Hemodynamic Support:
physiology & application

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Disclosures

- Consultant honoraria: Medtronic, Merck
- Research grants: Boston Scientific, InfraRedex
- Ownership: Mdcare Global, HygeiaTel

Hemodynamic Support: Topics

- Why and when do we need hemodynamic support?
- Percutaneous hemodynamic support devices during PCI
- Clinical evidence & recommendations for use of hemodynamic support devices
- Interactive Q&A

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Q&A

- **Please send a text message ‘dallascvi2015’ to 37607**
- Upon receipt of a return message you will be enrolled in the mobile audience response system
- Please type in the letter indicative of your response & send your text message

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Question 1

- How was tonight's dinner? Please share your experience by selecting one of the following options?
  - A. Just OK
  - B. Good
  - C. Excellent
  - D. Outstanding

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Physiology

Myocardial Oxygen Supply and Demand[a,b]

Myocardial oxygen supply

- Normal circulation: blood pressure changes in the aortic root do not affect blood flow/counter pulsation
- Pathologic conditions (eg, cardiogenic shock, post-MI): blood flow is dependent on diastolic pressure in the aortic root

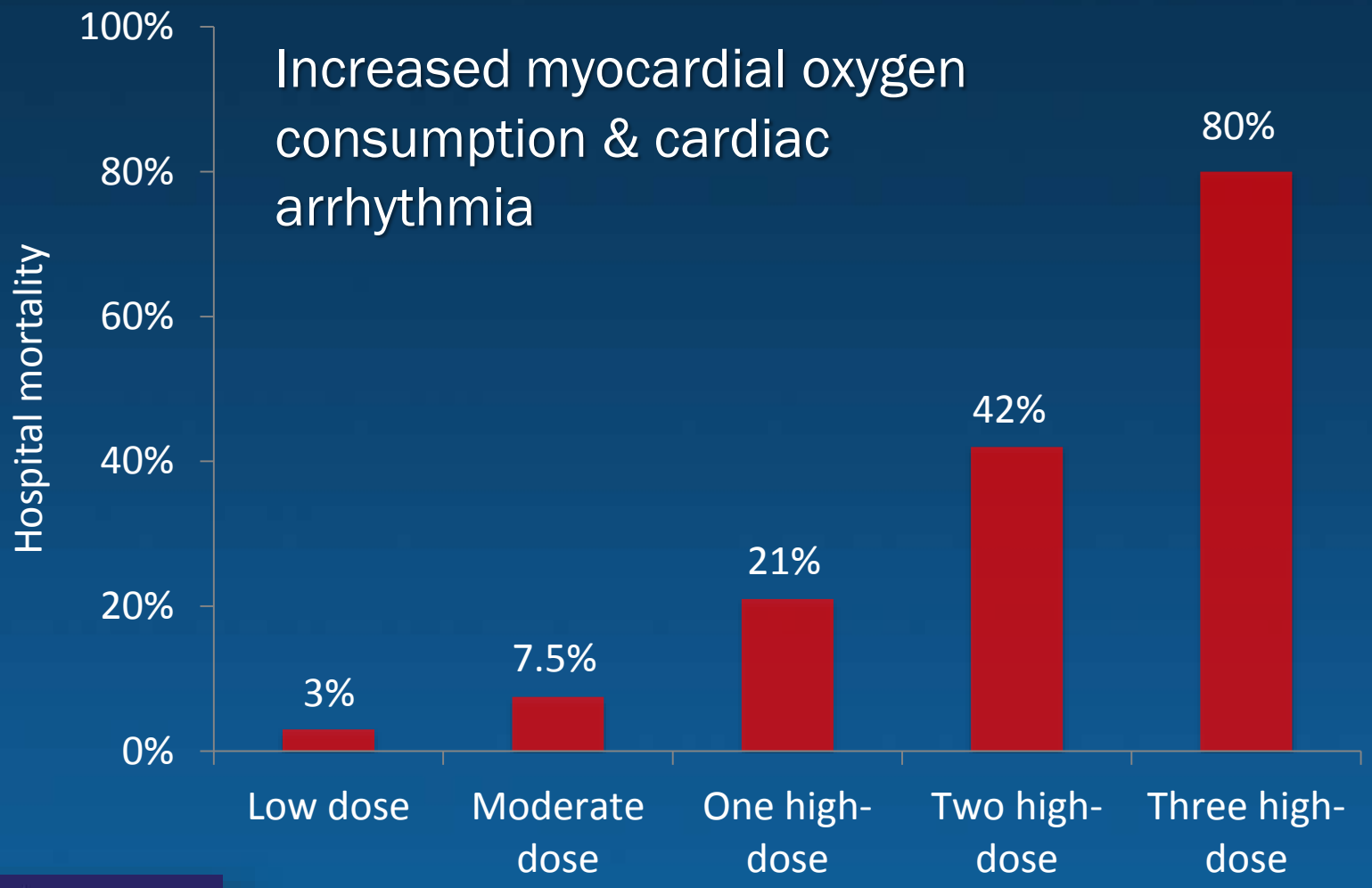
Myocardial oxygen demand

- Heart rate, stroke volume → cardiac output
- Wall stress
  - Pressure inside the ventricle
  - Ventricular volume
  - Laplace's law[c]

$$\textit{Wall Stress} = \frac{(\textit{Pressure} \times \textit{Radius})}{(2 \times \textit{Wall Thickness})}$$

a. Naidu S. *Circulation*. 2011;123:533-543[1]; b. Burkhoff D, et al. *Catheter Cardiovasc Interv*. 2012;80:816-829[2]; c. Rosendorff C. *Essential Cardiology: Principles and Practice*. 2013.[17]

Inotropes and Mortality



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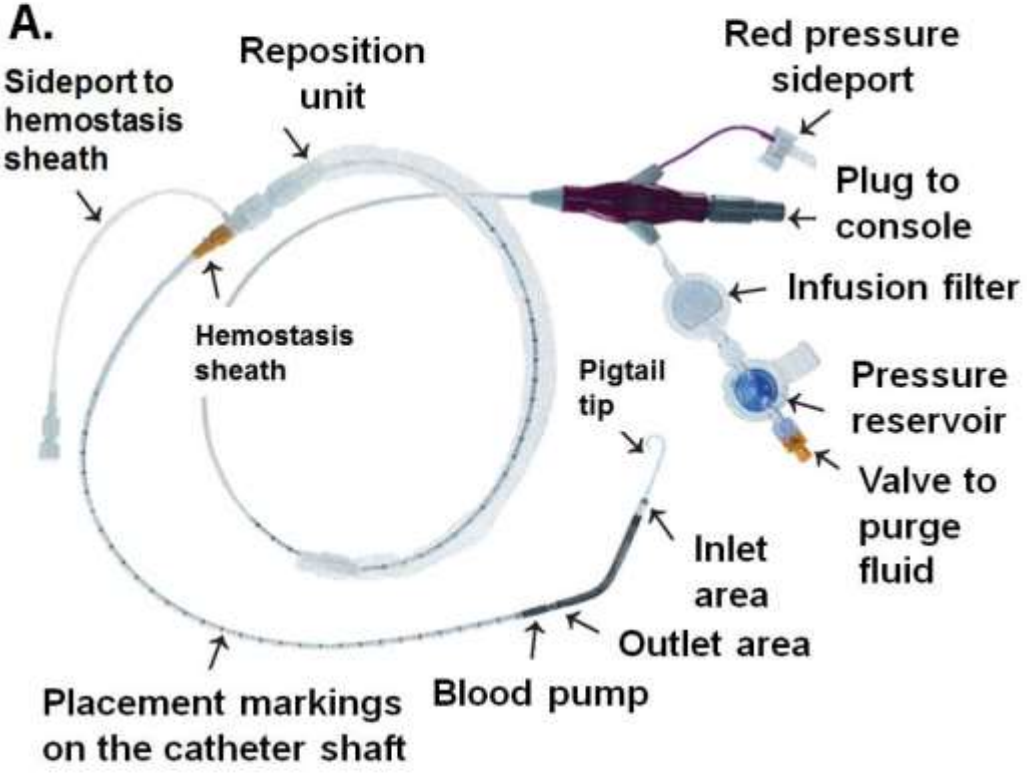
Samuels *et al.* J Cardiothoracic Surgery 1999

Percutaneous Cardiac Assist Devices

A.



