


Hong Kong College of Cardiology ASM 2020

Intravascular Shockwave Lithotripsy

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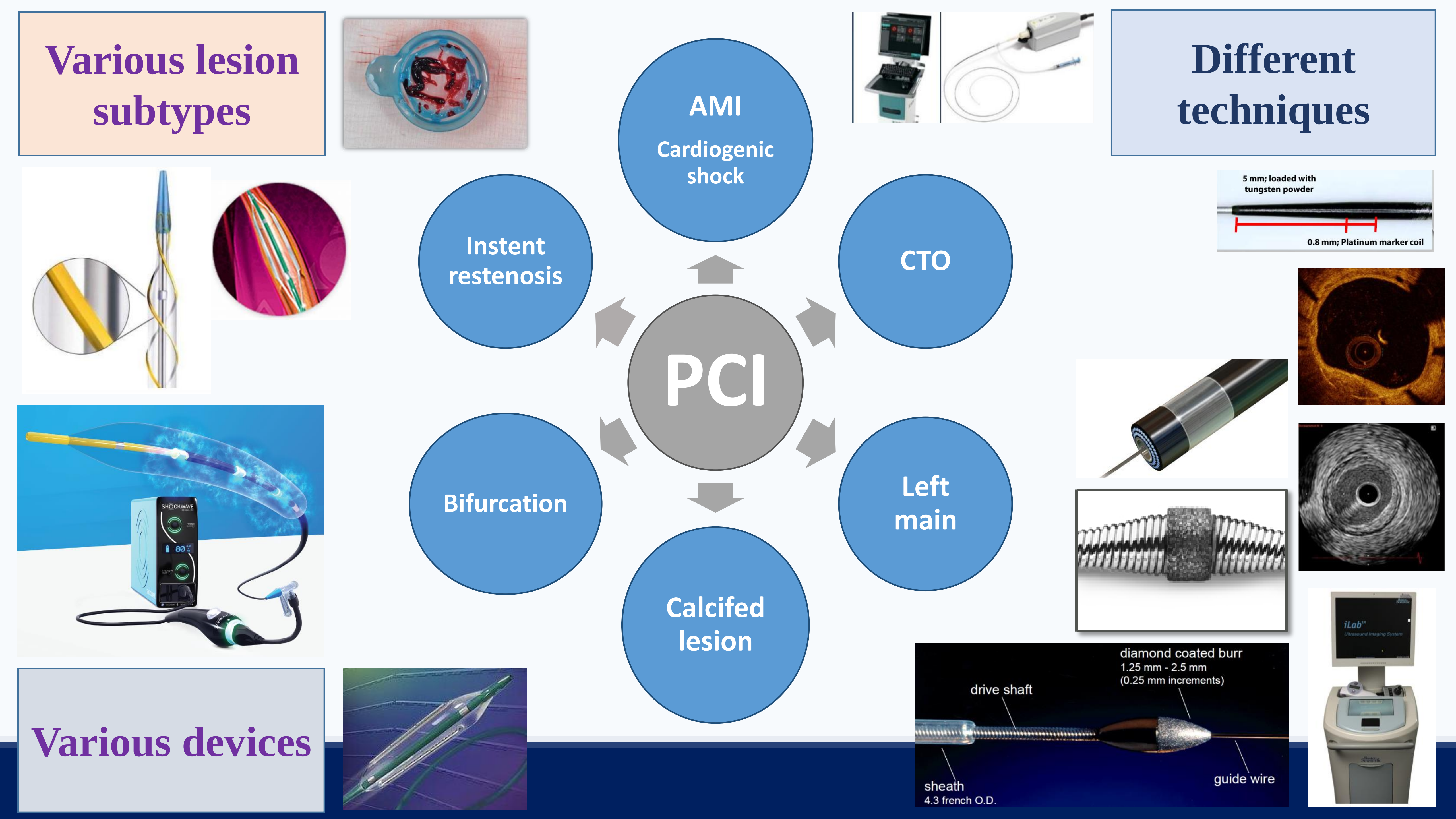
Various lesion subtypes
Different techniques
Various devices
PCI
AMI
Cardiogenic shock
CTO
Left main
Calcifed lesion
Bifurcation
Instent restenosis
5 mm; loaded with tungsten powder
0.8 mm; Platinum marker coil
diamond coated burr
1.25 mm - 2.5 mm
(0.25 mm increments)
drive shaft
sheath
4.3 french O.D.
guide wire
SHOCKWAVE
iLab
Ultrasound Imaging System


Various lesion subtypes
Different techniques
AMI
Cardiogenic shock
Instent restenosis
CTO
PCI
Bifurcation
Left main
Calcified lesion
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5 mm: loaded with tungsten powder
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(0.25 mm increments)
drive shaft
sheath
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guide wire

Coronary Calcifications

Problem of Heavy Coronary Calcifications

Impair stent delivery
stent dislodgement, abrade polymers

Dissections and perforations

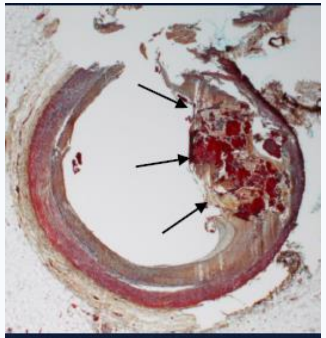
Stent expansion, apposition, asymmetry

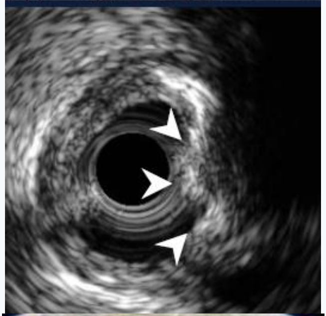
Stent thrombosis and restenosis

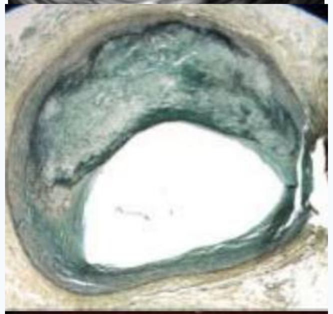
A meta-analysis of 7 contemporary PCI studies. At 3 years FU…

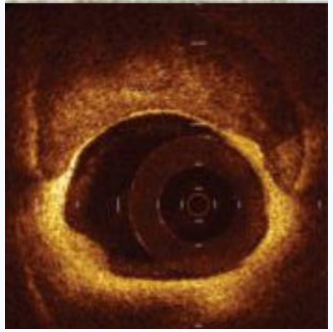
	With Severe Calcification (N=1291)	Without Severe Calcification (N = 5005)	P Value
Mortality	10.8%	4.4%	P <0.001
Combined Endpoint:			
MI & Death	22.9%	10.9%	P <0.001
MI, Death & Revascularization	31.8%	22.4%	P <0.001

Bourantas et al. BMJ 2014









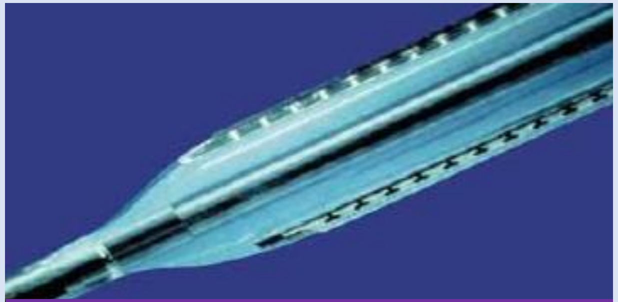
Coronary Calcifications

Importance of Lesion Preparation

To ensure a successful and safe procedure
To achieve better medium and long term outcome

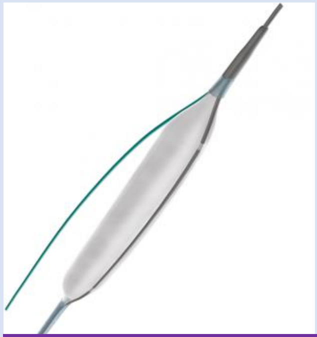
Armamentarium

NC balloon

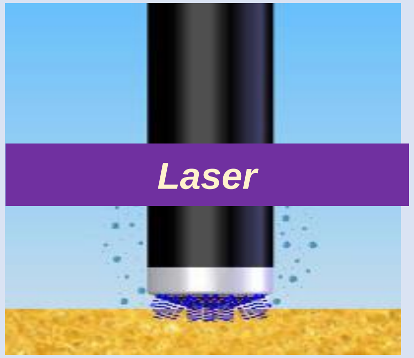


Cutting balloon

Scoring (Angiosculpt)

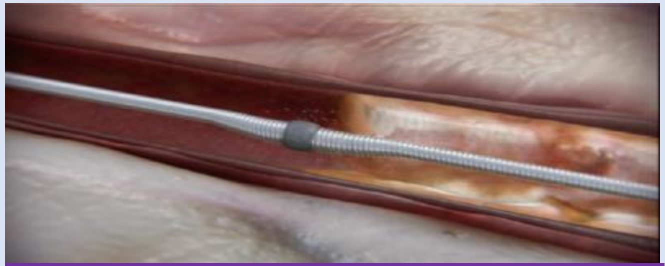


NC scoreflex



Laser

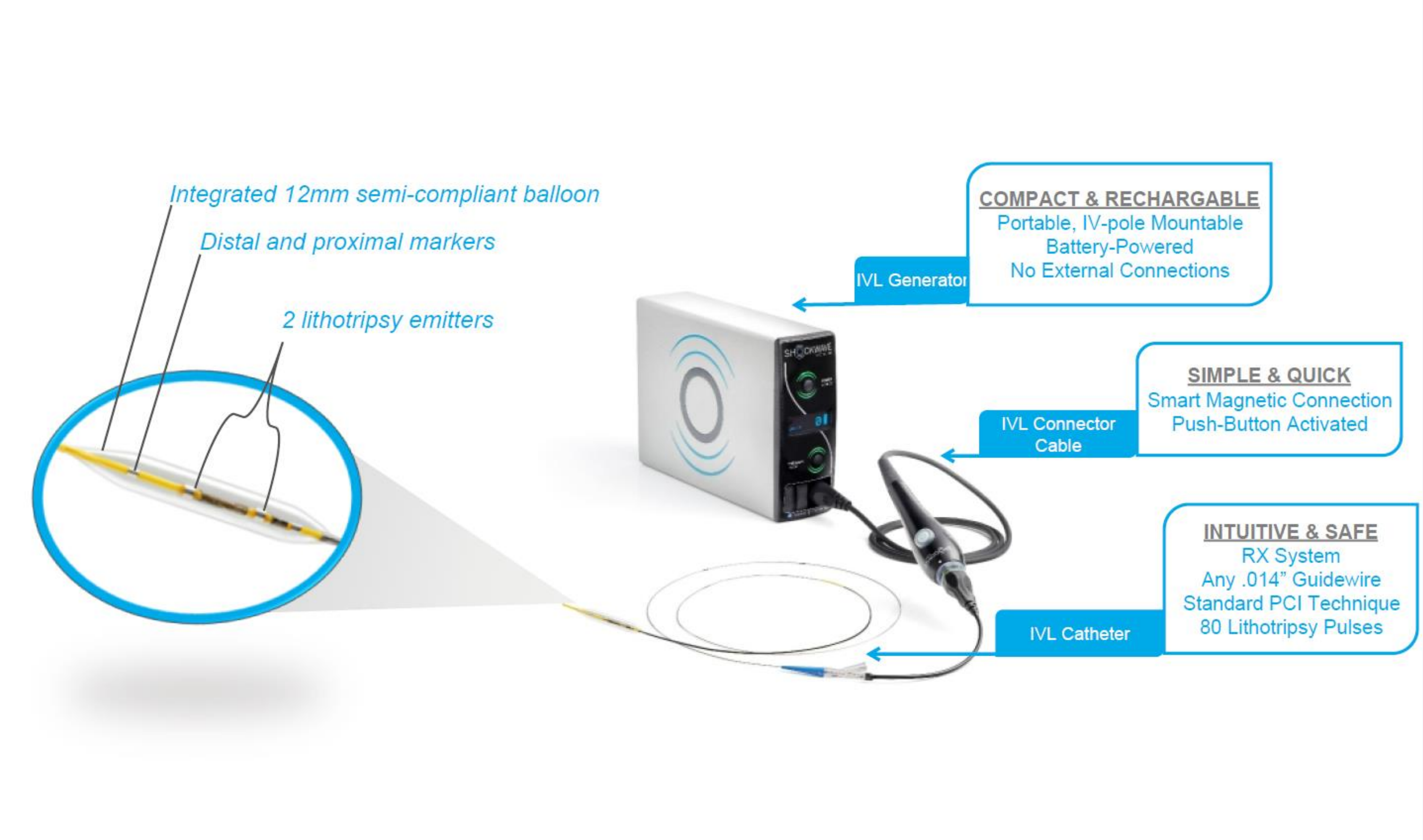
Rotational atherectomy



Orbital atherectomy

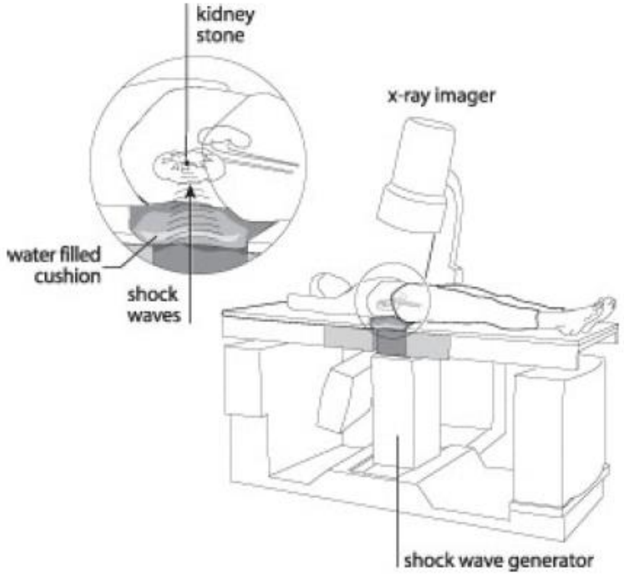
Lithotripsy

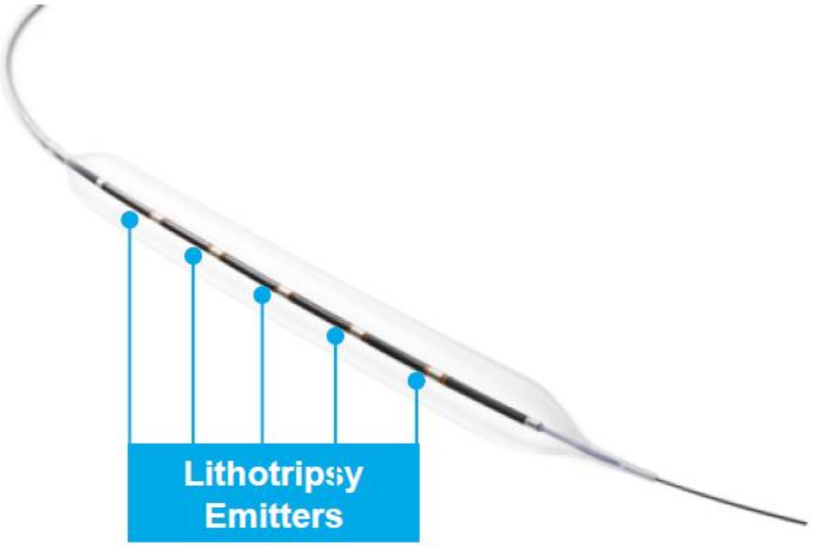
Intravascular lithotripsy (Shockwave)



Intravascular lithotripsy (Shockwave)

Lithotripsy	IVL Technology
30 years of safety data in kidney stone treatment	Miniaturized and arrayed Lithotripsy Emitters for localized lithotripsy at the site of the vascular calcium
Sonic Pressure Waves preferentially impact hard tissue, disrupt calcium, leave soft tissue undisturbed	Optimized for the treatment of vascular calcium





IVL's Unique Mechanism of Action

High Speed Sonic Pressure Wave Created Safely Inside Integrated Balloon

Electrical energy

↓

Spark inside fluid

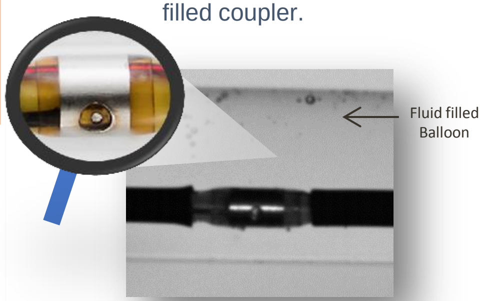
↓

Expanding and collapsing bubbles

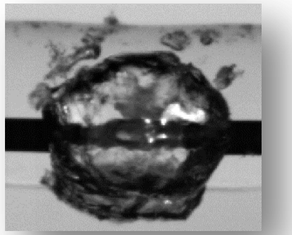
↓

Generate powerful sonic pressure waves

1 **Unfocused lithotripsy energy** is created at the emitters which are contained in a fluid filled coupler.



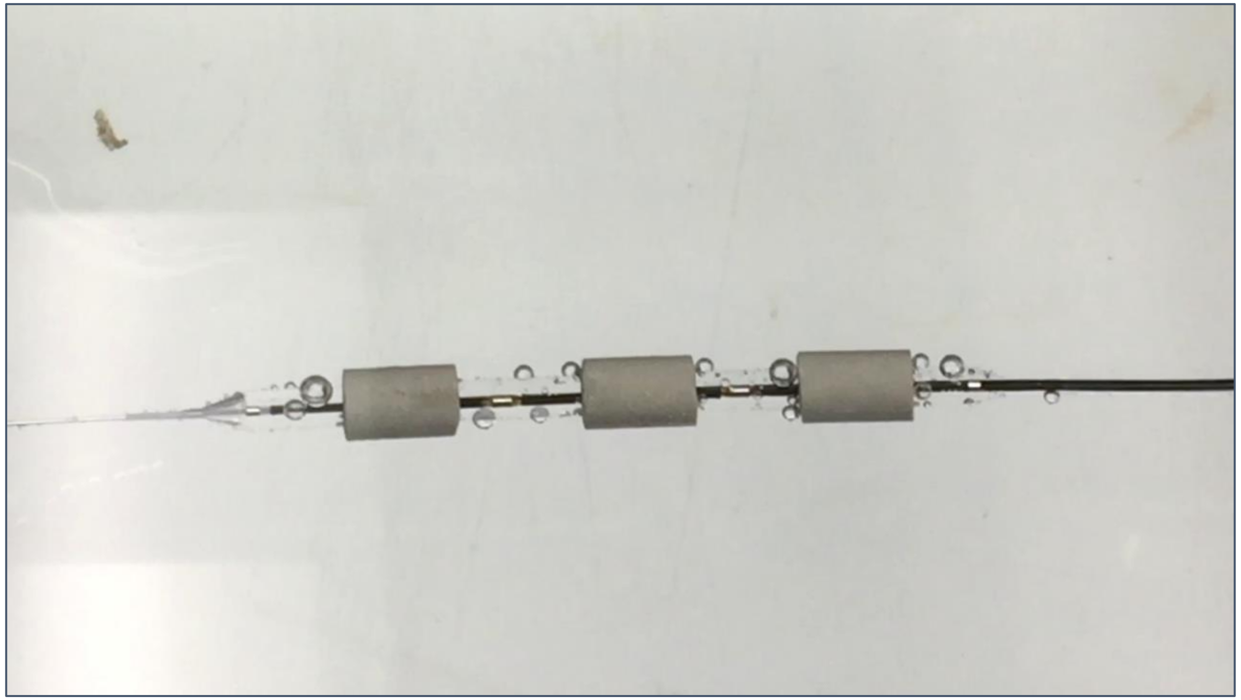
2 Electrical energy is delivered to the emitter, initiating the steam bubble, which expands & collapses – creating **sonic pressure waves**.



Video: Actuation of Single Pulse (20µs/frame)

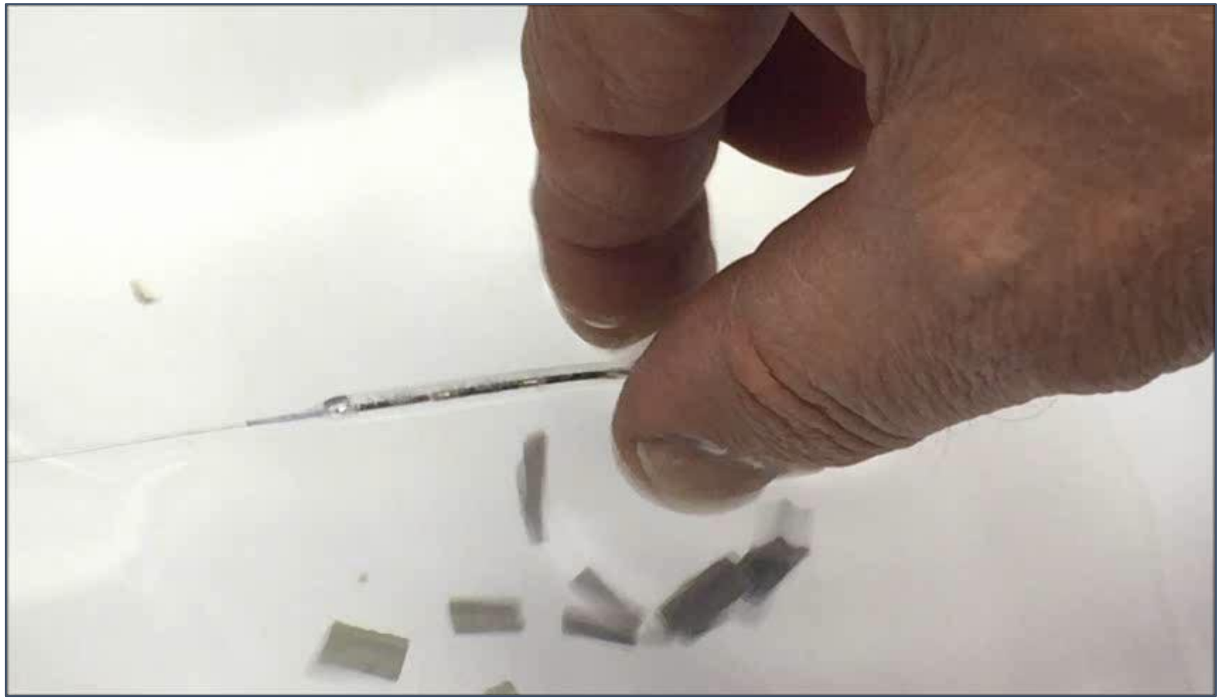
IVL Designed to Minimize Trauma While Crack Calcium

Hard on Hard



At the calcium interface, the relatively large difference in density, coupled with the concentration of multiple sonic pressure waves in a small area, produces a large dissipation of energy.

Soft on Soft



The sonic pressure waves propagate through the body with negligible dissipation of energy (and therefore damage) owing to the minimal difference in density of the soft tissues.

