ProEducar Fellows Course@SCAI: State of the art in bifurcations. From Simple to Complex Interventions

DK-Crush and DK Culotte Step by Step

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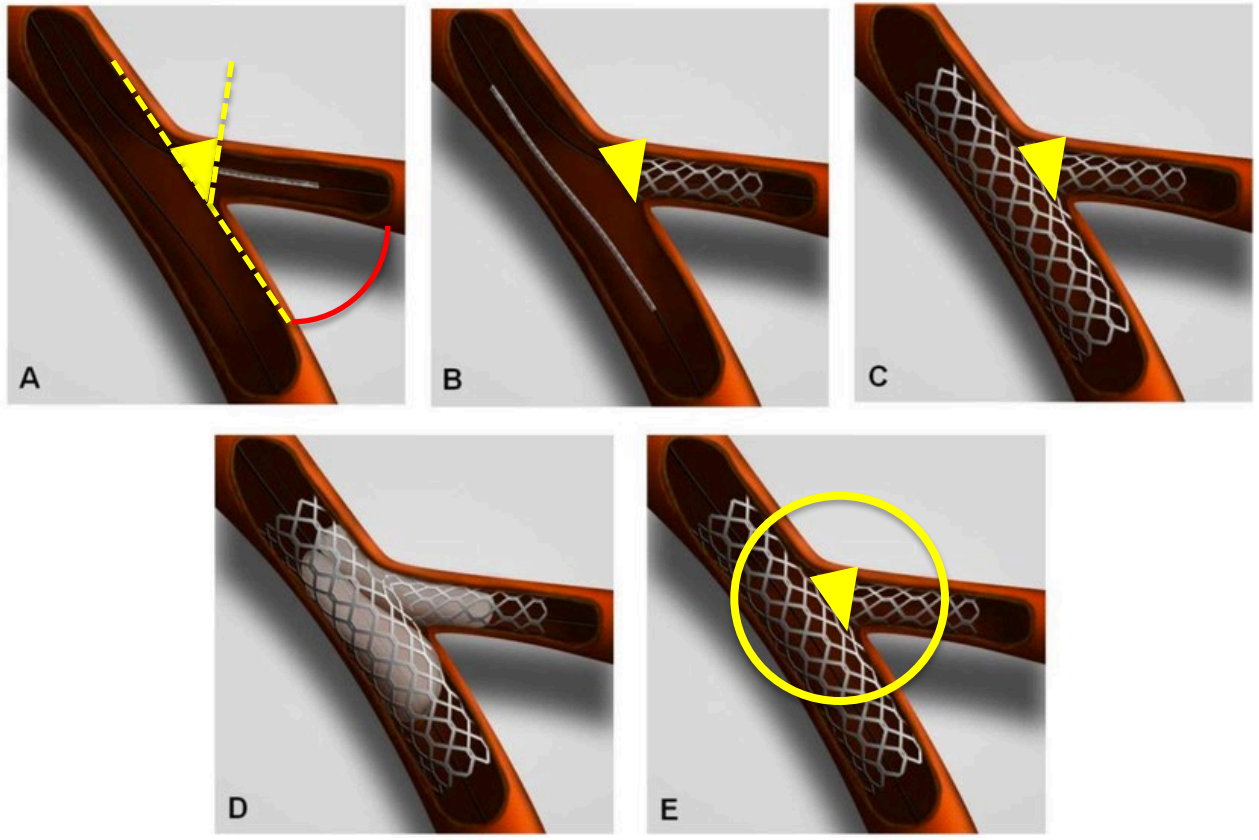
T-Stenting Limitations

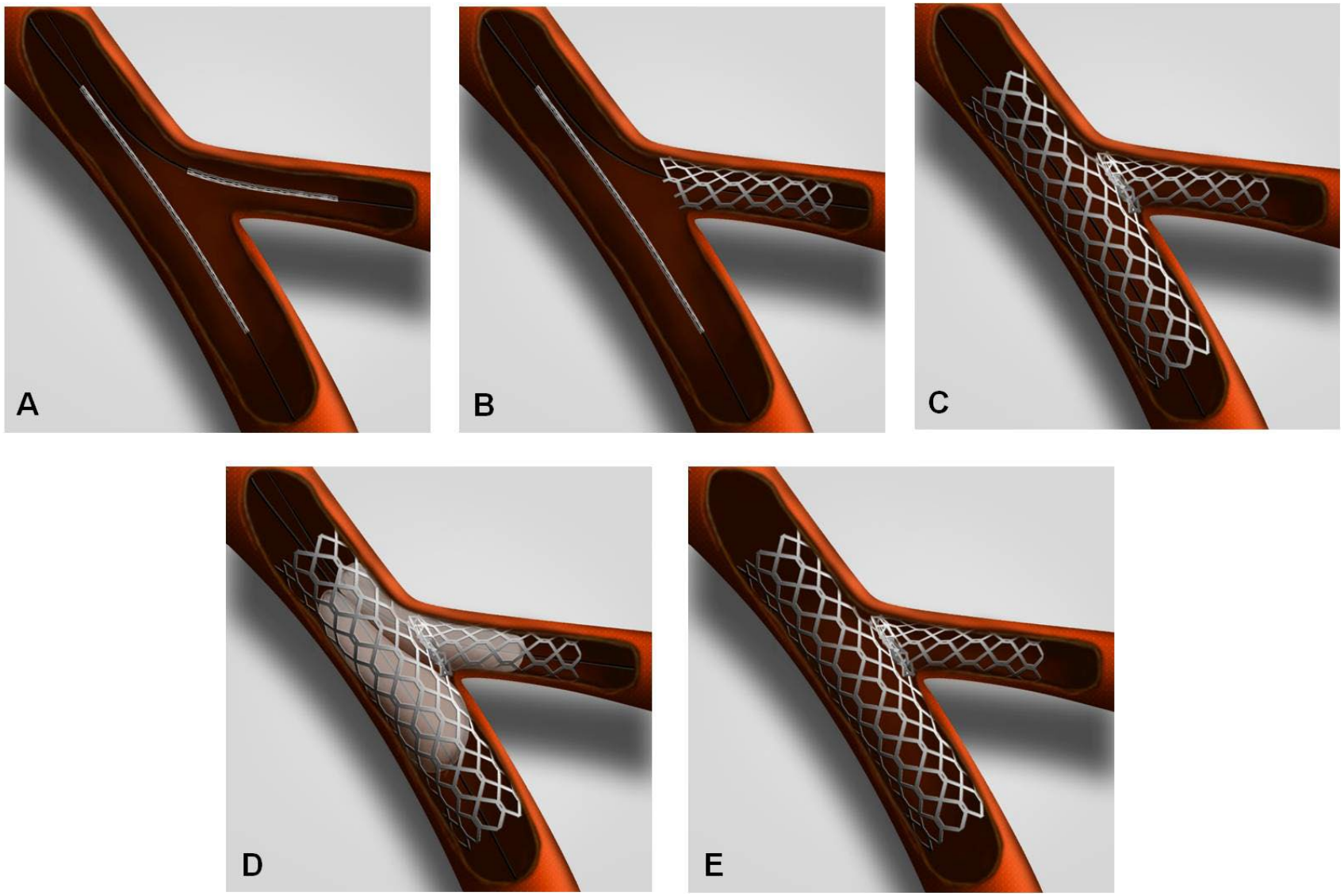
Classic "T" Stenting Technique



Incomplete SB ostium coverage relatively common (specially if distal angle <70 degrees) and associated with recurrences at this location[1,2]

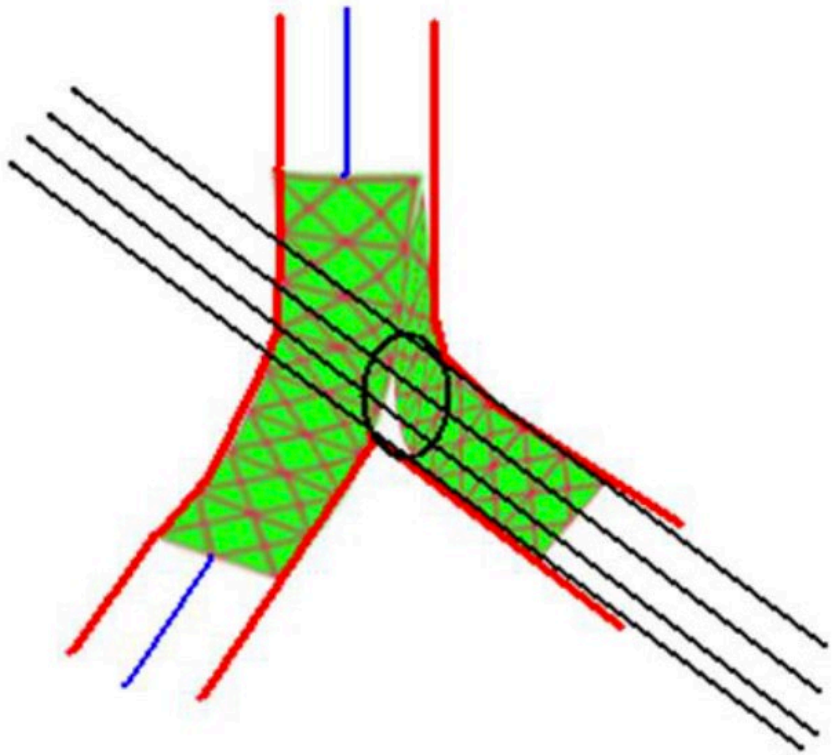
[1]Hahn et al. J Am Coll Cardiol 2009;54(2):110-7. [2]Colombo et al. Circulation 2004;109(10):1244-9.

CLASSIC CRUSH TECHNIQUE



PRIMARY STENTING IN SB

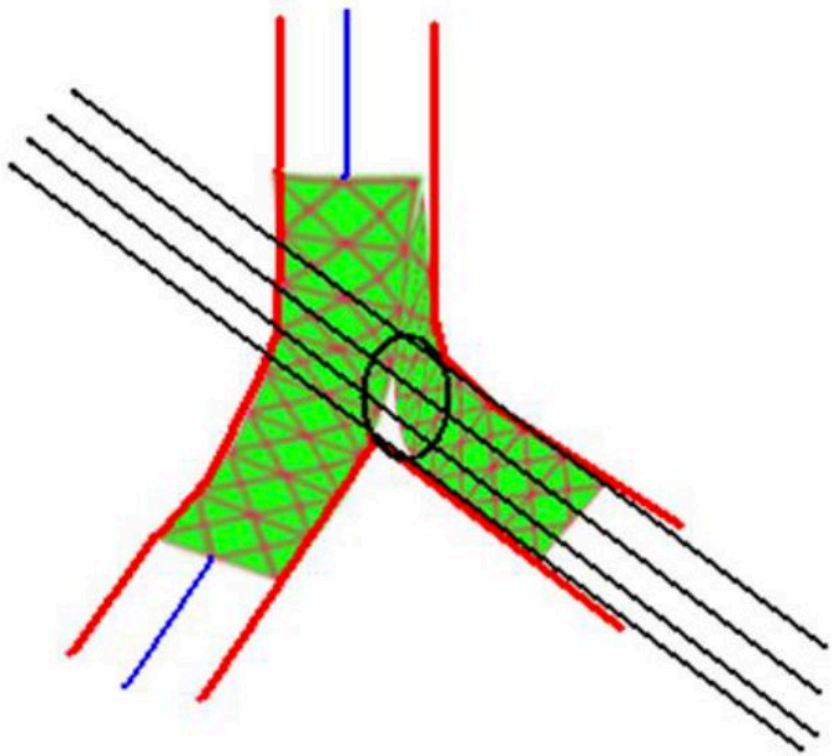
Potential issues with “original” crush technique



- **Two stenting technique, FKBI is mandatory to improve clinical outcomes (=70-80%, Classic crush has a lower rate of FKBI)**
- **KUS (kissing unsatisfactory)**

Chen et al. Chi M J 2005 / Chen et al. Journal of invasive cardiology 2006

Potential issues with “original” crush technique



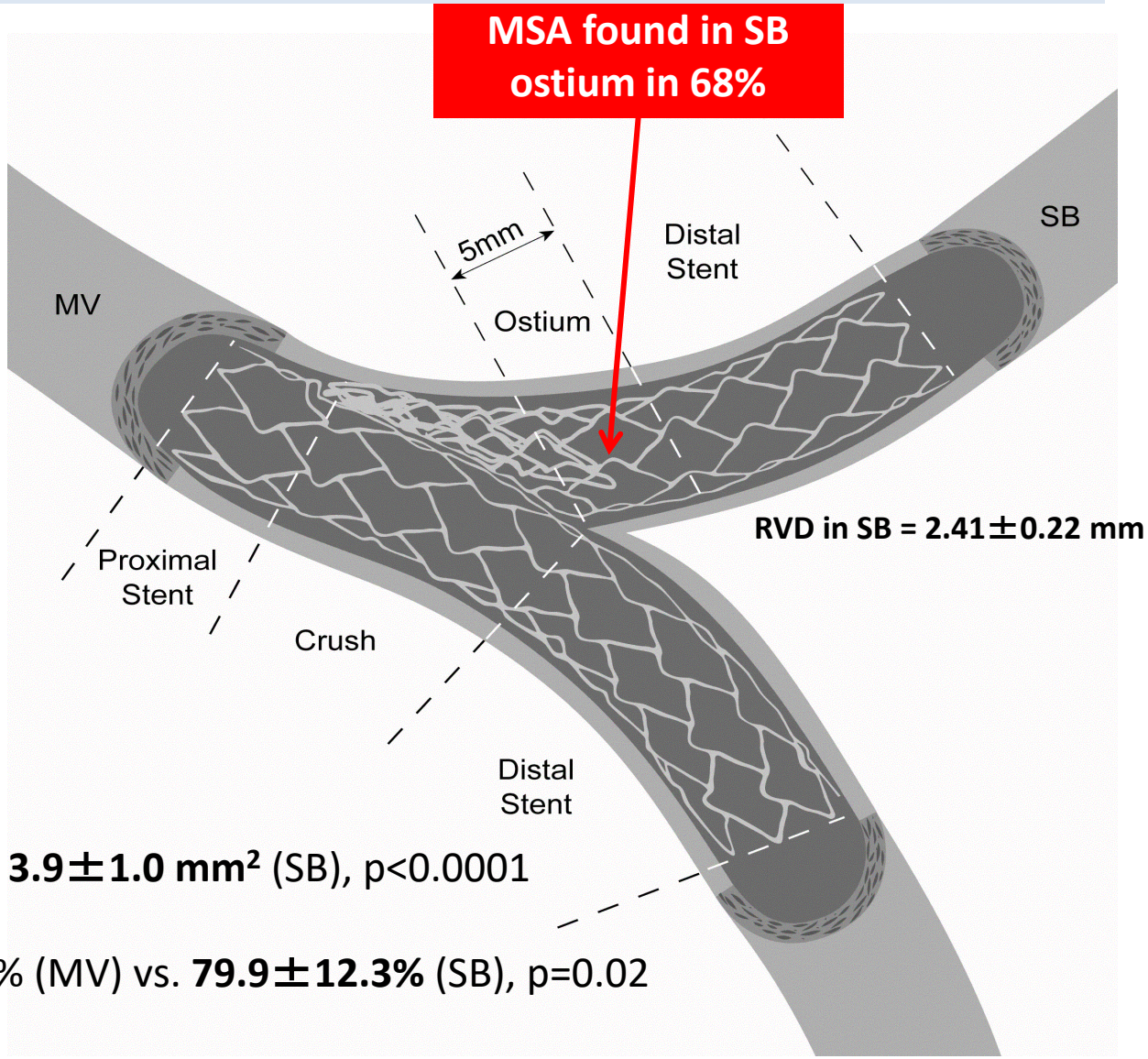
- Even after performance of FKBI Classic crush has more malaposition and more incomplete crush
- Classic crush leaves three layers of stent struts overlapping at the ostial SB

Costa R et al. JACC 2006

Serial IVUS Analysis Post-Crush

25 non-LM bifurcation lesions treated with the crush technique with final IVUS in both branches

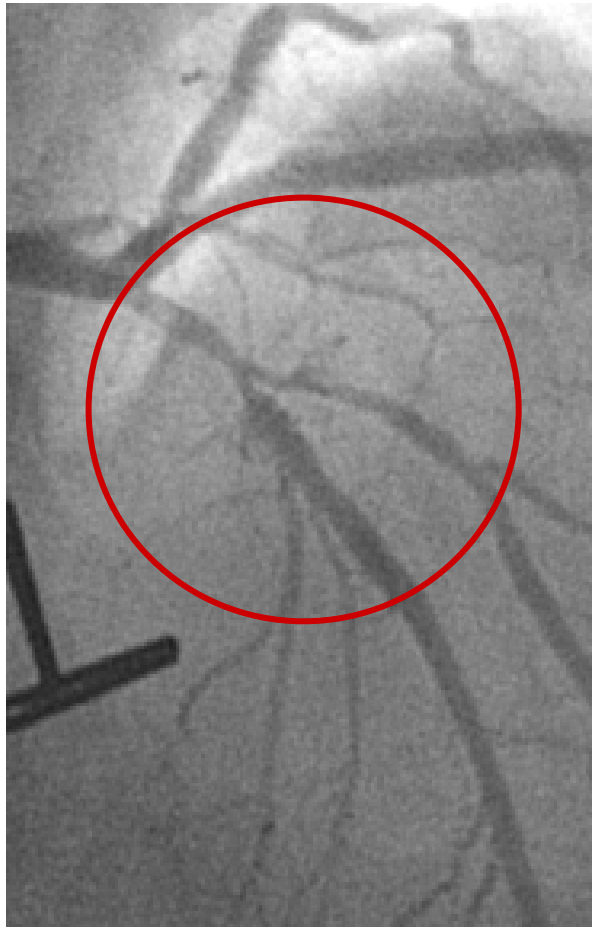
FKB in 100%



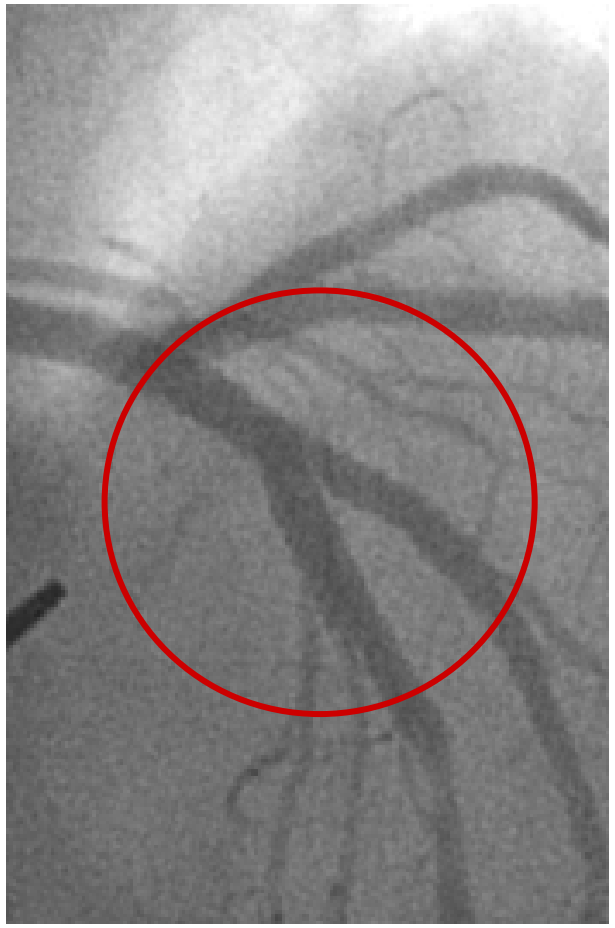
- MSA<5,0 mm^2 in 90% in SB
- MSA<4.0 mm^2 in 55% in SB
- MSA = 6.5±1.7 mm^2 (MV) vs. **3.9±1.0 mm^2** (SB), p<0.0001
- Stent expansion = 92.1±16.6% (MV) vs. **79.9±12.3%** (SB), p=0.02

