



Image guided MVD PCI

State – of – the – art image guided

Seung Hoon Lee. RT

Seoul ST Mary's Hospital, Catholic University



Today's Lecture

Hot Topic & Hot Discussion; **PCI Option for Multi vessel Disease**



FFR Guided MVD PCI

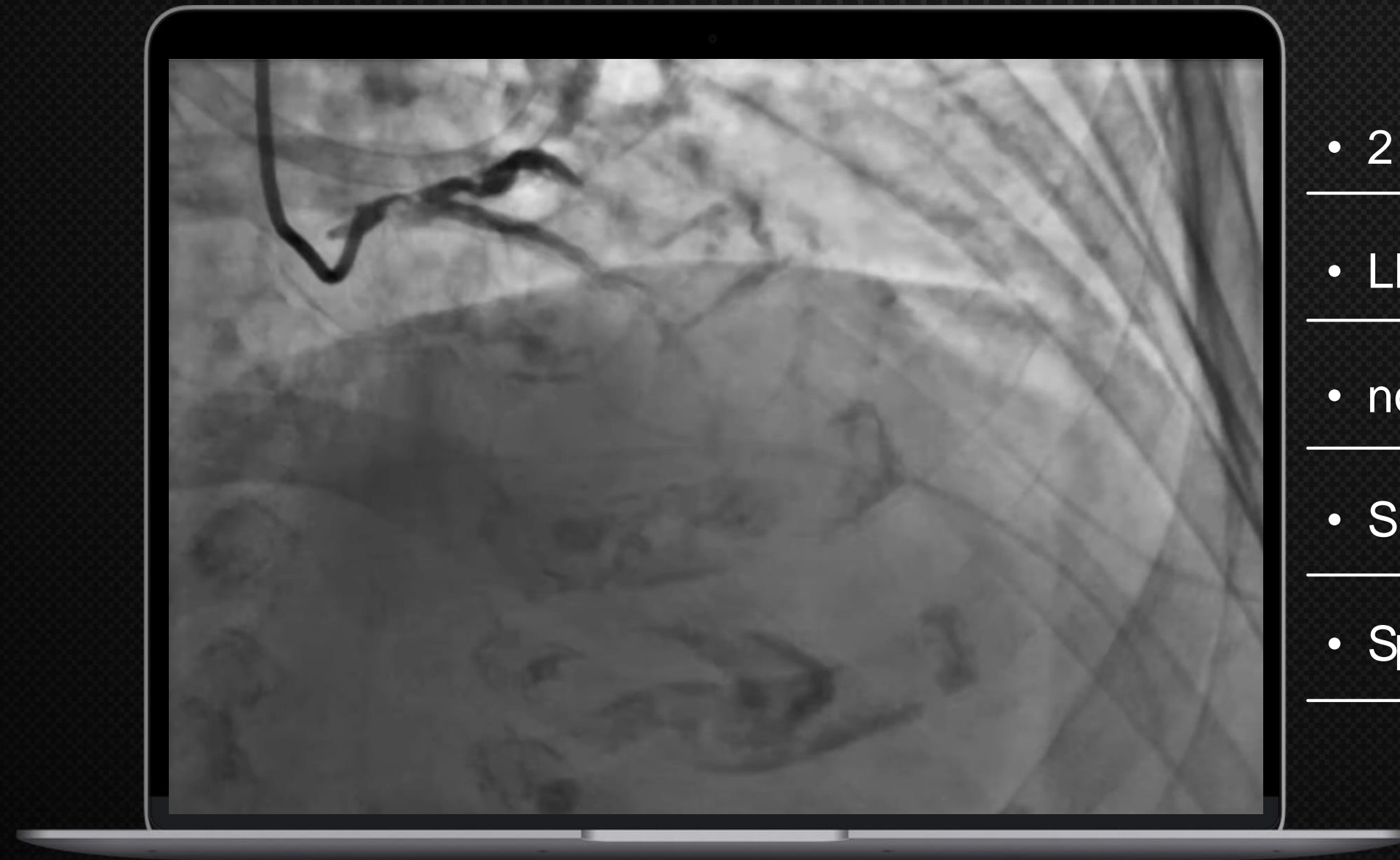
Do Hyeng Lim. RT



STEMI with MVD

Sang Man Park. RT

MVD



- 2 or 3 VD
- LM Bifurcation
- non - LM Bifurcation
- Serial or Diffuse
- Special situation - AMI, CTO, CABG

It is the most frequent lesion during PCI, and it is necessary to decide whether to treat or not.

The most important thing about MVD is how you treat it. .

MVD

Complex PCI

- 2 or 3 VD
- LM Bifurcation
- non-LM Bifurcation
- Serial or Diffuse
- Special situation - AMI, CTO, CABG

It is the most frequent lesion during PCI, and it is necessary to decide whether to treat or not.

The most important thing about MVD is how you treat it. .

What is complete?

Revascularisation of All stenosis

>50% or >70% or >90% on angiography?

with impact on physiology?

with impact on prognosis?

How to assess?

Revascularisation angio guided

vs physiology guided

What means?

Complete

revascularisation

Complete revascularization

clinical presentation

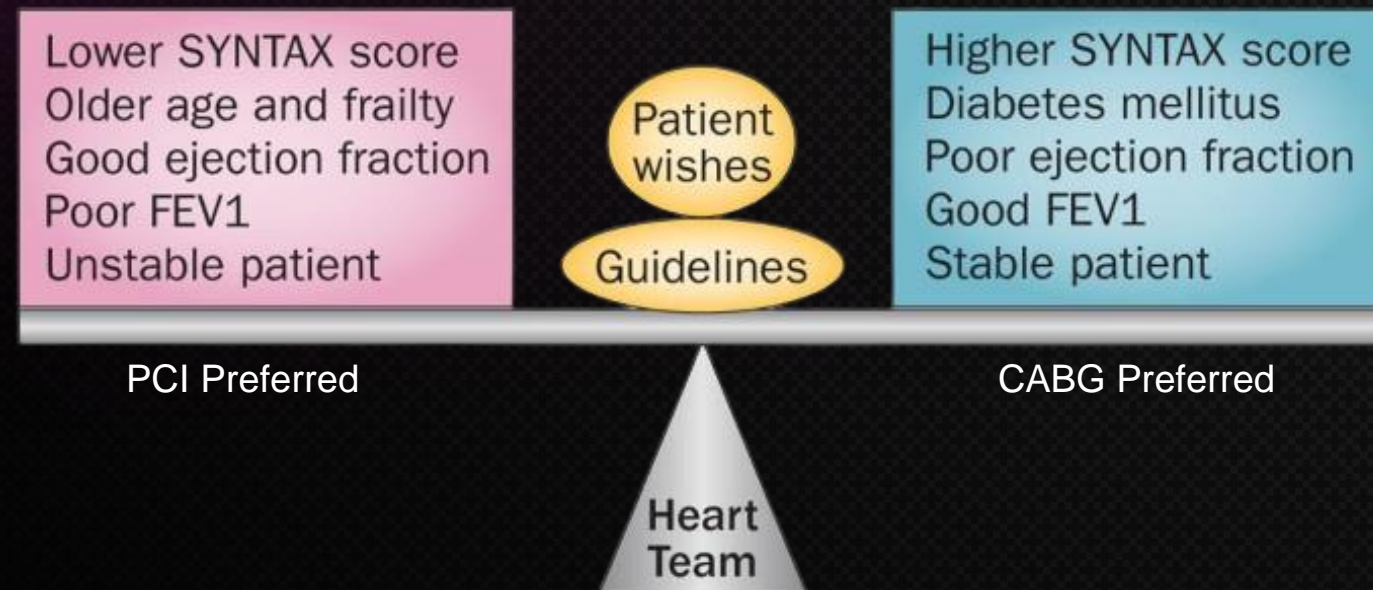
ACS

- Revascularisation of culprit lesion is life-saving procedure
- Non culprit lesions are considered as stable ones

CCS

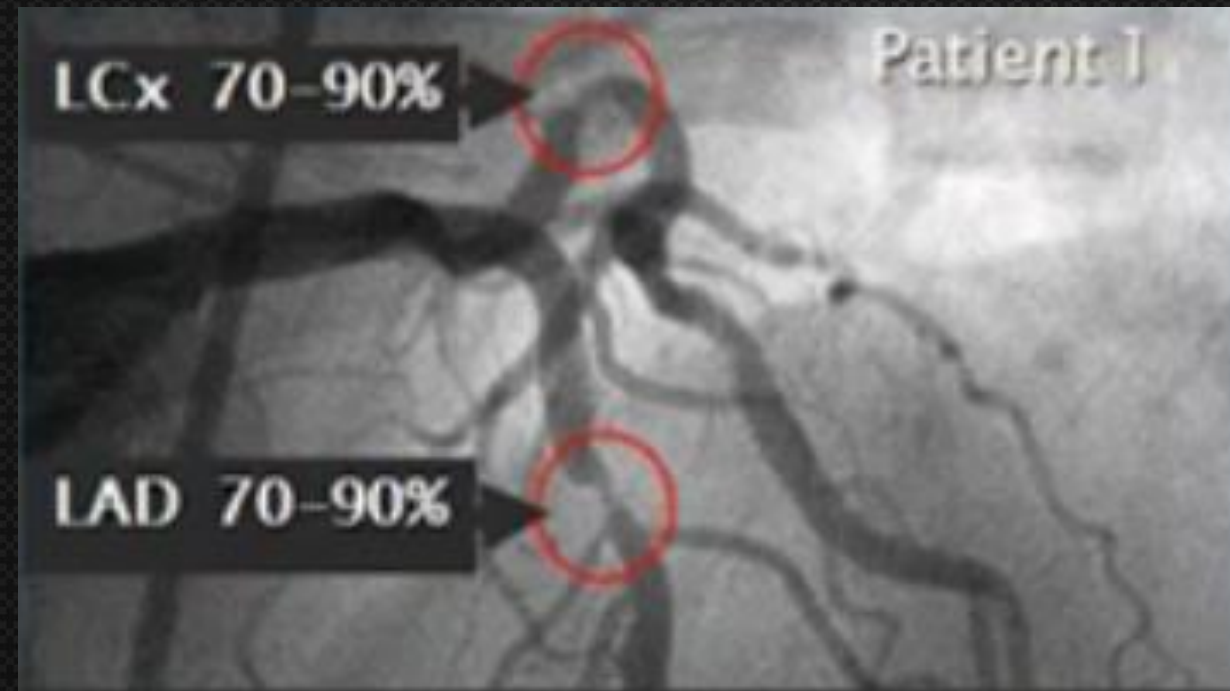
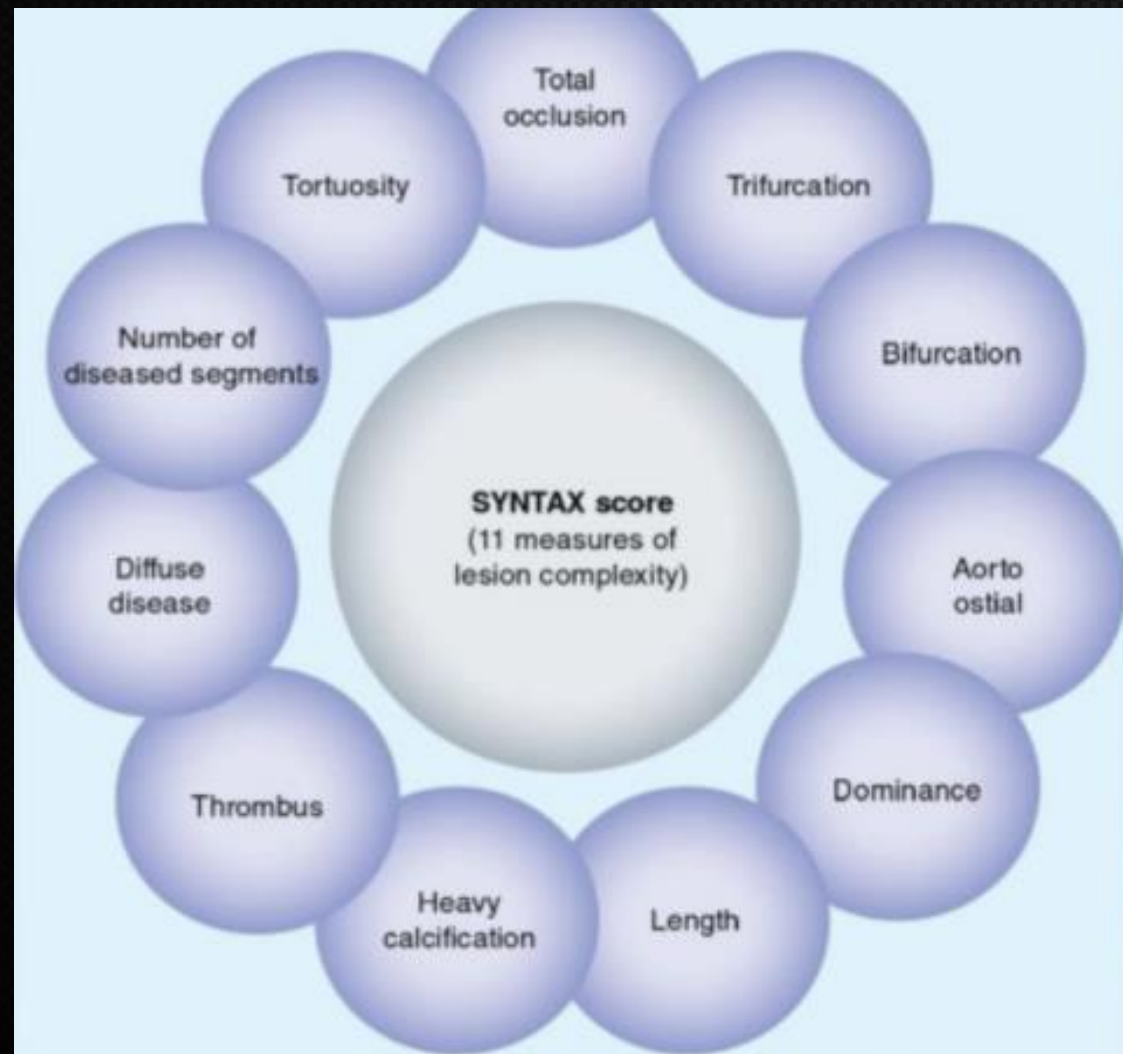
- All Lesion in MVD are considered as stable ones

Key decision points in MV Revascularization

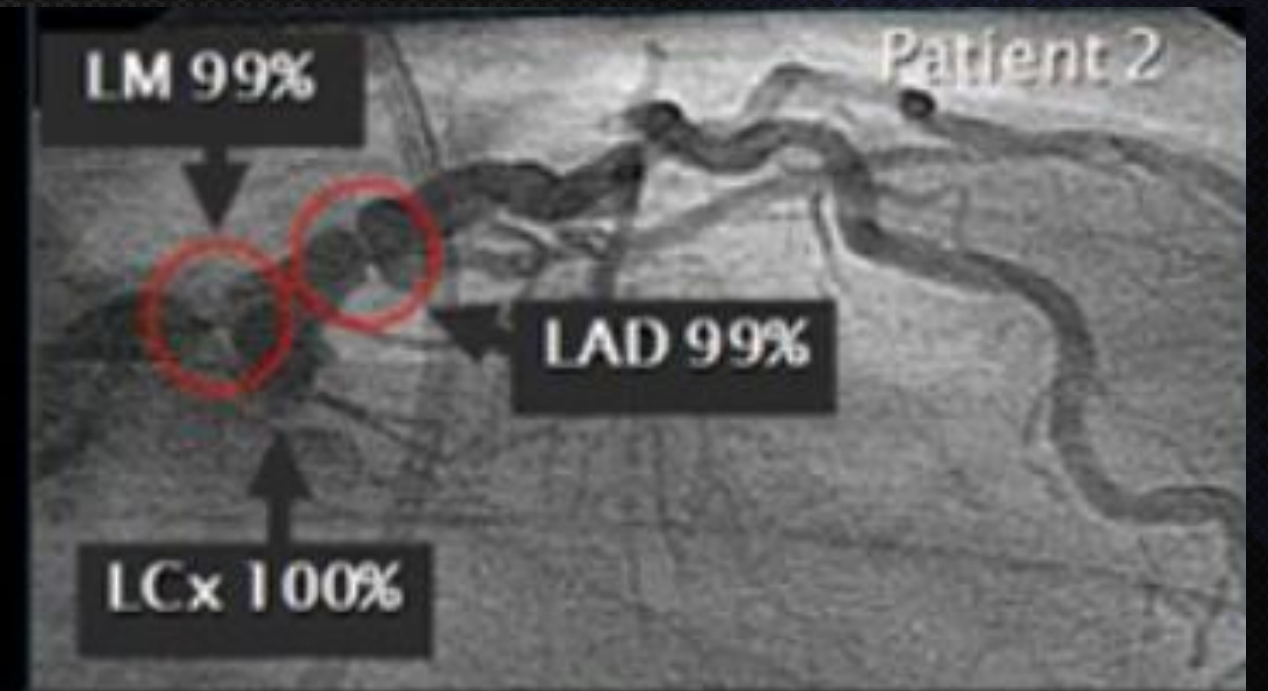


1. What are the goals of therapy?
2. Can the patient take/adhere to DAPT
3. Is the patient high surgical risk?
4. Is the patient insulin dependent?
5. WHAT DOSE THE PATIENT WANT?

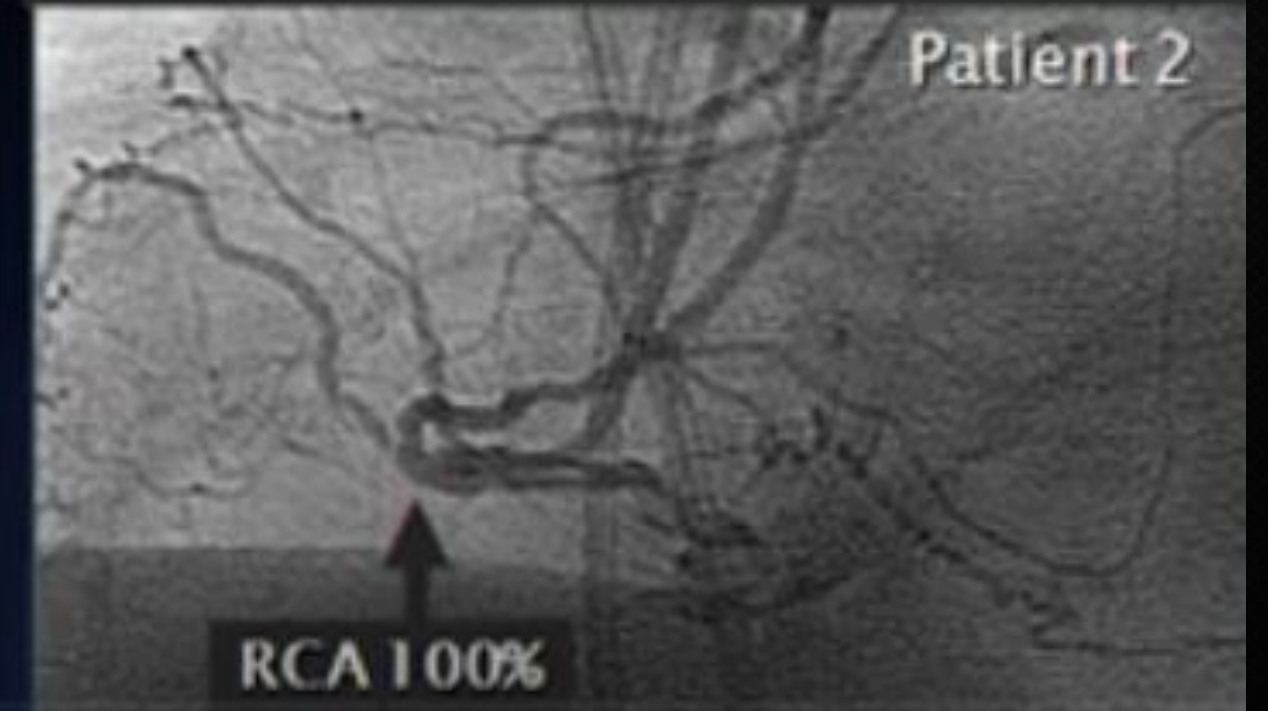
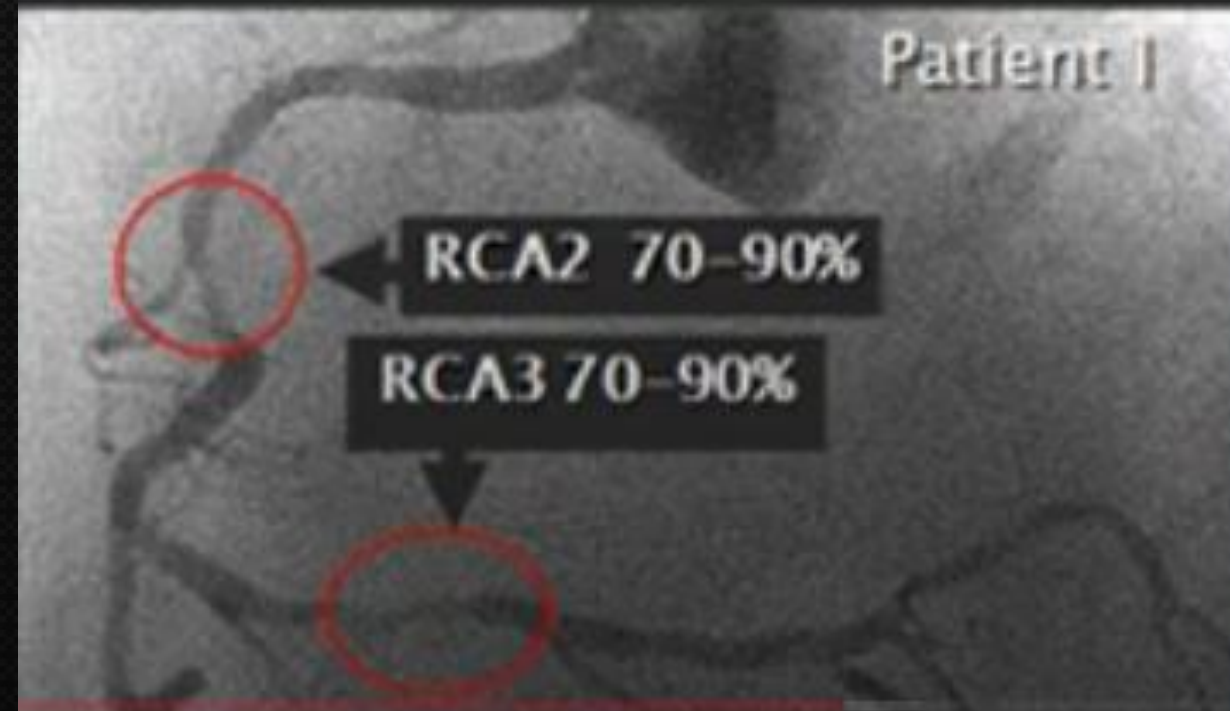
New Perspectives in Coronary Artery Disease Lessons from SYNTAX



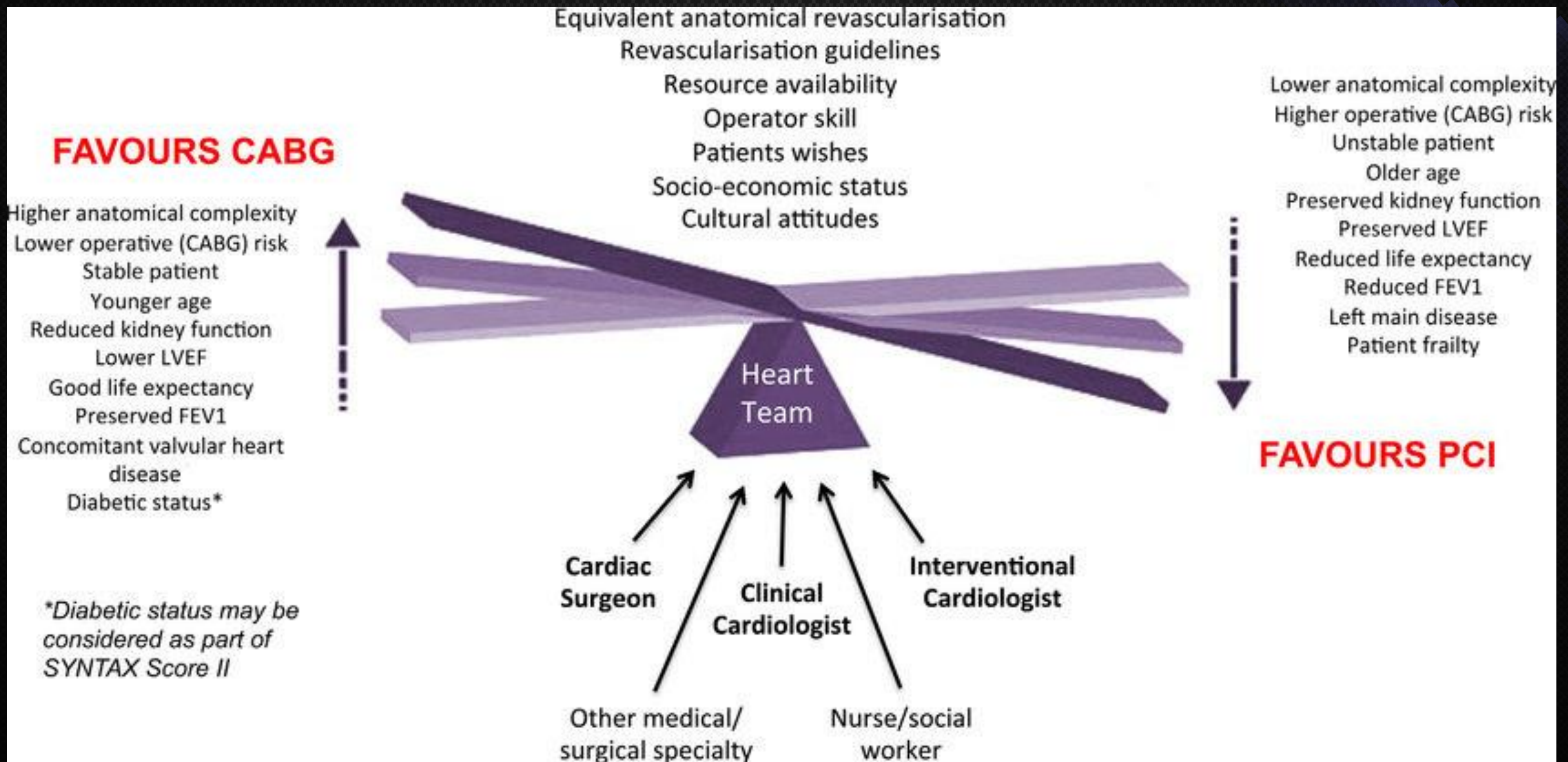
SYNTAX SCORE 21



SYNTAX SCORE 52



Arrangement of necessary elements for CABG



Pitfalls and issue relevant to SYNTAX score application in clinical practice

1. Time-consuming, with interobserver and intraobserver variability
2. Does not account for clinical or procedural variables that are known to impact outcomes during and after PCI
3. Underpowered outcomes based upon subgroup analysis
4. Does not include any subset of lesion (i.e. in-stent restenosis, stenotic bypass grafts, coronary abnormalities, muscular bridged, aneurysms)
5. Does not account for patient choice

Image guided MVD PCI



Whether to treat or not

Where to treat compared to FFR?