Action animation

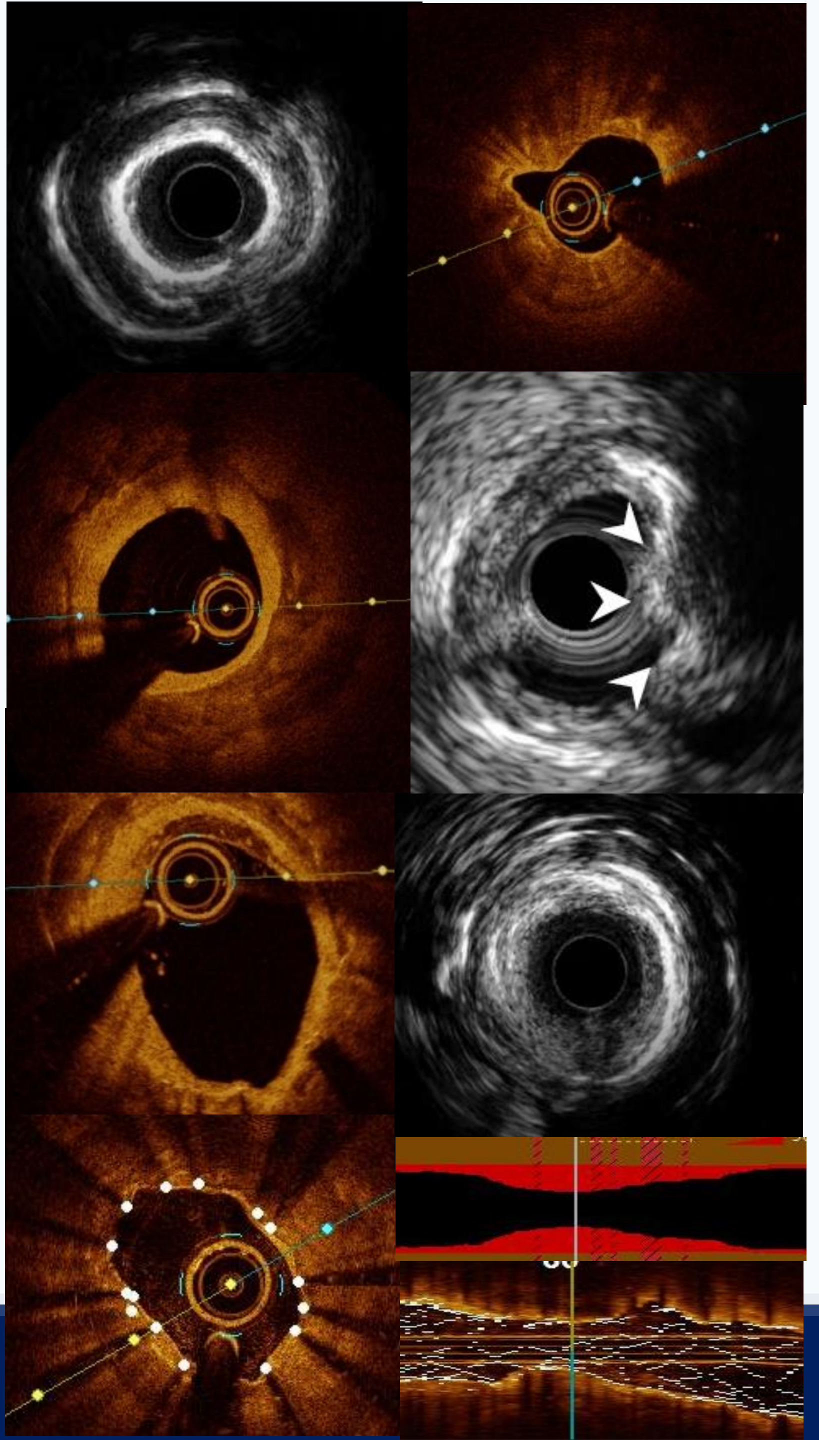
Action animation

Uses of Shockwave in CAD

- Calcified de novo stenosis
  - Concentric Ca
  - Eccentric Ca

- Balloon + Shockwave
- Atherectomy + Shockwave

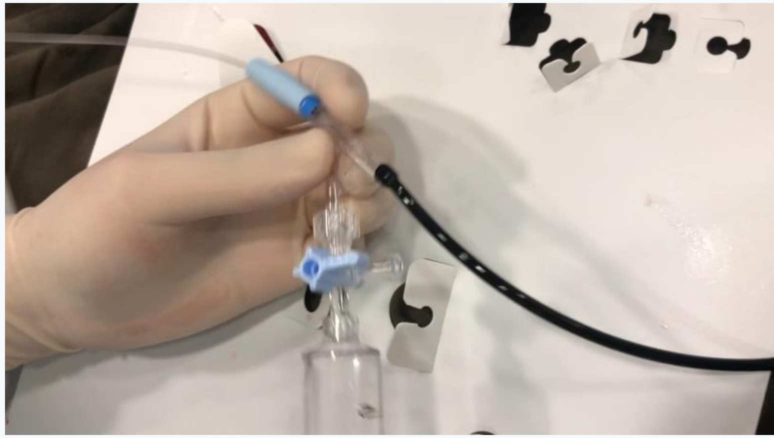
- In-stent restenosis (ISR)
  - In-stent calcified plaque
  - Stent under-expansion (Extrinsic calcification)



Procedure Step by Step

- Guiding catheter and workhose guide wire in place +/- Imaging

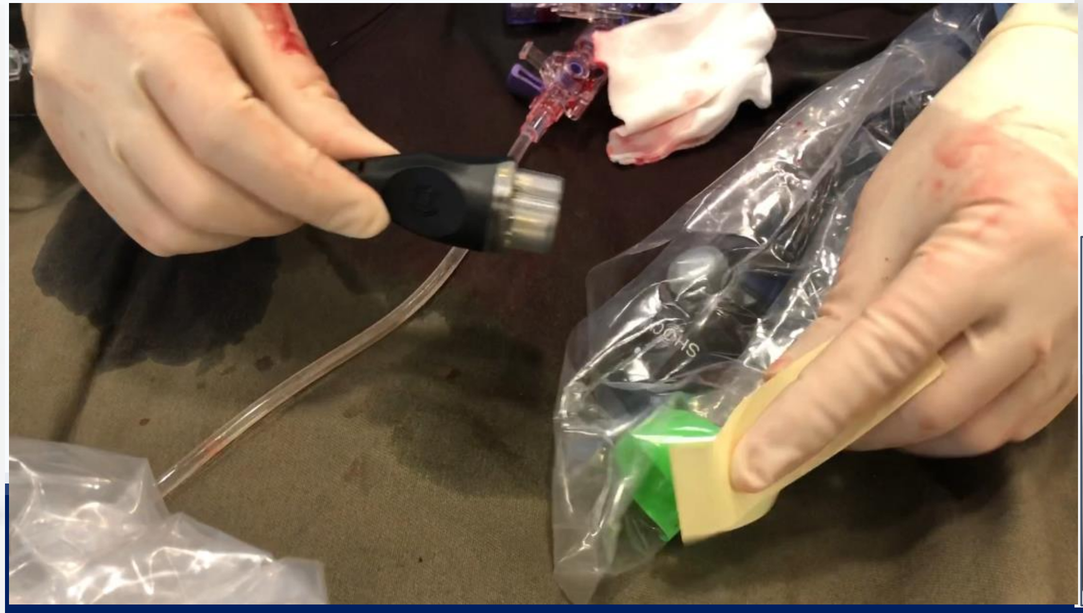
-Good Guiding support essential (Use of 6Fr Guide extension or Buddy wire ok)



- Prepare the shockwave balloon

-Use of 3-way to minimize air bubble. You need fluid to generate the sonic waves. So air bubbles will reduce efficacy

-Connect the balloon catheter to the IVL handle



Procedure Step by Step

- Position the balloon at site intended. Inflate the balloon at 4 atm

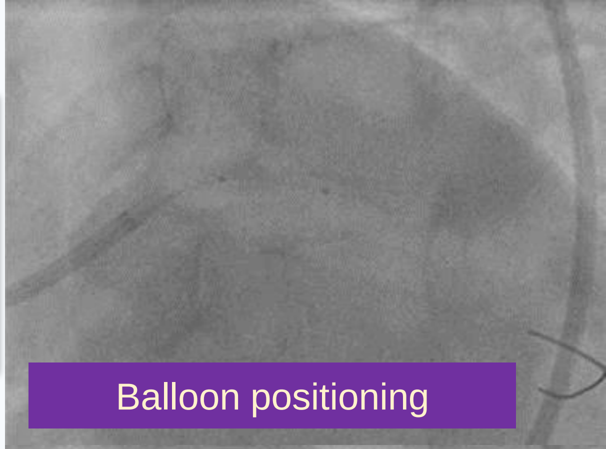
-Use of stent boost to visualize calcium (with balloon markers in-situ)

- Press the button. 10 seconds per cycle. Maximum 8 cycles per balloon

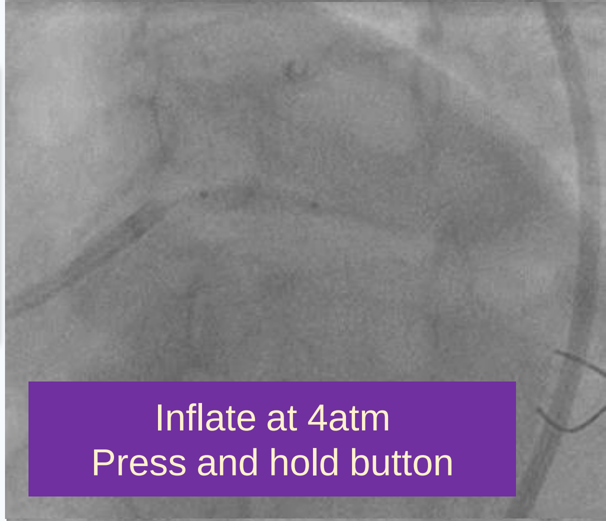
-Shockwave delivered as pulses. Pacing capture expected

-Continue to step on fluoroscopy and watch the pressure on indeflator to detect any balloon rupture. Immediately stop shockwave pulse and deflate the balloon if balloon rupture suspected

- Inflate the balloon to 6 atm and deflate



Balloon positioning



Inflate at 4atm
Press and hold button

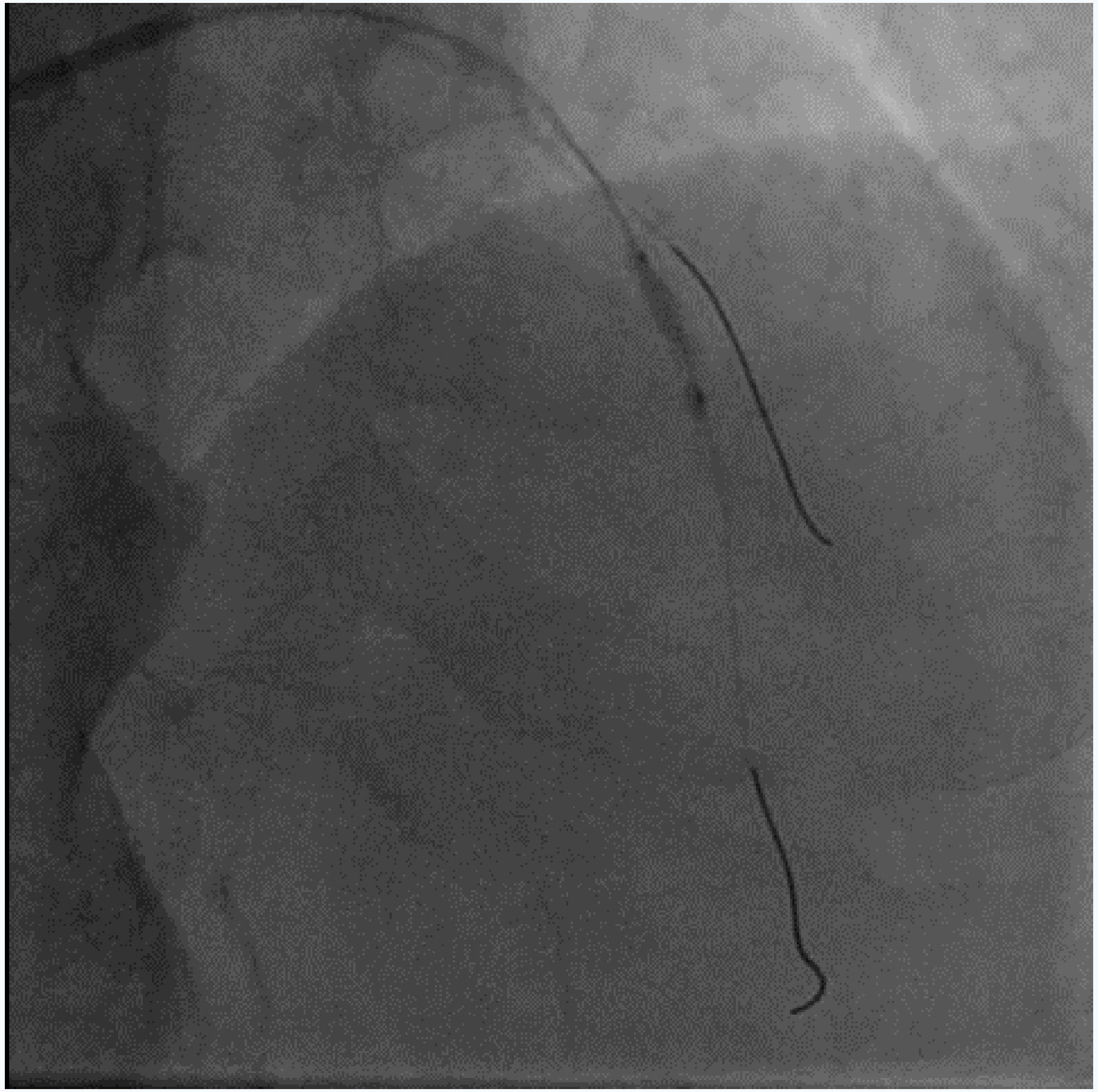
Inflate to 6atm and down

Procedure Step by Step

- Press the button. 10 seconds per cycle. Maximum 8 cycles per balloon

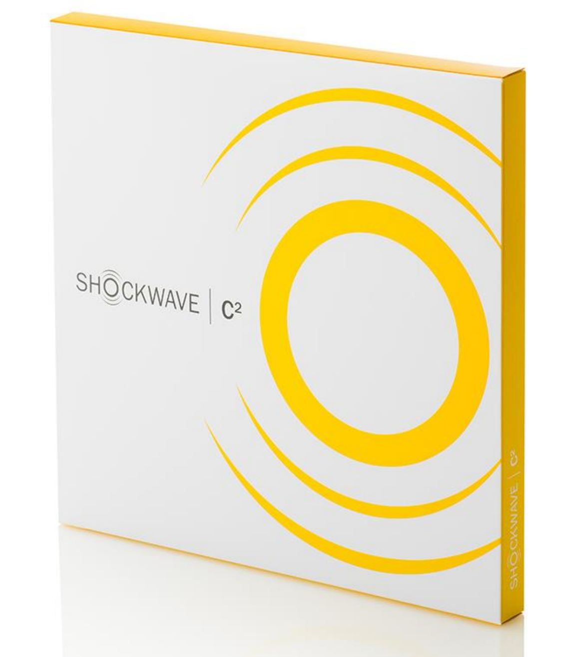
-Shockwave delivered as pulses. Pacing capture expected

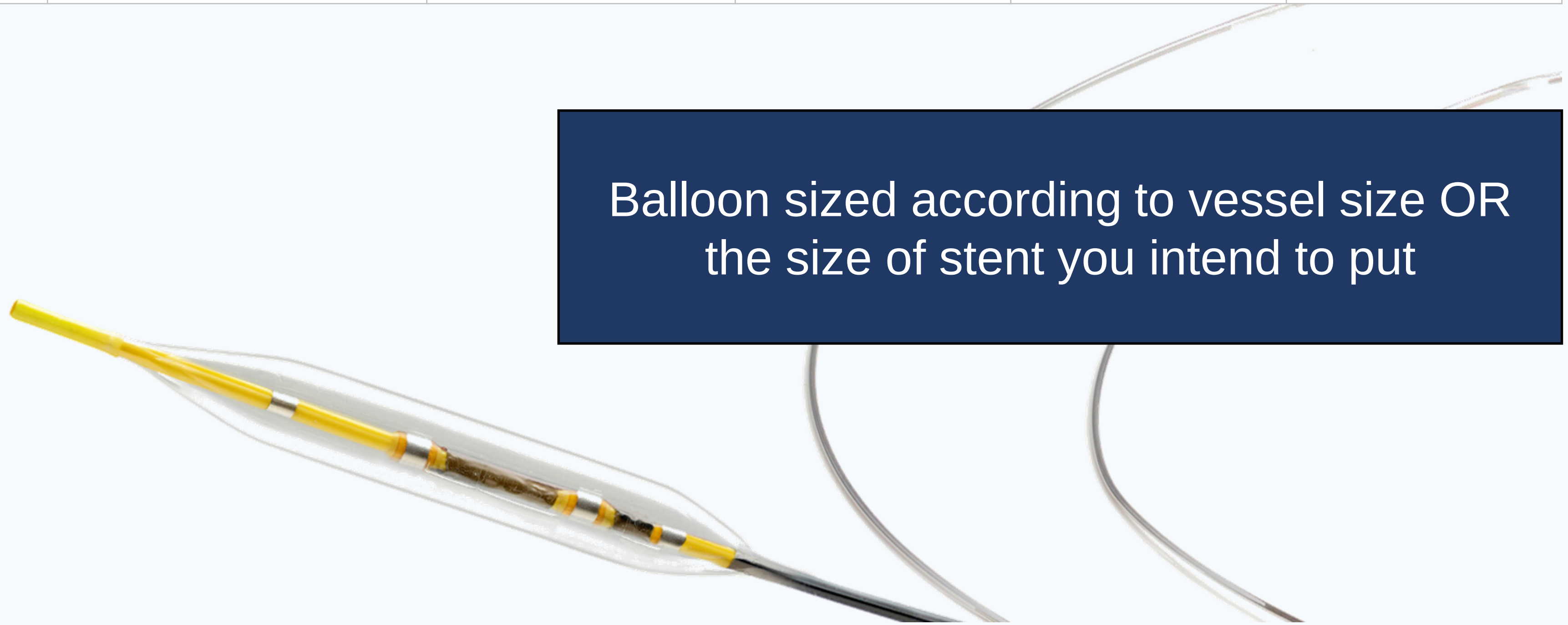
-Continue to step on fluoroscopy and watch the pressure on indeflator to detect any balloon rupture. Immediately stop shockwave pulse and deflate the balloon if balloon rupture suspected



Shockwave C^2 IVL Catheter Specs

Diameter (mm)	Length (mm)	Max Pulse Count	Guidewire Compatibility (in)	Guide Catheter Compatibility	Working Length (cm)	Tip Profile (in)*	Crossing Profile (in)*
2.5	12	80	0.014	6F	138	0.023	0.042
3.0	12	80	0.014	6F	138	0.023	0.042
3.5	12	80	0.014	6F	138	0.023	0.042
4.0	12	80	0.014	6F	138	0.023	0.042