Costa et al, J Am Coll Cardiol 2005; 46:599-605

Example of Side Branch Restenosis



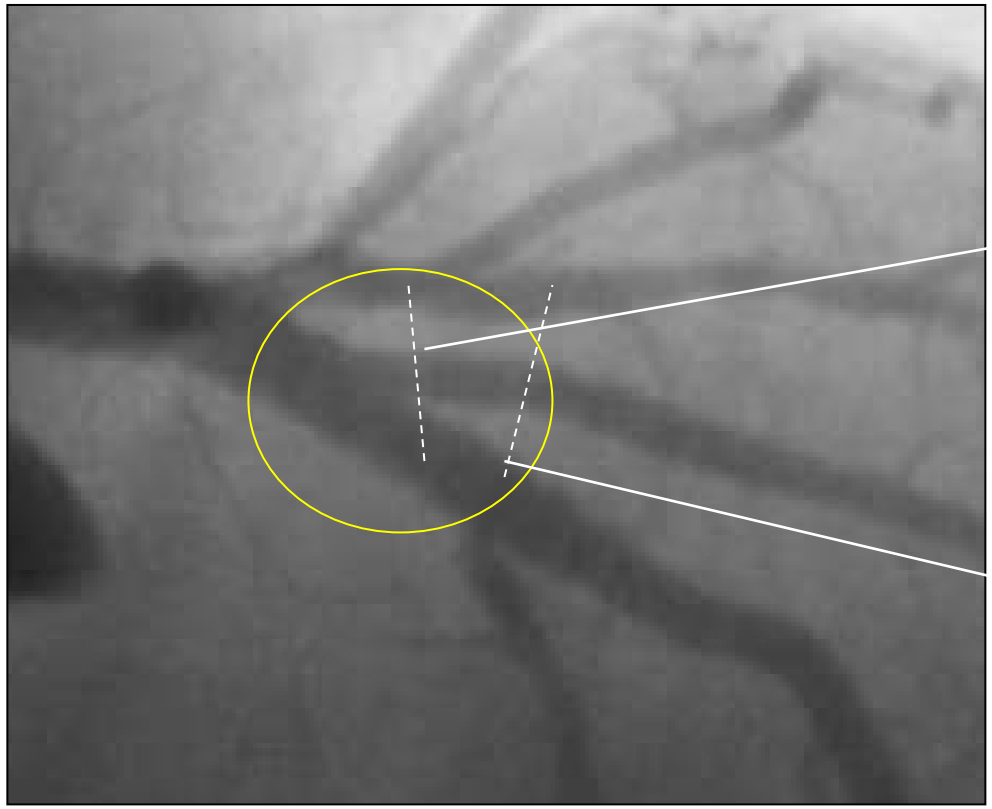
Preprocedure

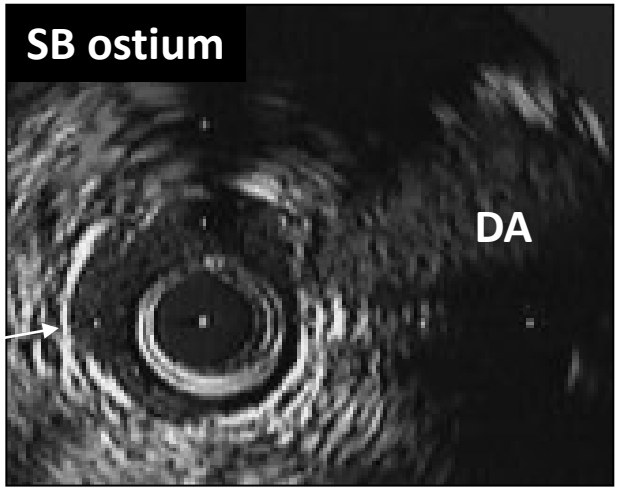


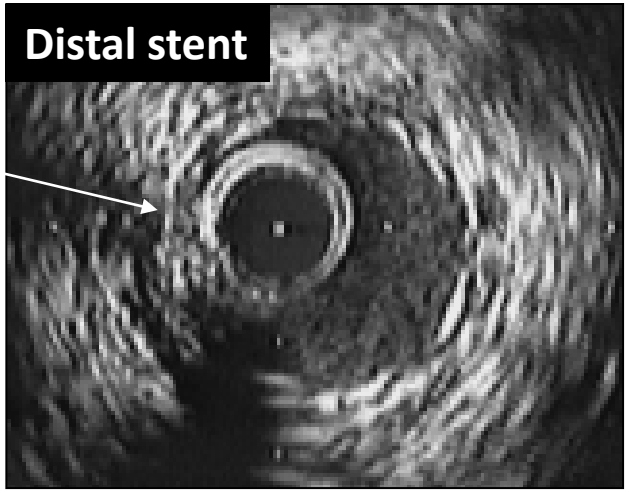
Final

6 Months Follow-Up

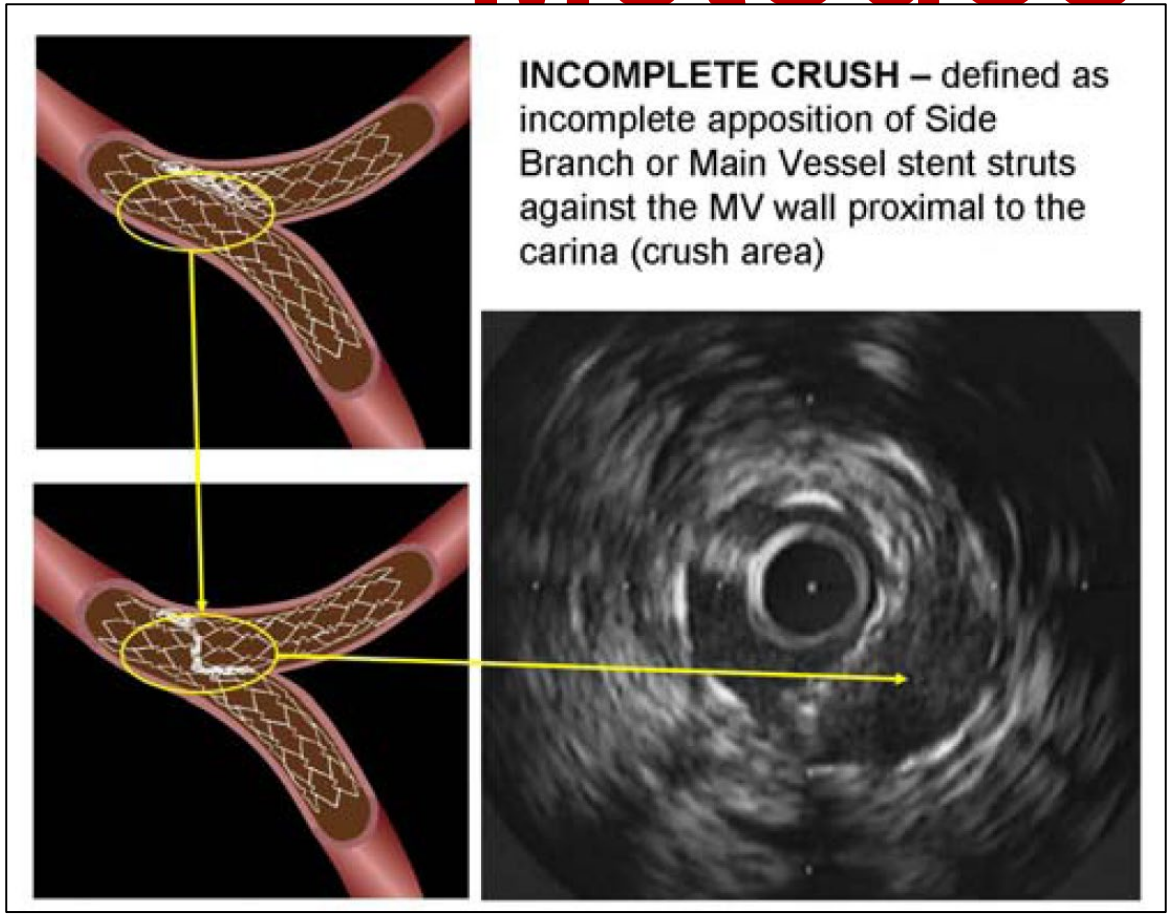
SB OSTIUM UNDEREXPANSION

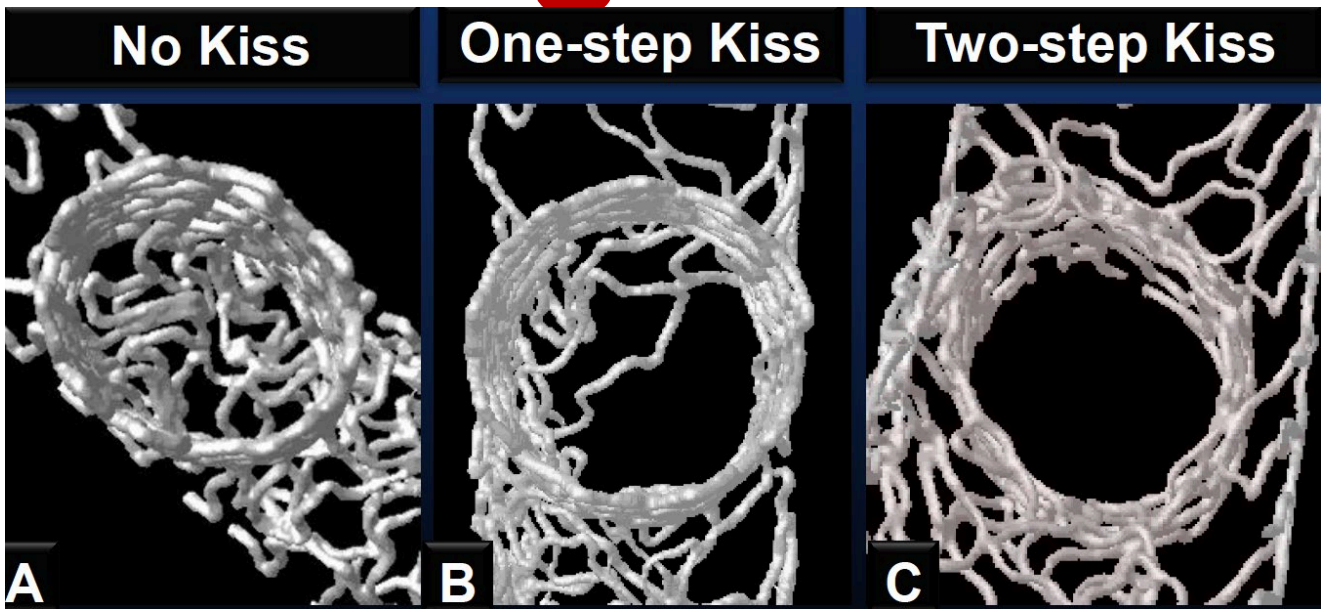






Métodos de Imagem





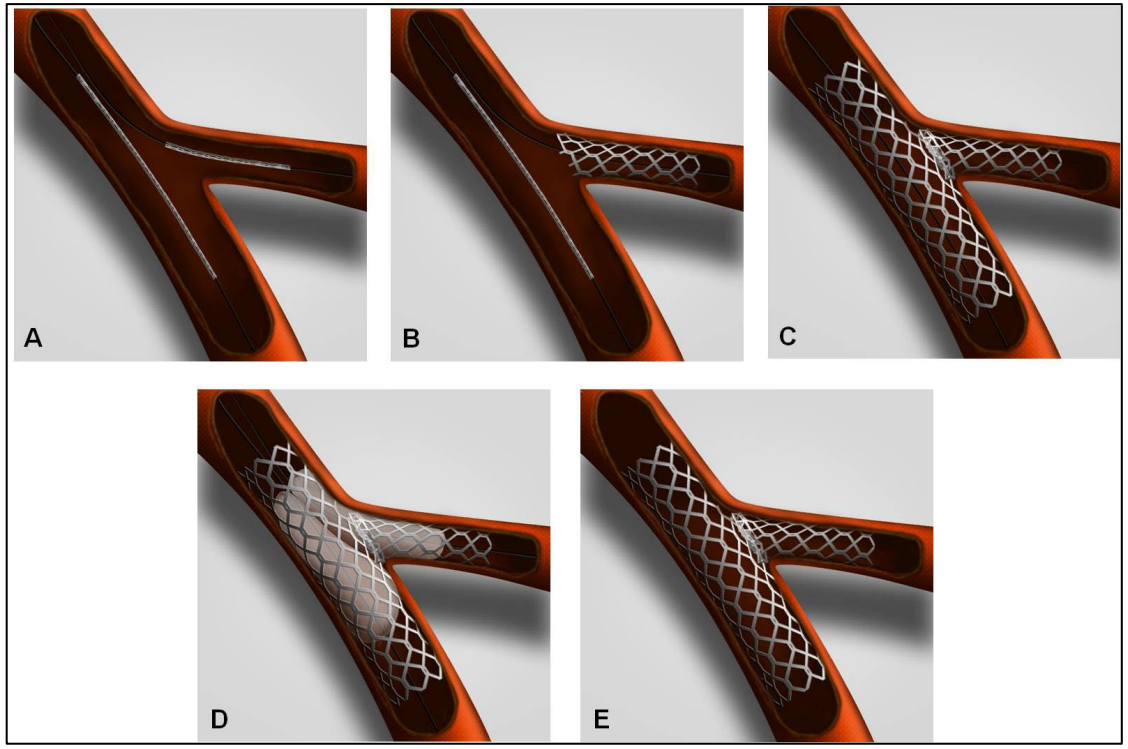
Achados mecanísticos que ajudaram no desenvol vimento do DK-crush e aperfeiçoamento técnico

Costa RA, et al. J Am Coll Cardiol. 2005;46(4):599-605

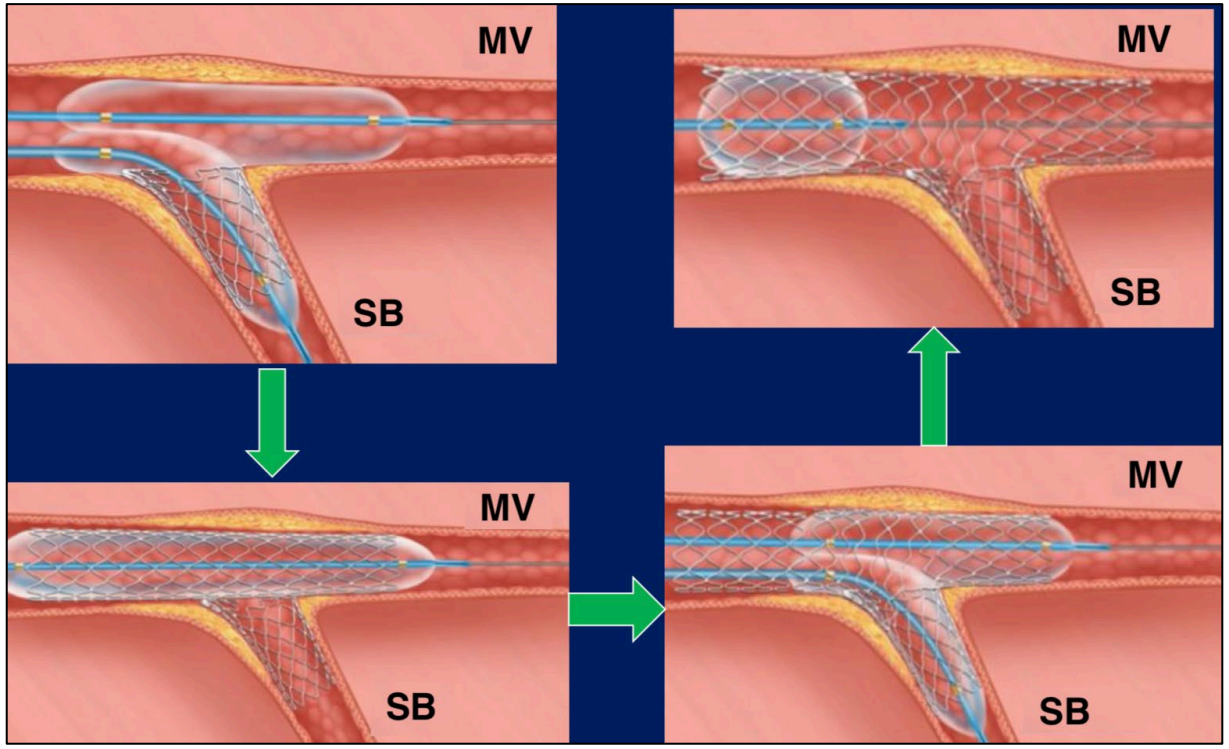
Evolução de Stent Duplo

- Compreensão dos mecanismos de falência
- Aprendizado a partir de modelos de bancada
- Aperfeiçoamento técnico
- Stents de nova geração
  - Hastes mais finas, maior flexibilidade, melhor acesso ao RL
  - Polímero/fármaco com melhor perfil de segurança