Which one is more realistic in an AMI environment?



Practical help of image guided

Help in the ambiguous CAD

Longitudinal Miss

Stent Optimization



The evolution of image tools

Combination with ANGIO.

Combining with other image sources

It is not a matter of which is more important

Anatomy

Physiology

Parameter	Value
FFR	0,83
Pd/Pa	0,94
Pa:iPa	82: 87
Pd:iPd	77: 73

mm Hg

State-of-the-art PCI in MVD

CORONARY INTERVENTIONS
CLINICAL RESEARCH

Clinical outcomes of state-of-the-art percutaneous coronary revascularisation in patients with three-vessel disease: two-year follow-up of the SYNTAX II study



Patrick W. Serruys^{1,2*}, MD, PhD; Norihiro Kogame³, MD; Yuki Katagiri³, MD; Rodrigo Modolo³, MD; Pawel E. Buszman^{4,5}, MD, PhD; Andres Iniguez⁶, MD, PhD; Javier Goicolea⁷, MD, PhD; David Hildick-Smith⁸, MD; Andrzej Ochala³, MD, PhD; Dariusz Dudek⁹, MD, PhD; Jan J. Piek³, MD, PhD; Joanna J. Wykrzykowska³, MD, PhD; Javier Escaned¹⁰, MD, PhD; Adrian P. Banning¹¹, MBBS, MD; Vasim Farooq¹², MBChB, PhD; Yoshinobu Onuma³, MD, PhD

Eurointervention 2019;15:e244-e252 published

1. Heart-team discussion
2. Functional-guided approach (FFR/iFR)
3. IVUS-guided PCI optimization
4. Contemporary PCI/CTO techniques
5. GDMT (guideline-directed medical therapy)

Anatomy vs. Functional significance

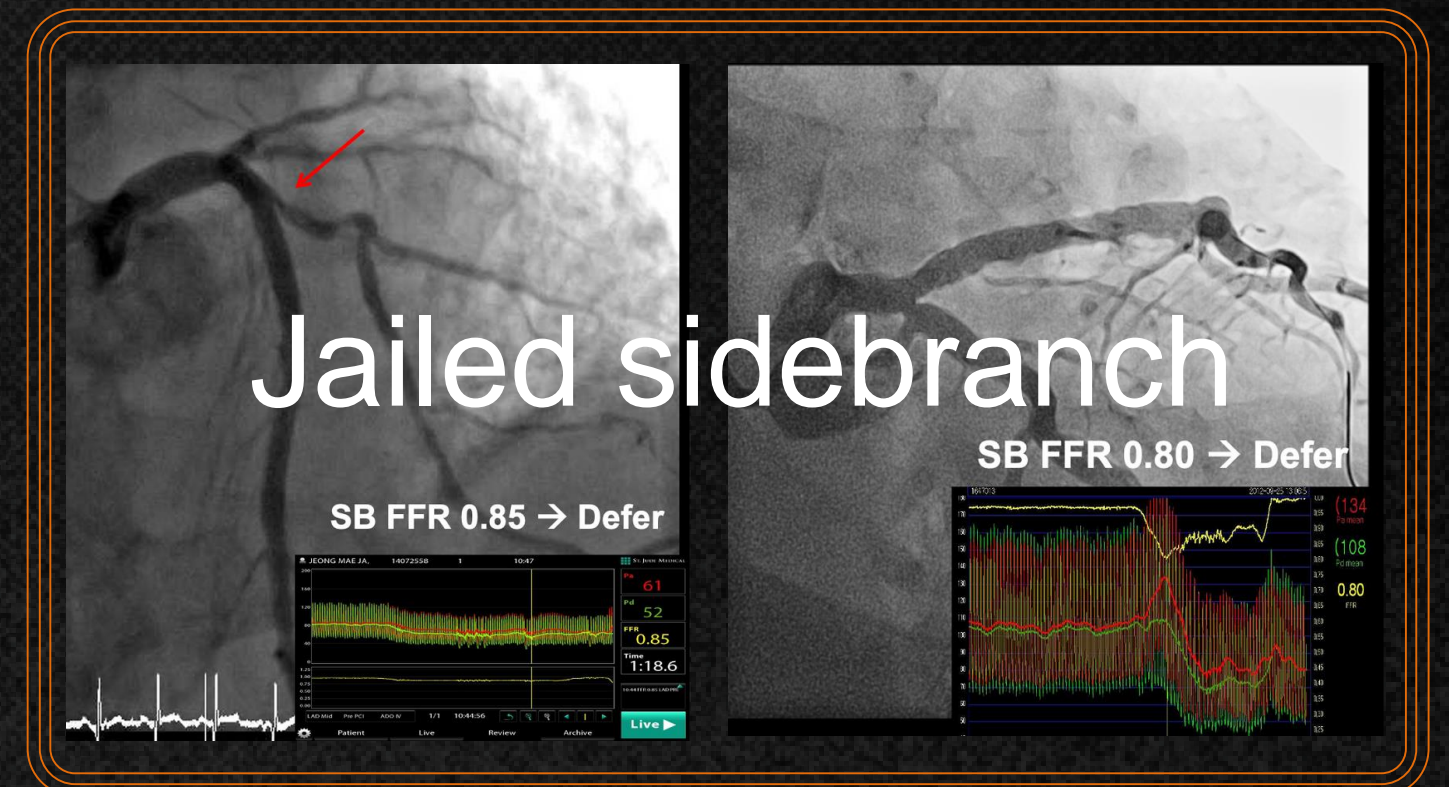
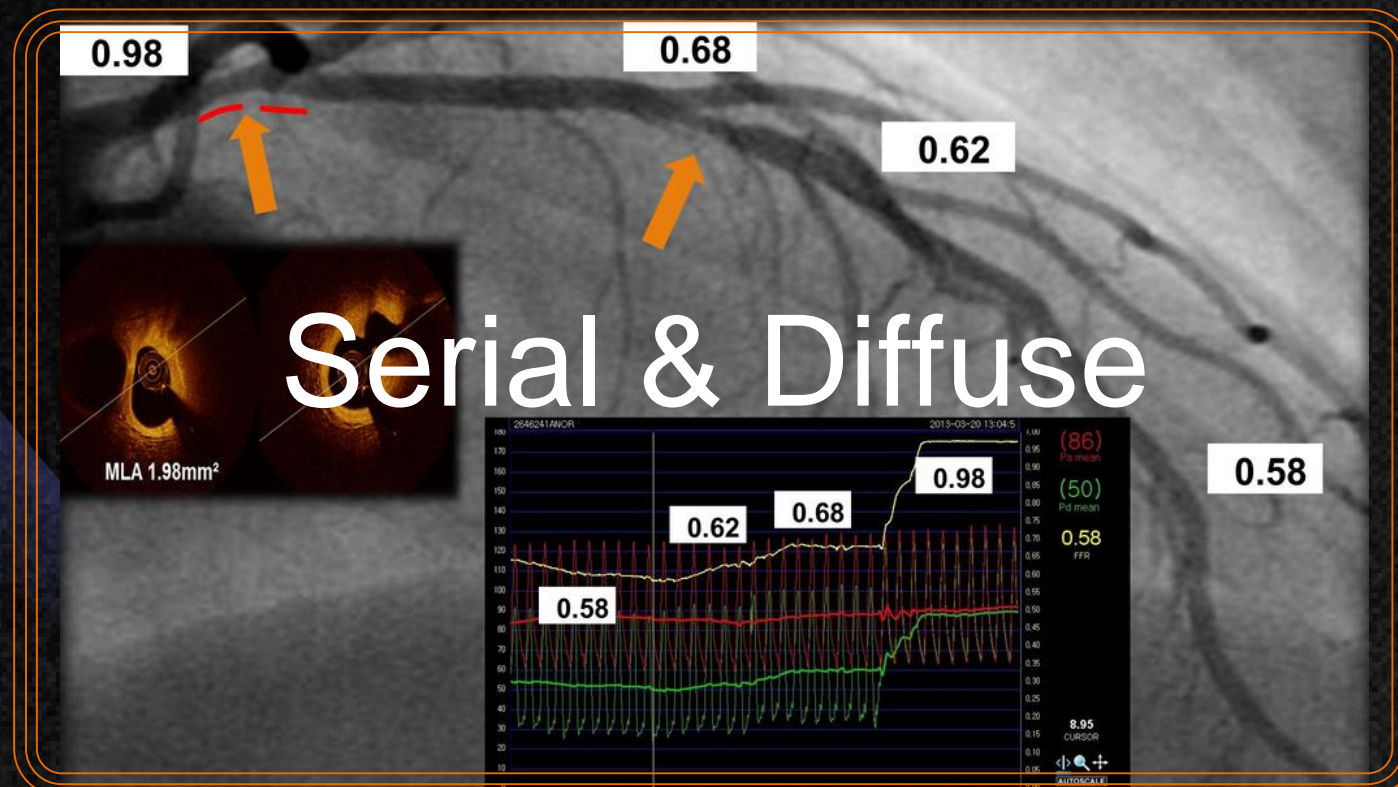
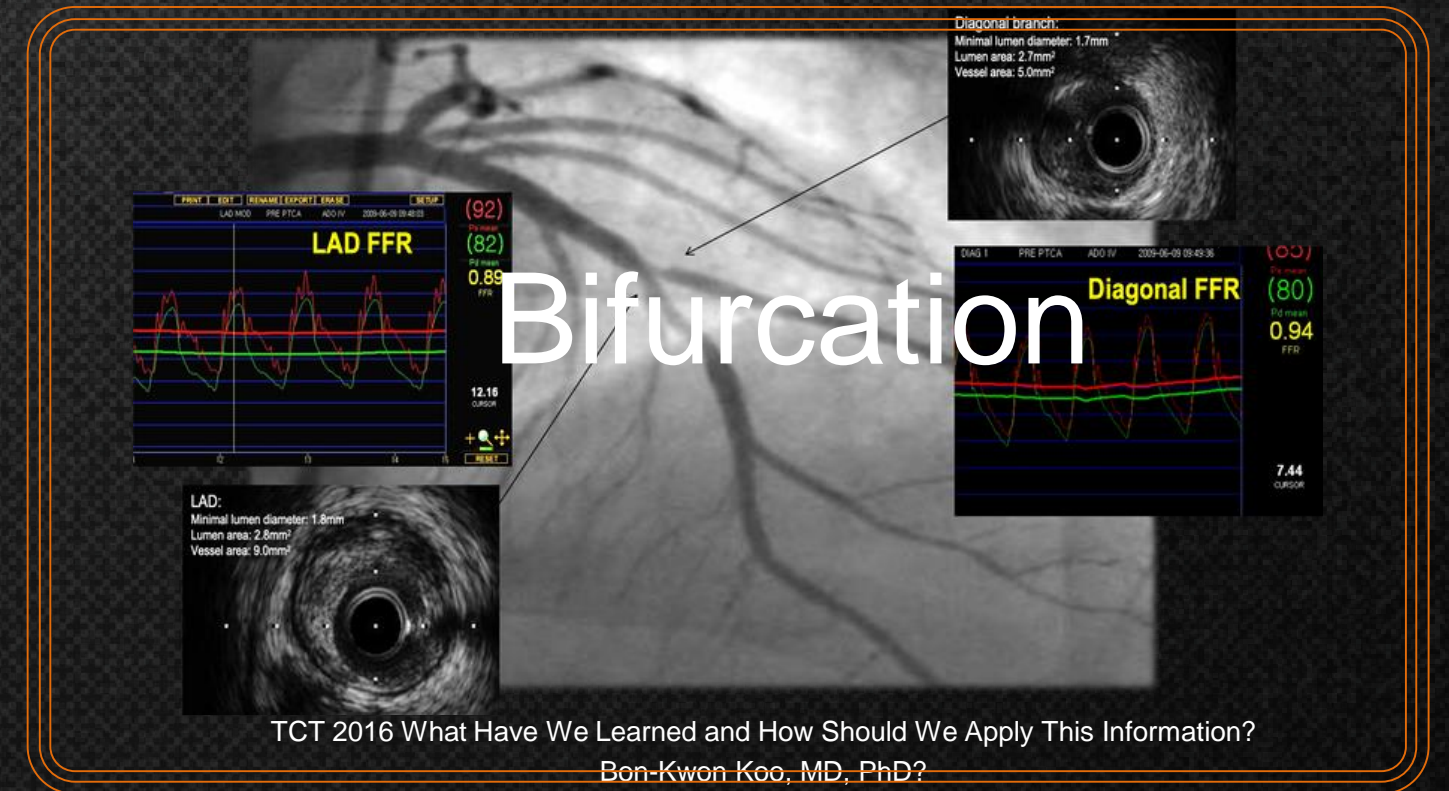
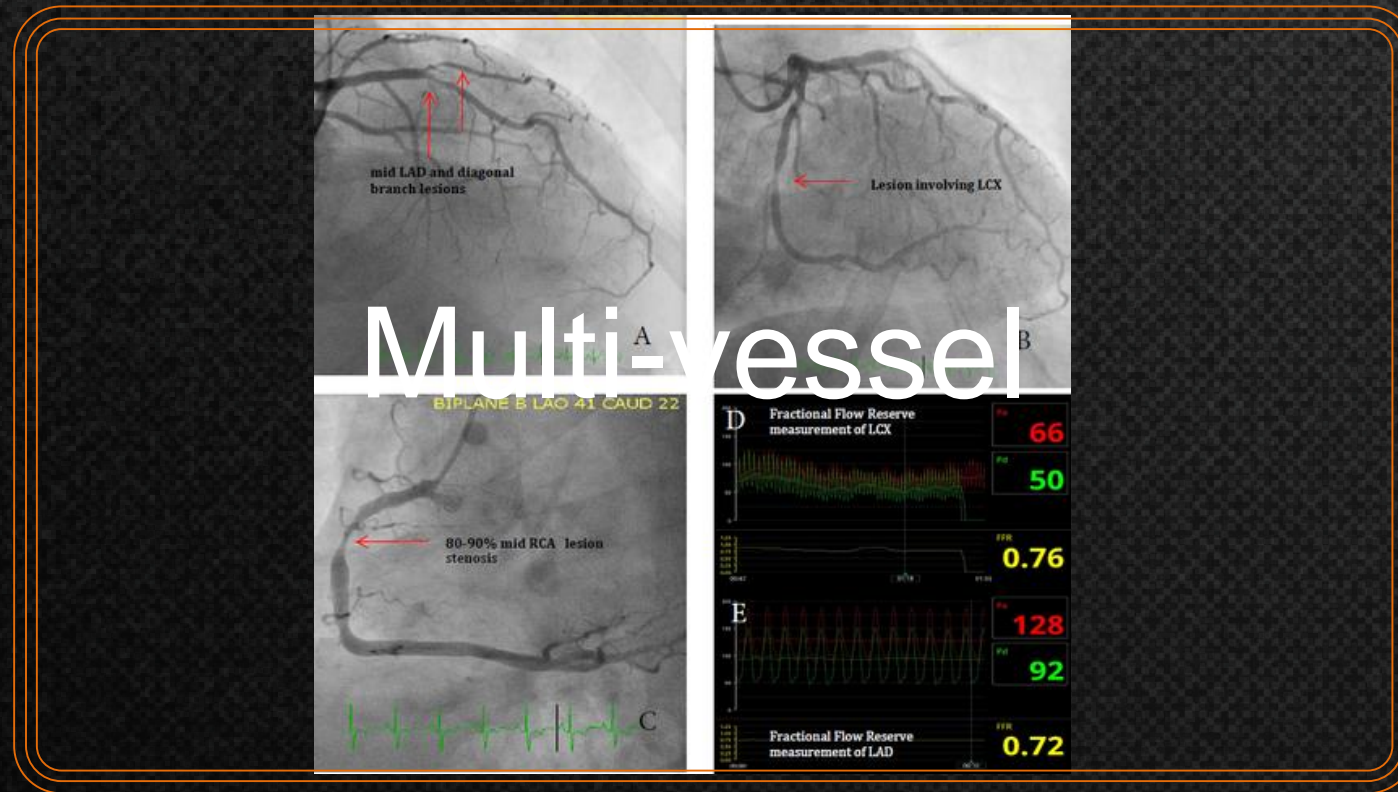
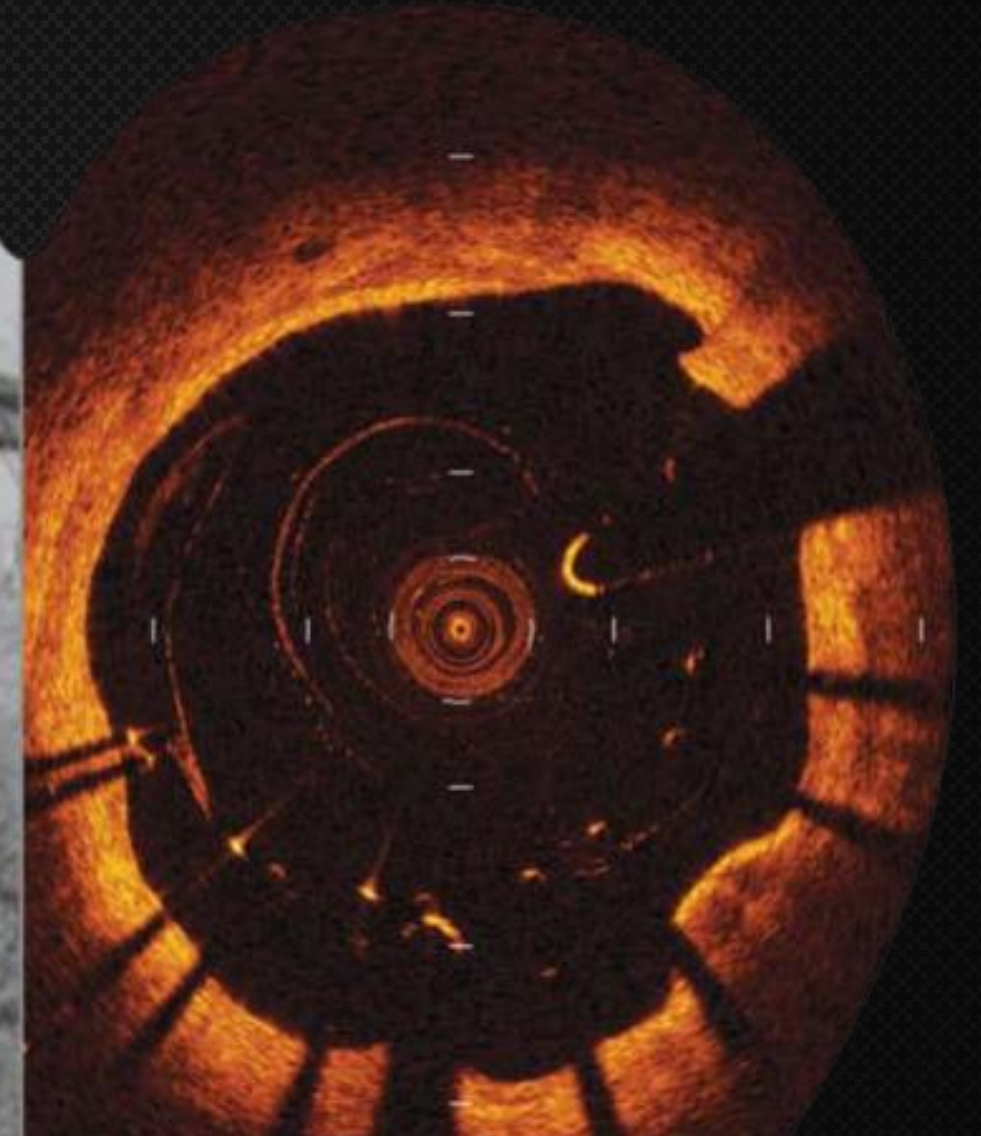