Axial flow pump fitted onto a pigtail catheter

Impella

B.

TandemHeart

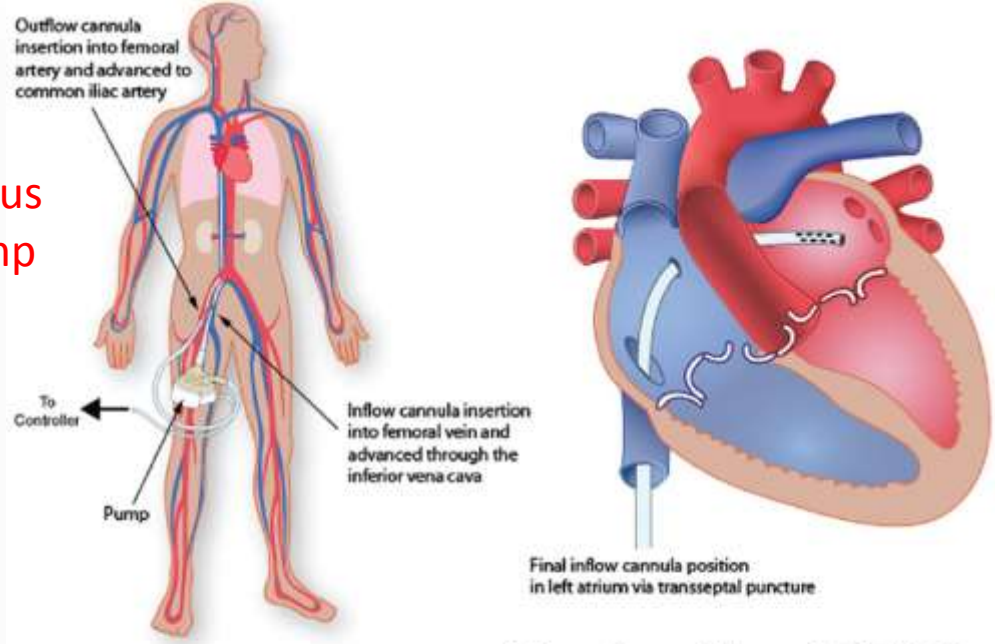
CFP-continuous flow pump

C.