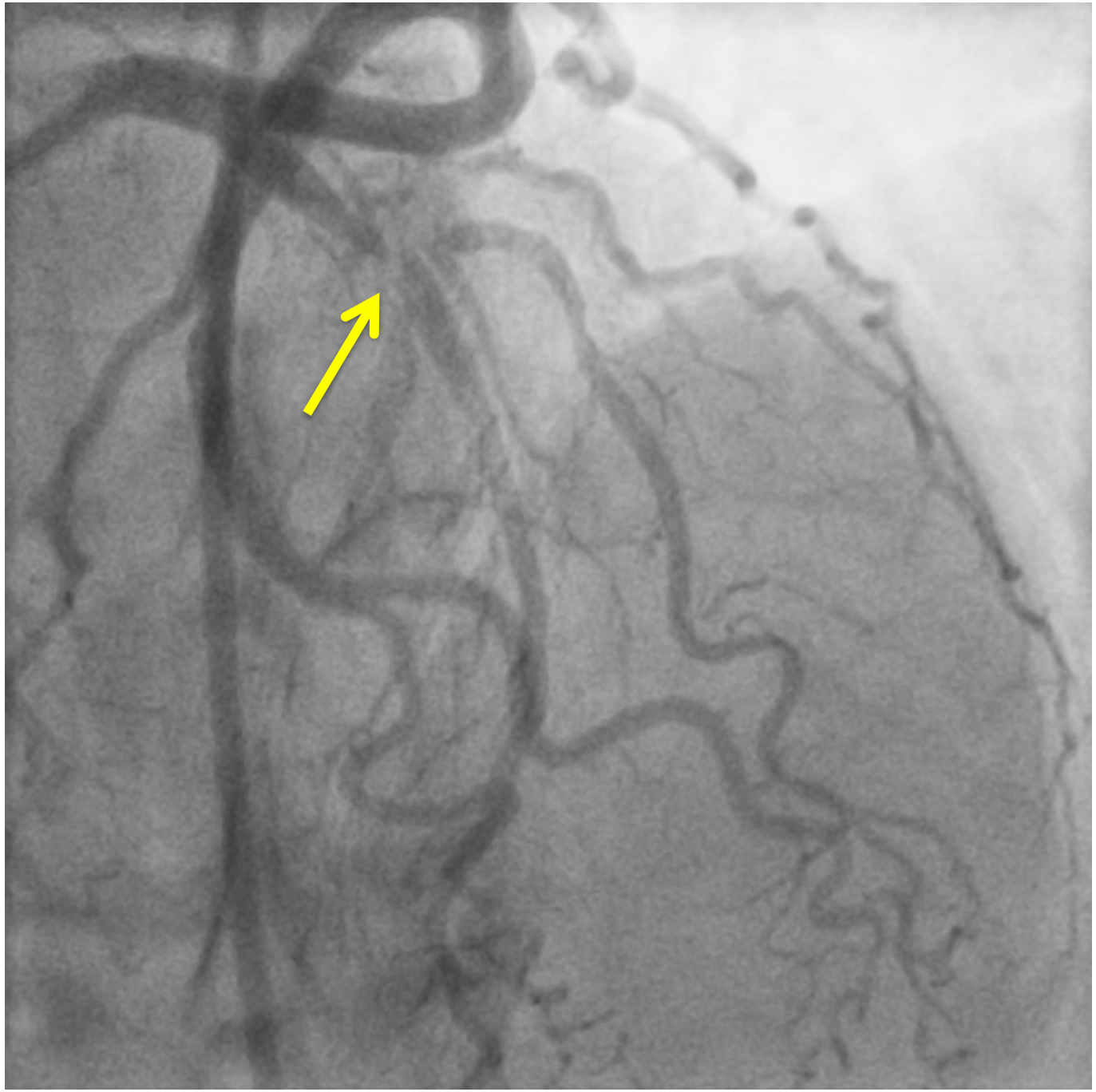
Técnica DK-crush

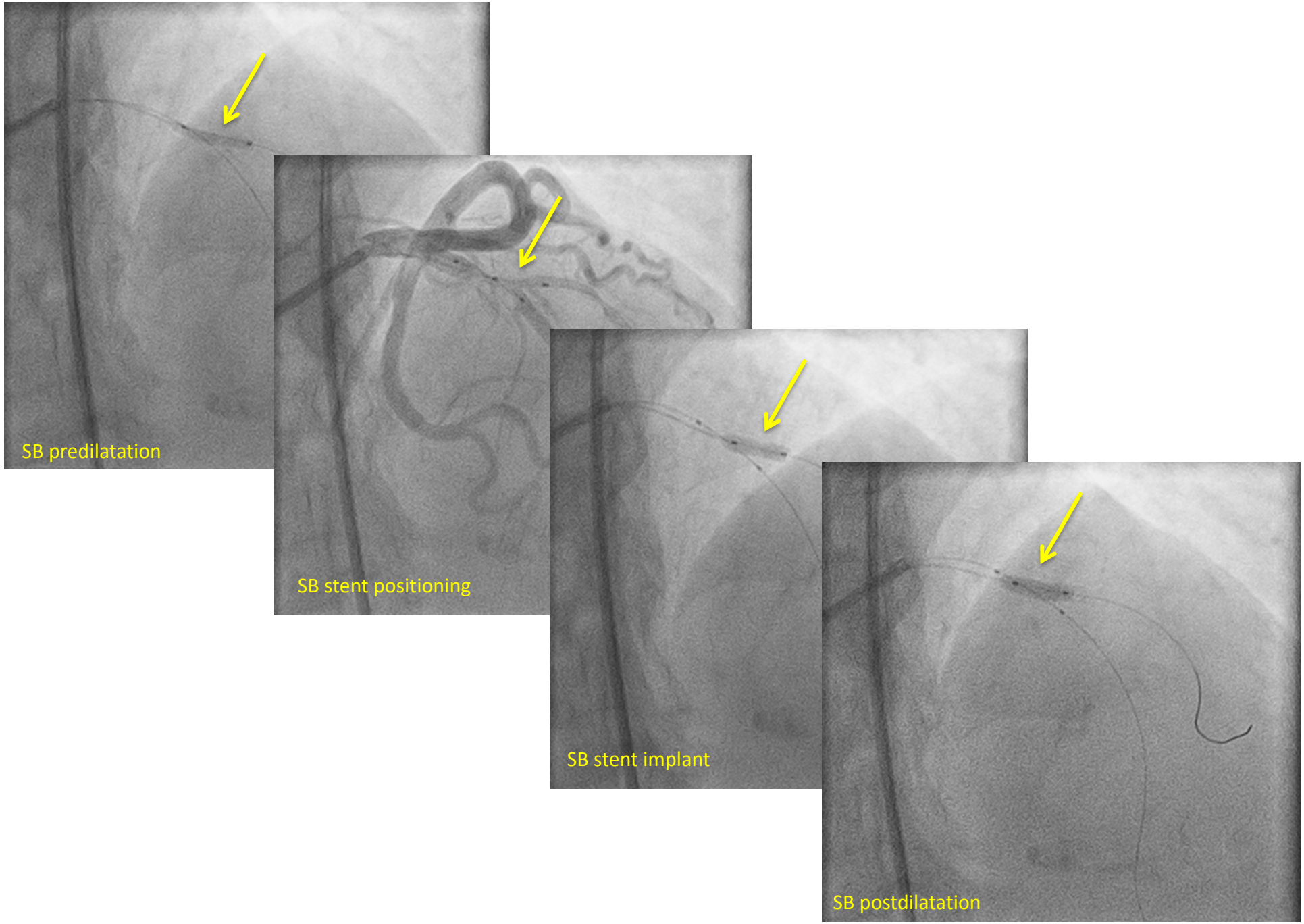


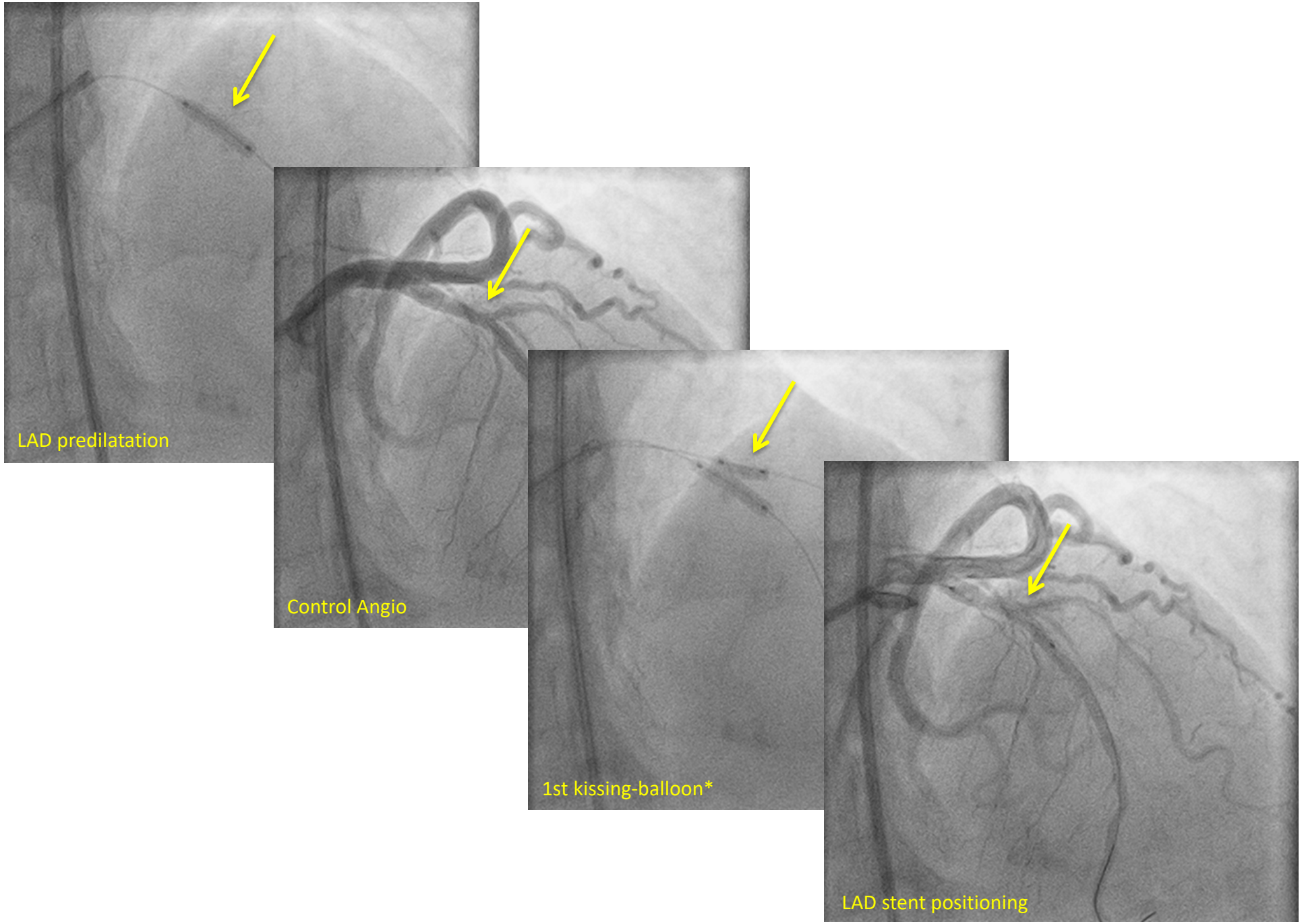
Crush clássico

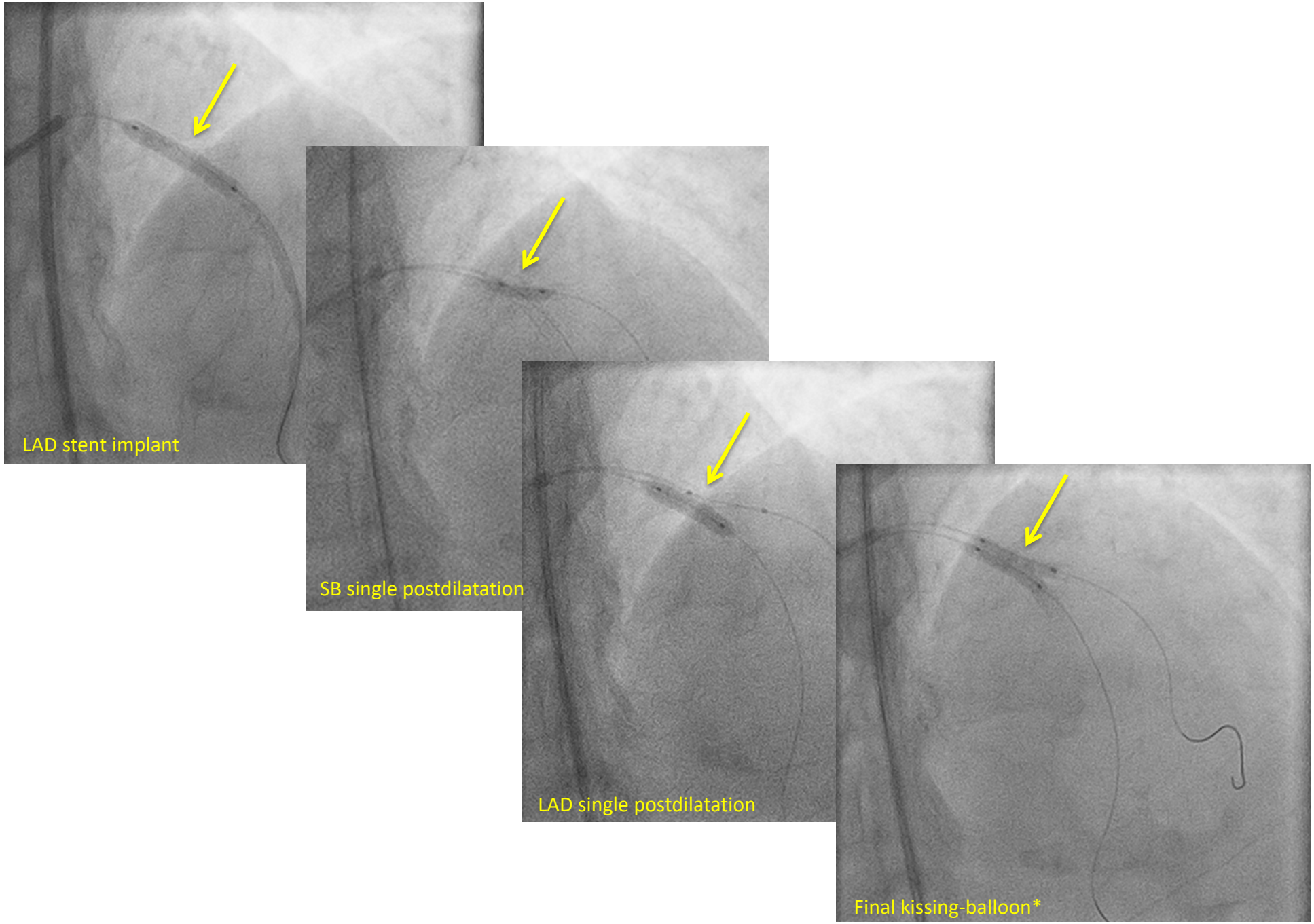


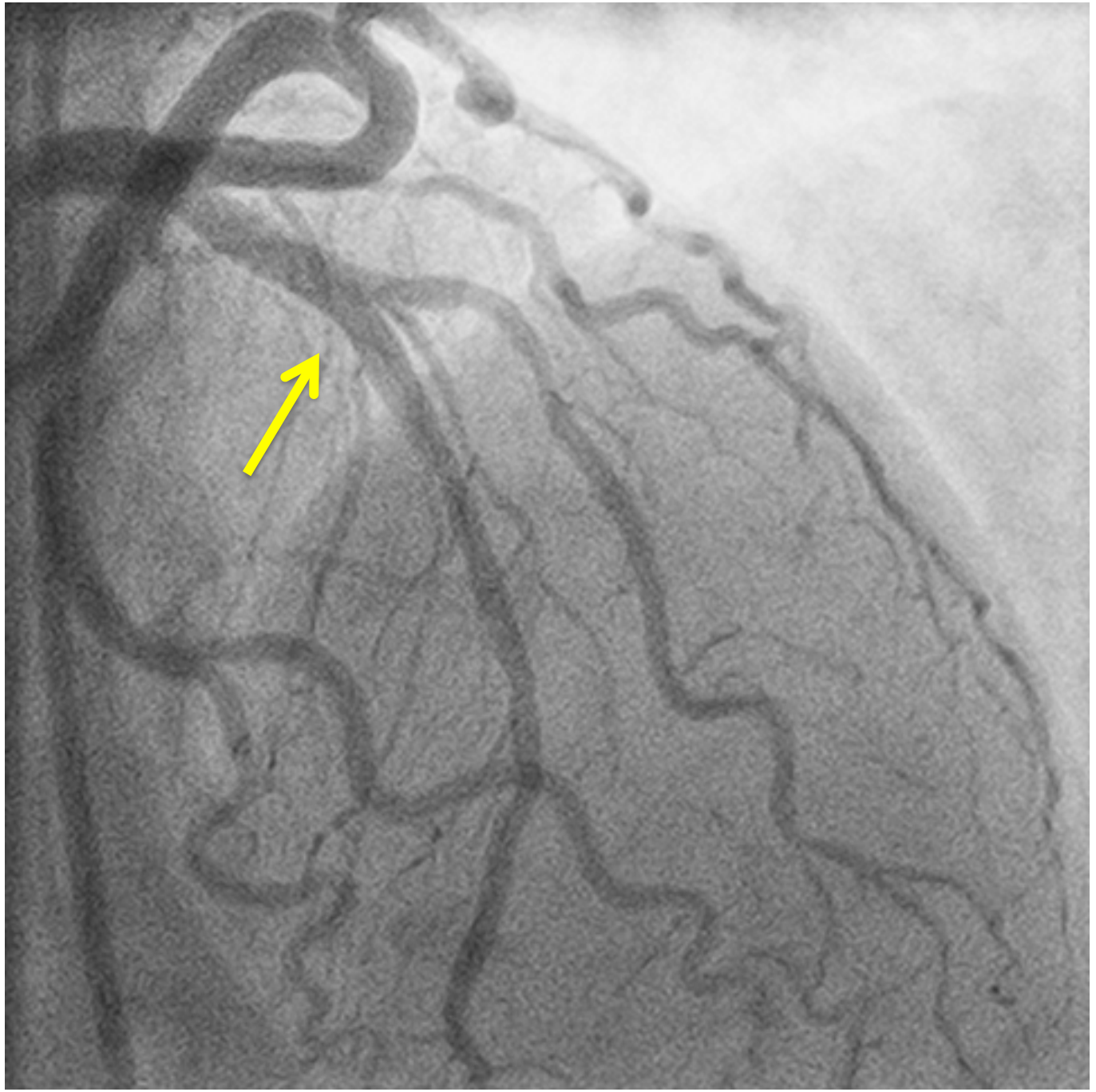
DK-crush

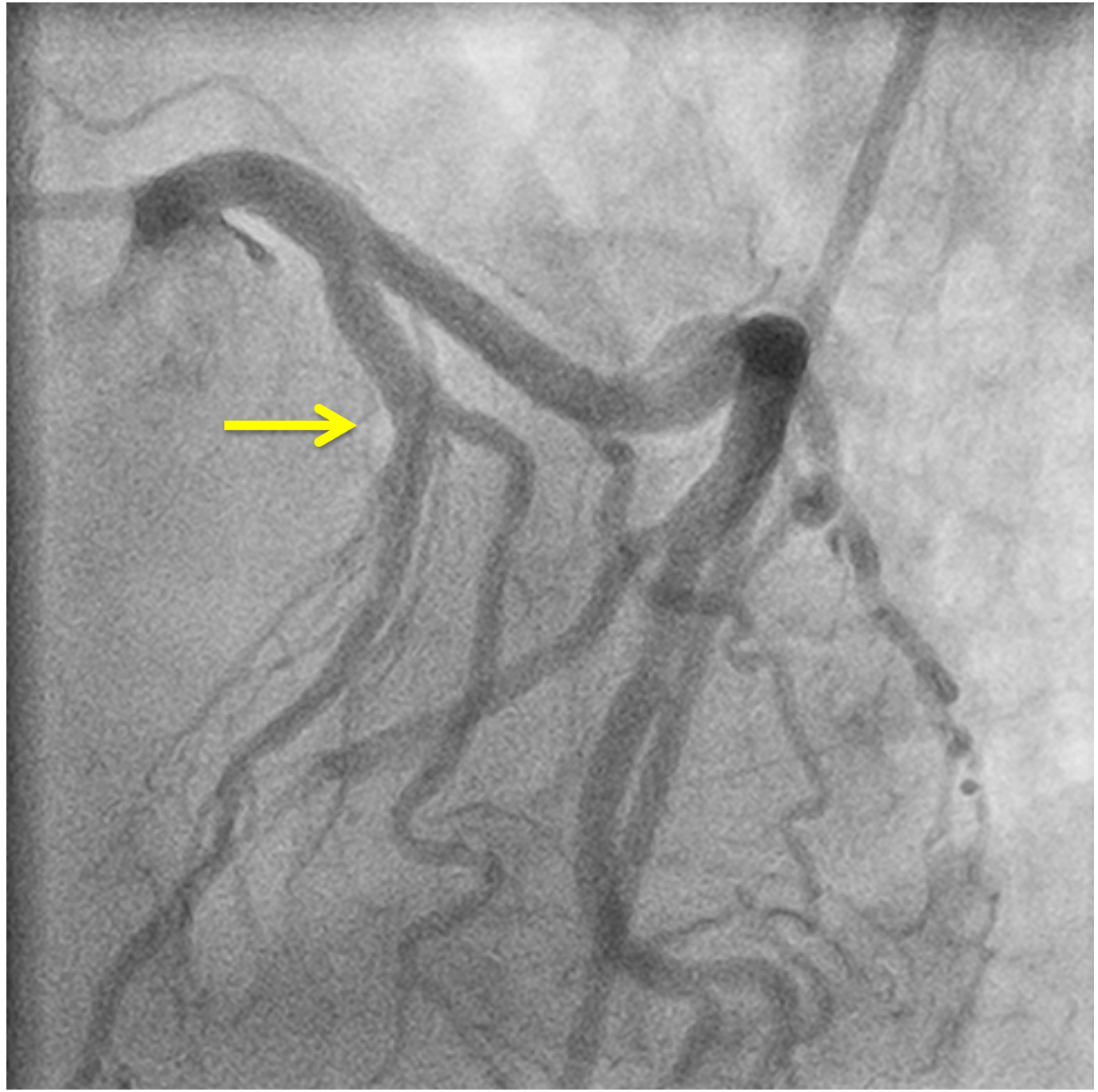



SB predilatation
SB stent positioning
SB stent implant
SB postdilatation


LAD predilatation
Control Angio
1st kissing-balloon*
LAD stent positioning

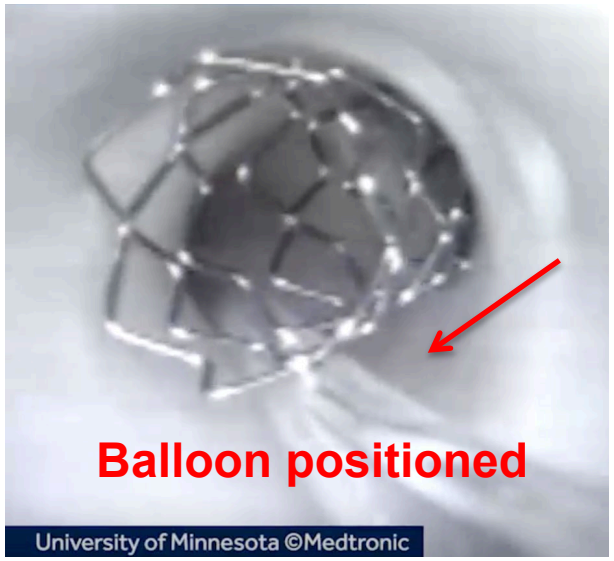

LAD stent implant
SB single postdilatation
LAD single postdilatation
Final kissing-balloon*

