Bulgarian Bifurcation Course

European Bifurcation Club

What is the best way to do single stenting of coronary bifurcation ?

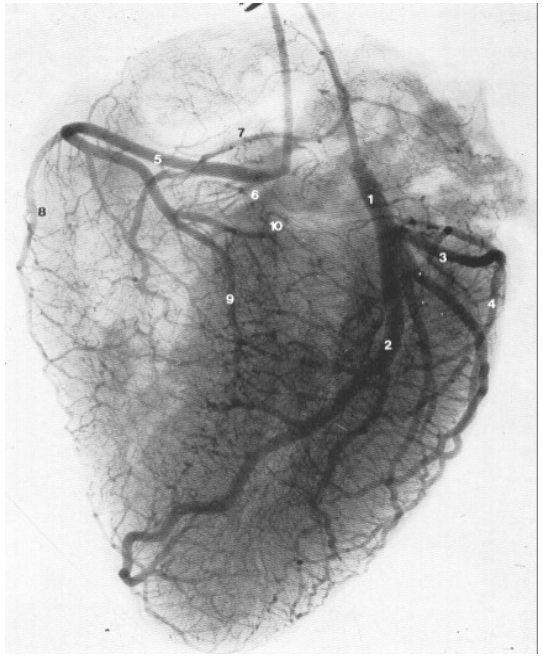
Y.Louvard, ICPS, Massy, Générale de santé, Ramsay, France

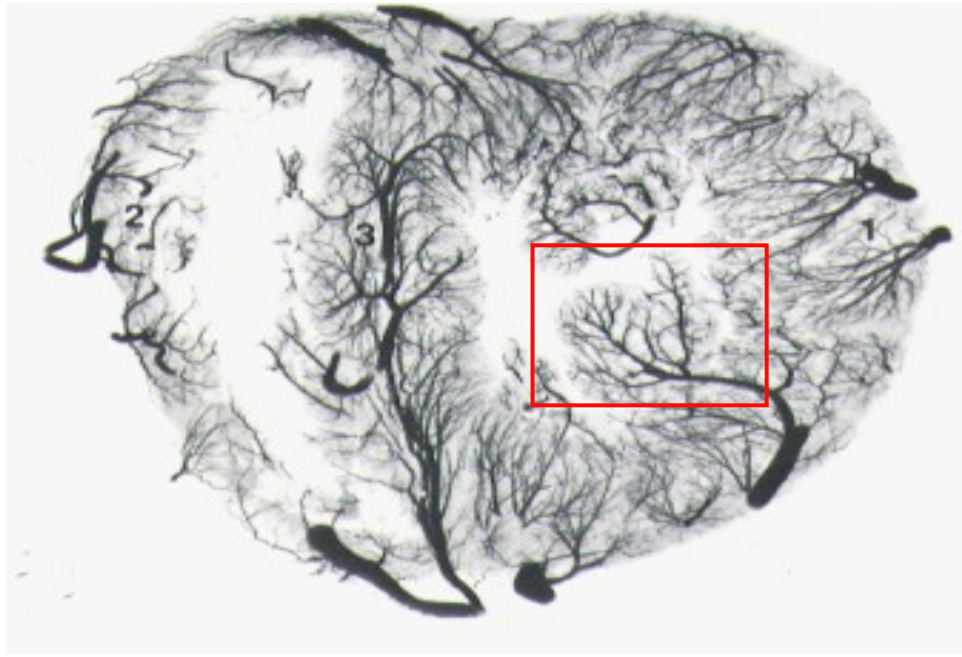
Bulgarian Bifurcation and Complex Coronary Interventions Course
22-23 January 2016
Tokuda Hospital, Sofia

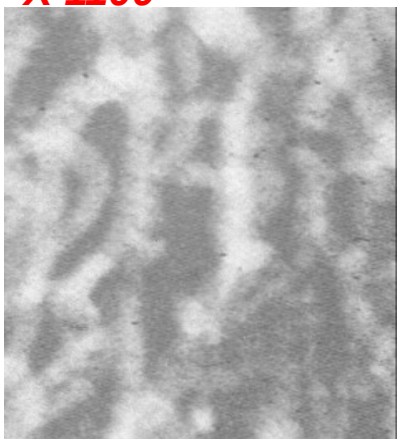
RAMSAY GÉNÉRALE DE SANTÉ

Coronary anatomy and function

Coronary artery tree: pseudo-fractal object

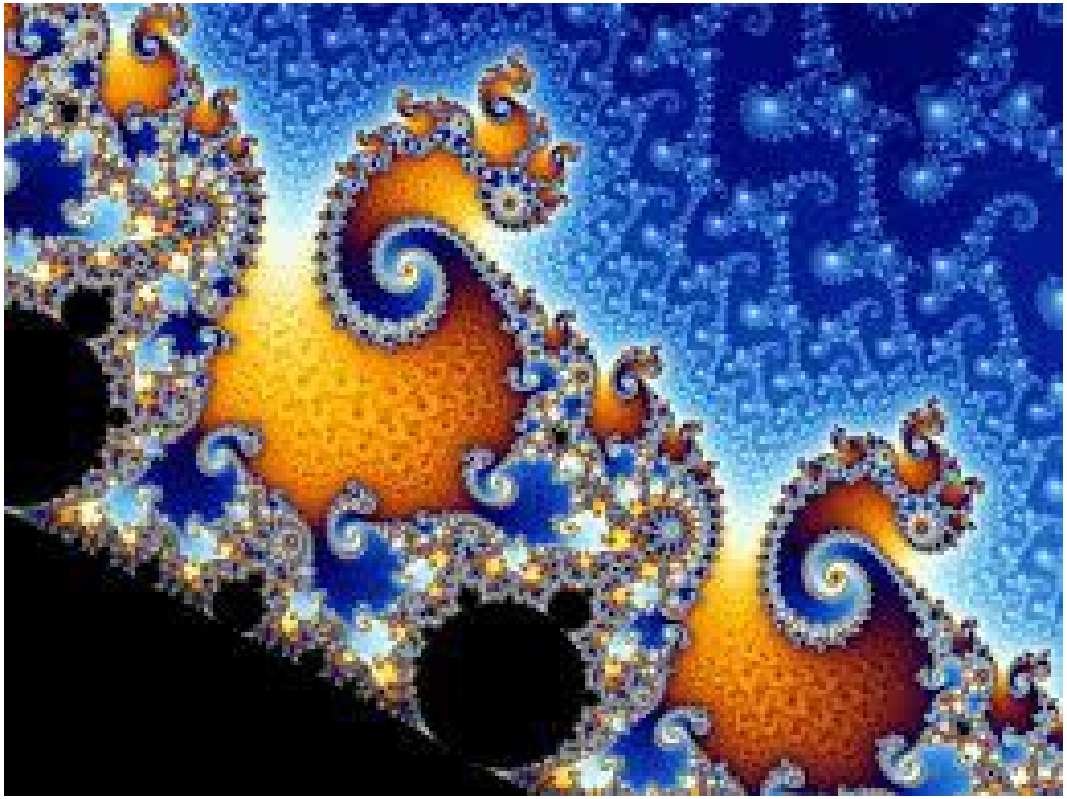




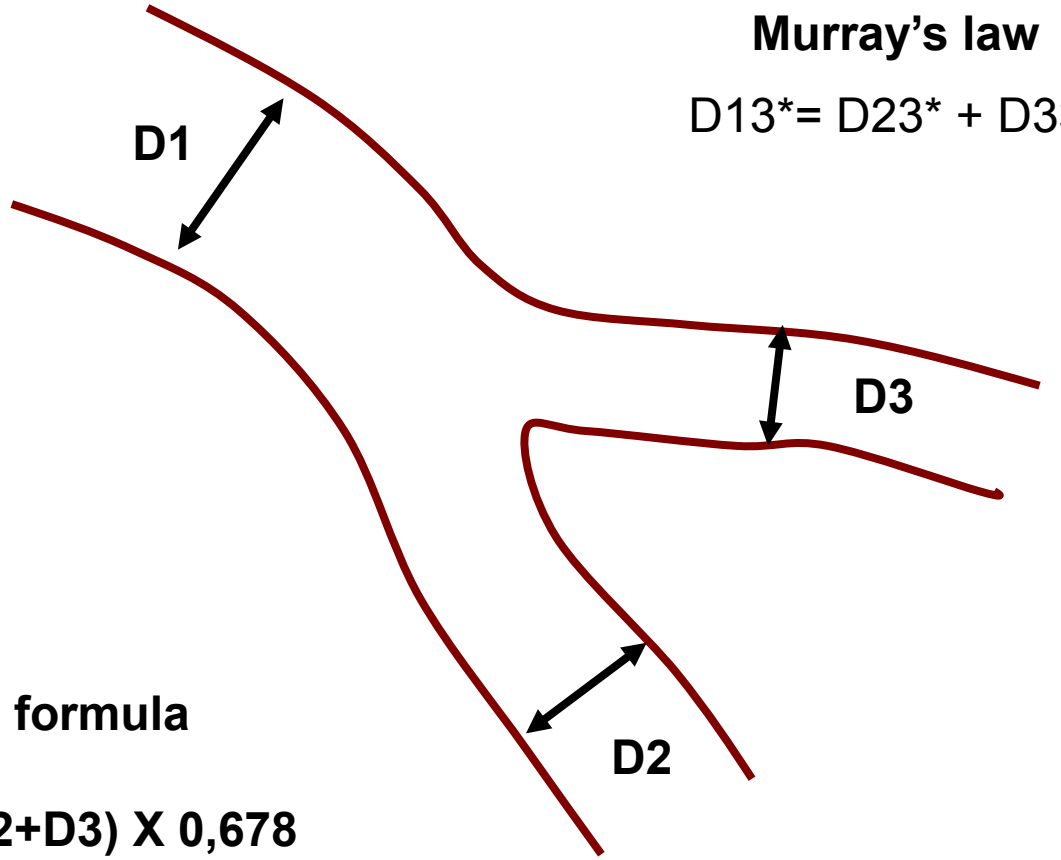


Finet et al. Eurointrevention 2007; 490-8

Benoit Mandelbrot (1924-2010): fractals



Structure-function scaling laws of vascular trees

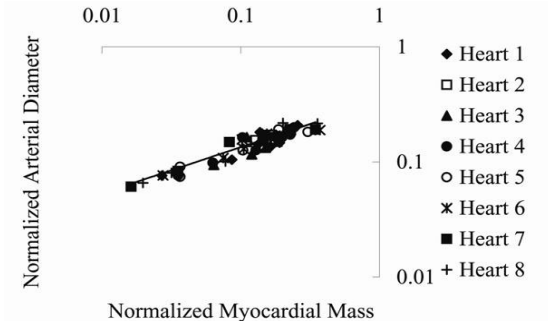


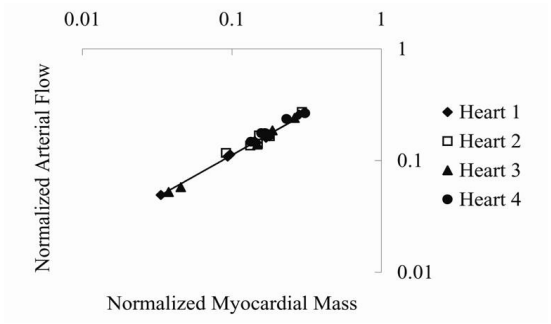
Murray's law

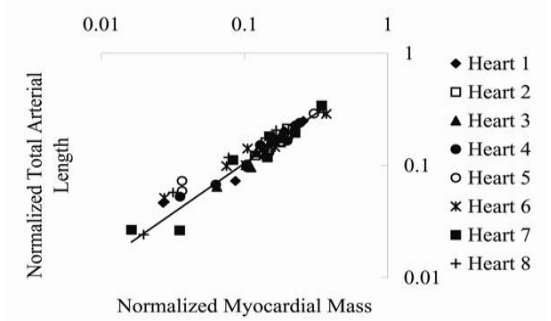
$D13^* = D23^* + D33^*$

Finet's formula

D1= (D2+D3) X 0,678



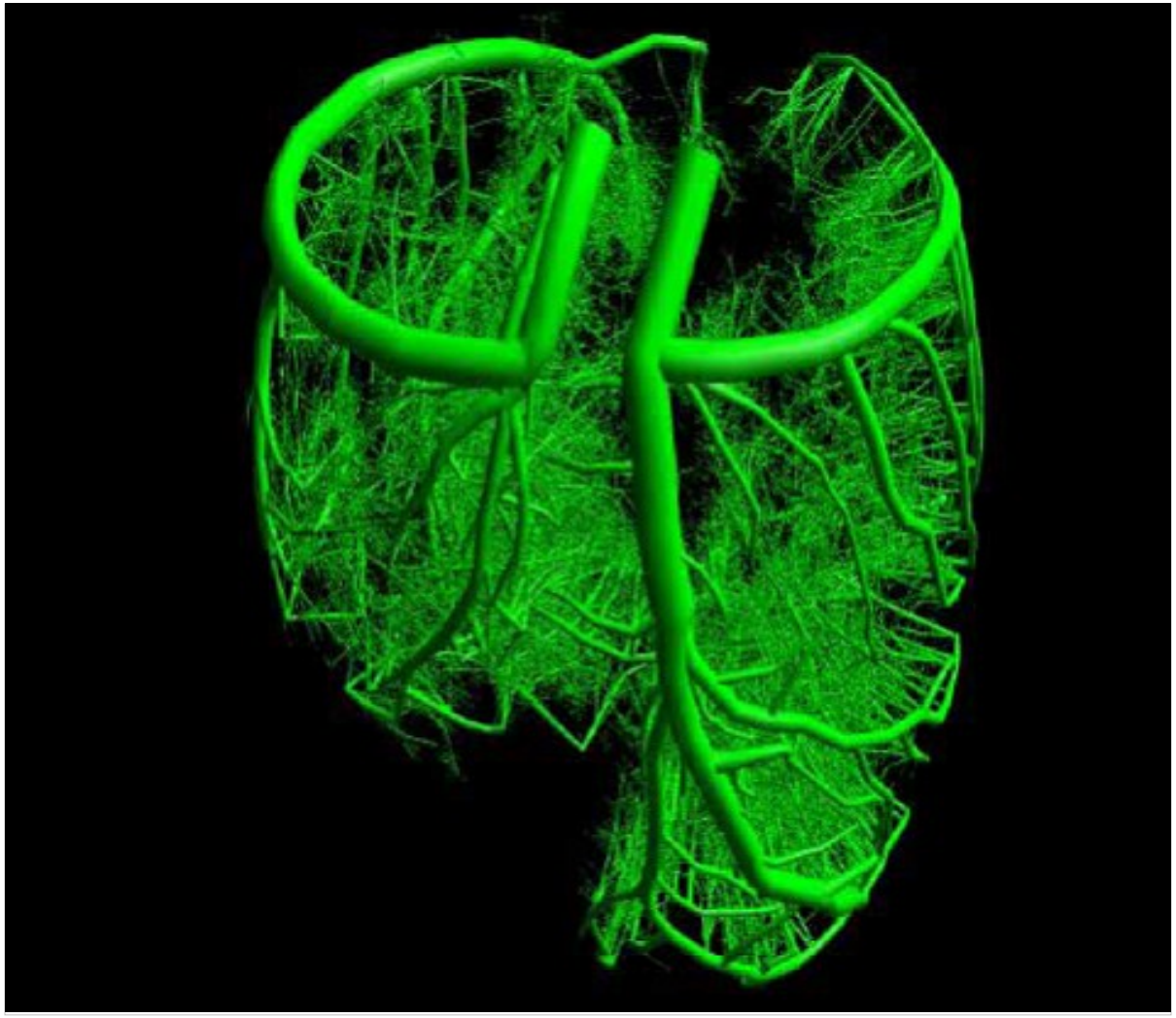




* 2.3 **(Huo-Kassab)**

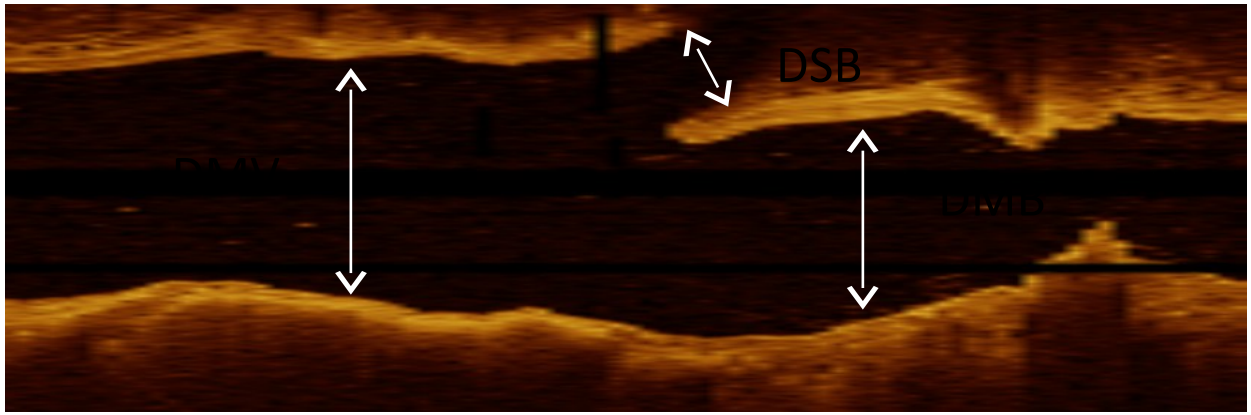
Adapted from G. Kassab

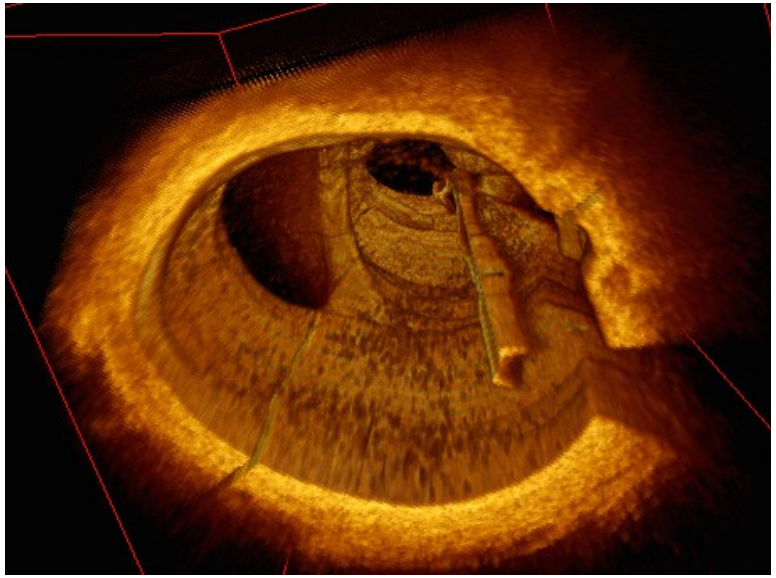
Mathematical model of coronary arterial tree



From G. Kassab

Anatomy of Bifurcations





	Principle	Relation	*Ratio Dm/Dd for Dd1~ Dd2*
Murray's law	Minimum Work	Dm3= Dd13 + Dd23	*1.26*
HK: Huo-Kassab	Minimum Energy	Dm7/3 = Dd17/3 + Dd27/3	*1.35*
Flow conservation	Qm= Qd1 + Qd2	Dm2= Dd12 + Dd22	*1.4*
Finet	Measurement	Dm= 0.678 (Dd1 + Dd2)	*1.36*

- **The larger the SB, the larger the change in MV diameter throughout the bifurcation**

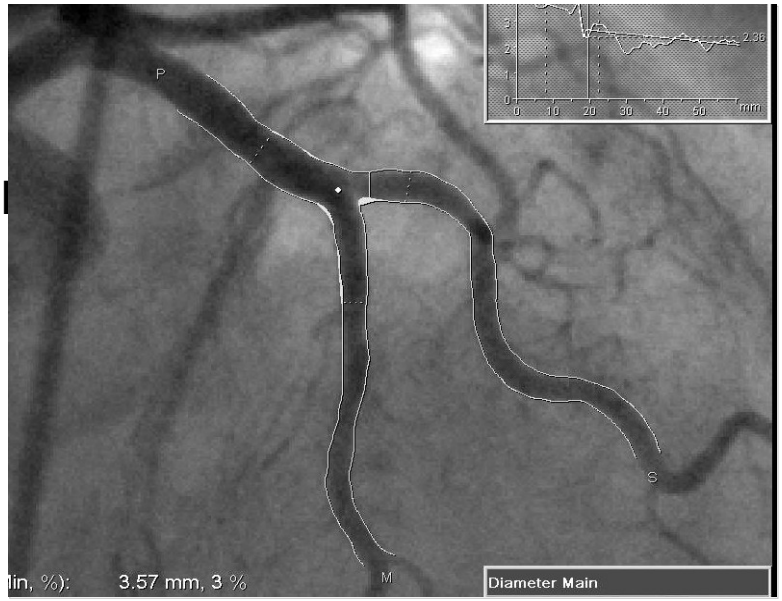
Courtesy of N Foin

Choose the stent from the distal MB diameter

Pseudo fractal geometry and dedicated QCA

The bigger the SB the larger the overestimation of DM stenosis

Systematic underestimation of PM stenosis



Murray's law

$D13 = D23 + D33$

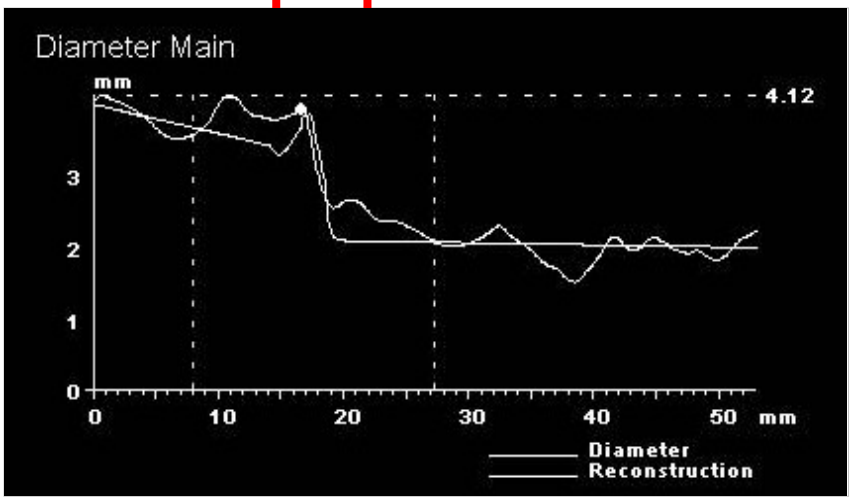
Finet's law

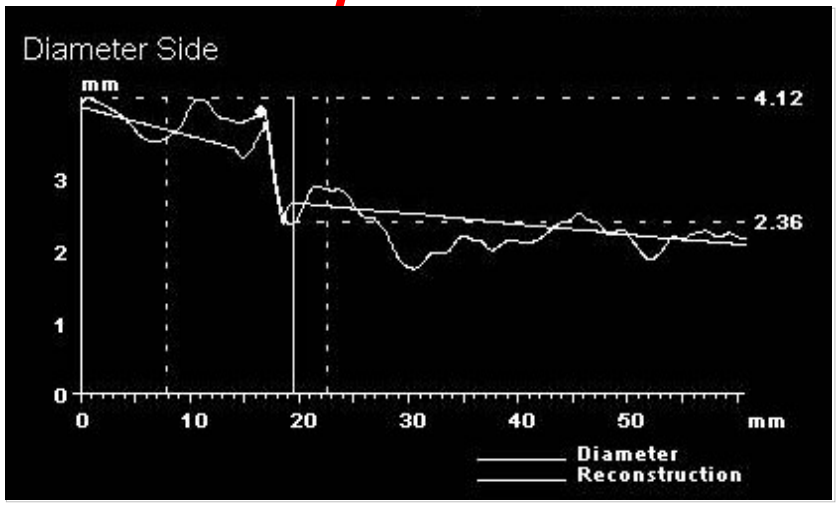
$D1 = 0.67(D2 + D3)$

Huo Kassab law

$D2^3 = D2.3^3 + D2.3^3$

Systematic overestimation of SB ostial stenosis

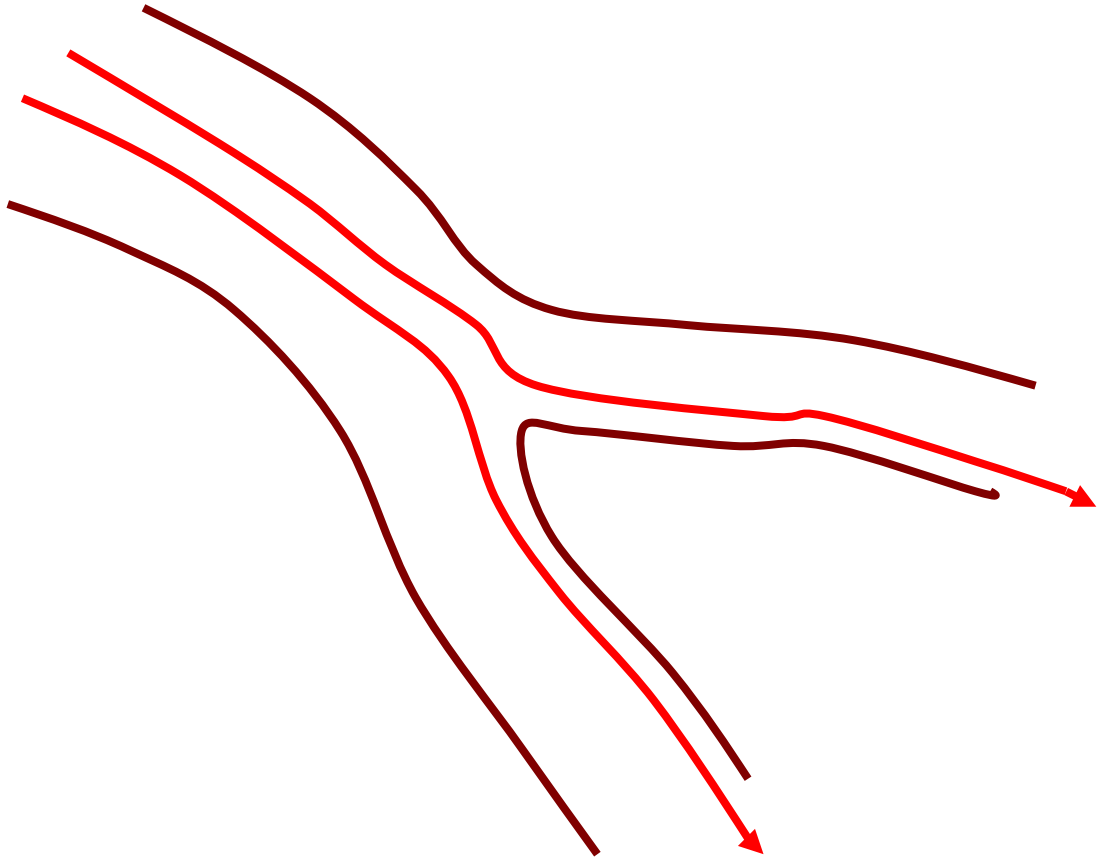




Modified from PIE medical

Why so many bifurcation stenosis ?

