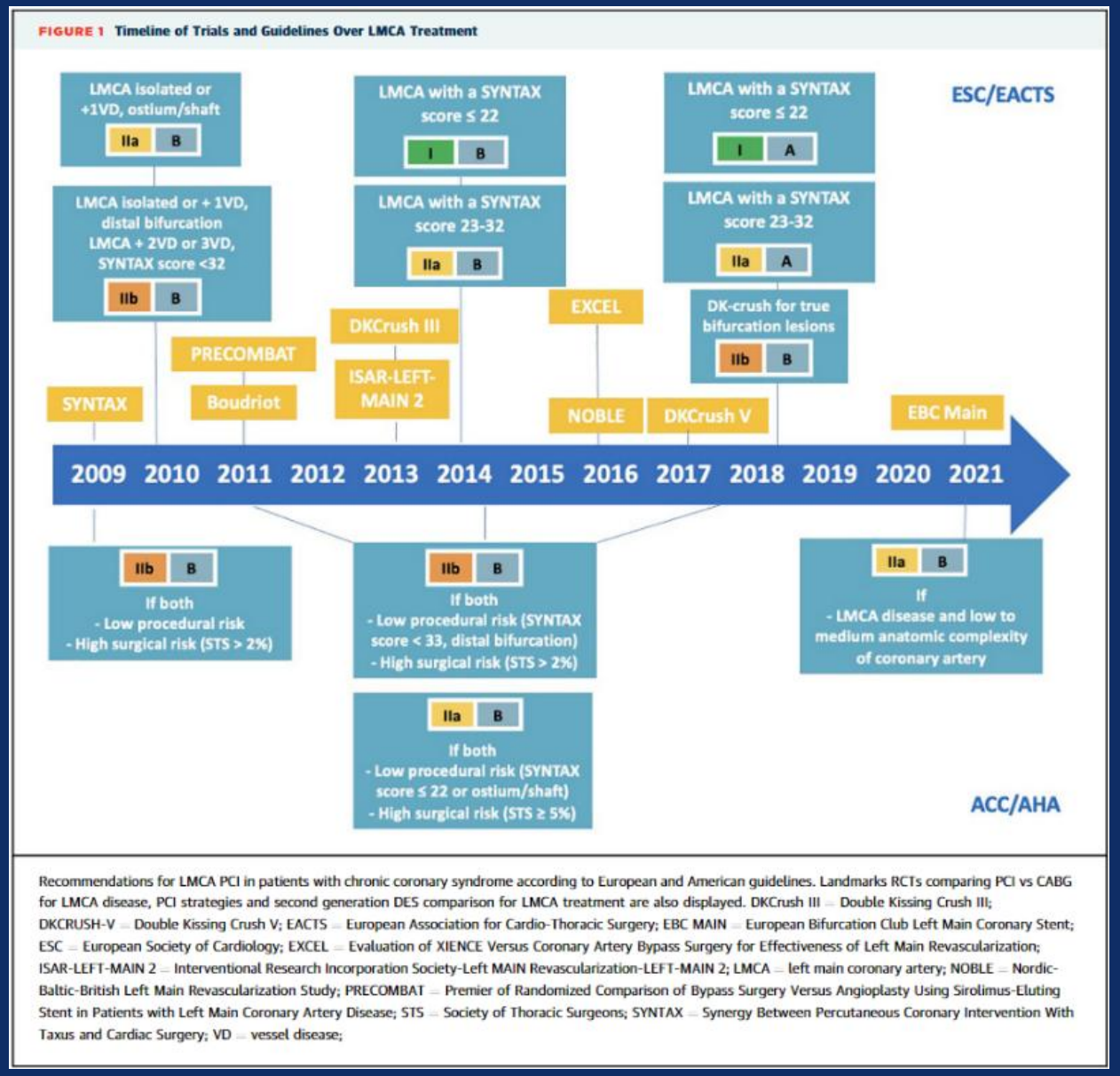
Figure 2 Kaplan–Meier curve for primary endpoint at 12 months.

CVRF

David Hildick-Smith et al, Eur Heart J. 2021 Oct 1;42(37):3829-3839.

Provisional Strategy for Left Main Stem Bifurcation Disease

- A State-of-the-Art Review of Technique and Outcomes



Recommendations for LMCA PCI in patients with chronic coronary syndrome according to European and American guidelines. Landmarks RCTs comparing PCI vs CABG for LMCA disease, PCI strategies and second generation DES comparison for LMCA treatment are also displayed. DKCrush III = Double Kissing Crush III; DKCRUSH-V = Double Kissing Crush V; EACTS = European Association for Cardio-Thoracic Surgery; EBC MAIN = European Bifurcation Club Left Main Coronary Stent; ESC = European Society of Cardiology; EXCEL = Evaluation of XIENCE Versus Coronary Artery Bypass Surgery for Effectiveness of Left Main Revascularization; ISAR-LEFT-MAIN 2 = Interventional Research Incorporation Society-Left MAIN Revascularization-LEFT-MAIN 2; LMCA = left main coronary artery; NOBLE = Nordic-Baltic-British Left Main Revascularization Study; PRECOMBAT = Premier of Randomized Comparison of Bypass Surgery Versus Angioplasty Using Sirolimus-Eluting Stent in Patients with Left Main Coronary Artery Disease; STS = Society of Thoracic Surgeons; SYNTAX = Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery; VD = vessel disease;

Paradies V, et al, JACC Cardiovasc Interv. 2023;16(7):743-758.

Provisional Strategy for Left Main Stem Bifurcation Disease

- A State-of-the-Art Review of Technique and Outcomes

TABLE 2 Overview of Different Definitions for Suboptimal LCx Result

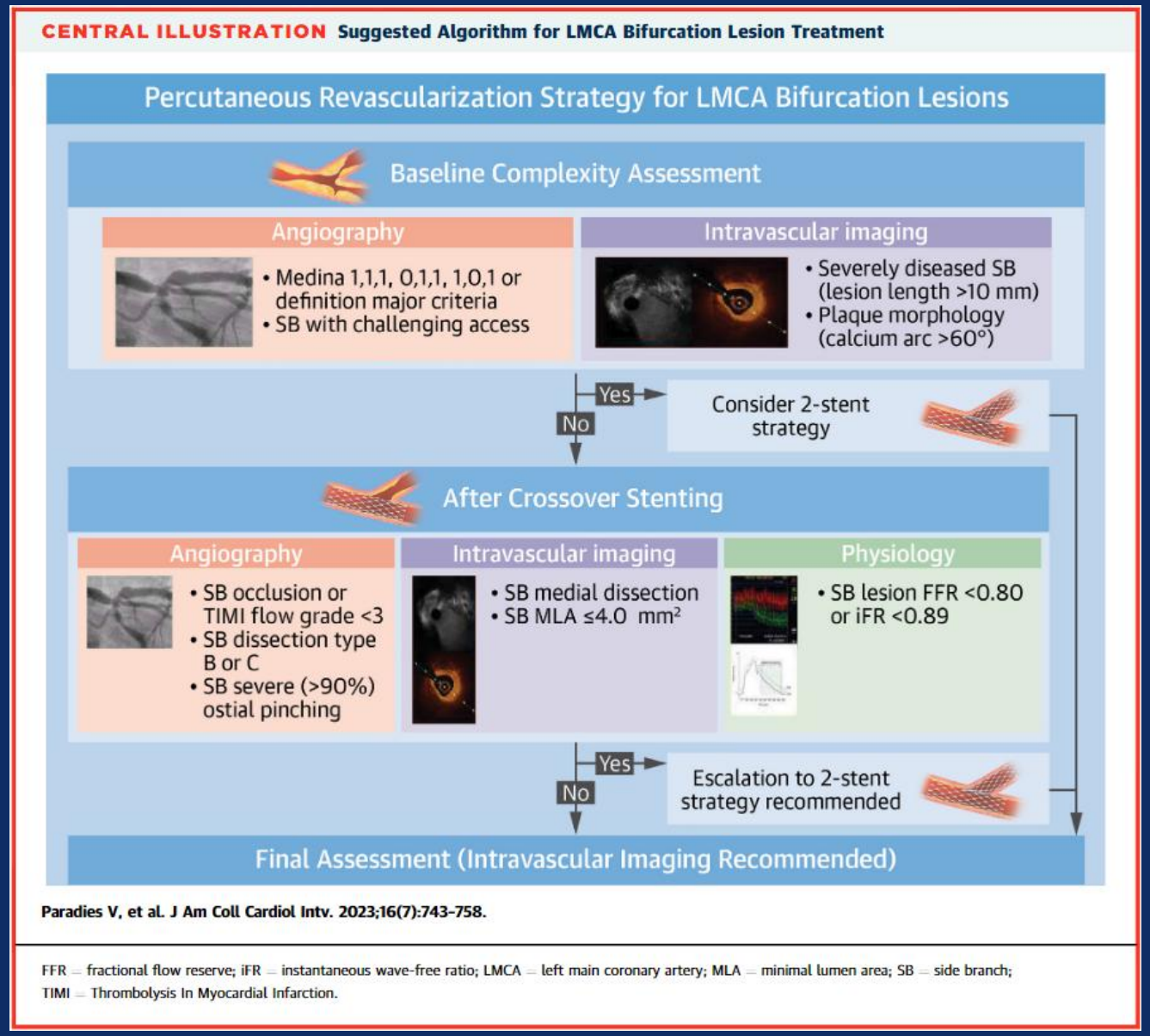
Study or First Author (Year)	Design	n	LM (%)	True Bifurcation Lesions (%)	Stenting Strategy	Suboptimal LCx Result Requiring Any Further Intervention (%)	Modality of Assessment	Definitions of Suboptimal LCx Results
SMART-STRATEGY (2016)[24]	RCT	258	44.0	66.0	Provisional + bailout TAP Conservative vs aggressive	47.0 (whole cohort)	Angiography	DS >75% (conservative strategy) DS >50% (aggressive strategy)
DKCRUSH-V (2017)[5]	RCT	482	100	100	Provisional vs DK crush	47.0 (provisional group)	Angiography	TIMI flow grade <3 or DS >75% or dissection type >B
EXCEL subanalysis (2018)[18]	Subanalysis of RCT	529	100	34.3 (PCI group)	Provisional + bailout 2 stents (65.0) vs elective 2 stents (35.0)	22.0 (provisional group)	Angiography Intravascular ultrasound Fractional flow reserve	Dissection ≥grade B or TIMI <3 or DS >70% angiographic MLA ≤4.0 mm^2 with PB >60% ≤0.80
DEFINITION II (2020)[4]	RCT	653	29.0	100	Provisional vs 2 stents	28.0 (provisional group)	Angiography	SB occlusion or type B/C dissection or TIMI flow grade <3
EBC MAIN (2021)[25]	RCT	467	100	100	Stepwise provisional vs elective 2 stents	22.0 (provisional group)	Angiography	TIMI flow grade <3 or severe (>90%) ostial pinching or threatened SB closure or dissection type >A
Burzotta et al (2012)[27]	Prospective observational study	150	15.0	43.0	Provisional MB stenting + bailout TAP technique	18.0 (whole cohort)	3D quantitative coronary analysis	SB lumen area <50% of SB reference area
FAILS-2 substudy (2017)[28]	Retrospective observational study	377	100	100	Provisional vs elective 2 stents	9.7 (provisional)	Angiography	Major dissections or compromised flow
Lee et al (2019)[30]	Retrospective study	83	100	0	Provisional MB stenting	16.8	Fractional flow reserve	≤0.80

3D = 3-dimensional; LCx = left circumflex artery; MB = main branch; MLA = minimal lumen area; PB = plaque burden; TIMI = Thrombolysis In Myocardial Infarction; other abbreviations as in Table 1.

Paradies V, et al, JACC Cardiovasc Interv. 2023;16(7):743-758.

Provisional Strategy for Left Main Stem Bifurcation Disease

- A State-of-the-Art Review of Technique and Outcomes



Paradies V, et al, JACC Cardiovasc Interv. 2023;16(7):743-758.

The 17th expert consensus document of the European Bifurcation Club

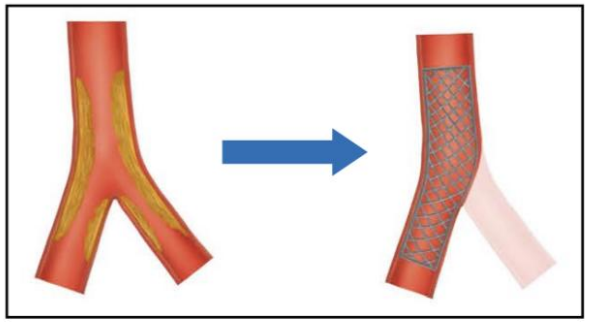
CENTRAL **ILLUSTRATION** Preserving SB access during provisional stenting.

Prevention

Conventional

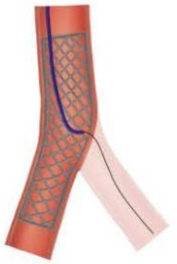
- Preshaped wires
- Reverse wire technique
- Dual lumen microcatheter
- Angulated microcatheter
- Deflectable microcatheter

Jailed wire



Troubleshooting

Preshaped wires
CTO wires



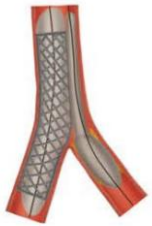
Angulated microcatheter

Active protection

Jailed balloon

Balloon-stent kissing

Modified



Semi-inflated

Jailed *Corsair*

Risk factors:

- Plaque on the same side of the SB
- Reduced TIMI flow at the SB
- Severe % DS of bifurcation core ≥70%
- Unfavourable bifurcation angle ≥90°
- High ratio MV/SB ≥2
- Severe % DS at SB ≥90%
- Spiky carina
- RESOLVE score >10

Deflectable microcatheter

Rescue jailed balloon

CTO: chronic total occlusion; DS: diameter stenosis; MV: main vessel; RESOLVE: Risk prEdiction of Side branch OccLusion in coronary bifurcation intervention; SB: side branch; TIMI: Thrombolysis in Myocardial Infarction

Intravascular imaging in bifurcation PCI

Intravascular imaging in bifurcation PCI

Long-term outcomes of intravascular ultrasound-guided stenting in coronary bifurcation lesions.

Am J Cardiol. 2010;106:612-8.

- Patients receiving DESs, IVUS-guided stenting for treatment of bifurcation lesions significantly reduced the 4-year mortality compared to conventional angiographically guided stenting.
- In addition, IVUS guidance reduced the development of very late stent thrombosis in patients receiving DES

Impact of intravascular ultrasound guidance on long-term clinical outcomes in patients treated with drug-eluting stent for bifurcation lesions: data from a Korean multicenter bifurcation registry

Am Heart J. 2011;161:180-7.

- Periprocedural creatine kinase-MB elevation (>3 times of upper normal limits) was frequently observed in the angiography-guided group.
- The incidence of death or myocardial infarction was significantly lower in the IVUS-guided group compared to the angiography-guided group (3.8% vs 7.8%, log rank test P = .03, hazard ratio 0.44, 95% CI 0.12-0.96, Cox model P = .04).