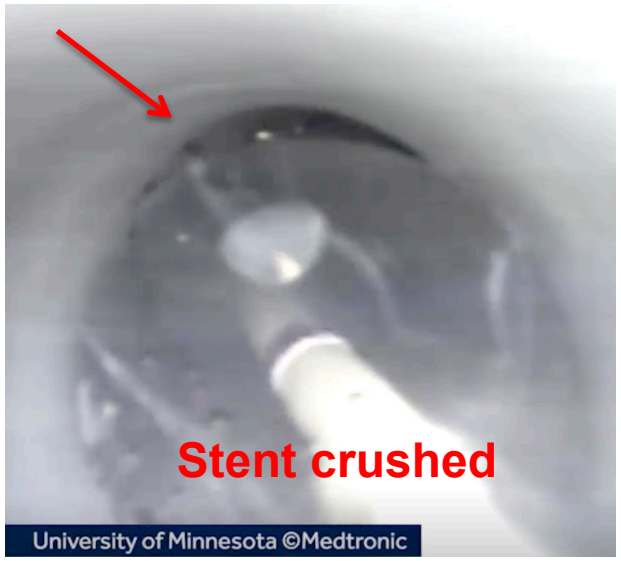


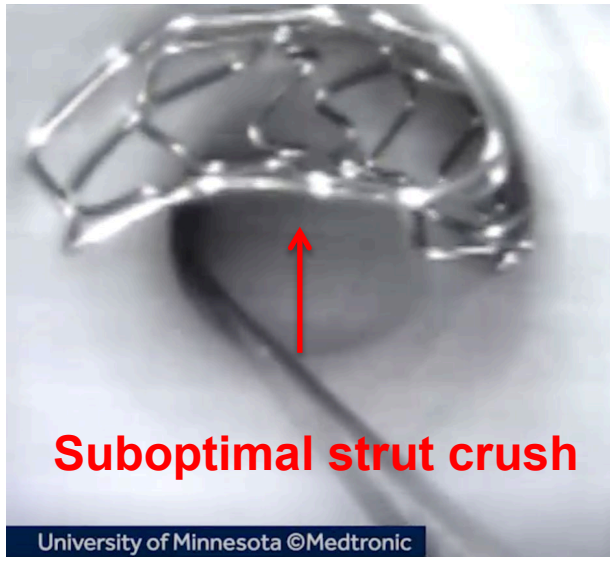


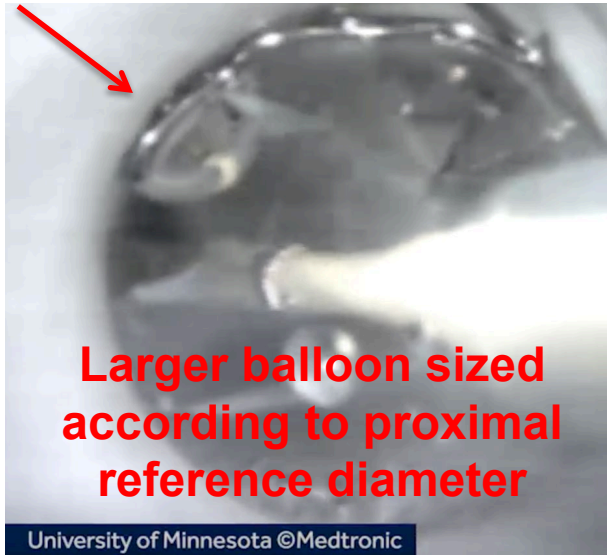
Critical Technical Steps

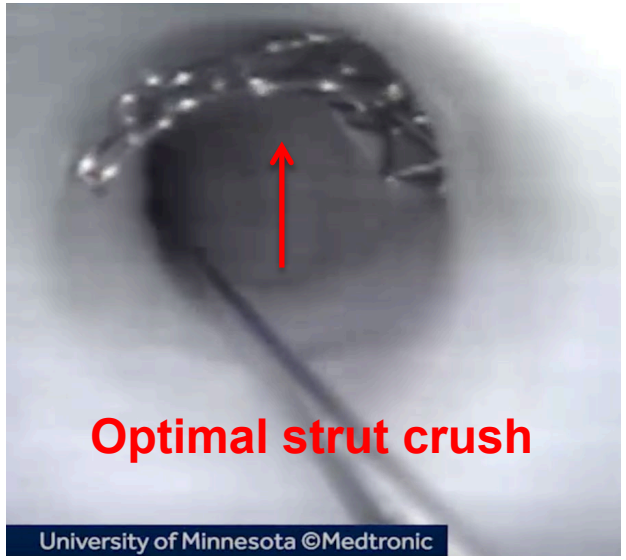
Stent Crush and Rewire

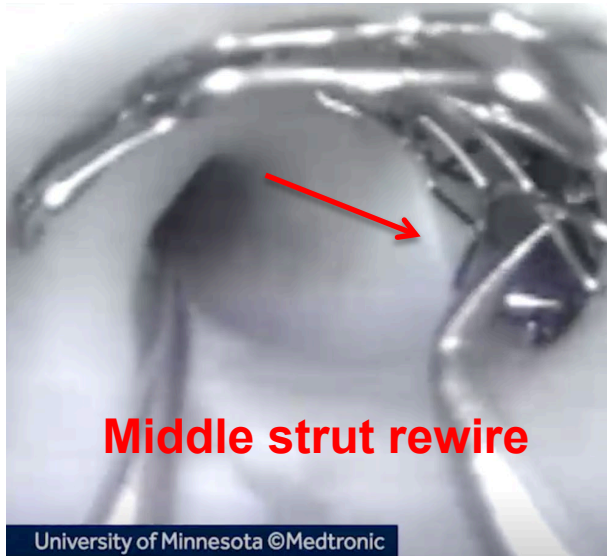




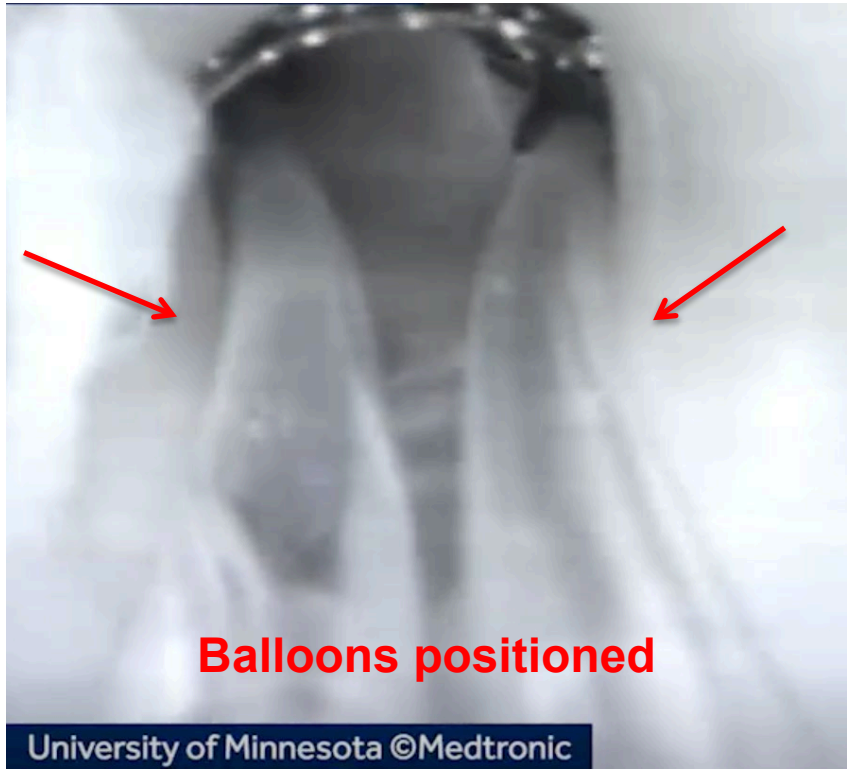


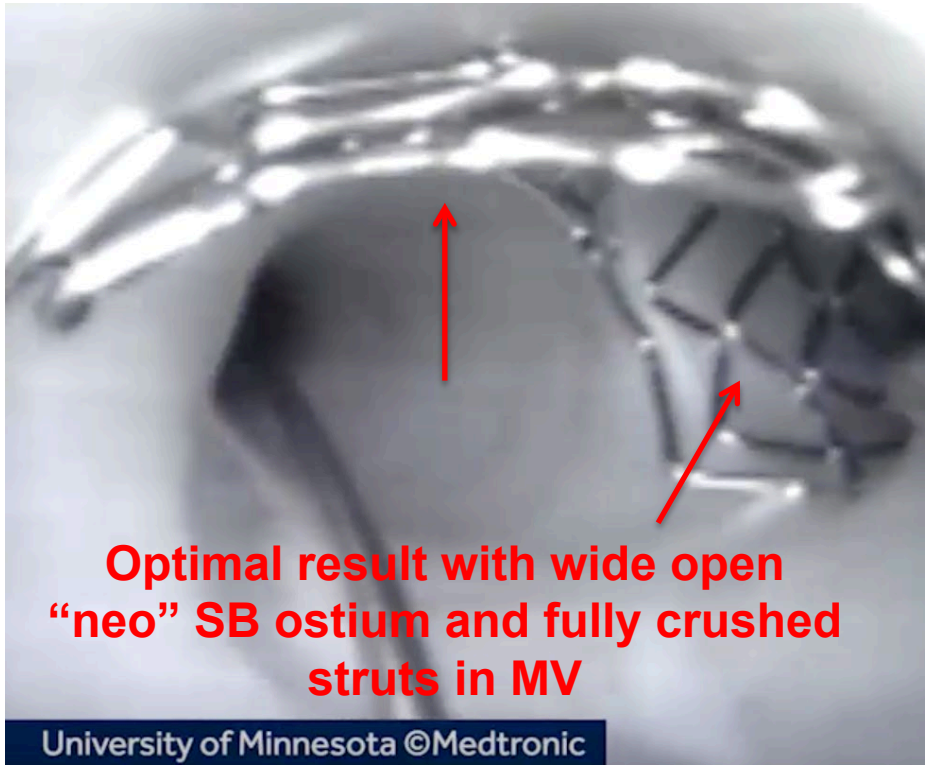




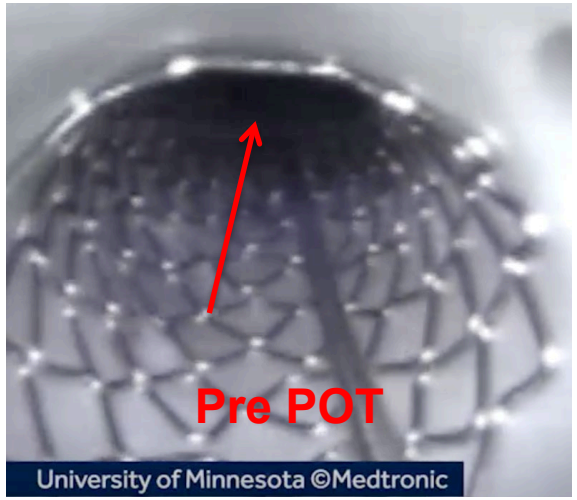


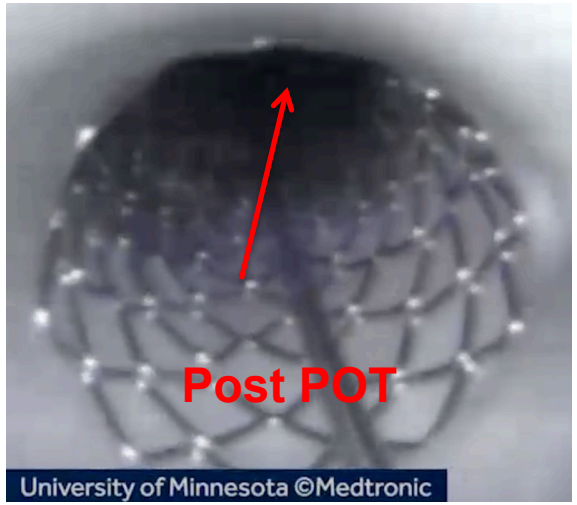
First Kissing-Balloon

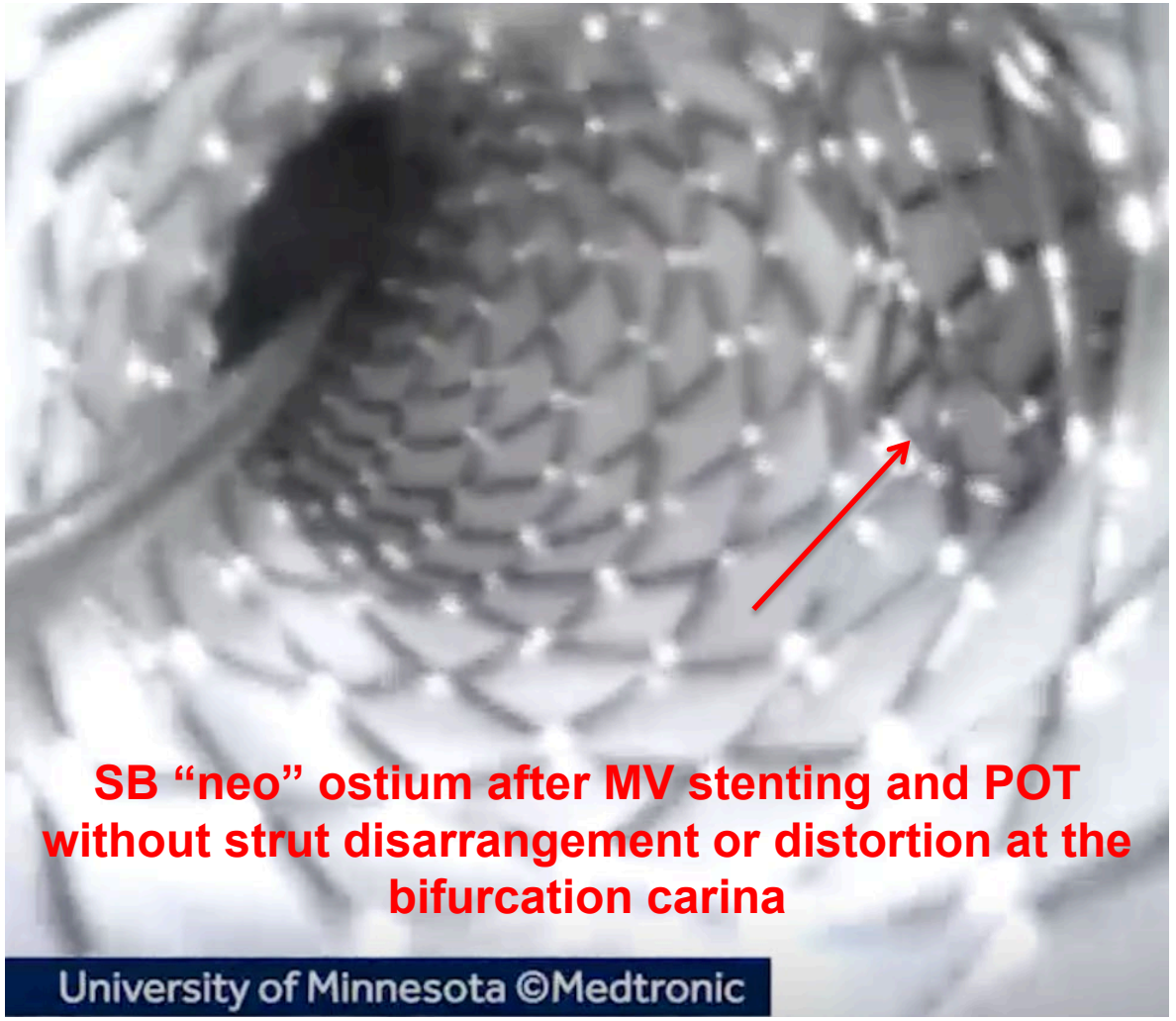




After MV Stenting and POT



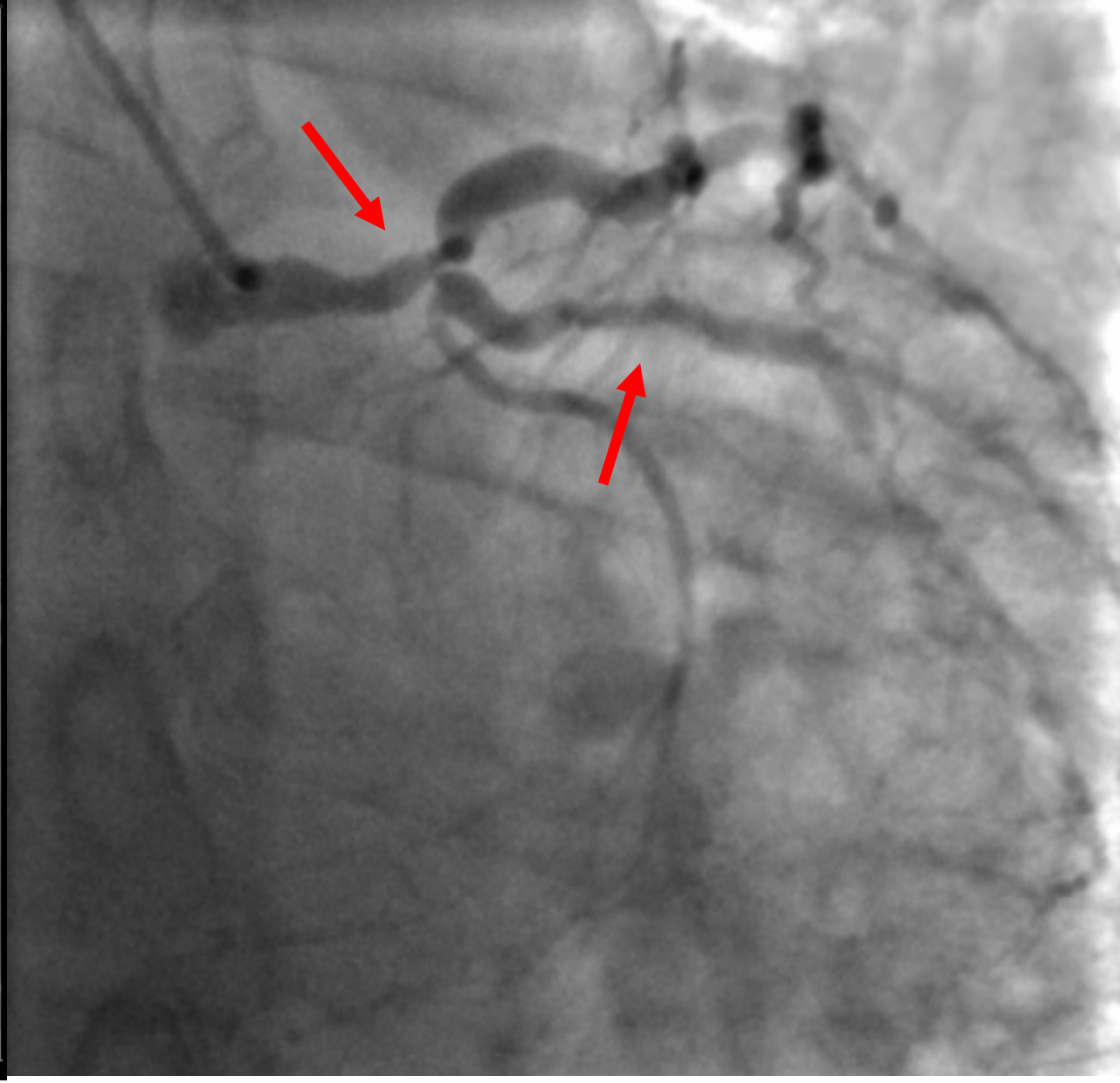


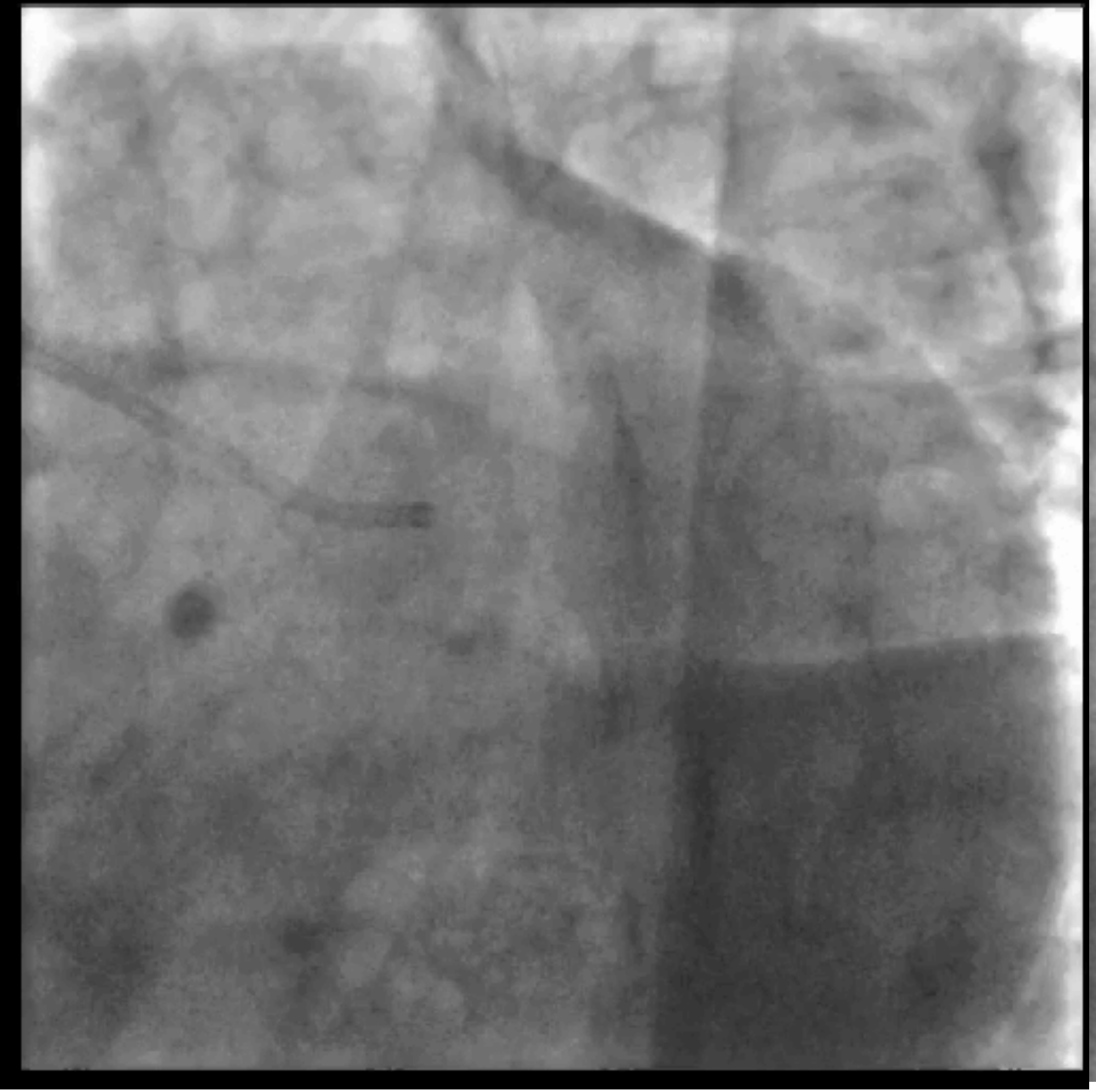


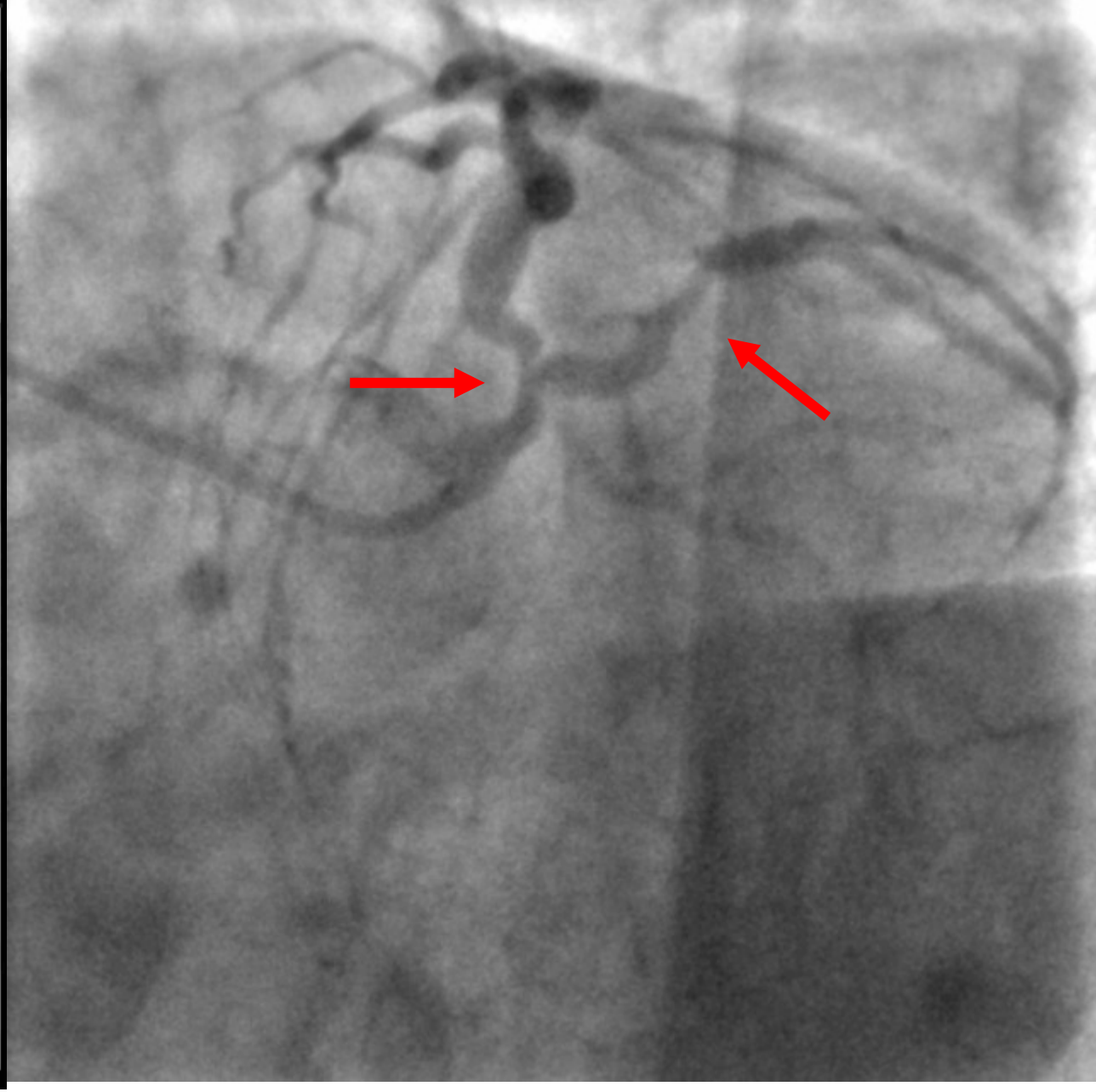
Final Result Post FKB and POT

"Crush" Series

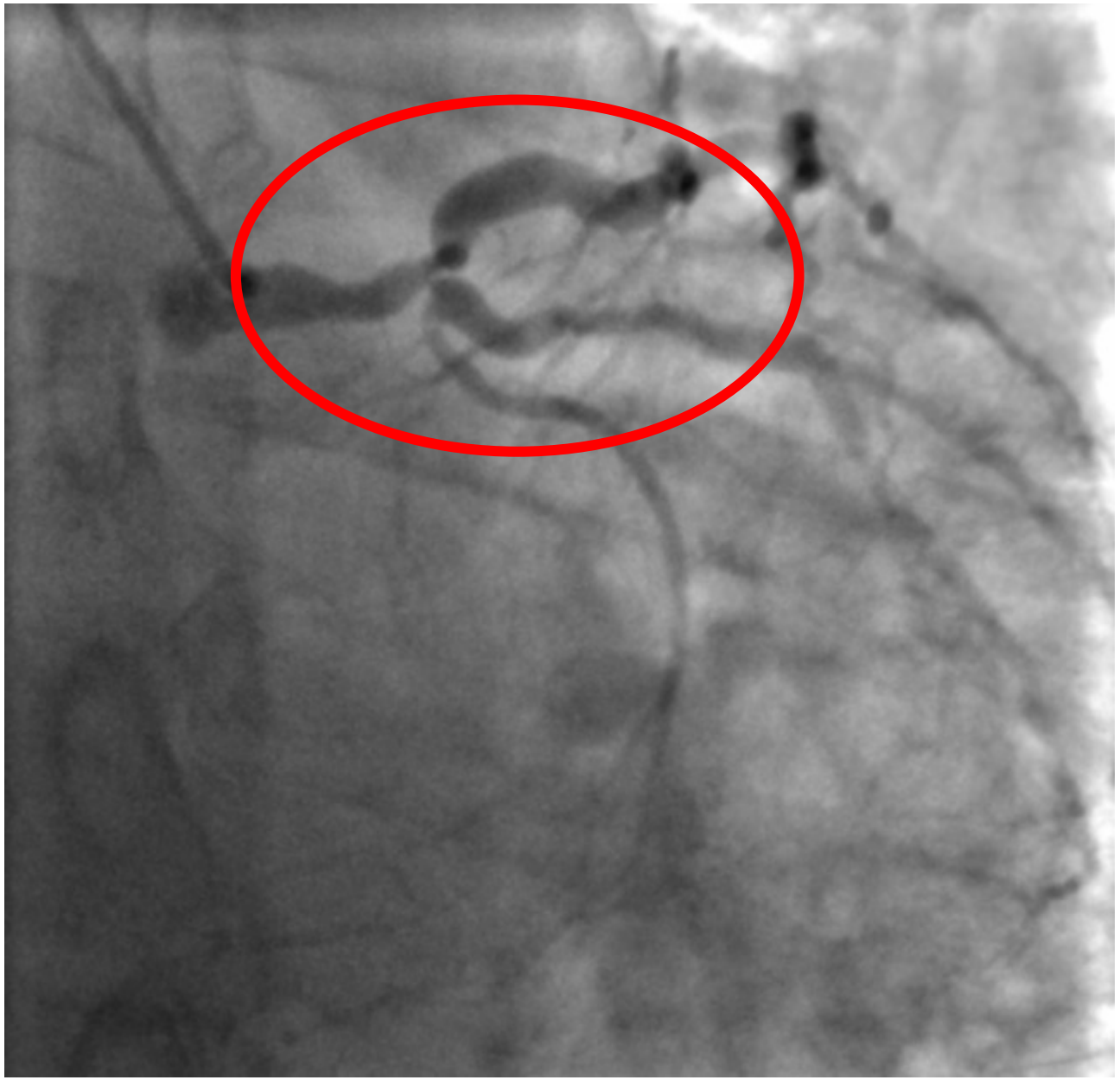
- **Crush: Técnica** – *Colombo A, Catheter Cardiovasc Interv. 2003;60(2):145-51*
- **Crush: Mecanismos de falência** – *Costa RA, J Am Coll Cardiol. 2005;46(4):599-605*
- **Crush: Mundo real EUA** – *Moussa I, Am J Cardiol. 2006;97(9):1317-21*