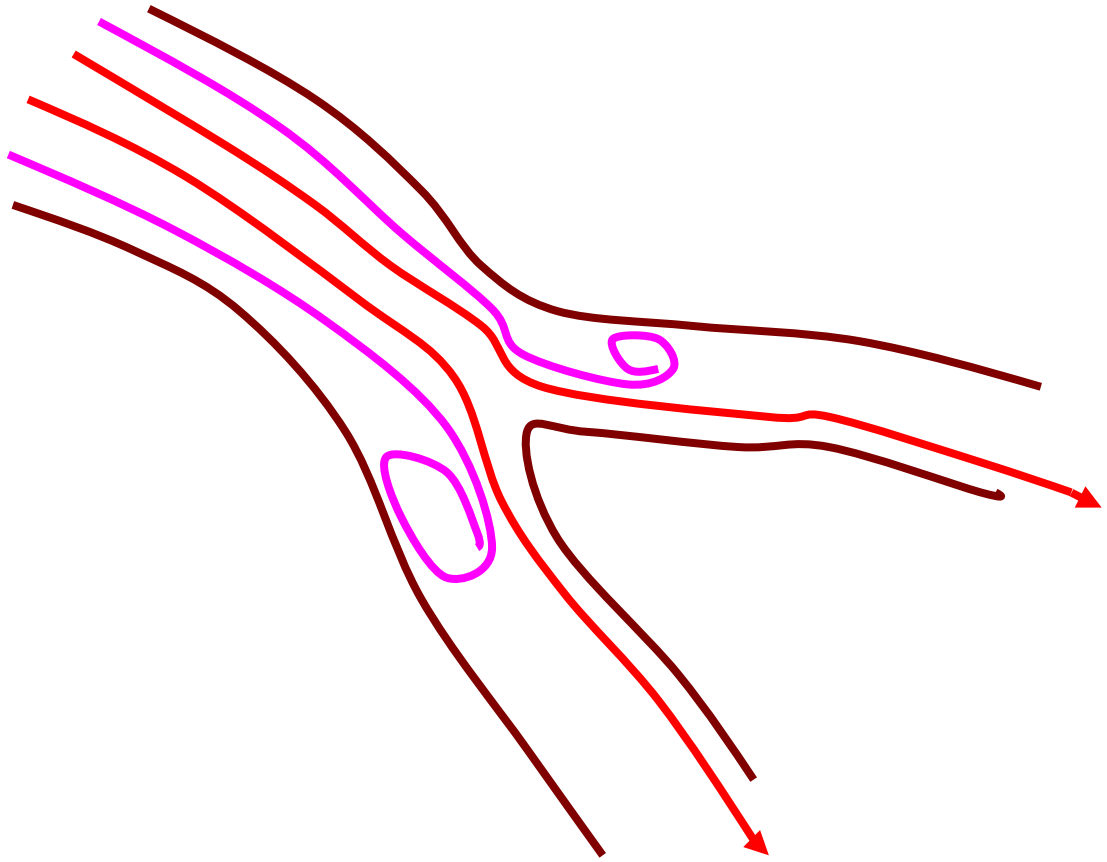
Flow Patterns and Spatial Distribution of Atherosclerotic Lesions in Human Coronary Arteries



High wall shear stress = antiatherogenic

Asakura, Circulation Research 1990; 66:1045-1066

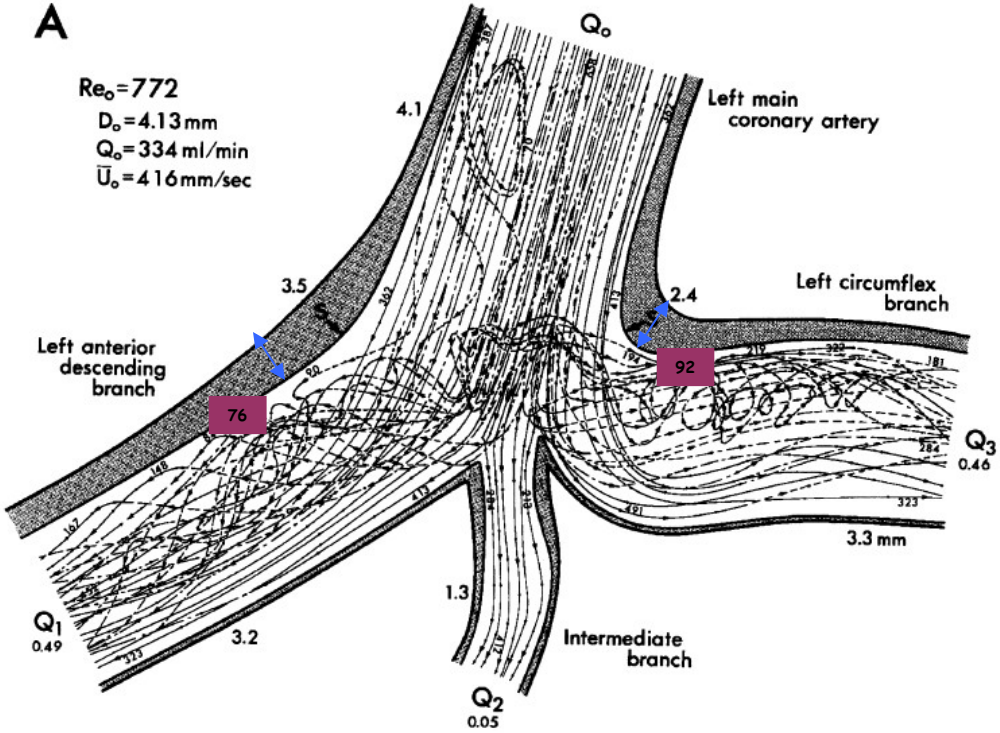
Flow Patterns and Spatial Distribution of Atherosclerotic Lesions in Human Coronary Arteries

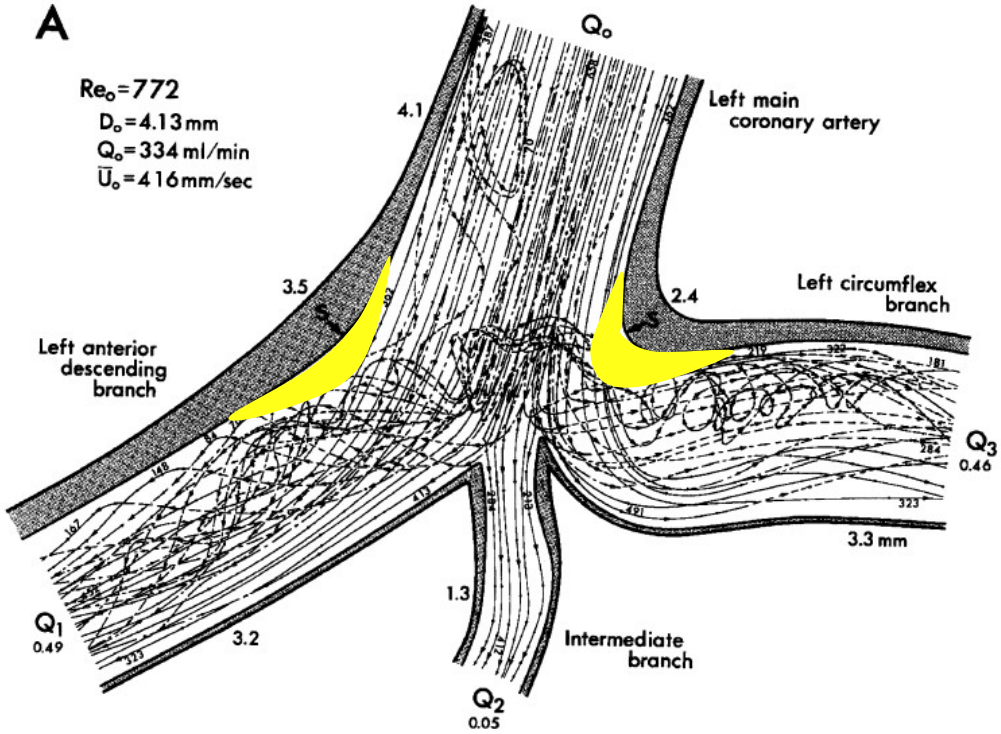


Low wall shear stress = proatherogenic

Asakura, Circulation Research 1990; 66:1045-1066

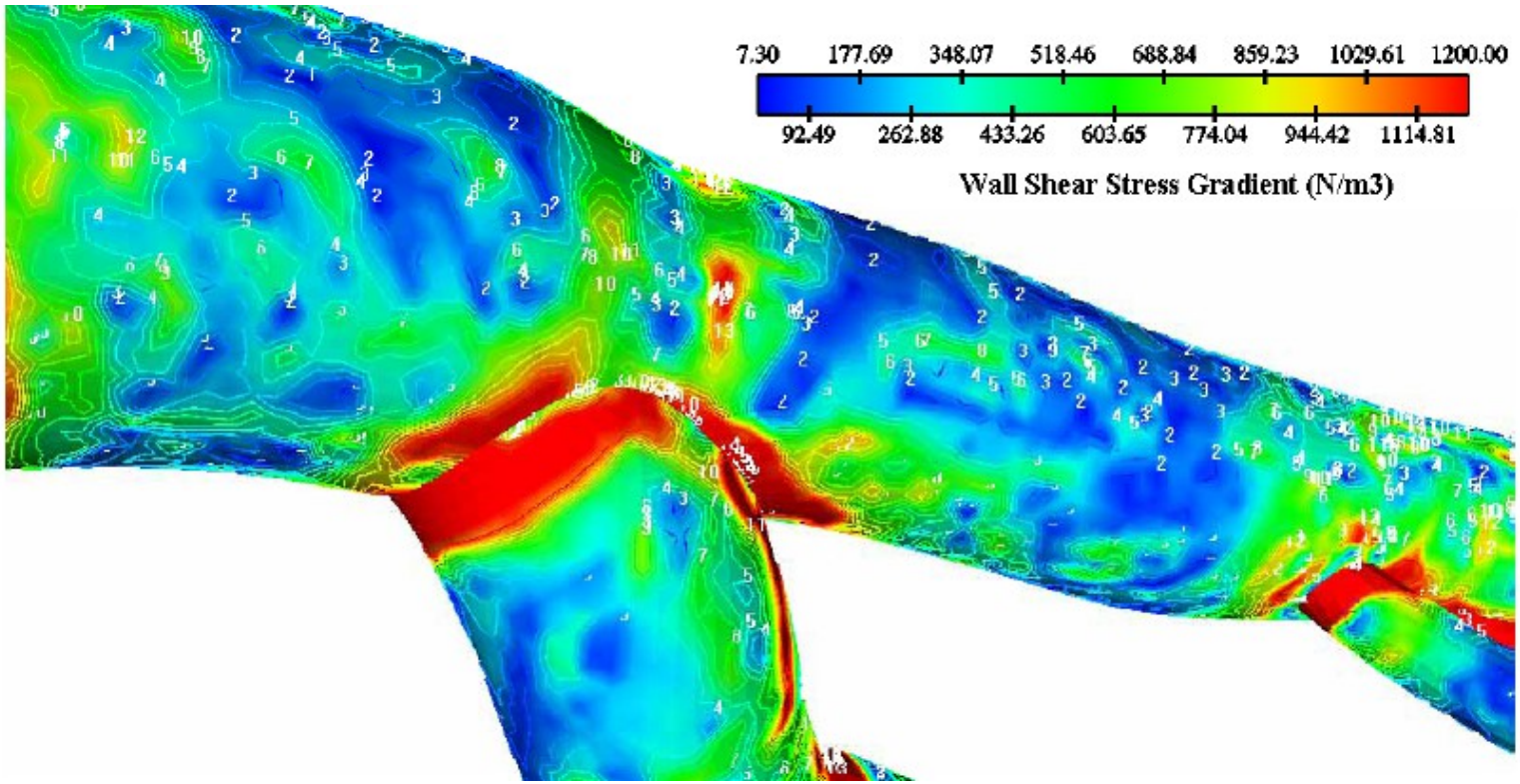
Flow Patterns and Spatial Distribution of Atherosclerotic Lesions in Human Coronary Arteries





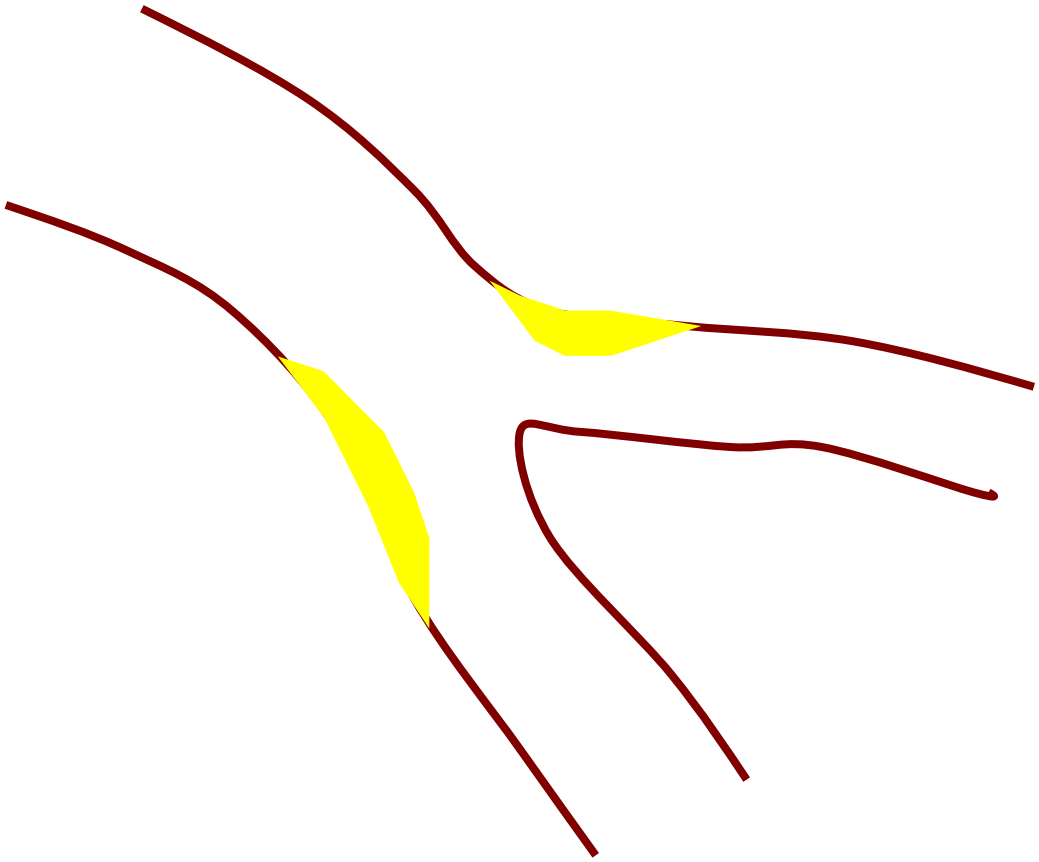
Asakura, Circulation Research 1990; 66:1045-1066

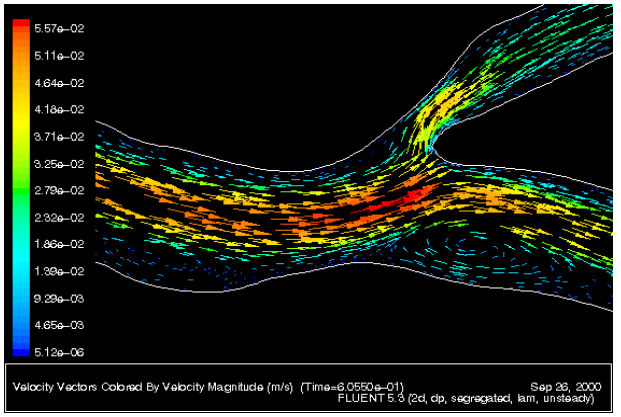
The low WSS values distribution is in accordance with the frequent localization of atherosclerosis lesion

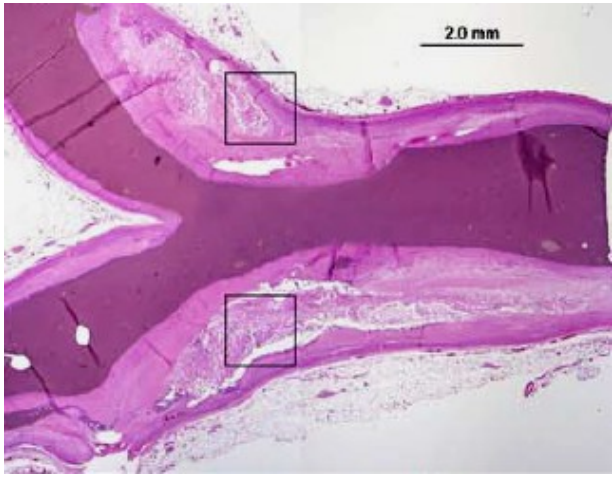


Soulis et al. J of Biomechanics 2006;39:742

Low wall shear stress and atheroma in bifurcation



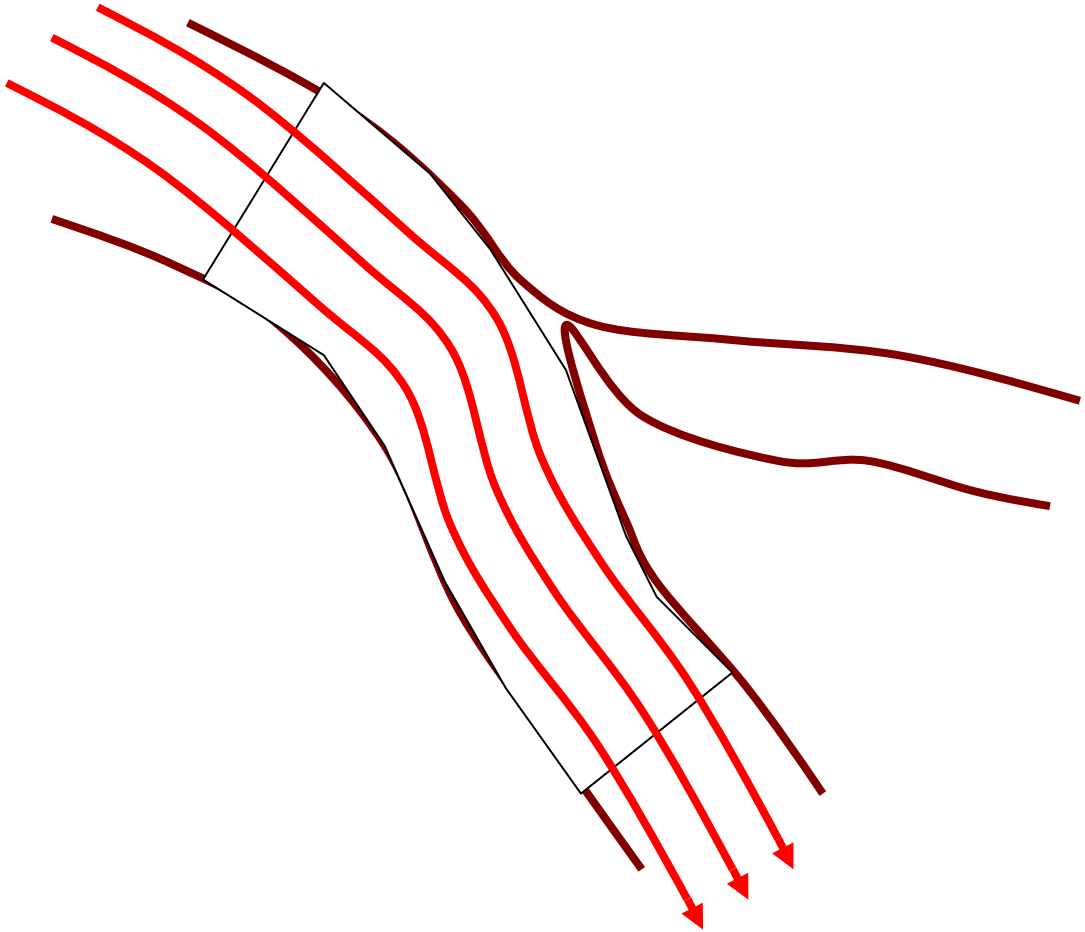




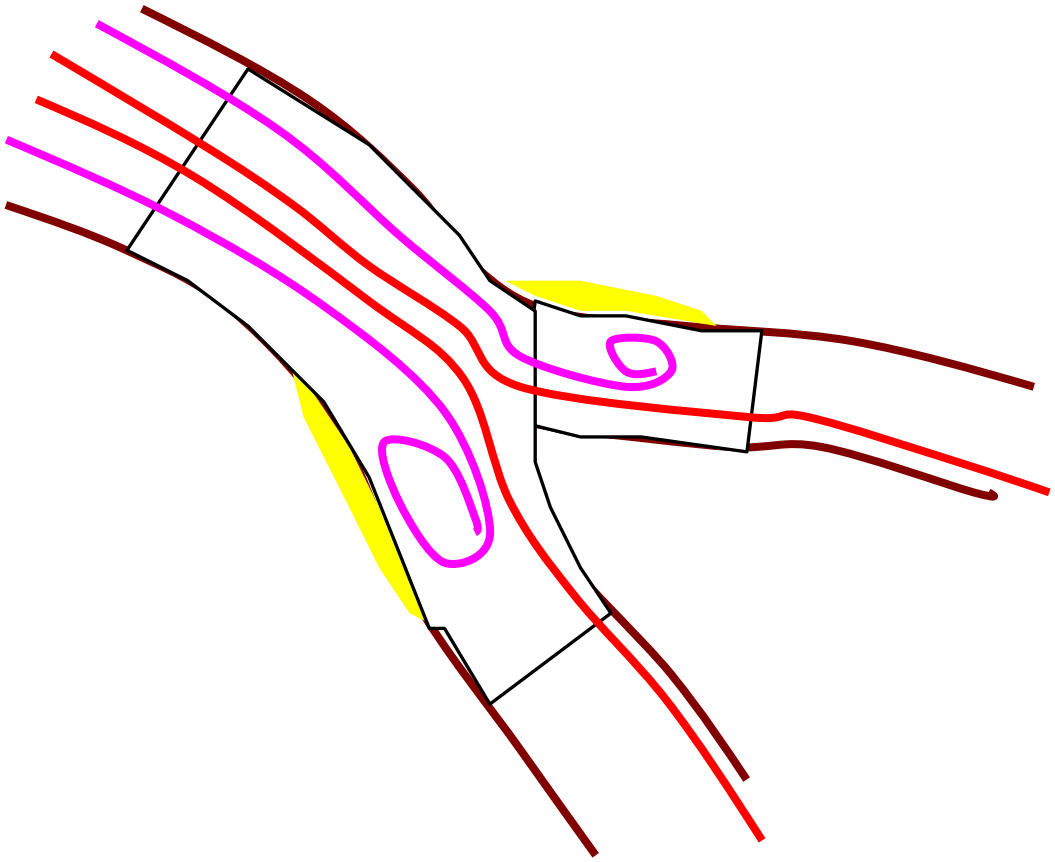
Virmani, Chatzizisis

Stenting, bifurcation anatomy and wall stress

Best solution ?