OCTOBER
; Imaging-guided PCI vs. Angiography-guided PCI in complex bifurcation lesions

Primary endpoint (A composite of death from a cardiac causes, target-lesion MI, ischemia-driven target-lesion revascularization)

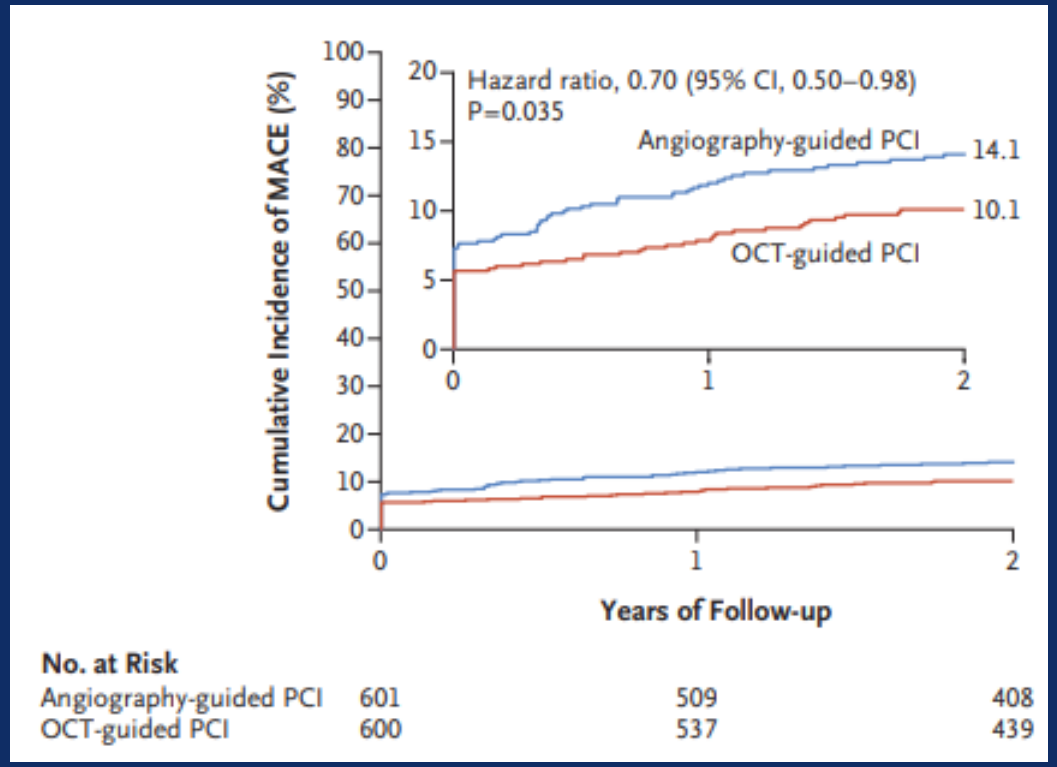


Table 3. Primary and Secondary End Points.*

End Point	Total (N=1201)	OCT-Guided PCI (N=600)	Angiography-Guided PCI (N=601)	Hazard Ratio (95% CI)
	events	*events (estimated percentage)*		
Primary end point: MACE†	142	59 (10.1)	83 (14.1)	0.70 (0.50–0.98)
Clinical secondary end points				
Patient-oriented composite end point‡	182	79 (13.6)	103 (17.7)	0.76 (0.56–1.01)
Death from any cause	36	13 (2.4)	23 (4.0)	0.56 (0.28–1.10)
Death from a cardiac cause	23	8 (1.4)	15 (2.6)	0.53 (0.22–1.25)
Target-lesion myocardial infarction	97	46 (7.8)	51 (8.5)	0.90 (0.60–1.34)
Ischemia-driven target-lesion revascularization§	42	16 (2.8)	26 (4.6)	0.61 (0.32–1.13)
Stent thrombosis	29	12 (2.1)	17 (3.0)	0.70 (0.34–1.47)
Definite	7	3 (0.5)	4 (0.7)	0.75 (0.17–3.34)
Probable	3	2 (0.3)	1 (0.2)	1.99 (0.18–22.0)
Possible	19	7 (1.3)	12 (2.1)	0.58 (0.23–1.47)

Niels R Holm et al, N Engl J Med. 2023 Oct 19;389(16):1477-1487.

RENOVATE-COMPLEX
; Imaging-guided PCI vs. Angiography-guided PCI in complex coronary artery

Primary endpoint (A composite of death from a cardiac causes, target-vessel MI, clinically driven target-vessel revascularization)

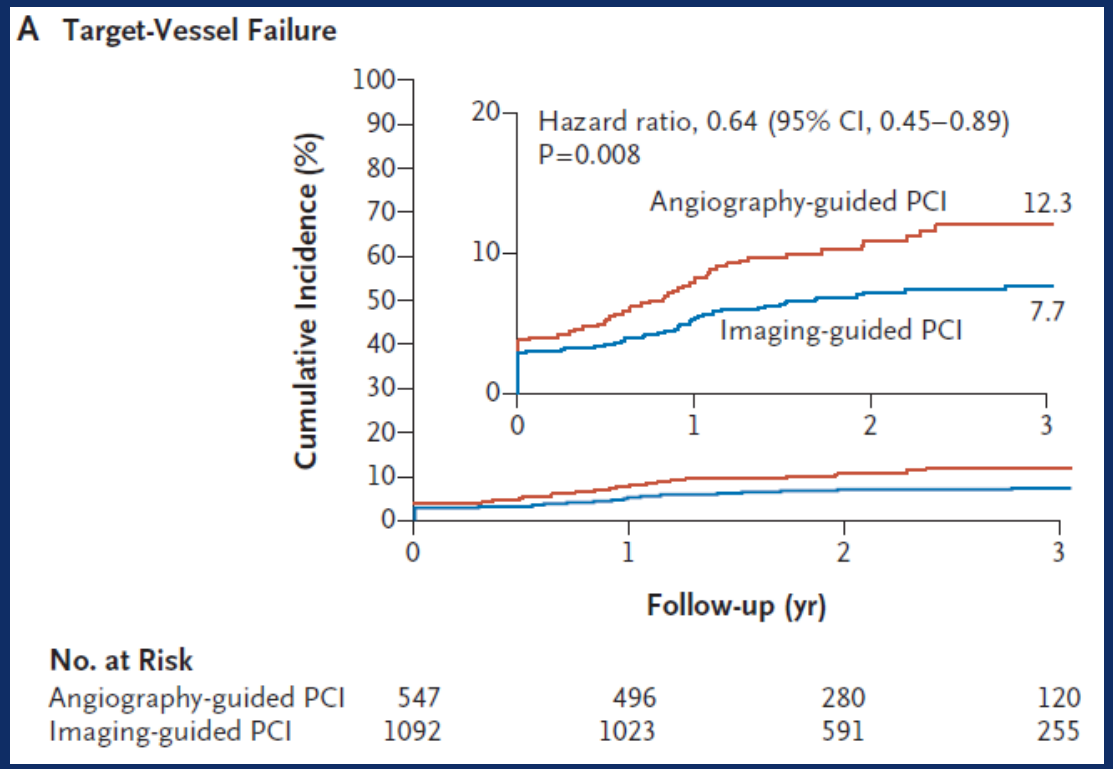


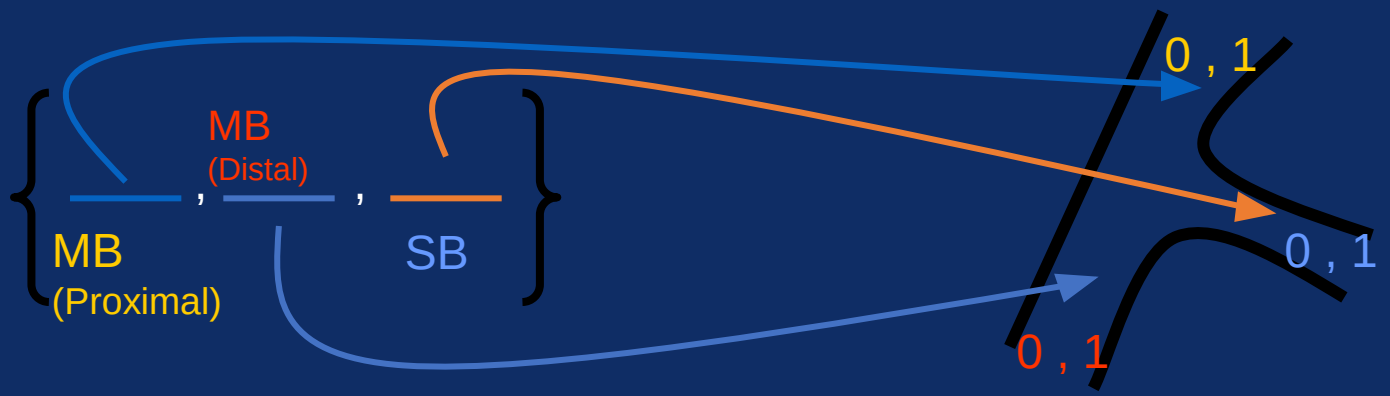
Table 2. Target-Lesion and Procedural Characteristics.*

Characteristic	Total (N=1639)	Intravacular Imaging–Guided PCI Group (N=1092)	Angiography-Guided PCI Group (N=547)
Target-lesion characteristics			
Complex coronary lesions — no. (%)†			
True bifurcation lesion	359 (21.9)	233 (21.3)	126 (23.0)
Chronic total occlusion	319 (19.5)	220 (20.1)	99 (18.1)
Unprotected left main coronary artery disease	192 (11.7)	138 (12.6)	54 (9.9)
Diffuse long coronary-artery lesion	898 (54.8)	617 (56.5)	281 (51.4)
Multivessel PCI involving ≥2 major coronary arteries	622 (37.9)	409 (37.5)	213 (38.9)
Lesion necessitating use of ≥3 stents	305 (18.6)	208 (19.0)	97 (17.7)
Lesion with in-stent restenosis	236 (14.4)	158 (14.5)	78 (14.3)
Severely calcified lesion	231 (14.1)	157 (14.4)	74 (13.5)
Ostial lesions of major coronary artery	251 (15.3)	182 (16.7)	69 (12.6)
≥3 Complex coronary lesions — no. (%)	505 (30.8)	352 (32.2)	153 (28.0)

J.M. Lee et al, N Engl J Med. 2023 May 4;388(18):1668-1679.

Bifurcation technique

Medina Classification



1,1,1

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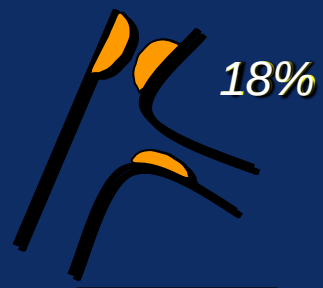
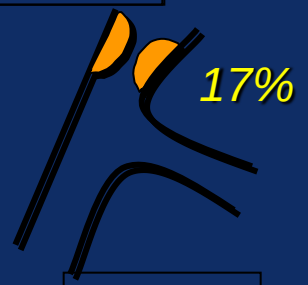


1,0,1

0,1,1



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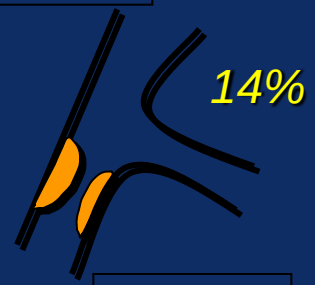
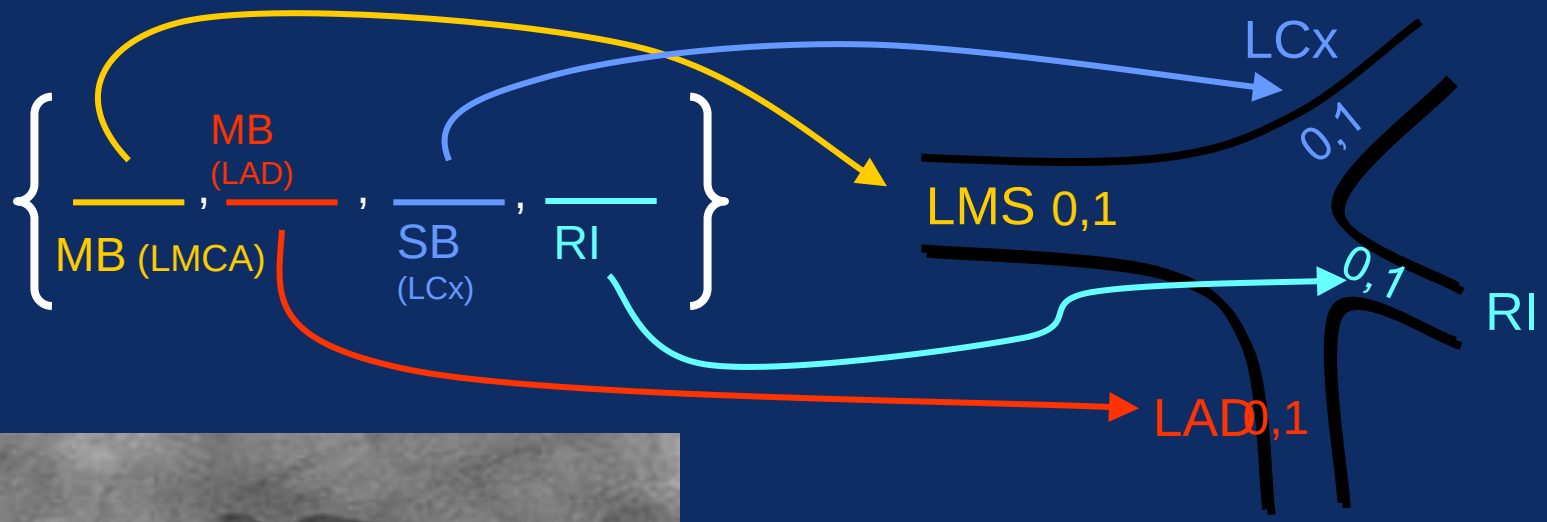
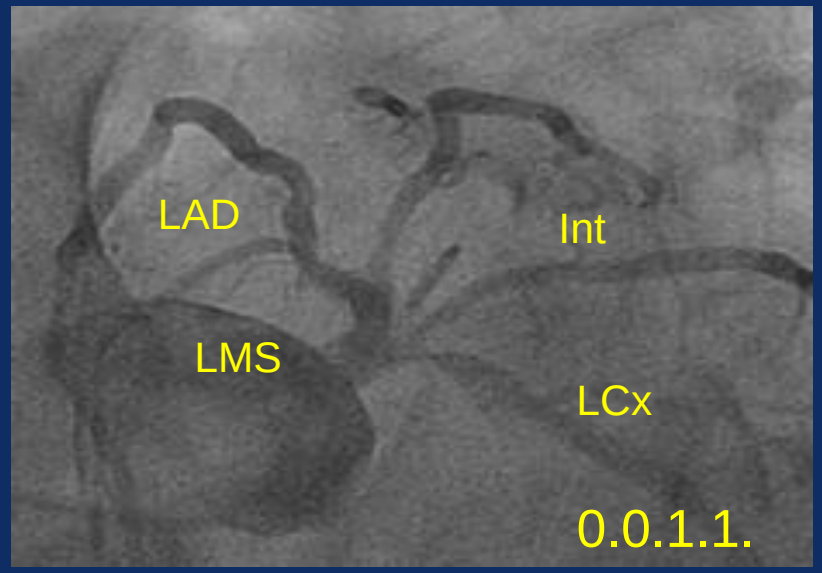