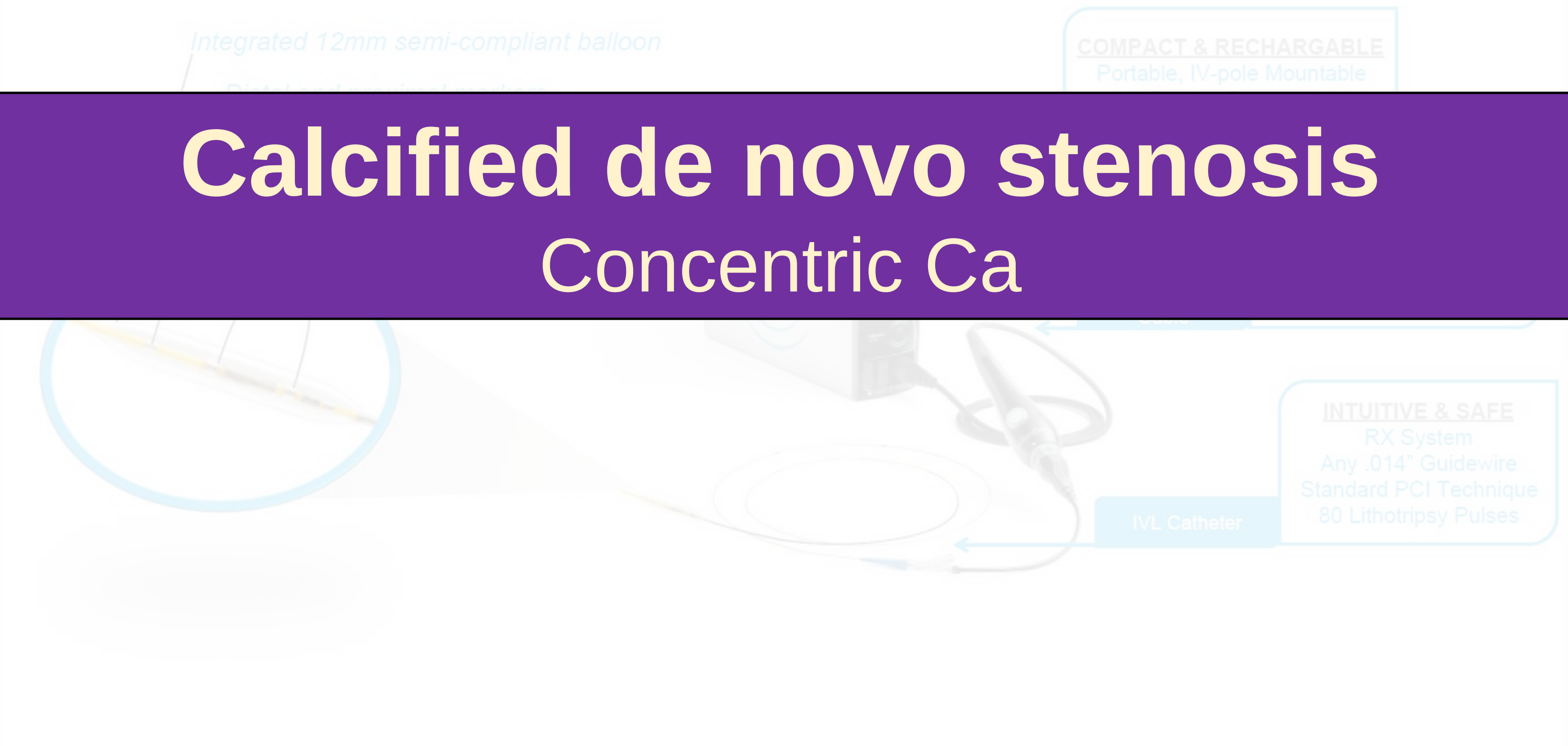




Balloon sized according to vessel size OR the size of stent you intend to put

* ±0.001-in

Shockwave Lithotripsy in CAD



Calcified de novo stenosis

Concentric Ca

Case History

- Demographics and Hx

76/F

Hypertension and Hyperlipidemia

- HPI

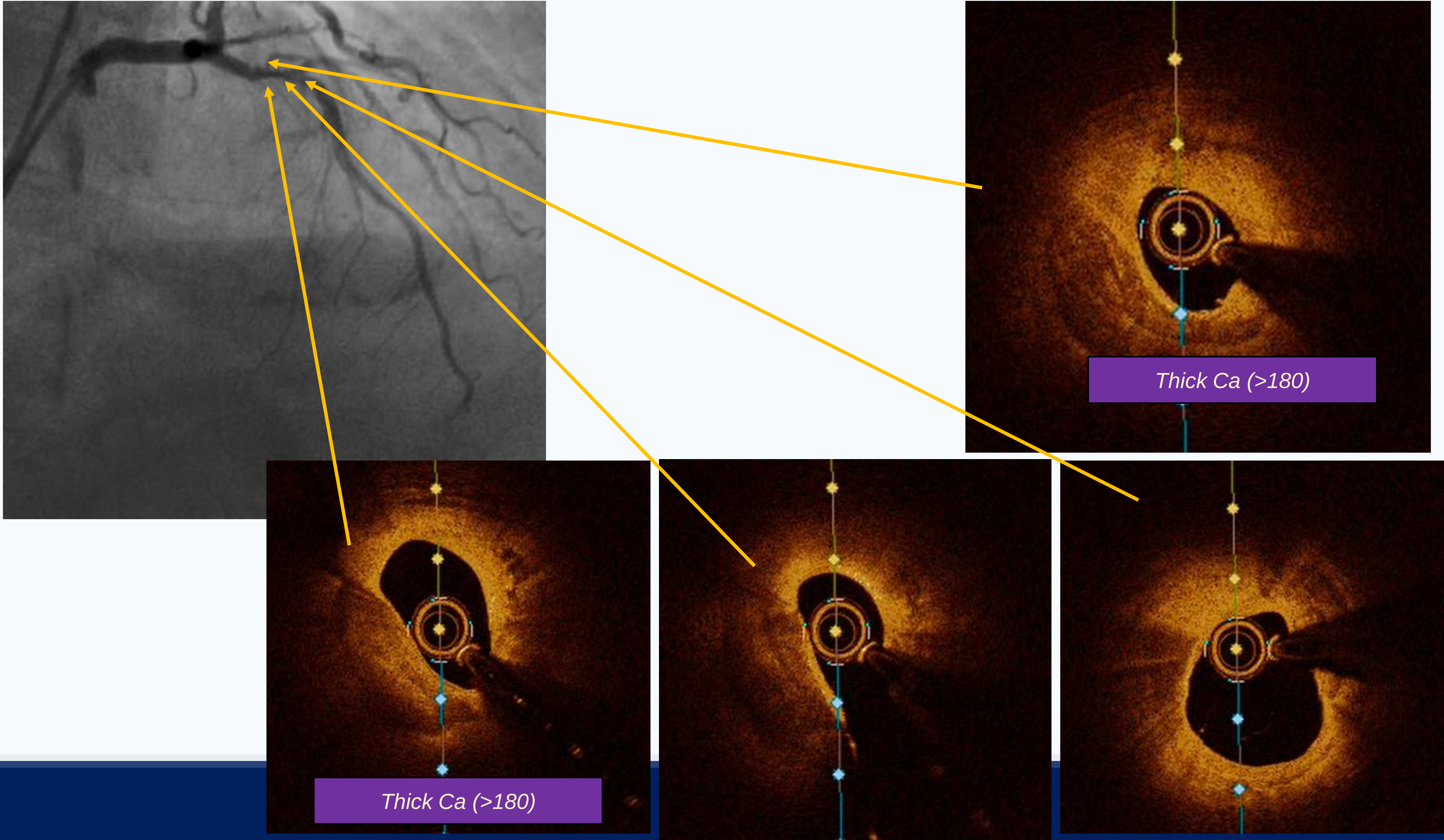
Angina, CCS II

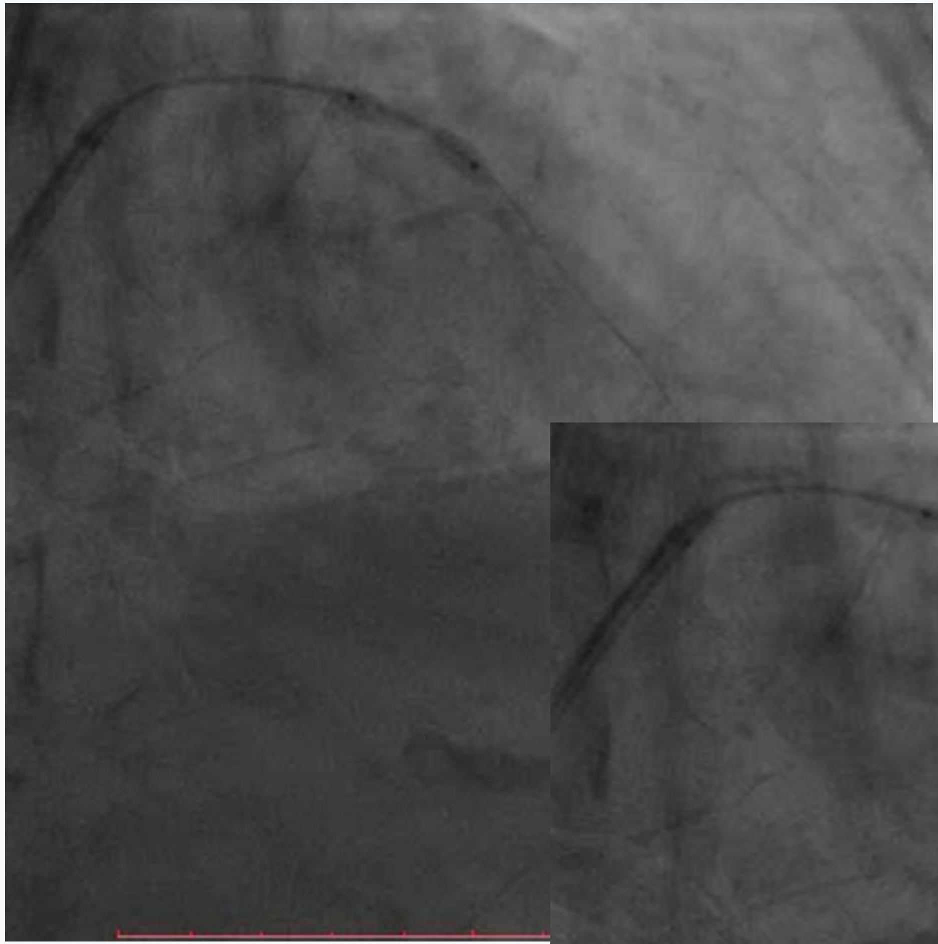
MRI: LAD ischemia+

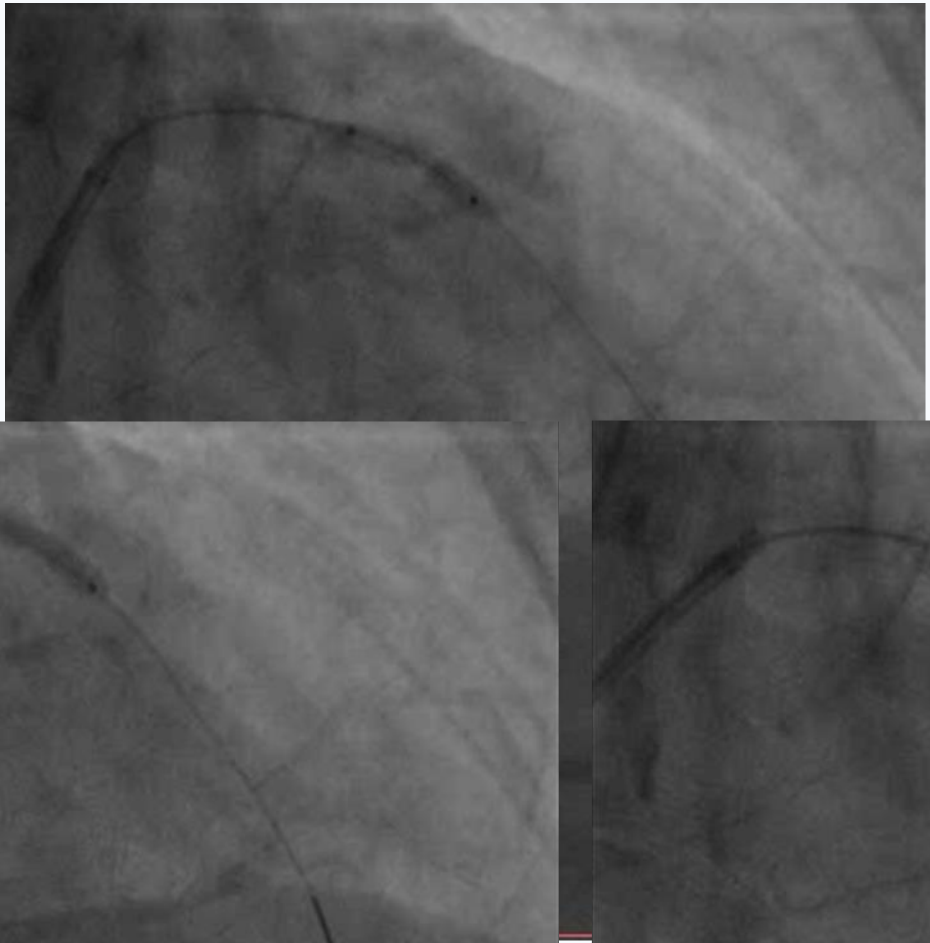
- Plan

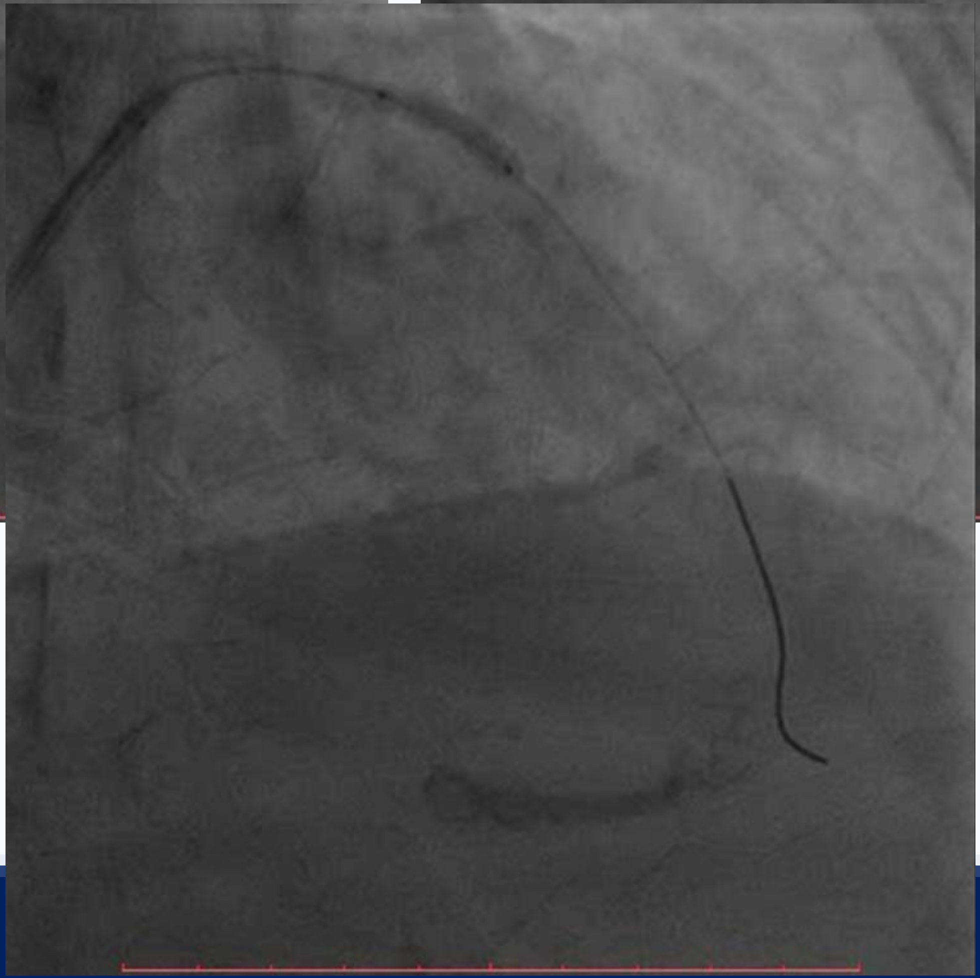
PCI to LAD

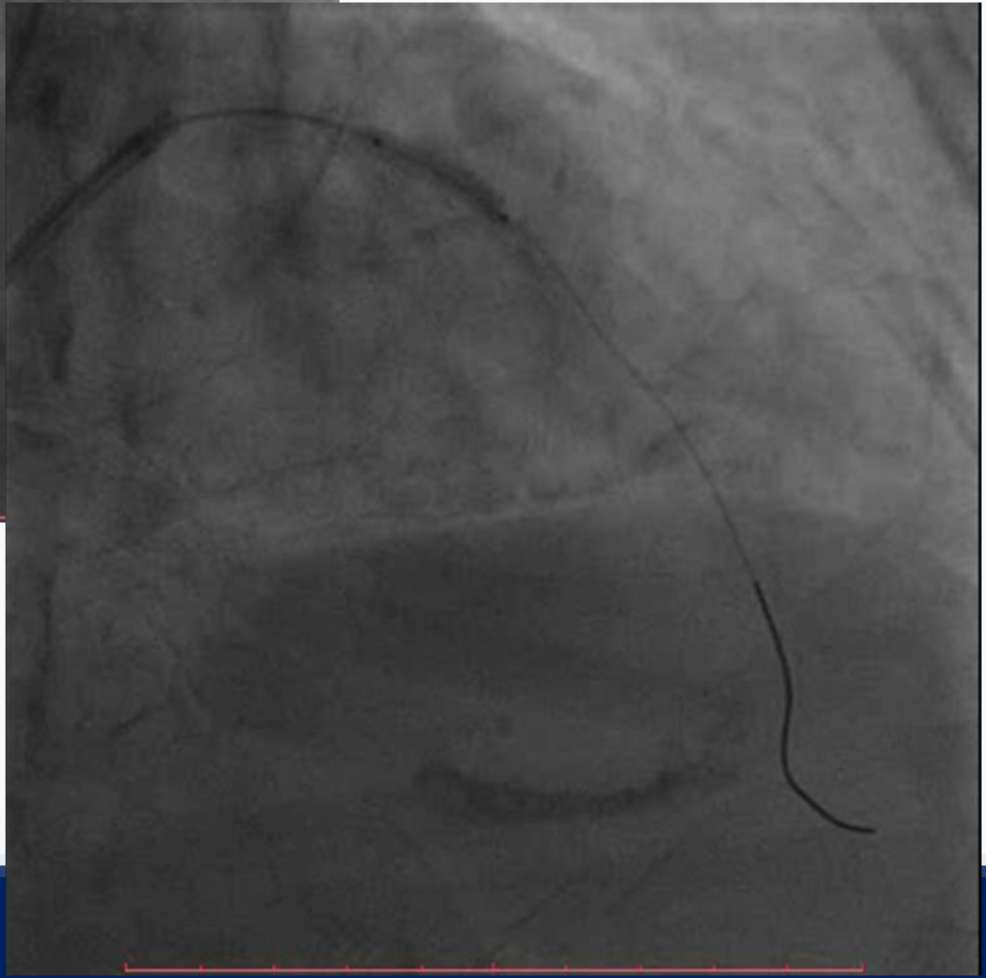

OCT


Thick Ca (>180)
Thick Ca (>180)