Image Guided

Angio Guided vs IVUS/OCT Guided



arteries visualized with 2D angiography

arteries visualized in 3D OCT guided angiography

Low resolution black and white image

High resolution color image



no inside view of artery

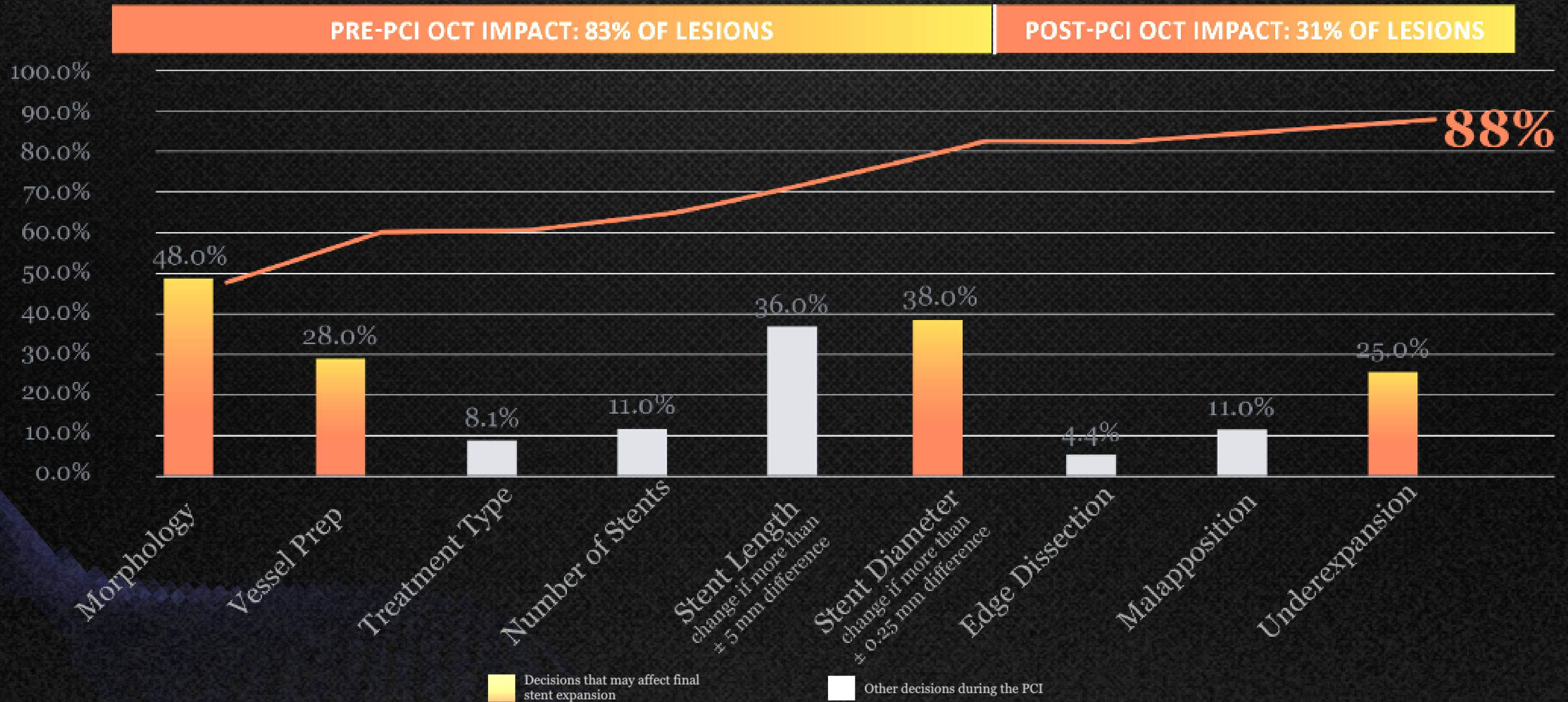
possibility of improper stent placement

helps improving clinical results

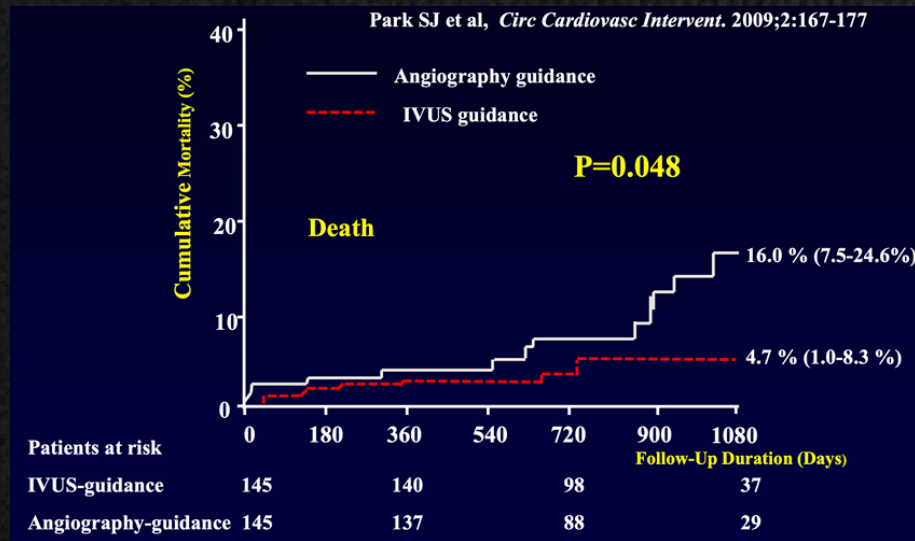
35% less procedural complications

OCT Changed Angiographic-based Decisions in 88% of Lesions

OCT significantly changes physician decisions at steps in a PCI that MAY AFFECT EXPANSION, A LEADING INDICATOR OF ADVERSE EVENTS:



LM



Bifurcation

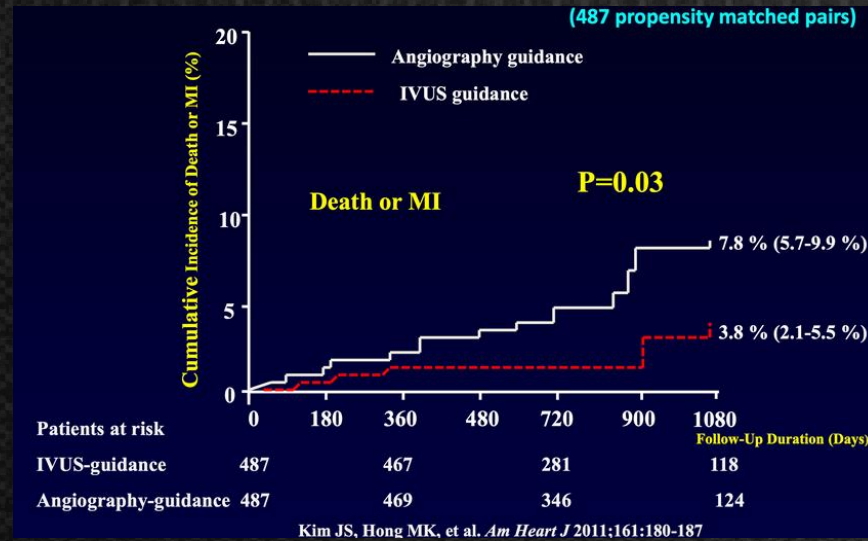
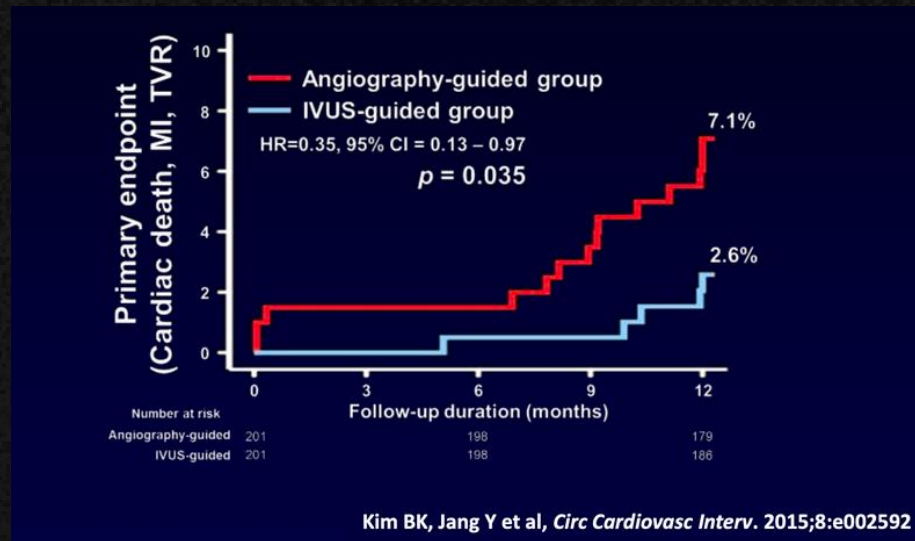


Image guided

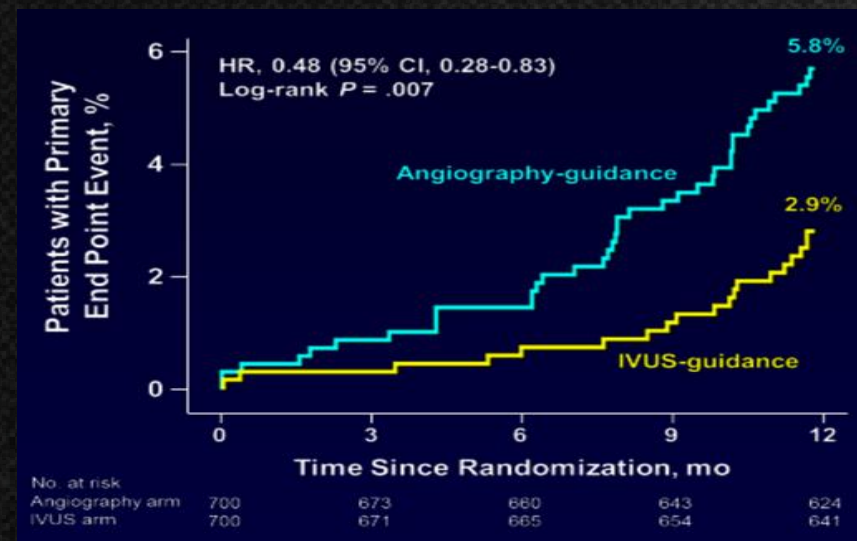
VS

Angio guided

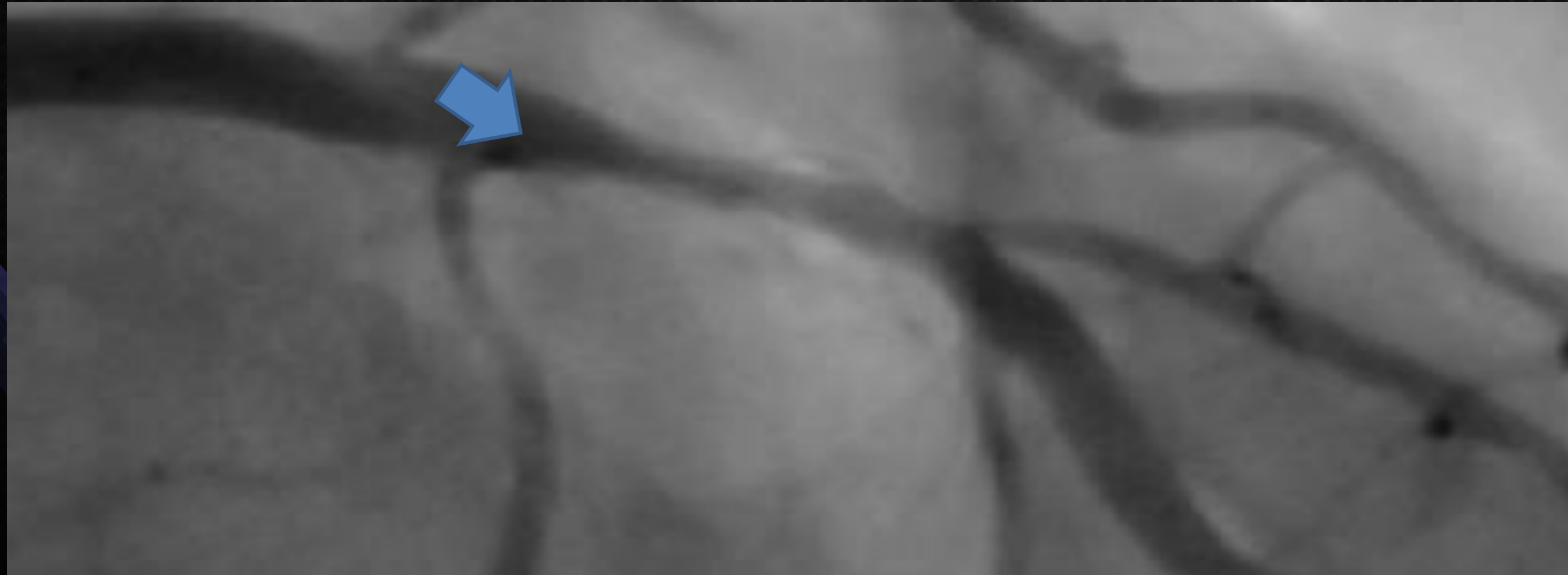
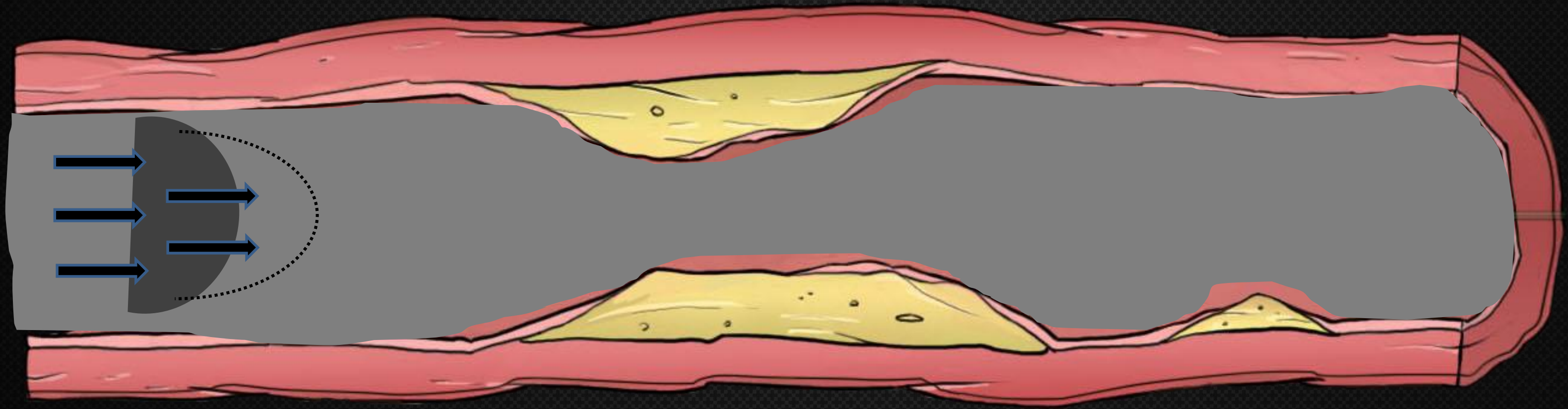
CTO



Diffuse

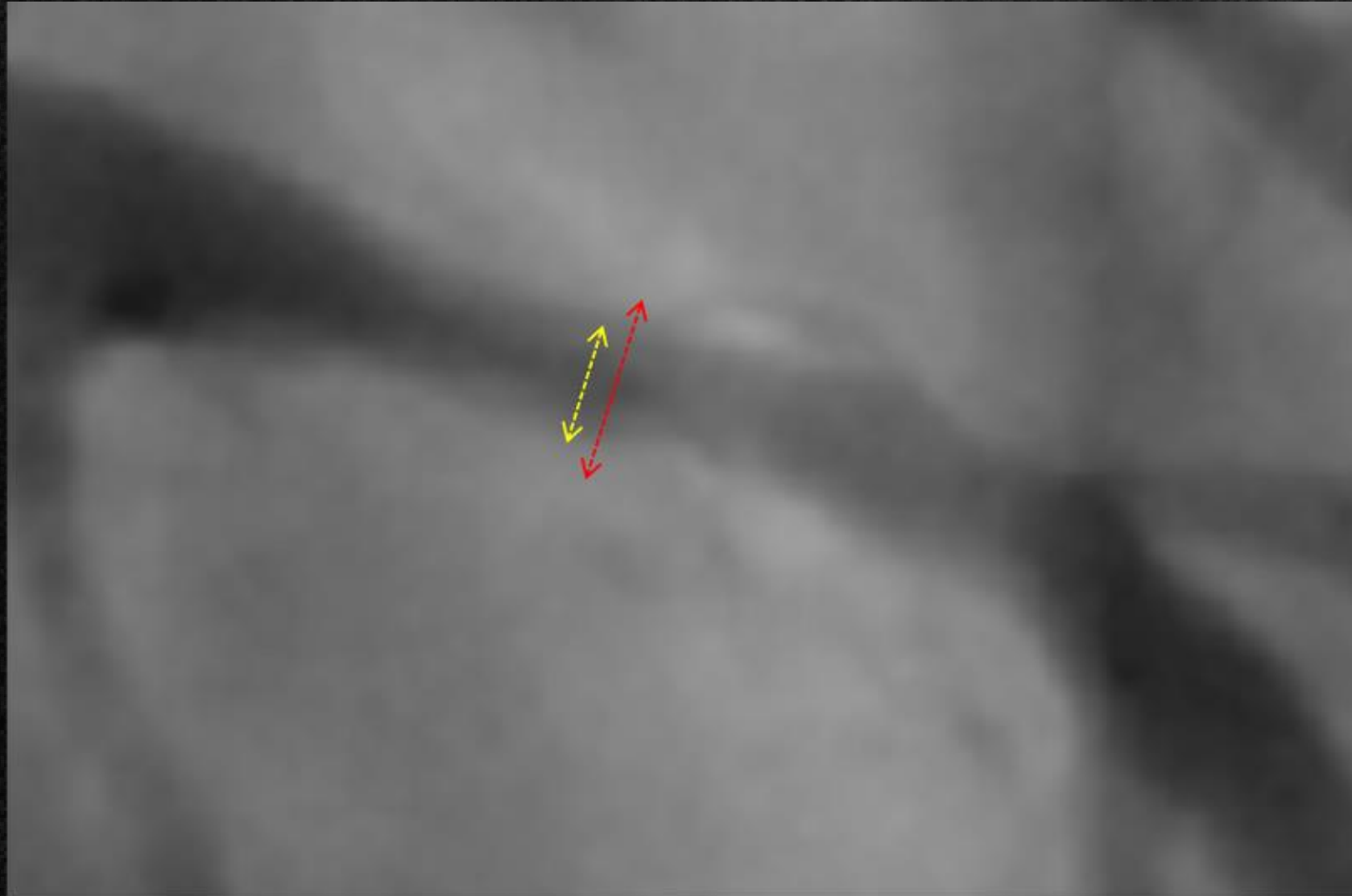


Angiogram → Lumino-gram

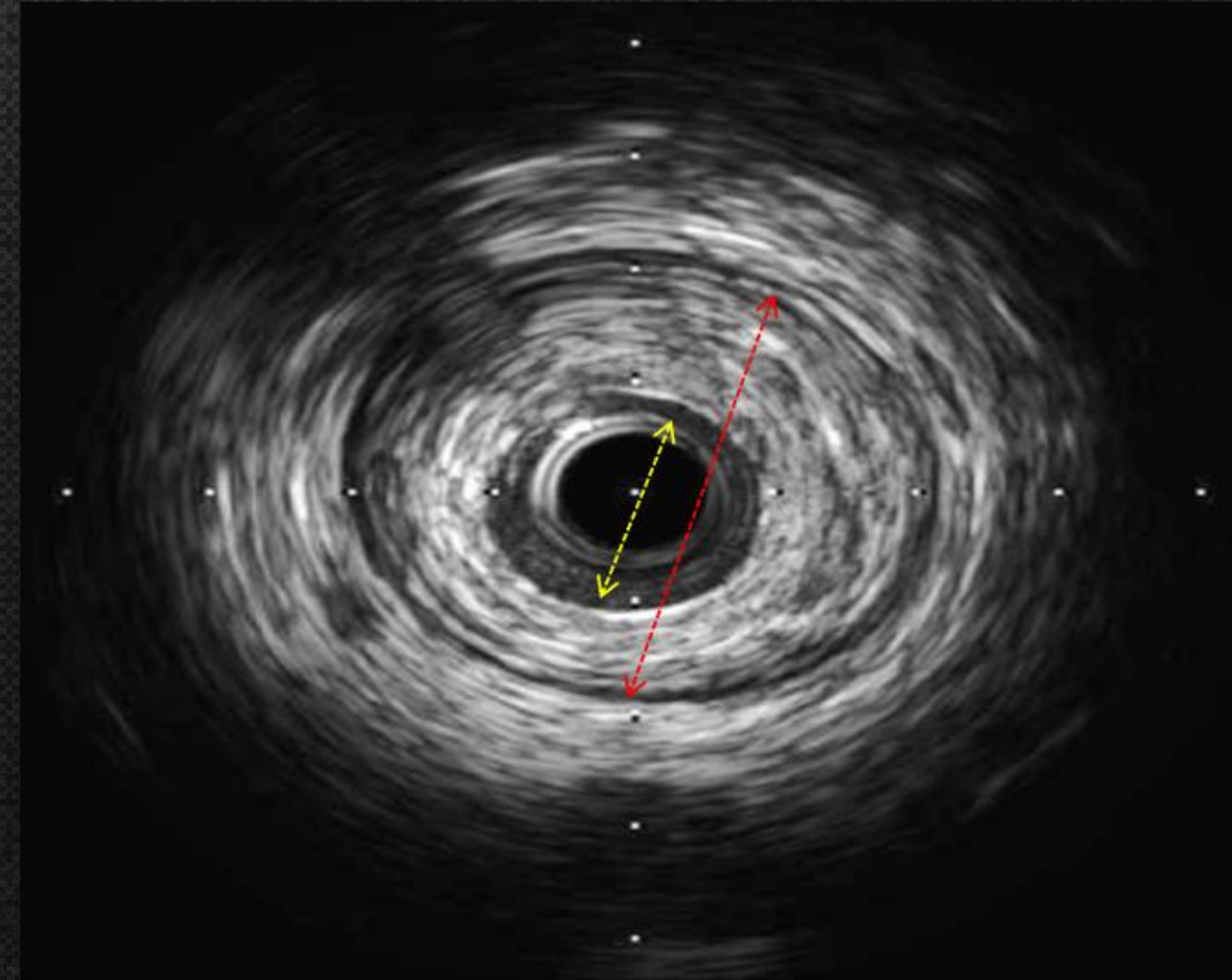


Lumino-gram
:혈관내강조영

Angiogram (Lumino-gram) vs IVUS (Tomo-gram)

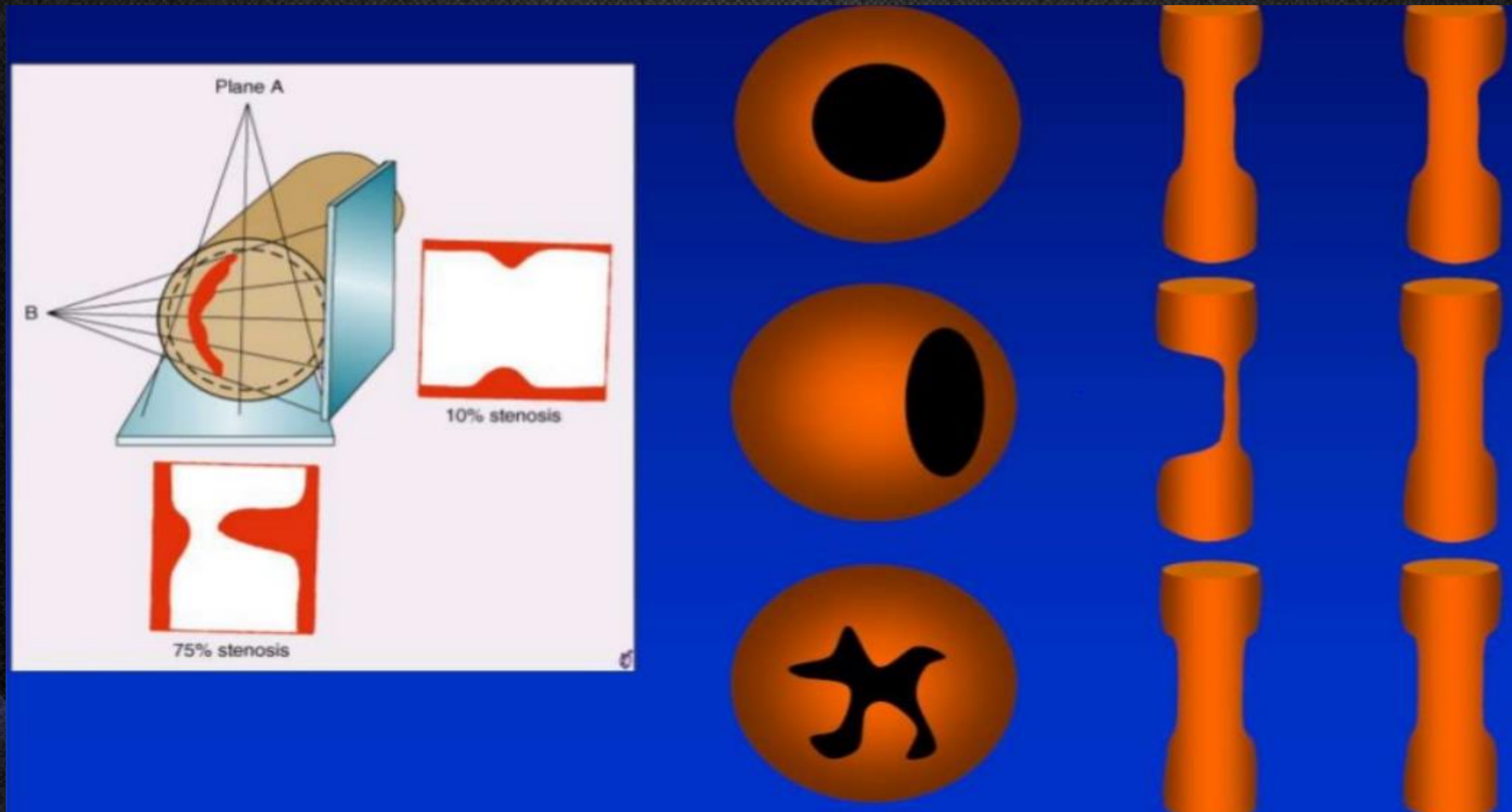


MLD 1.3 mm

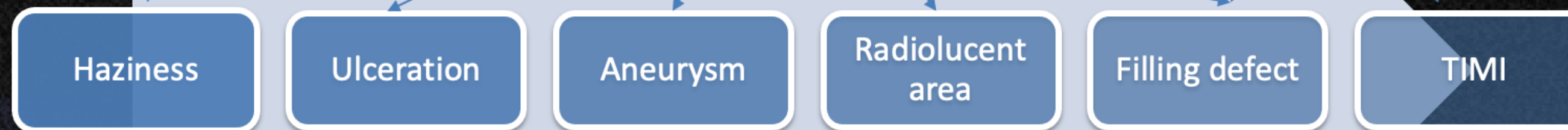
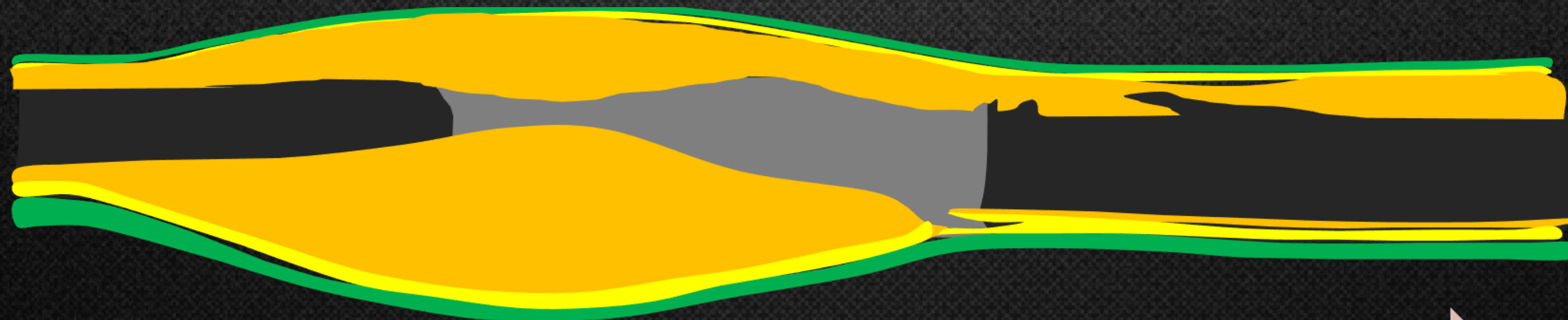