Restauration of initial flow (+ stent turbulences)



WSS < 0.5 Pa =
risk of restenosis

Flow mediated NIH and neo-atheroma

Ku 1997, Malek et al. 1999

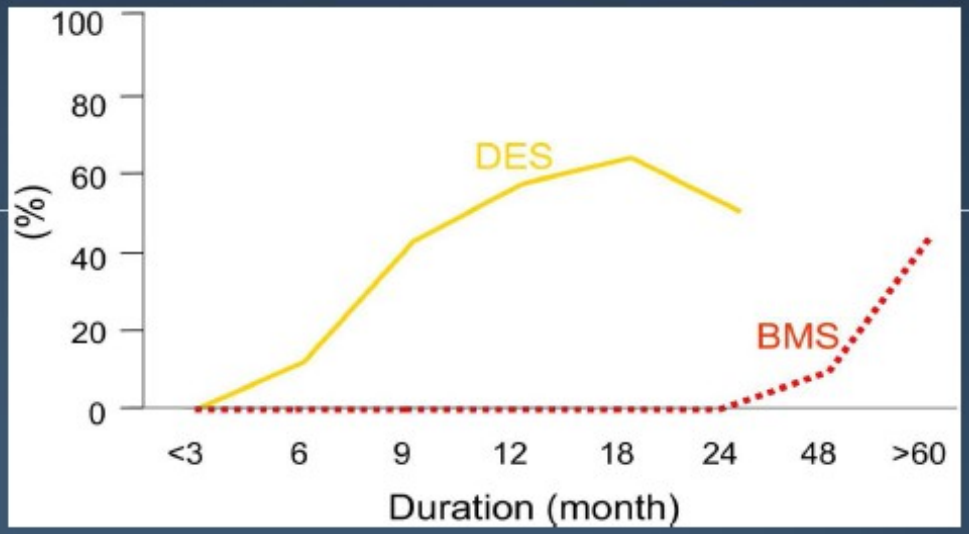
Virmani, Mintz …

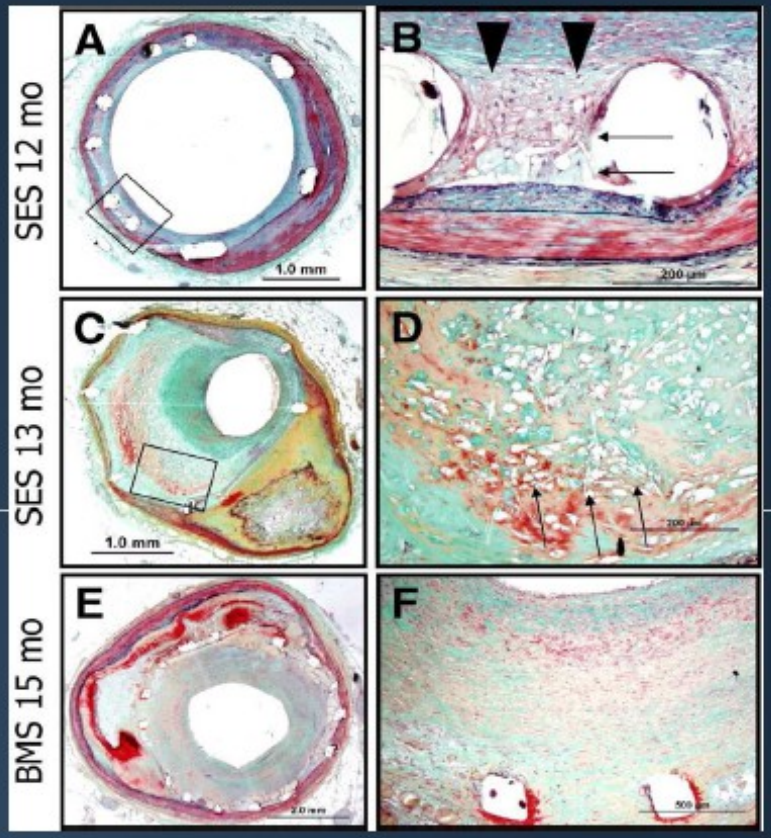
Pathological Findings at Bifurcation Lesions: Impact of Flow Distribution on Atherosclerosis and Arterial Healing After Stent Implantation

	DES (12 Lesions, 17 Stents)			BMS (14 Lesions, 18 Stents)			p Value for DES vs. BMS	
	Flow Divider	Lateral	p Value	Flow Divider	Lateral	p Value	Flow Divider	Lateral
Neointimal thickness (mm)	0.07 (0.03-0.15)	0.17 (0.09-0.23)	0.001	0.26 (0.16-0.73)	0.44 (0.17-0.67)	0.25	0.0002	0.004
Fibrin deposition (% struts)	60 (21-67)	17 (0-55)	0.01	8 (0-33)	3 (0-21)	0.21	0.008	0.19
Uncovered struts (% struts)	40 (16-76)	0 (0-15)	0.001	0 (0-21)	0 (0-0)	0.10	0.004	0.38

Nakazawa, Virmani, J Am Coll Cardiol 2010;55:1679–87

Percentage of Patients With Atherosclerotic Changes in DES Versus BMS in Relation to Duration of Implant at Autopsy





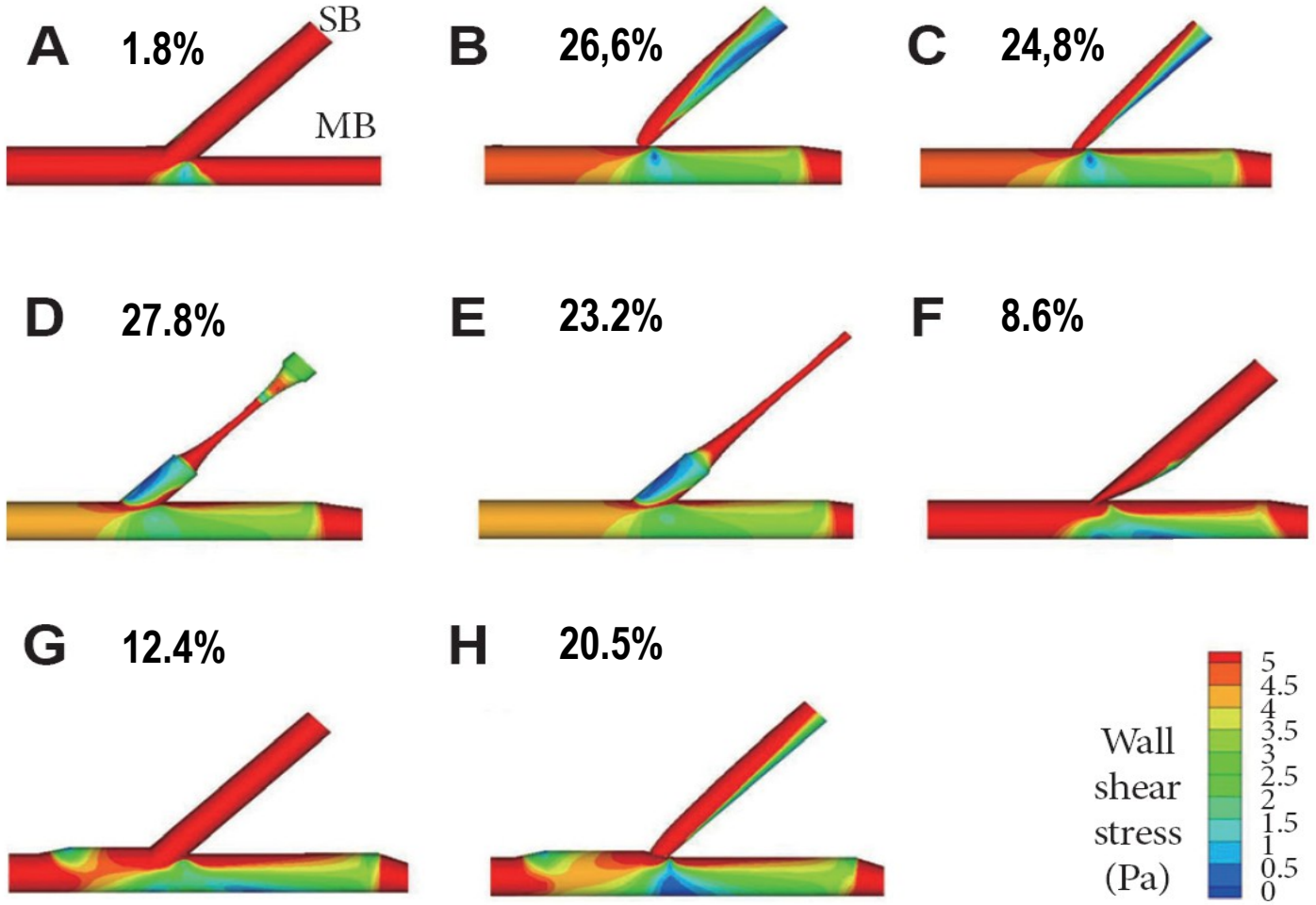
CARDIOVASCULAR RESEARCH FOUNDATION

Nakazawa et al. J Am Coll Cardiol Img 2009;2:625-8

COLUMBIA UNIVERSITY MEDICAL CENTER

Evaluation of Local Flow Conditions in Jailed Side Branch Lesions Using Computational Fluid Dynamics

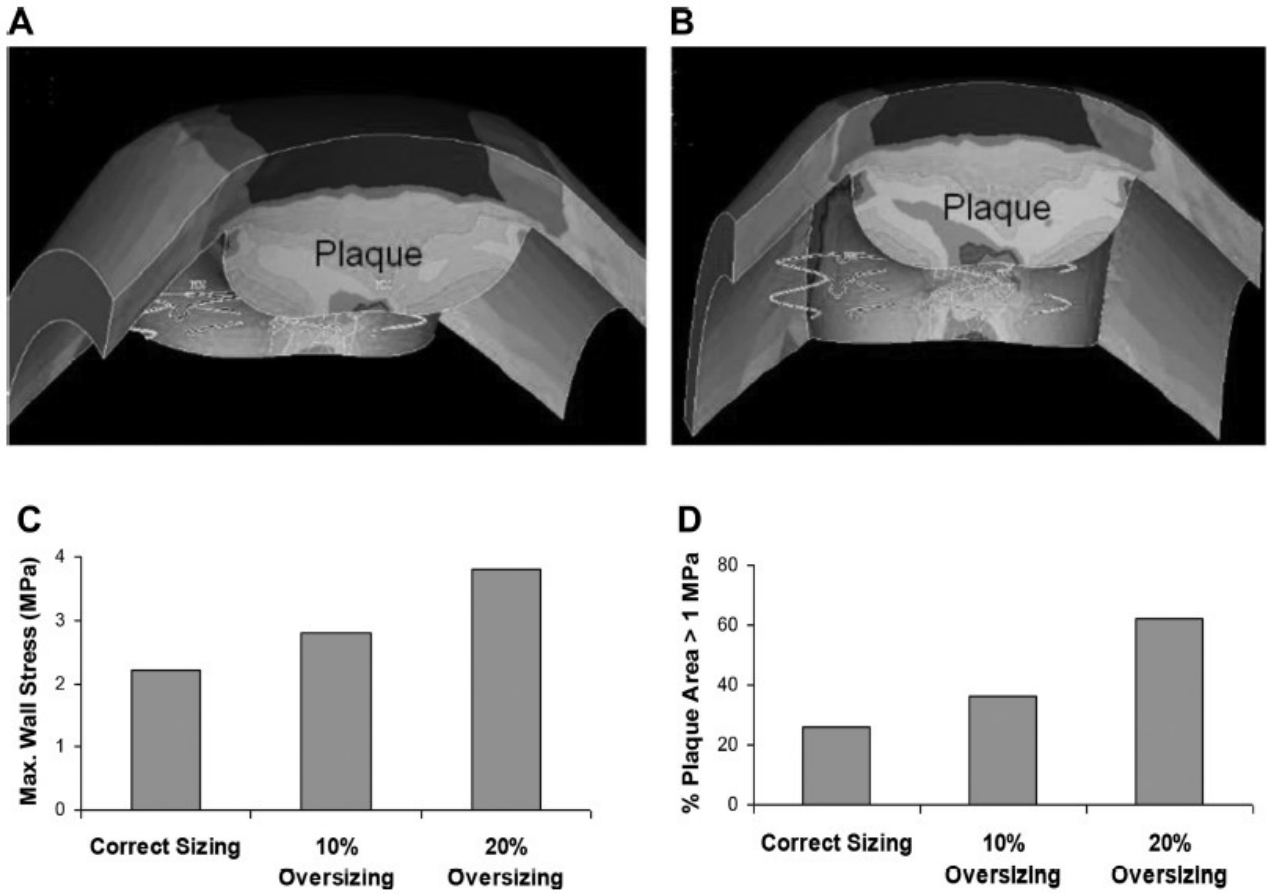
Area of low WSS (<4 Pa) in 8-computational bifurcation models



SH. Na, BK. Koo, Korean Circ J 2011;41:91-96

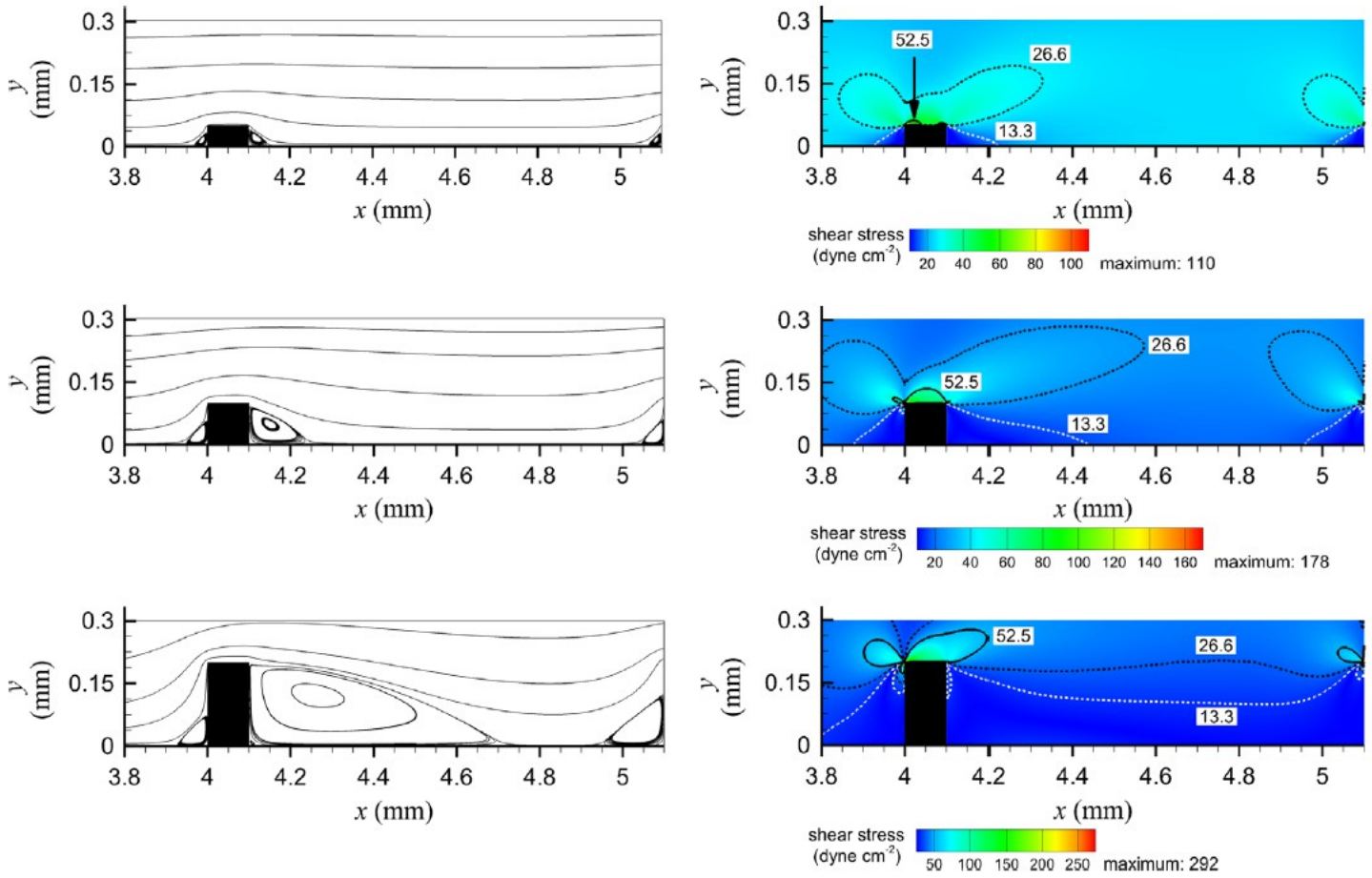
Impact of stent mis-sizing and mis-positioning on coronary fluid wall shear and intramural stress

Effects of radial geographical miss or stent oversizing: 10% oversizing (*A*) and 20% oversizing (*B*)



Chen, Kassab, J Appl Physiol 115: 285–292, 2013

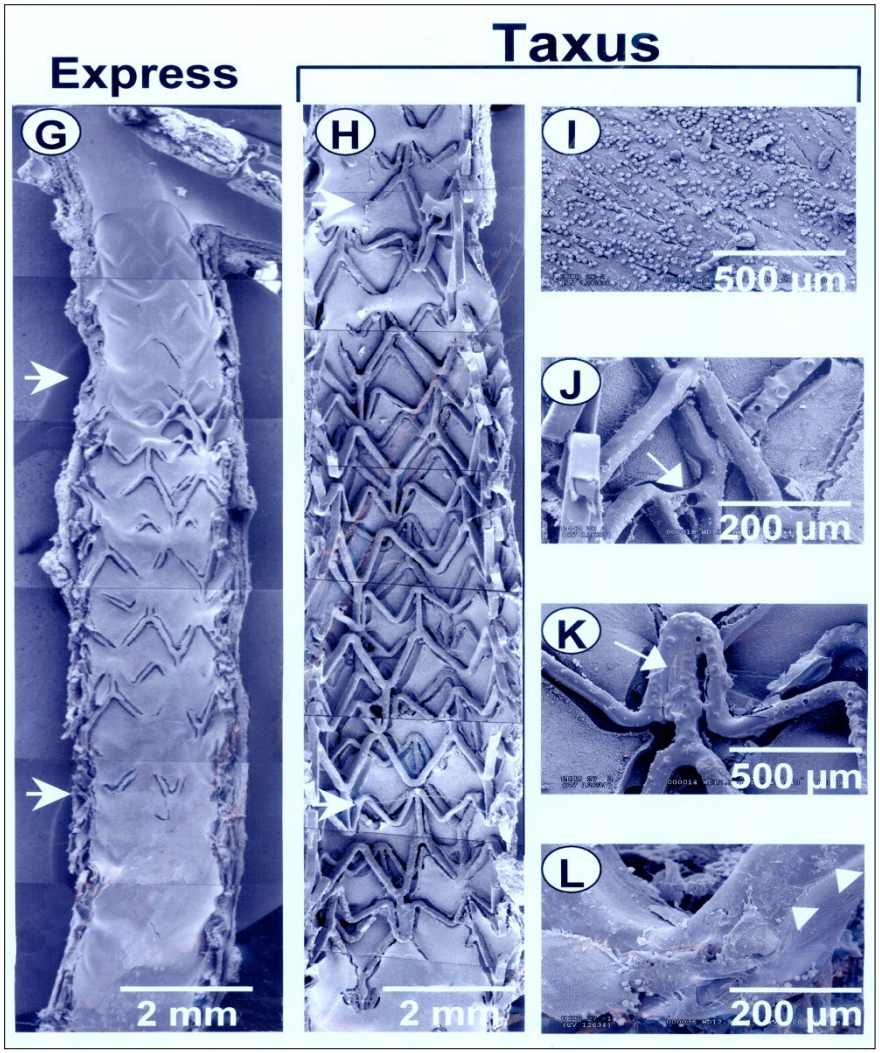
Simulation of the microscopic process during initiation of stent thrombosis



Streamlines (left panels) and shear stress contours (right panels) for different strut heights,including 50 (top panels), 100 (middle panels), and 200 mm (bottom panels)