0,1,0

0,0,1

Trifurcation



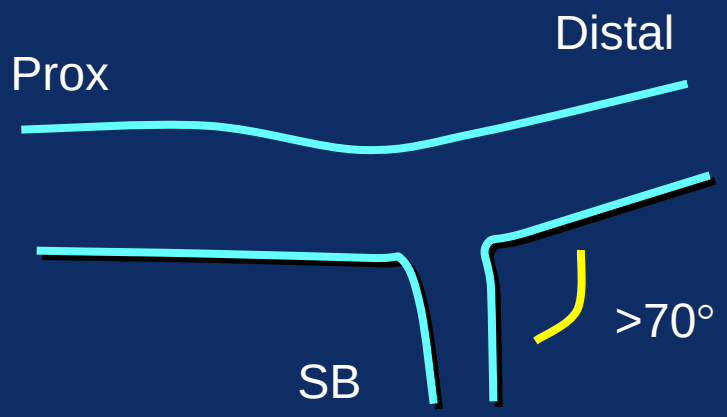


- **If, RI size > LCx**

  → LM, LAD, RI, LCx

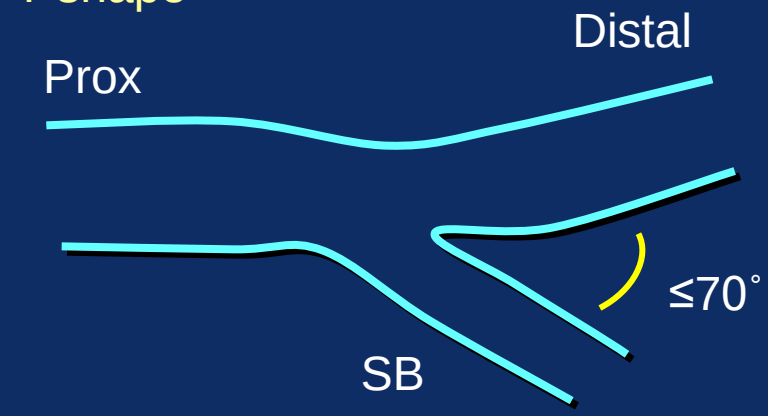
Angulation

T-shape



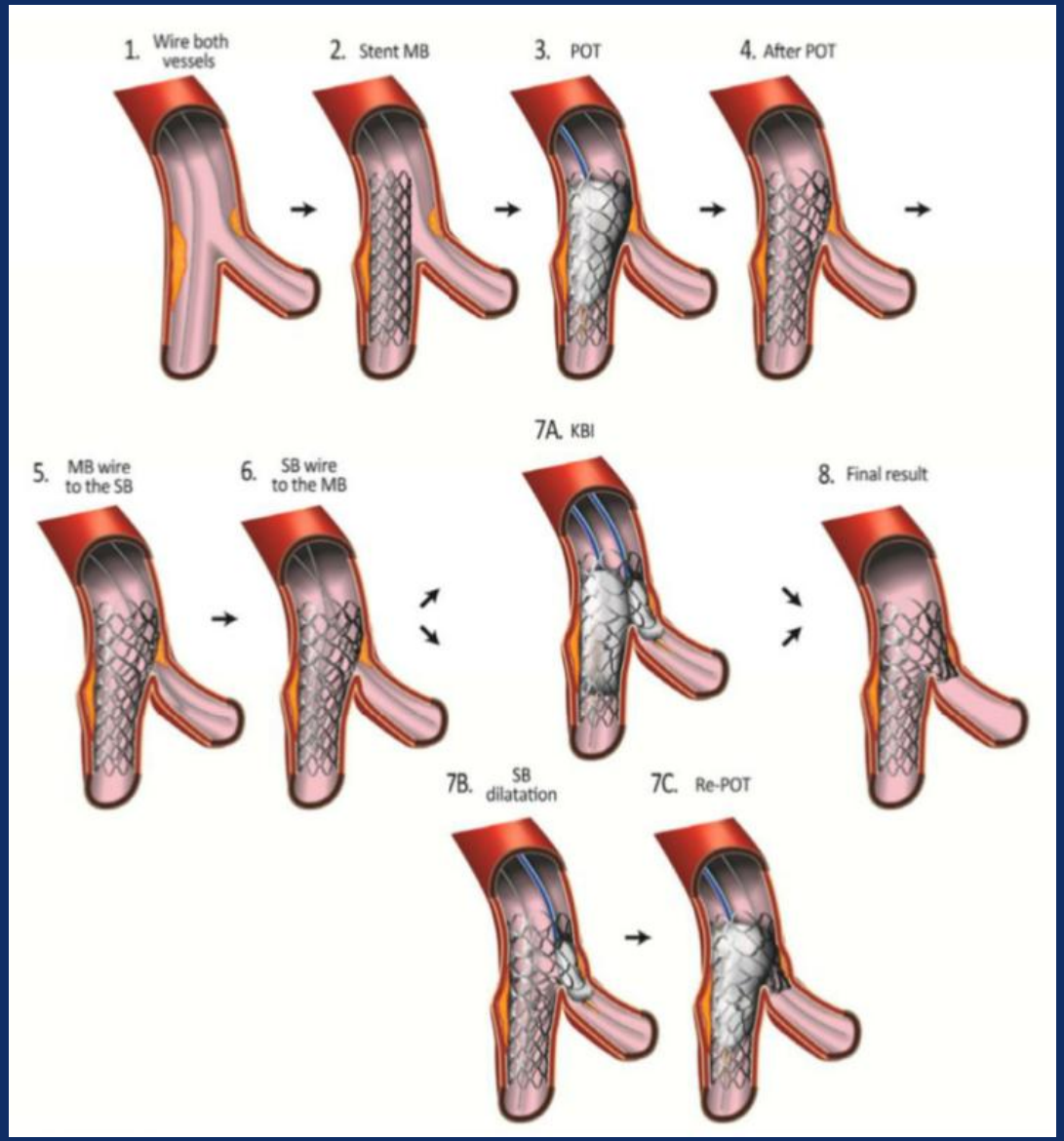
- **Difficult SB access**
- **Less plaque shifting**
- **T-stenting better**

Y-shape



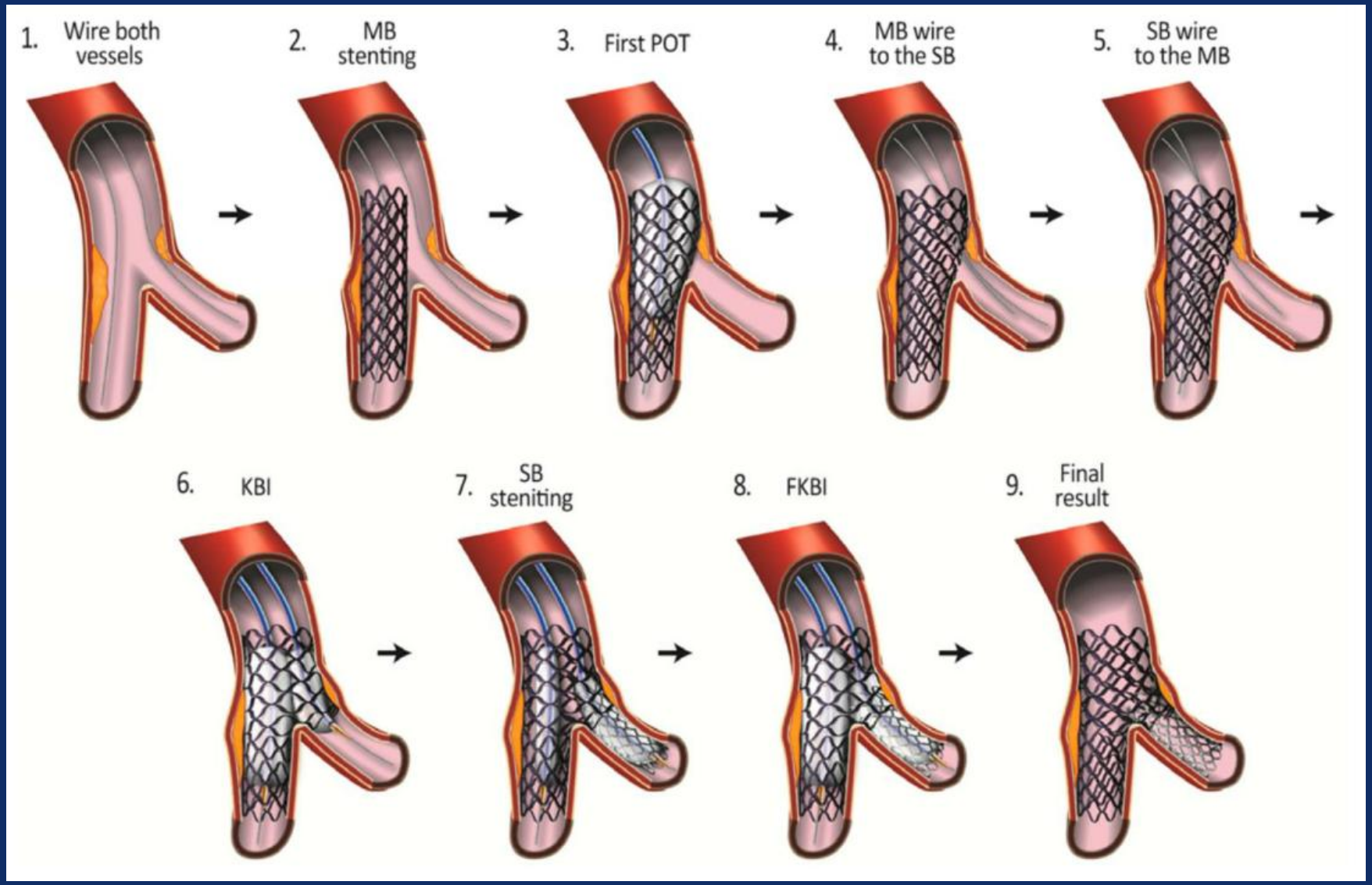
- **Easier SB access**
- **More plaque shifting**
- **Cullotte or Crush better**

Provisional stenting



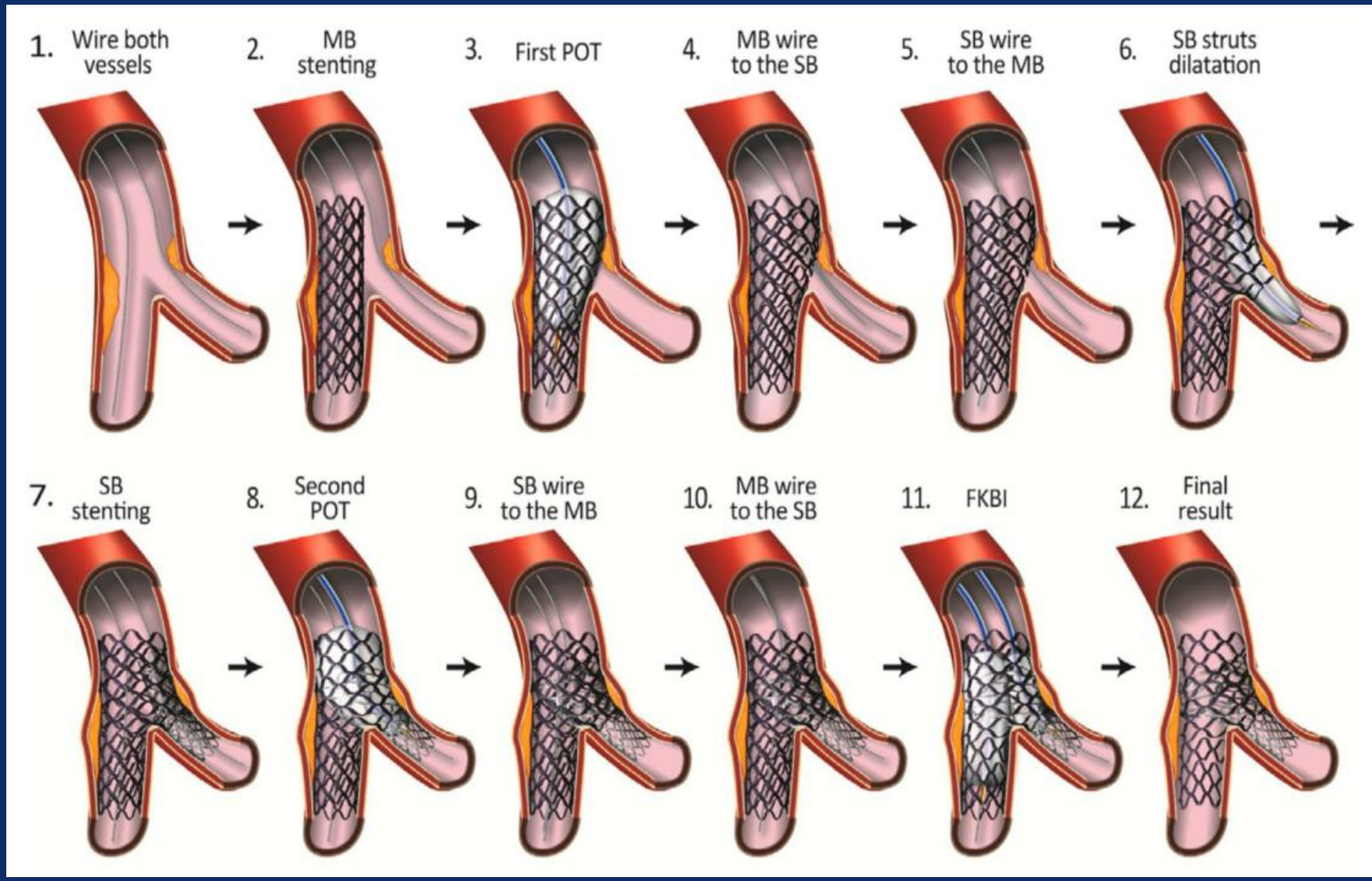
Carlos Collet et al, Expert Rev Cardiovasc Ther. 2018 Oct;16(10):725-734.

T stenting and T and protrusion (TAP)



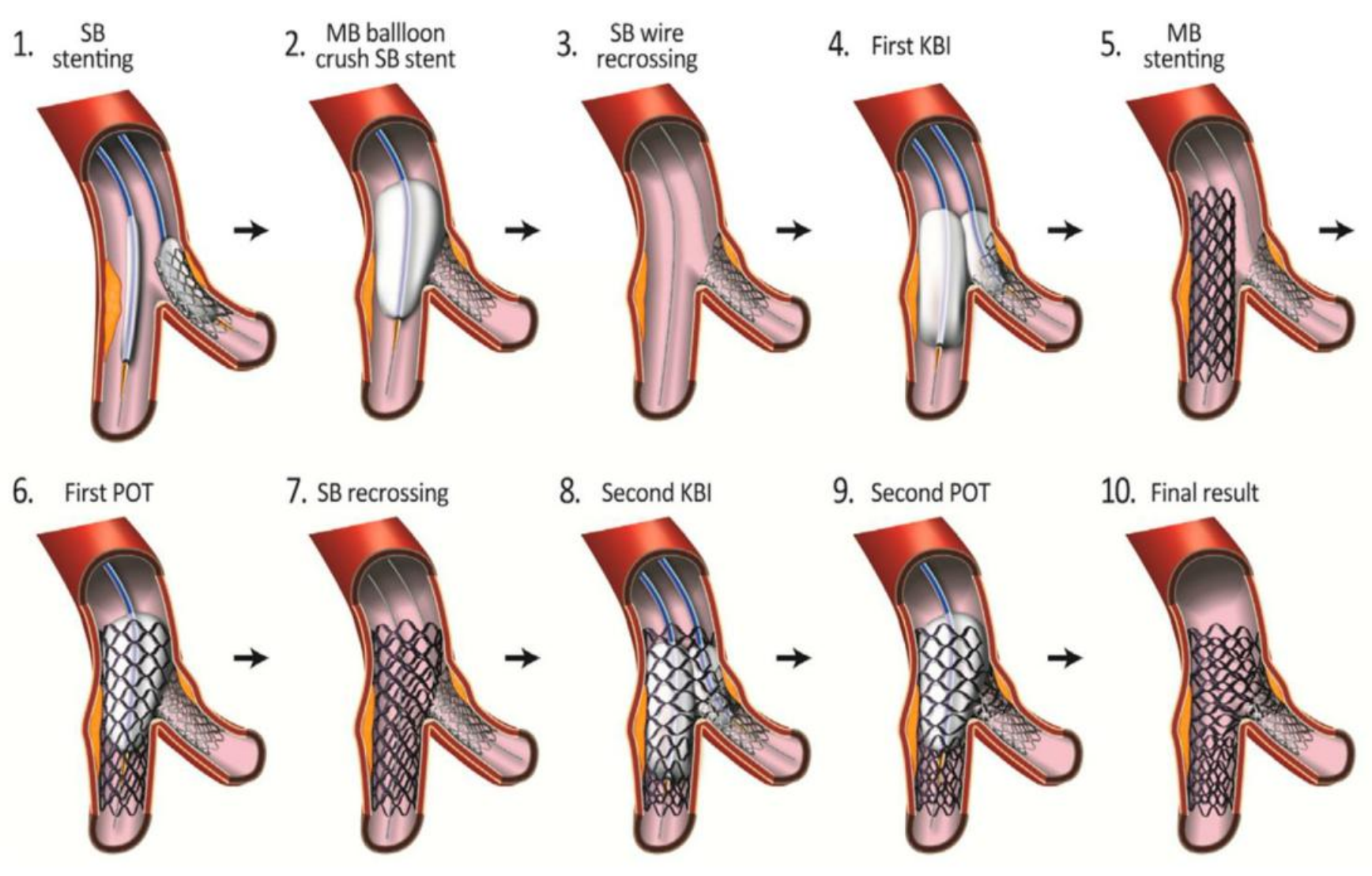
Carlos Collet et al, Expert Rev Cardiovasc Ther. 2018 Oct;16(10):725-734.