MLD 1.3 mm / M to M 3.4mm

Pitfall of CAG – Axial miss



In to the deep dive about plaque morphology



Brightness

Contour

Velocity

Haziness

Ulceration

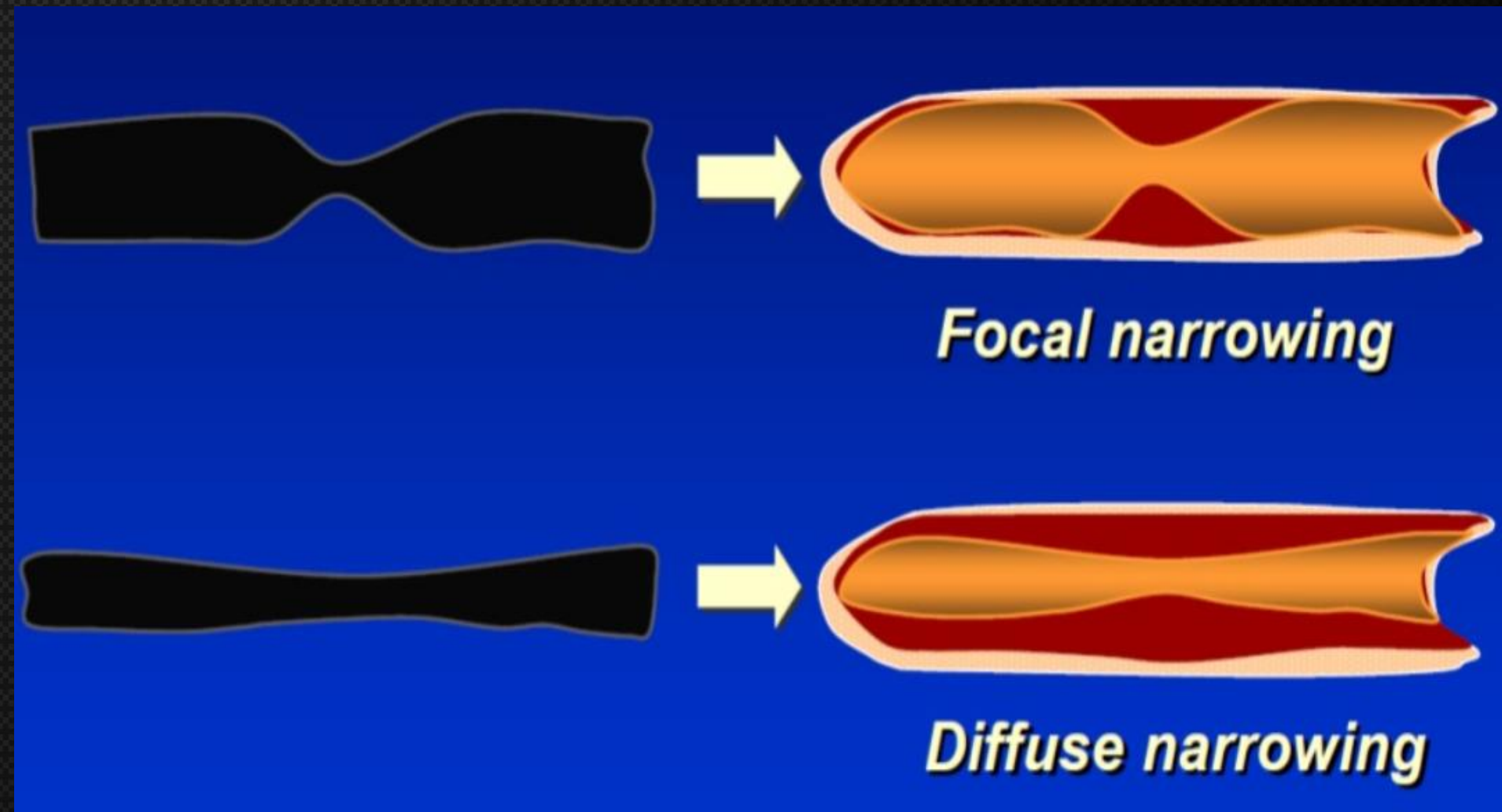
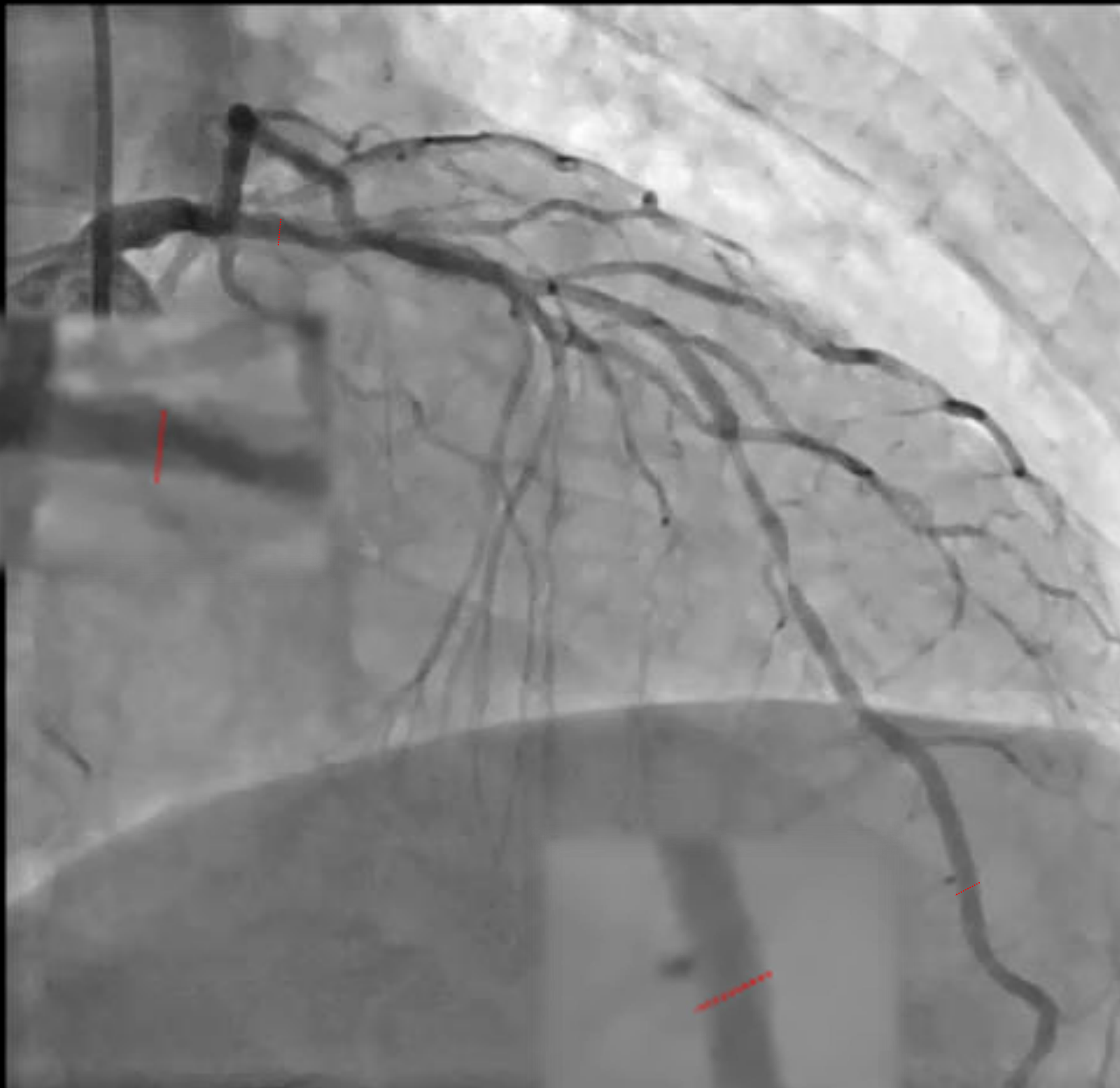
Aneurysm

Radiolucent
area

Filling defect

TIMI

Pitfall of CAG – Longitudinal miss



Very diffuse lesion (Os to distal) →

Ref. miss →

Image & physiology miss →

Hard to Procedure

CASE 1

widowmaker heart attack

Heart attacks can be deadly, and the widow maker is one of the deadliest kind. It can happen suddenly when a key artery that moves blood to the heart gets almost or completely blocked. Without emergency treatment, you may not survive.



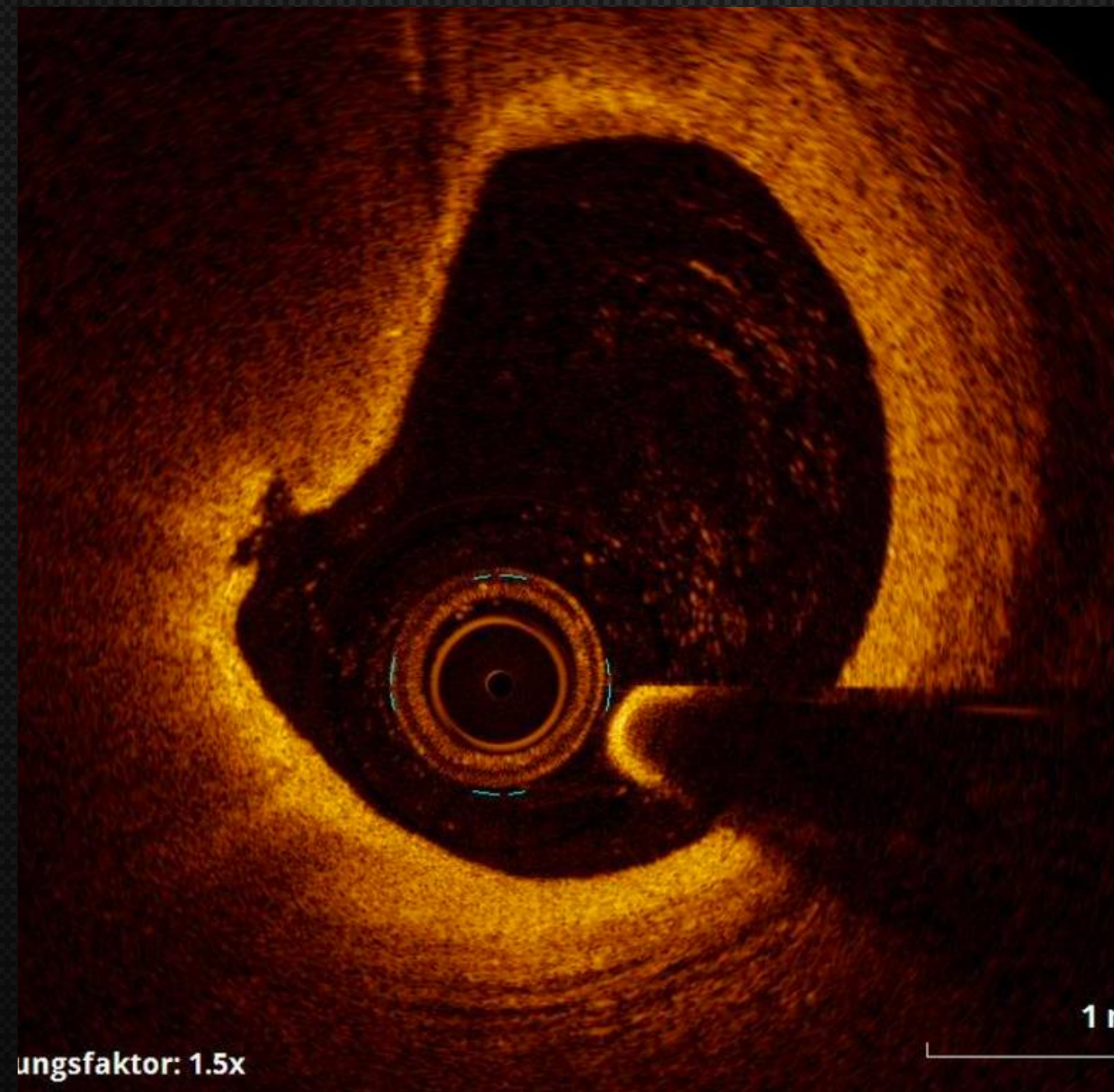
ECG: SR, no Qs, no ST-abnormalities

Echo: good LV function, no regional wall motion abnormalities

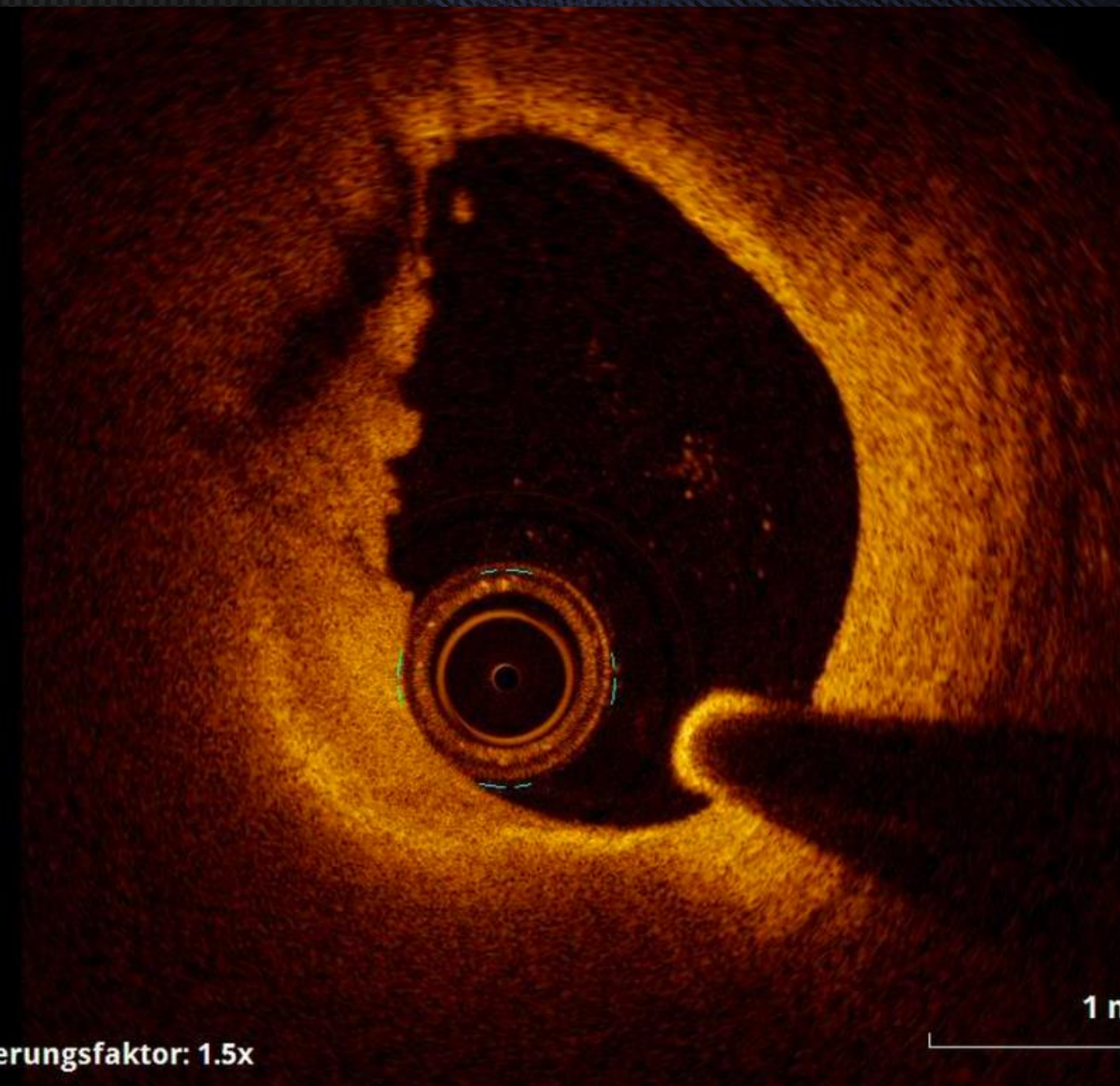
Diagnosis: NSTEMI, suspected myocarditis

CASE 1

OCT-imaging of the proximal LAD



Thin-cap fibroatheroma with ruptured intima
at 9 o'clock

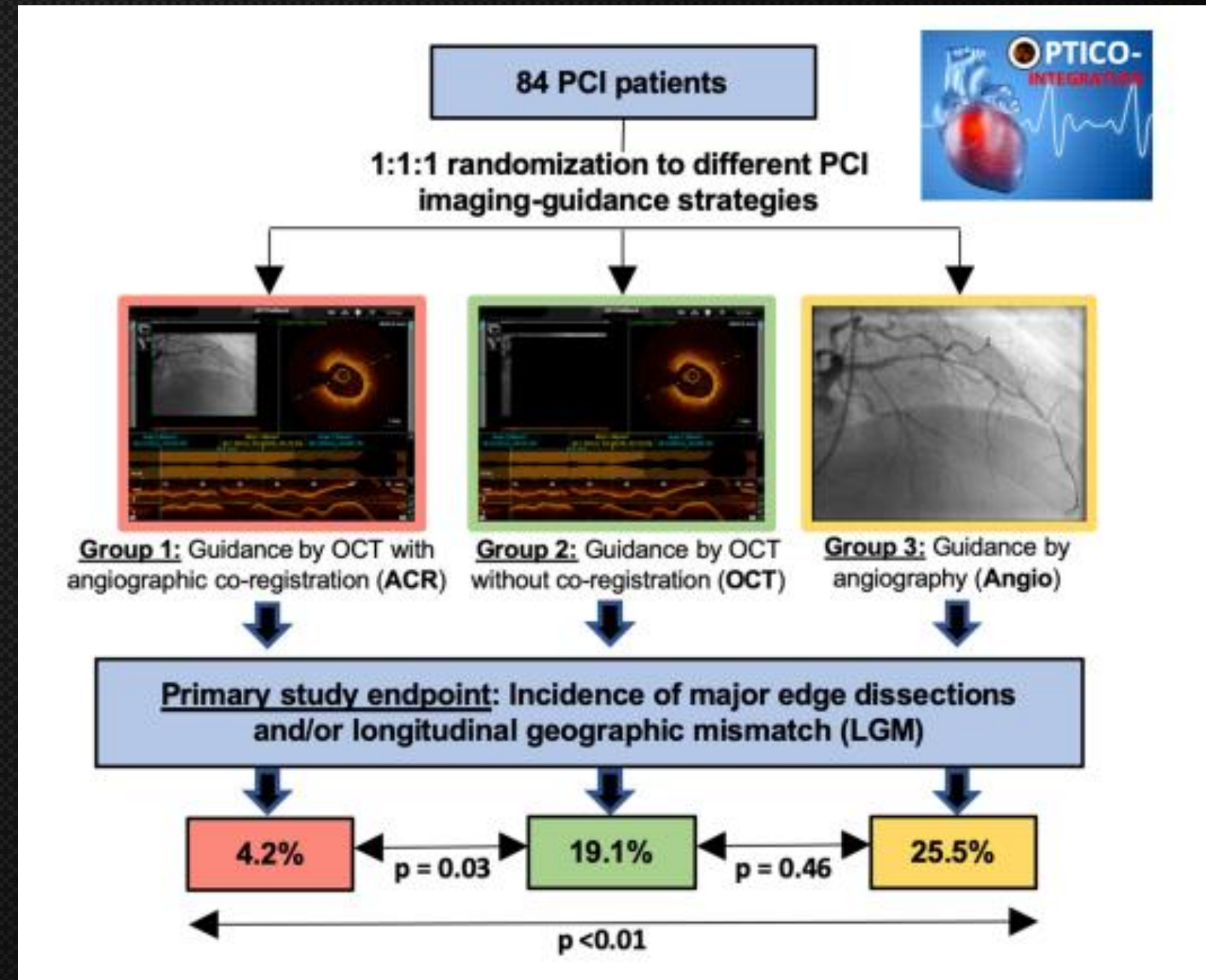


Thrombus on the surface of the lipid rich plaque

CASE 2

OPTICO-integration II

Impact of real-time angiographic co-registered optical coherence tomography on percutaneous coronary intervention

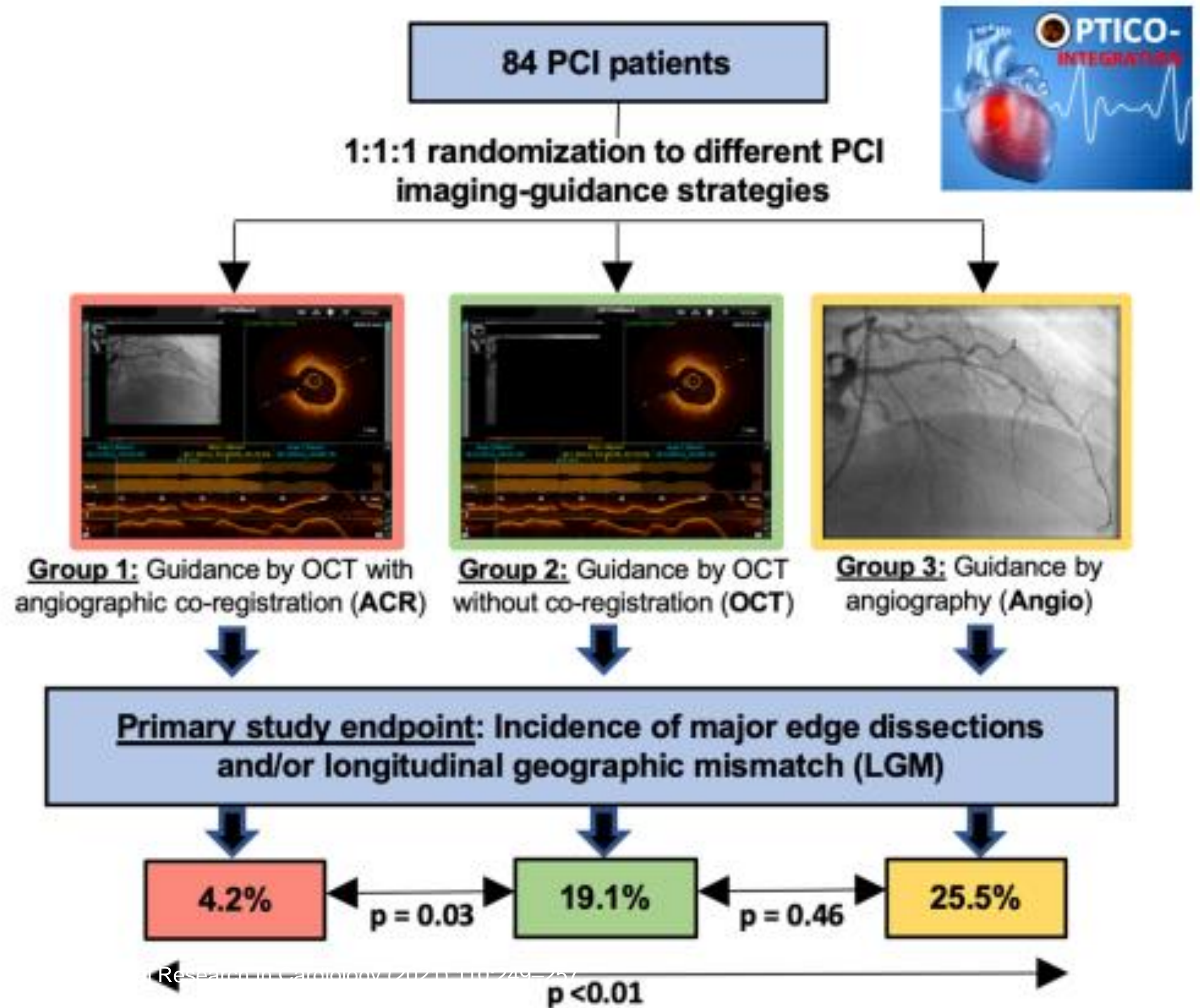


This study for the first time demonstrates superiority of ACR-guided PCI over OCT- and angiography-guided PCI in reducing the composite endpoint of major edge dissection and LGM, which was mainly driven by a reduction of LGM.