J. Chesnutt, Computers in Biology and Medicine 56 (2015) 182–191

Excess of Metal

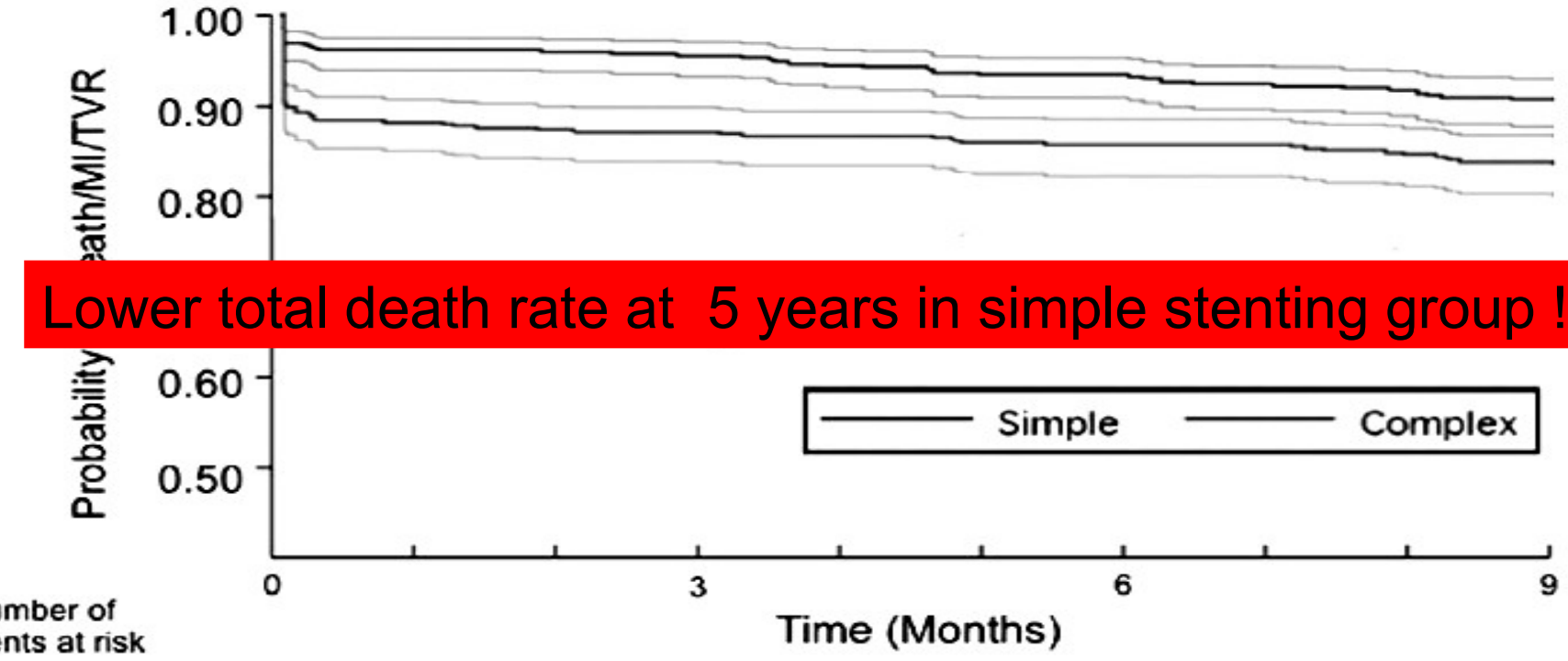


Finn et al ACC 2005

Clinical datas about non-Left-Main bifurcation stenting

Simple or Complex Stenting for Bifurcation Coronary Lesions: A Patient-Level Pooled-Analysis of Nordic 1 and BBC

Kaplan-Meier freedom from the composite event



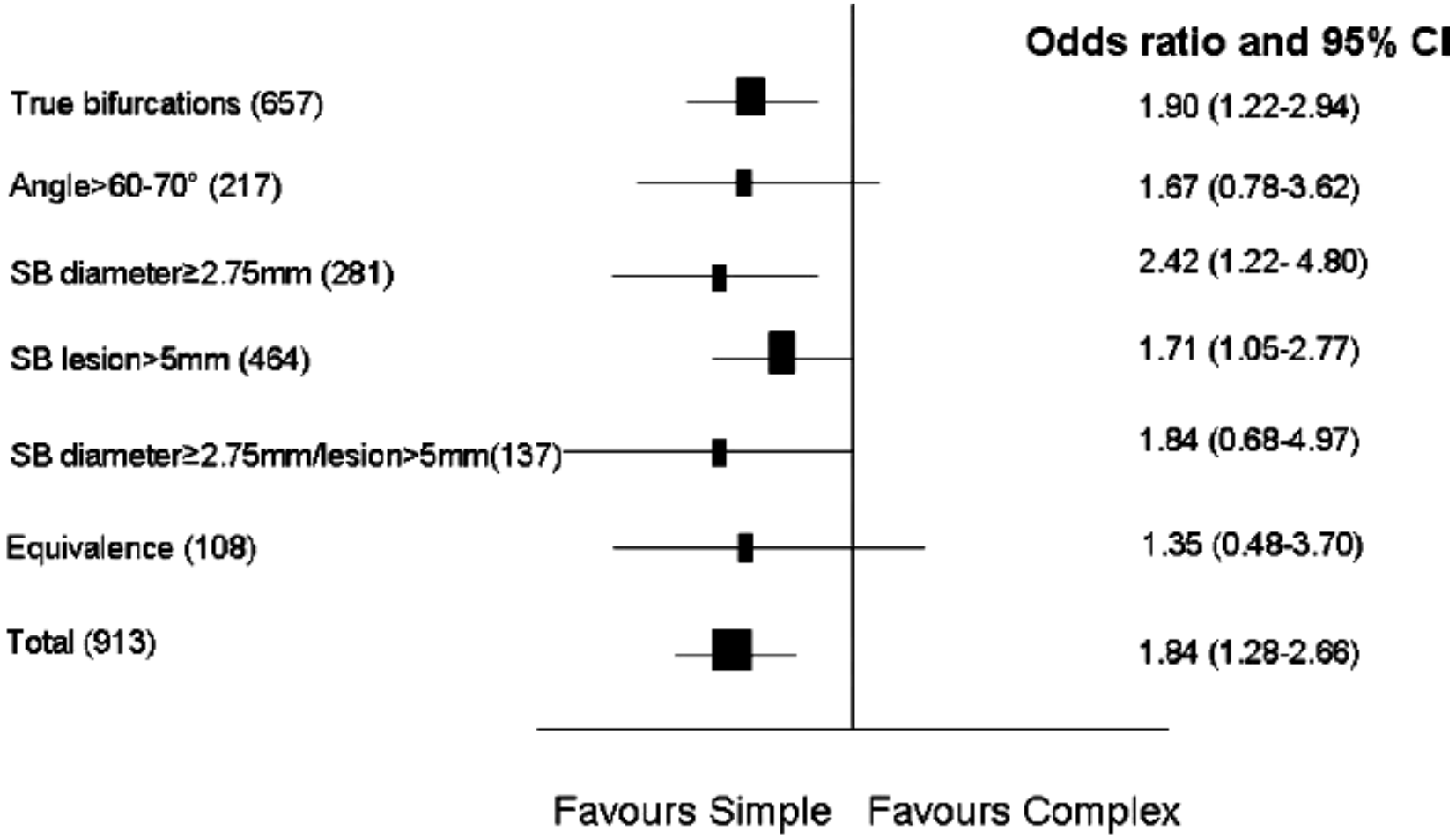
Lower total death rate at 5 years in simple stenting group !

Number of patients at risk				
Complex	456	396	389	377
Simple	457	433	422	411

Behan Circ Cardiovasc Interv. 2011;4:57-64

Simple or Complex Stenting for Bifurcation Coronary Lesions : A Patient-Level Pooled-Analysis of Nordic 1 and BBC

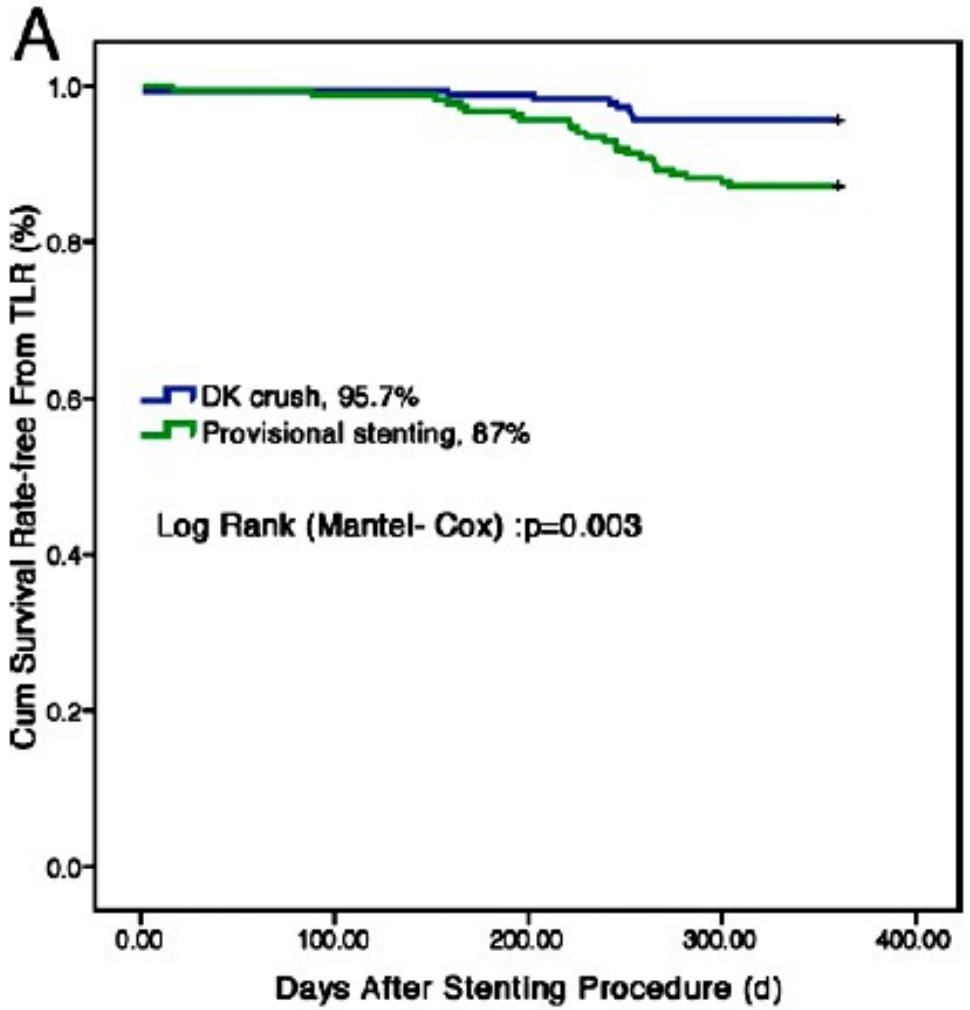
Primary outcome for individual subgroups



Behan Circ Cardiovasc Interv. 2011;4:57-64

Randomized study comparing Double Kissing Crush with Provisional Stenting for treatment of coronary bifurcation lesions: DK-CRUSH-II

Comparison of Survival Rate Free From TLR Between DK Crush and PS Groups



SL Chen J. Am. Coll. Cardiol. 2011;57;914-920

Randomized study comparing Double Kissing Crush with Provisional Stenting for treatment of coronary bifurcation lesions: DK-CRUSH-II

Clinical outcome (2)

	DK Group (n = 185)	PS Group (n =185)	p Value
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

Follow-up coronary angiography at 8 months

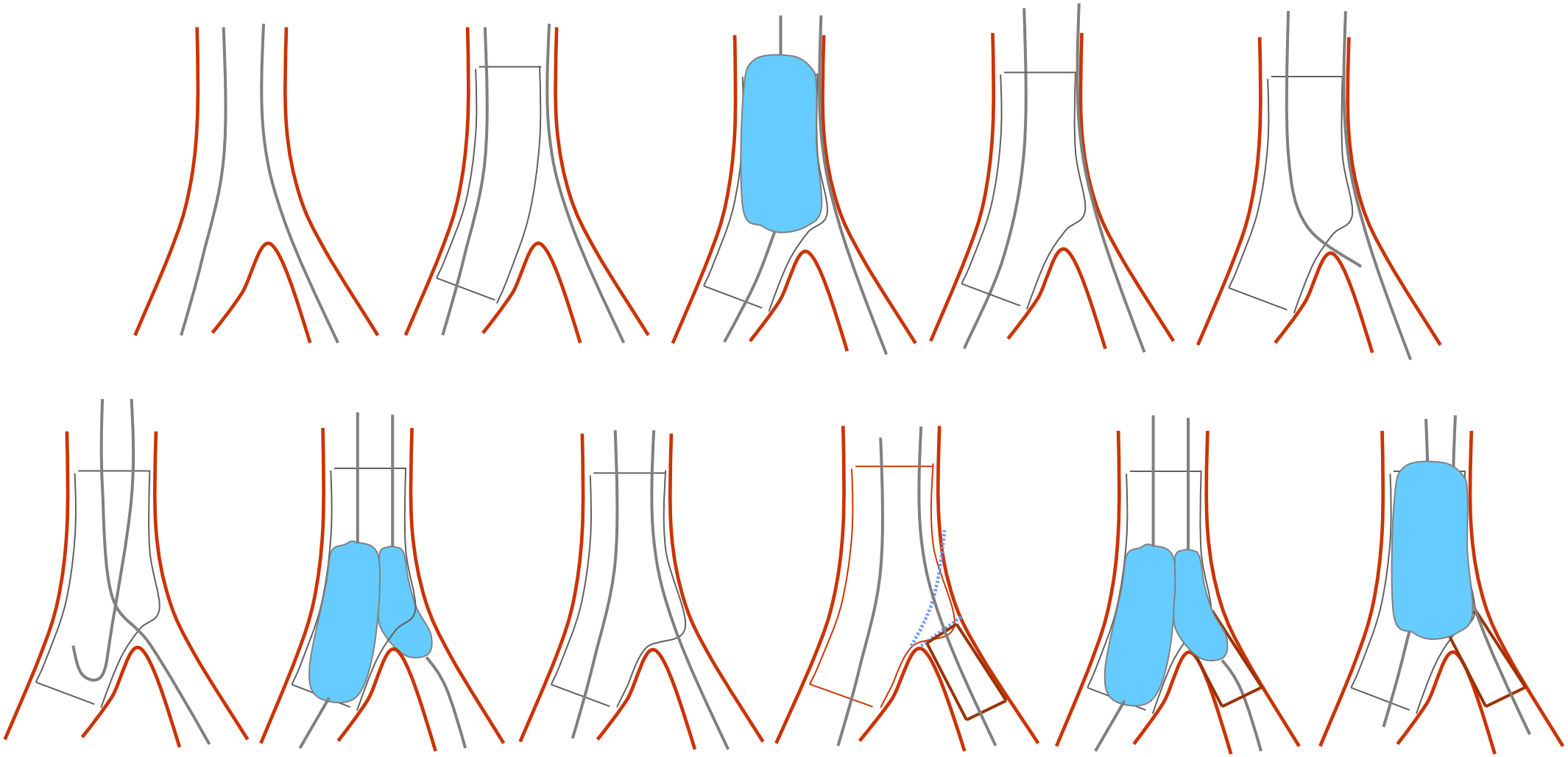
SL Chen J. Am. Coll. Cardiol. 2011;57;914-920

Bifurcation lesion treatment principles

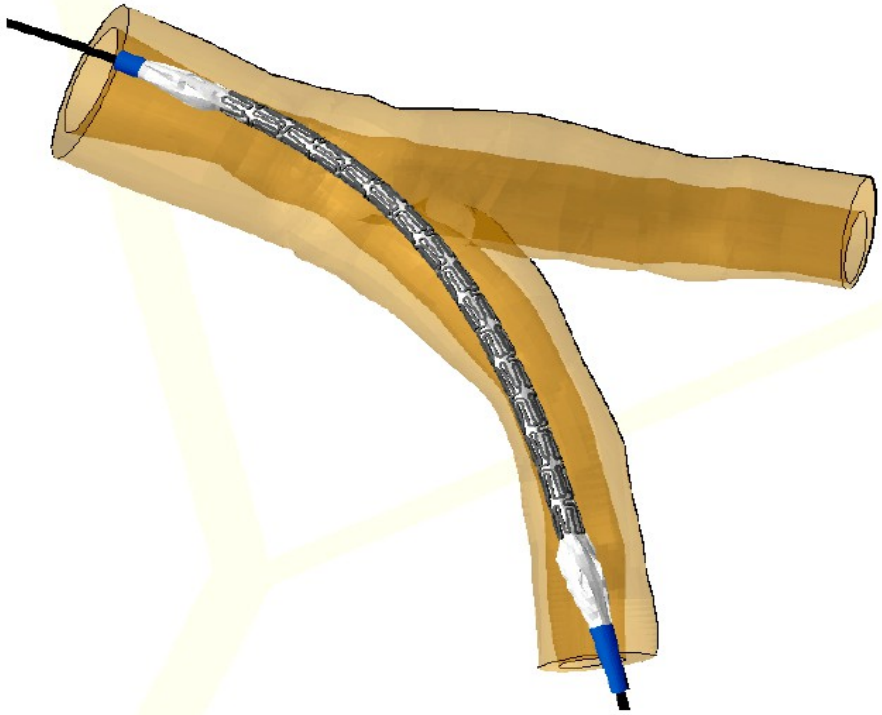
1. **Limit the number of stents (carena)**
2. **Apposition (no overlapping ?)**
3. **Respect the original anatomy (speculative)**

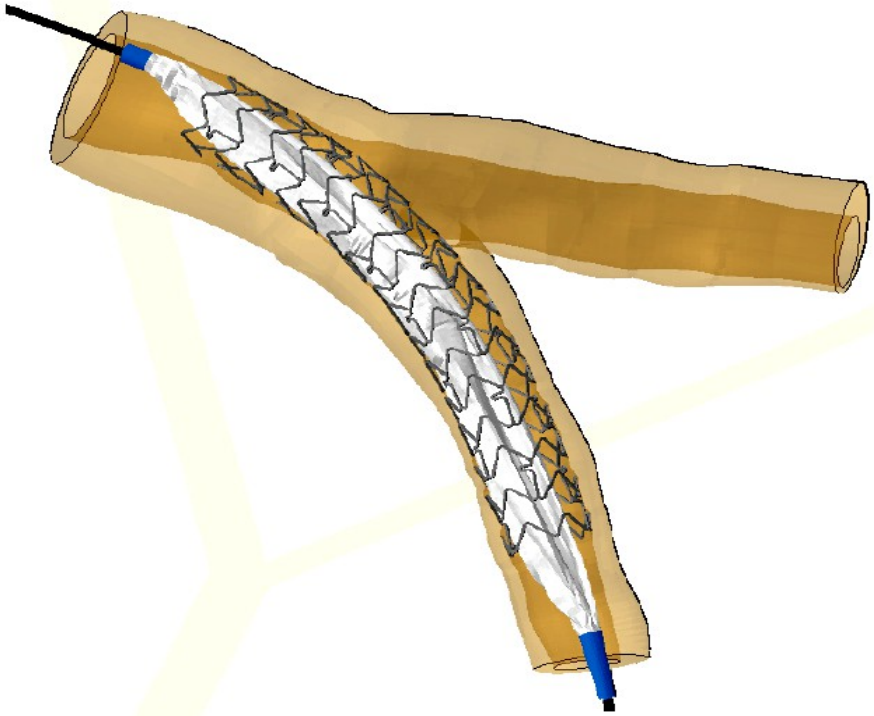
Provisional SB stenting strategy

Provisional Side Branch Stenting



Patient's specific simulation





Predictors and Outcomes of SB Occlusion After Main Vessel Stenting in Coronary Bifurcation Lesions Results From the COBIS II Registry

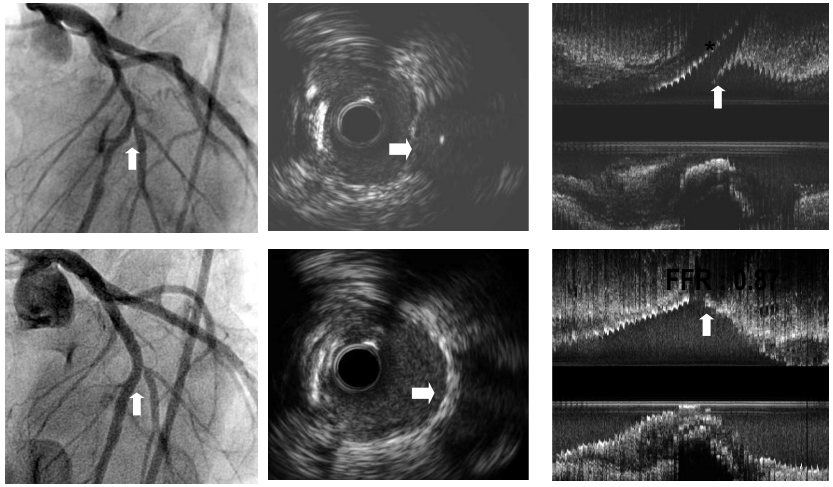
Independent Predictors of SB Occlusion

Variable	Odds Ratio (95% CI) (range)	p Value
Pre-procedural %DS of the SB ≥50%	2.34 (1.59–3.43)	<0.001
Pre-procedural %DS of the proximal MV ≥50%	2.34 (1.57–3.50)	0.03
SB lesion length	1.03 (1.003–1.06)	<0.001
Acute coronary syndrome	1.53 (1.06–2.19)	0.02
Left main lesions (vs. non-left main lesions)	0.34 (0.16–0.72)	0.005

Hahn, J Am Coll Cardiol 2013;62:1654–9

IVUS findings of Carina shift vs. Plaque shift

carina shift



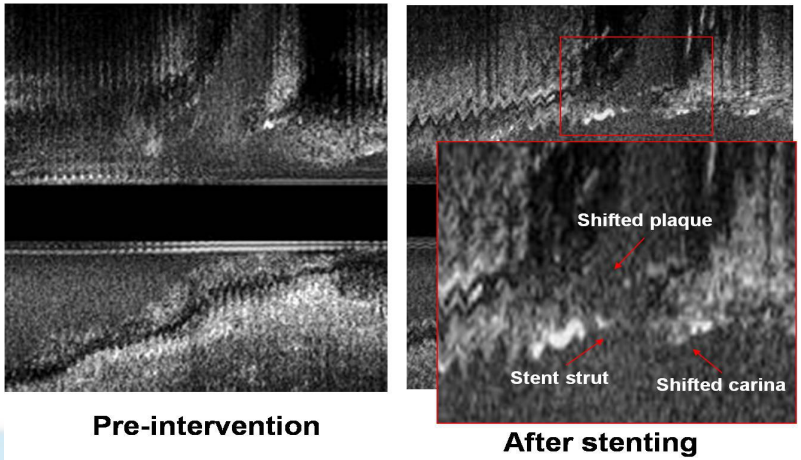
Angiogram | Cross-sectional IVUS | Longitudinal IVUS

Before MB stent

After MB stent

* : A 0.014 inch coronary wire

Both plaque shift and carina shift ➔ Aggravation of SB luminal narrowing after MB stent implantation