- **Crush: Segurança** – *Hoye A, J Am Coll Cardiol. 2006;47(10):1949-58*
- **DK-crush: Técnica** – *Chen SL, Chin Med J (Engl). 2005;118(20):1746-50*
- **DK-crush I: Crush clássico vs. DK-crush** – *Chen SL, Eur J Clin Invest. 2008;38(6):361-71*
- **DK-crush II: Provisional vs. DK-crush** – *Chen SL, J Am Coll Cardiol. 2011;57(8):914-20*
- **DK-crush III: Culotte vs. DK-crush** – *Chen SL, J Am Coll Cardiol. 2013;61(14):1482-8*
- **DK-crush IV: Provisional vs. DK-crush com FFR**– *Ye F, Chin Med J (Engl). 2012;125(15):2658-62*
- **DK-crush V: Provisional vs. DK-crush em TCE** – *Chen SL, J Am Coll Cardiol. 2017;70(21):2605-17*
- **DK-crush VI: Angio vs. FFR em provisional** – *Chen SL, JACC Cardiovasc Interv. 2015;8(4):536-46*
- **DK-crush VII: FFR em lesões não bifurcadas** – *Li SJ, JACC Cardiovasc Interv. 2017;10(10):986-95*
- **DK-crush VIII: Angio vs. USIC** – *Ge Z, Am Heart J. 2021;234:101-10 (desenho do estudo)*