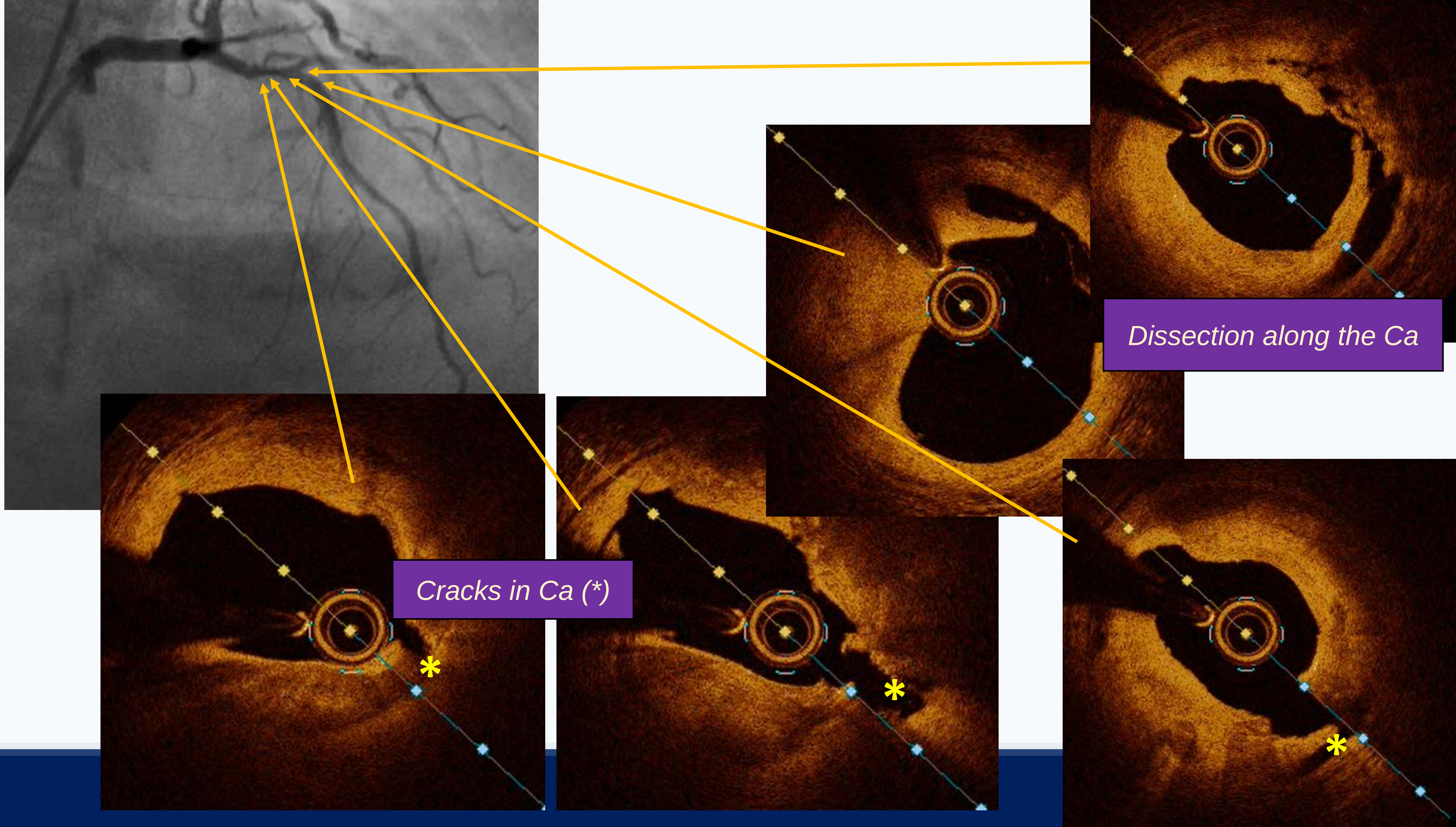


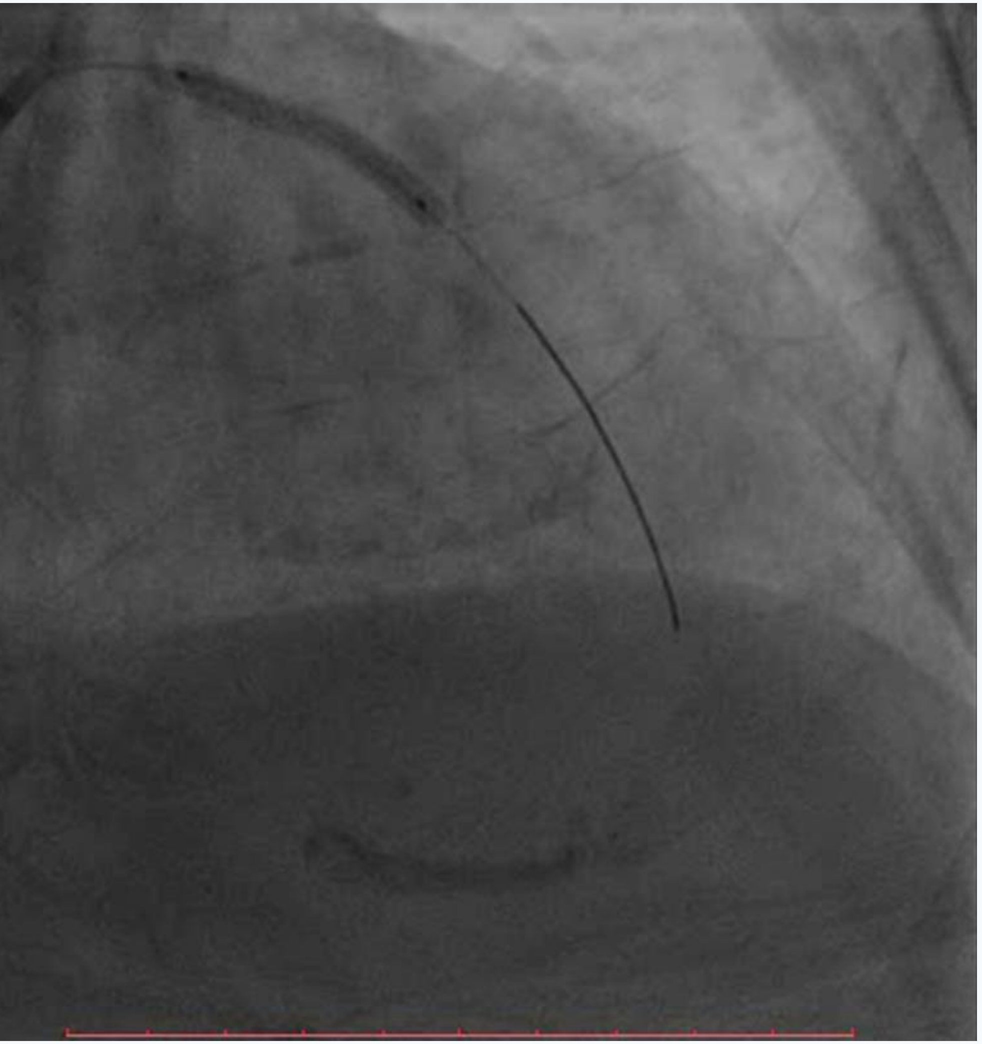


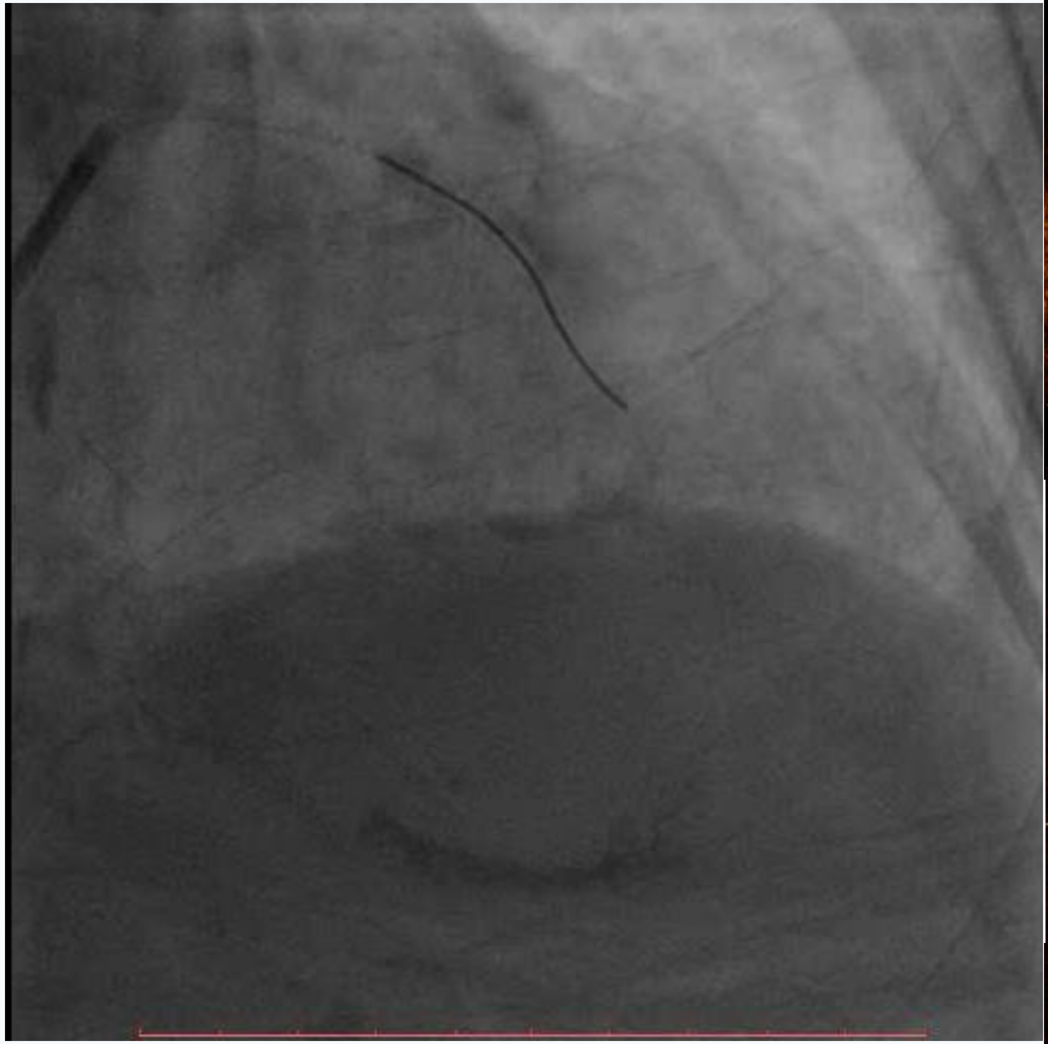


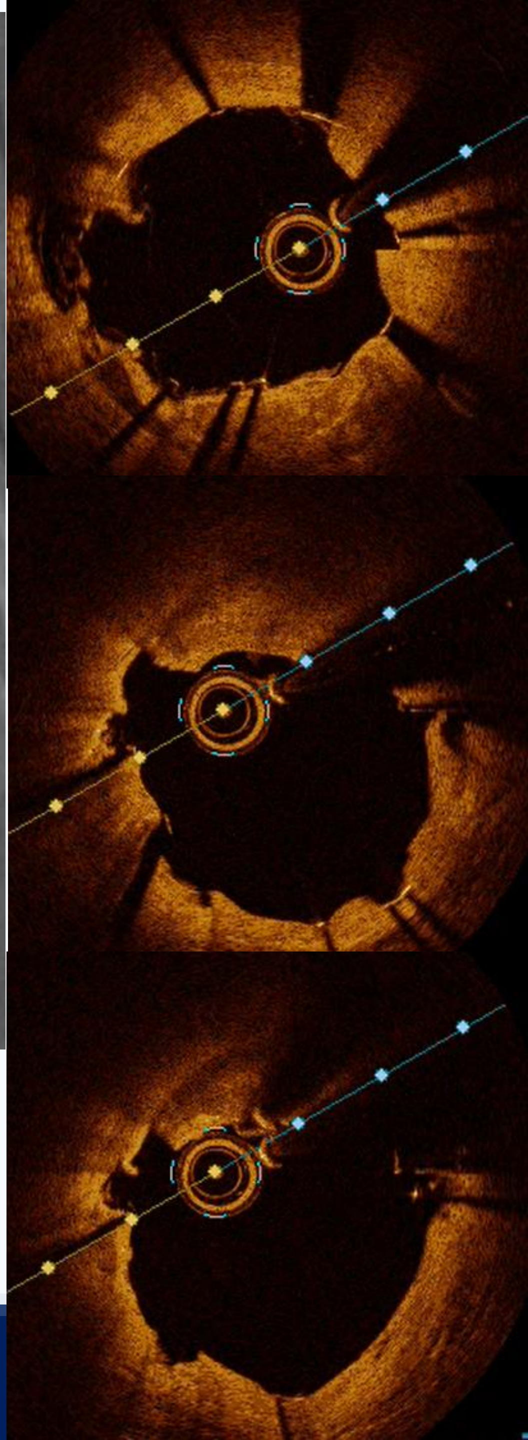


Shockwave lithotripsy
3.0 at 4 atm
10s cycle x 6


Dissection along the Ca
Cracks in Ca (*)
*
*
*







DES 3.0/33, NC 3.0 and NC 3.5

Shockwave Lithotripsy in CAD

Calcified de novo stenosis

Eccentric Ca

Case History

- Demographics and Hx

63/M

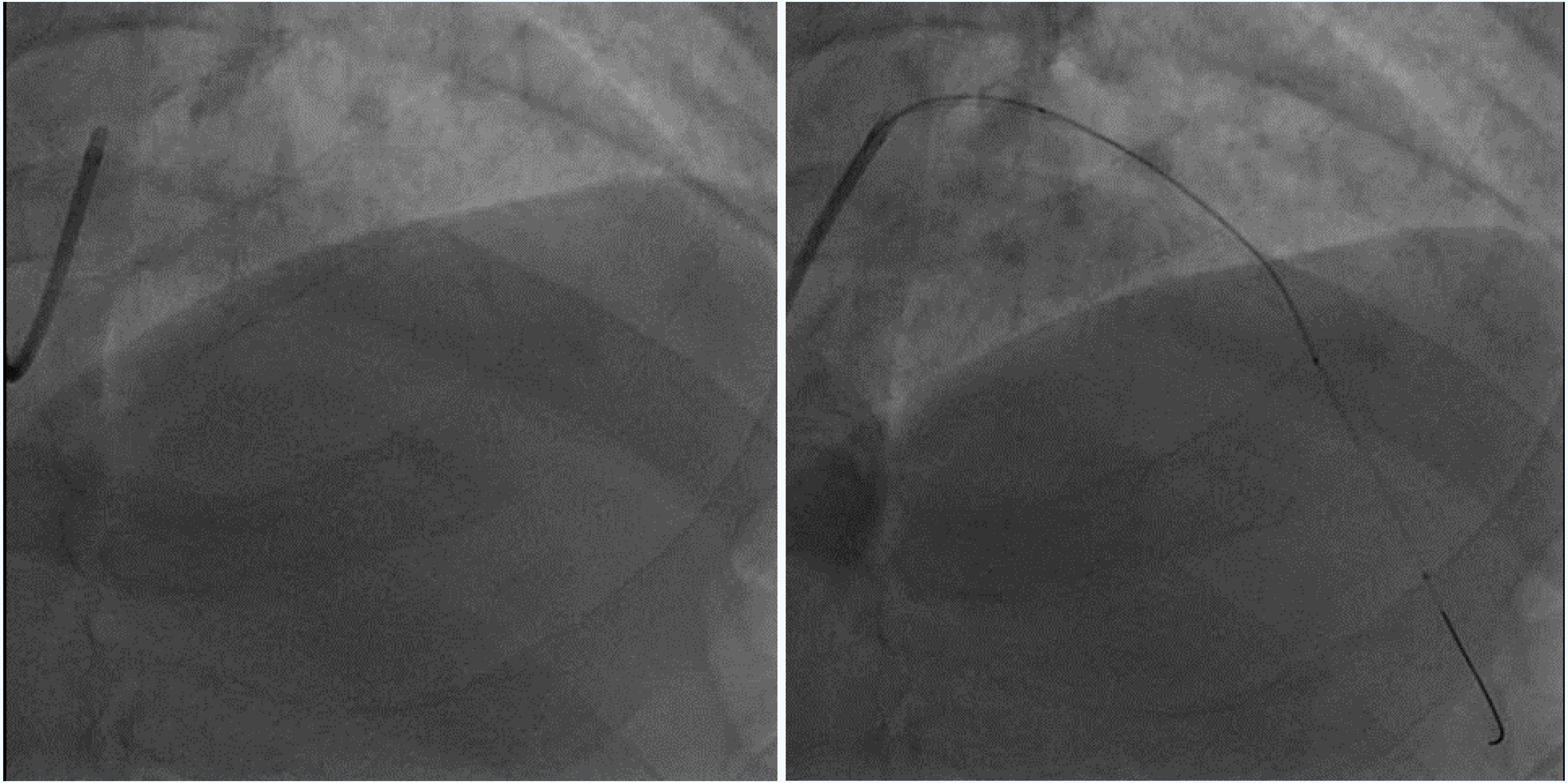
Diabetes, Atrial fibrillation

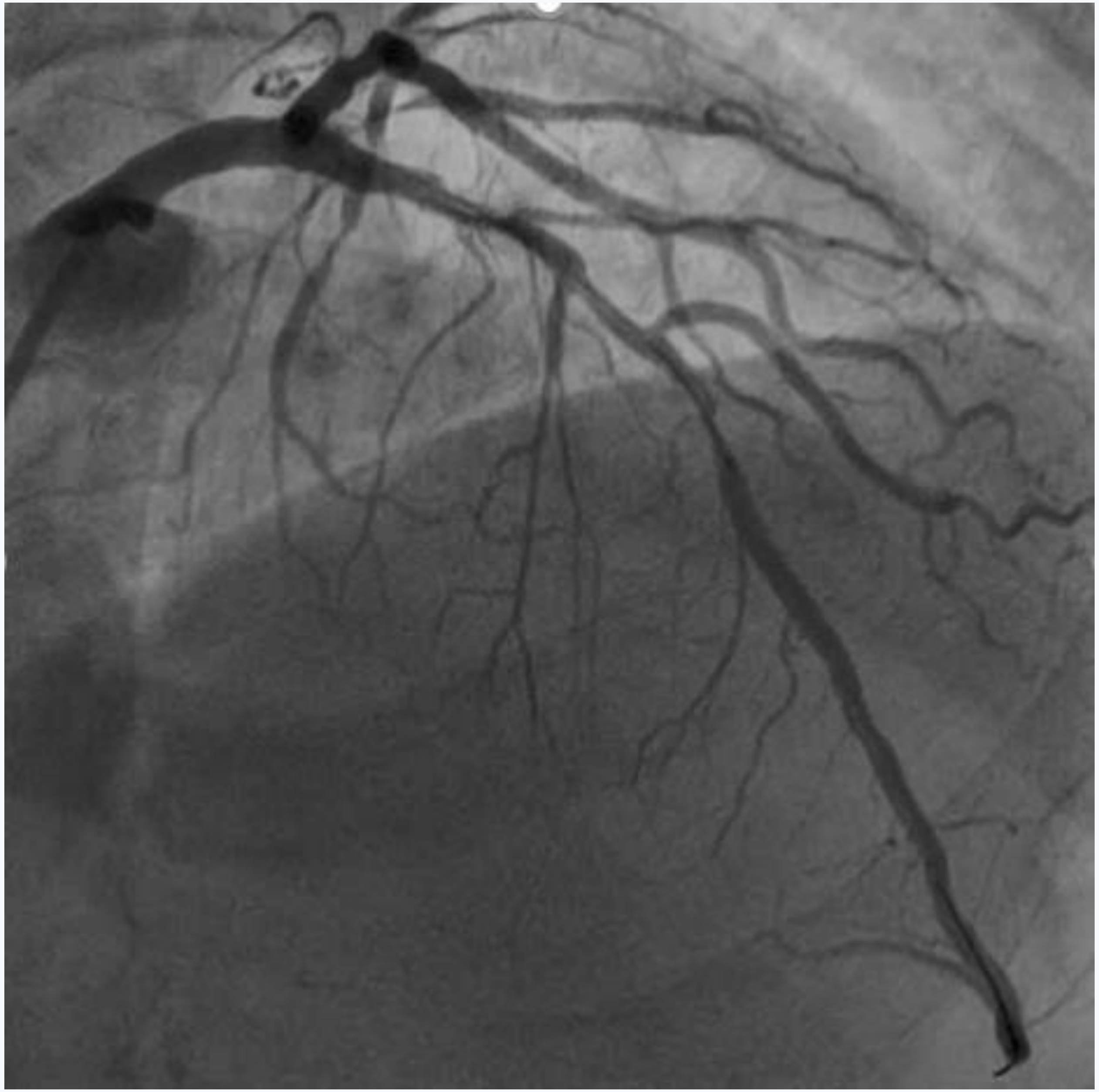
- HPI

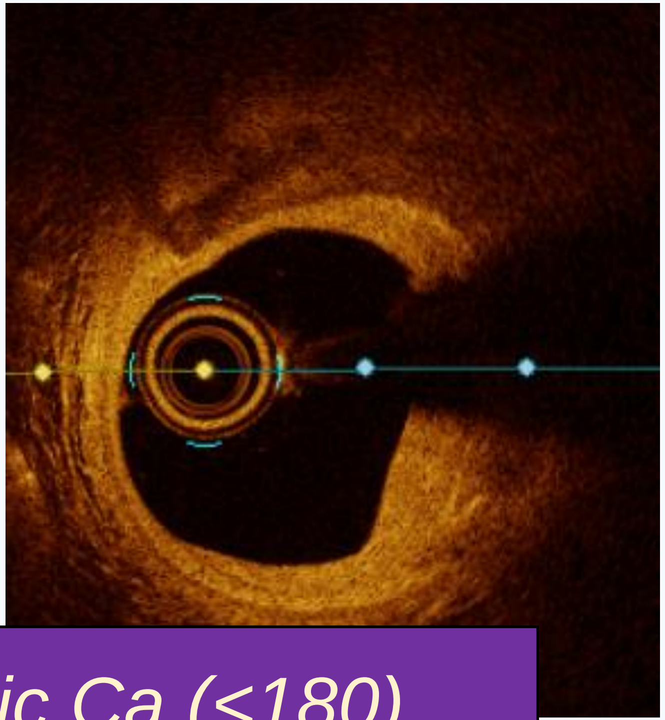
Angina, CCS II

- Plan

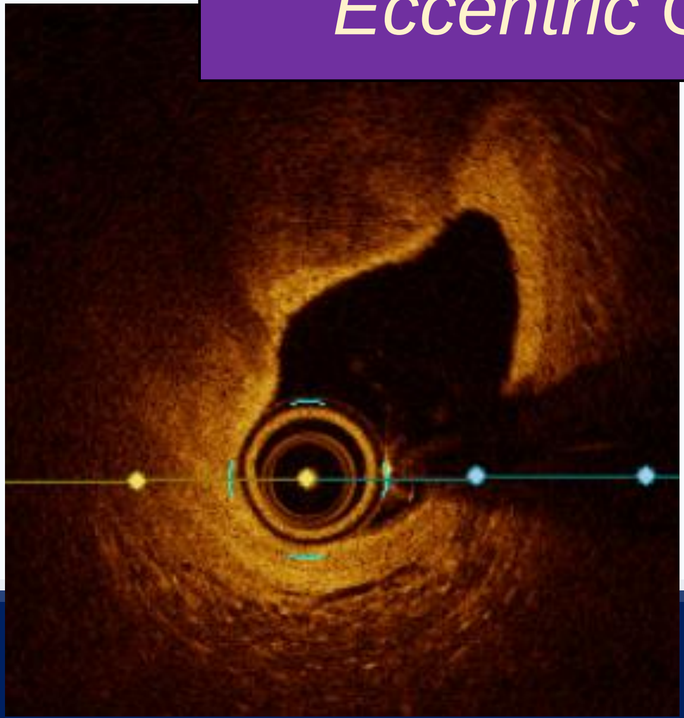
LAD stenosis, PCI to LAD

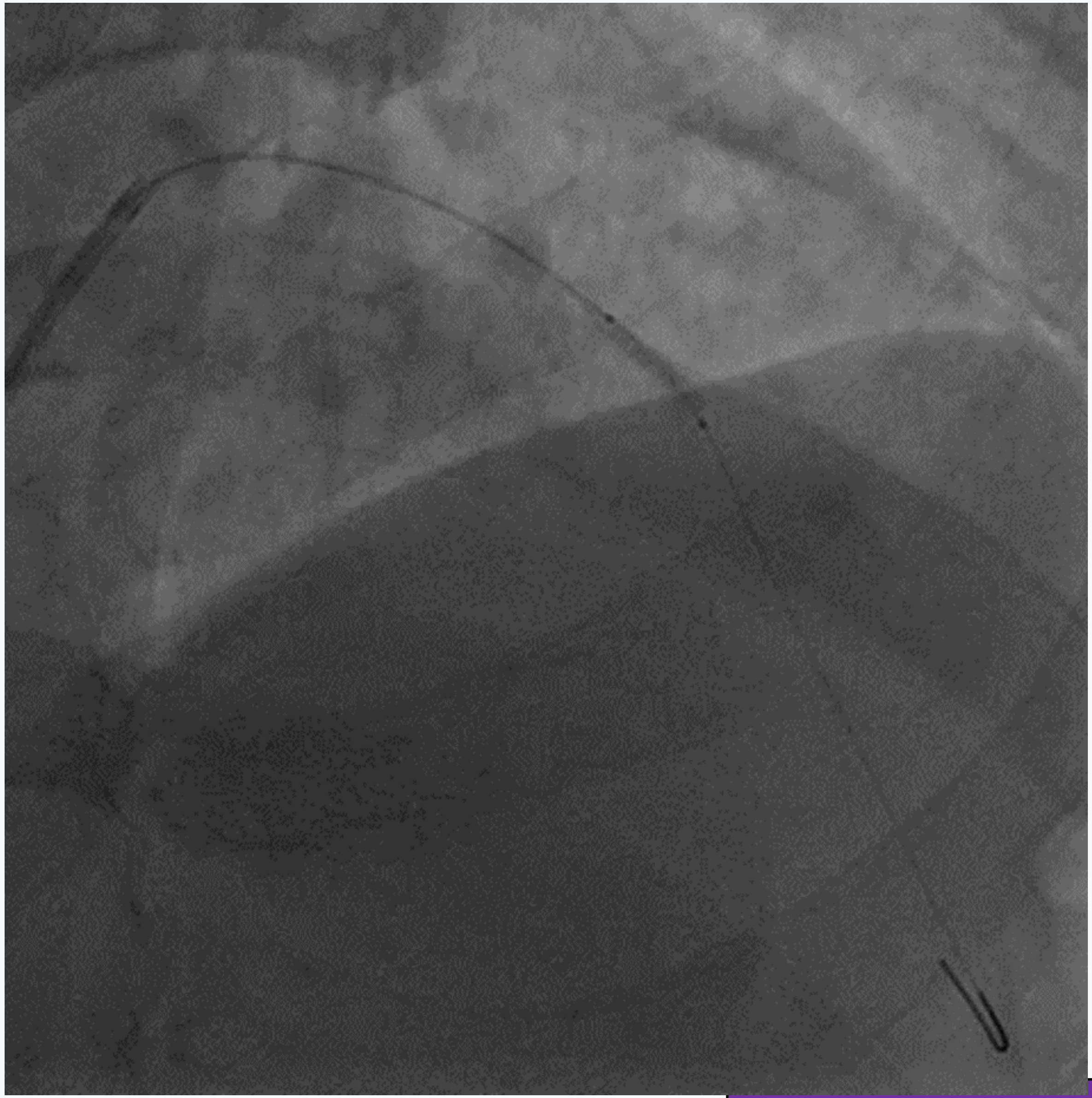


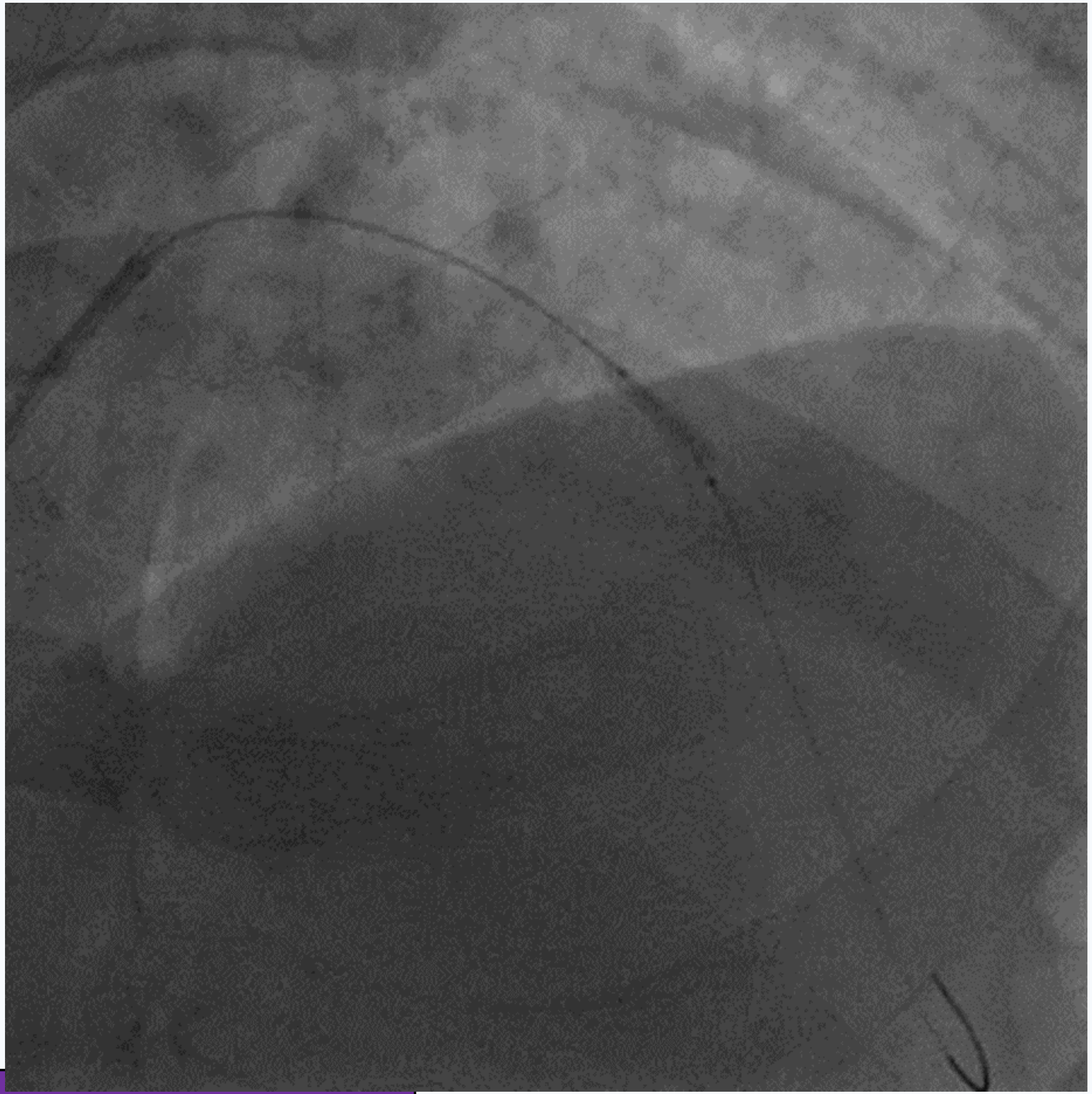




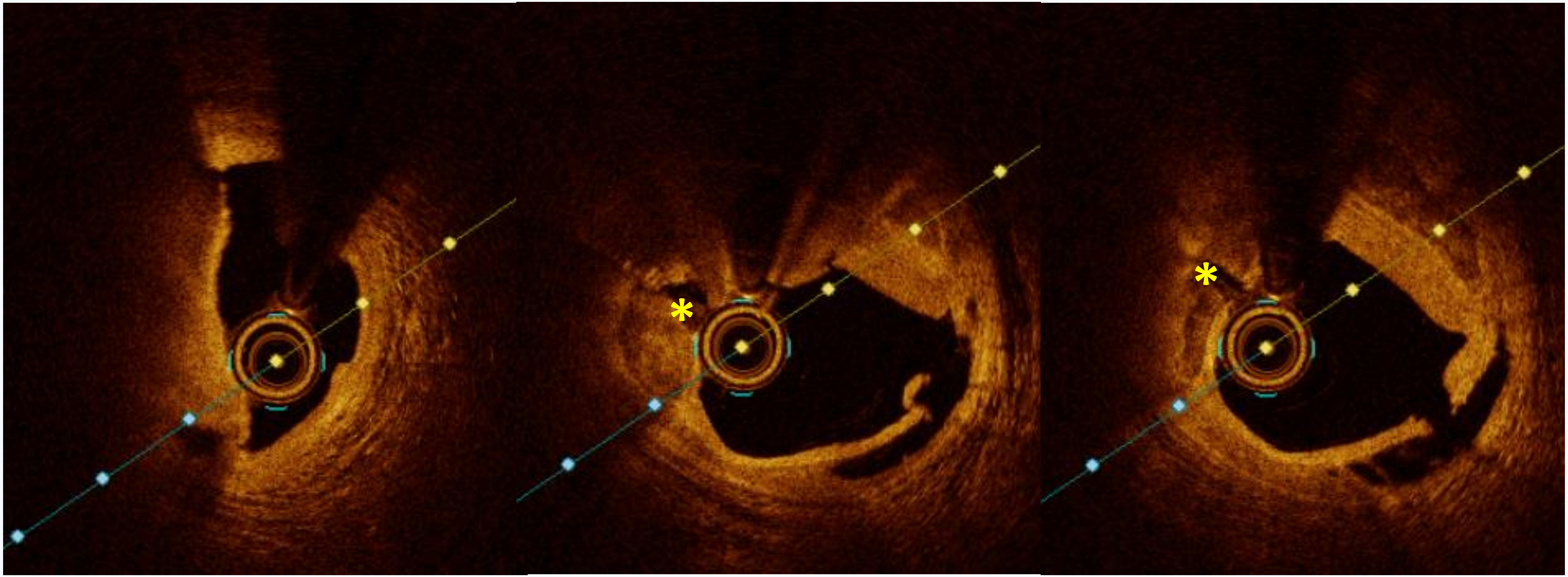
Eccentric Ca (<180)