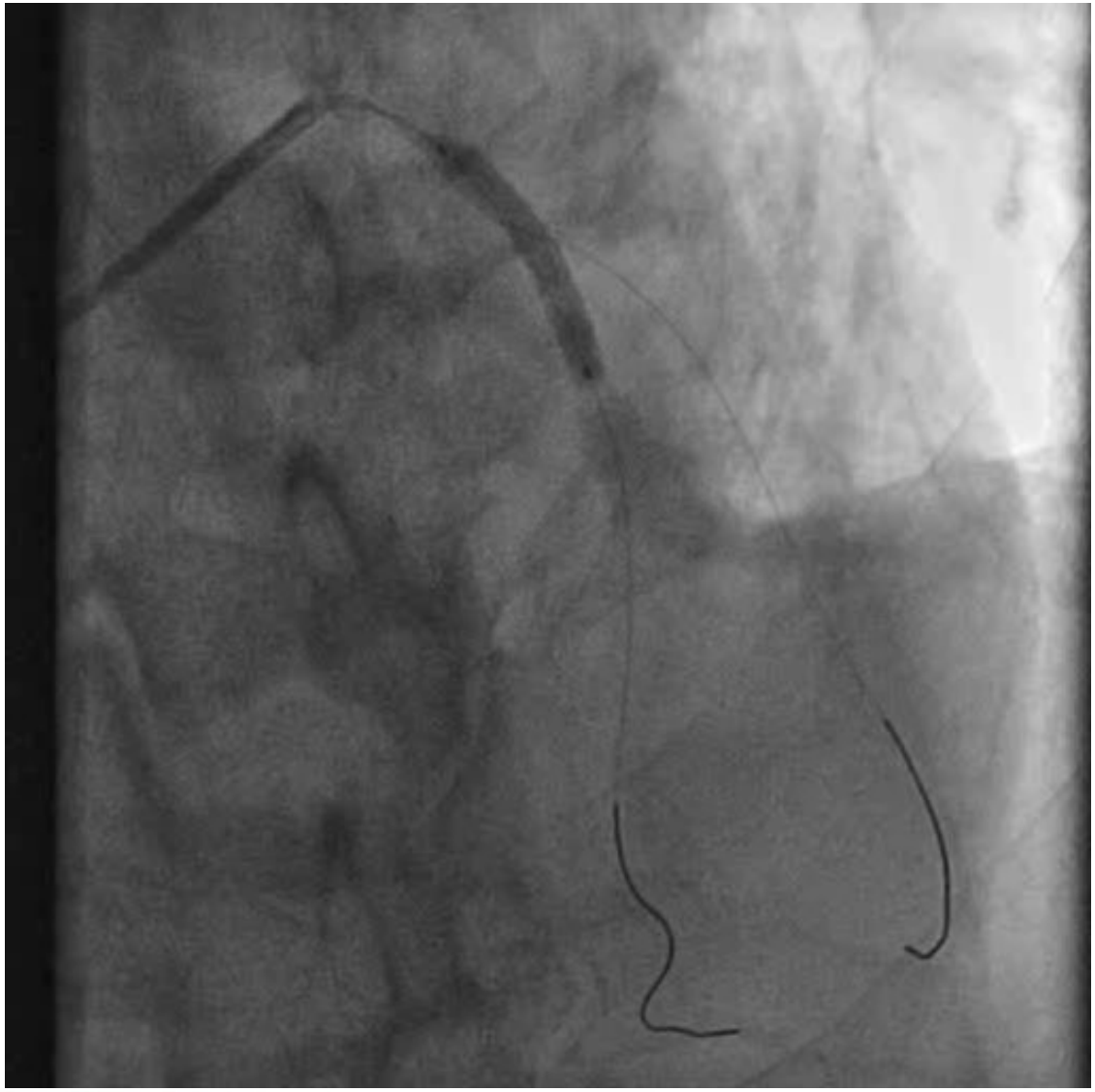
Pre-intervention

After stenting

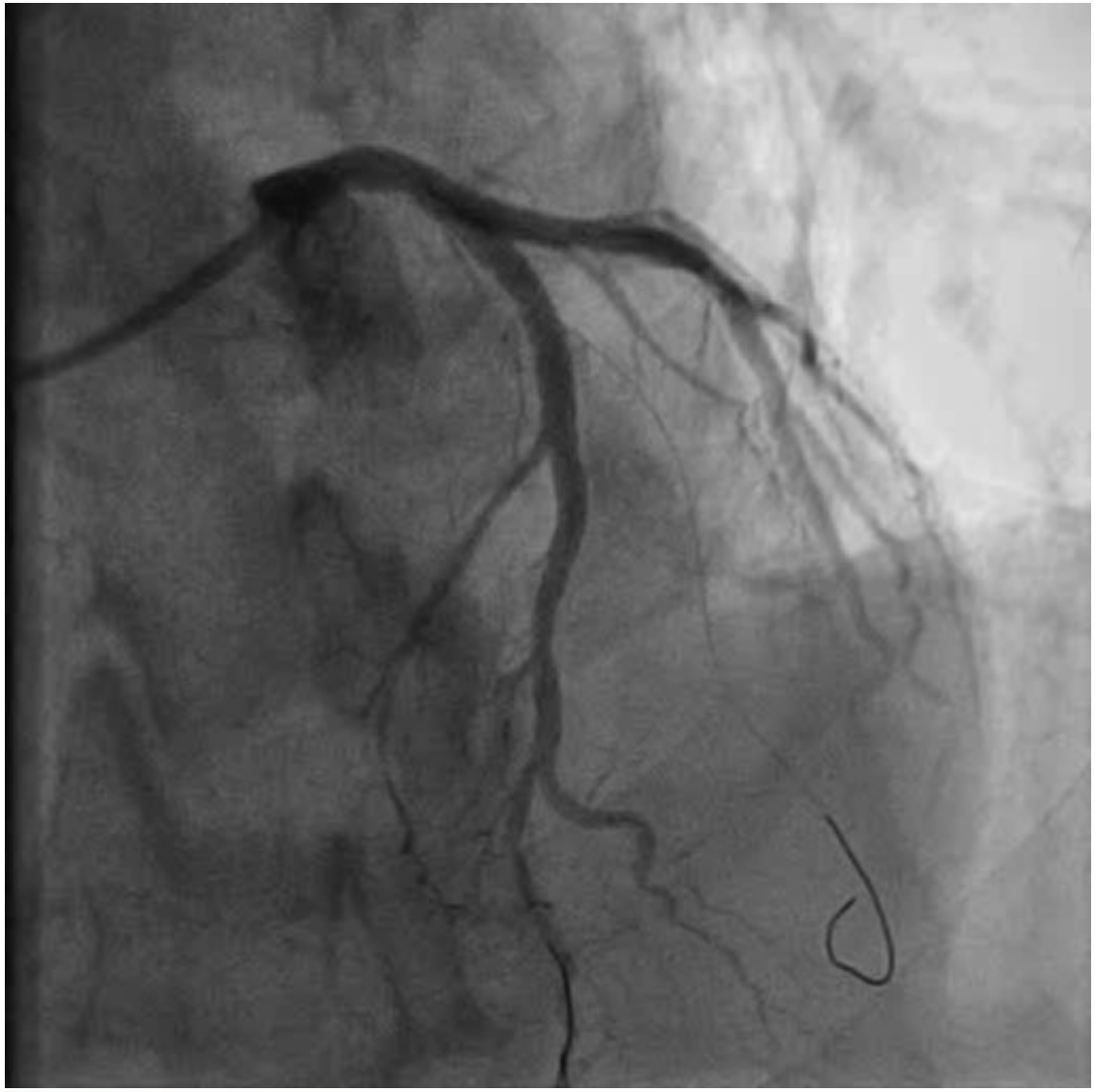
from Bon Kwon Koo, EBC

SB salvage technique

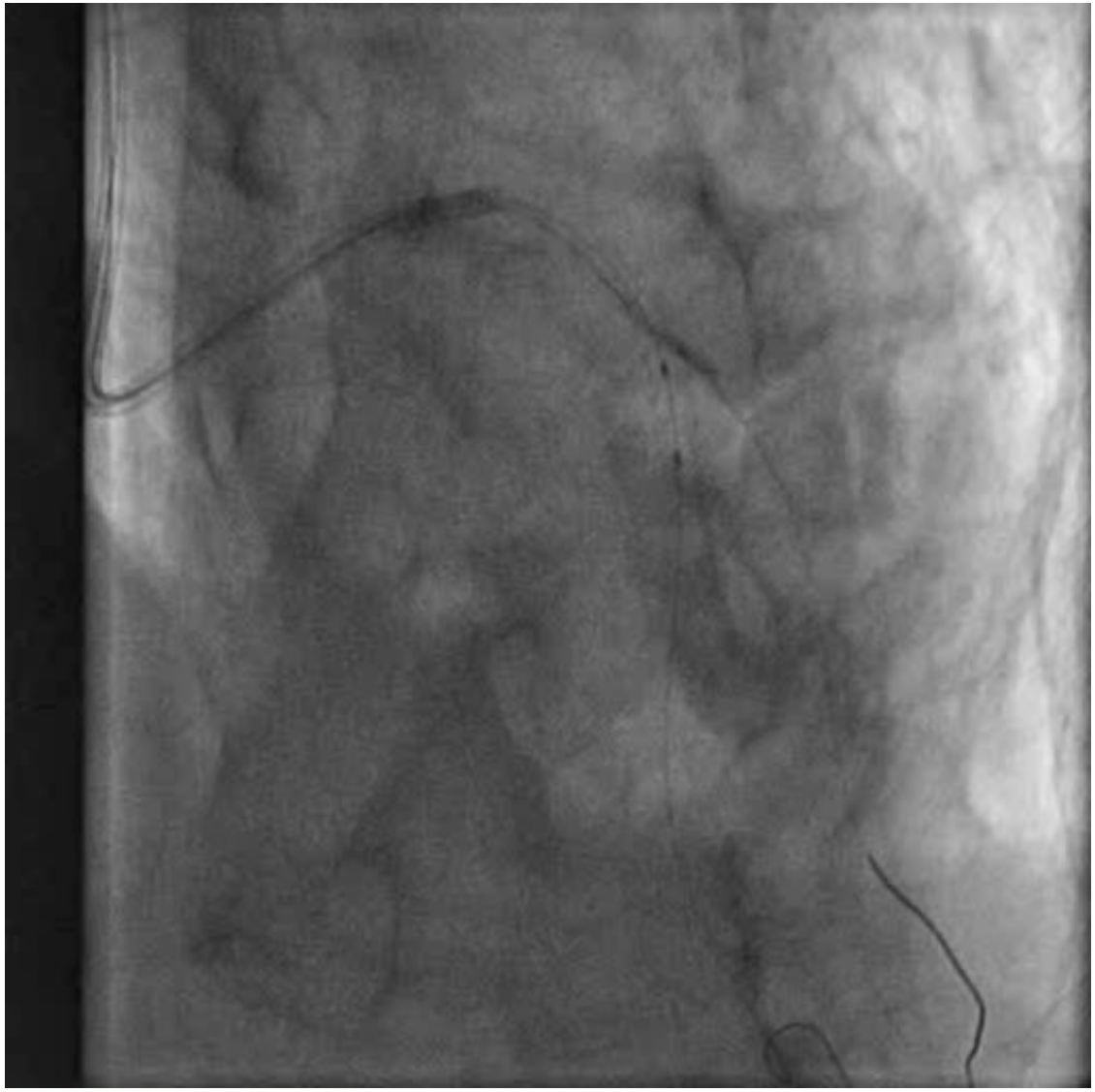
SB salvage technique



SB salvage technique



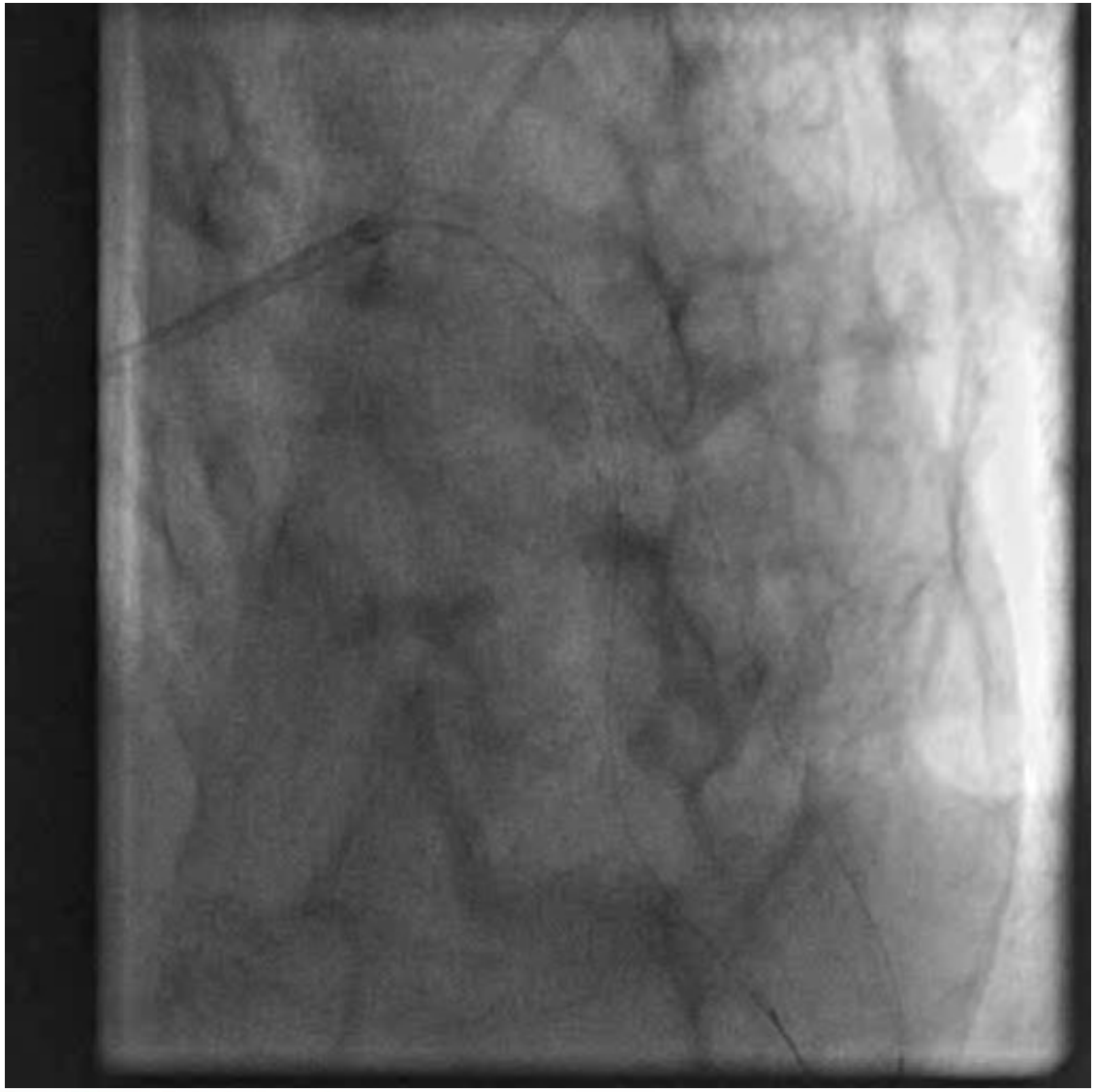
SB salvage technique



SB salvage technique

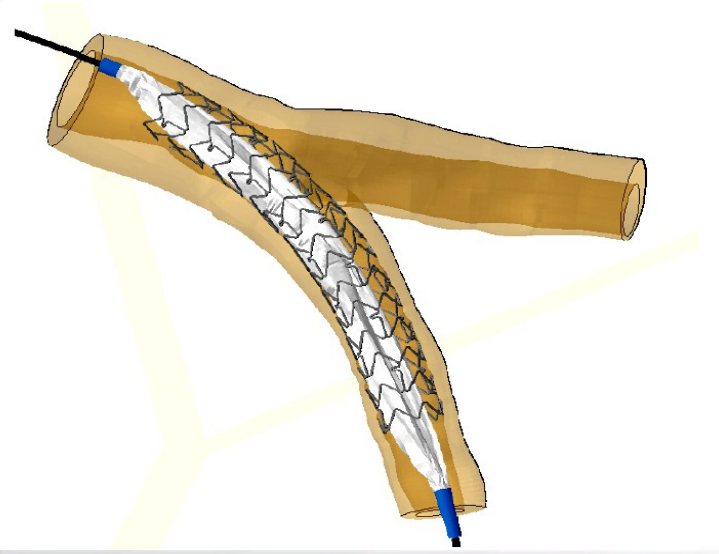
SB salvage technique

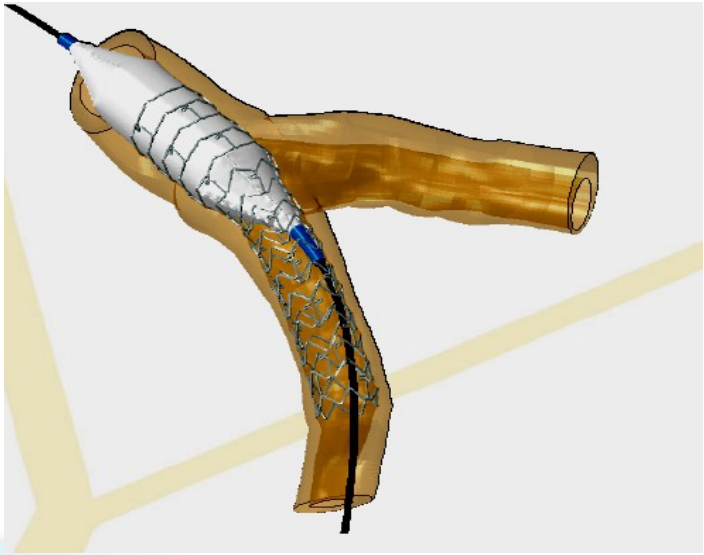
SB salvage technique

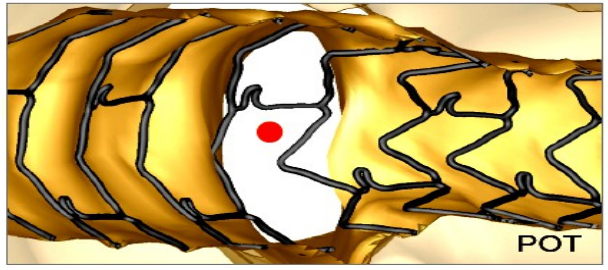


Why the POT ?

- To give to the cross over stent the 2 diameters of the 2 covered segment (respect the anatomy/function)
- To exchange safely the wires for kissing (no exchange outside the undeployed proximal part of the stent)
- Open the stent cells in front of the SB ostium (better access for balloon/stent)







Post-dilatation expansion and DES designs

Balloon Max. size		Element	Xience	Taxus	Integrity	BioMatrix	Cypher
4.0	2.25	Very Small WH (2 cells) *max exp.: 3.0mm*	Medium Workhorse (6 crowns , 3 cells) *max. expansion: 4.4mm*	Small workshorse (6 crowns, 2 cells) *max expansion: 3.4mm*	Small workhorse (7crowns, 2 cells*) *max expansion: 4.9mm* **1.5 cell in Resolute*	Medium workhorse (6 crowns, 2 cells) max expansion: 4.6mm	Medium workhorse (6 crowns, 6 cells) max expansion: 4.7mm
	2.50	Small workshorse (8 crowns, 2 cells) *max expansion : 3.8mm*					
5.0	2.75			Medium Workhorse (9 crowns, 3 cells) *max expansion: 4.8mm*			
	3.00	Medium Workhorse (8 crowns, 2 cells) *max expansion : 4.4mm*			Medium workhorse (10 crowns, 2 cells) *max expansion : 5.4mm*		
	3.50		Large workhorse: (9 crowns , 3 cells) *max expansion : 5.6mm*			Large workhorse (9 crowns, 3 cells) max expansion: 5.9mm	Large workhorse (7 crowns, 7 cells) max expansion: 5.8mm
6.0	4.00	Large workhorse (10 crowns, 2 cells) *max expansion: 5.7mm*		Large workhorse (9 crowns, 3 cells) *max expansion: 6.0mm*			
	4.50						
	5.00						

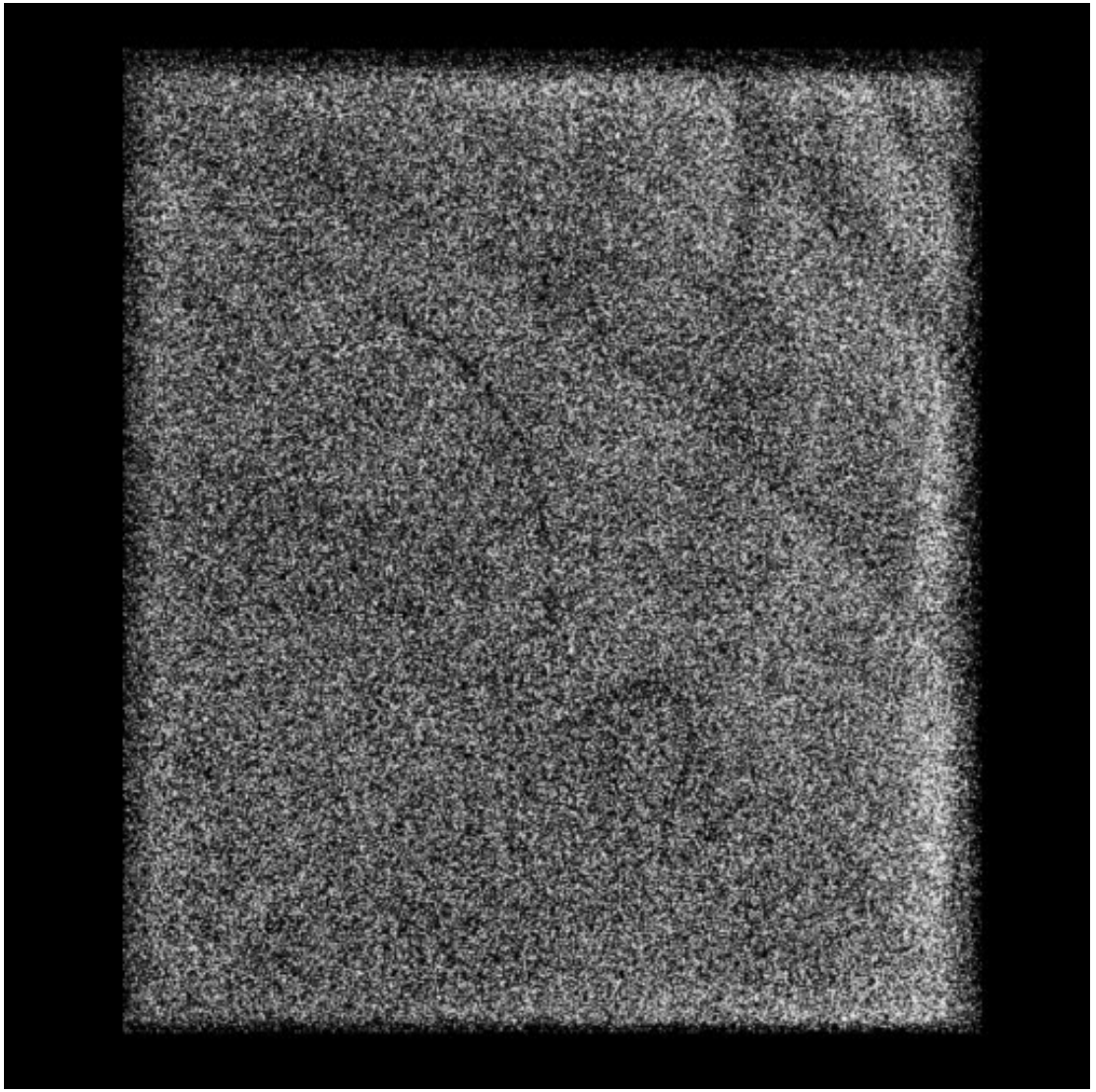
- *Minimal stent LD excluding struts*
- *Limited to 6.0 mm SC balloon at 14 ATM*

- *Stent MLD (inner lumen) achieved after stepwise overexpansion and 2x final post-dilatation*

Foin, Sen, Di Mario, Davies. 2012

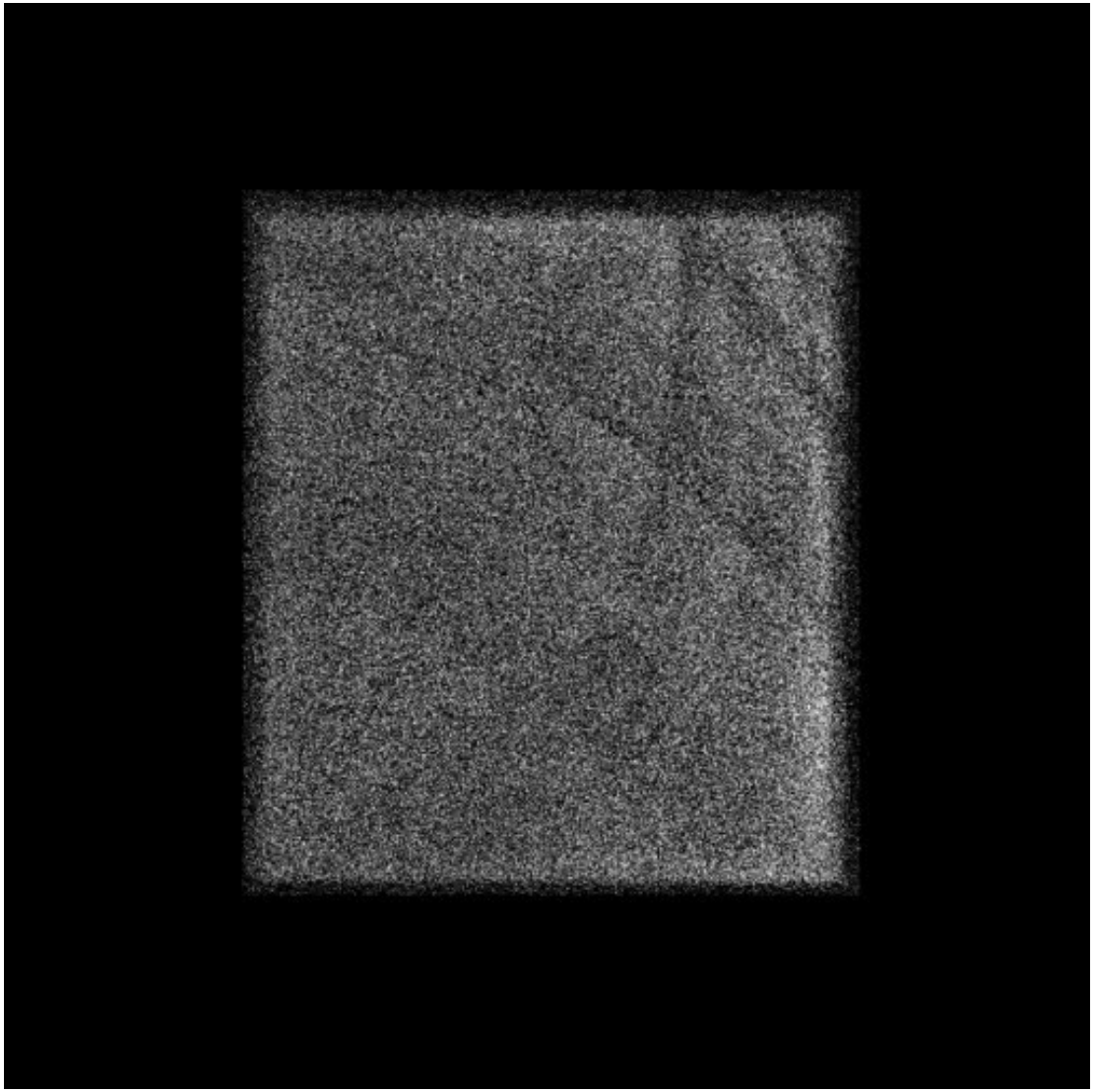
Wire exchange

MB wire: long shape !