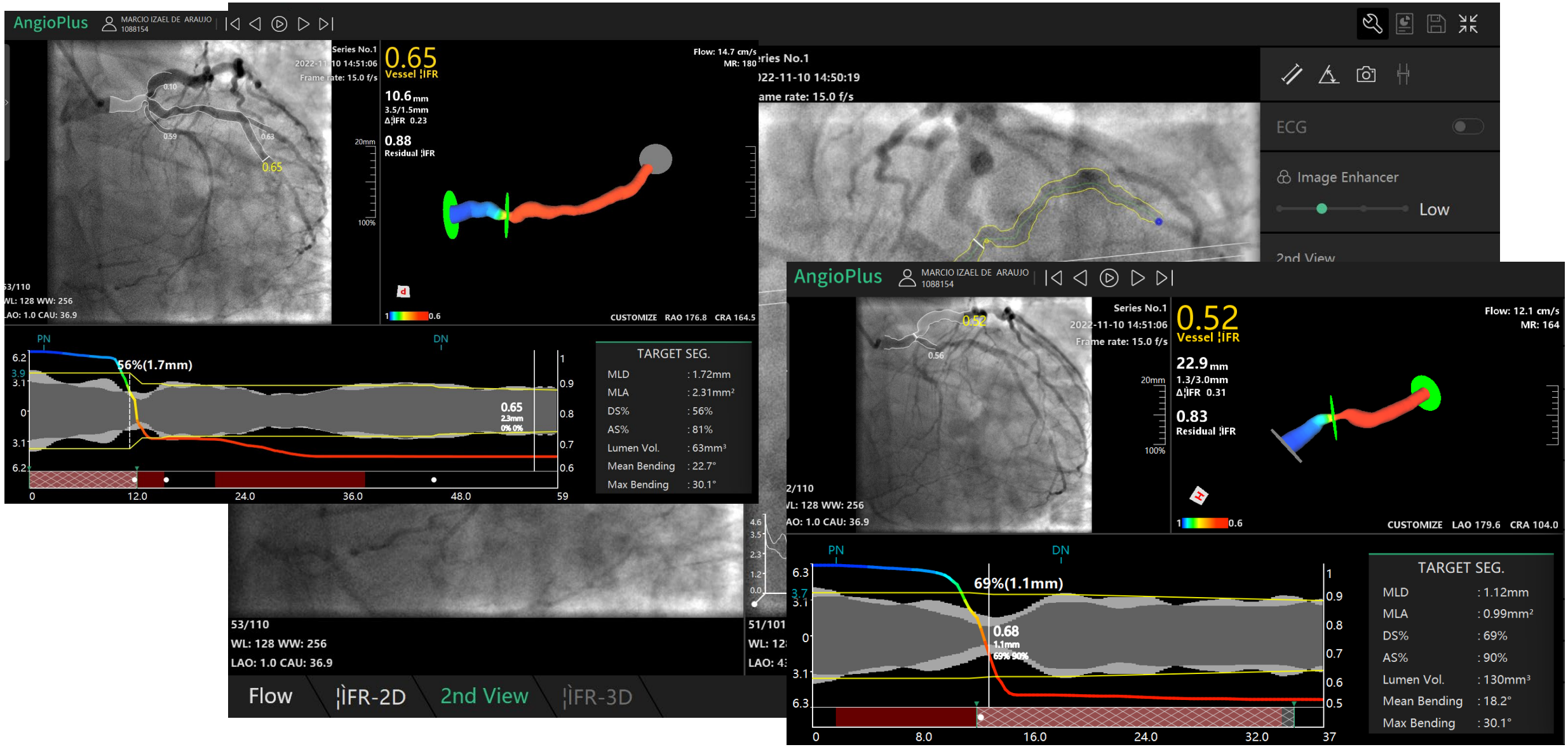


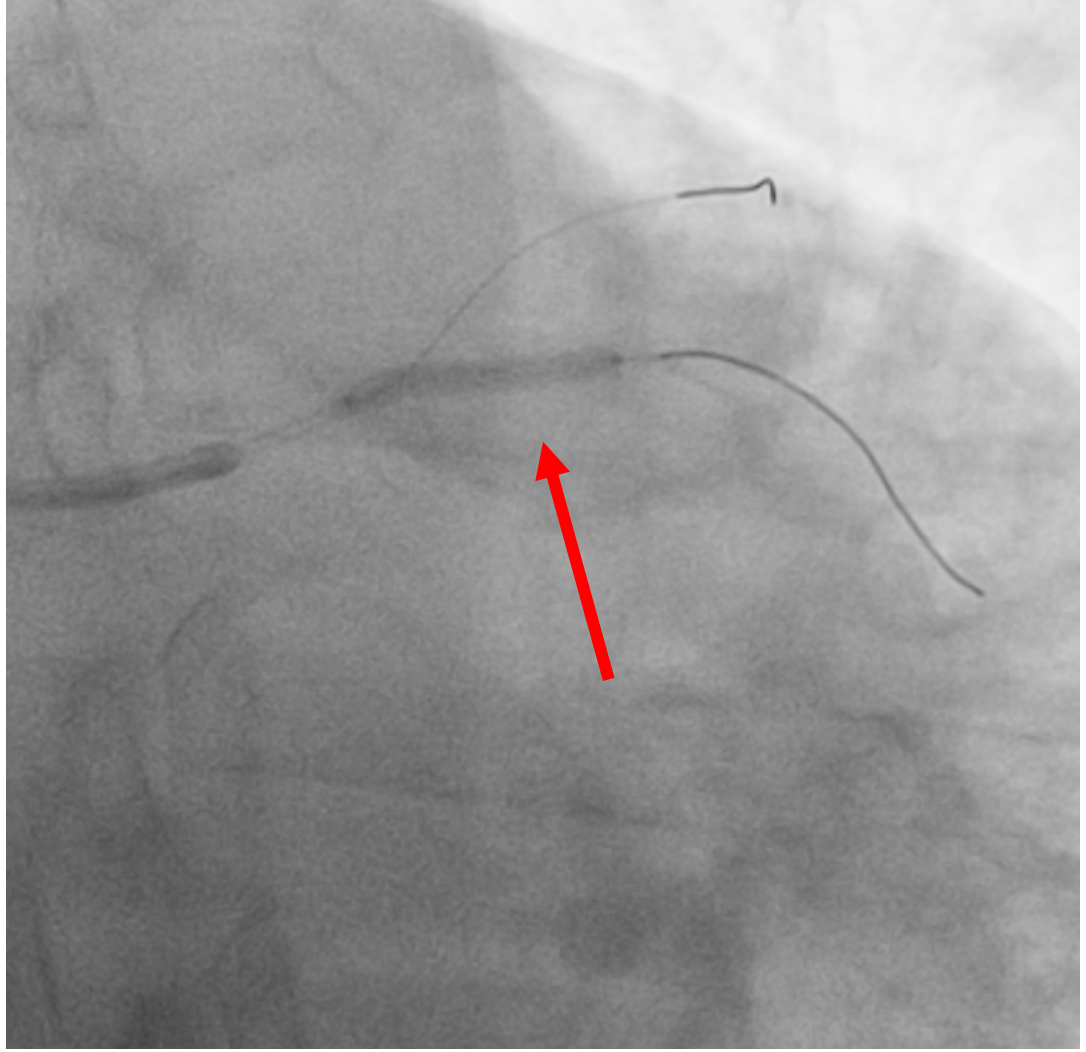


LM lesion evaluation

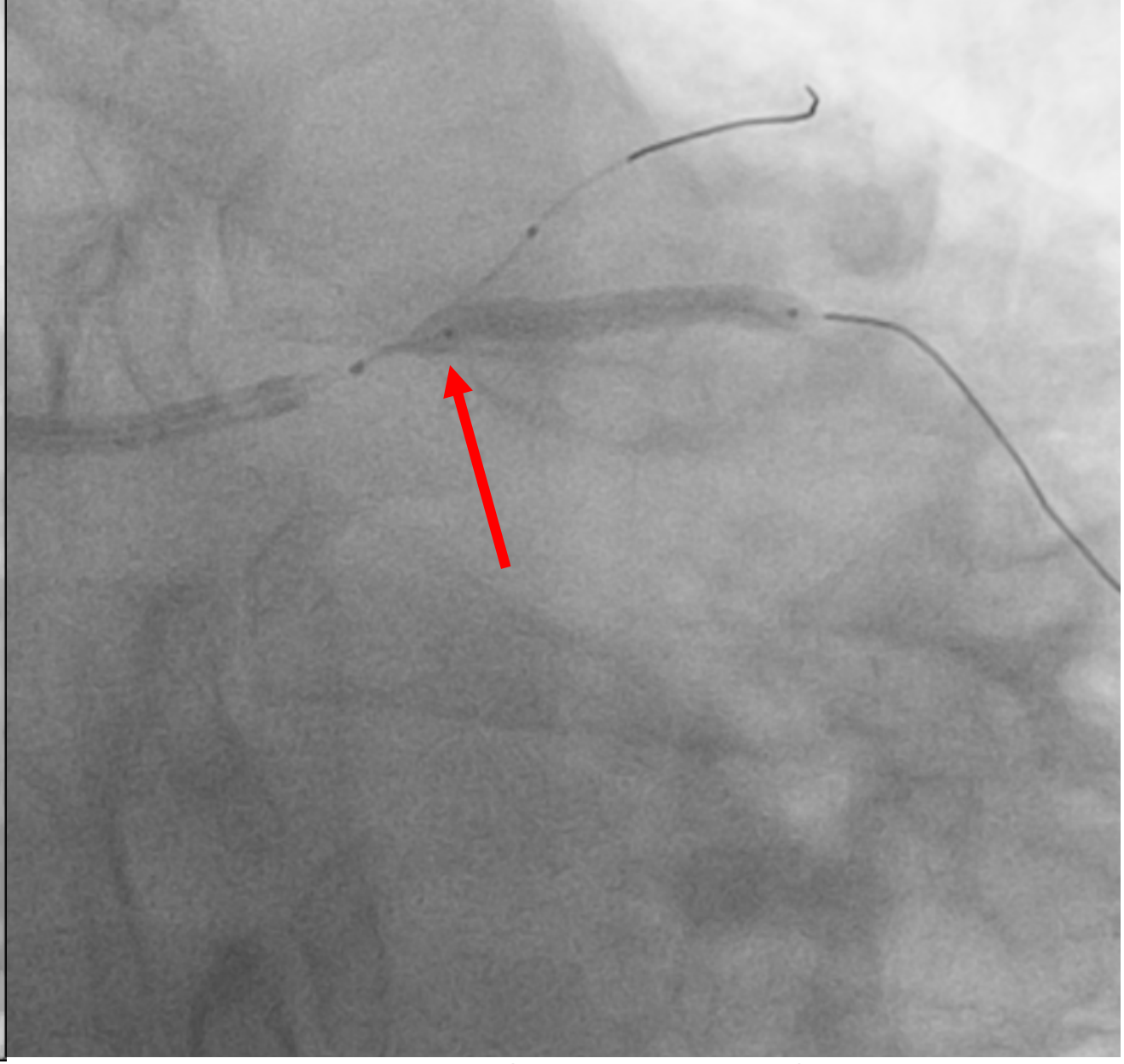


Angiography-based physiology (µFR)



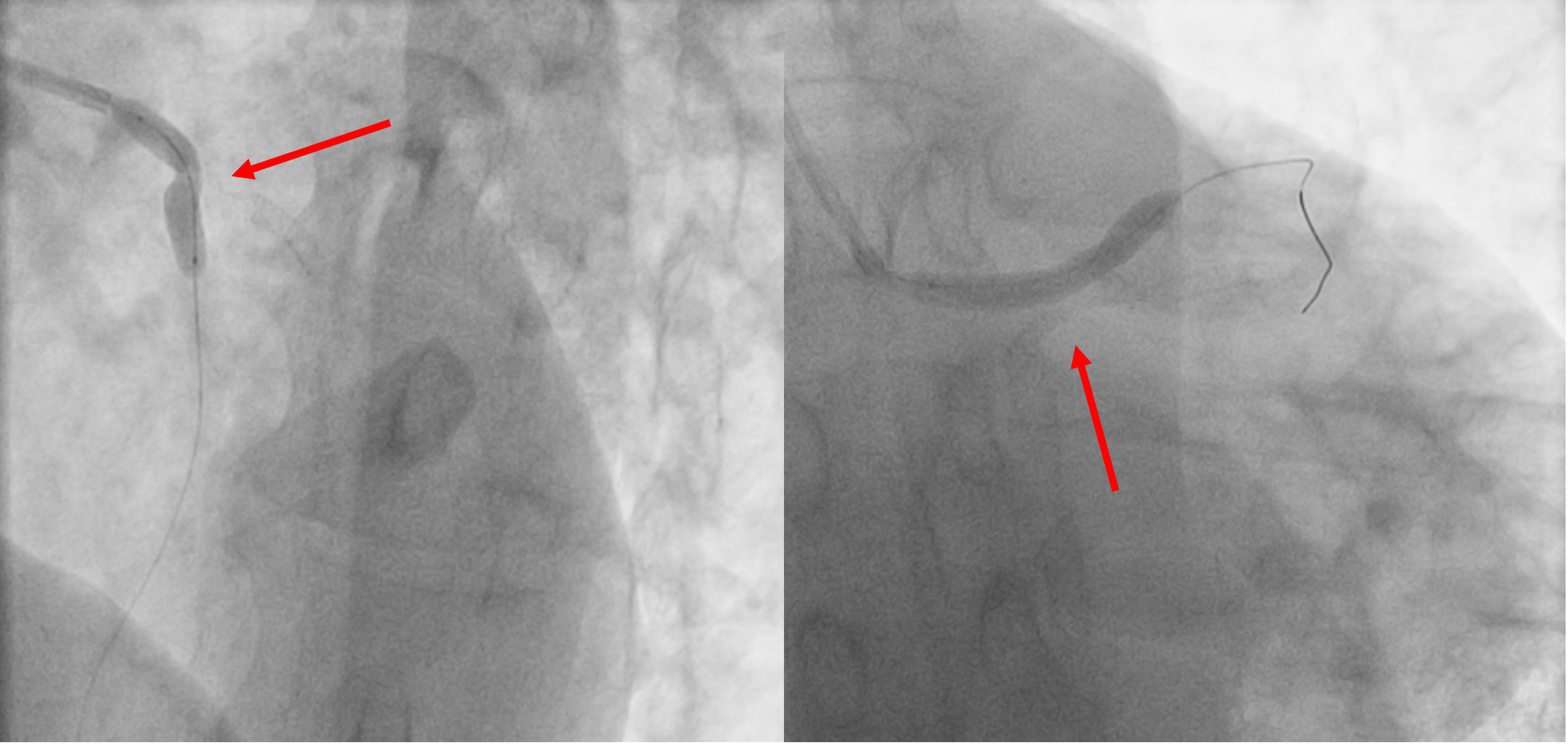


Balloon positioned in LM-LAD

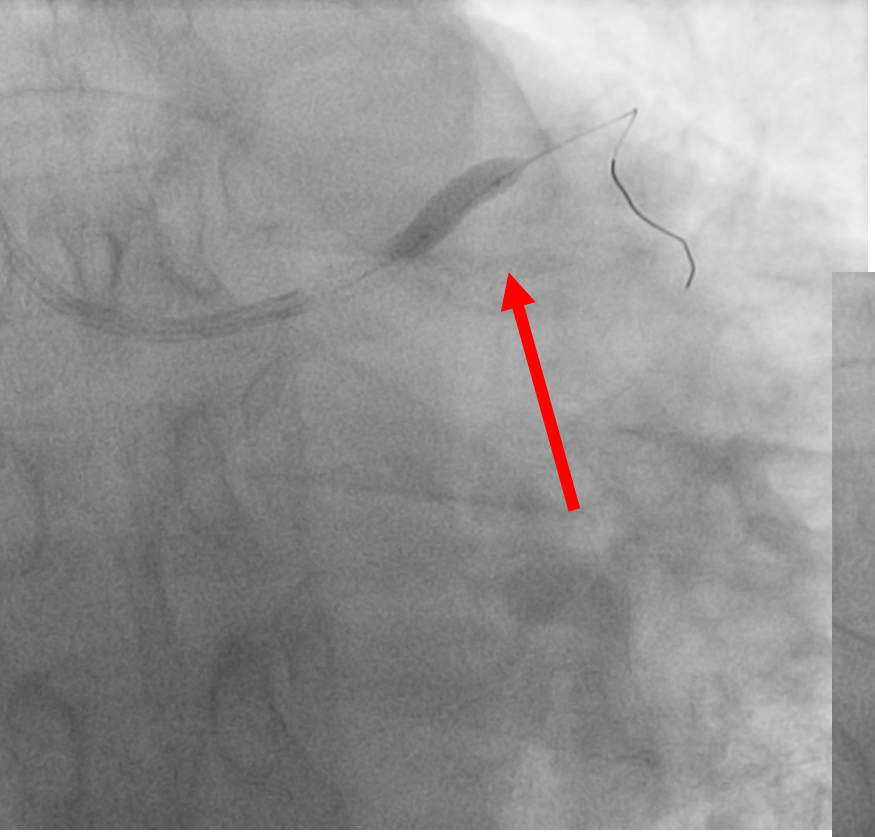


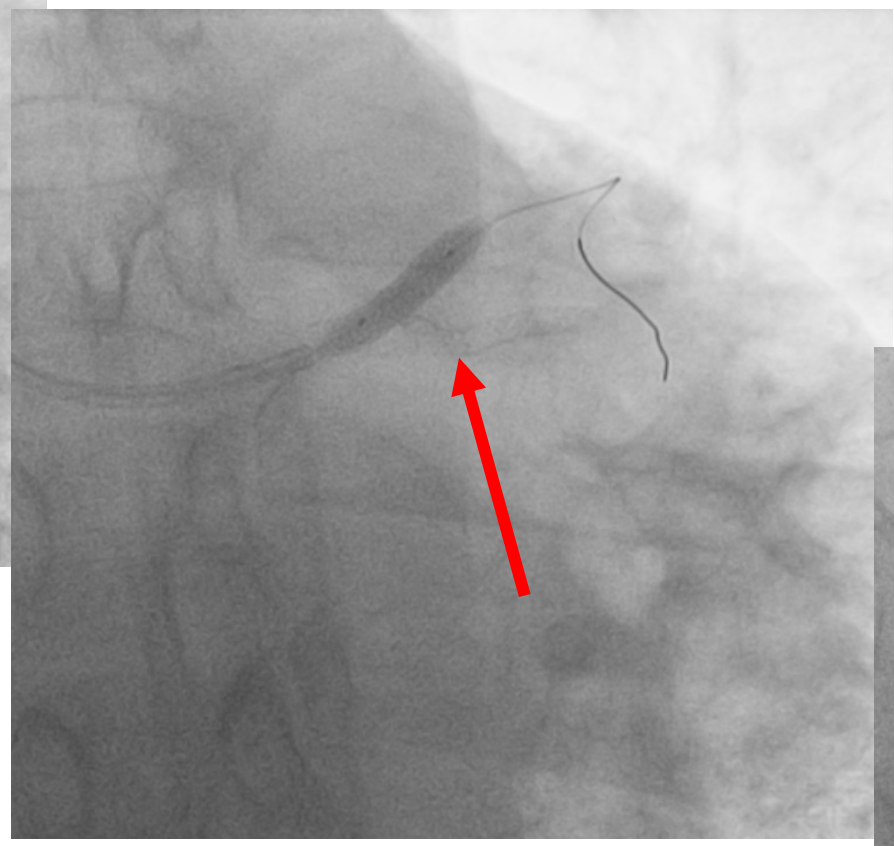
LCx SES (3.0 x 23 mm)