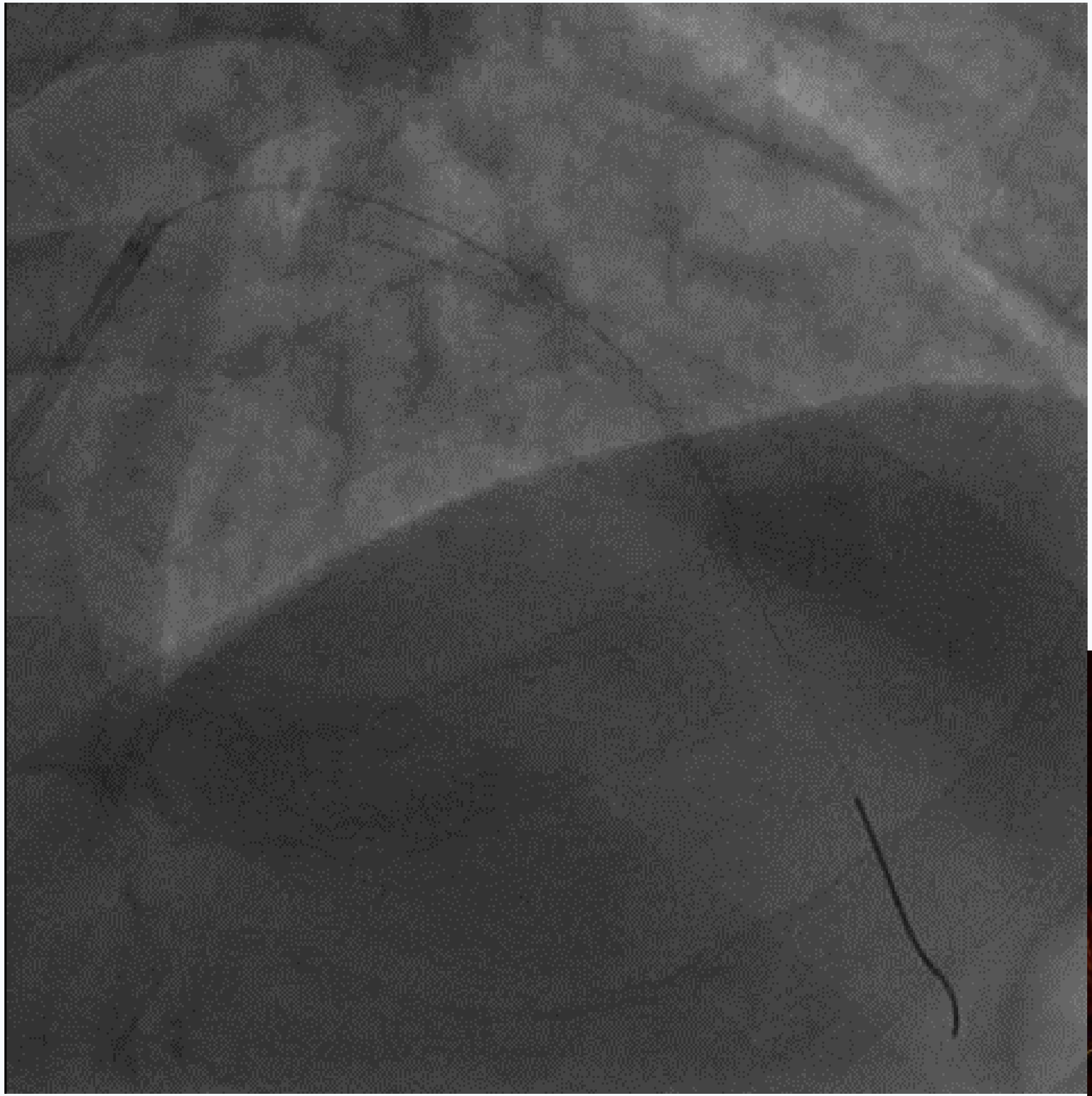


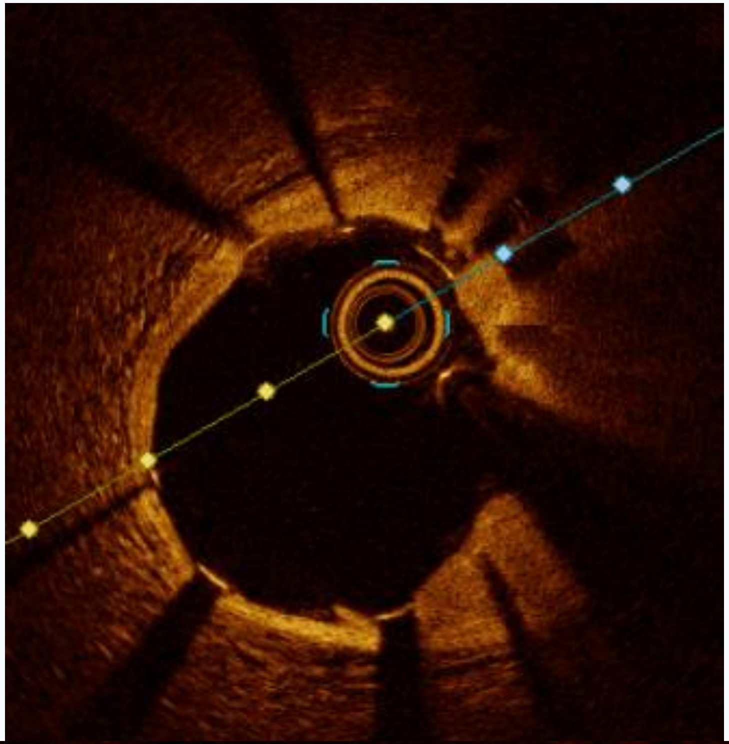
Shockwave 2.5 at 4 atm
10s cycle x 6

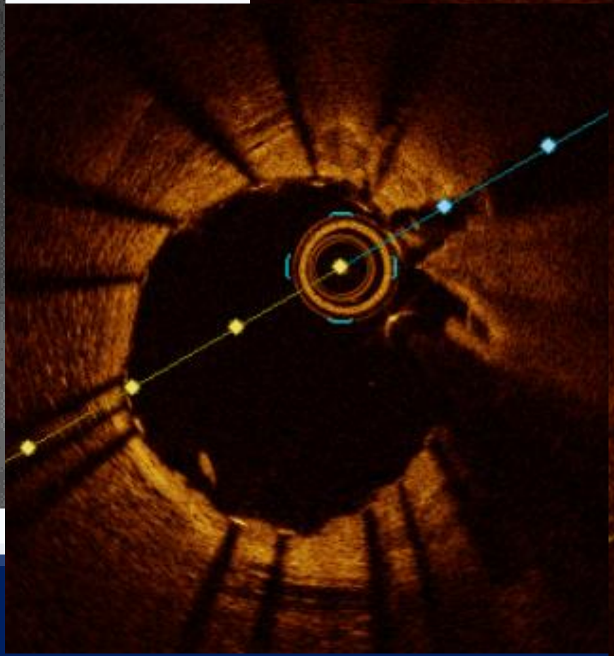


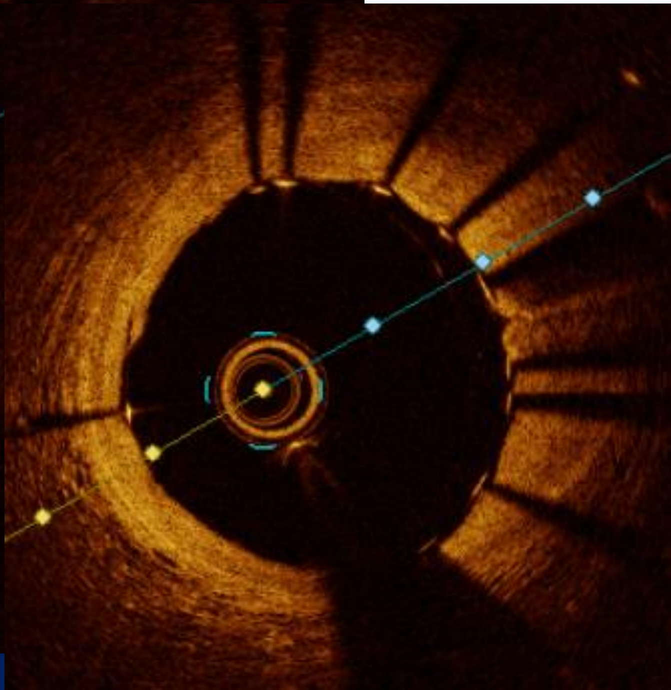
Dissection along the Ca

Cracks in Ca (*)



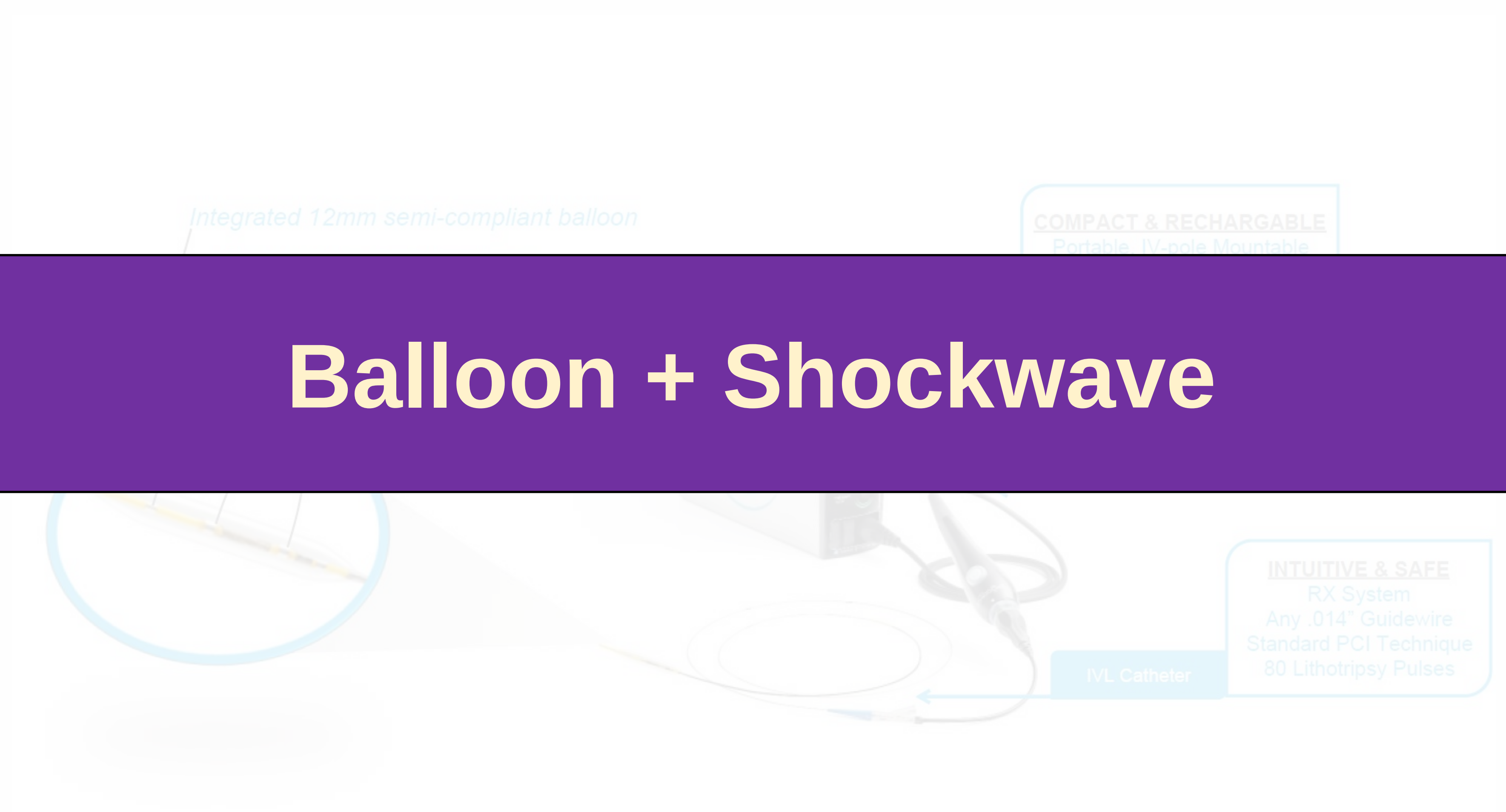






DES 2.5/33 + 3.5/18, NC 3.5, NC 4.0

Shockwave Lithotripsy in CAD



Balloon + Shockwave

Case History

- Demographics and Hx

85/F

Diabetes, Hypertension

- HPI

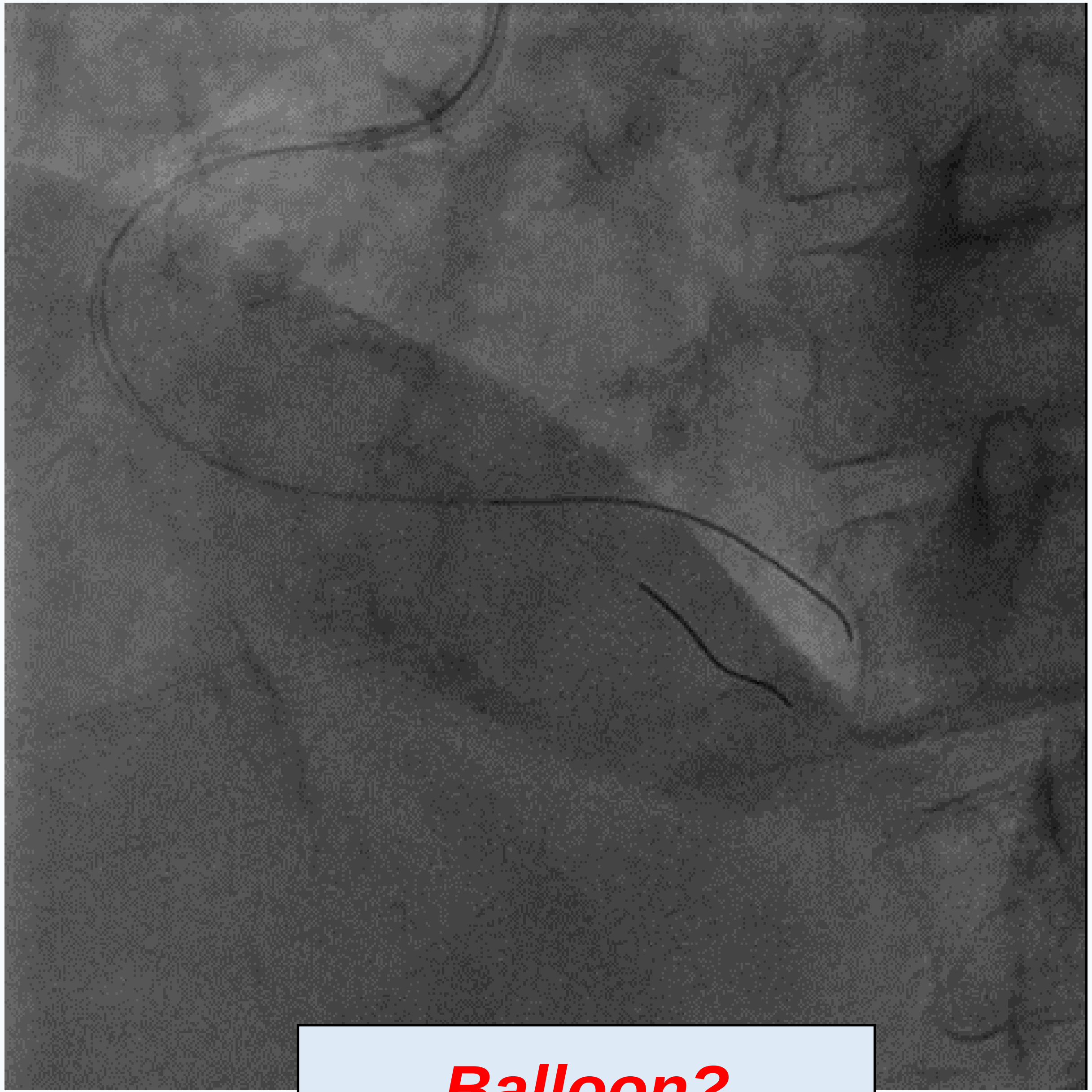
Acute NSTEMI

- Plan

RCA 95% stenosis, LAD 80%, LCX 80%

PCI to RCA and LAD

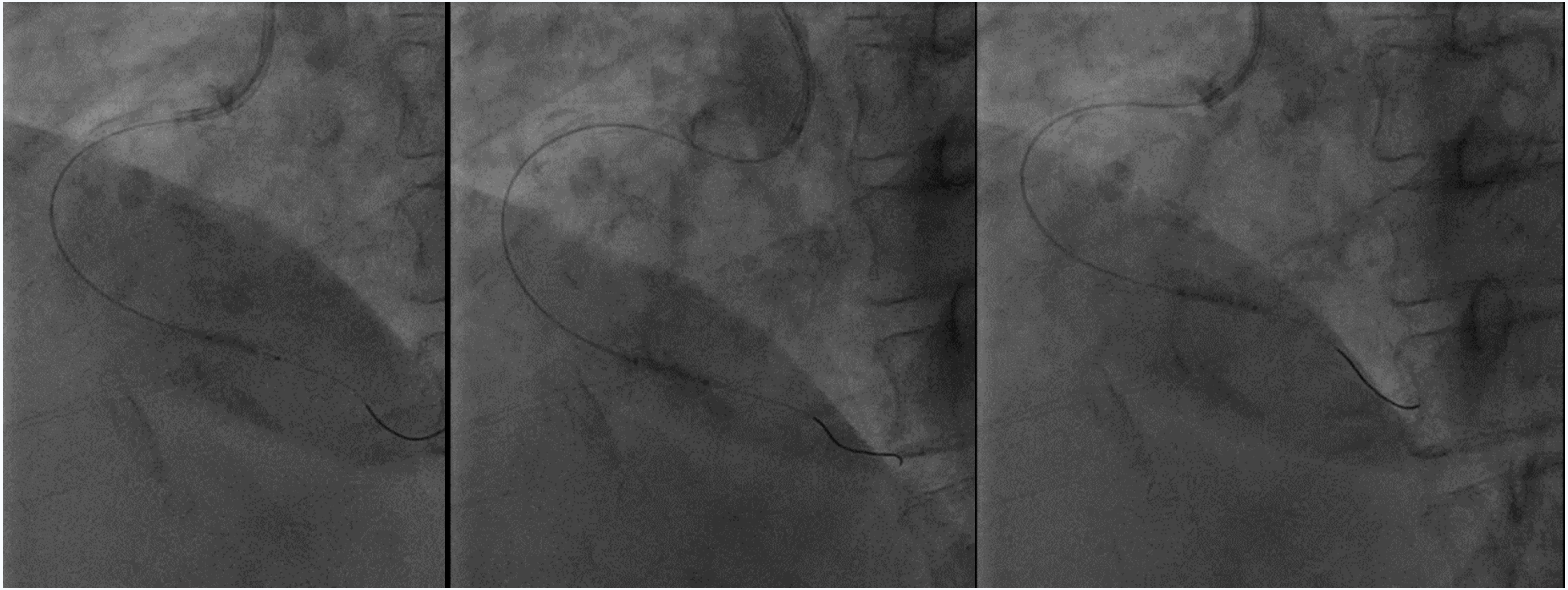
Ucooperative patient



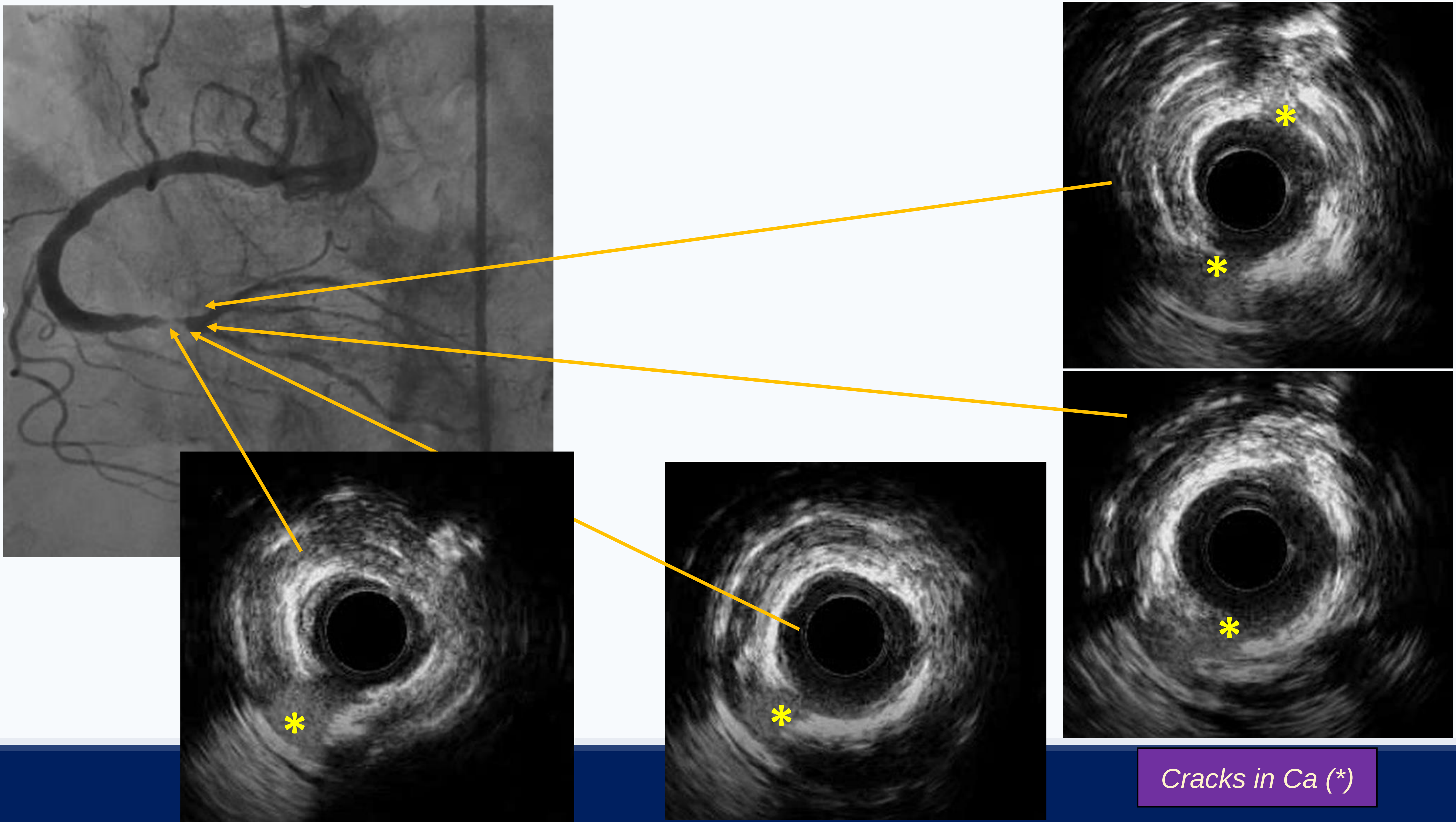
Tight and calcified stenosis
Unable to pass via IVUS catheter

Balloon?
Rotablation?