Culotte



Carlos Collet et al, Expert Rev Cardiovasc Ther. 2018 Oct;16(10):725-734.

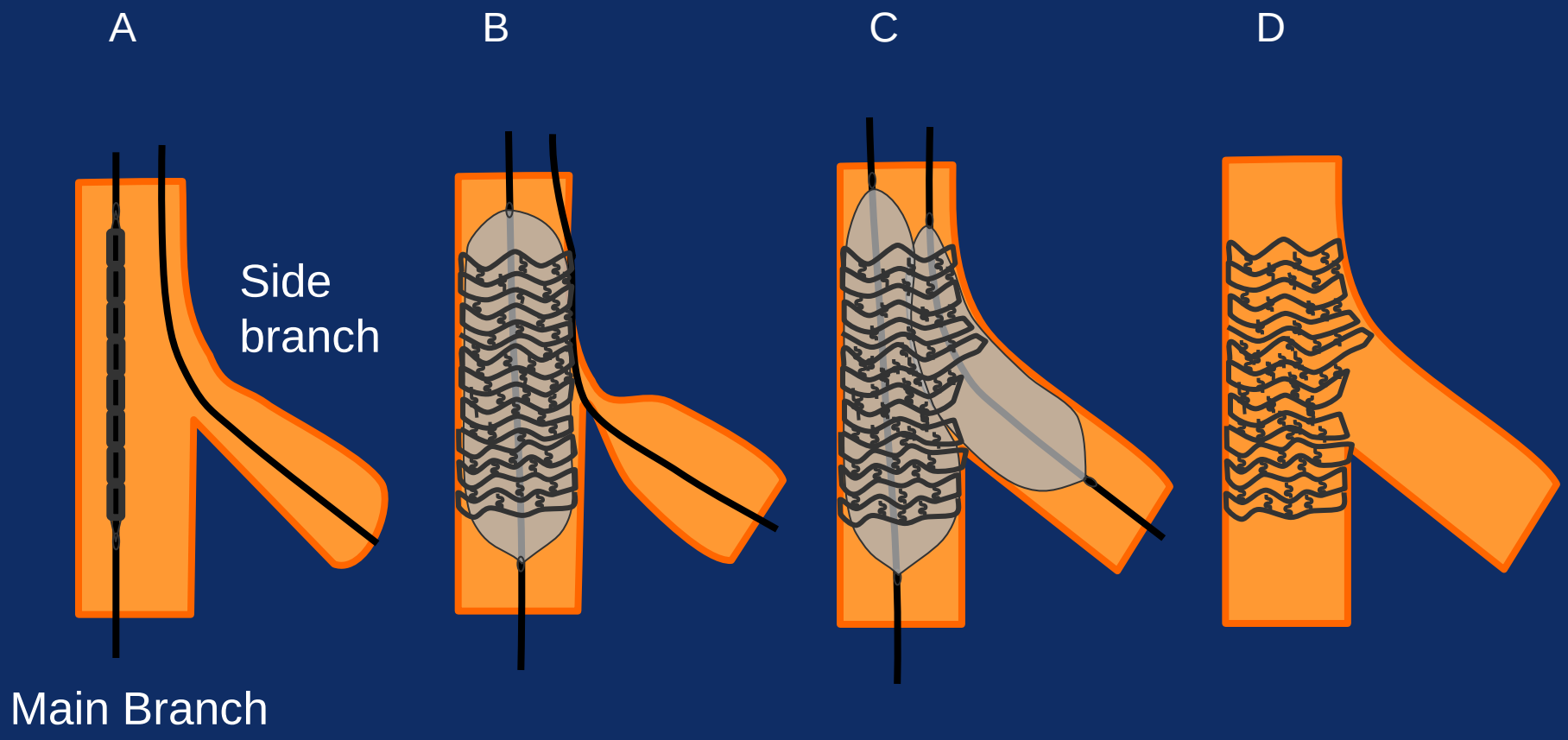
Double kissing Crush



Carlos Collet et al, Expert Rev Cardiovasc Ther. 2018 Oct;16(10):725-734.

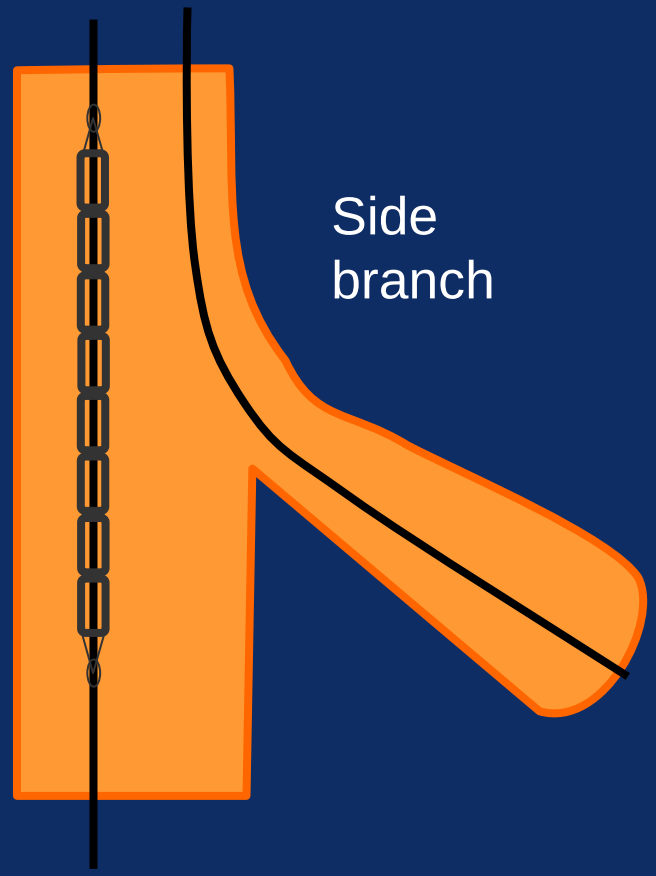
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

Normal or diminutive side branch ostium



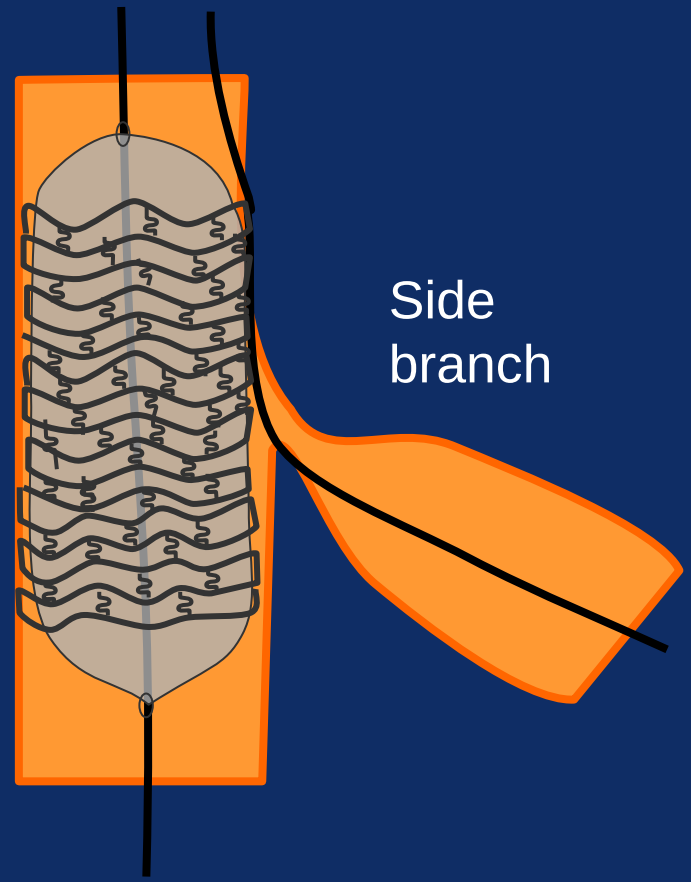
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

A. Wire both branches and predilate if needed



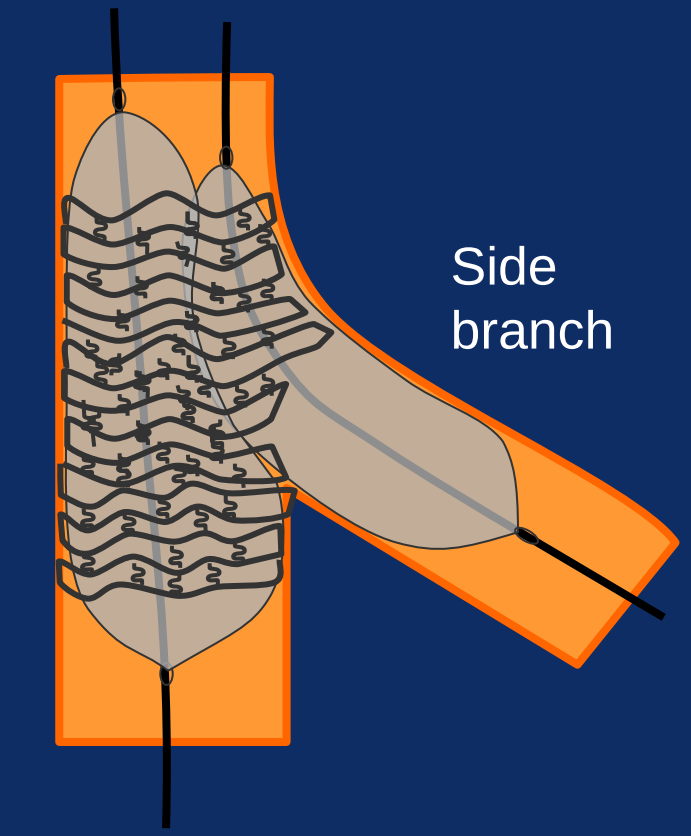
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

B. Stent the MB leaving a wire in the SB



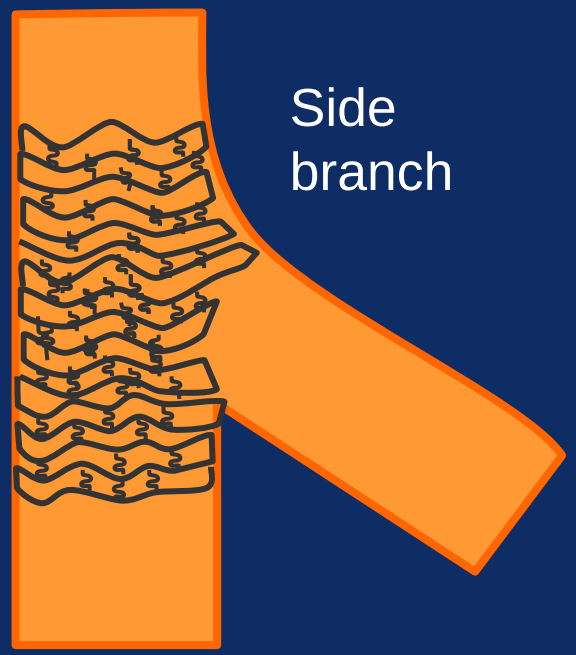
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

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



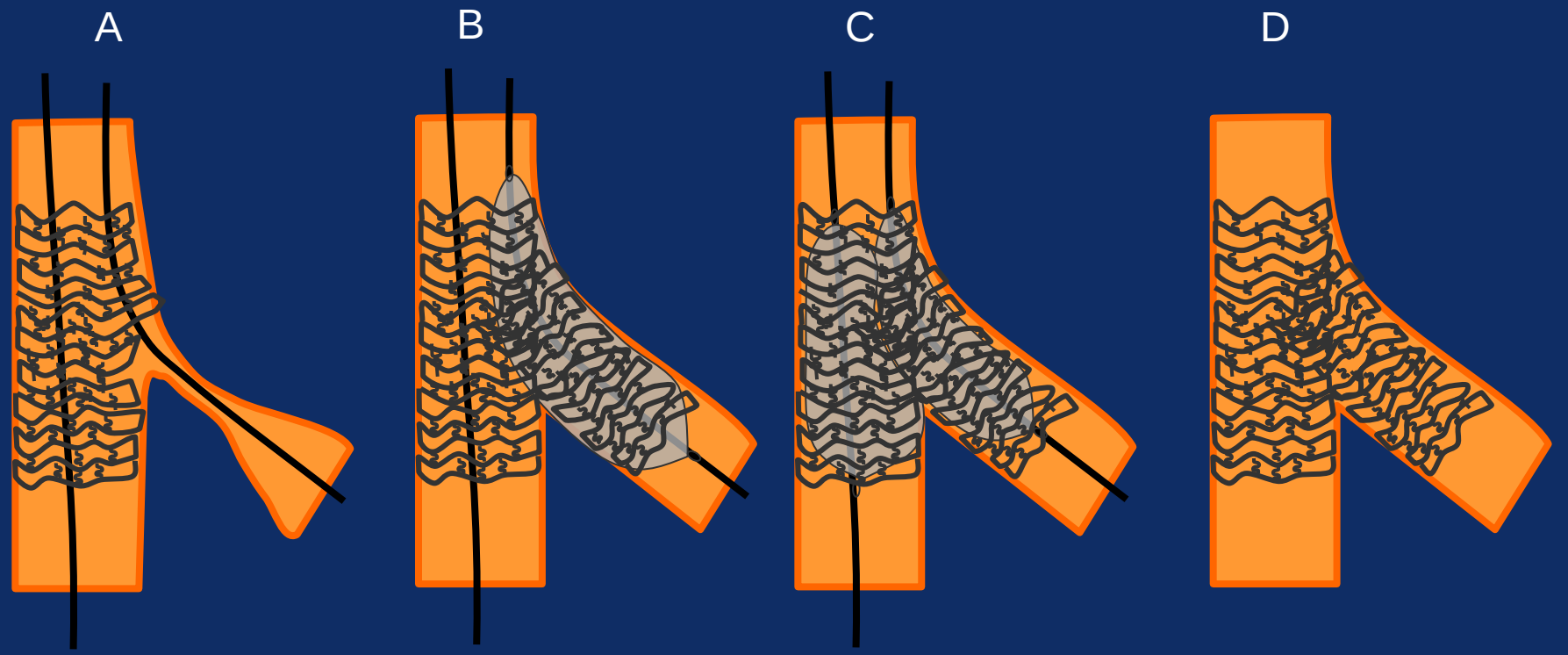
Stenting Crossing Side Branch With Optional Kissing Balloon Inflation