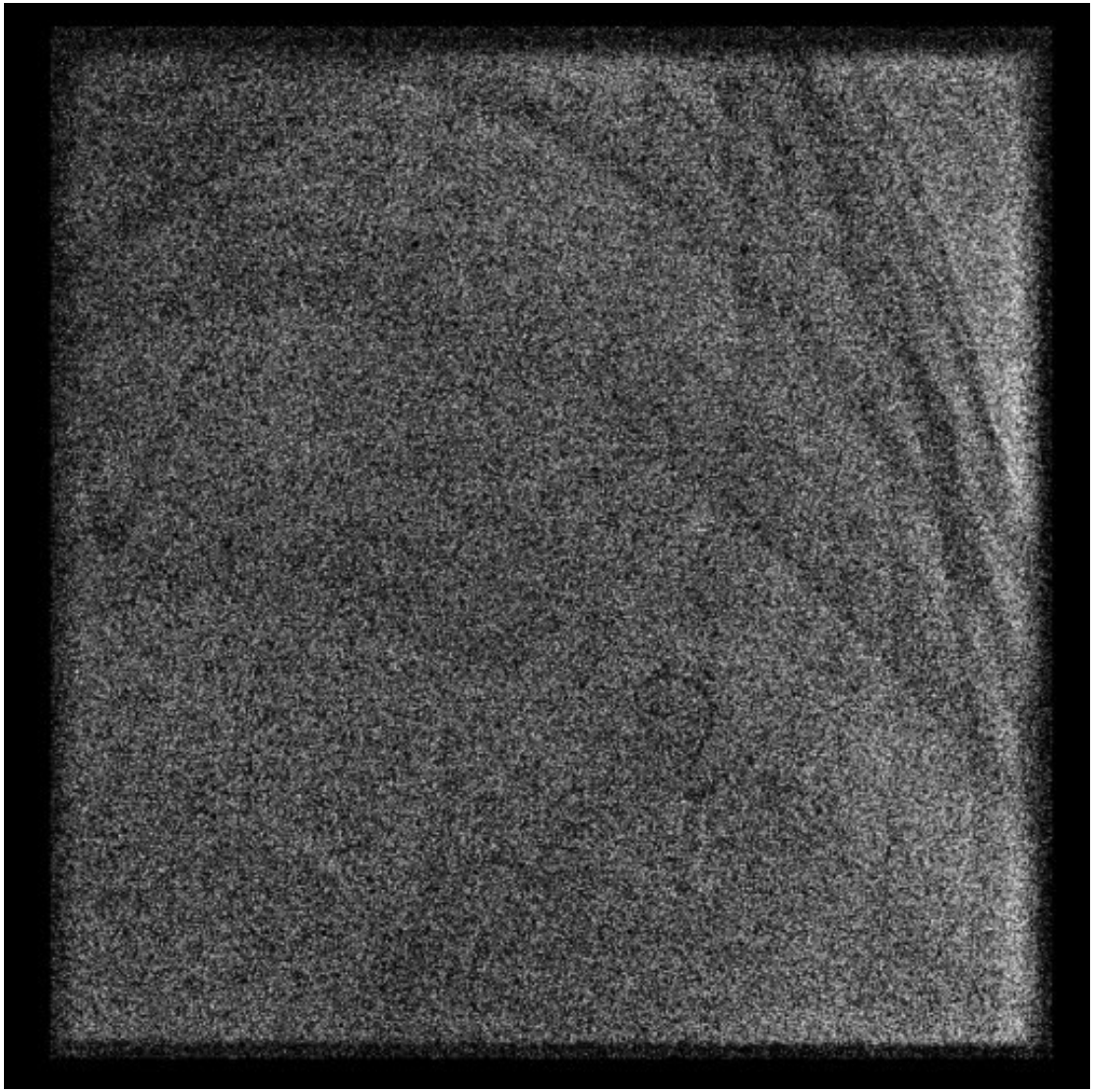


Wire exchange

MB wire: long shape !

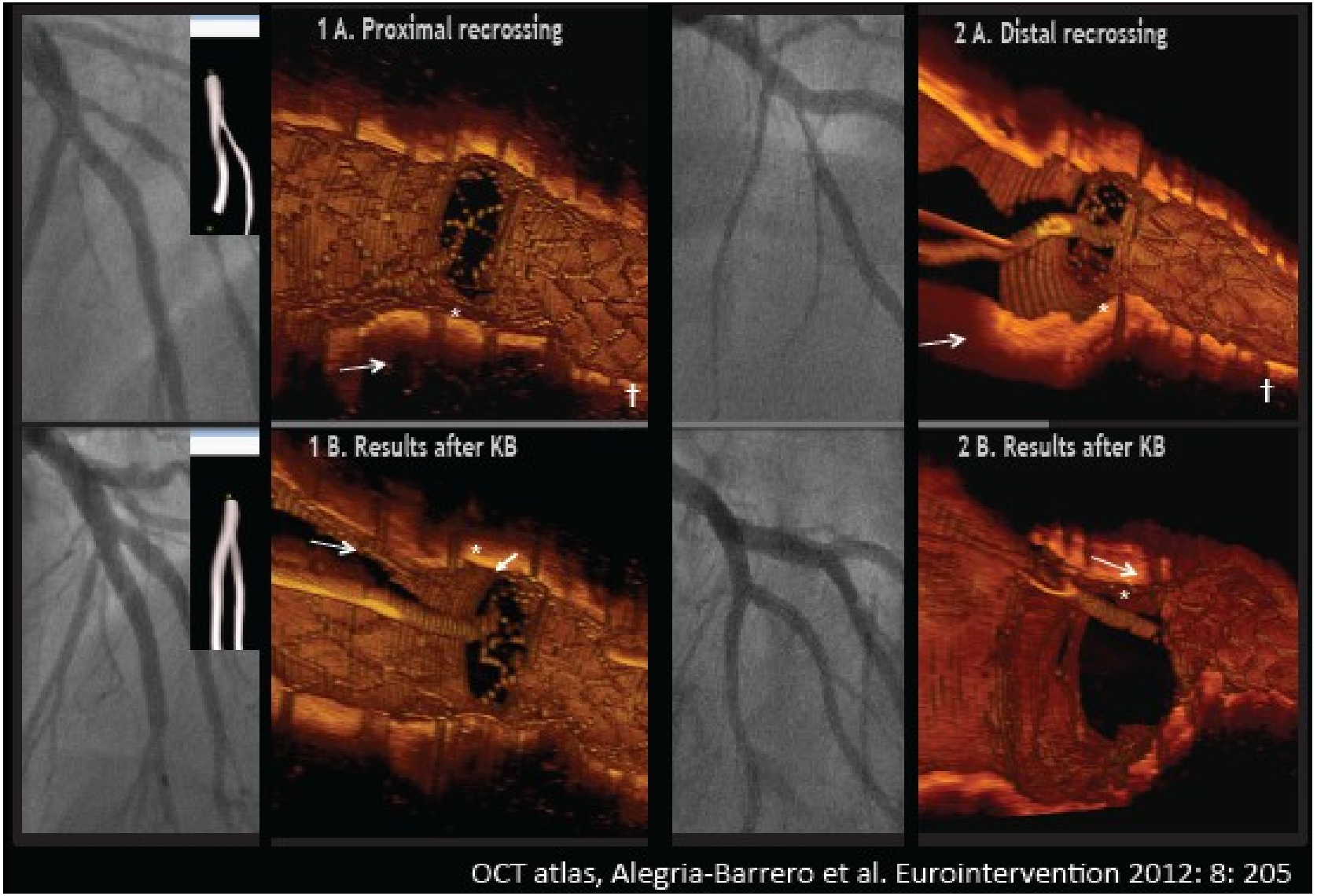


Wire exchange

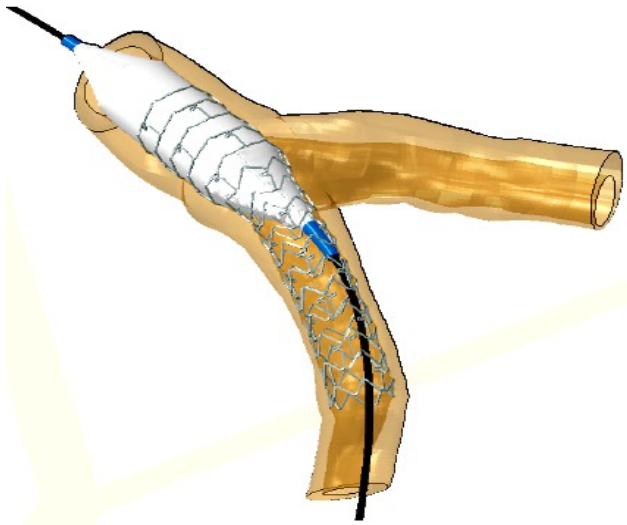


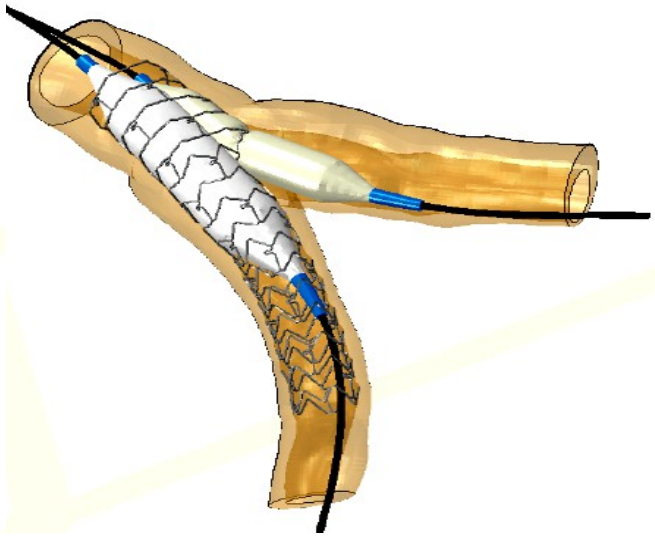
SB wire: short loop !

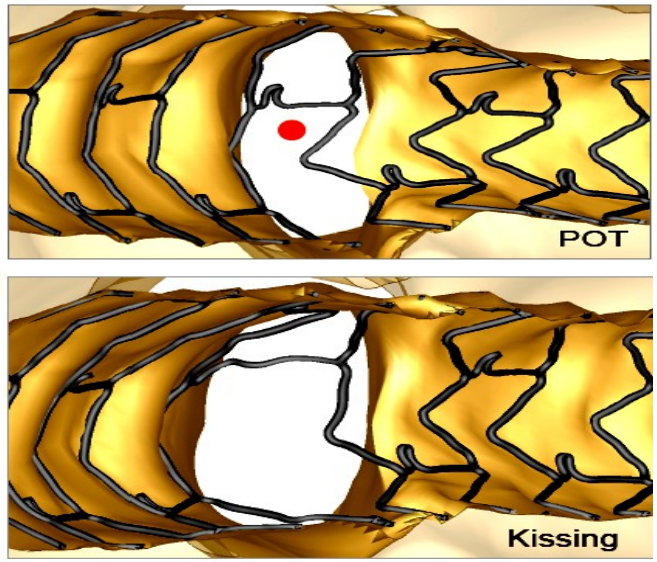
Proximal vs distal recrossing toward side branch



POT ± Kissing balloon inflation







Long-term Clinical outcomes of final KB in coronary bifurcation lesions treated with the 1-stent technique: results from the COBIS II registry

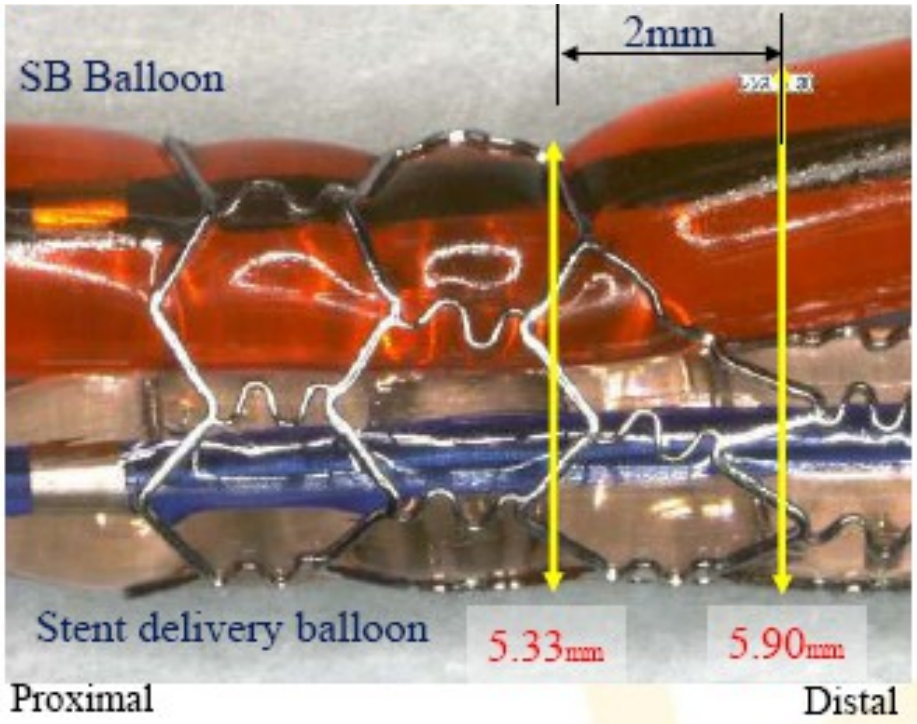
Clinical Outcomes in FKB Group Compared With Non-FKB Group in Propensity-Matched Population During FU Period

	FKB (n = 545)	Non-FKB (n = 545)	Unadjusted HR (95% CI)	p Value	Adjusted HR* (95% CI)	p Value
All-cause death	17 (3.1)	20 (3.7)	0.67 (0.30-1.48)	0.32	0.68 (0.28-1.63)	0.39
Cardiac death	3 (0.6)	8 (1.5)	0.43 (0.11-1.66)	0.22	0.50 (0.11-2.29)	0.37
MI	4 (0.7)	5 (0.9)	0.50 (0.09-2.73)	0.42	0.18 (0.01-20.36)	0.48
Stent thrombosis†	3 (0.6)	4 (0.7)	0.72 (0.16-3.23)	0.67	0.77 (0.17-3.45)	0.73
Target lesion revascularization	32 (5.9)	43 (7.9)	0.53 (0.30-0.94)	0.03	0.51 (0.28-0.91)	0.02
Main vessel	31 (5.7)	40 (7.3)	0.53 (0.30-0.96)	0.04	0.51 (0.28-0.93)	0.03
Side branch	12 (2.2)	18 (3.3)	0.57 (0.24-1.36)	0.21	0.57 (0.24-1.37)	0.21
Both vessels	23 (4.2)	38 (7.0)	0.47 (0.25-0.88)	0.02	0.47 (0.25-0.90)	0.02
MACE‡	37 (6.8)	53 (9.7)	0.54 (0.32-0.89)	0.02	0.50 (0.30-0.85)	0.01

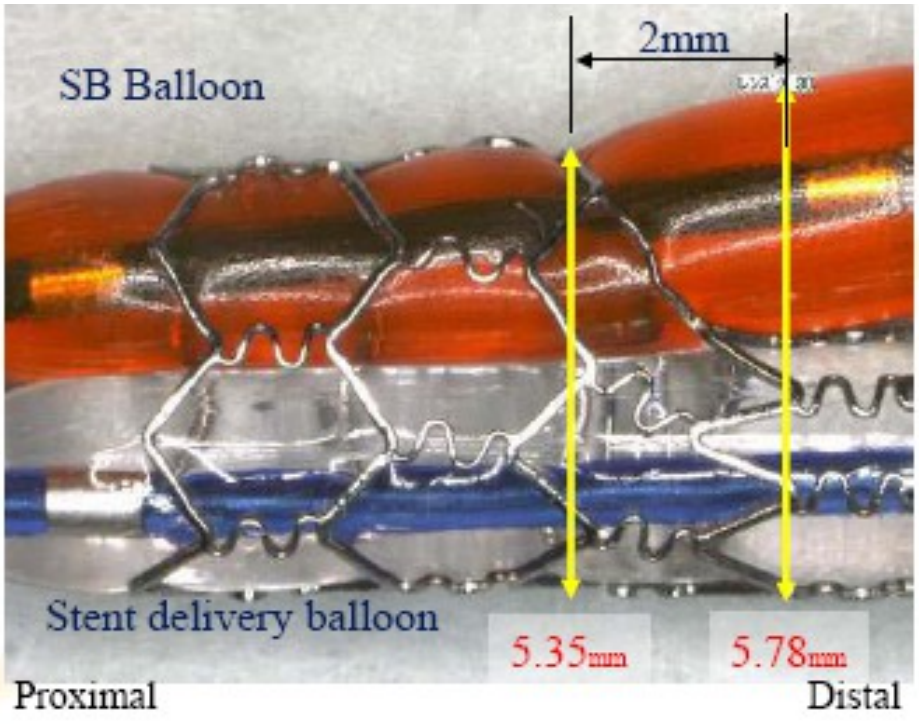
*Adjusted covariates include hypertension, history of coronary artery bypass graft, and distal RD of SB

CW Yu, J Am Coll Cardiol Intv 2015;8:1297–307

Non compliant balloons for kissing



Semi-Compliant Balloon
(Ryujin Plus, Terumo)



Non-Compliant Balloon
(Hiryu, Terumo)

Kinoshita, EBC 2009

XI European Bifurcation Club meeting – Athens – Greece – September 2015

(re)-Proximal Optimazing Technique in provisional coronary bifurcation stenting

The full version…

Gérard Finet MD PhD

On behalf of **F. derimay, P. Motreff, P. Guerin, P. Pilet, J. Ohayon, O. Darrement, G. Rioufol**

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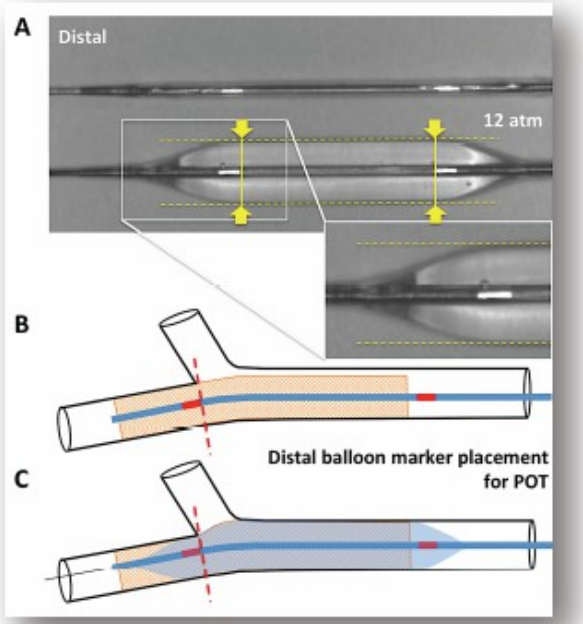
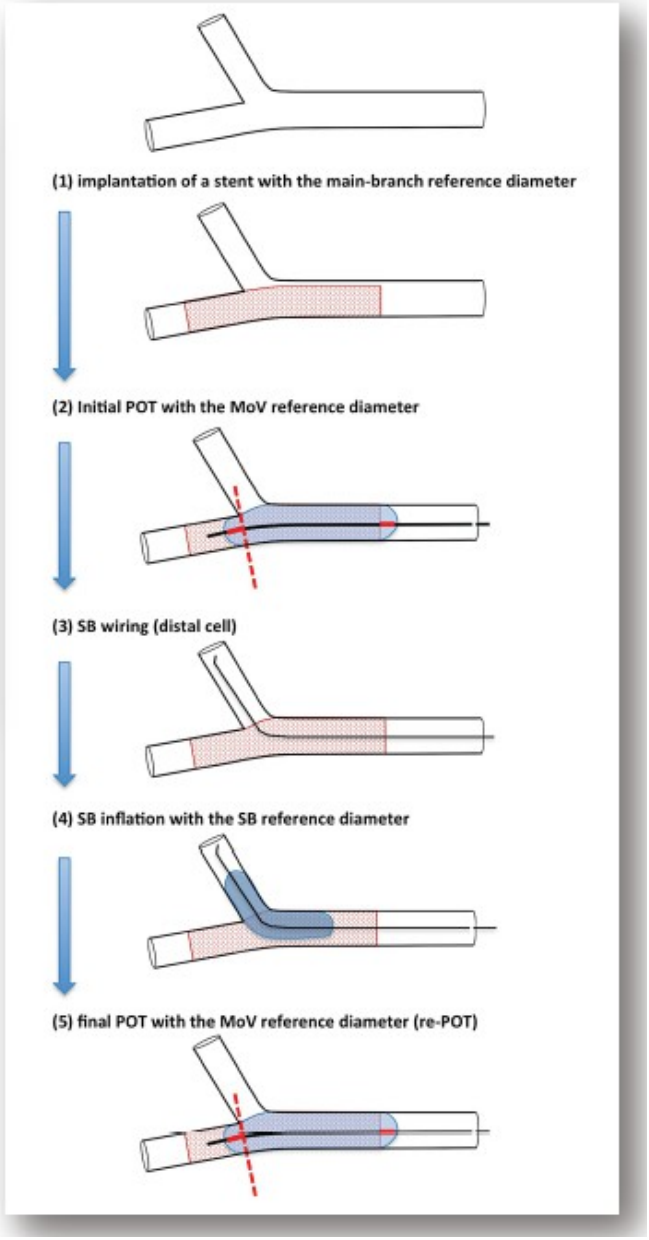
The rePOT sequence