CASE 2

OPTICO-integration II

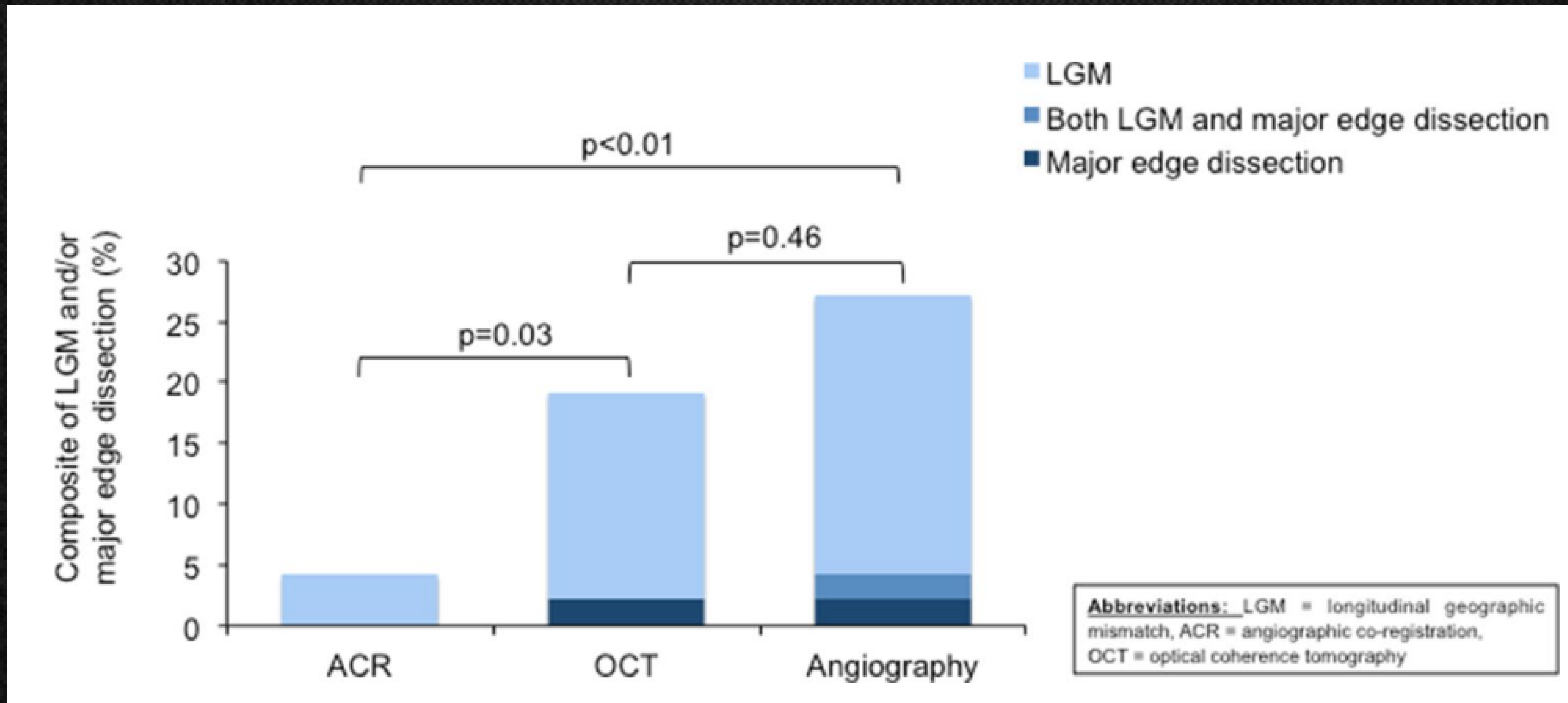
Impact of real-time angiographic co-registered optical coherence tomography on percutaneous coronary intervention:



CASE 2

OPTICO-integration II

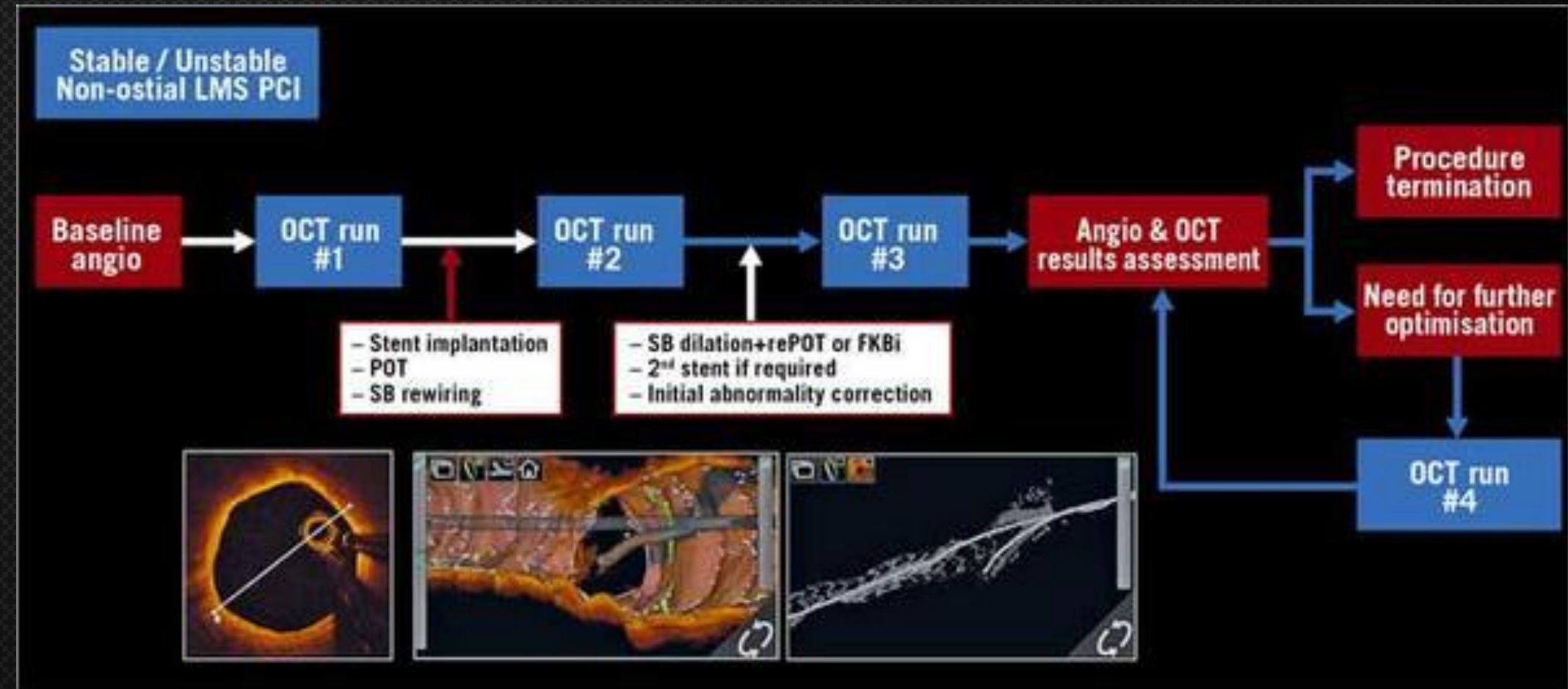
Predictors of longitudinal geographic mismatch and/or major edge dissection



CASE 3

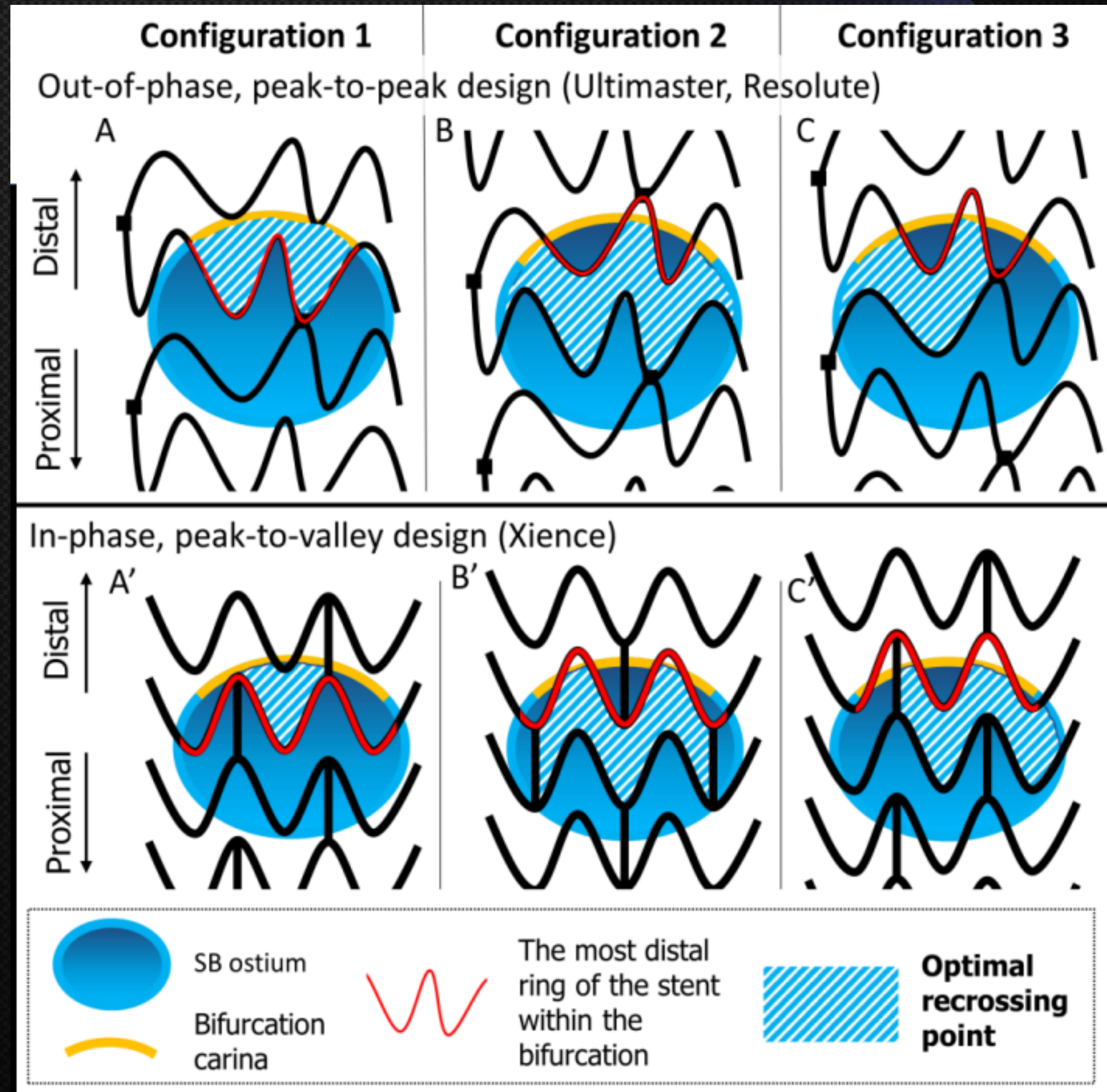
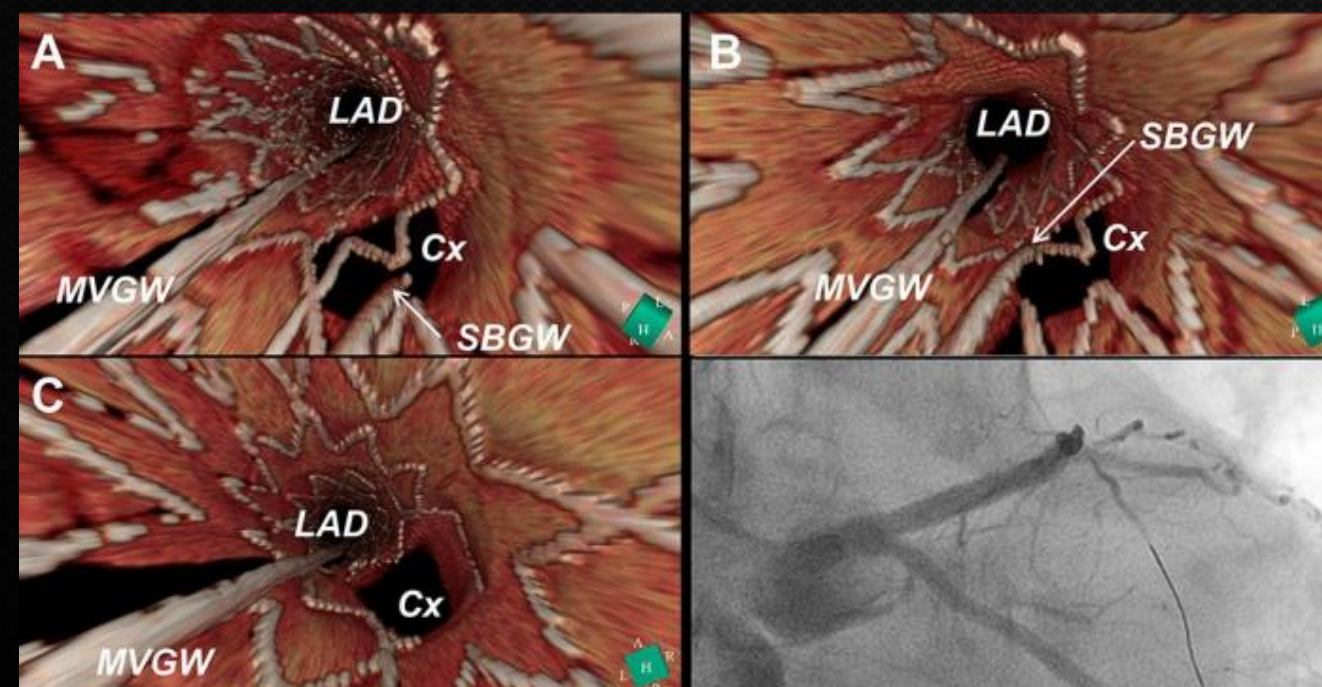
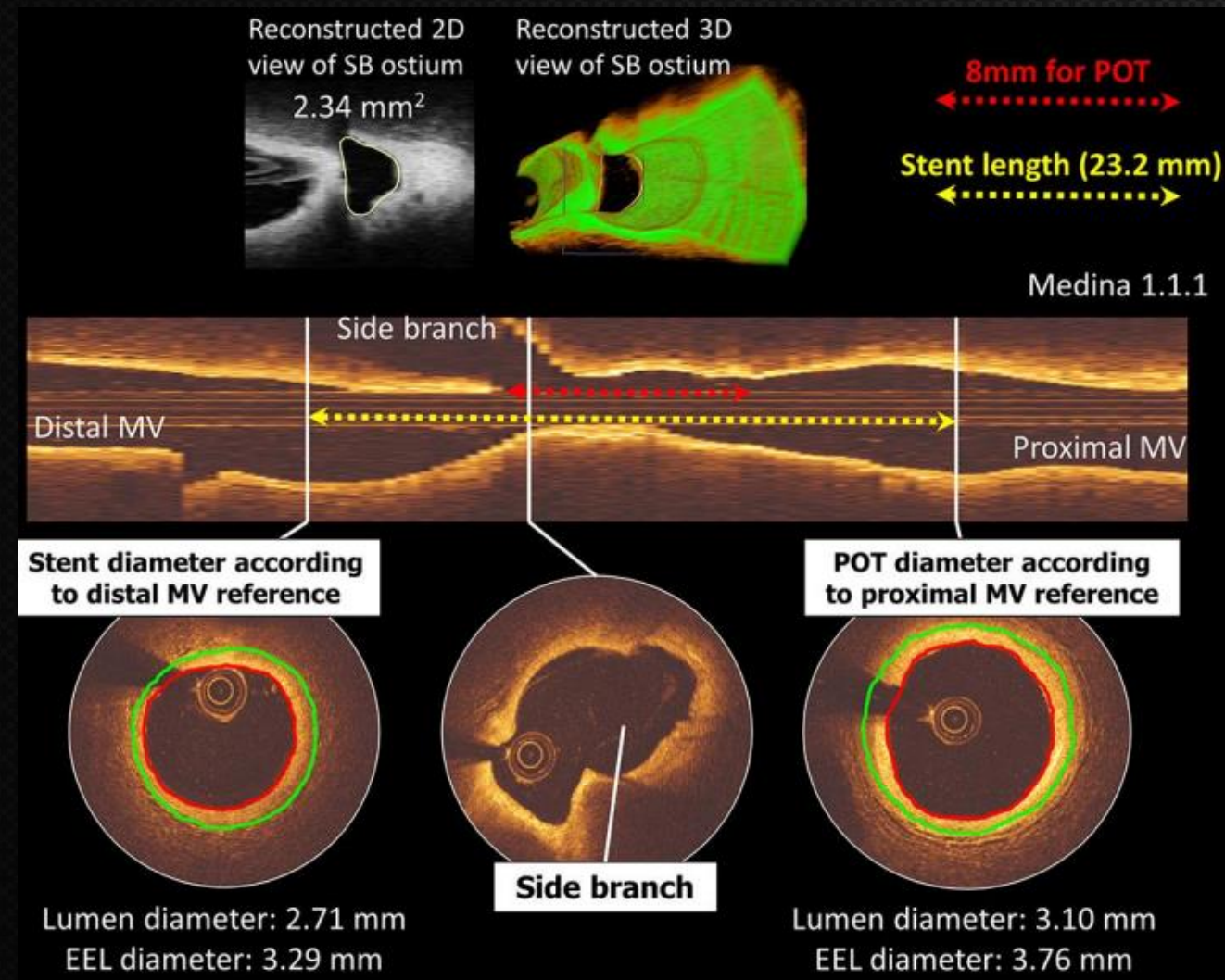
LEMON study

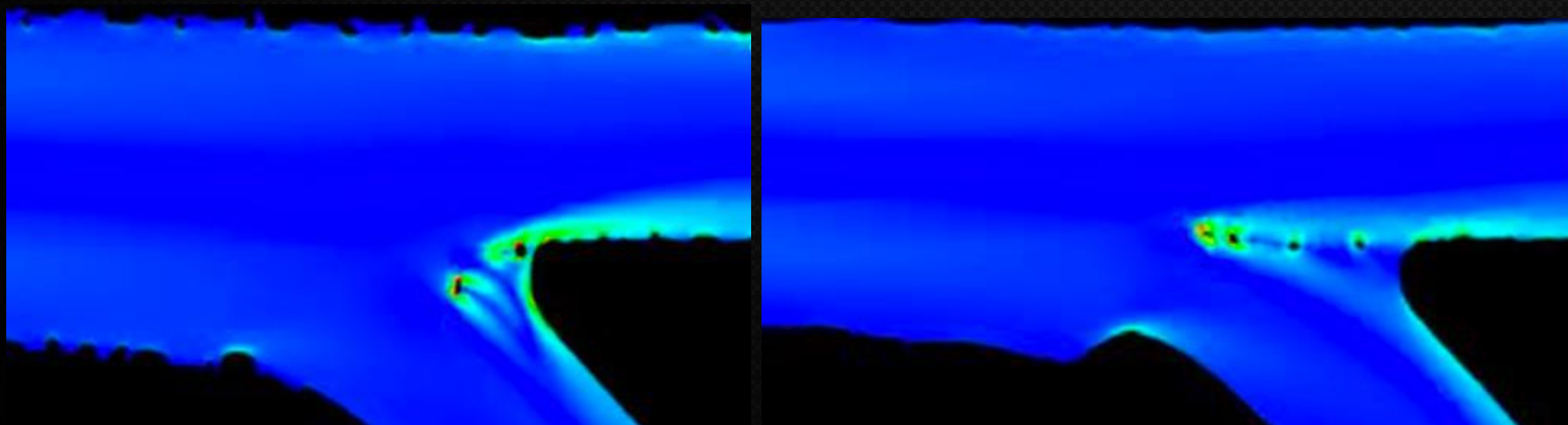
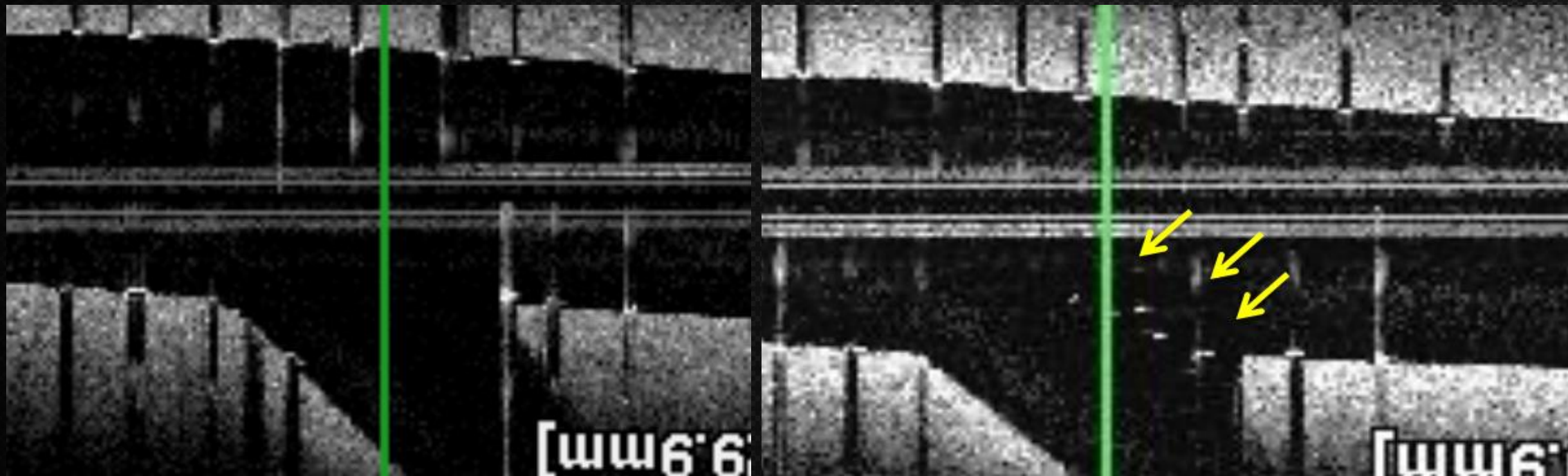
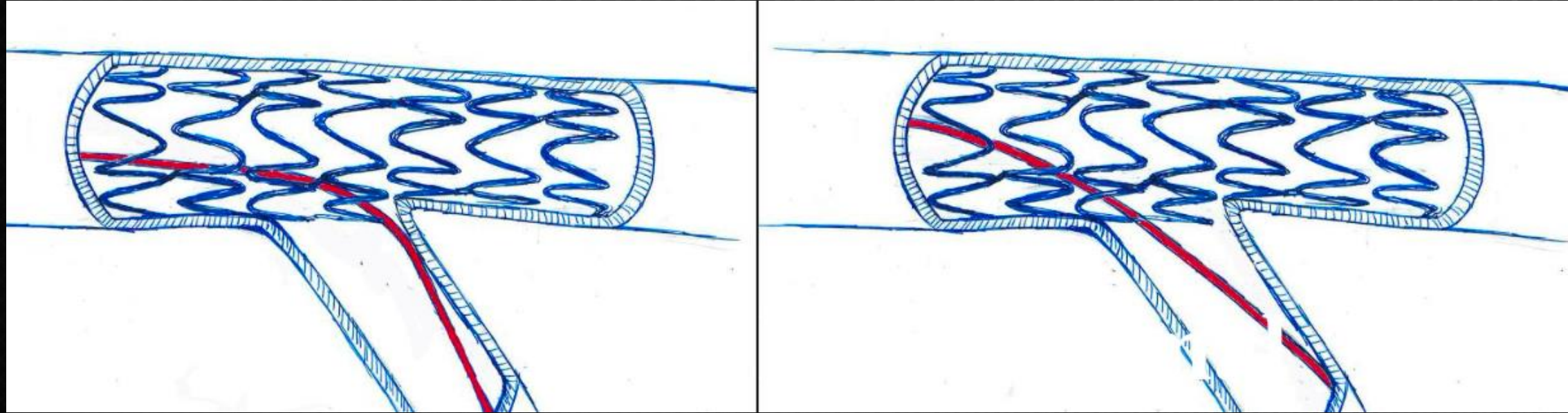
Optical coherence tomography to guide percutaneous coronary intervention of the left main coronary artery: the LEMON study



This pilot study is the first to report the feasibility and performance of OCT-guided LMS PCI according to a pre-specified protocol.