D. Final result



Provisional T Stenting

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



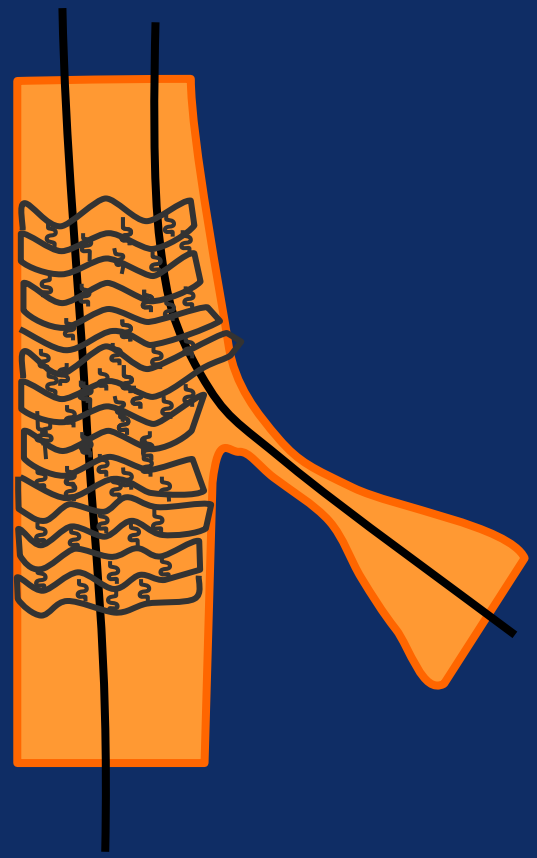
A	B	C	D
Jailed SB after MB stenting	SB stenting with minimal protrusion	Final kissing is necessary	Slightly protruded stent strut to MB

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

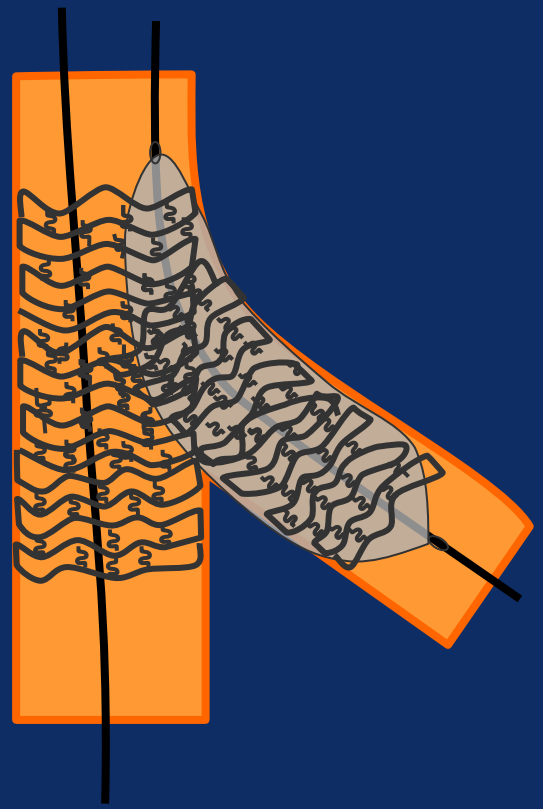
A. Jailed SB after MB stenting



Provisional T Stenting

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

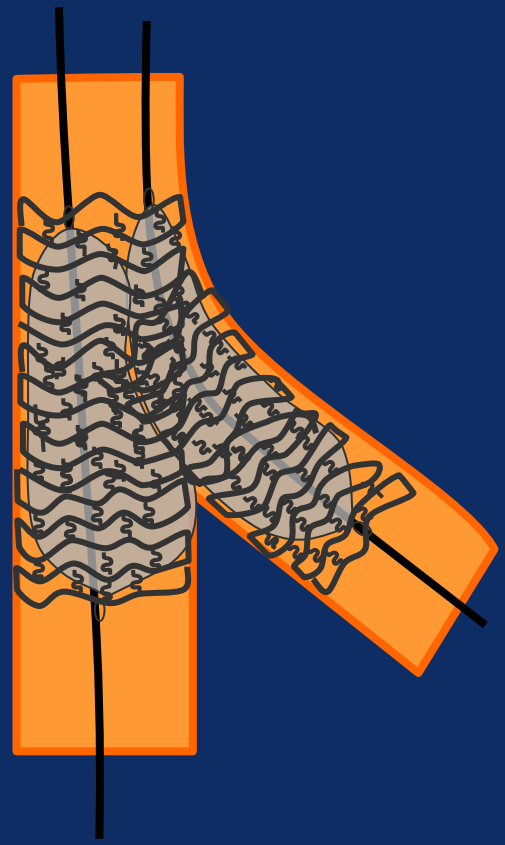
B. SB stenting with minimal protrusion



Provisional T Stenting

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

C. Final kissing is necessary



Provisional T Stenting

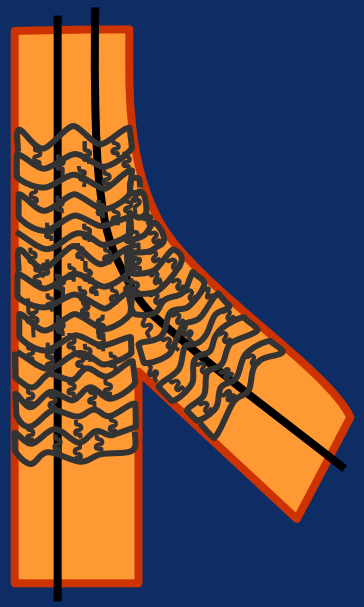
In cases with significant narrowing of side branch after main branch stenting

D. Slightly protruded stent strut to MB

“Internal” or “Reverse” Crush

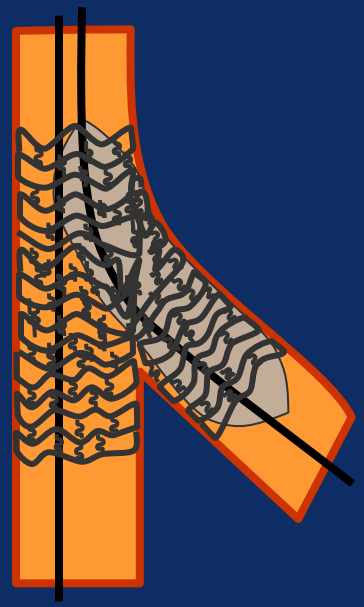
Final kissing balloon dilatation is mandatory

D



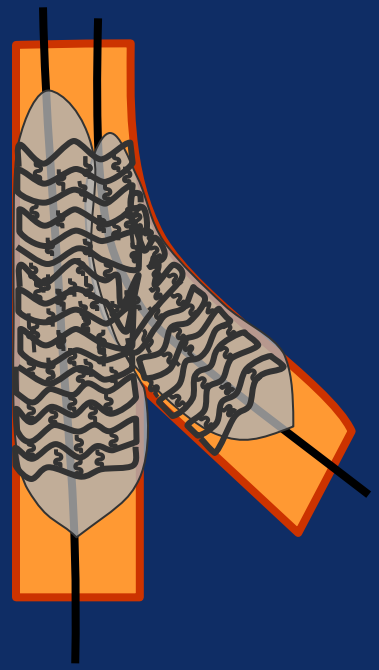
Re-advancement of wire into the side branch

E



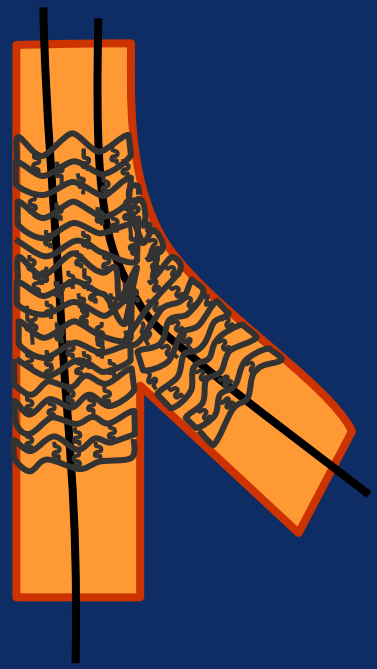
Opening of the side branch ostium

F



Final kissing balloon inflation

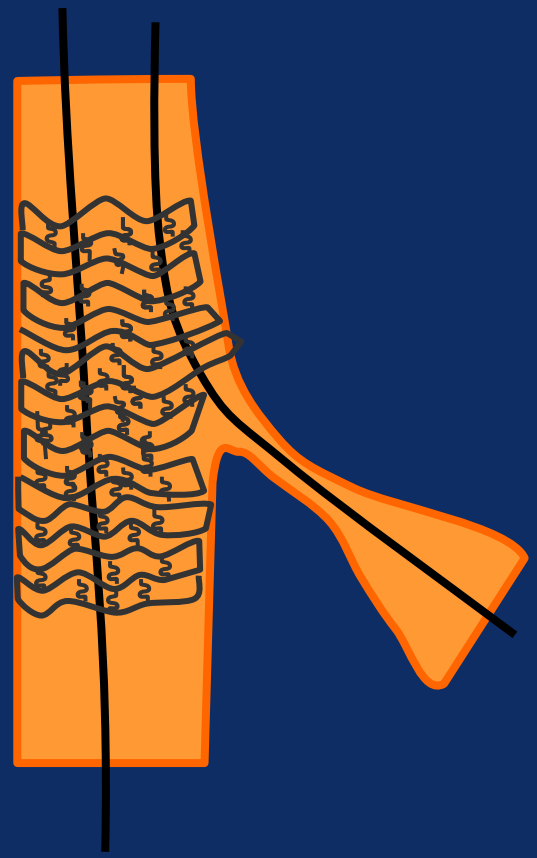
G



“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

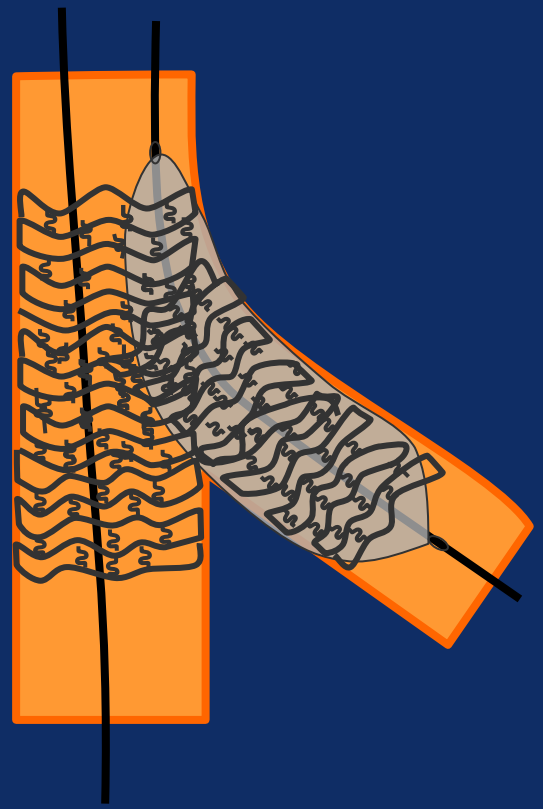
A. Jailed SB after MB stenting



“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

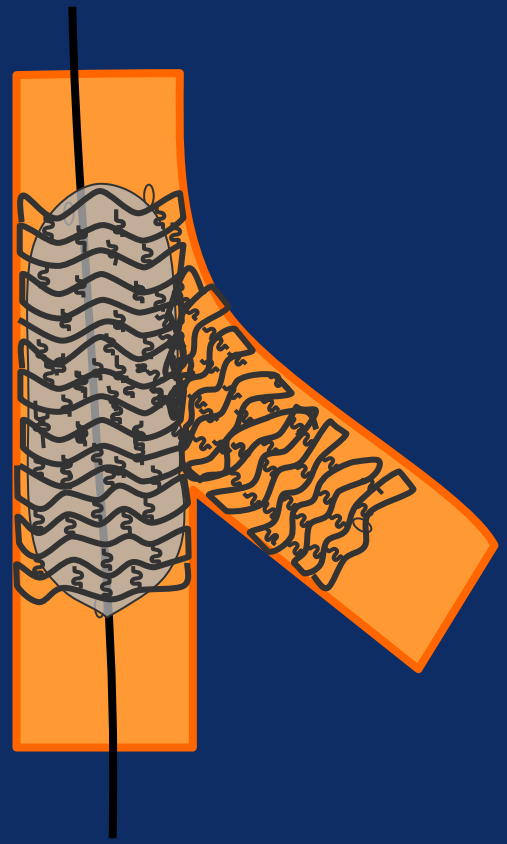
B. SB stenting with minimal protrusion



“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

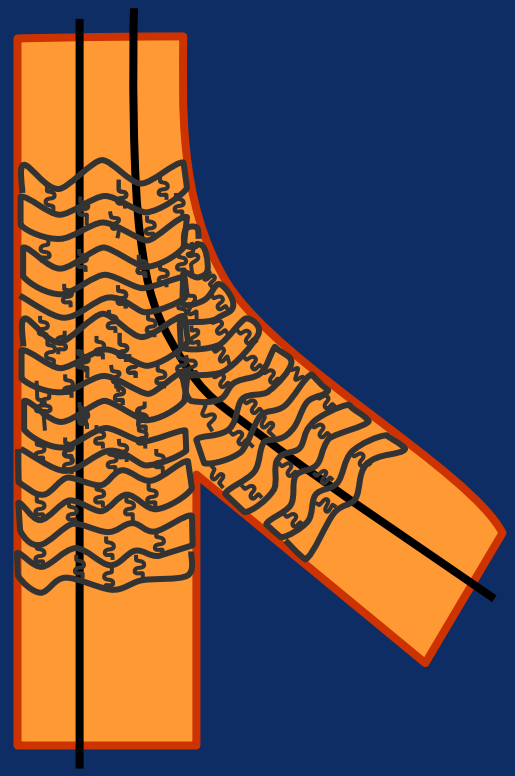
C. Remove SB balloon & wire,
and inflate MB at high pressure to crush SB stent



“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

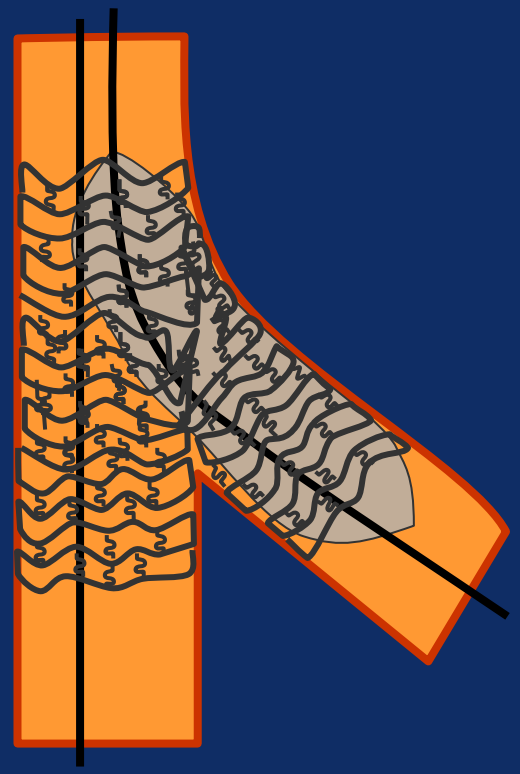
D. Re-advancement of wire into the side branch