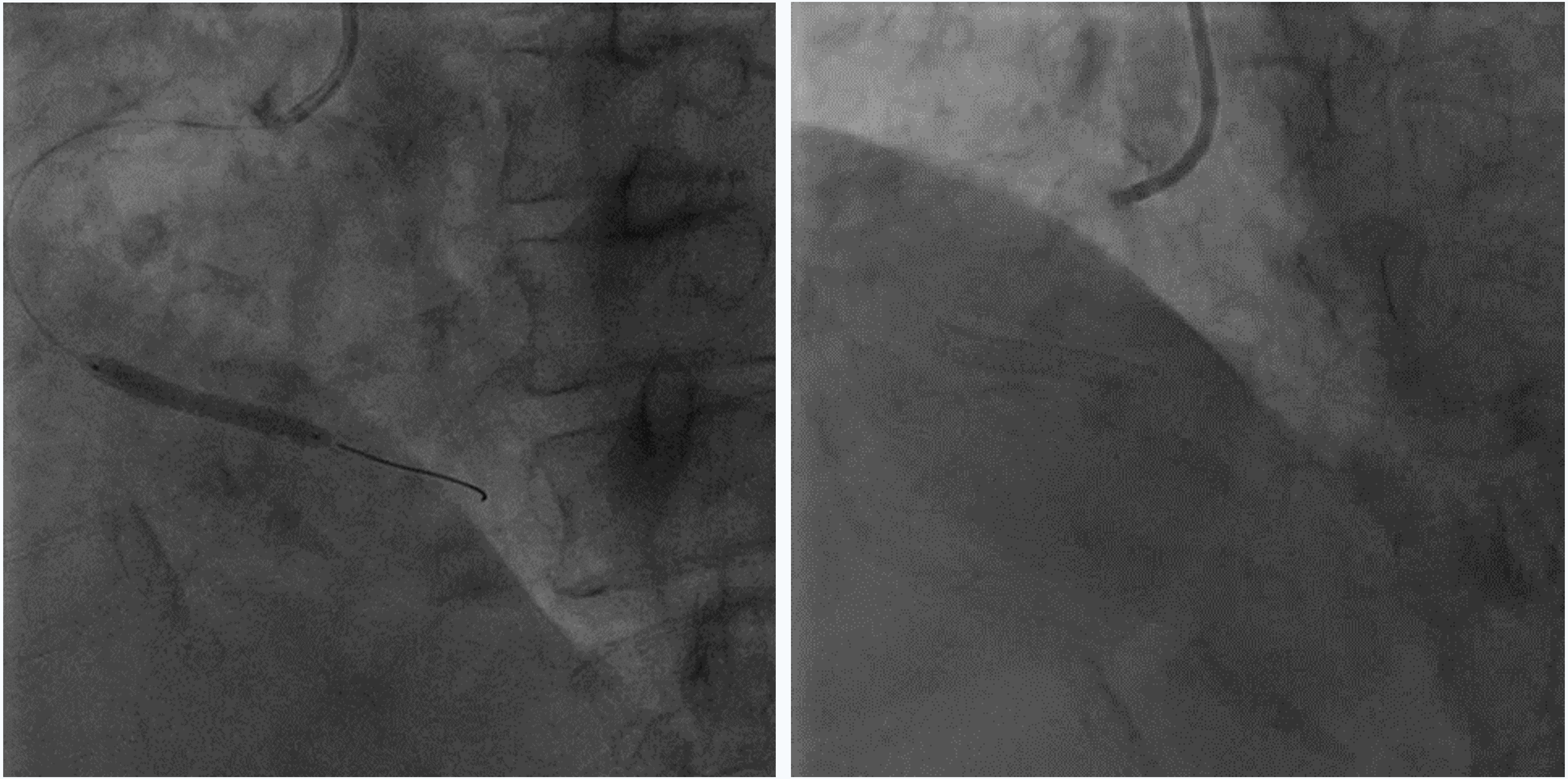
Pass via 1.5 and then NC 1.5 balloon



Shockwave 2.5 at 4 atm
10s cycle x 4



Cracks in Ca (*)



DES 3.5/28, NC 3.5

Shockwave Lithotripsy in CAD

In-stent restenosis
Stent underexpansion

Case History

- Demographics and Hx

63/M

Hyperlipidemia, Diabetes

End stage renal failure on hemodialysis

History of PCI to LAD and LCX with BMS

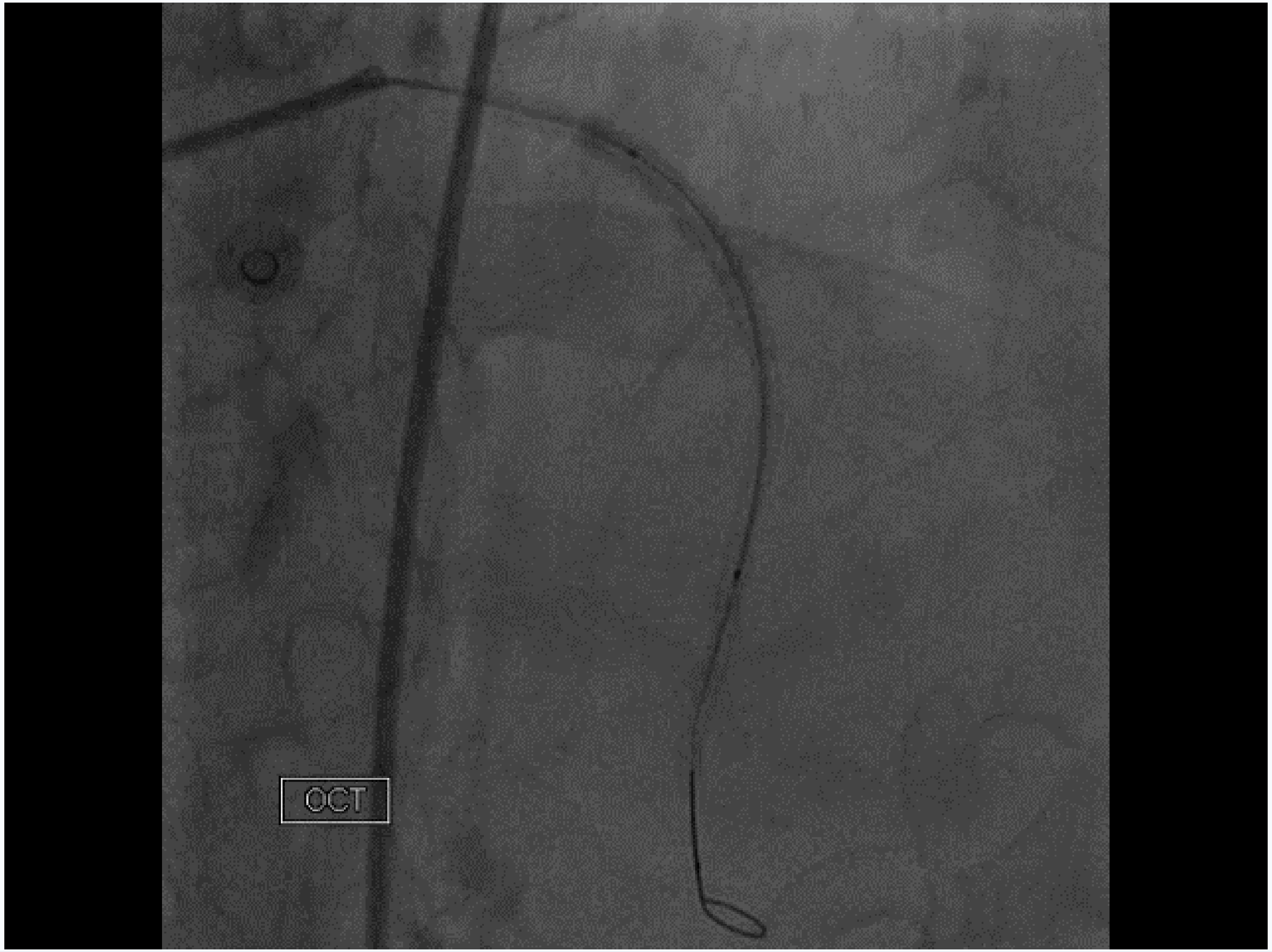
- HPI

CCS II angina, FFR to LAD : 0.74

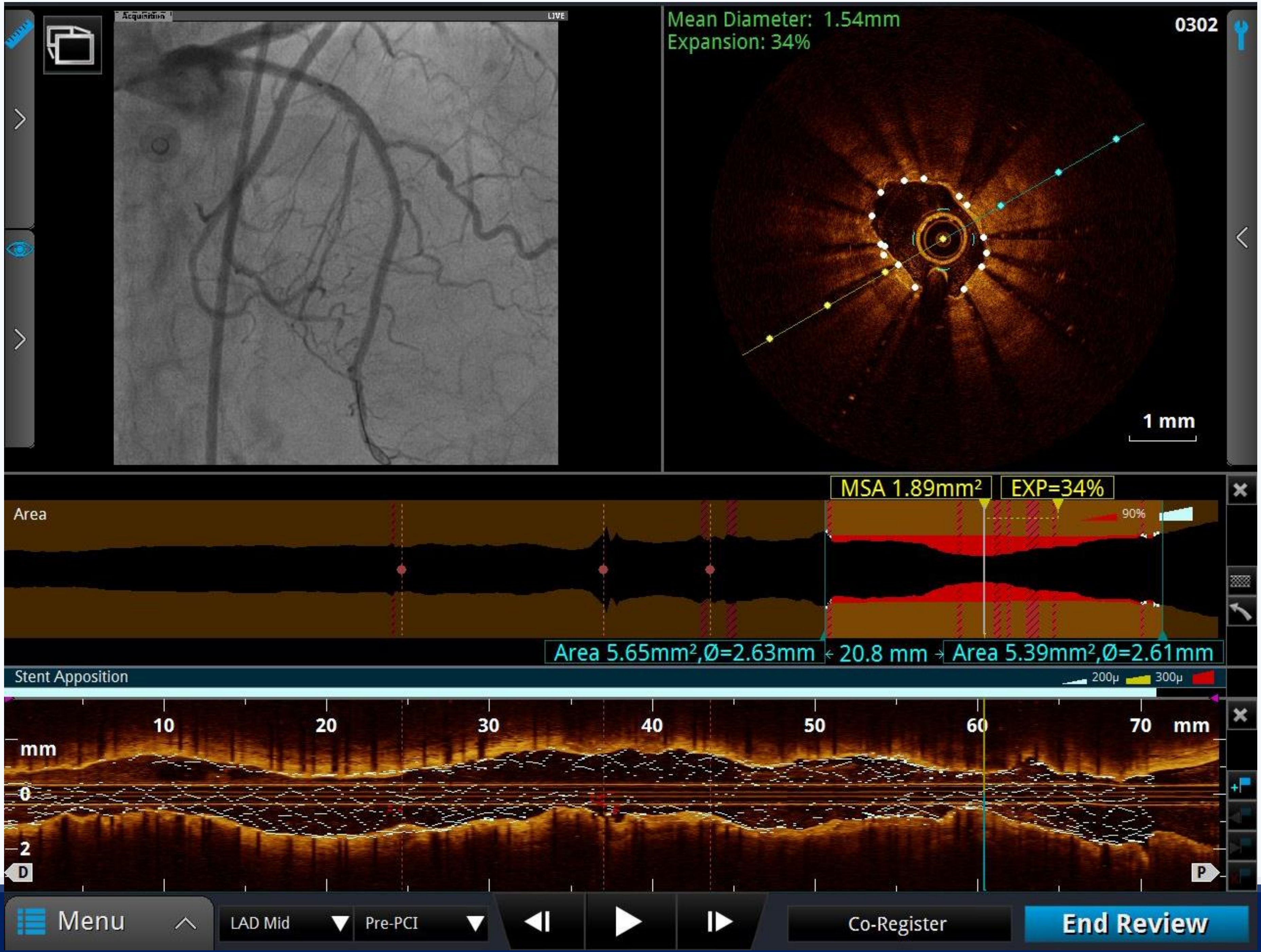
- Plan

PCI to LAD ISR

Angiogram



pLAD stent underexpansion



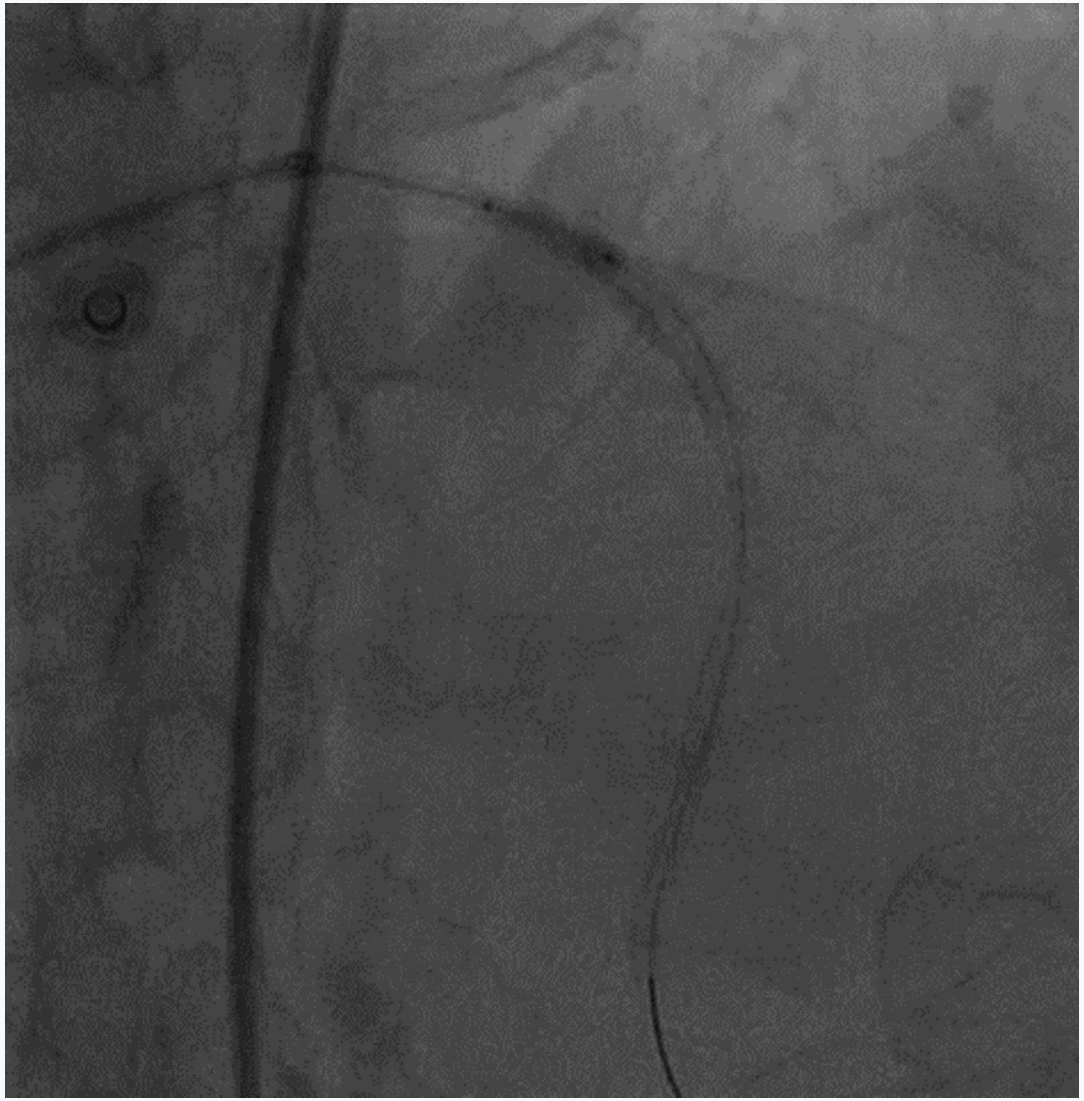
pLAD stent underexpansion (34%), MSA 1.89mm2

Stent expansion limited by extrinsic concentric calcium

Options

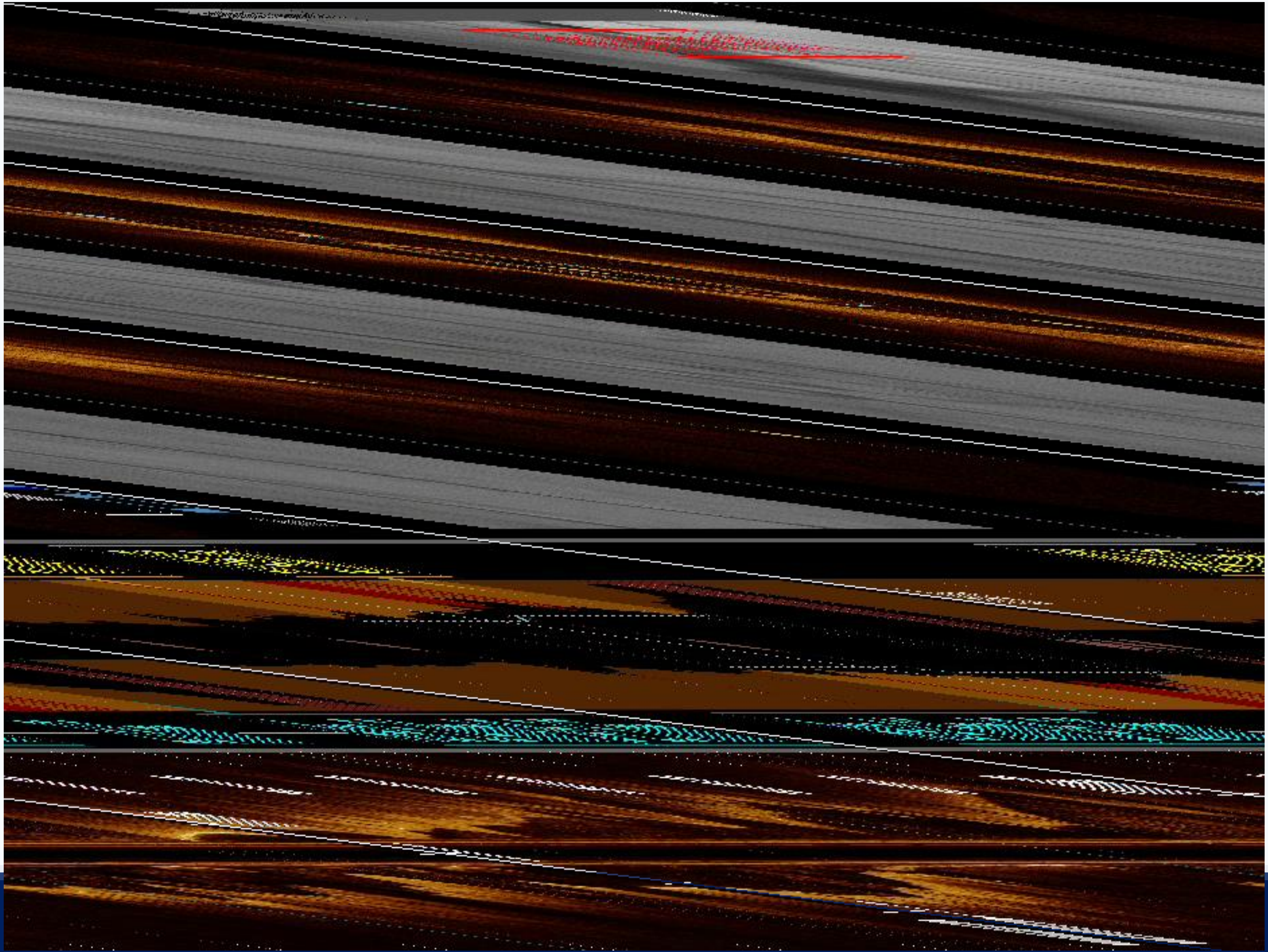
-High pressure inflation (OPN balloon)
-Stent Rotablation
-Laser (+/-contrast)
-IV lithotripsy