Joint consensus on the use of OCT in coronary bifurcation lesions by the European and Japanese bifurcation clubs



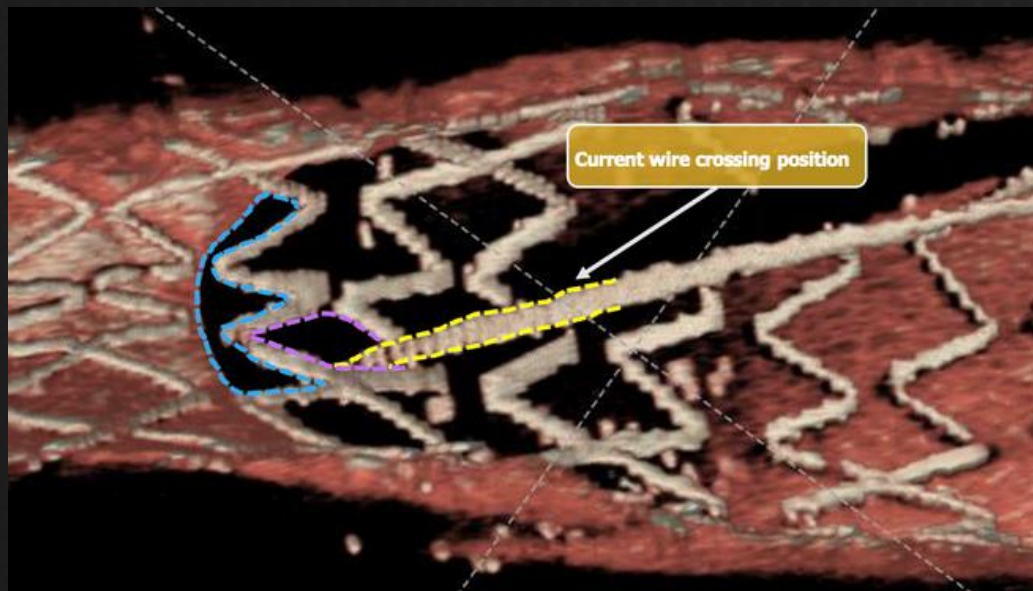


**Impact of recrossing wire
position on shear stress
after ballooning**

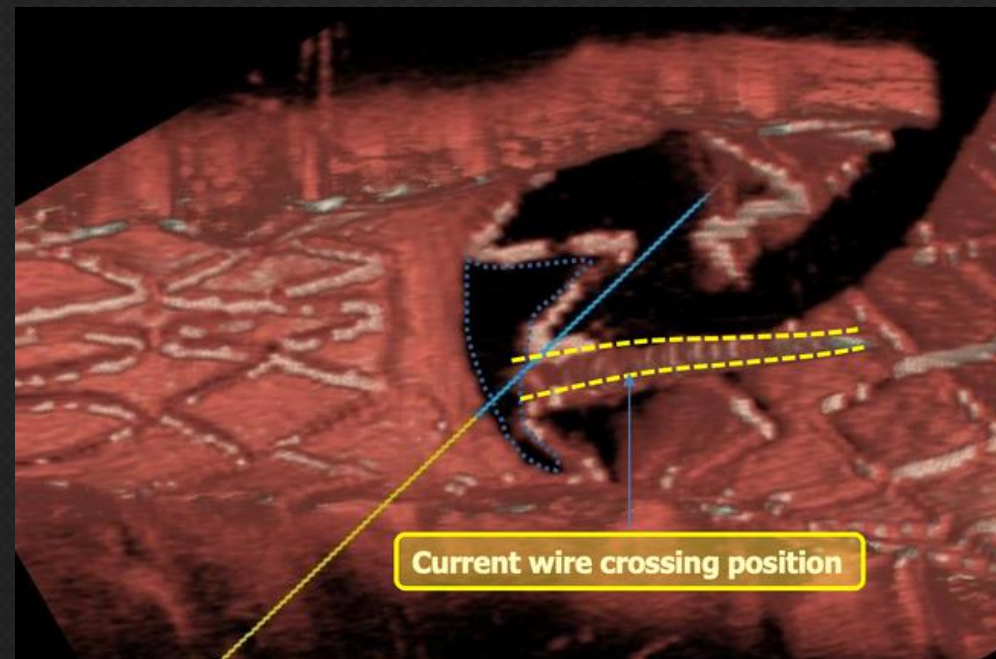
OCT is Better than IVUS especially for bifurcation PC,
Yoshinobu Onuma

Wire re-crossing to side branch after stent deployment

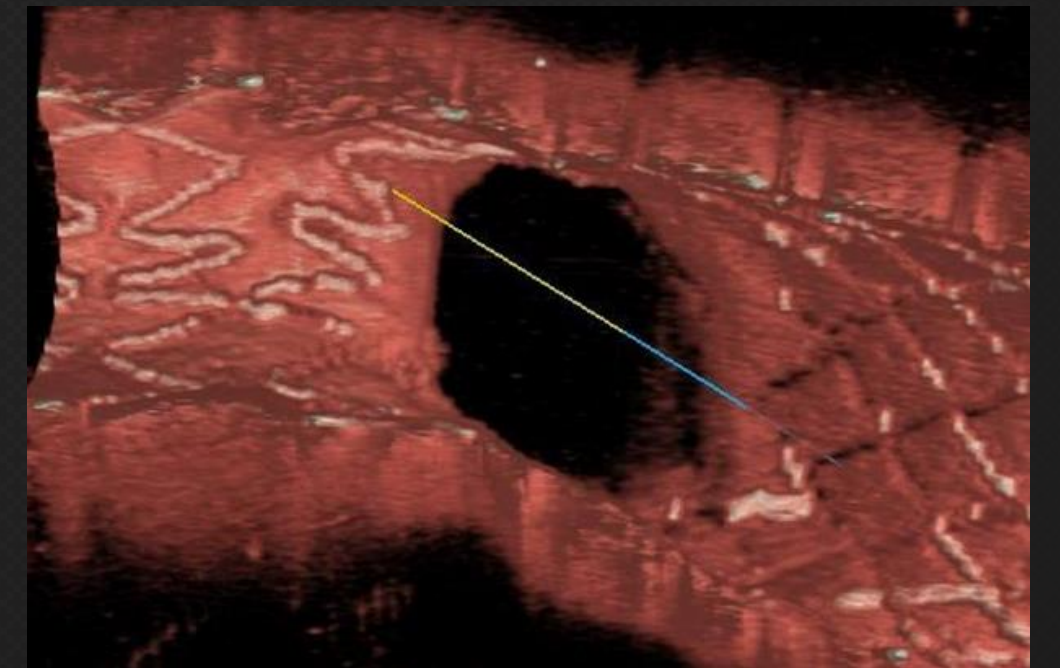
1



2



3



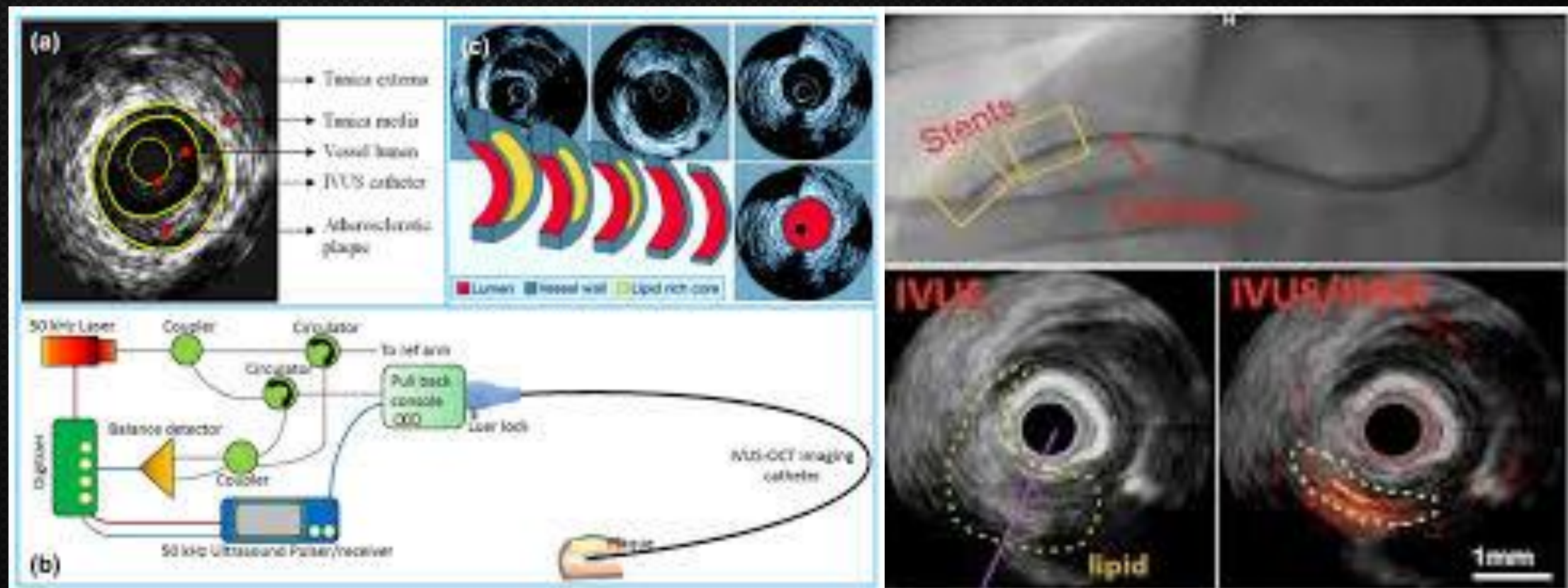
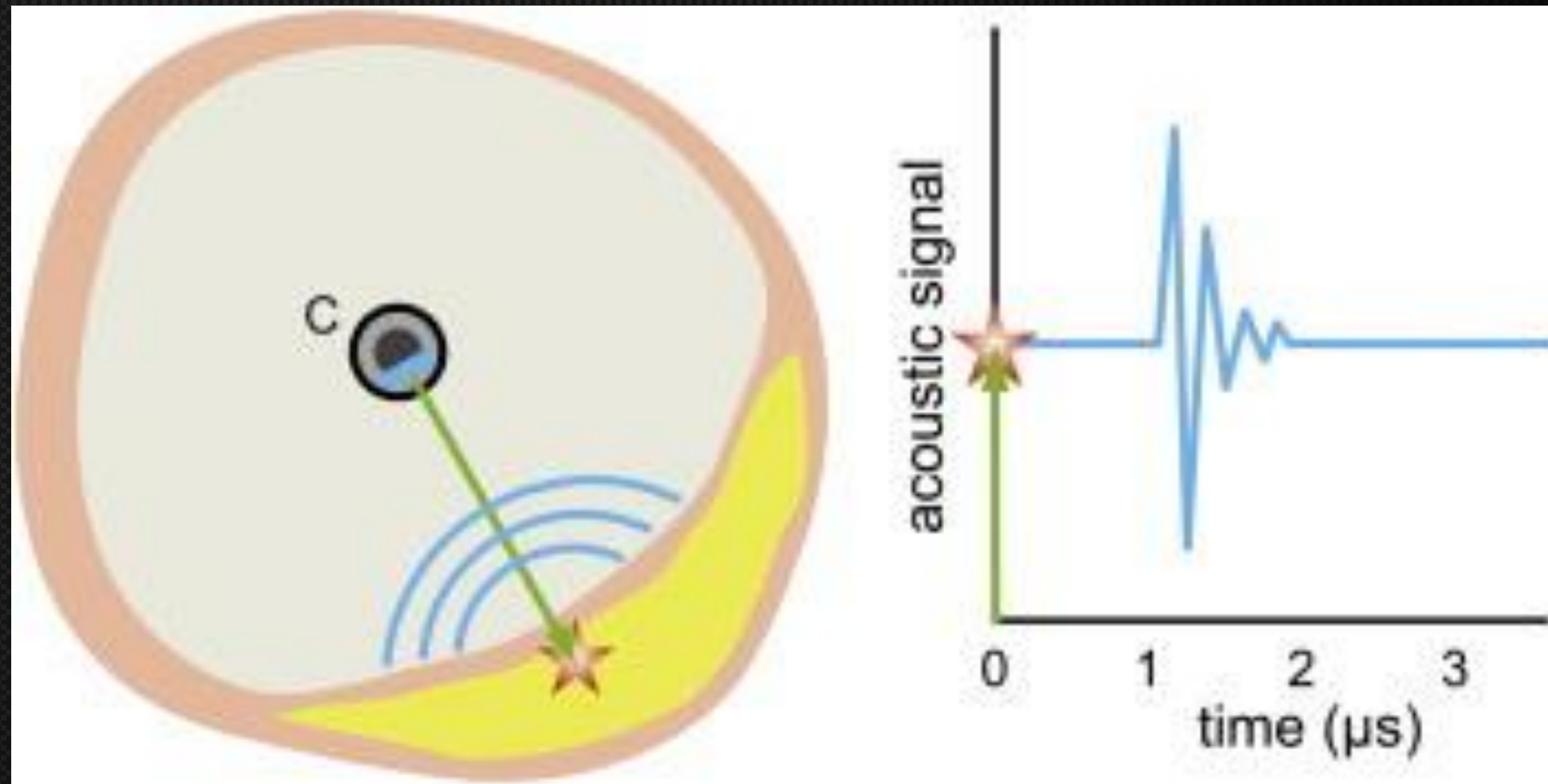
Ongoing RCTs comparing OCT versus angiography-guided bifurcation PCI

	Number of patients	Endpoint
DOCTOR Recross	60 (angiography: 30, OCT: 30)	Cross sectional stent strut malapposition in the main vessel bifurcation segment facing the side-branch ostium after procedure
OPTIMUM	103 (angiography guided: 53, OCT guided: 53)	Acute incomplete strut malapposition in bifurcation
OCTOBER	1200 (angiography guided: 600, OCT guided: 600)	To compare median two-year clinical outcome after OCT guided vs. standard guided revascularization of patients requiring complex bifurcation stent implantation

Latest intravascular image

- It will be possible to detection of LIPID Pool in a better way through combination with a new image source.

- Change of treatment policy through prediction if vulnerable groups



Through the new modality, it is possible to predict the change of treatment indication.

- It will be possible to detection of LIPID Pool in a better way through combination with a new image source.
- Change of treatment policy through prediction of vulnerable groups

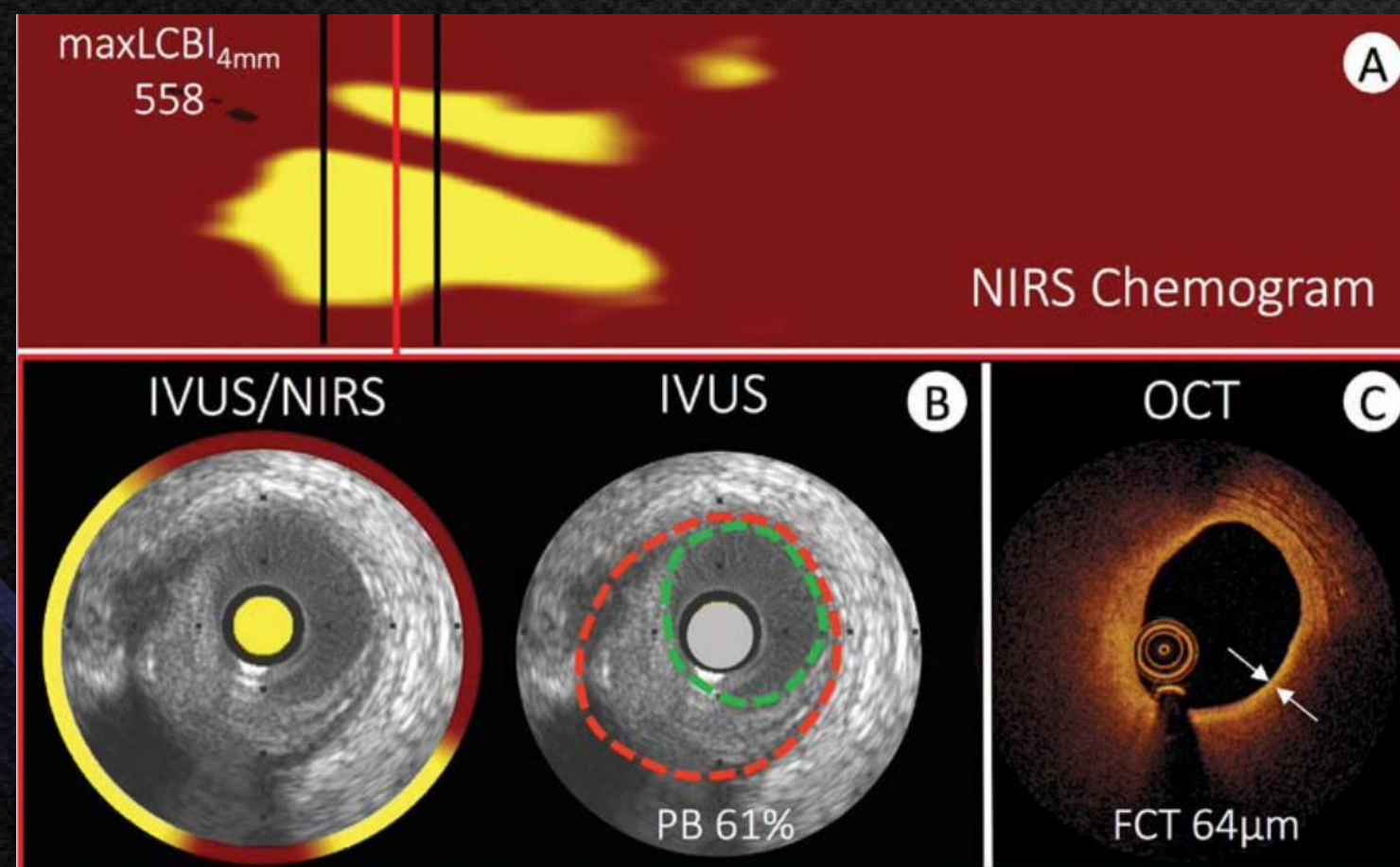
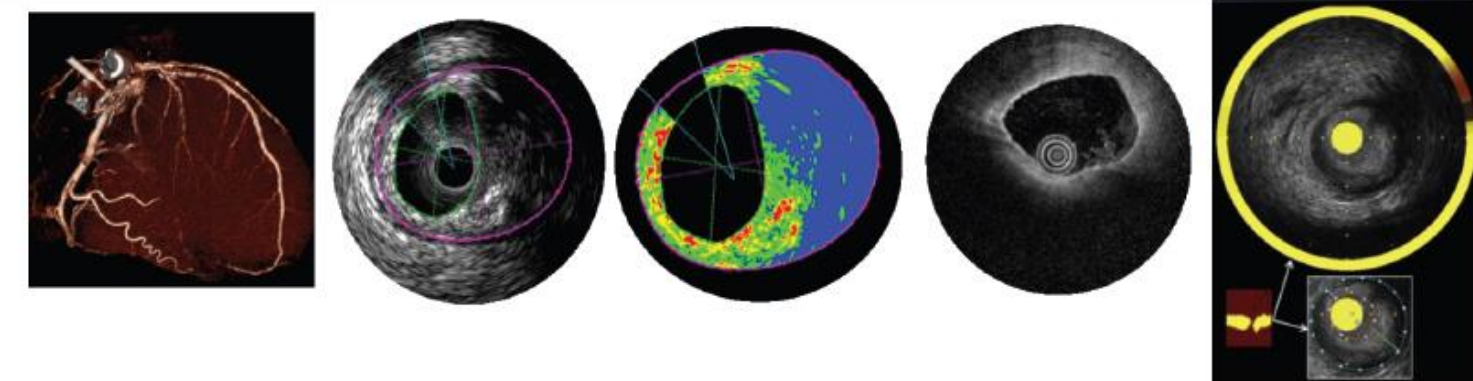


Figure 2: Characteristics of Invasive and Non-invasive Coronary Imaging Modalities to Detect High-risk Vulnerable Plaques

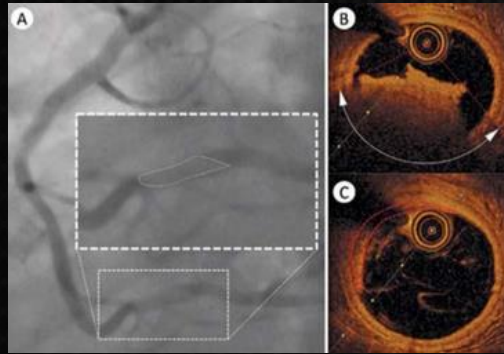
Modality	CCTA	IVUS	IVUS-RF Analysis	OCT/OFDI	NIRS
Energy source	X-ray	Ultrasound (20–60 MHz)	Ultrasound (20–40 MHz)	Near-Infrared light	Near-Infrared light
Resolution	0.5–1 mm	100–200 µm	100–200 µm	10–15 µm	NA
Penetration	NA	8–10 mm	8–10 mm	2–3 mm	1–2 mm
Features of high-risk plaque	Eccentric pattern, outward remodelling, low attenuation plaque by HU, spotty calcification, napkin ring sign	Eccentric pattern, outward remodelling, large plaque burden, large lipid core (echolucent core), spotty calcification	Plaque composition (fibrous, fibro-fatty, necrotic core, And calcification), large necrotic core (RF-IVUS-derived TCFA)	Thin fibrous cap, macrophage infiltration, neovascularization, large lipid core, spotty calcification	High lipid contents (high LCBI)
Limitation	Radiation, contrast agent, limited spatial resolution	Invasiveness, limited spatial resolution	Invasiveness, limited spatial resolution,	Invasiveness, limited tissue penetration, need for flushing	Invasiveness, limited tissue penetration



CCTA = coronary CT angiography; HU = Hounsfield unit; IVUS = intravascular ultrasound; RF = radiofrequency; OCT = optical coherence tomography; OFDI = optical frequency domain imaging; NIRS = near-infrared spectroscopy; NA = not applicable; TCFA = thin-cap fibroatheroma; LCBI = lipid-core burden index. Source: Maddur et al.⁹³ Adapted with permission from Elsevier.

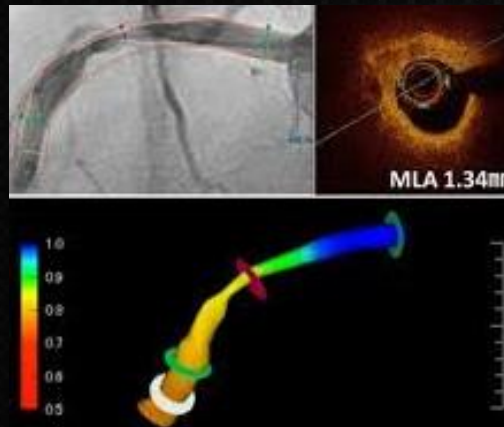
Ambiguous CAD

- Imaging of angiographically ambiguous coronary findings
- Find of reference size



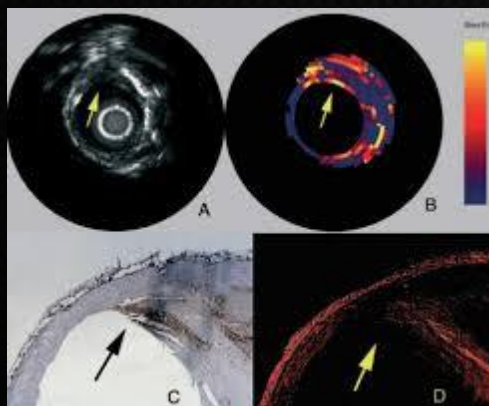
MLA

- Anatomical significant is used as a reference value



Vulnerability

- Change of treatment policy through prediction of vulnerable groups

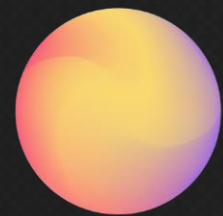


Hot Topic & Hot Discussion; **PCI Option for Multivessel Disease**

Image guided MVD PCI

- 1**
Whether to treat or not
Where to treat compared to FFR?
Which one is more realistic in an AMI environment?
- 2**
Practical help of image guided
Help in the ambiguous CAD
Longitudinal Miss
Stent Optimization
- 3**
The evolution of image tools
Combination with ANGIO.
Combining with other image sources

Today's Message



What is the key to **complete revascularization** in MVD?
What treatment will help the patient?
It evaluates and decides which treatment to perform.