“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

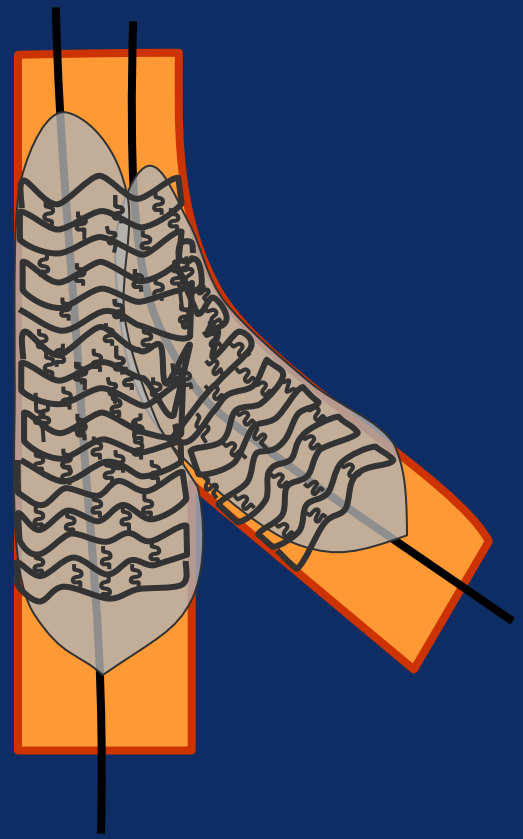
E. Opening of the side branch ostium



“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

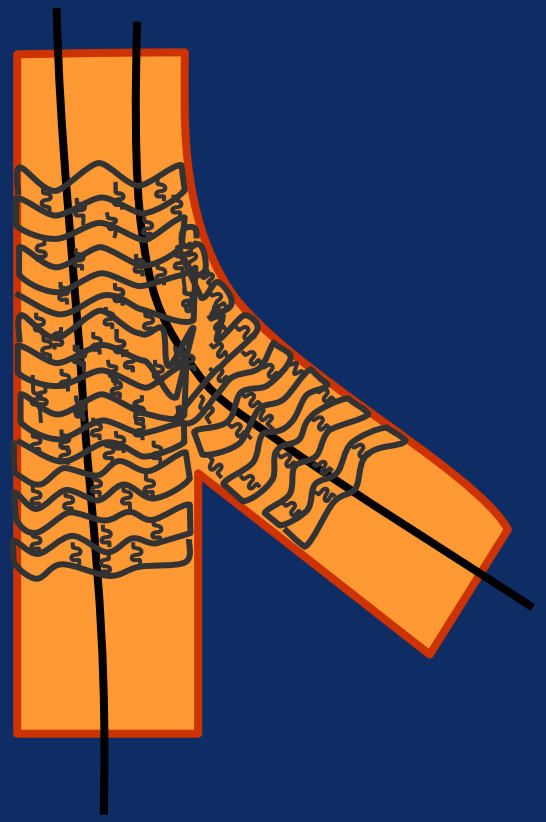
F. Final kissing balloon inflation



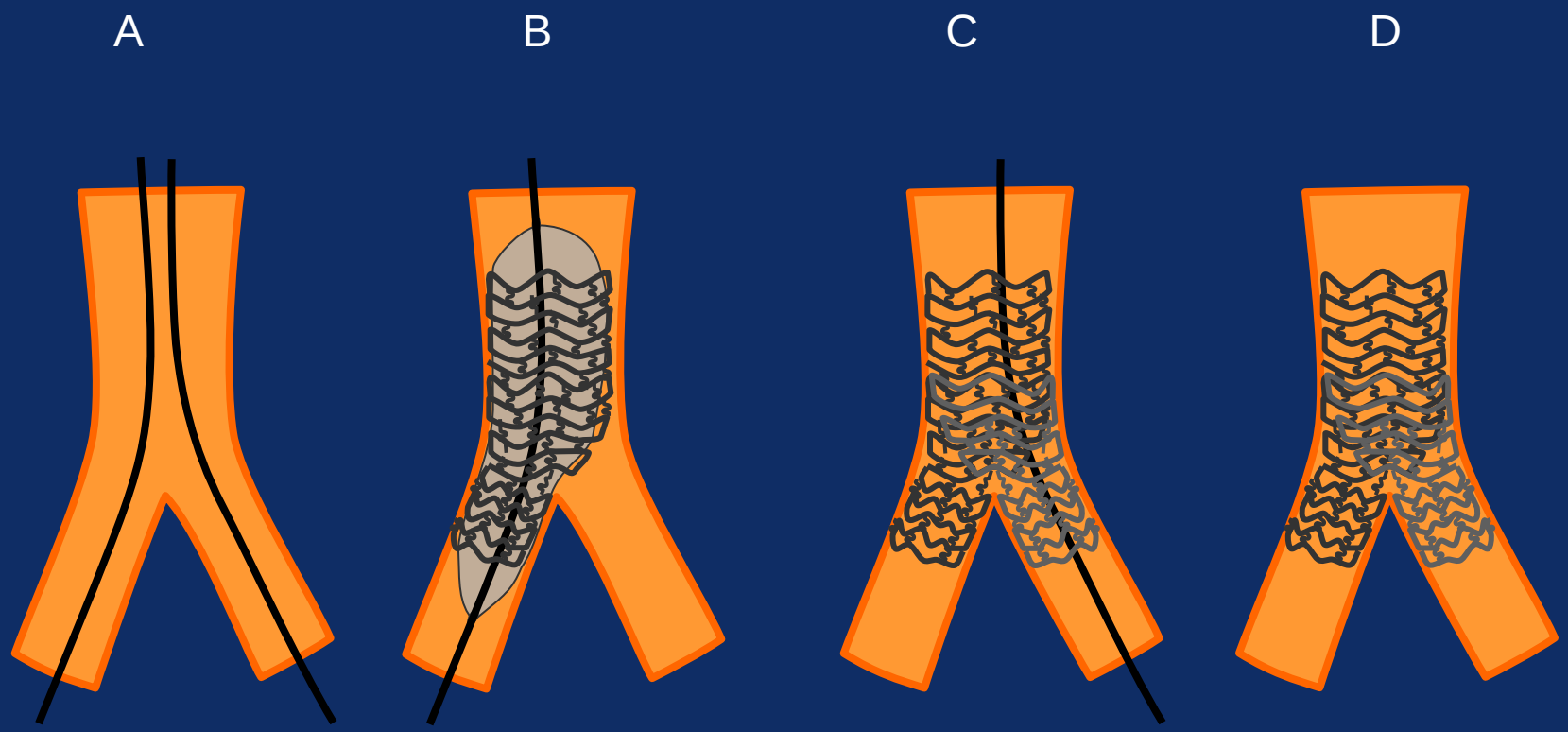
“Internal” or “Reverse” Crush

Final kissing balloon dilatation is mandatory

G. Final result



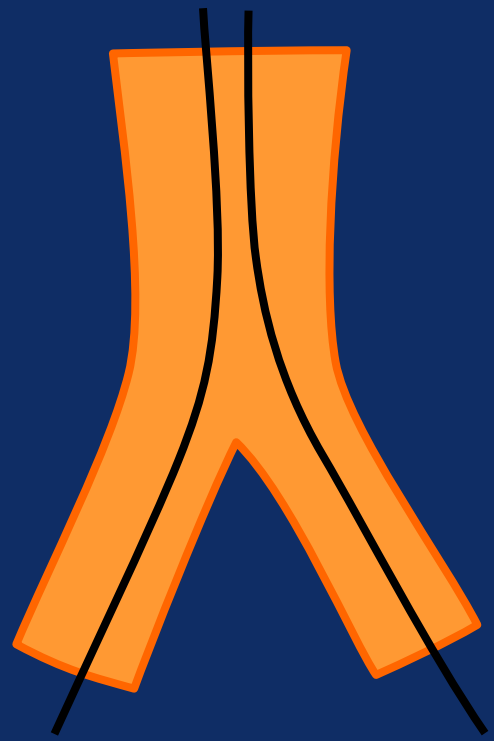
Y (Culotte) Stenting



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)

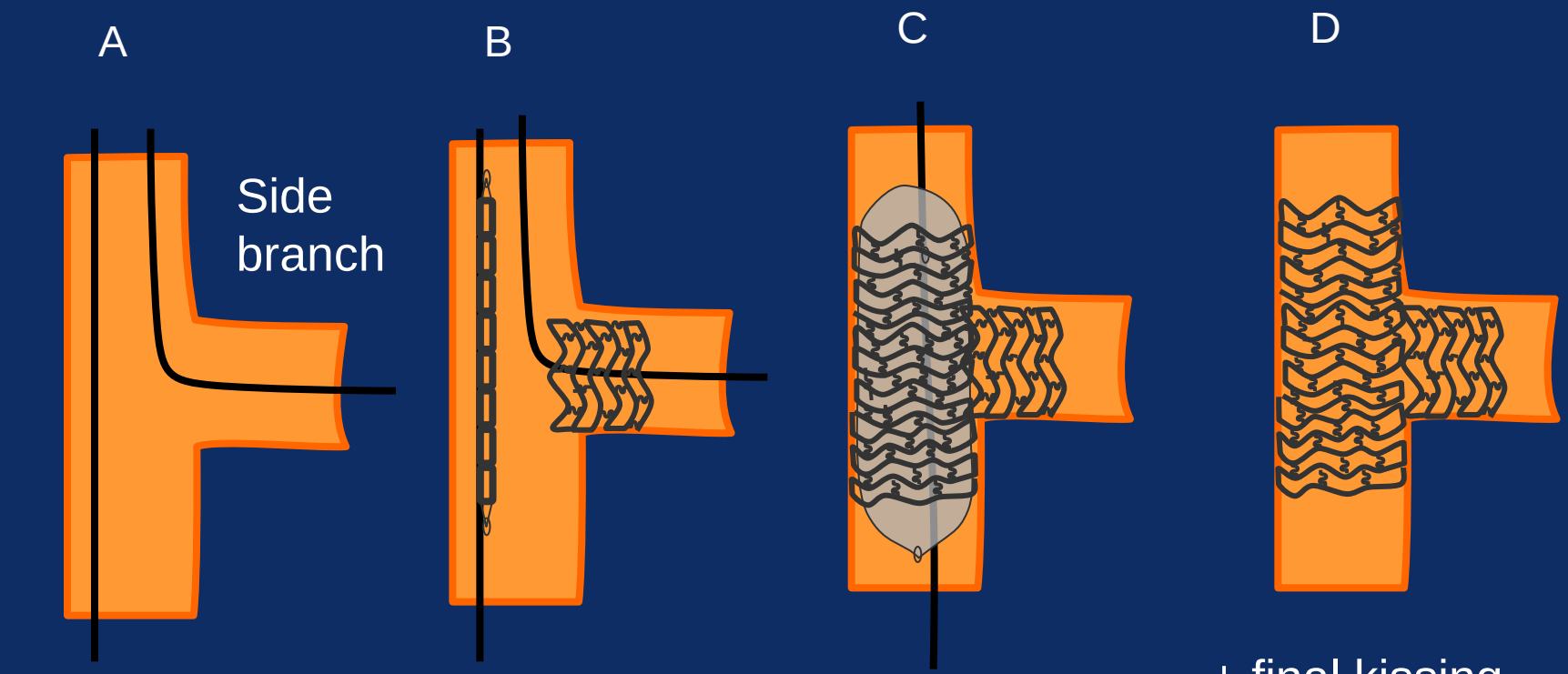
Y (Culotte) Stenting

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

Y (Culotte) Stenting

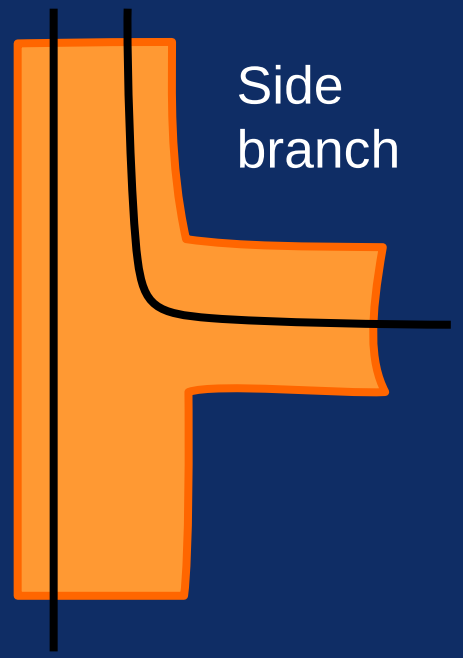
D. Final result after final kissing balloon