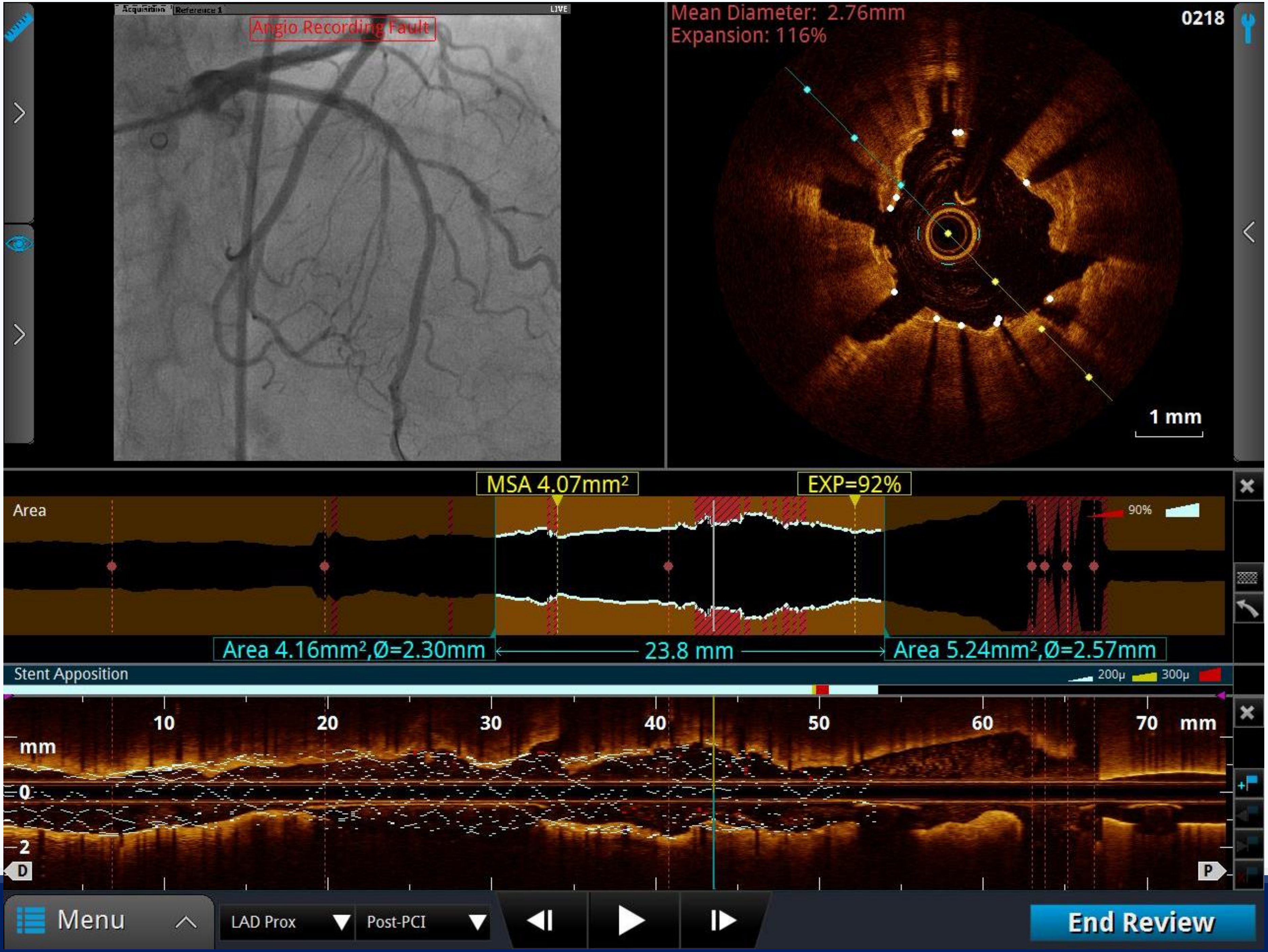
PCI to LAD



3.5mm shockwave balloon

10s cycle x 4

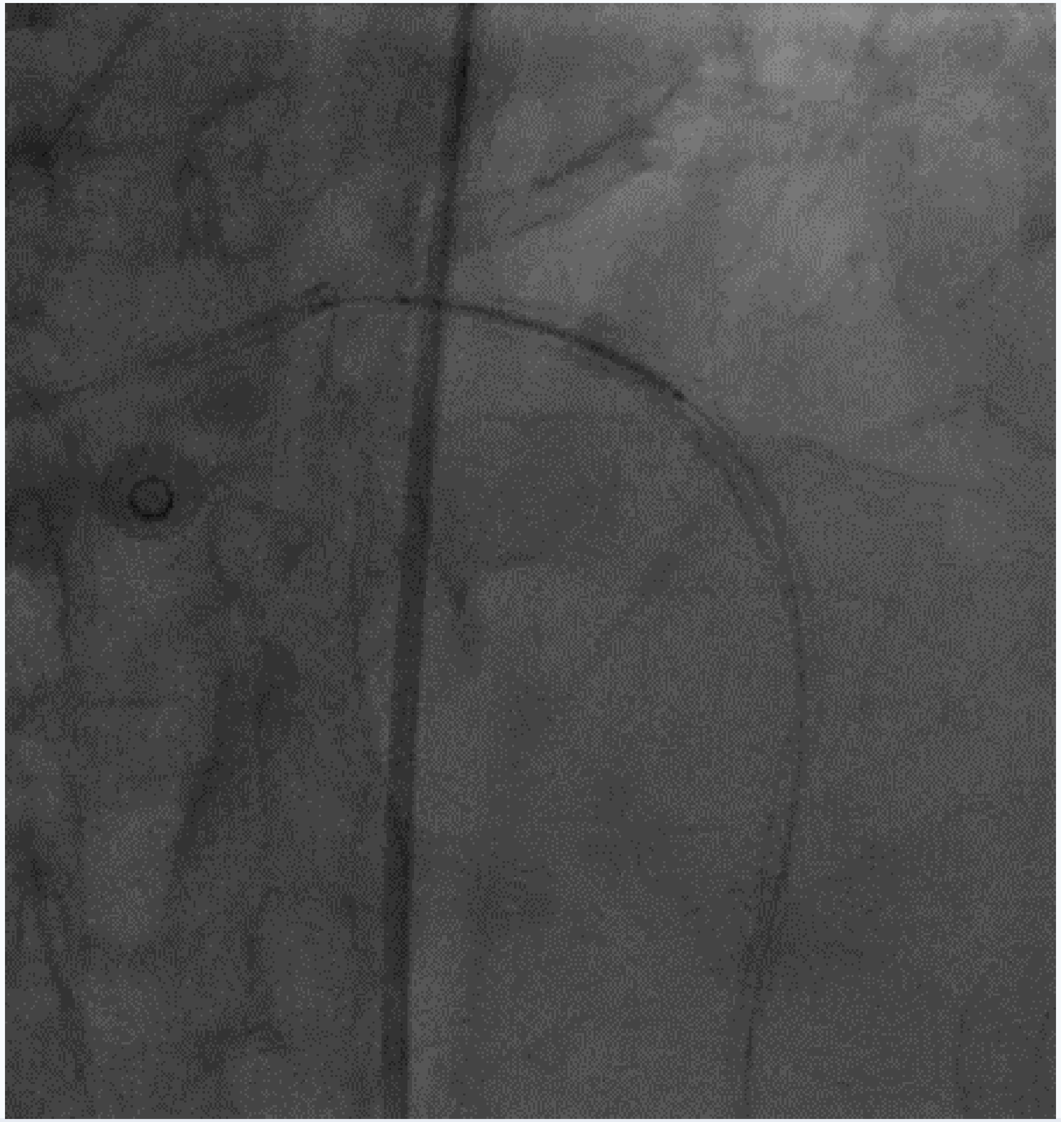


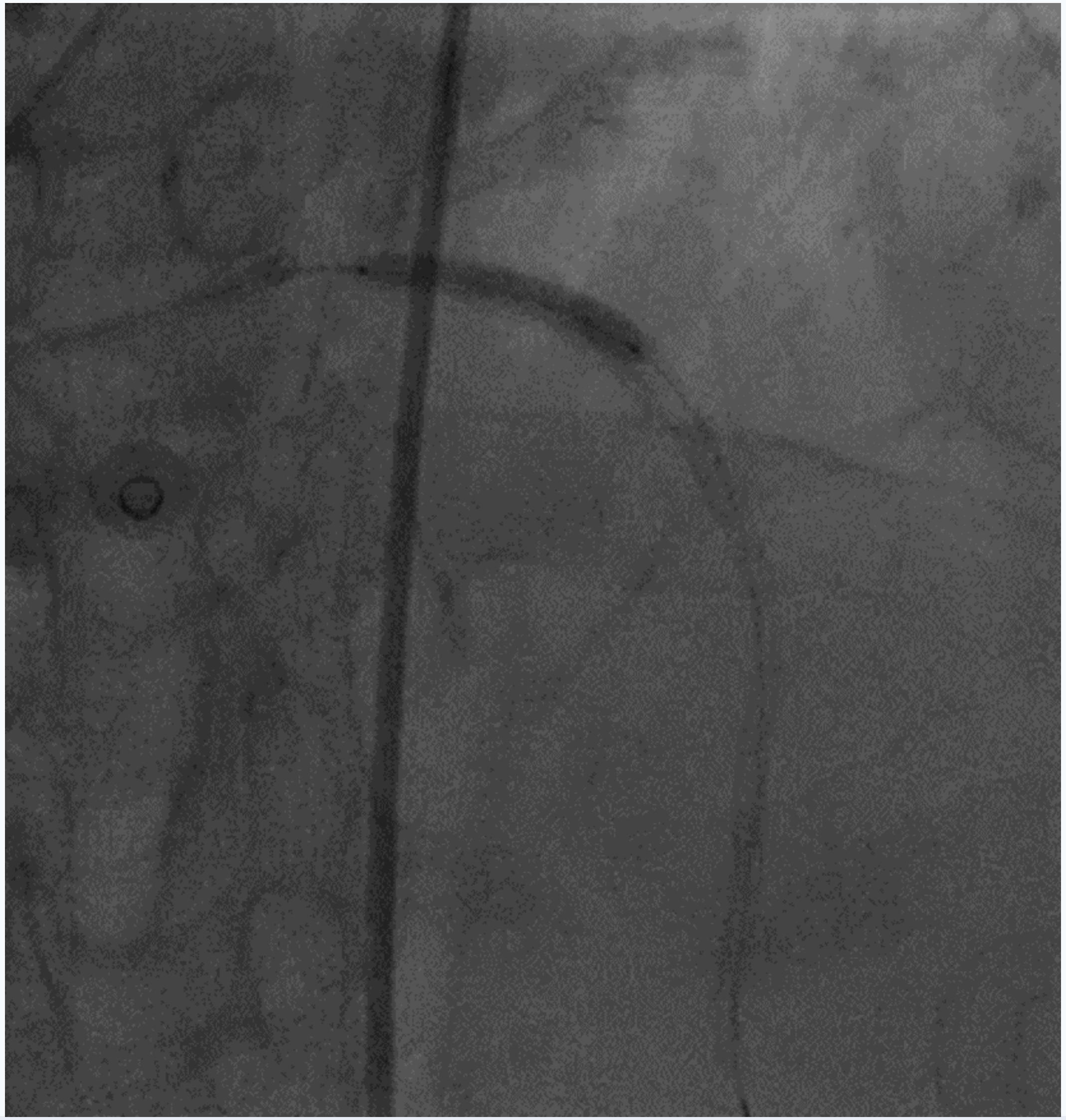


Deep crack seen in extrinsic calcium

pLAD stent expansion (92%), MSA 4.07mm2

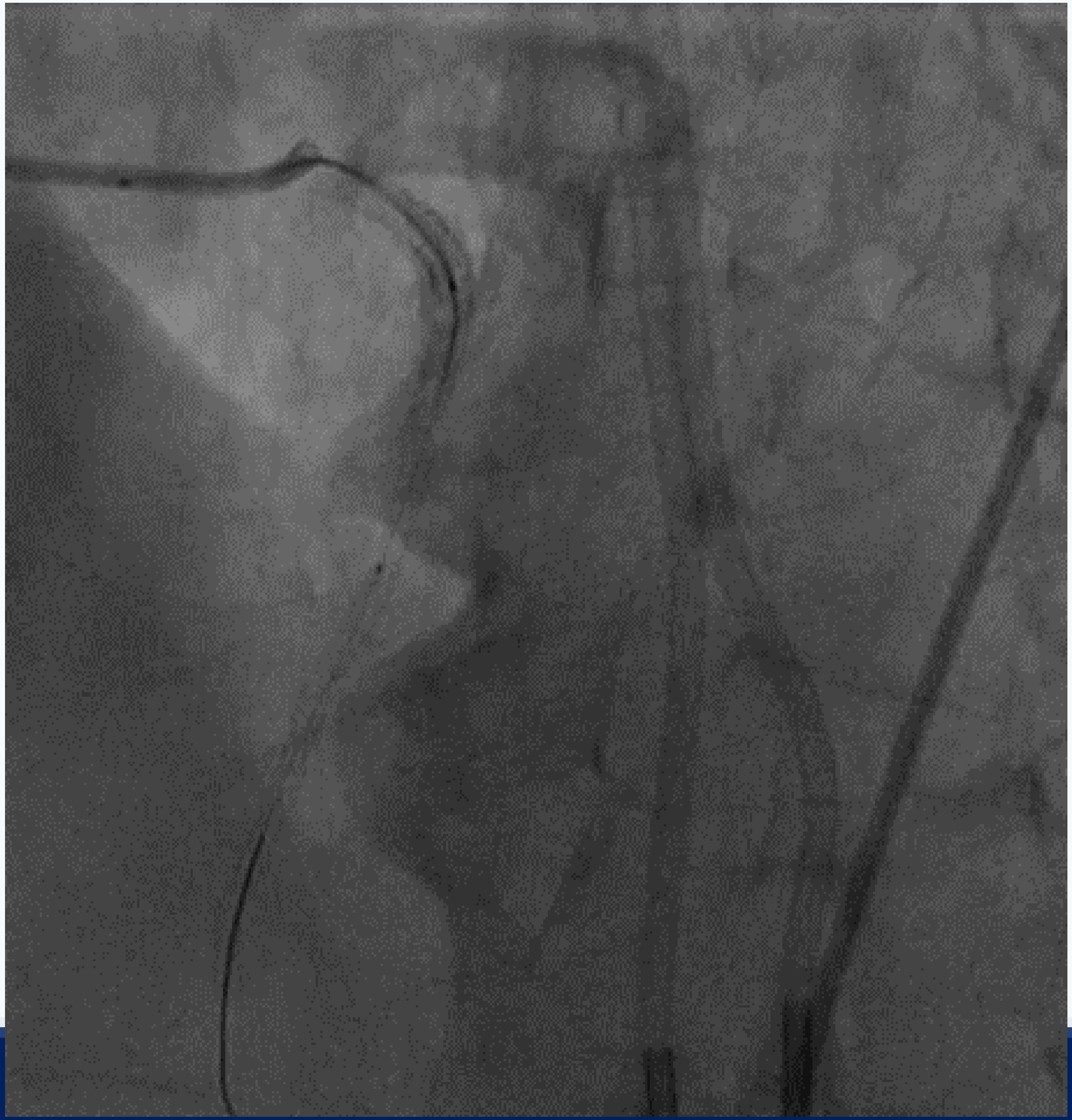
PCI to LAD

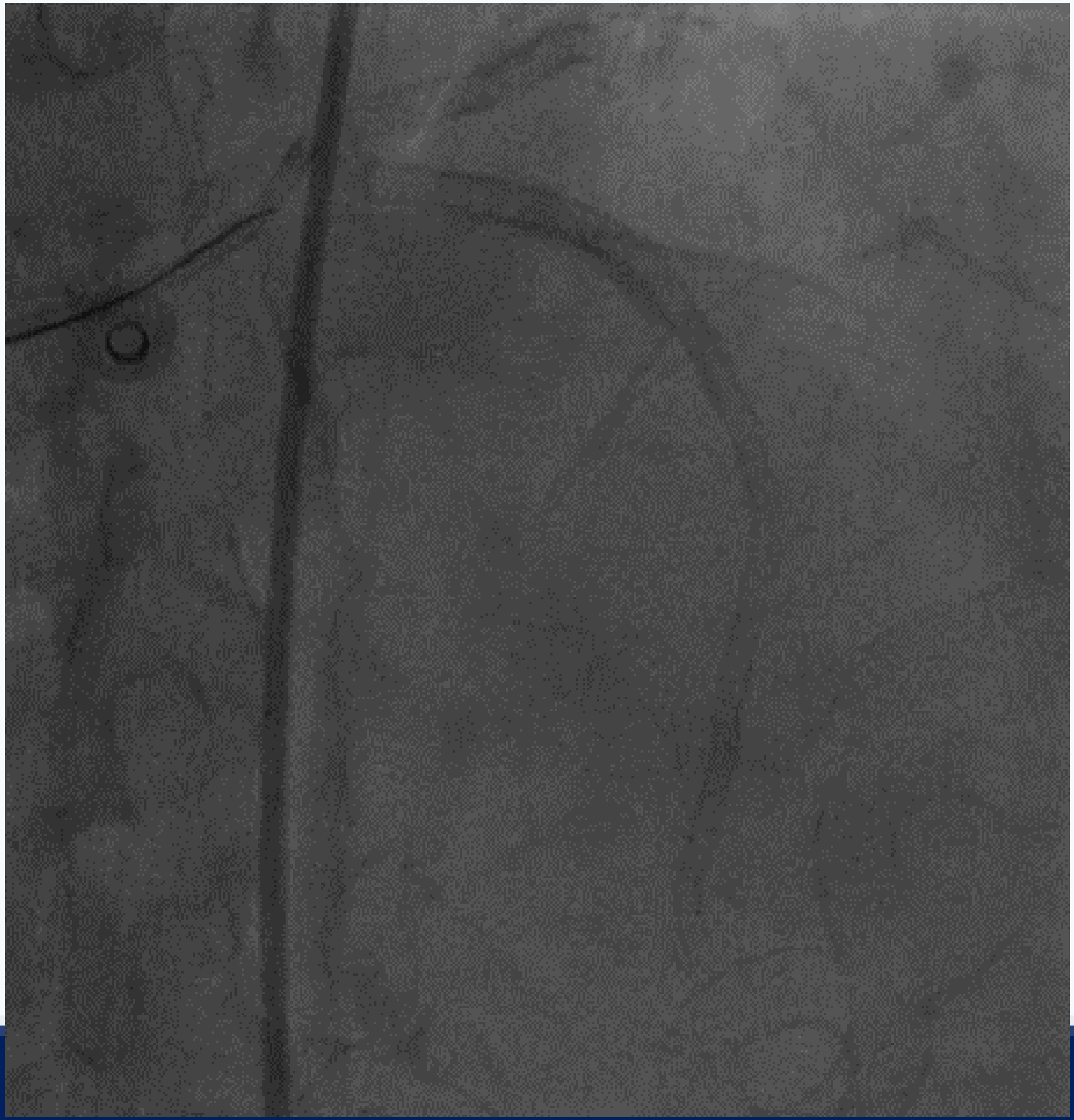


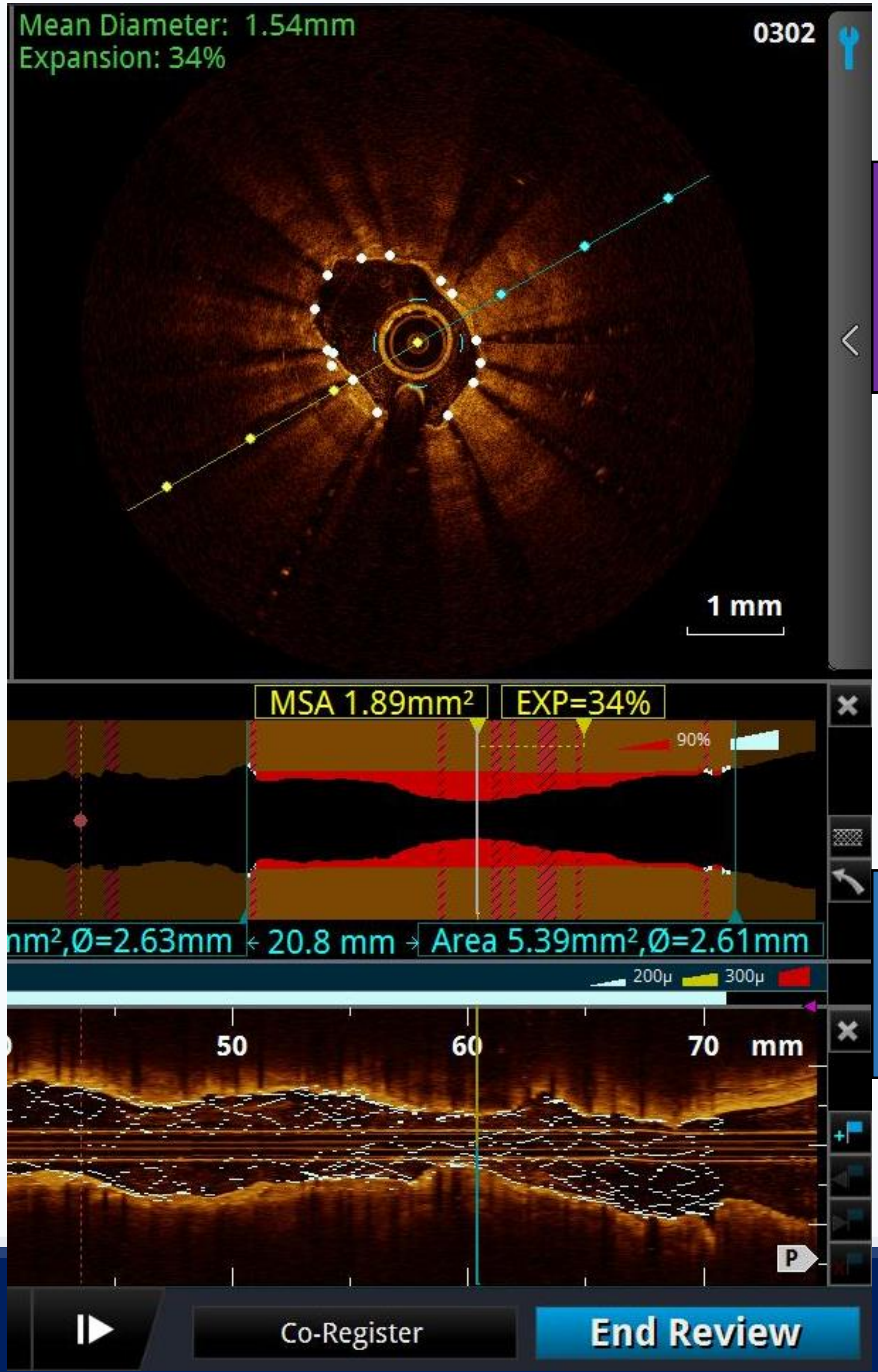


DES 3.5/26

Final results

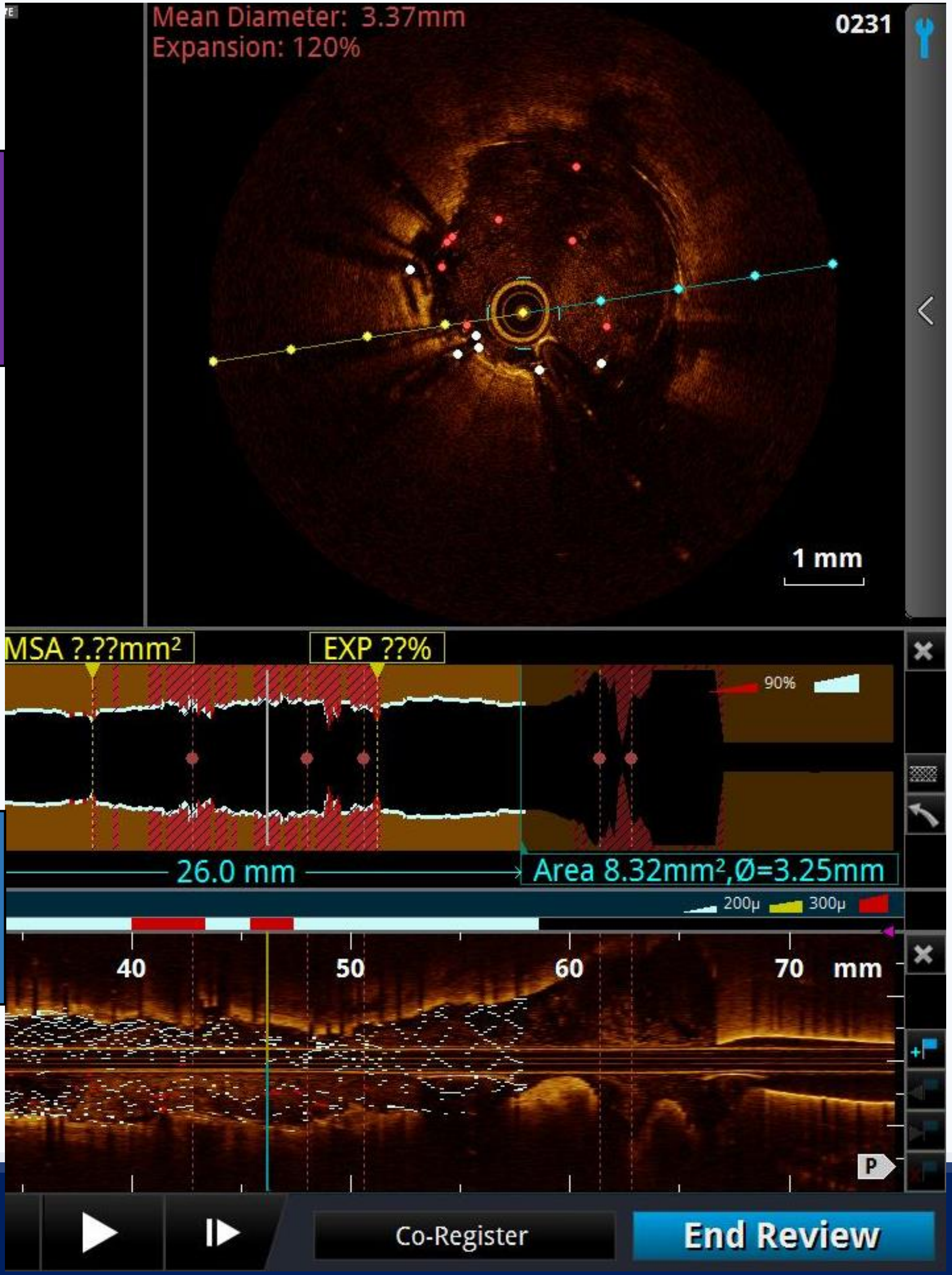






Stent expansion (34%)
MSA 1.89mm2
MLD 1.54mm

Stent expansion (100%)
MSA >8mm2
MLD 3.37mm



Conclusions

- Calcium is the enemy of coronary intervention
- Proper pre-treatment of calcium is important for safe/successful stenting procedure and better medium/long term results
- There are various devices to tackle different types of calcifications
- Shockwave lithotripsy emerges to an invaluable tool to tackle coronary calcific stenosis
- Combination of devices allows better management of severe coronary Ca

Queen Mary Hospital

Hong Kong College of Cardiology ASM 2020

Thank You

Dr Tam Frankie CC 譚礎璋醫生

Division of Cardiology, Medicine

Queen Mary Hospital, University of Hong Kong

QMH experience

- 8/2019-6/2020
- N=63
- 78 IVL balloons
- 2.5 (14); 3.0 (24); 3.5 (34); 4.0 (8)
- 11/63 experienced balloon rupture: 17.4%
- OCT/OFDI 21 IVUS 43
- 17/63 ISR
- 6/63 need rotational atherectomy/CSI
- 7/63 failed to have cracks in calcium (eccentric Ca or ISR)

Coronary IVL System Set-up

1. Start

- Press Power Button to turn Generator ON
- The ON indicator will turn green

Note: If Power Button light turns yellow, please refer to the Generator Manual

2. Confirm

- Confirm Battery capacity via battery symbol
- If the battery symbol is empty, additional charging of the battery is recommended before use

3. Detach

- Detach the Charger Cable from the Generator

4. Slide

- Slide the Connector Door to the left

5. Attach

- Insert the proximal end of the Connector Cable to the Generator

[1]Refer to the Generator Manual for full details and Warnings and Precautions.

Generator Lights Cheat Sheet

Normal Power On

Normal Ready/Standby

Normal Ready

Catheter Error

System Error

Passed Self Test

Generator Troubleshooting: Catheter Errors

Catheter Errors

Power button illuminates amber and an error message is displayed on the screen

What it means		Recommended Actions

Error 80
Catheter beginning of life unsuccessful.
	The generator was unable to mark the catheter for beginning of life.
	Possible causes are
	• Loose connection between the generator and catheter.
	• Defective Connector cable
	• Defective Catheter
		• Turn the generator power OFF
		• Check catheter and connector cable connection
		    • Make certain that the sterile sleeve is not interfering with the catheter and cable connection.
		    • Make certain that the connection to the generator is secure and that the generator connector door is not interfering with the cable connector.
		• Purge and re-prep the balloon
		• Turn the generator power ON
		• Press the generator front panel therapy button when ready
		• Resume pulse delivery.
		• If the error condition persists, replace the catheter.

Error 81 Catheter identification unsuccessful	Generator was unable to identify the catheter type. Possible causes are • Loose connection between the generator and catheter. • Defective Connector cable • Defective Catheter	
Error 88 Pulse delivery timeout.	The generator was unable to measure pulse energy delivery to the catheter within allowed time limit. Possible causes are • Gas bubbles in the balloon • Loose connection between the generator and catheter. • Defective Connector cable • Defective Catheter	
Error 89 Catheter end of life has been reached (EOL).	All pulses have been used • This catheter was previously used more than 6 hours previous • This catheter was previously connected to another generator • Bad connection at generator or catheter ends of the connector cable.	

SHOCKWAVE C2

Generator Troubleshooting: System Errors

System Errors

Power button illuminates red and an error message is displayed on the screen

	What it means	Recommended Actions
Error 90 and 93 Internal Generator Error	The generator has detected an error. Possible causes are: • Voltage out of range	• Internal generator errors are generally not recoverable. To attempt recovery: • Turn off for a few seconds, then turn on and run self-test mode.

Self Test Mode:

- Self-Test Mode
  - Plug the charger into the generator and an AC outlet.
  - Make certain that the battery symbol indicates charging (lightning bolt).
  - Turn the generator power ON (momentarily press the power button)
  - Once the generator finishes the power on sequence, press and hold the THERAPY button until the THERAPY button logo lights GREEN (approximately 3 seconds), then release the THERAPY button.
- The self-test will complete in approximately 20 seconds.

- PASS is indicated by four audible beeps and GREEN POWER button logo.
- FAIL is indicated by three audible beeps and RED POWER button logo.