Image guided is essential for MVD treatment, and the recent development of the device helps **more accurate and effective** treatment.

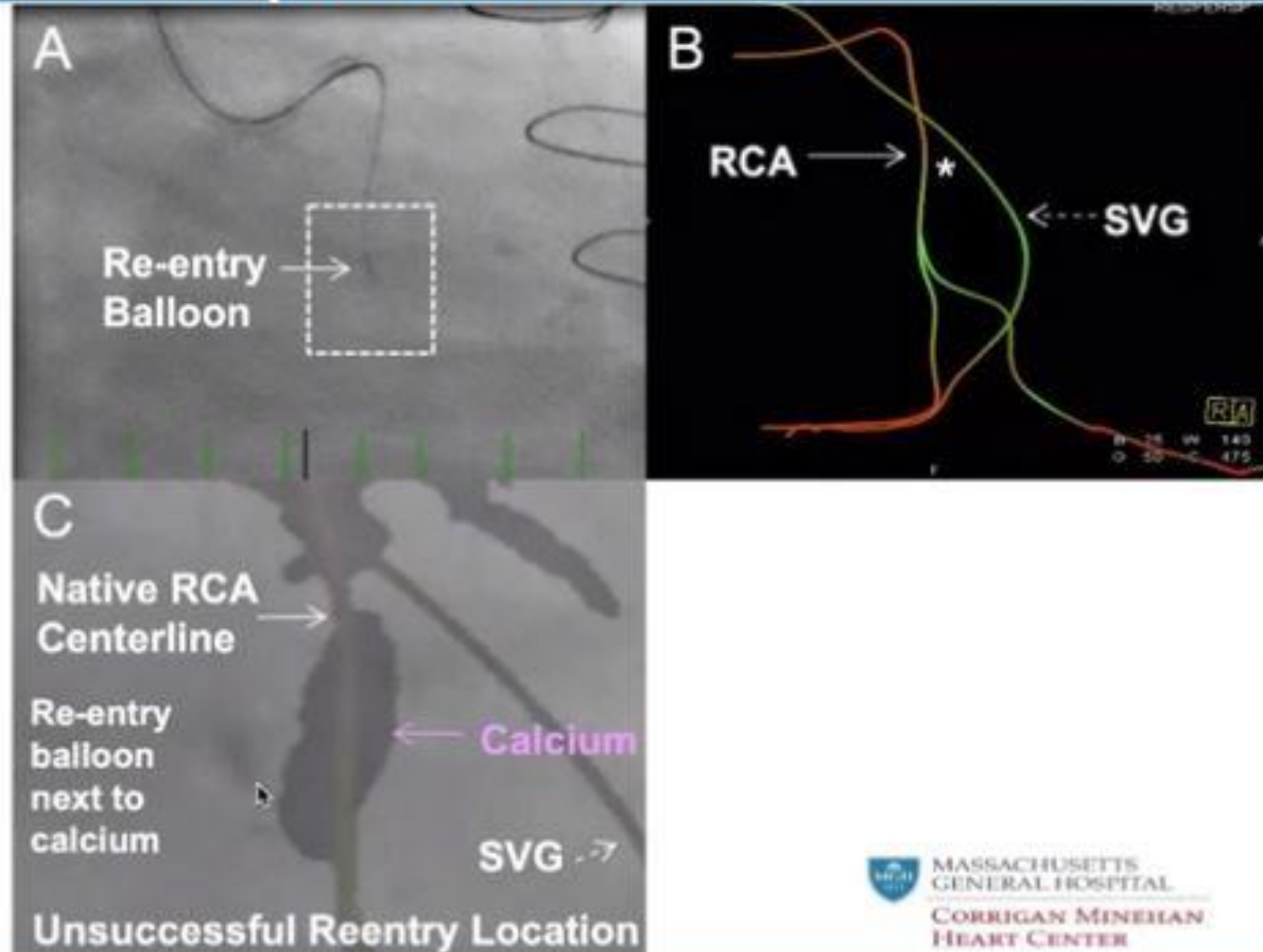


If the **vulnerability** of the lesion is evaluated through the synthesis and development of various modalities in the future, the treatment direction will be more diversified.

It is not a matter of which is more important

Real-time CT fusion reveals how calcium affects ADR procedures

- Antegrade dissection reentry (ADR) requires re-entering the true lumen. Reentry is facilitated using a controlled balloon such as the Stingray.
- However, reentry may not be successful due to lesional factors.
- Real-time CT fusion showed how calcium affected an ADR failure and success



← *European Radiology 2017*

MASSACHUSETTS
GENERAL HOSPITAL
CORRIGAN-MINEHAN
HEART CENTER

OFR

OCT based FFR

Reliable

High Diagnostic Accuracy

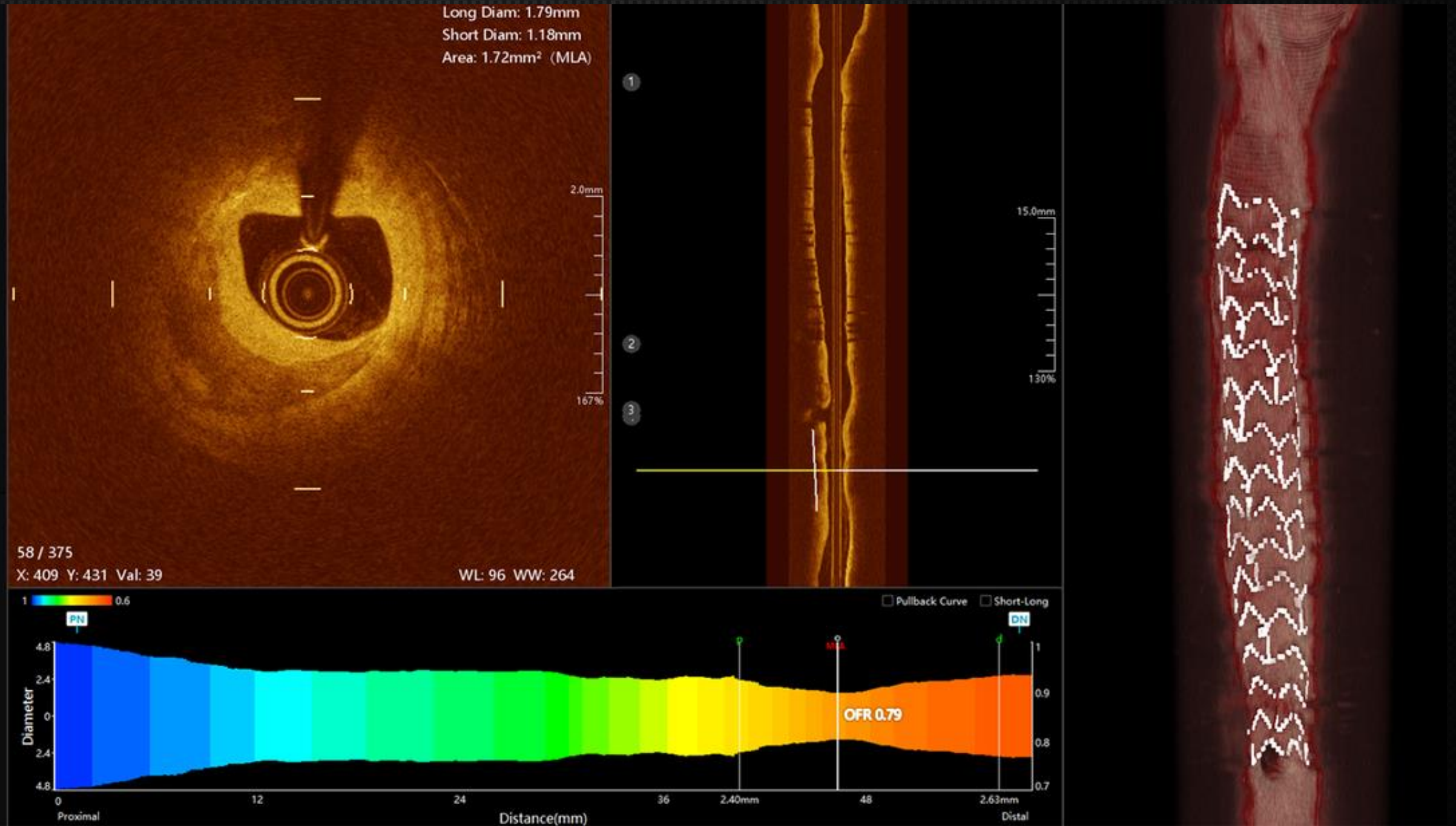
Accuracy	92%
Sensitivity	85%
Specificity	96%

High Reproducibility

Intra-Observer:	0.00 ± 0.02
Inter-Observer:	0.00 ± 0.03

Vessel OFR
0.75

MLA(mm²)
1.72
Lesion Length(mm)
15.61
Lesion OFR
0.78
Residual OFR
0.84



Dogma of complete revascularisation

Balancing the risks

PRO

Less Ischemia

Less Symptom

=> Better Prognosis





CONS

Procedural complication

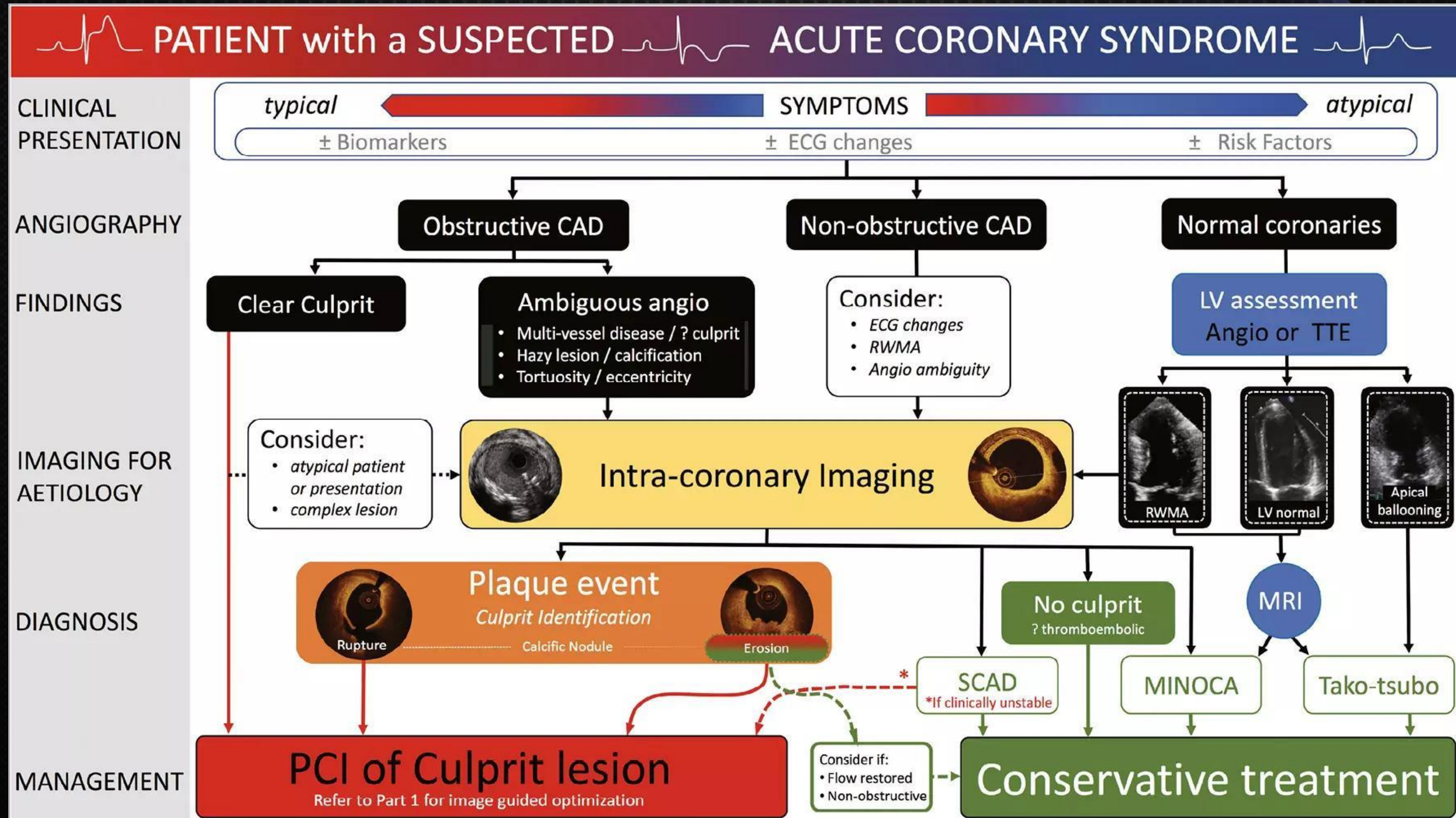
More Stents (High risk ST and ISR)

=> Impaired Prognosis

Physiology guided MVD PCI

	FAME 3	SYNTAX	FREEDOM	BEST	EXCEL	NOBLE
		PCI 17.8% vs. CABG 12.4% (@ 1 year) Left main & MVD	PCI 16.8% vs. CABG 11.8% (@ 1 year) MVD + Diabetes	PCI 19.9% vs. CABG 13.3% (@ median 4.6 y) MVD	PCI 23.1% vs. CABG 19.1% (@ 3 years) Left main disease	PCI 29% vs. CABG 19% (@ median 3 y) Left main disease
FFR-guided PCI 10.6% vs. CABG 6.9% (@ 1year)		PCI		vs.		CABG
		Death, MI, (stroke) or repeat revascularization				
		FFR guidance		vs.		Angiography alone
		ffr≤0.8 stable CAD PCI 4.3% vs. OMT 12.7% (@ mean 7m)	stable CAD FFR+PCI 13.2% vs. Angio+PCI 18.3% (@ 1 year)	stable CAD + ACS FFR+PCI 9.5% vs. Angio+PCI 8.7% (@ 1 year)	all-comers MVD FFR+PCI 14.6% vs. Angio+PCI 14.4% (@ 1 year)	STEMI & MVD FFR+PCI 5.5% vs. Angio+PCI 4.2% (@ 1 year)
	FAME 3	FAME 2	FAME	RIPCARD 2	FUTURE	FLOWER MI

Clinical use of intracoronary imaging



Five years follow-up of IVUS XPL trial

Randomized Trials

- 1) Jakubcin J, Szlachetka R, Bystron M, et al. Long-term health outcome and mortality evaluation after invasive coronary treatment using drug-eluting stents with or without the IVUS guidance. Randomized control trial. *HIMT DES IVUS. Catheter Cardiovasc Interv* 2010;75:578-583.
- 2) Chieffo A, Laha A, Casarin C, et al. A prospective, randomized trial of intravascular ultrasound-guided compared to angiography-guided stent implantation in complex coronary lesions: the RIVO trial. *Am Heart J* 2013;165:65-72.
- 3) Kim JS, Kang TS, Mintz GS, et al. Randomized comparison of clinical outcomes between intravascular ultrasound and angiography-guided drug-eluting stent implantation for long coronary artery stenoses. *JACC Cardiovasc Interv* 2014;7:389-397.
- 4) Hong SJ, Kim BK, Shin DH, et al. IVUS-XPL vs. angiography. Effect of intravascular ultrasound-guided versus angiography-guided everolimus-eluting stent implantation: the IVUS-XPL randomized clinical trial. *JAMA* 2015;314:215-223.
- 5) Tian NL, Gami SK, Ye F, et al. Angiographic vs. optical coherence tomography-guided drug-eluting stent implantation for patients with chronic total occlusion lesions: five-year results from a randomized controlled study. *Circ Cardiovasc Interv* 2015;8:e002582.
- 6) Kim BK, Shin DH, Hong MK, et al. CTO-IVUS Study Investigators. Clinical impact of intravascular ultrasound-guided chronic total occlusion intervention with zotarolimus-eluting versus biolimus-eluting stent implantation: randomized study. *Circ Cardiovasc Interv* 2015;8:e002582.
- 7) Tan O, Wang Q, Liu D, et al. Intravascular ultrasound-guided unprotected left main coronary artery stenting in the elderly. *Saudi Med J* 2015;36:549-53.
- 8) Zhang JQ, Shi R, Peng W, et al. Application of intravascular ultrasound in stent implantation for small coronary arteries. *J Clin Intervent Cardiol* 2016;3:1-8.
- 9) Martini J Jr, Guedes C, Soares P, et al. Intravascular ultrasound guidance to minimize the use of iodine contrast in percutaneous coronary intervention: the MDZART (Minimizing Contrast Utilization With IVUS Guidance in Coronary Angioplasty) randomized controlled trial. *JACC Cardiovasc Interv* 2014;7:1287-93.
- 10) Habara M, Hase K, Tereshima M, et al. Impact of frequency-domain optical coherence tomography guidance for optimal coronary stent implantation in comparison with intravascular ultrasound guidance. *Circ Cardiovasc Interv* 2012;5:193-201.
- 11) Al-Za'abi ZA, Muehler A, Grolms P, et al. Optical coherence tomography compared with intravascular ultrasound and with angiography to guide coronary stent implantation (LUMEN III OPTIMIZE PCI): a randomized controlled trial. *Lancet* 2016;387:1011-19.
- 12) Meuwass N, Sadosky D, Mehrhoff P, et al. Optical Coherence Tomography Versus Results of Percutaneous Coronary Intervention in Patients with Non-ST-Elevation Acute Coronary Syndrome: Results of the Multicenter, Randomized DOCTORS Study (Does Optical Coherence Tomography Optimize Results of Stenting). *Circulation* 2016;134:906-17.
- 13) Kubo T, Shimizu T, Okamura T, et al. Optical frequency domain imaging vs. intravascular ultrasound in percutaneous coronary intervention (OPFIMON trial): one-year angiographic and clinical results. *Eur Heart J* 2017;38:2120-47.
- 14) Killa P, Cornuda P, Jaki M, et al. OCT guidance during stent implantation in primary PCI: A randomized multicenter study with one-month results of optical coherence tomography follow-up. *Int J Cardiol* 2018;250:85-103.

Meta-analyses

- 1) Zhang Y, Farooq V, Garcia-Garcia HM, et al. Comparison of intravascular ultrasound versus angiography-guided drug-eluting stent implantation: a meta-analysis of one randomized trial and ten observational studies involving 19,619 patients. *EuroIntervention* 2012;8:855-65.
- 2) Klermy C, Parfisi M, Razzano A, et al. Use of IVUS guided coronary stenting with drug eluting stent: a systematic review and meta-analysis of randomized controlled clinical trials and high quality observational studies. *Int J Cardiol* 2015;170:54-63.
- 3) Jang JS, Song YJ, Kang W, et al. Intravascular ultrasound-guided implantation of drug-eluting stents to improve outcome: a meta-analysis. *JACC Cardiovasc Interv* 2014;7:233-43.
- 4) Ahn JM, Kang SJ, Yoon SH, et al. Meta-analysis of outcomes after intravascular ultrasound-guided versus angiography-guided drug-eluting stent implantation in 26,503 patients enrolled in three randomized trials and 14 observational studies. *Am J Cardiol* 2014;113:1333-47.
- 5) Zhang YJ, Paeng S, Chen XY, et al. Comparison of intravascular ultrasound-guided versus angiography-guided drug eluting stent implantation: a systematic review and meta-analysis. *BMC Cardiovasc Disord* 2015;15:153.
- 6) Akidawi S, Elbar M, Rahman S, Abulata M, Lohani M. The role of intravascular imaging guidance in percutaneous coronary interventions: A meta-analysis of bare metal stent and drug-eluting stent trials. *Cardiovasc Ther* 2015;2015:166-8.
- 7) Narkisar N, Cheshko CJ, Verma KP, et al. Intravascular ultrasound and guidance improves clinical outcomes during implantation of both first and second-generation drug-eluting stents: a meta-analysis. *EuroIntervention* 2017;12:1632-40.
- 8) Shrivastava A, Zhang YJ, Lee SY, et al. Intravascular ultrasound-guided drug-eluting stent implantation: a meta-analysis of randomized controlled trials and observational studies. *Int J Cardiol* 2016;216:133-9.
- 9) Elgendy IF, Mahmoud AN, Elgendy AY, et al. Outcomes of intravascular ultrasound-guided stent implantation: A meta-analysis of randomized trials in the era of drug-eluting stents. *Circ Cardiovasc Interv* 2016;9:e00706.
- 10) Shin DH, Hong SJ, Mintz GS, et al. Effects of intravascular ultrasound-guided versus angiography-guided first-generation drug-eluting stent implantation: Meta-Analysis With Individual Patient-Level Data From 2,345 Randomized Patients. *JACC Cardiovasc Interv* 2016;9:2232-9.
- 11) Dentelli C, Sestier P, Chaffagne S, et al. Intravascular ultrasound-guided vs angiography-guided drug-eluting stent implantation in complex coronary lesions: Meta-analysis of randomized trials. *Am Heart J* 2017 Mar;185:26-34.
- 12) Fan ZD, Gao XF, Li XS, Shen MX, Gao YL, Chen SL, Tian ML. The outcomes of intravascular ultrasound-guided drug-eluting stent implantation among patients with complex coronary lesions: a comprehensive meta-analysis of 15 clinical trials and 6,004 patients. *Angiol J Cardiol* 2017;17:258-66.
- 13) Ye Y, Yang M, Zhang S, Zhang Y. Percutaneous coronary intervention in acute coronary artery disease with or without intravascular ultrasound: A meta-analysis. *PLoS One* 2017 Jun 22;12(6):e0170054.
- 14) Biondi S, Franchini G, Hamao S, Puglisi S, Verhe G, D'Angelo J, Pizzarello S, Scuto M, Condorelli G, Barbanti M, Capozzeco P, Tamburino G, Capetani D. Clinical outcomes following intravascular imaging-guided versus coronary angiography-guided percutaneous coronary intervention with stent implantation: A systematic review and Bayesian network meta-analysis of 31 studies and 17,882 patients. *JACC Cardiovasc Interv* 2017;10:2483-96.
- 15) Kaku KO, Charemski E, Aziz V, et al. Optical coherence tomography-guided percutaneous coronary intervention compared with other imaging guidance: a meta-analysis. *Int J Cardiovasc Imaging* 2018;34:583-13.