Modified T-Stenting



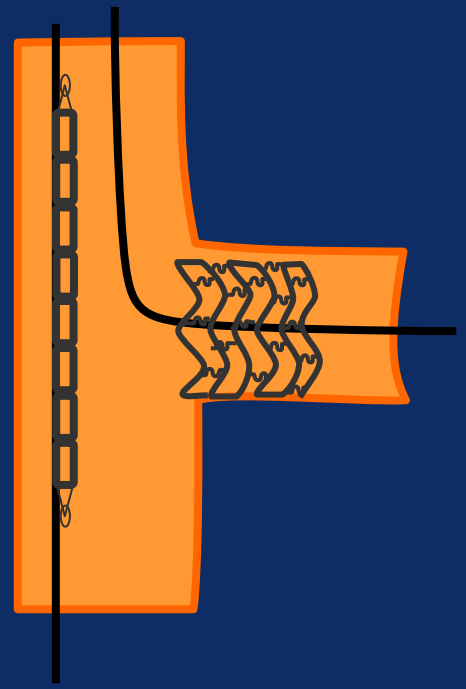
Modified T-Stenting

A. Wire both branches and predilate if needed



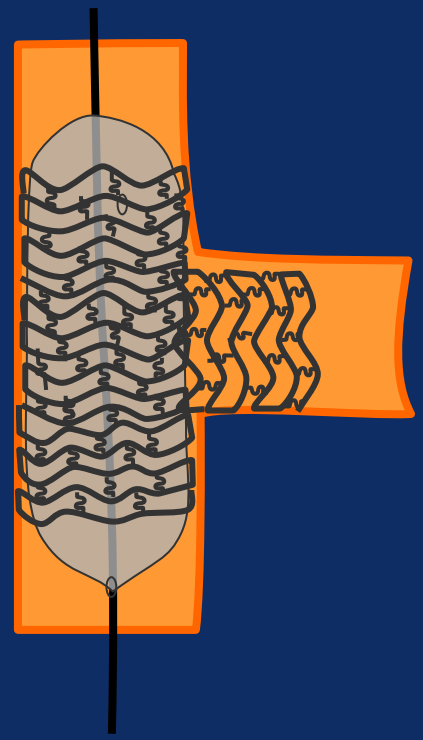
Modified T-Stenting

B. SB stent deployed at nominal pressure



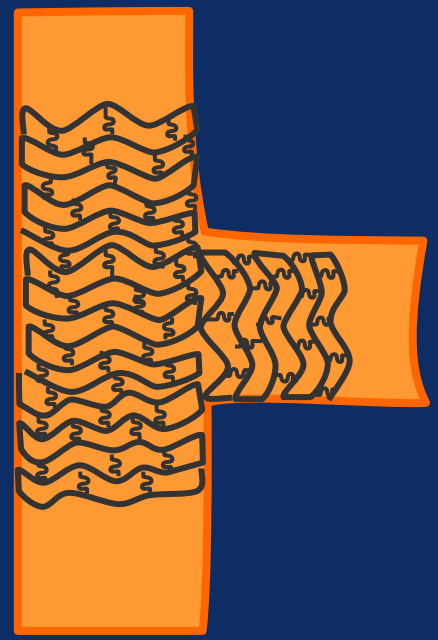
Modified T-Stenting

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



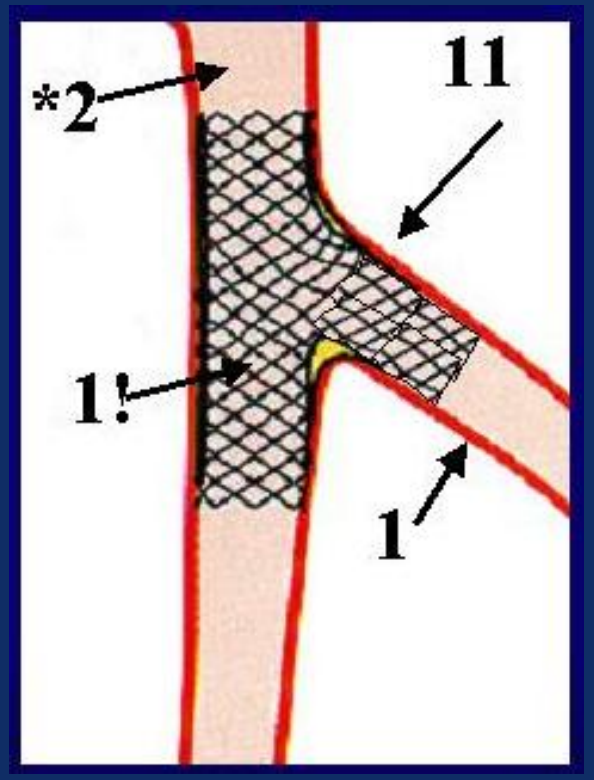
Modified T-Stenting

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

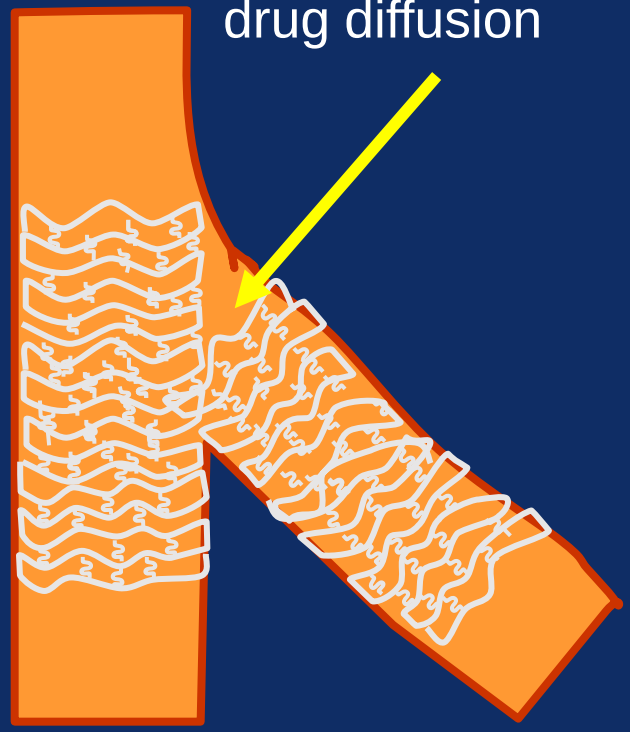


Limitation of Modified T Stenting

Restenosis site of T stenting in SIRIUS bifurcation



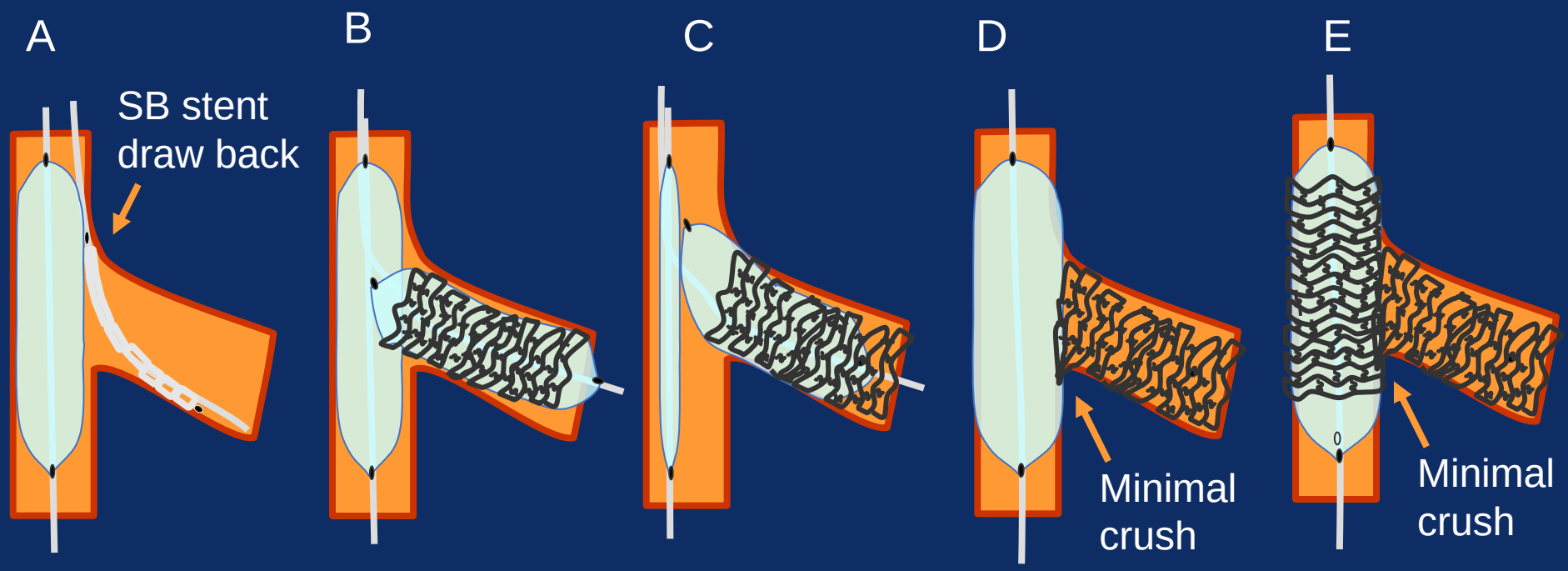
Potential gap without enough drug diffusion