SHOCKWAVE | C²

CLINICAL DATA

IVL. Your Sound Calcium Strategy.

DISRUPT CAD I Study

- Objective: To assess the safety and performance of the IVL System
- Primary Safety Endpoint: 30-day MACE (Cardiac death, MI or TVR)
- Primary Performance Endpoint: Clinical success (residual stenosis <50%) post-PCI with no evidence of in-hospital MACE.
- Enrollment: 60 subjects, across 7 sites, completed enrollment Sept 2016
- Core Angiographic & OCT Labs: Yale University & CRF
- Follow Up: 30 day and 6 month

Inclusion:

Stable angina, unstable angina or silent ischemia → **Moderate and severely calcified, *de novo* coronary lesions RVD 2.5 – 4.0 mm, stenosis ≥50%, Lesion length ≤ 32 mm**

Investigator	Site	Enrollment
Jean Fajadet, MD (PI)	Clinic Pasteur, France	10
Carlo Di Mario, MD (Co-PI)	Royal Brompton, England	15
Ian Meredith, MD	Monash Health, Australia	13
Jonathan Hill, MD	King's College, England	14
Nicolas Van Mieghem, MD	Erasmus, Netherlands	4
Robert Whitbourn, MD	St Vincent's, Australia	3
Matthias Götberg, MD	Skane University Hospital, Sweden	1

Baseline Characteristics & Angiographic Findings†

	Medical History N= 60
Age	72.1 (9.6)
Male gender	80.0%(48)
Diabetes	30.0% (18)
Hypertension	80.0% (48)
Hyperlipidemia	80.0% (48)
Myocardial Infarction	40.0% (24)
Prior CABG	23.3% (14)
Stroke/TIA	13.3% (8)
Current Smoker	15.0% (9)
Renal insufficiency	10.0% (6)
Angina Classification	
Class I	32%
Class II	48%
Class III	17%
Class IV	3%

	Pre-Procedure N=60
RVD (mm)	3.0 ± 0.5
MLD (mm)	0.9 ± 0.4
% Diameter stenosis	68.1 ± 13.1
Lesion length (mm)	20.3 ± 10.5
Calcified length (mm)	22.3 ± 12.5
Heavy Calcification‡	100%
Lesion Assessment	
Concentric	78.3% (47)
Eccentric	21.7% (13)
Side branch involvement	28.3% (17)

Brinton, T. *Presentation*, EuroPCR, 2016, Paris, France

†core lab adjudicated

‡Heavy Calcification: Radiopacities noted on fluoroscopy prior to contrast injection involving both sides of the arterial wall.

SHOCKWAVE | C²

DISRUPT CAD I Results

Low Complications and Strong Efficacy/Safety

Complications	Procedural	Final
Dissections (D/E/F)	3.3%(2)/0%/0%	0%/0%/0%
Perforation	0.0%	0.0%
Abrupt Closure	0.0%	0.0%
Slow Flow	0.0%	0.0%
No Reflow	0.0%	0.0%

Safety	Results	Events
30 day MACE‡ Cardiac death, MI or TVR	5%	Death N = 0 QWMI N = 0 *NQWMI N = 3 TVR N = 0
6 month MACE‡ Cardiac death, MI or TVR	8.5%	Death N = 2 QWMI N = 0 *NQWMI N = 3 TVR N = 0

Efficacy	Results
Clinical Success‡† Residual stenosis <50% post-PCI with no evidence of in-hospital MACE	95%
Device Success Successful device delivery and IVL treatment at target lesion	98.3%
Stent Delivery	100%

†Core lab adjudicated
‡CEC adjudicated
*NQMI defined as 3x upper limit CK-MB

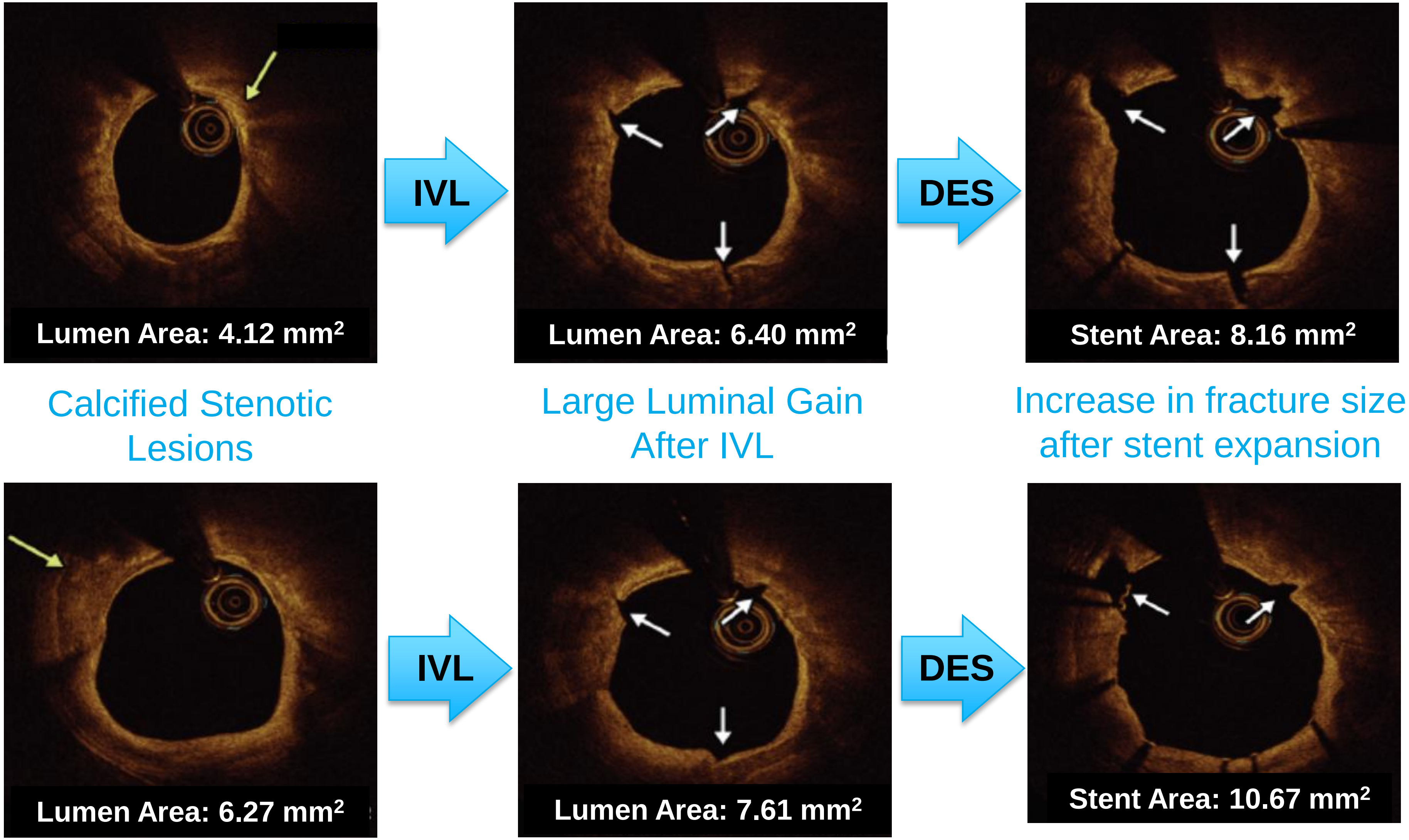
OCT Sub-study Verifies Calcium Fractures

2.1mm² Acute Area Gain Post-IVL

5.9mm² Mean Stent Area

Most heavily calcified lesions demonstrated transmural fractures

- Trend toward greatest fracture highest tertile ($p=0.057$)
- Heavier calcium burden = more calcium fractures per lesion ($p=0.009$)
- Stent expansion similar across all lesions, despite arc of calcium ($p=0.21$)



Ali, Z. et al. J Am Coll Cardiol Imaging 2017;10(8): 897-906.

DISRUPT CAD I Recap: IVL Safety & Efficacy Confirmed

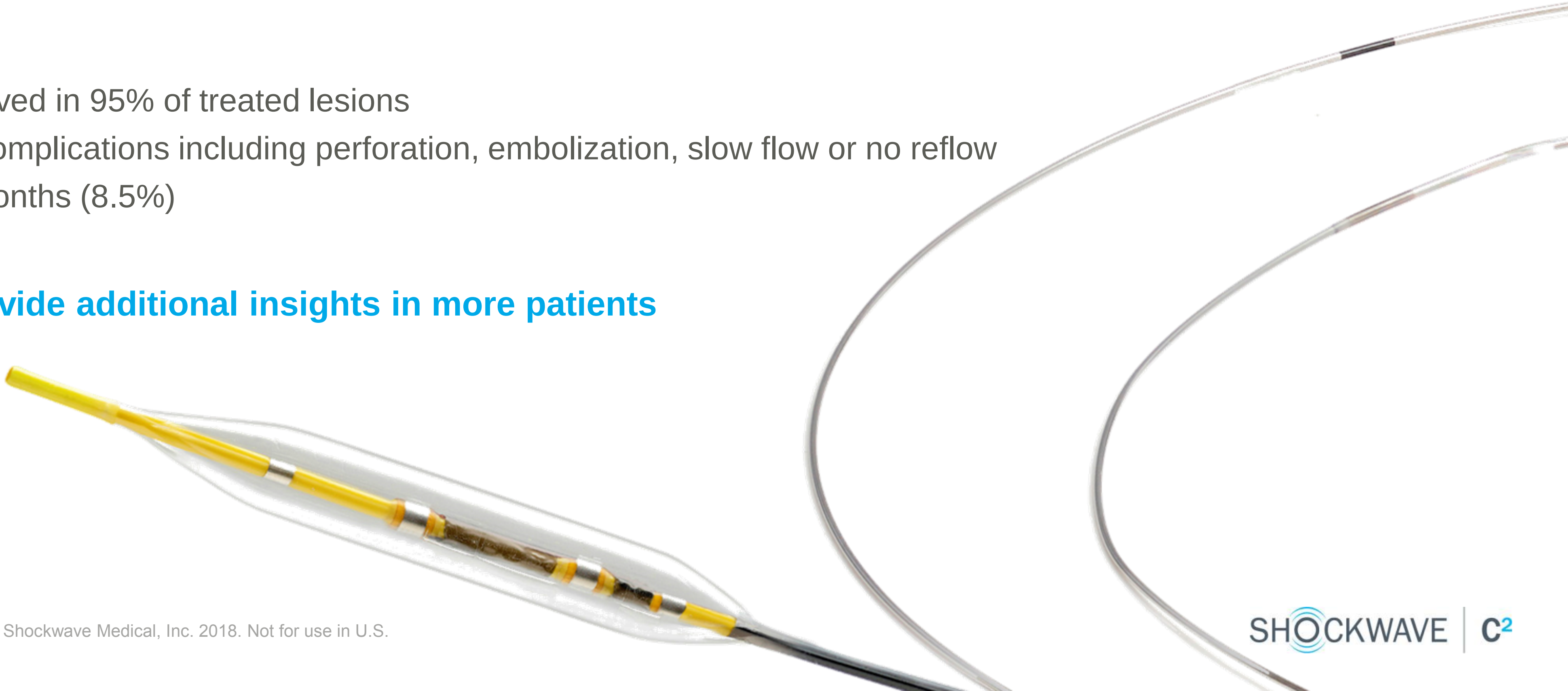
IVL treatment in highly calcified coronary arteries is highly effective for delivery of stents and reducing stenosis

- 100% stent deployment
- High rate of acute gain and low rates of residual stenosis

IVL procedure is safe

- Primary endpoint was achieved in 95% of treated lesions
- No major intra-procedural complications including perforation, embolization, slow flow or no reflow
- Low MACE rates out to 6 months (8.5%)

DISRUPT CAD II & III to provide additional insights in more patients



SHOCKWAVE | C²

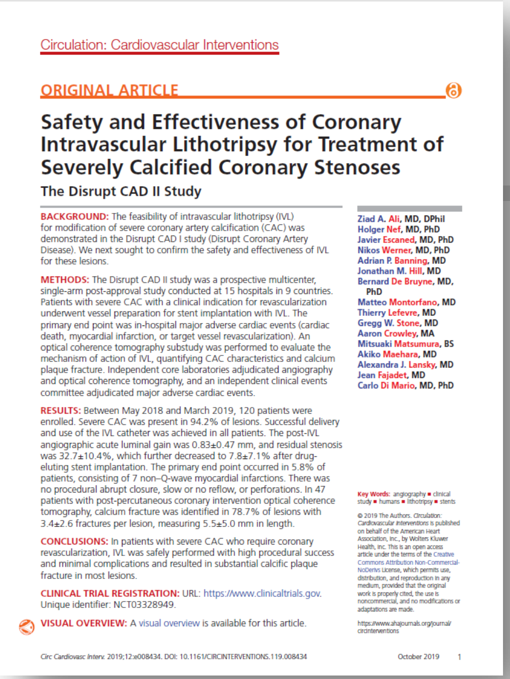
DISRUPT CAD II: Study Design

Inclusion:

Stable angina, unstable angina or silent ischemia

↓

Moderate and severely calcified,
***de novo* coronary lesions RVD 2.5 – 4.0 mm, stenosis ≥50%,**
Lesion length ≤ 32 mm



Circulation: Cardiovascular Interventions

ORIGINAL ARTICLE

Safety and Effectiveness of Coronary Intravascular Lithotripsy for Treatment of Severely Calcified Coronary Stenoses

The Disrupt CAD II Study

Ziad A. Ali, MD, DPhil
Holger Nef, MD, PhD
Javier Escaned, MD, PhD
Nikos Werner, MD, PhD
Adrian P. Banning, MD
Jonathan M. Hill, MD
Bernard De Bruyne, MD, PhD
Matteo Montorfano, MD
Thierry Lefevre, MD
Gregg W. Stone, MD
Aaron Crowley, MA
Mitsuaki Matsumura, BS
Akiko Maehara, MD
Alexandra J. Lansky, MD
Jean Fajadet, MD
Carlo Di Mario, MD, PhD

BACKGROUND: The feasibility of intravascular lithotripsy (IVL) for modification of severe coronary artery calcification (CAC) was demonstrated in the Disrupt CAD I study (Disrupt Coronary Artery Disease). We next sought to confirm the safety and effectiveness of IVL for these lesions.

METHODS: The Disrupt CAD II study was a prospective multicenter, single-arm post-approval study conducted at 15 hospitals in 9 countries. Patients with severe CAC with a clinical indication for revascularization underwent vessel preparation for stent implantation with IVL. The primary end point was in-hospital major adverse cardiac events (cardiac death, myocardial infarction, or target vessel revascularization). An optical coherence tomography substudy was performed to evaluate the mechanism of action of IVL, quantifying CAC characteristics and calcium plaque fracture. Independent core laboratories adjudicated angiography and optical coherence tomography, and an independent clinical events committee adjudicated major adverse cardiac events.

RESULTS: Between May 2018 and March 2019, 120 patients were enrolled. Severe CAC was present in 94.2% of lesions. Successful delivery and use of the IVL catheter was achieved in all patients. The post-IVL angiographic acute luminal gain was 0.83±0.47 mm, and residual stenosis was 32.7±10.4%, which further decreased to 7.8±7.1% after drug-eluting stent implantation. The primary end point occurred in 5.8% of patients, consisting of 7 non–Q-wave myocardial infarctions. There was no procedural abrupt closure, slow or no reflow, or perforations. In 47 patients with post-percutaneous coronary intervention optical coherence tomography, calcium fracture was identified in 78.7% of lesions with 3.4±2.6 fractures per lesion, measuring 5.5±5.0 mm in length.

CONCLUSIONS: In patients with severe CAC who require coronary revascularization, IVL was safely performed with high procedural success and minimal complications and resulted in substantial calcific plaque fracture in most lesions.

CLINICAL TRIAL REGISTRATION: URL: https://www.clinicaltrials.gov. Unique identifier: NCT03328949.

VISUAL OVERVIEW: A visual overview is available for this article.

Key Words: angiography ■ clinical study ■ humans ■ lithotripsy ■ stents

https://www.ahajournals.org/journal/circinterventions

Circ Cardiovasc Interv. 2019;12:e008434. DOI: 10.1161/CIRCINTERVENTIONS.119.008434 October 2019 1

Objective: A post-market study to assess the safety and performance of the Coronary IVL System with more patients in more centers

Primary Safety Endpoint: In-hospital MACE (Cardiac death, MI or TVR)

Secondary Performance Endpoints:

- Clinical success: low residual stenosis after stenting without in-hospital MACE
- Angiographic success: stent delivery with low residual stenosis without angiographic complications

Enrollment: 120 subjects, across 15 sites

Follow Up: Procedural and 30 day

Core Angiographic & OCT Labs: Yale University & CRF

Disrupt CAD II: Outcomes

Complex, calcified lesions enrolled in the study

- 94% Severe calcification
- ~26mm calcified length
- ~30% eccentric calcium
- 30% side branch involvement

	N = 120
Clinical success	94.2 (113)
Angiographic success	100.0 (120)
Stent delivery	100.0 (120)
Final in-stent angiographic outcomes (core lab)	
Minimum lumen diameter, mm	2.88 ± 0.47
Residual diameter Stenosis, %	7.8 ± 7.1
Acute gain, mm	1.67 ± 0.49
Residual diameter stenosis <50%	100.0 (120)
Residual diameter stenosis <30%	100.0 (120)

CEC & Core Lab Adjudicated

	N = 120
Final angiographic complications	**0.0 (0/120)**
Dissections, type D- F	0.0 (0/120)
Perforations	0.0 (0/120)
Abrupt closure	0.0 (0/120)
Slow flow	0.0 (0/120)
No reflow	0.0 (0/120)
Major adverse cardiac events in-hospital	**5.8 (7/120)**
Cardiac death	0.0 (0/120)
Non–Q-wave myocardial infarction	5.8 (7/120)
Q-wave myocardial infarction	0.0 (0/120)
Target vessel revascularization	0.0 (0/120)
Major adverse cardiac events through 30 days*	**7.6 (9/119)**
Cardiac death	0.8 (1/119)
Non–Q-wave myocardial infarction	5.9 (7/119)
Q-wave myocardial infarction	0.8 (1/119)
Target vessel revascularization	0.8 (1/119)
Stent thrombosis (definite or probable)	1.7 (2/119)

Ali, Nef, Escaned, et al. Circ Cardiovasc Interv. 2019

OCT Sub-Study

Objective: Determine the mechanistic effects of IVL on heavily calcified coronary lesions and subsequent stent placement using optical coherence tomography (OCT).

Protocol: Images were obtained at predefined time points (pre IVL and completion of procedure)
Calcific plaque was defined by standard OCT definitions

Enrollment: 47 subjects with matched pre and final images from 7 sites

Ali, Nef, Escaned, et al. Circ Cardiovasc Interv. 2019

OCT Sub-Study: Summary

- IVL significantly increased luminal area
- Calcium fracture is the mechanism of action of IVL
- Demonstrated circumferential calcium modification leading to full stent expansion

	Pre-IVL	Post-stent	P-value
At pre-IVL max calcium site, n	48	38	
Lumen area, mm^2	3.64±1.78	8.47±3.04	<.0001
Calcium angle, °	266.3±77.1	215.1±69.4	<.0001
Max calcium thickness, mm	0.93±0.2	0.89±0.2	0.004
Acute area gain, mm^2		4.79±2.45	
Stent Expansion, %		102.8 ±30.6	

	N=47
Calcium fracture, %	78.7 (37/47)
Multiple Fractures, %	55.3 (26/47)
Calcium fracture per lesion	3.4 ± 2.6

Core Lab Adjudicated

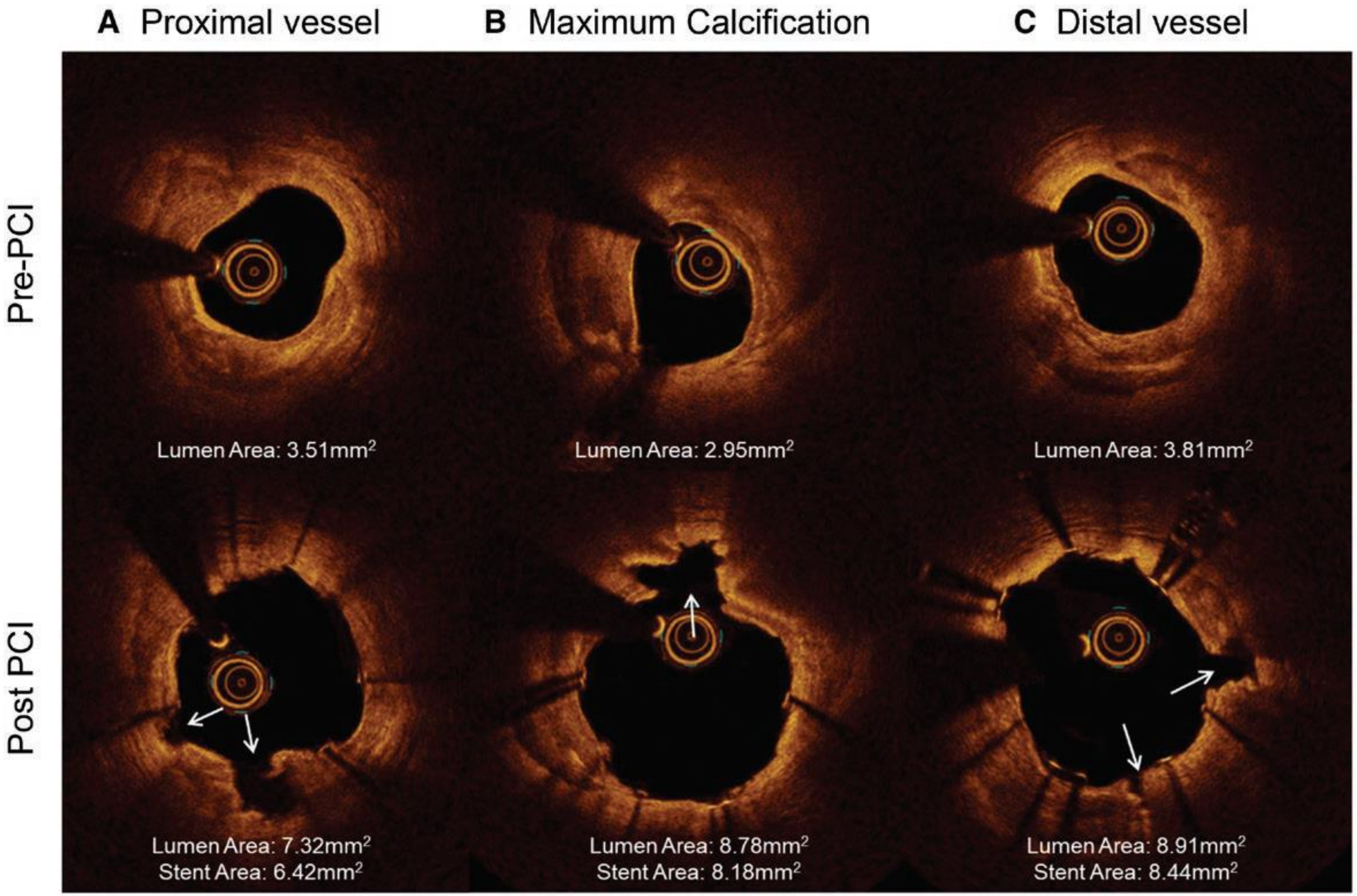
Ali, Nef, Escaned, et al. Circ Cardiovasc Interv. 2019

OCT Sub-study Case Example:
Proximal LAD with side branch involvement

Severe Calcification:
>270º & >1mm thick

Calcium Fractures:
Multiple locations
(white arrows)

Final Result:
Full stent expansion
Large acute gain



OCT co-registered with the pre-PCI image

Core Lab Adjudicated

Ali, Nef, Escaned, et al. Circ Cardiovasc Interv. 2019

DISRUPT CAD I & II Recap: IVL Safety & Effectiveness Confirmed

IVL treatment in highly calcified coronary arteries is highly effective for delivery of stents and reducing stenosis

- 100% stent deployment
- High rate of acute gain and low rates of residual stenosis

IVL procedure is safe

- Primary endpoint was achieved in 95% of treated lesions in Disrupt CAD I
- No major intra-procedural complications including perforation, embolization, slow flow or no reflow in 180 patients (Disrupt CAD I/II)
- Low MACE rates out to 6 months (8.5%)

Proper lesion preparation is needed in severely calcified lesions prior to PCI

- Ineffective lesion prep leads to stent under-expansion, complications and worse outcomes
- Current vessel prep strategies have similar and predictable challenges with severe CAC leading to less effective intervention
- The unique MOA of Intravascular Lithotripsy optimizes stent delivery, expansion and apposition
  - Calcium fractures seen in ~80% of lesions analyzed by OCT
  - Full stent expansion secondary to circumferential calcium modification

Coronary IVL U.S. IDE Study Initiated

Enrollment Expected to Be Completed by 2020; Trial Design Follows ORBIT II Study

Objective: Designed to assess safety and effectiveness of the Shockwave Medical Coronary Intravascular Lithotripsy (IVL) System

Performance Goal: Based on Orbit II

- Primary safety endpoint: 30d MACE rate
- Primary effectiveness endpoint: <50% residual and no in-hospital MACE

Enrollment: ~400 subjects, across 50 sites

Sub-Studies: OCT, PPM/ICD and Hemodynamics

Follow Up: Procedural, 30 day, 6, 12 and 24 months

The Shockwave Coronary IVL System (C²) is *investigational use only* in the U.S.