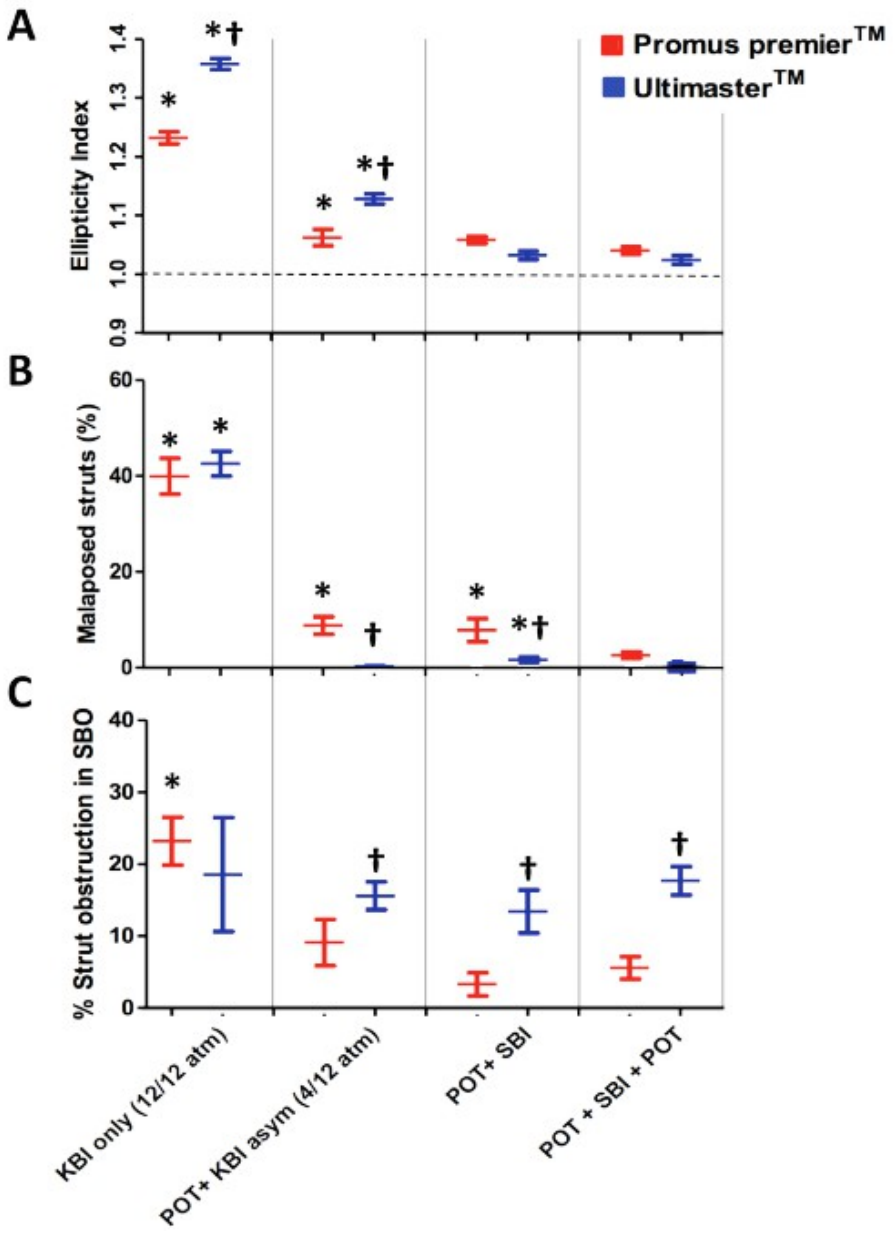
Balloon positioning for the POT





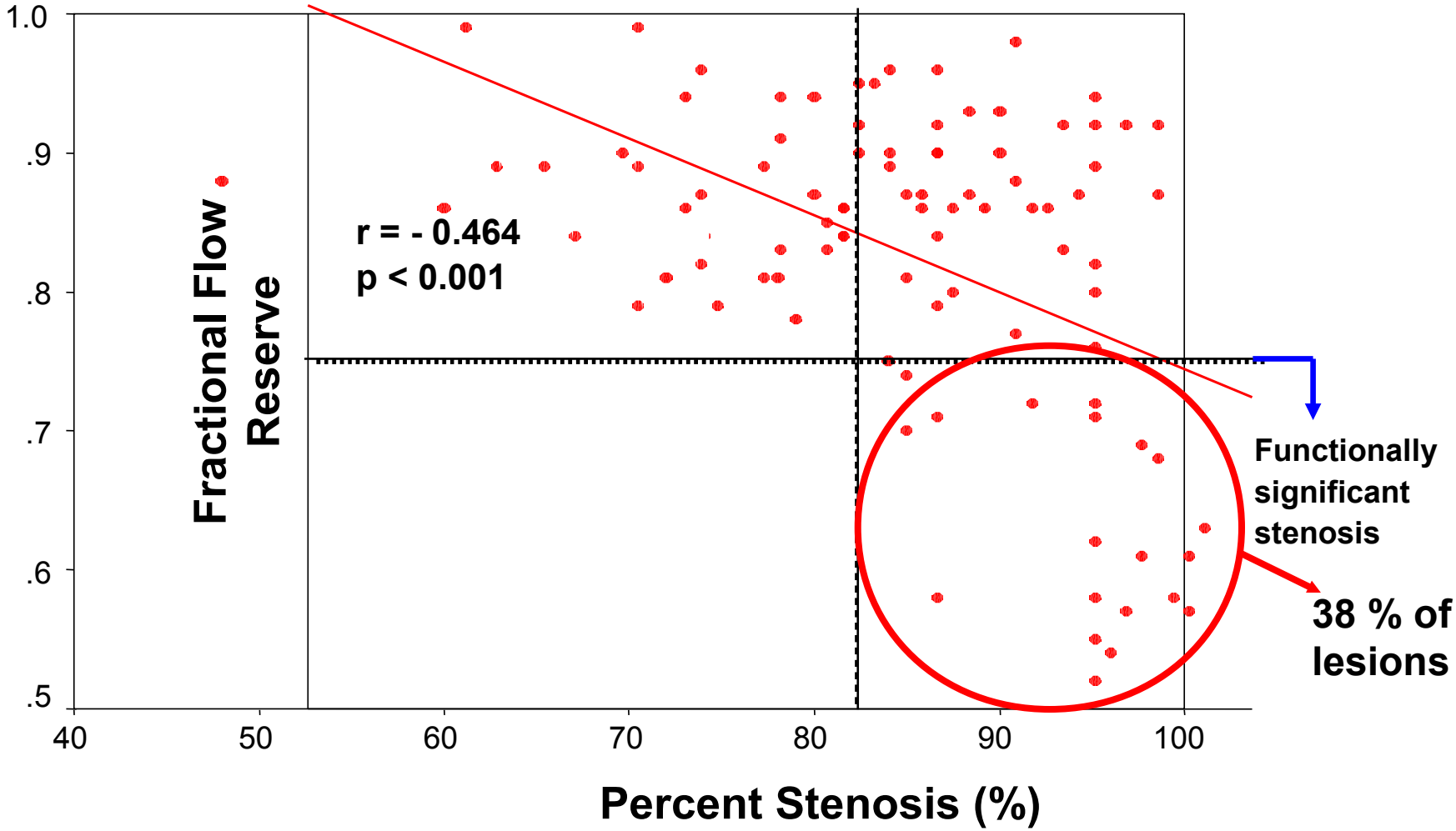
RESULTS

Comparison of ellipticity index, global malapposed strut ratio (%), and strut obstruction ratio in side branch ostium (SBO) (%)



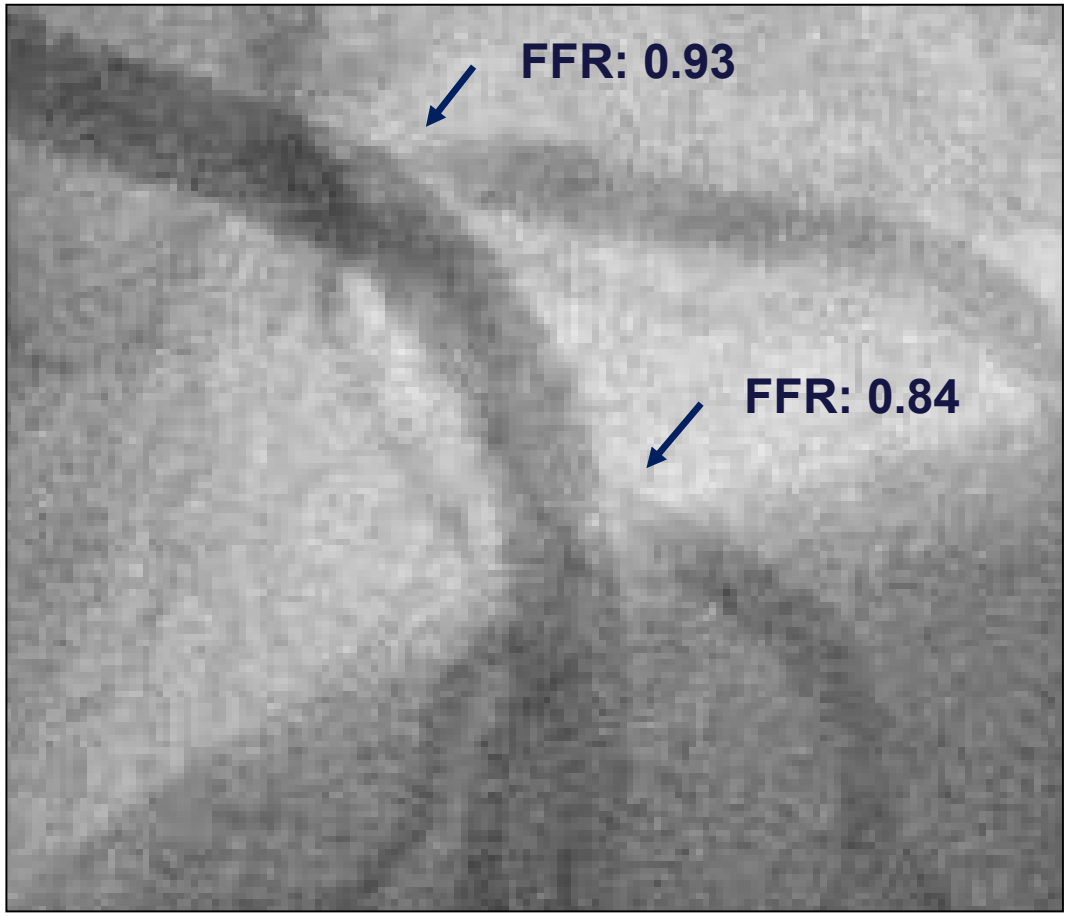
Significant Post Stenting SB Stenosis:QCA vs FFR

(jailed side branch lesions, n=94)



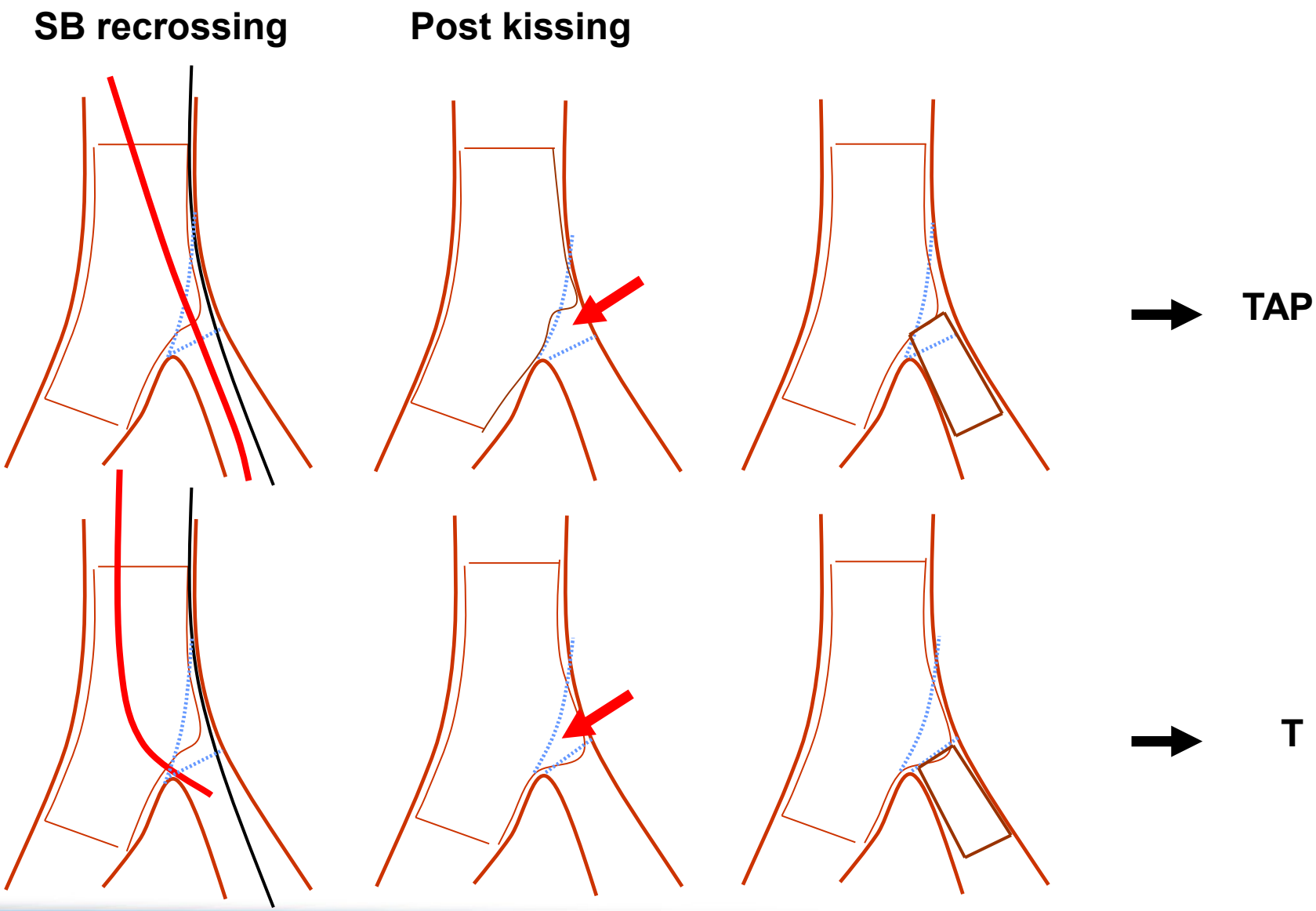
Bon-Kwon Koo et al JACC 2005; 46: 633-7

SB Ostial Lesions Are Overestimated

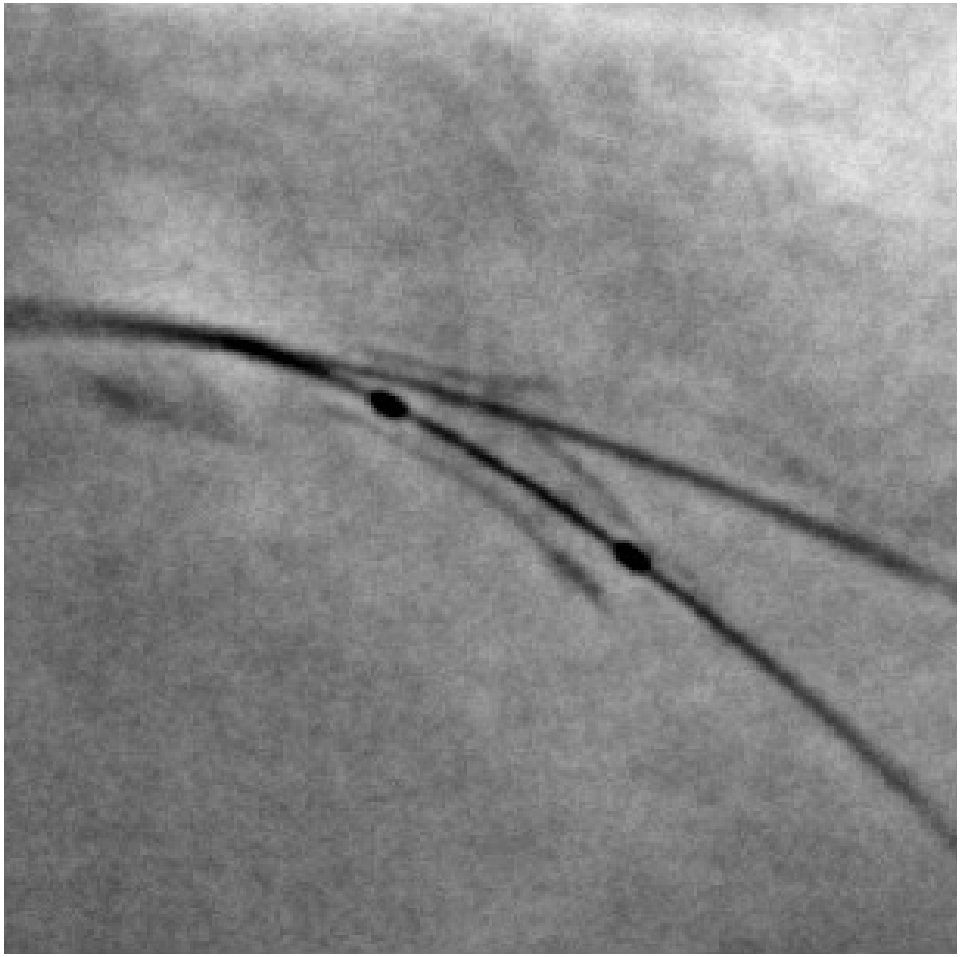


Koo et al. EBC 2006

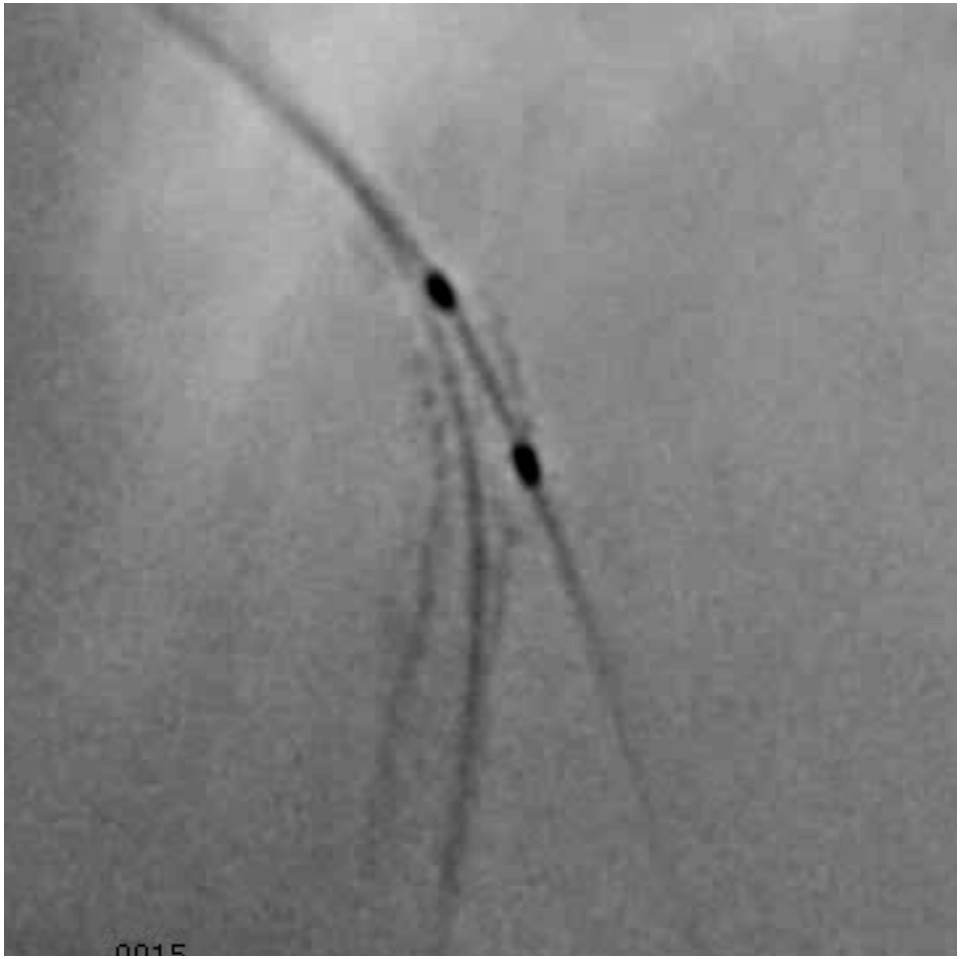
T or TAP ?



T or TAP ? (stent boost)