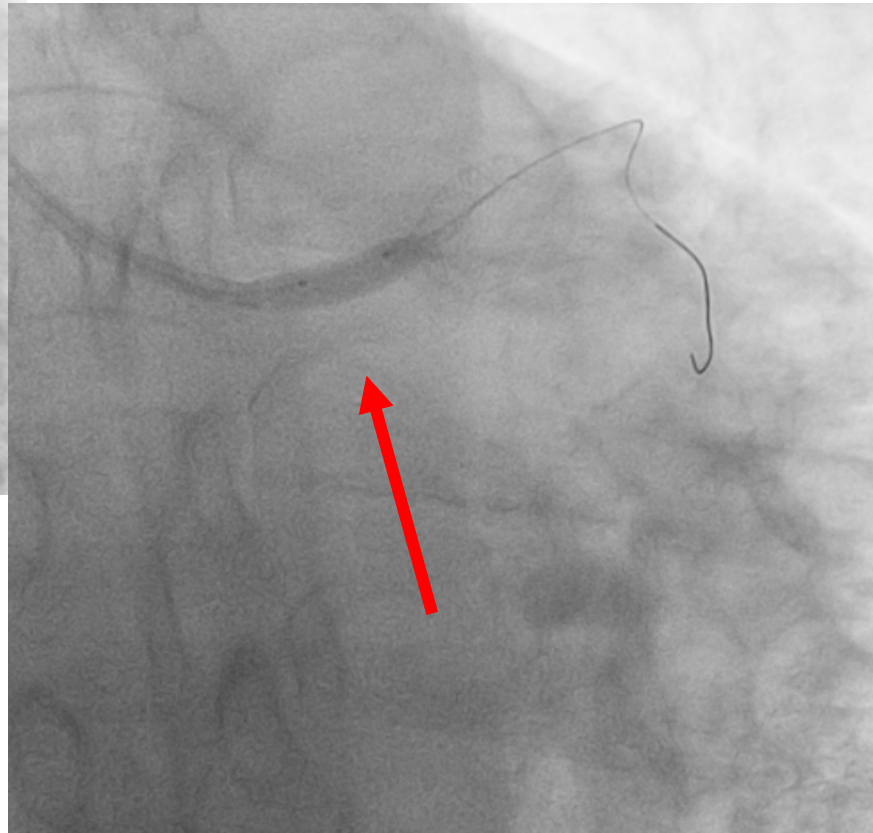
Control angio after 1st KBI



LM-LAD SES (4.0 x 29 mm)
Modified T (“nano DK-crush”) technique

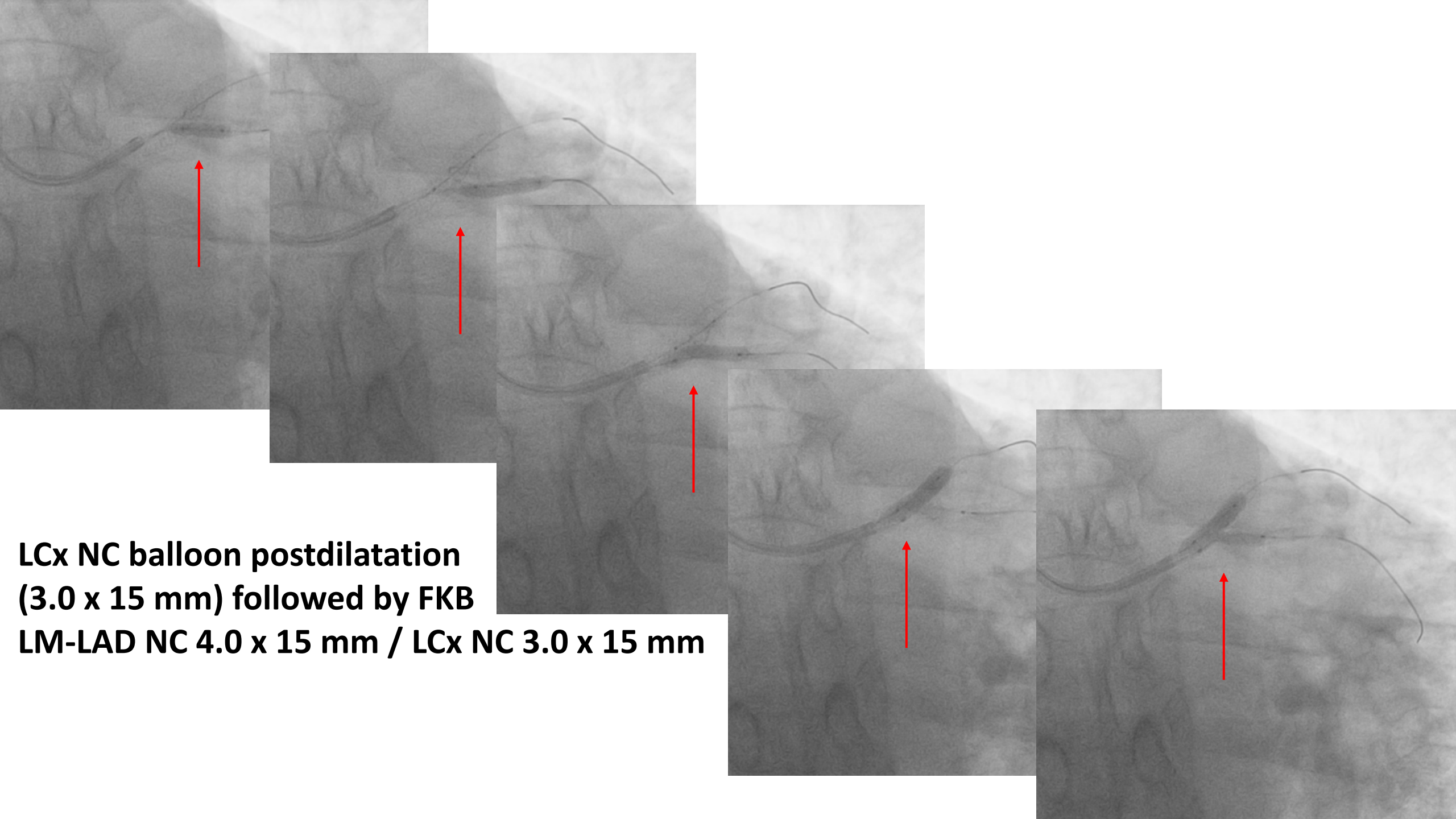




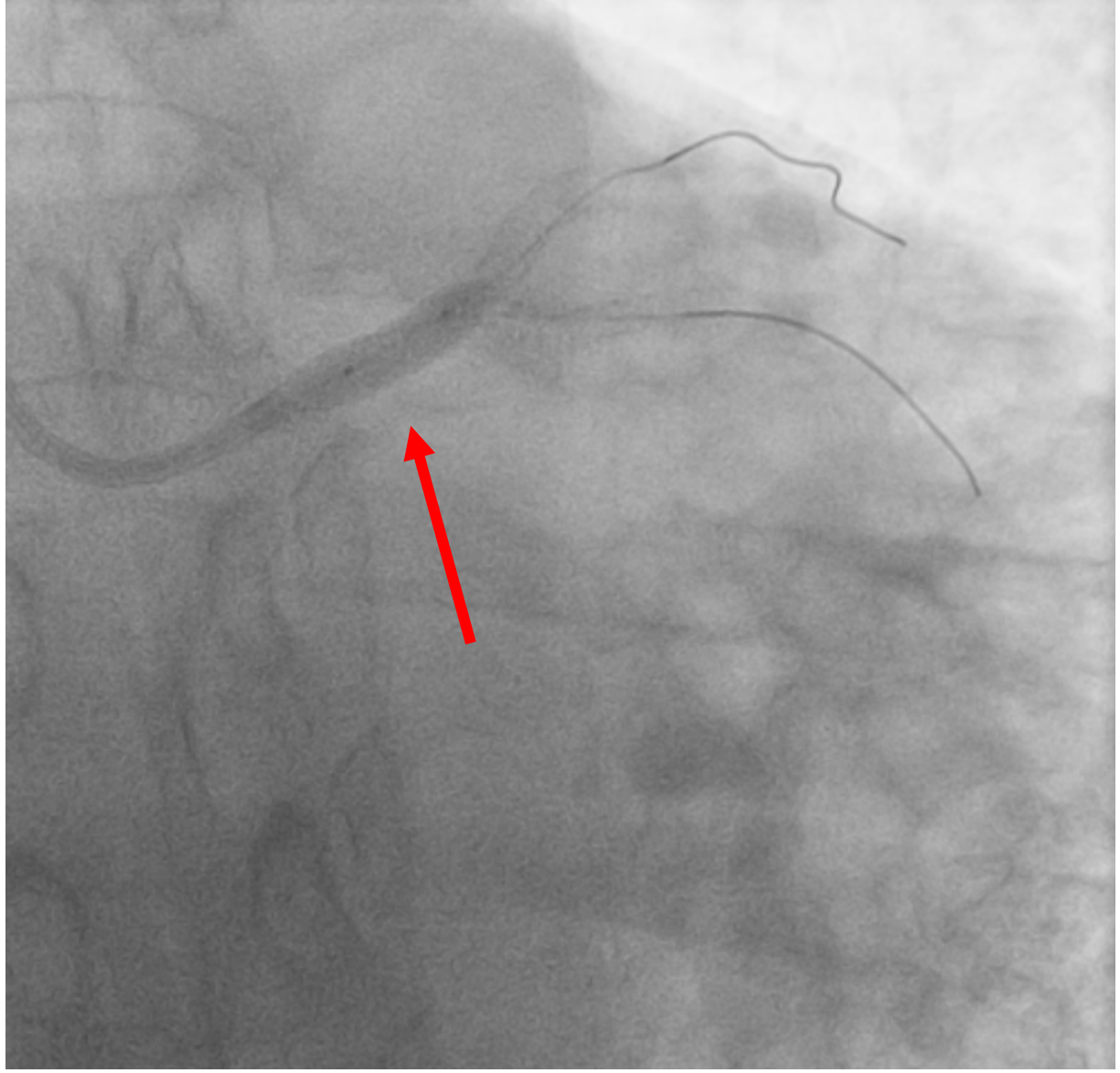


LM-LAD NC balloon postdilatation (4.0 x 15 mm)
POT NC balloon 4.5 x 10 mm

Control angio



LCx NC balloon postdilatation (3.0 x 15 mm) followed by FKB LM-LAD NC 4.0 x 15 mm / LCx NC 3.0 x 15 mm



Re-POT

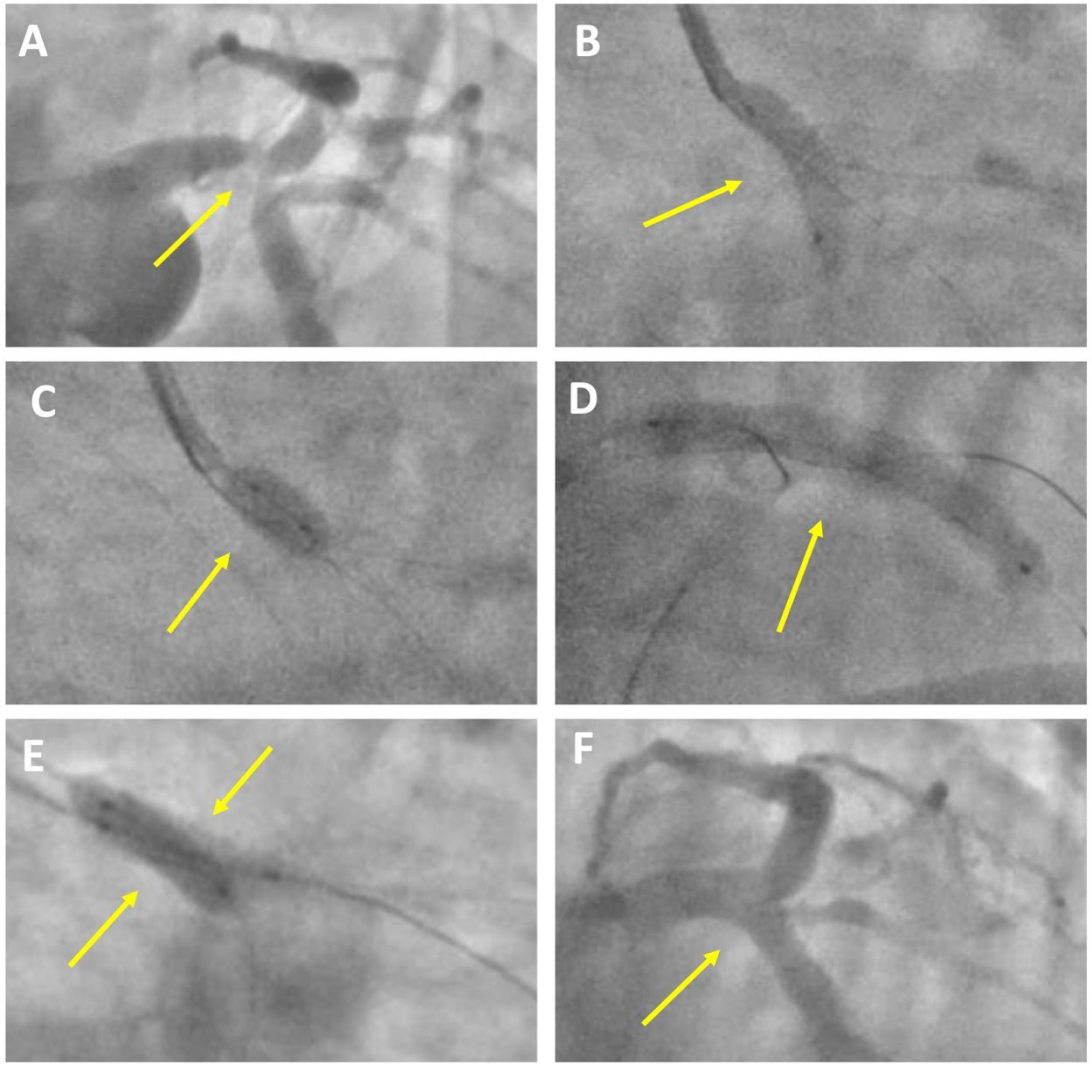
NC balloon 4.5 x 10 mm

Final angio

Step by step:

1) Wire both branches
2) SB (and MV) lesion preparation/balloon predilatation (as required)
3) SB stent implant with short protrusion into the MV (stent sized according to distal landing area), with a balloon parked in the MV
4) Remove SB wire if vessel is patent and without distal dissection that might require further treatment
5) MV balloon dilatation with a properly sized balloon to crush the protruded stent struts (option to perform a first POT at this point if required)
6) SB rewire (preferably in a central cell)
7) Kissing-balloon dilatation (balloons sized according to branches' reference diameter)
8) SB wire removed
9) MV stent implant (stent sized according to distal landing area)
10) POT (balloon sized according to LM reference diameter)
11) SB rewire (preferably in a central cell)
12) High-pressure single NC balloon postdilatation in the SB followed by the MV (balloons sized according to branches' reference diameter)
13) Kissing-balloon dilatation
14) Final POT

Classic Culotte:



Step by step:

1) Wire both branches
2) SB (and MV) lesion preparation/balloon predilatation (as required)
3) LM-SB stent implant (stent sized according to distal landing area)
4) LM-SB stent implant
5) POT (balloon sized according to LM reference diameter)
6) MV rewire (preferably in a more distal cell) – remove jailed wire after
7) Kissing-balloon dilatation (balloons sized according to branches' reference diameter)
8) SB wire removed
9) LM-MV stent implant (stent sized according to distal landing area), with proximal overlapping of stents
10) POT
11) SB rewire (preferably in a more distal cell)
12) High-pressure single NC balloon postdilatation in the SB followed by the MV (balloons sized according to branches' reference diameter)
13) Kissing balloon dilatation
14) Final POT

Different or Complimentary?

Study	DK-crush V	EBC MAIN	DEFINITION II
Study design	Superiority (double stenting)	Superiority (provisional)	Superiority (double stenting)
Number of patients	482	467	653
Sites	26	31	49
Region	Asia (mainly)	Europe	Asia (mainly)
Enrollment period	Dec/2011 - Feb/2016	Feb/2016 - Nov/2019	Dec/2015 - Nov/2018
Mean age (years)	64 - 65	70.8 - 71.4	63 - 64
Diabetes	25.6 - 28.8%	27 - 29%	34.1 - 35.7%
Unprotected LM	100%	100%	28.8%
Medina entry criteria	1,1,1 / 0,1,1	1,1,1 / 0,1,1	1,1,1 / 0,1,1
Medina type 1,1,1	**78.5 - 85.0%**	**89 - 90%**	**82.5 - 86.3%**
SB reference diameter criteria	**Not specified**	**≥ 2.75 mm**	**≥ 2.5 mm**
SB diameter stenosis criteria	**> 50%**	**> 50%**	**≥ 70% or 90%**
Complexity criteria	True bifurcation lesion	True bifurcation lesion	DEFINITION complex
Calcification (moderate/severe)	37.1 - 39.7%	44 - 54%	38.7 - 40.3%
Mean distal angle	**76.3 - 79.7º**	**80.4 - 82.3º**	**54.4 - 54.9º**
Trifurcation	17.8 - 17.9%	4 - 5%	6.8 - 9.5%
Mean Syntax score	**30.1 - 31.1**	**22.6 - 23.2**	**24.2 - 24.7**

Different or Complimentary?

Study	DK-crush V	EBC MAIN	DEFINITION II
Mean SB lesion length	**16.2 - 16.6 mm**	**5.8 - 7.9 mm**	**19.88 - 20.71 mm**
Mean SB diameter stenosis	**60.8 – 61.8%**	**51.9 - 55.4%**	**61.5 - 62.3%**
Crossover from single to double stenting	**47.1%**	**22%**	**22.5%**
SB crossover criteria	a) Ostial stenosis > 75% b) Dissection ≥ type B c) TIMI < 3	a) Ostial stenosis > 90% b) Dissection > type A c) TIMI < 3	a) Pinched ostium b) Dissection ≥ type B c) TIMI < 3
Double stenting arm techniques	**- DK-crush (100%)**	- **Culotte (53%)** - T or TAP (32%) **- DK-crush (5%)** - Others (10%)	**- DK-crush (77.8%)** **- Culotte (17.9%)** - T and protrusion (3.3%) - Others (1%)
Intravascular imaging use	**40.5 - 42.9%**	**38 - 40%**	**24.4 - 31.1%**
Primary endpoint	TLF (cardiac death, target vessel MI or clinically-driven TLR) at 1 year	All-cause death, MI or TLR at 1 year	TLF (cardiac death, target vessel MI or clinically-driven TLR) at 1 year
Outcomes (provisional vs. double stenting)	**10.7 vs. 5.0% (p=0.02)**	**14.7 vs. 17.7% (p=0.34)**	**11.4 vs. 6.1% (p=0.02)**
Favors	**Double stenting**	**None**	**Double stenting**

Impacto da Otimização com 2-Stents

ORIGINAL ARTICLE

Optimal Minimal Stent Area and Impact of Stent Underexpansion in Left Main Up-Front 2-Stent Strategy

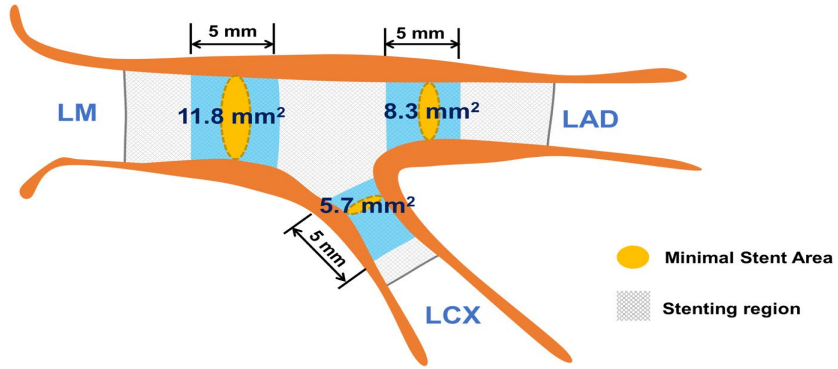
Ju Hyeon Kim, MD; Do-Yoon Kang, MD, PhD; Jung-Min Ahn, MD, PhD; Jihoon Kweon, PhD; Yeonwoo Choi, MD; Hoyun Kim, MD; Jinho Lee, MD; Jihye Chae, BS; Soo-Jin Kang, MD, PhD; Duk-Woo Park, MD, PhD; Seung-Jung Park, MD, PhD

BACKGROUND: We previously reported the use of minimal stent area to predict angiographic in-stent restenosis after drug-eluting stent implantation for unprotected left main (LM) disease. We aimed to evaluate the optimal minimal stent area criteria for up-front LM 2-stenting based on long-term clinical outcomes.

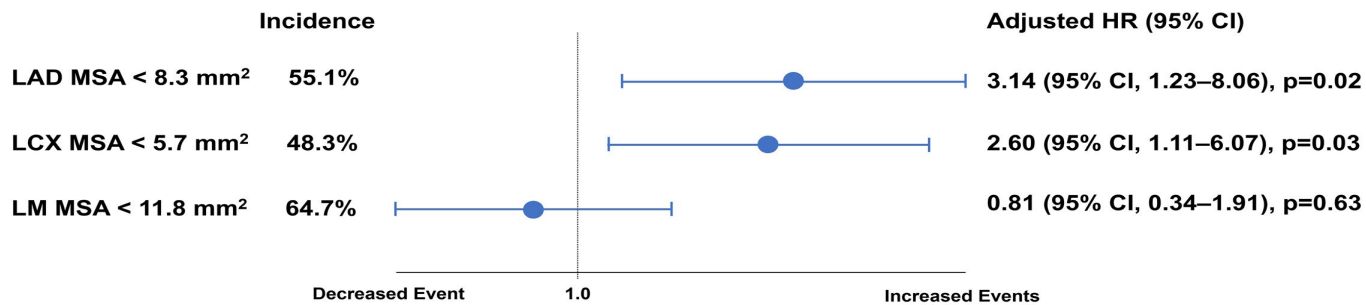
METHODS: We identified 292 consecutive patients with LM bifurcation stenosis who were treated using the crush technique. The final minimal stent area was measured in the ostial left anterior descending artery (LAD), ostial left circumflex artery (LCX), and distal LM. The primary outcome was 5-year major adverse cardiac events, including all-cause death, myocardial infarction, and target lesion revascularization.

Kim JH et al. Circ Cardiovasc Interv. 2024;17:e013006

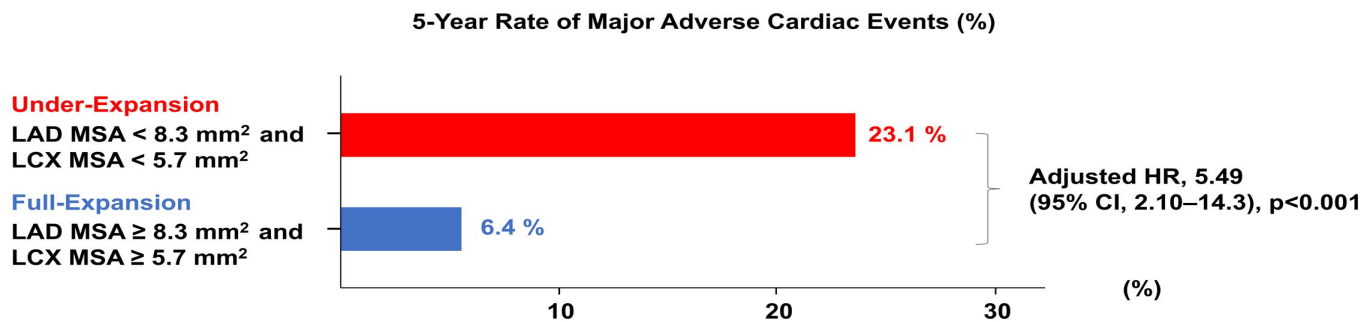
The Optimal Minimal Stent Area within Each Left Main Segment