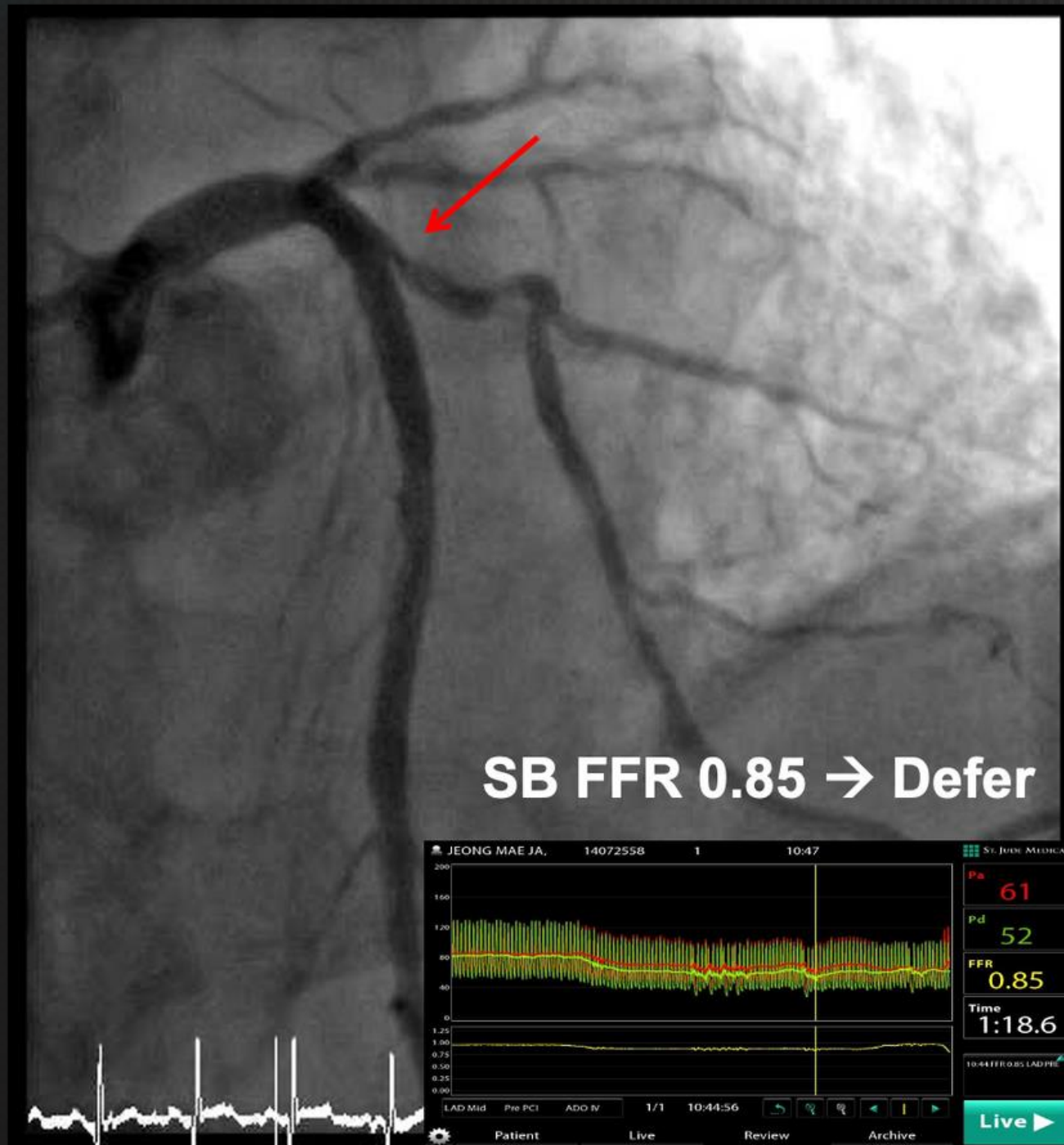
Registries

- 1) Aggolini P, Valgimigli M, Van Mieghem CA, et al. Comparison of early outcomes of percutaneous coronary intervention for unprotected left main coronary artery disease in the drug-eluting stent era with versus without intravascular ultrasound guidance. *Am J Cardiol* 2005;95:644-547.
- 2) Roy P, Shrivastava DH, Seshinsky SJ, et al. The potential clinical utility of intravascular ultrasound guidance in patients undergoing percutaneous coronary intervention with drug-eluting stents. *Eur Heart J* 2009;30:1851-7.
- 3) Fujimoto H, Taz S, Dohi T, et al. Primary and mid-term outcome of drug-eluting stent implantation with angiographic guidance alone. *J Cardiol* 2008;31:15-24.
- 4) Park SJ, Kim YH, Park DW, et al. Investigators M C. Impact of intravascular ultrasound guidance on long-term mortality in stenting for unprotected left main coronary artery stenosis. *Circ Cardiovasc Interv* 2009;2:167-177.
- 5) Kim SH, Kim YH, Kang SJ, et al. Long-term outcomes of intravascular ultrasound-guided stenting in coronary bifurcation lesions. *Am J Cardiol* 2010;106:812-818.

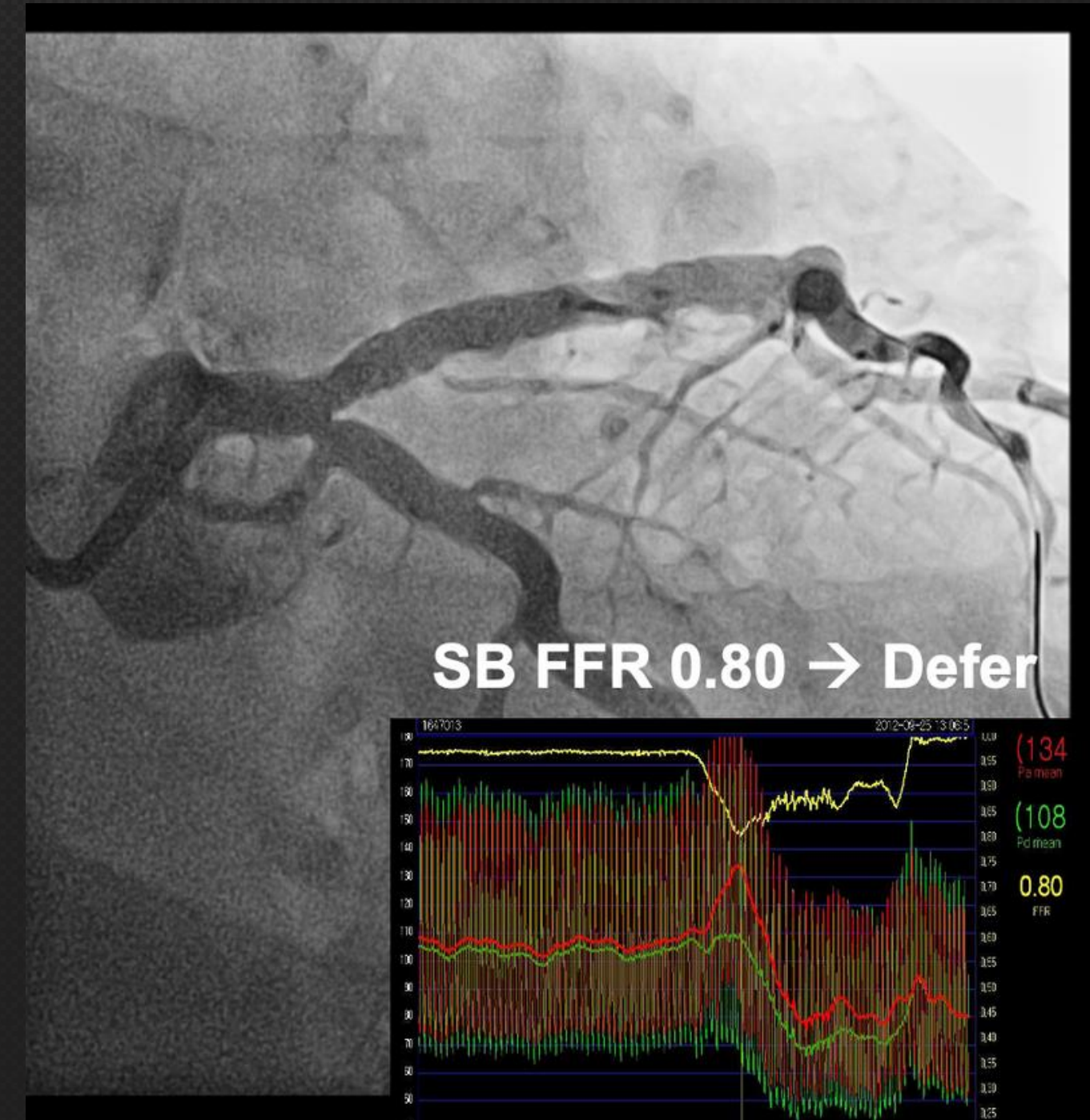
- 6) Maturica G, Lemesle G, Ben-Dor I, et al. Impact of intravascular ultrasound guidance in patients with acute myocardial infarction undergoing percutaneous coronary intervention. *Catheter Cardiovasc Interv* 2010;75:86-90.
- 7) Claessens BE, Meuwass N, Mintz GS, et al. Impact of intravascular ultrasound imaging on early and late clinical outcomes following percutaneous coronary intervention with drug-eluting stents. *JACC Cardiovasc Interv* 2011;4:574-581.
- 8) Kim JS, Hong MK, Ko YD, et al. 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;161:180-187.
- 9) Yoon YJ, Yoon J, Lee JW, et al. Intravascular ultrasound-guided primary percutaneous coronary intervention with drug-eluting stent implantation in patients with ST-segment elevation myocardial infarction. *Clin Cardiol* 2011;34:706-713.
- 10) Chen SL, Ye F, Zhang JJ, et al. Intravascular ultrasound-guided systematic two-stent techniques for coronary bifurcation lesions and reduced late stent thrombosis. *Catheter Cardiovasc Interv* 2013;81:456-463.
- 11) Hui SH, Kang SJ, Kim YH, et al. Impact of intravascular ultrasound-guided percutaneous coronary intervention on long-term clinical outcomes in a real world population. *Catheter Cardiovasc Interv* 2013;81:407-418.
- 12) Park KW, Kang SH, Yang HM, et al. Impact of intravascular ultrasound guidance in routine percutaneous coronary intervention for conventional lesions: data from the EXCELLENT trial. *Int J Cardiol* 2013;167:721-726.
- 13) Wlozyniecki B, Muehler A, Weisz G, et al. Relationship between intravascular ultrasound guidance and clinical outcomes after drug-eluting stents: The ADAPT-DES Study. *Circulation* 2014;129:463-70.
- 14) Ahn SG, Yoon J, Sung JK, et al. Intravascular ultrasound-guided percutaneous coronary intervention improves the clinical outcome in patients undergoing multiple overlapping drug eluting stents implantation. *Korean Circ J* 2013;43:224-8.
- 15) Ahn JM, Han S, Park YK, et al. RESIST Investigators. Differential prognostic effect of intravascular ultrasound use according to implanted stent length. *Am J Cardiol* 2013;111:829-835.
- 16) Yoon YW, Shin S, Kim BK, et al. Investigators R. Usefulness of intravascular ultrasound to predict outcomes in short-length lesions treated with drug-eluting stents. *Am J Cardiol* 2013;112:840-846.
- 17) de la Torre Hernandez JM, Baz Alonso JA, Gómez Huelat JA, et al. IVUS-TRONCO-ICP Spanish study. Clinical impact of intravascular ultrasound guidance in drug-eluting stent implantation for unprotected left main coronary disease: pooled analysis of the patient-level of 4 registries. *JACC Cardiovasc Interv* 2014;7:294-304.
- 18) Hong SJ, Kim BK, Shin DH, et al. K-CTO Registry. Usefulness of intravascular ultrasound guidance in percutaneous coronary intervention with second-generation drug-eluting stents for chronic total occlusions (from the Multicenter Korean-Chronic Total Occlusion Registry). *Am J Cardiol* 2014;114:534-48.
- 19) Gao XF, Kuo J, Zhang YJ, et al. Comparison of one-year clinical outcomes between intravascular ultrasound-guided versus angiography-guided implantation of drug-eluting stents for left main lesions: a single center study in 1,015 patients. *Am J Geriatr Cardiol* 2014;8:10-17.
- 20) Probstlitz DM, Radwan S, Rabl H, et al. Long-term survival in patients undergoing percutaneous coronary intervention with or without intracoronary pressure wire guidance or intracoronary ultrasonographic imaging: a long-term study. *J Intervent Cardiol* 2014;174:1329-35.
- 21) Yazici NU, Agunluoglu M, Ayar A, et al. Effect of intravascular ultrasound-guided drug-eluting stent implantation on angiographic outcomes. *Eur Rev Med Pharmacol Sci* 2015;18:3612-7.
- 22) Singh V, Barchetta AO, Avora S, et al. Comparison of hospital mortality, length of hospital stay, costs, and quality of life of percutaneous coronary interventions guided by ultrasound versus angiography. *Am J Cardiol* 2015;115:1357-64.
- 23) Magalhães MA, Mehta S, Torguson R, et al. The effect of complete percutaneous revascularization with or without intravascular ultrasound guidance in the drug-eluting stent era. *EuroIntervention* 2015;11:825-31.
- 24) Nakamura K, Shimizu H, Morimoto T, et al. CREDO-IVUS-AMI Investigators. Impact of intravascular ultrasound-guided optical coherence tomography-guided primary percutaneous coronary intervention for ST-segment elevation myocardial infarction: Long-Term Clinical Outcomes From the CREDO-IVUS-AMI Registry. *Circ J* 2016;80:477-84.
- 25) Patel Y, Depla JP, Patel JS, et al. Impact of intravascular ultrasound on the long-term clinical outcomes in the treatment of coronary ostial lesions. *Catheter Cardiovasc Interv* 2016;87:232-40.
- 26) Ahmed K, Jeong MH, Chakraborty R, et al. Role of intravascular ultrasound in patients with acute myocardial infarction undergoing percutaneous coronary intervention. *Am J Cardiol* 2011;108:6-14.
- 27) Ray P, Torguson R, Daboe T, et al. Angiographic and procedural correlates of stent thrombosis after intracoronary implantation of drug-eluting stents. *J Interv Cardiol* 2007;20:307-13.
- 28) Gerber RT, Laha A, Jellai A, et al. Defining a new standard for IVUS optimized drug eluting stent implantation: the PRAWO study. *Catheter Cardiovasc Interv* 2009;74:340-56.
- 29) Bondi-Zoccali G, Sheiban I, Rosengreni C, et al. Is intravascular ultrasound beneficial for percutaneous coronary intervention of bifurcation lesions? Evidence from a 4314 patient registry. *Clin Res Cardiol* 2011;100:1921-8.
- 30) Wakabayashi K, Lindsay J, Lopez-Carricero A, et al. Utility of intravascular ultrasound guidance in patients undergoing percutaneous coronary intervention for type C lesions. *J Interv Cardiol* 2012;25:452-9.
- 31) Patel Y, Depla JP, Novak E, et al. Long-term outcomes with use of intravascular ultrasound for the treatment of coronary bifurcation lesions. *Am J Cardiol* 2012;109:960-5.
- 32) De la Torre Hernandez JM, Alfonso F, Sanchez Recalde A, et al. ESTROFA-LM Study Group. Comparison of paclitaxel-eluting stents (Taxus) and everolimus-eluting stents (Orion) in left main coronary artery disease with 3 years follow-up (from the ESTROFA-LM registry). *Am J Cardiol* 2013;111:678-83.
- 33) Patel Y, Depla JP, Patel JS, Muehler SK, Novak E, Zayas A, Kim H, Lakata JM, Back RG, Singh J. Impact of intravascular ultrasound on the long-term clinical outcomes in the treatment of coronary ostial lesions. *Catheter Cardiovasc Interv* 2016;87:232-40.
- 34) Anshel P, Karlsson S, Mohammad MA, Ostberg M, James S, Jevson J, Fritzer O, Angeles G, Nilsson J, Dimerovic E, Lagerstedt B, Penson J, Kral S, Erlinge D. Intravascular ultrasound guidance is associated with better outcome in patients undergoing unprotected left main coronary artery stenting compared with angiography guidance alone. *Circ Cardiovasc Interv* 2017;10:e004013.
- 35) Tian J, Guan C, Wang W, Zhang K, Chen J, Wu Y, Yan H, Zhao Y, Gao S, Yang Y, Mintz GS, Xu B, Tang Y. Intravascular Ultrasound Guidance Improves the Long-term Progress in Patients with Unprotected Left Main Coronary Artery Disease Undergoing Percutaneous Coronary Intervention. *Sol Rep* 2017 May 24;7(11):2377.
- 36) Pishi P, Di Wu L, Bondi-Zoccali G, et al. Angiography alone versus angiography with intravascular ultrasound (IVUS) guidance to guide decision-making during percutaneous coronary intervention: the Centro per la Lefta contro l'Obstacolo-Optimization of Percutaneous Coronary Intervention (CLO-OPCI) study. *EuroIntervention* 2012;8:602-8.
- 37) Wijns W, Shih J, Jones MR, et al. Optical coherence tomography imaging during percutaneous coronary intervention impacts physician decision-making: LUMEN I study. *Eur Heart J* 2015;36:3246-55.
- 38) Muehler A, Ben-Veruta O, Ali Z, et al. Comparison of Stent Expansion Guided by Optical Coherence Tomography Versus Intravascular Ultrasound: The LUMEN I Study (Observational Study of Optical Coherence Tomography [OCT] in Patients Undergoing Fractional Flow Reserve [FFR] and Percutaneous Coronary Intervention). *JACC Cardiovasc Interv* 2015;8:1784-14.
- 39) Iannaccone M, D'Ascenzo F, Frangich A, et al. Impact of an optical coherence tomography-guided approach in acute coronary syndromes: A propensity matched analysis from the international FORWARD-III-CARDIOGROUP IV and US2 Registry. *Catheter Cardiovasc Interv* 2017;90:e48-e52.
- 40) Smith TH, Kujala DA, Lavi S, et al. Optical Coherence Tomography-Guided Percutaneous Coronary Intervention in ST-Segment-Elevation Myocardial Infarction: A Prospective Randomly Matched Cohort of the Thrombolysis Versus Percutaneous Coronary Intervention Wave Trial. *Circ Cardiovasc Interv* 2016 Apr 9;9(4):e003414. doi: 10.1161/

Evaluation of Jailed side branch

LAD-D1

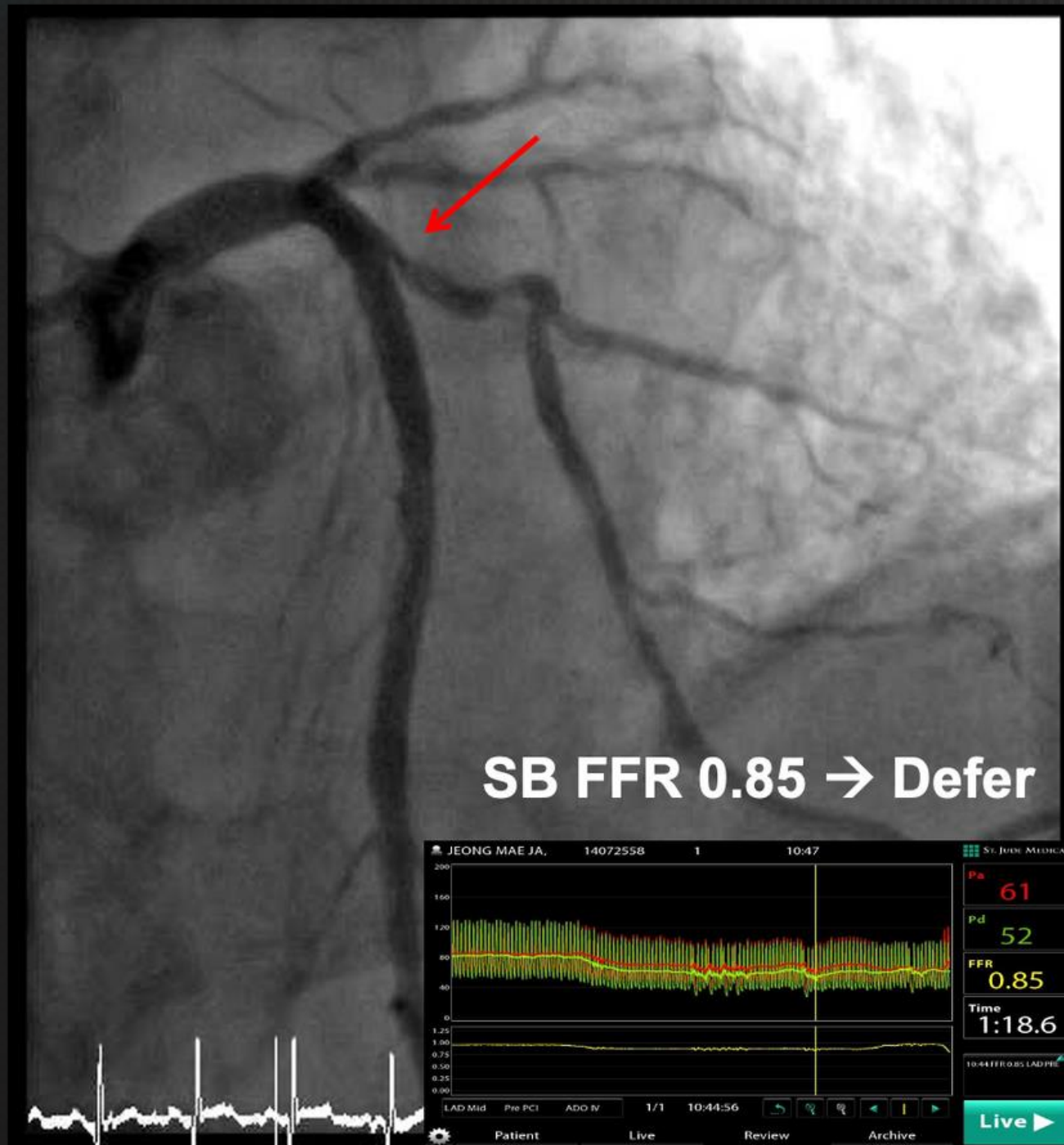


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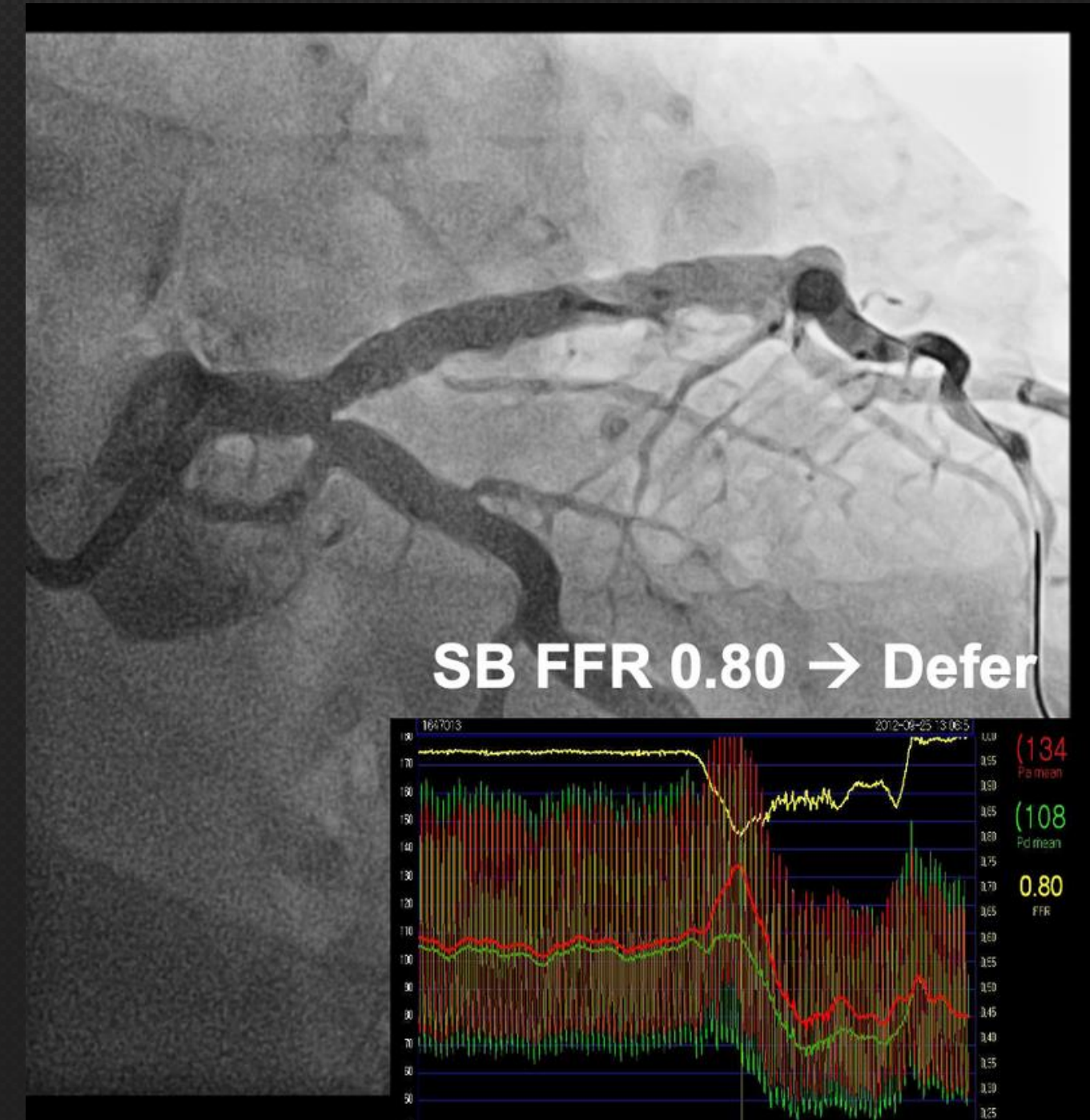


Evaluation of Jailed side branch

LAD-D1



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Meta-analysis of IVUS-Guided DES