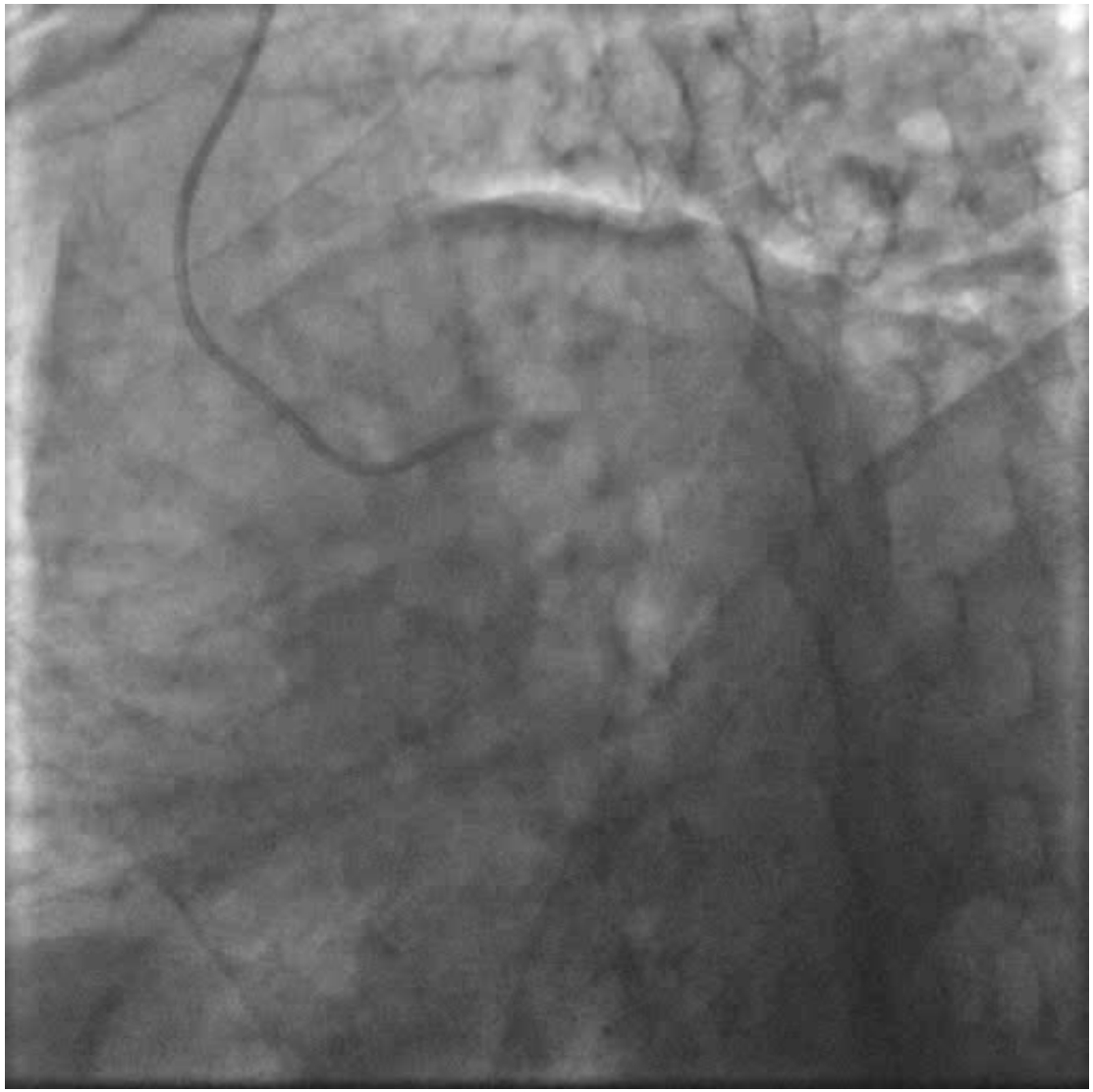
T



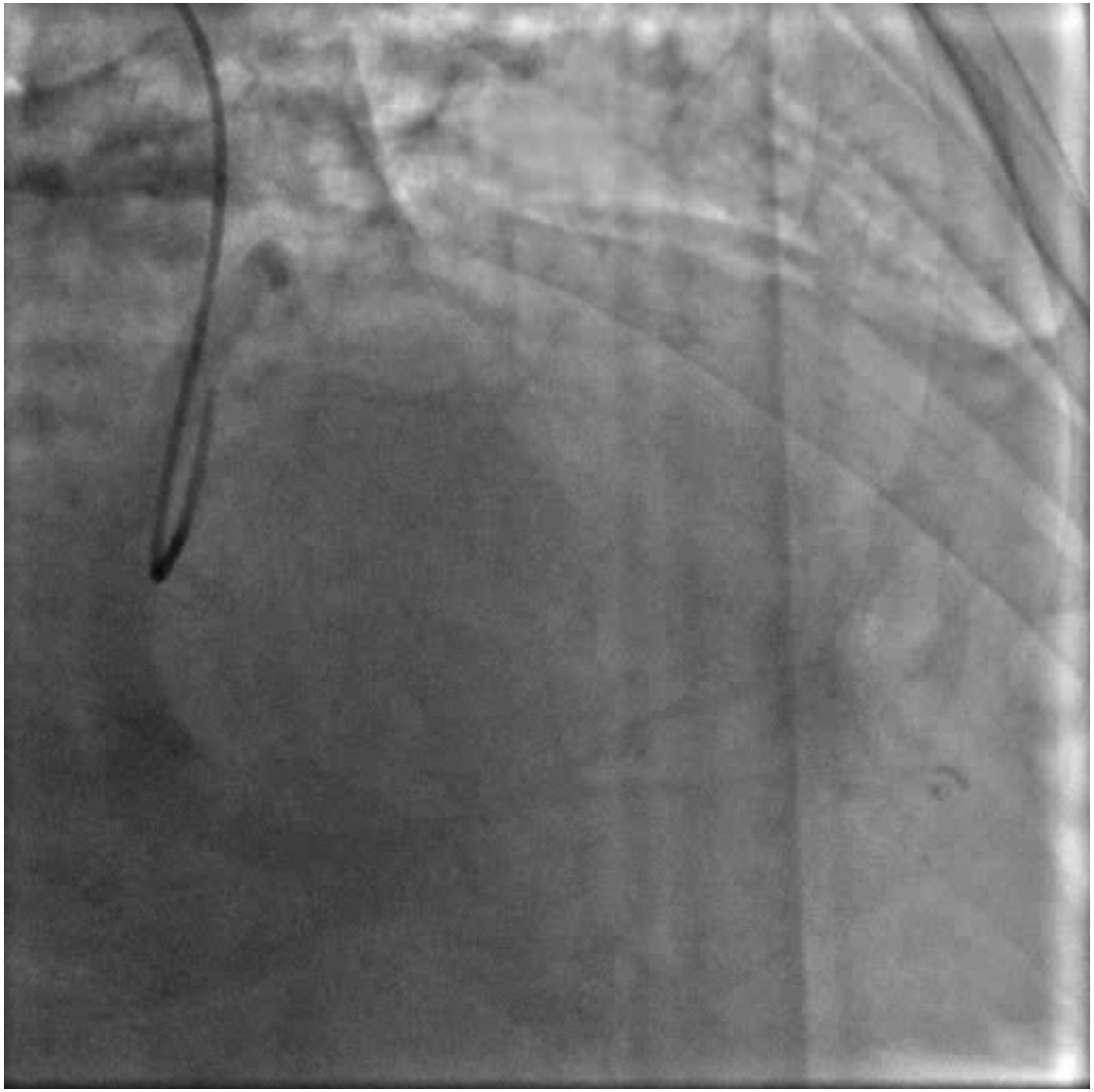
TAP

ACS ST- , ulcerated LAD1,LAD1,Diag1 bifurcation 1,0,1

Ulcerated LAD1,LAD1,Diag1 bifurcation 1,0,1



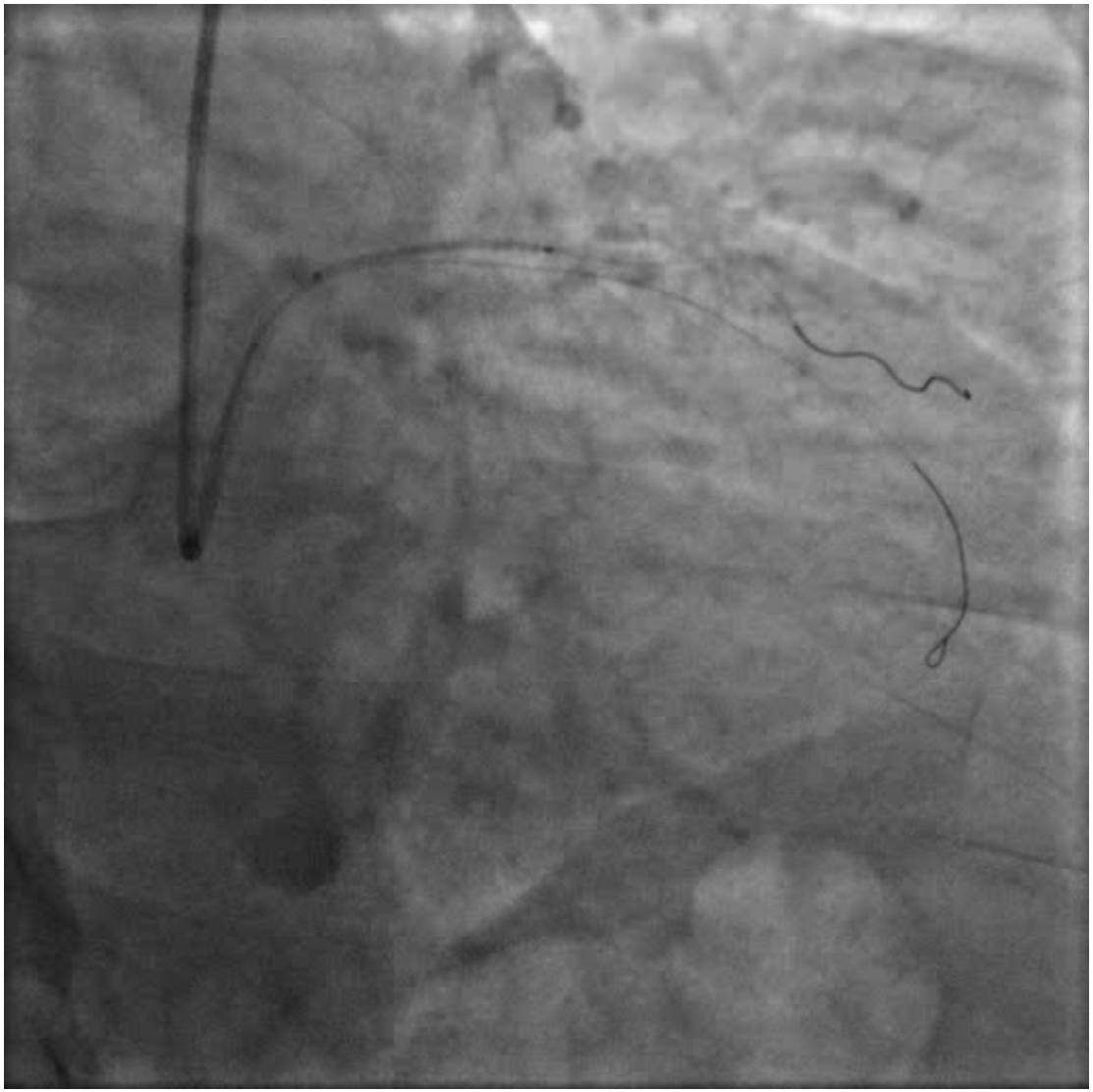
LAD1,LAD1,Diag1 bifurcation 1,0,1



2 BMW wires

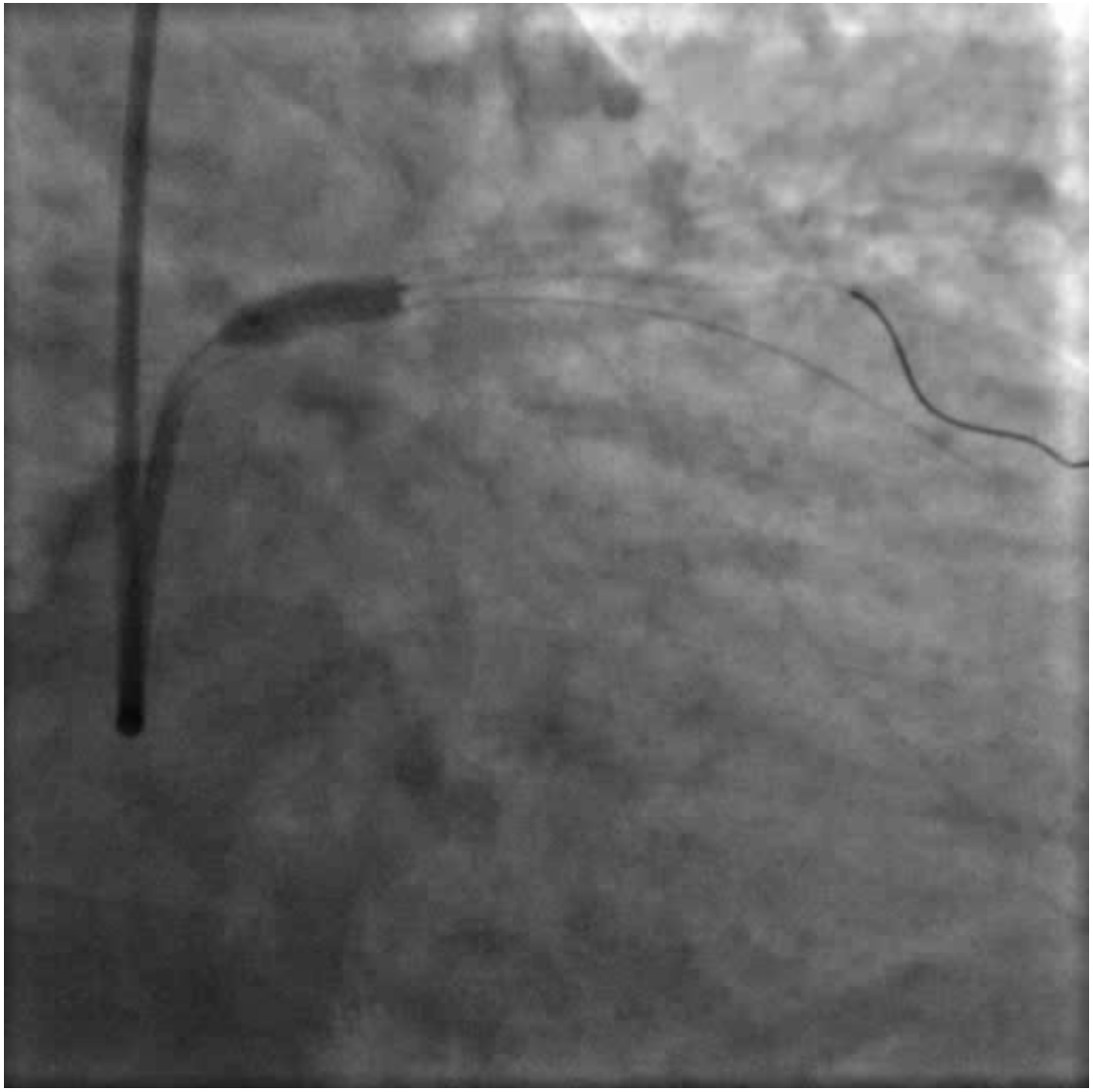
Predilatation with 2.5 X 20 mm (length)

Nobori 3x24 mm from LAD to Diagonal

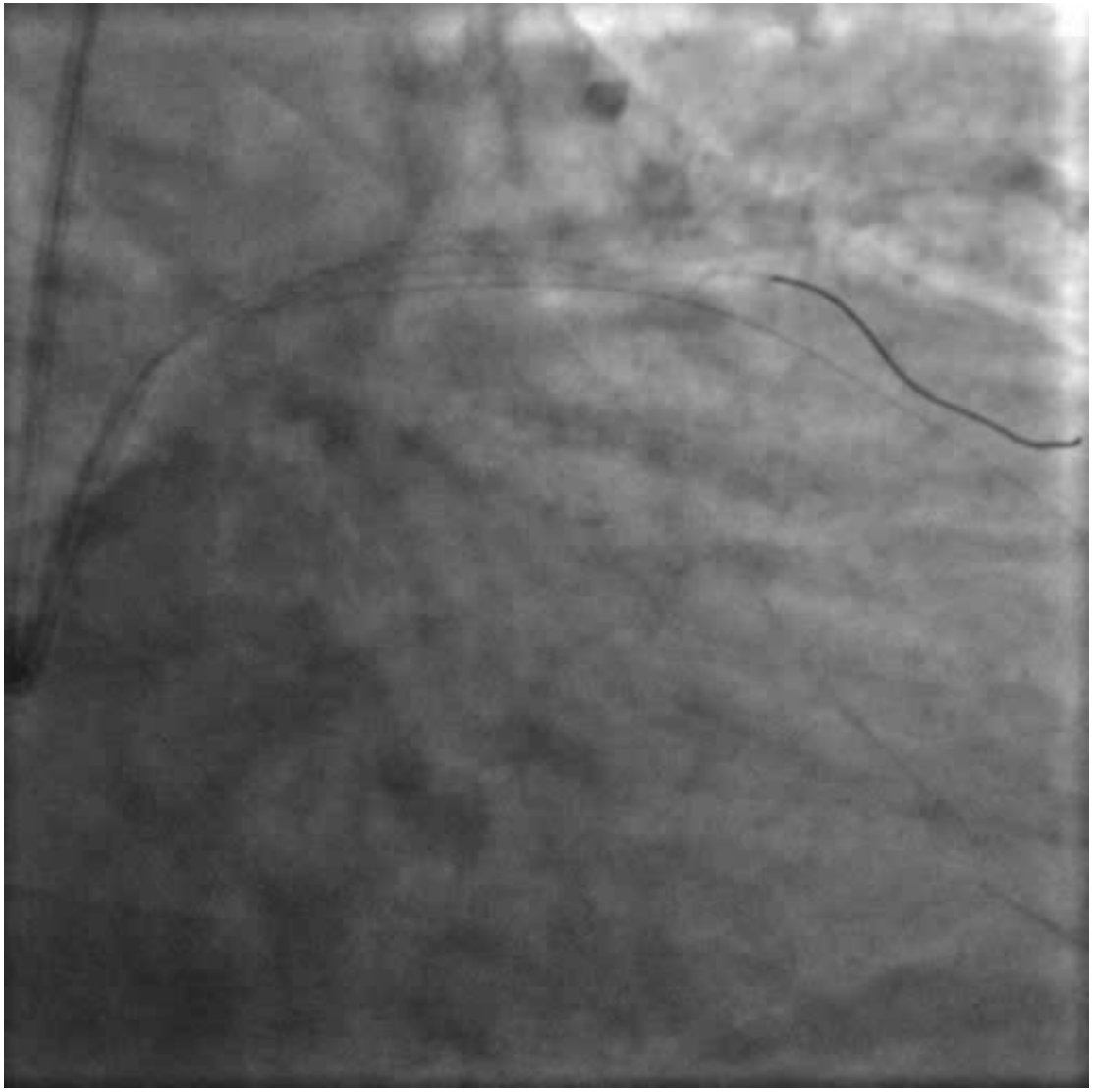


Post stenting

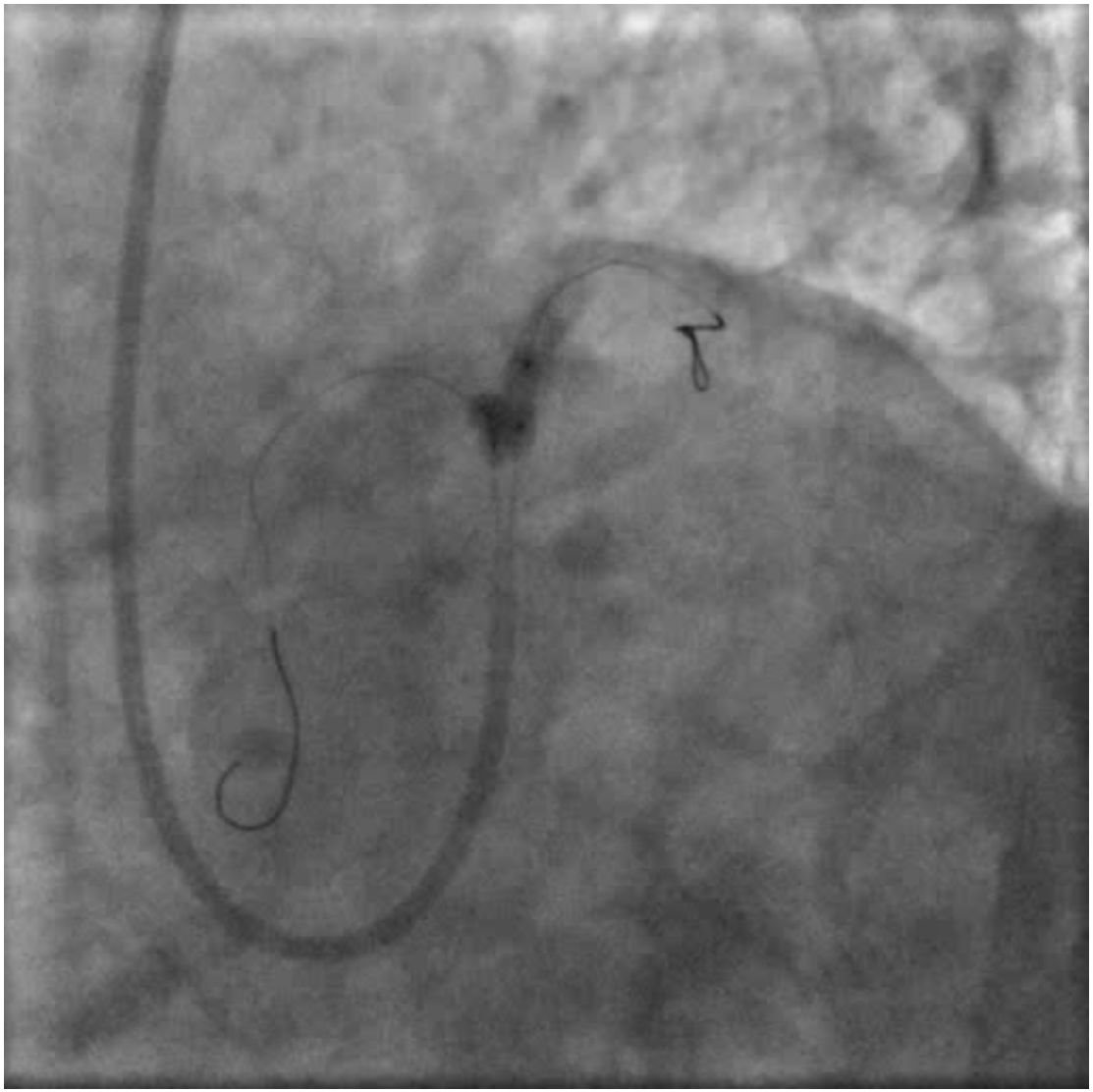
POT with a 3.5X9 mm balloon



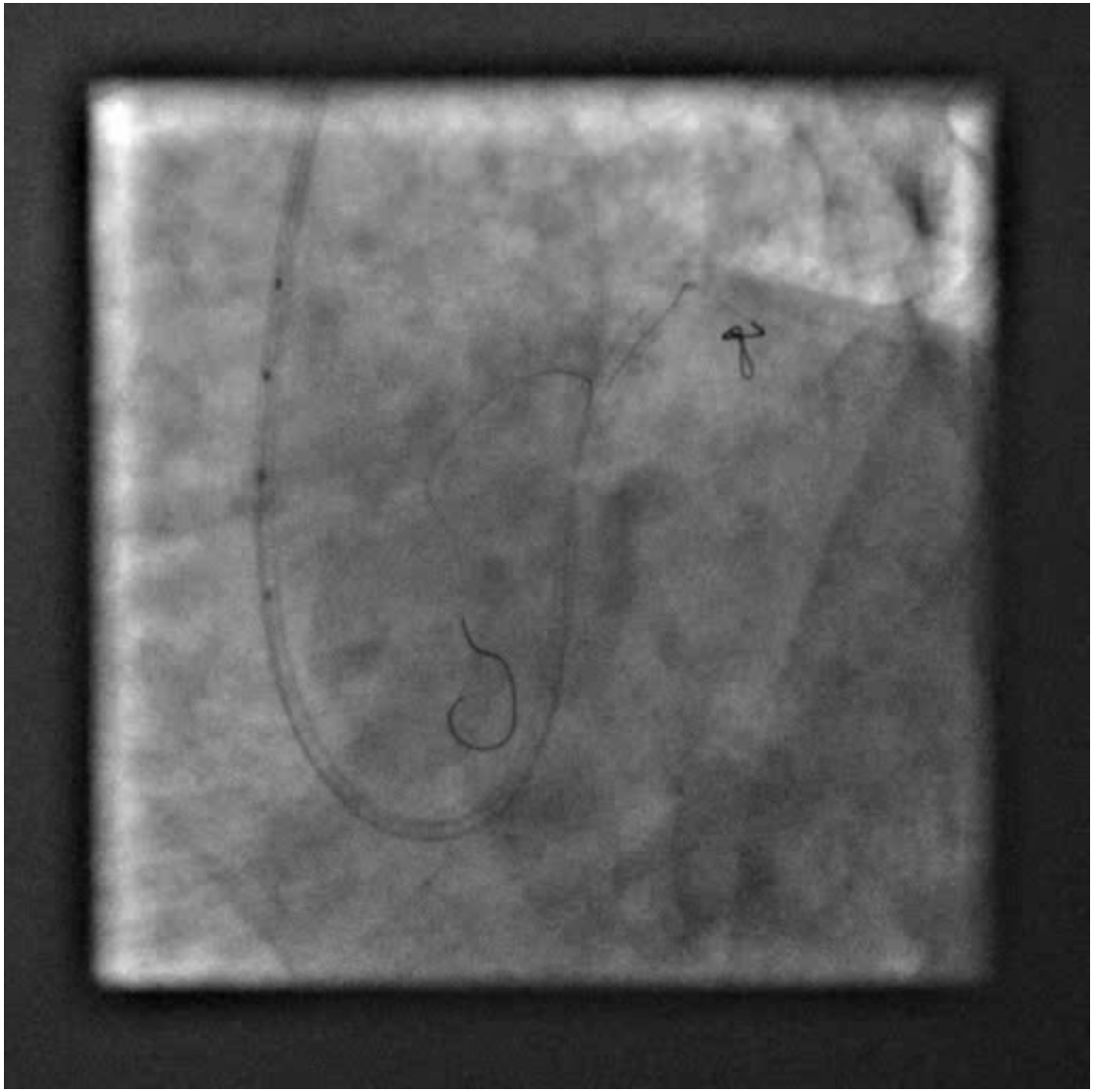
Post POT



Kissing



Post kissing



Final result

Conclusion

- Good knowledge of anatomy / fonction of a coronary bifurcation is useful for classification, quantification and treatment of coronary bifurcation stenosis
- In the majority of situations a bifurcation stenosis can be treated with 1 (or even 2 stents) using the Provisional SB stenting strategy
- Choice of an adapted stent with a diameter of the DM segment is followed by a POT using a short balloon adapted to PM segment diameter, final kissing balloon inflation is useful when the SB is big (alternative: POT, Side, POT ?)
- When the access to SB is very difficult, SB may be stented first (mini DK crush)
- Clinical validation of informations coming from patient specific simulation is necessary
- Treatment principles: **limit stent number, apposition, respect initial anatomy**