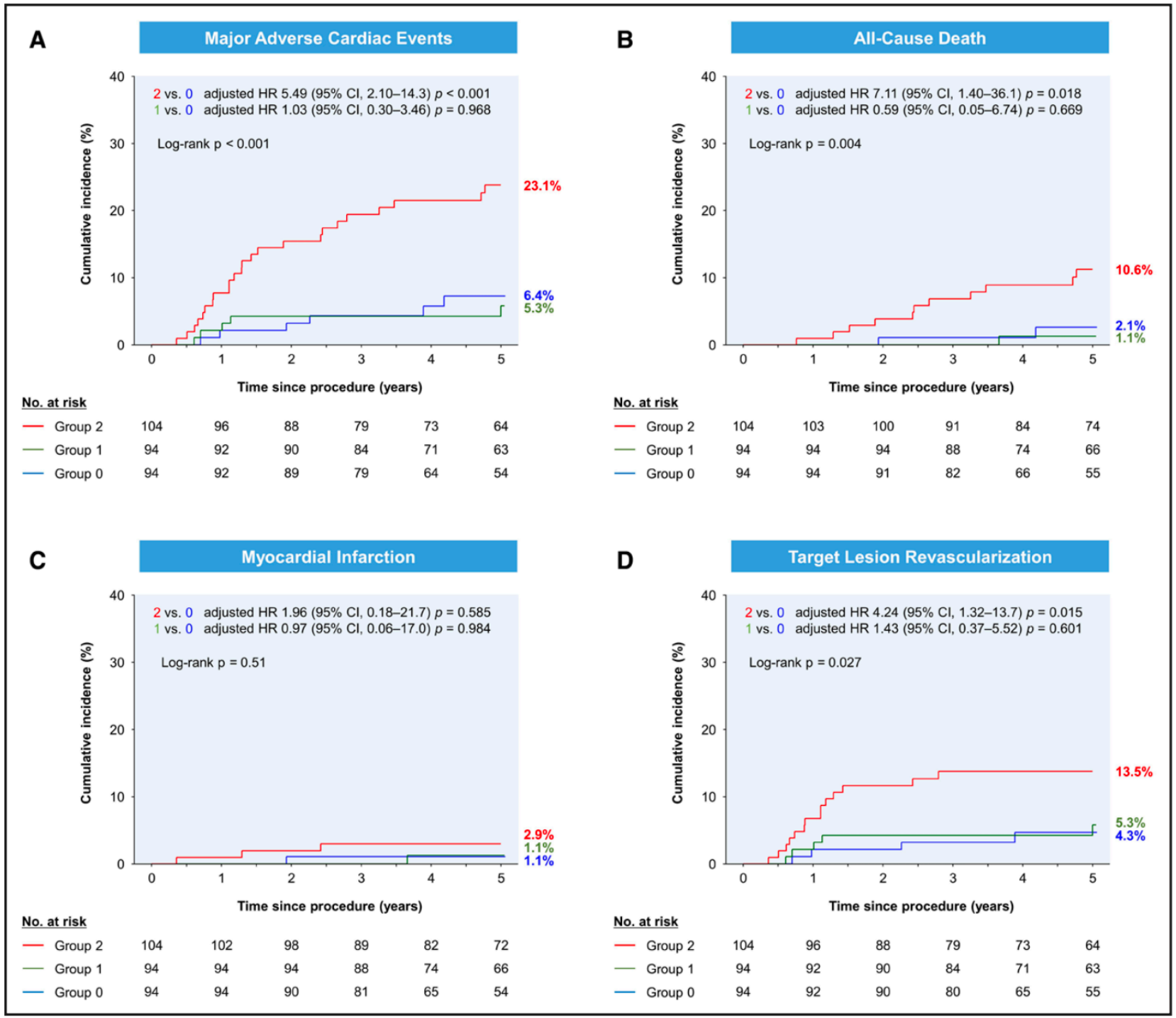


Stent Under-Expansion Criteria in LM Two-Stenting With the Crush Technique

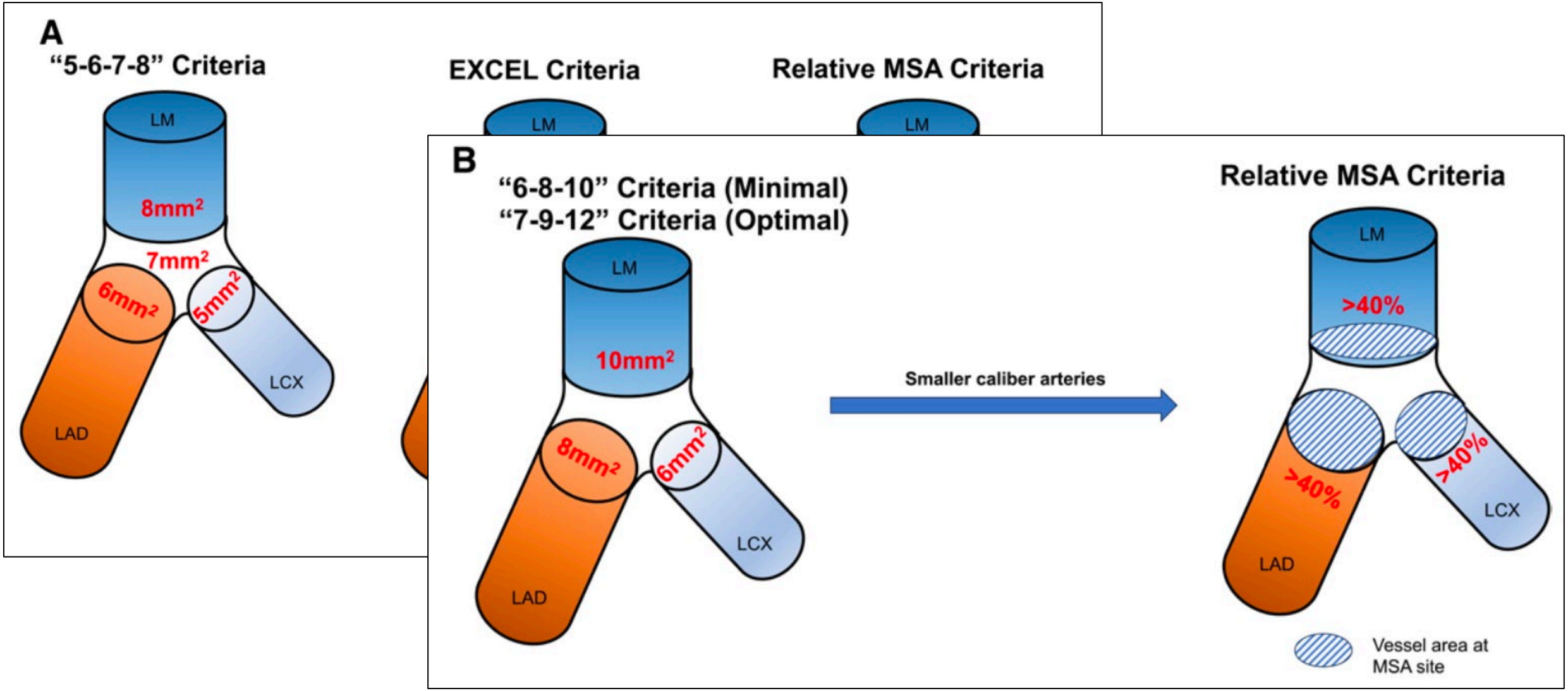


Major Adverse Cardiac Events at 5 Years according to Stent Under-Expansion




A
Major Adverse Cardiac Events
2 vs. 0 adjusted HR 5.49 (95% CI, 2.10–14.3) p < 0.001
1 vs. 0 adjusted HR 1.03 (95% CI, 0.30–3.46) p = 0.968
Log-rank p < 0.001
Cumulative incidence (%)
Time since procedure (years)
23.1%
6.4%
5.3%
No. at risk
Group 2 104 96 88 79 73 64
Group 1 94 92 90 84 71 63
Group 0 94 92 89 79 64 54
B
All-Cause Death
2 vs. 0 adjusted HR 7.11 (95% CI, 1.40–36.1) p = 0.018
1 vs. 0 adjusted HR 0.59 (95% CI, 0.05–6.74) p = 0.669
Log-rank p = 0.004
Cumulative incidence (%)
Time since procedure (years)
10.6%
2.1%
1.1%
No. at risk
Group 2 104 103 100 91 84 74
Group 1 94 94 94 88 74 66
Group 0 94 94 91 82 66 55
C
Myocardial Infarction
2 vs. 0 adjusted HR 1.96 (95% CI, 0.18–21.7) p = 0.585
1 vs. 0 adjusted HR 0.97 (95% CI, 0.06–17.0) p = 0.984
Log-rank p = 0.51
Cumulative incidence (%)
Time since procedure (years)
2.9%
1.1%
1.1%
No. at risk
Group 2 104 102 98 89 82 72
Group 1 94 94 94 88 74 66
Group 0 94 94 90 81 65 54
D
Target Lesion Revascularization
2 vs. 0 adjusted HR 4.24 (95% CI, 1.32–13.7) p = 0.015
1 vs. 0 adjusted HR 1.43 (95% CI, 0.37–5.52) p = 0.601
Log-rank p = 0.027
Cumulative incidence (%)
Time since procedure (years)
13.5%
5.3%
4.3%
No. at risk
Group 2 104 96 88 79 73 64
Group 1 94 92 90 84 71 63
Group 0 94 92 90 80 65 55

Critérios de Otimização pelo USIC



Bangalore et al. Cardiovasc Interv. 2024;17:e013691

Metanálise 2022 – 29 Estudos

8.318 pacientes randomizados (2004-2021): Provisional vs. Stent duplo

Figure S3. Forest plot of two-stent versus provisional stent on major adverse cardiac events.

Study	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio Random, 95% CI
EBC MAIN	42.0	237	34.0	230	6.8%	1.20 [0.79; 1.81]
NBBS IV	5.0	228	12.0	218	2.9%	0.40 [0.14; 1.11]
DEFINITION II	20.0	328	37.0	325	5.9%	0.54 [0.32; 0.90]
DKCRUSH-V	20.0	240	41.0	242	6.0%	0.49 [0.30; 0.81]
DKCRUSH-II	29.0	183	44.0	183	6.7%	0.66 [0.43; 1.00]
POLBOS II	12.0	102	15.0	100	4.5%	0.78 [0.39; 1.59]
EBC TWO	10.0	97	8.0	103	3.5%	1.33 [0.55; 3.22]
SMART-STRATEGY	8.0	130	1.0	128	0.9%	7.88 [1.00; 62.08]
Zhang et al. (2016)	4.0	52	2.0	52	1.4%	2.00 [0.38; 10.45]
Zheng et al. (2016)	10.0	150	8.0	150	3.4%	1.25 [0.51; 3.08]
BBK I	23.0	101	23.0	101	6.0%	1.00 [0.60; 1.66]
TRYTON	65.0	355	45.0	349	7.3%	1.42 [1.00; 2.02]
POLBOS I	16.0	120	15.0	123	4.8%	1.09 [0.57; 2.11]
PERFECT	38.0	213	38.0	206	6.8%	0.97 [0.64; 1.45]
NSTS	43.0	209	36.0	215	6.9%	1.23 [0.82; 1.83]
NBS	44.0	202	32.0	202	6.8%	1.38 [0.91; 2.07]
Ye et al. (2012)	1.0	38	5.0	30	0.9%	0.16 [0.02; 1.28]
BBC One	38.0	250	20.0	250	5.9%	1.90 [1.14; 3.17]
Lin et al. (2010)	6.0	54	21.0	54	3.8%	0.29 [0.13; 0.65]
Ye et al. (2010)	0.0	25	1.0	26	0.4%	0.35 [0.01; 8.12]
CACTUS	28.0	177	26.0	173	6.1%	1.05 [0.64; 1.72]
Cervinka et al. (2008)	4.0	30	4.0	30	2.1%	1.00 [0.28; 3.63]
Total (95% CI)		**3522**		**3491**	**100.0%**	**0.95 [0.77; 1.17]**

Heterogeneity: $Tau^2 = 0.1274$; $Chi^2 = 51.91$, df = 21 (P < 0.01); $I^2 = 60\%$

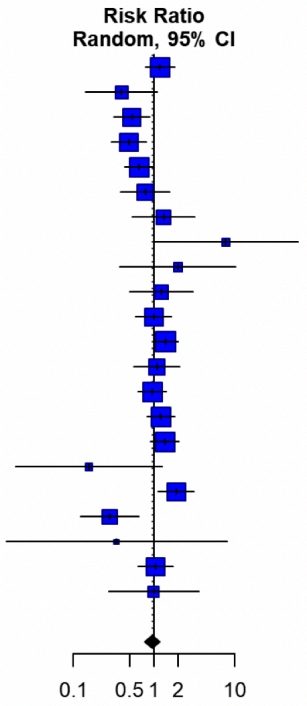
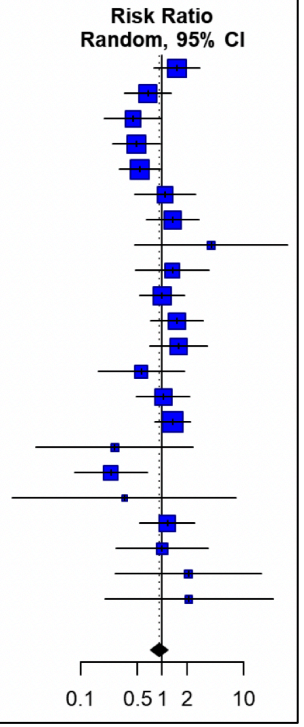


Figure S6. Forest plot of two-stent versus provisional stent on target lesion revascularization.

Study	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio Random, 95% CI
EBC MAIN	22.0	237	14.0	230	6.8%	1.53 [0.80; 2.91]
NBBS IV	14.0	228	20.0	218	6.7%	0.67 [0.35; 1.29]
DEFINITION II	8.0	328	18.0	325	5.2%	0.44 [0.19; 1.00]
DKCRUSH-V	12.0	240	25.0	242	6.6%	0.48 [0.25; 0.94]
DKCRUSH-II	16.0	183	30.0	183	7.6%	0.53 [0.30; 0.94]
POLBOS II	10.0	102	9.0	100	4.9%	1.09 [0.46; 2.57]
SMART-STRATEGY	15.0	130	11.0	128	5.9%	1.34 [0.64; 2.81]
Zhang et al. (2016)	4.0	52	1.0	52	1.1%	4.00 [0.46; 34.59]
Zheng et al. (2016)	8.0	150	6.0	150	3.8%	1.33 [0.47; 3.75]
BBK I	16.0	101	16.0	101	6.9%	1.00 [0.53; 1.89]
TRYTON	17.0	355	11.0	349	5.8%	1.52 [0.72; 3.20]
POLBOS I	14.0	120	9.0	123	5.4%	1.59 [0.72; 3.54]
PERFECT	4.0	213	7.0	206	3.0%	0.55 [0.16; 1.86]
NSTS	13.0	209	13.0	215	5.8%	1.03 [0.49; 2.17]
NBS	31.0	202	23.0	202	8.4%	1.35 [0.82; 2.23]
Ye et al. (2012)	1.0	38	3.0	30	1.1%	0.26 [0.03; 2.40]
Lin et al. (2010)	4.0	54	17.0	54	3.9%	0.24 [0.08; 0.65]
Ye et al. (2010)	0.0	25	1.0	26	0.6%	0.35 [0.01; 8.12]
CACTUS	13.0	177	11.0	173	5.6%	1.16 [0.53; 2.51]
Cervinka et al. (2008)	4.0	30	4.0	30	2.7%	1.00 [0.28; 3.63]
Colombo et al. (2004)	6.0	63	1.0	22	1.2%	2.10 [0.27; 16.45]
Pan et al. (2004)	2.0	44	1.0	47	1.0%	2.14 [0.20; 22.74]
Total (95% CI)		**3282**		**3207**	**100.0%**	**0.92 [0.72; 1.17]**

Heterogeneity: $Tau^2 = 0.1120$; $Chi^2 = 33.38$, df = 21 (P = 0.04); $I^2 = 37\%$



Park DY, et al. J Am Heart Assoc. 2022;11(12):e025394

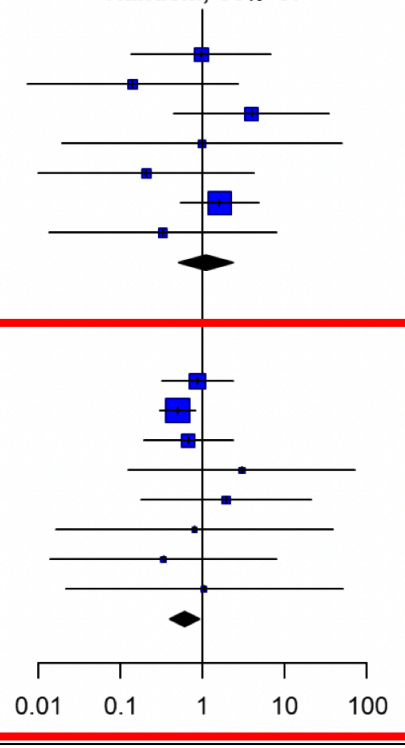
Extensão da Lesão no RL

Figure S10. Comparison of two-stent versus provisional stent stratifie

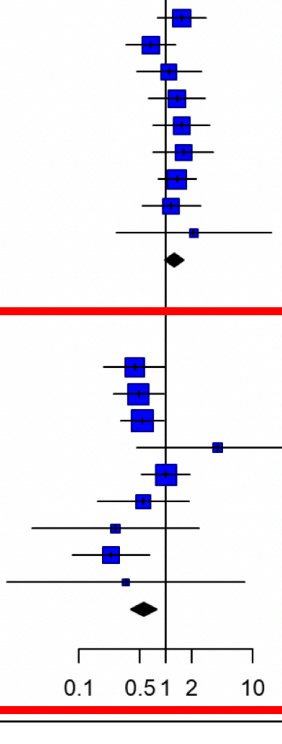
Study or Subgroup	Experimental Events	Total	Control Events	Total	Risk Random
Group = SB <10mm					
EBC MAIN	42.0	237	34.0	230	1.20 [0.
NBBS IV	5.0	228	12.0	218	0.40 [0.
POLBOS II	12.0	102	15.0	100	0.78 [0.
SMART-STRATEGY	8.0	130	1.0	128	7.88 [1.
TRYTON	65.0	355	45.0	349	1.42 [1.
POLBOS I	16.0	120	15.0	123	1.09 [0.
NBS	44.0	202	32.0	202	1.38 [0.
CACTUS	28.0	177	26.0	173	1.05 [0.
Total (95% CI)		**1551**		**1523**	**1.20 [1.**
Heterogeneity: Tau^2 = < 0.0001; Chi^2 = 10.67, df = 7 (P = 0.15); I^2 =					
Group = SB ≥10mm					
DEFINITION II	20.0	328	37.0	325	0.54 [0.
DKCRUSH-V	20.0	240	41.0	242	0.49 [0.
DKCRUSH-II	29.0	183	44.0	183	0.66 [0.
EBC TWO	10.0	97	8.0	103	1.33 [0.
Zhang et al. (2016)	4.0	52	2.0	52	2.00 [0.
BBK I	23.0	101	23.0	101	1.00 [0.
PERFECT	38.0	213	38.0	206	0.97 [0.
Ye et al. (2012)	1.0	38	5.0	30	0.16 [0.
Lin et al. (2010)	6.0	54	21.0	54	0.29 [0.
Ye et al. (2010)	0.0	25	1.0	26	0.35 [0.
Total (95% CI)		**1332**		**1323**	**0.68 [0.**
Heterogeneity: Tau^2 = 0.0966; Chi^2 = 17.5, df = 9 (P = 0.04); I^2 = 49					
Test for subgroup differences: Chi^2 = 9.64, df = 1 (P < 0.01)					

Figure S9. Comparison of two-stent versus provisional stent stratified to lesion length of side branch on cardiac death.

Study or Subgroup	Experimental Events	Total	Control Events	Total	Risk Ratio Random, 95% CI
Group = SB <10mm					
NBBS IV	2.0	228	2.0	218	0.96 [0.14; 6.73]
POLBOS II	0.0	102	3.0	100	0.14 [0.01; 2.68]
SMART-STRATEGY	4.0	130	1.0	128	3.94 [0.45; 34.76]
TRYTON	0.0	355	0.0	349	0.98 [0.02; 49.41]
POLBOS I	0.0	120	2.0	123	0.20 [0.01; 4.23]
NBS	8.0	202	5.0	202	1.60 [0.53; 4.81]
CACTUS	0.0	177	1.0	173	0.33 [0.01; 7.94]
Total (95% CI)		**1318**		**1297**	**1.10 [0.51; 2.37]**
Heterogeneity: Tau^2 = 0; Chi^2 = 5.4, df = 6 (P = 0.49); I^2 = 0%					
Group = SB ≥10mm					
DEFINITION II	7.0	328	8.0	325	0.87 [0.32; 2.36]
DKCRUSH-V	20.0	240	41.0	242	0.49 [0.30; 0.81]
DKCRUSH-II	4.0	183	6.0	183	0.67 [0.19; 2.32]
Zhang et al. (2016)	1.0	52	0.0	52	3.00 [0.13; 71.99]
PERFECT	2.0	213	1.0	206	1.93 [0.18; 21.17]
Ye et al. (2012)	0.0	38	0.9	38	0.79 [0.02; 38.93]
Lin et al. (2010)	0.0	54	1.0	54	0.33 [0.01; 8.01]
Ye et al. (2010)	0.0	25	0.0	26	1.04 [0.02; 50.43]
Total (95% CI)		**1137**		**1122**	**0.60 [0.40; 0.90]**
Heterogeneity: Tau^2 = 0; Chi^2 = 3.28, df = 7 (P = 0.86); I^2 = 0%					
Test for subgroup differences: Chi^2 = 1.83, df = 1 (P = 0.18)					



d to lesion length of side branch on target lesion revascularization.



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Thanks!