Intra-aortic balloon pump

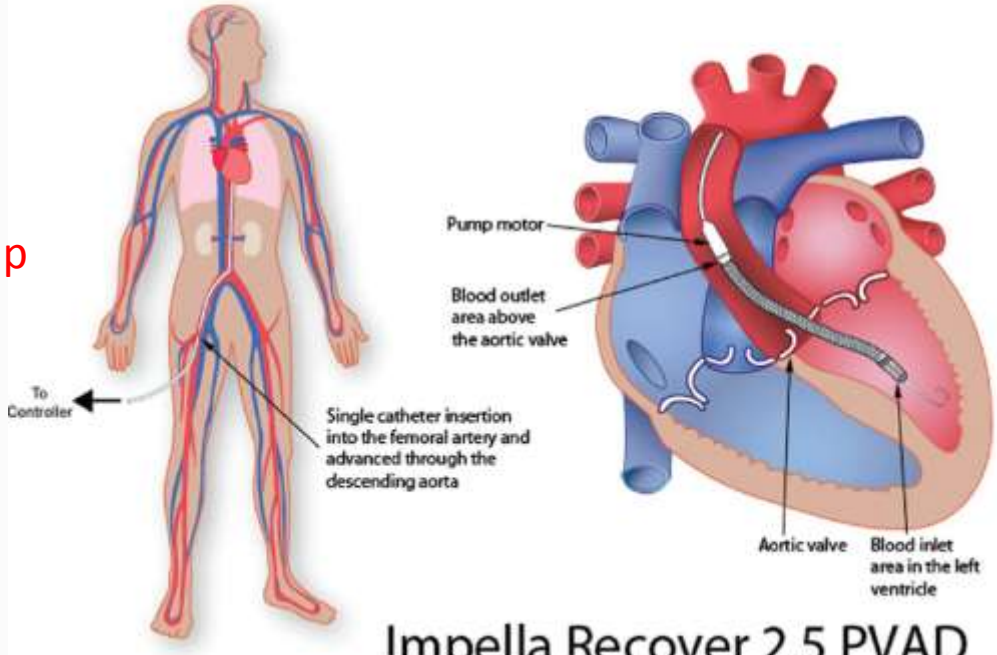
IABP

Continuous flow pump

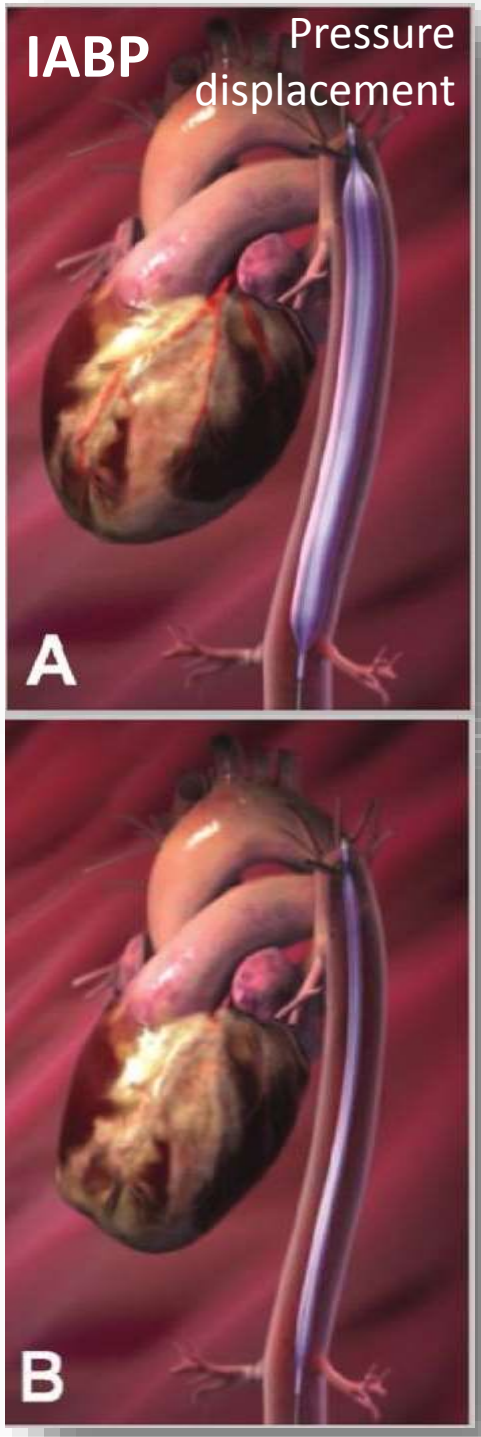


TandemHeart PVAD

Axial flow pump



Impella Recover 2.5 PVAD



Goals of Hemodynamic Support During High-Risk PCI

- Stabilizing systemic perfusion
- Balancing myocardial perfusion against demand and supply
- Augmenting perfusion
- Creating a window to perform complete revascularization, if appropriate

Burkhoff D, et al. *Catheter Cardiovasc Interv*. 2012;80:816-829.[2]

Assist Treatments
Effect on Myocardial Oxygen Demand

Inotropes and vasopressors[a] (eg, dobutamine, digoxin, vasopressin)