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



MB balloon
4-6 atm

MB balloon 4-6 atm
SB stent 16 atm

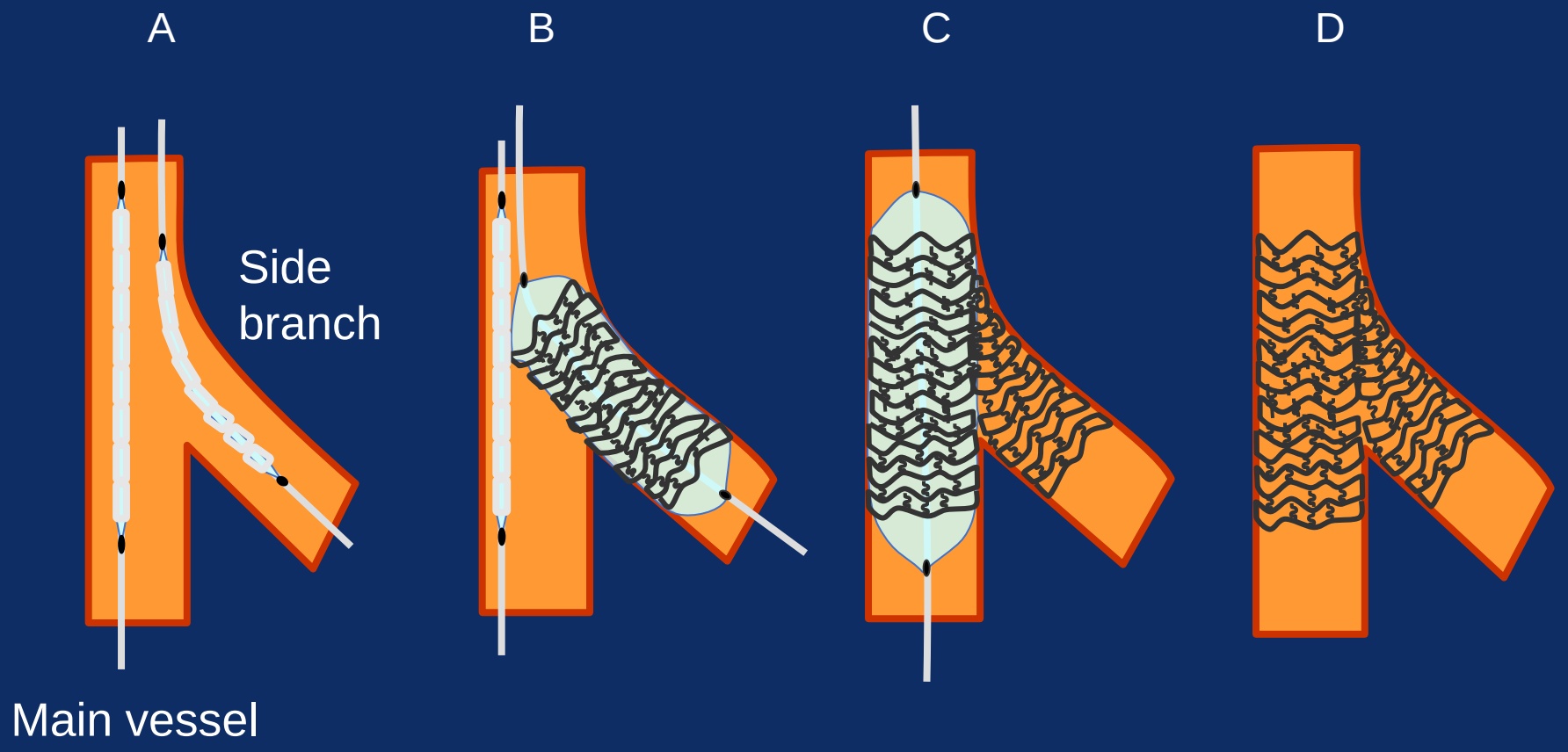
SB balloon
Pull back
18-20 atm

MB balloon
12-16 atm

MB stenting
Final kissing
recommended

CVRF

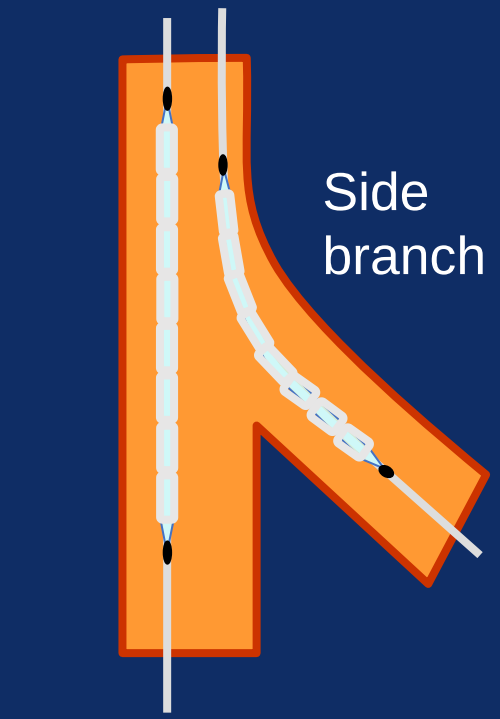
Crush Technique



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

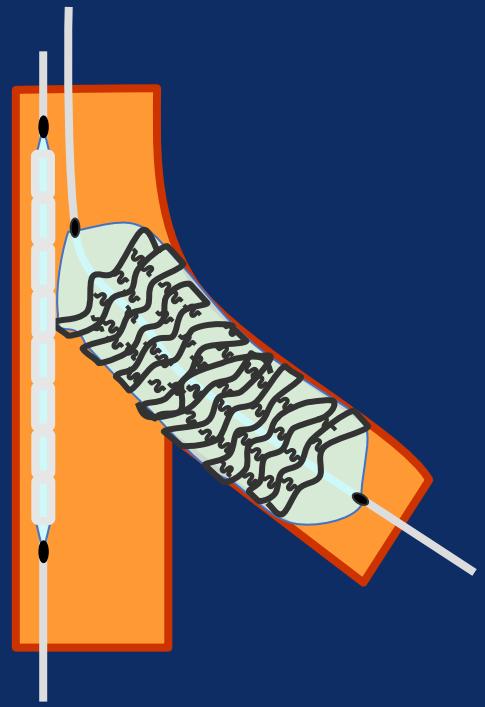
Crush Technique

A. Advance 2 stents



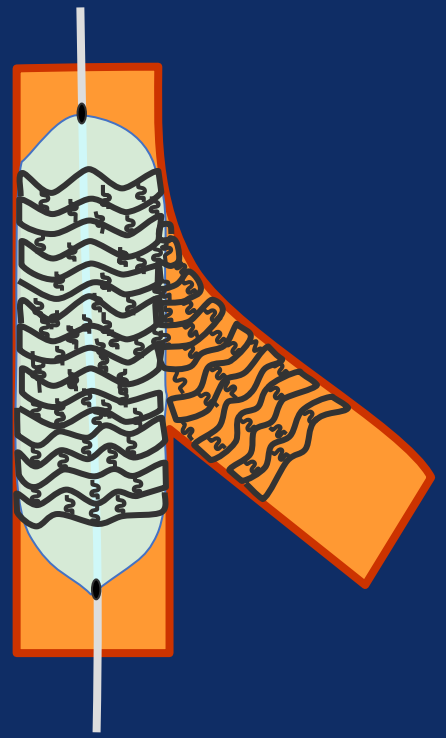
Crush Technique

B. Deploy the SB stent



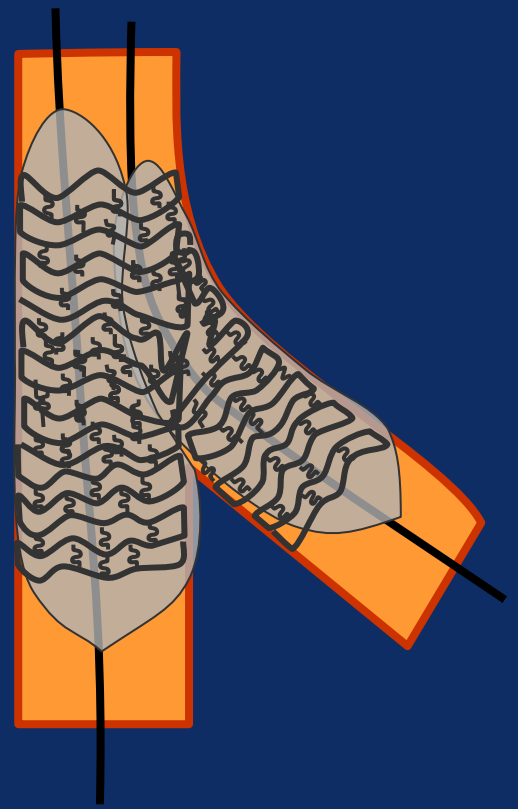
Crush Technique

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



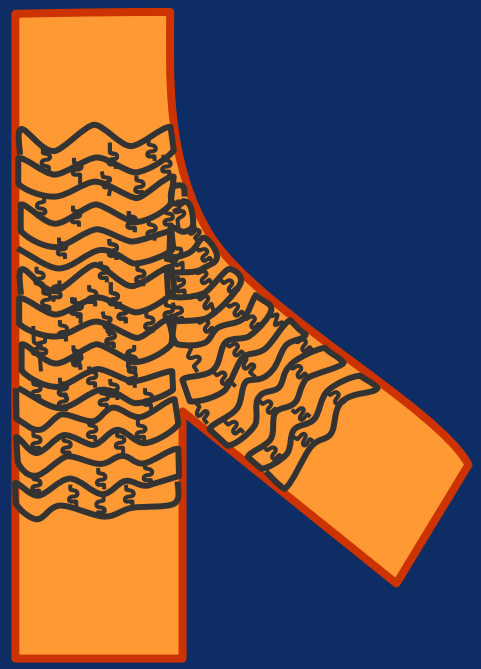
Crush Technique

D. Perform final kissing inflation



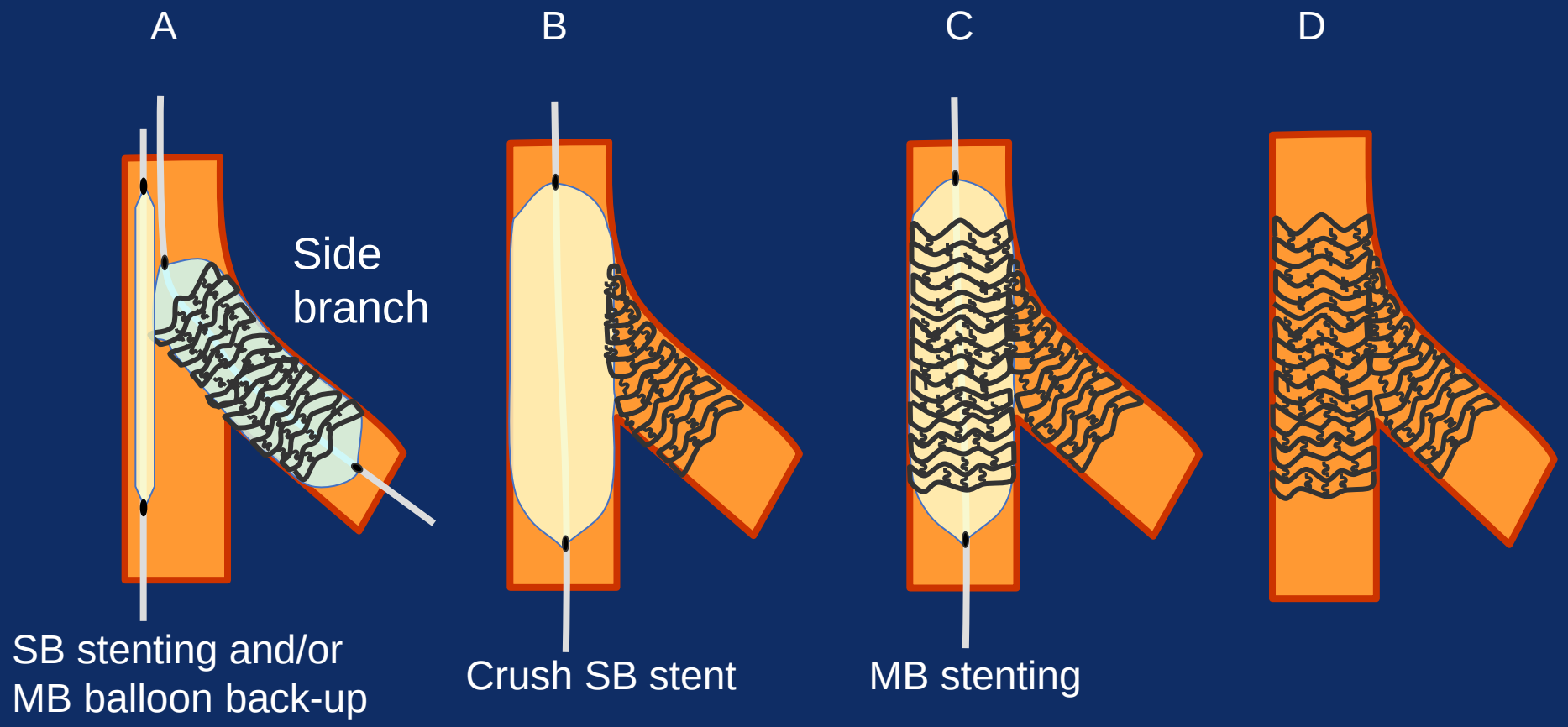
Crush Technique

D. Final result



Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

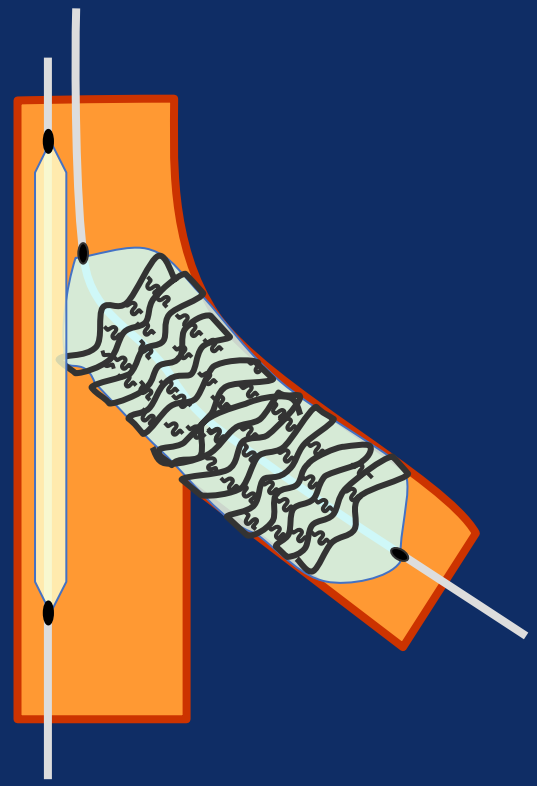


Advantages	Disadvantages
Minimizes multi-layers of struts Good scaffolding at SB ostium Facilitates FKI Compatible with 6-Fr guider	Still leaves multiple layers of strut

Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

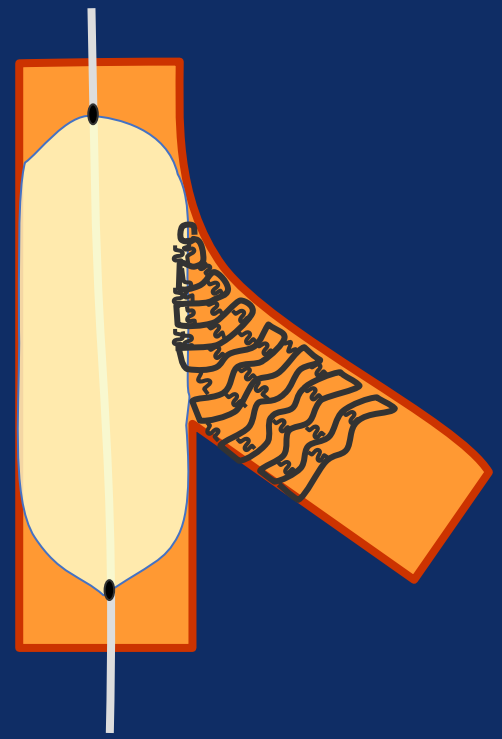
A. Deploy the SB stent ± MB balloon backup



Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

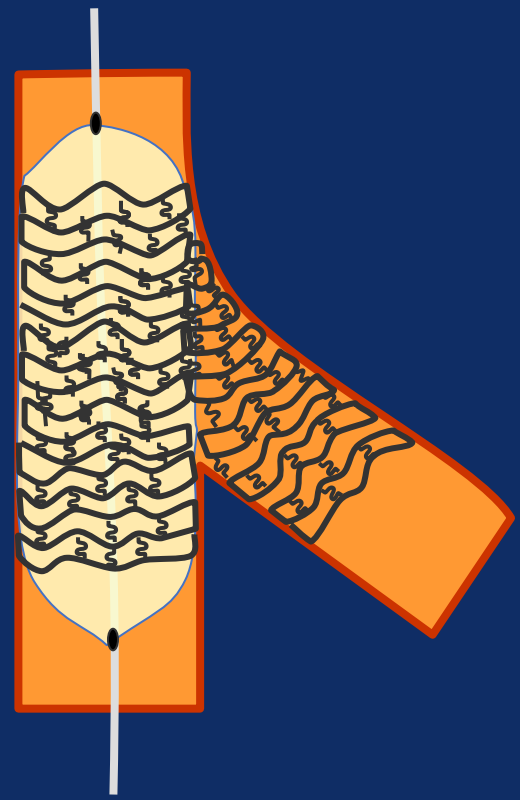
B. Crush SB stent



Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

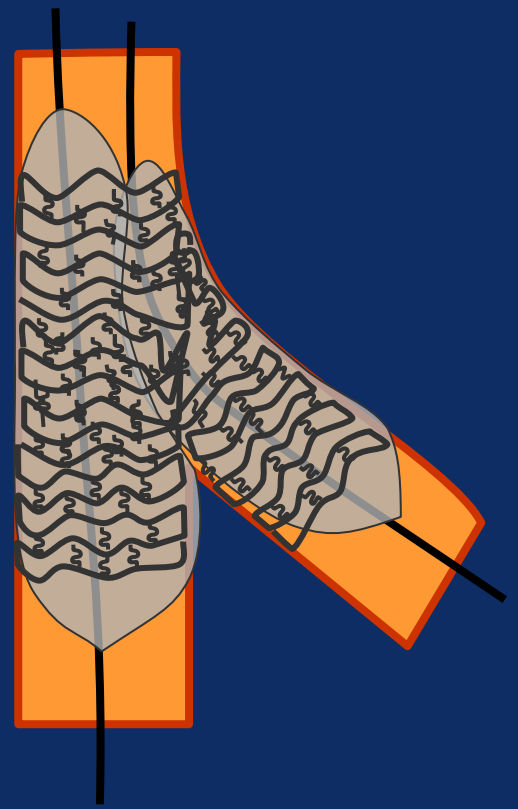
C. Deploy stent in MB,
then rewire SB and perform high-pressure dilatation



Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

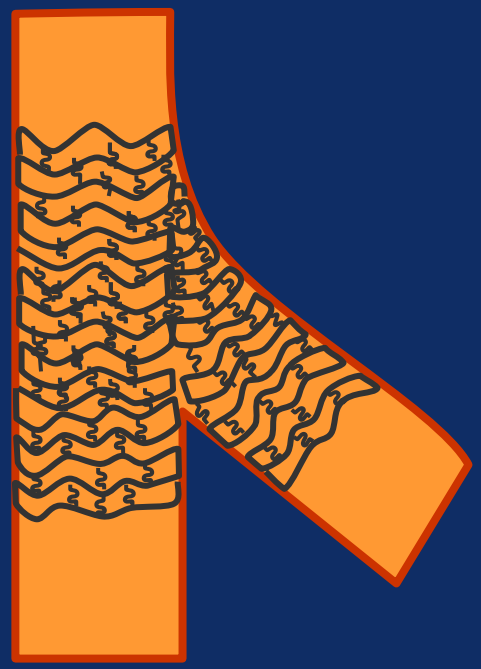
E. Perform final kissing inflation



Mini-Crush with balloon

Performed with 6~7Fr guiding catheter

F. Final result

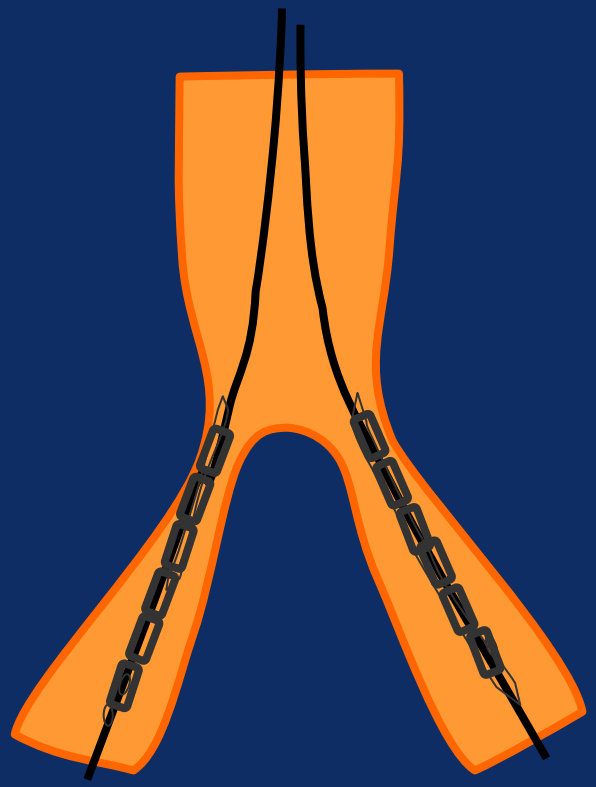


V Stenting

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

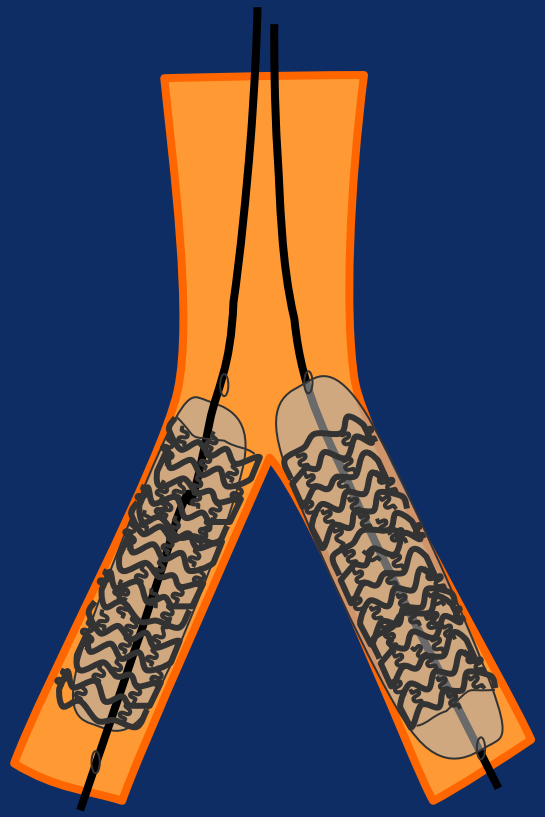
V Stenting

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

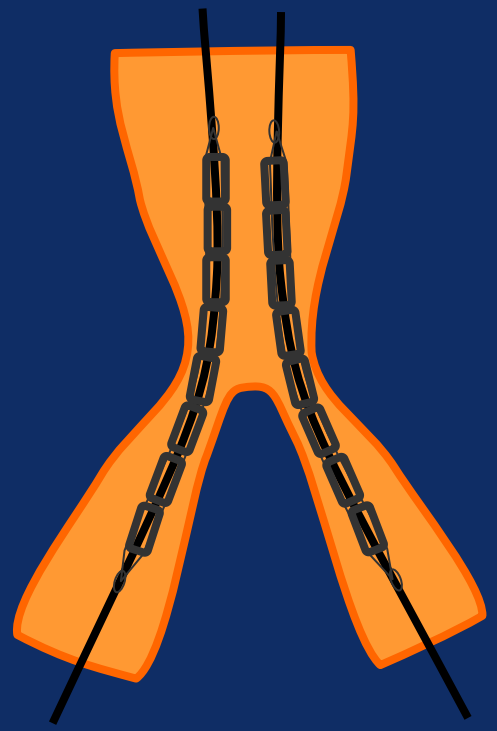
- Large proximal reference
- Bifurcation with stenosis proximal to the bifurcation

A B C

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

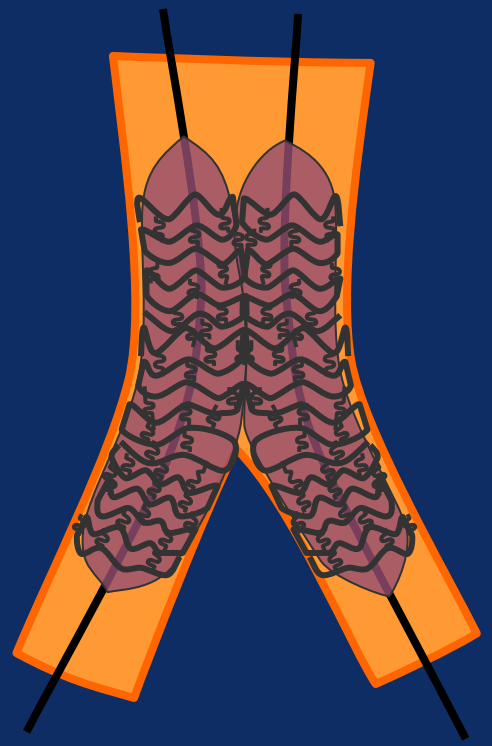
Simultaneous Kissing Stenting

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