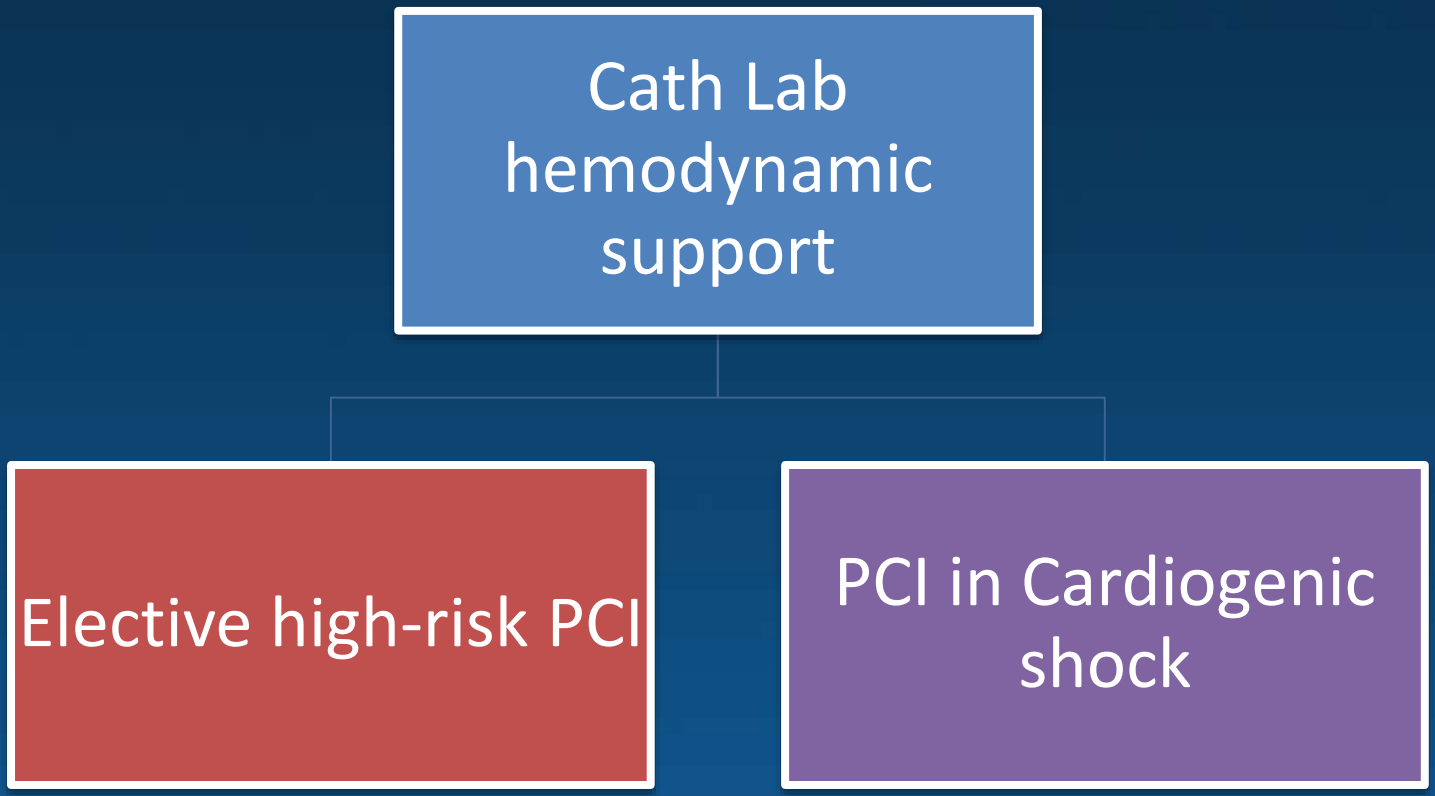
- Increase myocardial oxygen demand
- Increase cardiac workload; potential trigger for arrhythmia
  - Heart rate
  - Contractile function
- Increase mean arterial pressure
- Few benefits, increase in morbidity and mortality

a. Overgaard CB, et al. *Circulation*. 2008;118:1047-1056[5]; b. Emergency Management & Safety Solutions website[4]; c. Naidu S. *Circulation*. 2011;123:533-543.[1]

Hemodynamic Target

- Adequate perfusion: cardiac output (CO) & mean arterial pressure (MAP)
- Cardiac power output (CPO) measured in watts, has been elucidated:
  - $\frac{\text{MAP X CO}}{451}$ (watts)
  - CO is necessary, but not sufficient for end-organ perfusion; adequate MAP also required

Indications for Cath Lab Hemodynamic Support



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Question 2

- Which one of the following is a primary goal of hemodynamic support during high-risk PCI?
  - A. Increasing myocardial oxygen supply and demand
  - B. Decreasing myocardial oxygen supply and demand
  - C. Balancing myocardial perfusion against oxygen demand and supply
  - D. Ensuring complete revascularization during stent placement

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Question 3

- An axial flow pump affects myocardial oxygen demand by:?
  - A. Moving blood from the left ventricle to the aorta
  - B. Moving blood from left atrium into the systemic circulation
  - C. Creating a "pressure sink" in the left ventricle
  - D. Displacing venous blood into the arterial system

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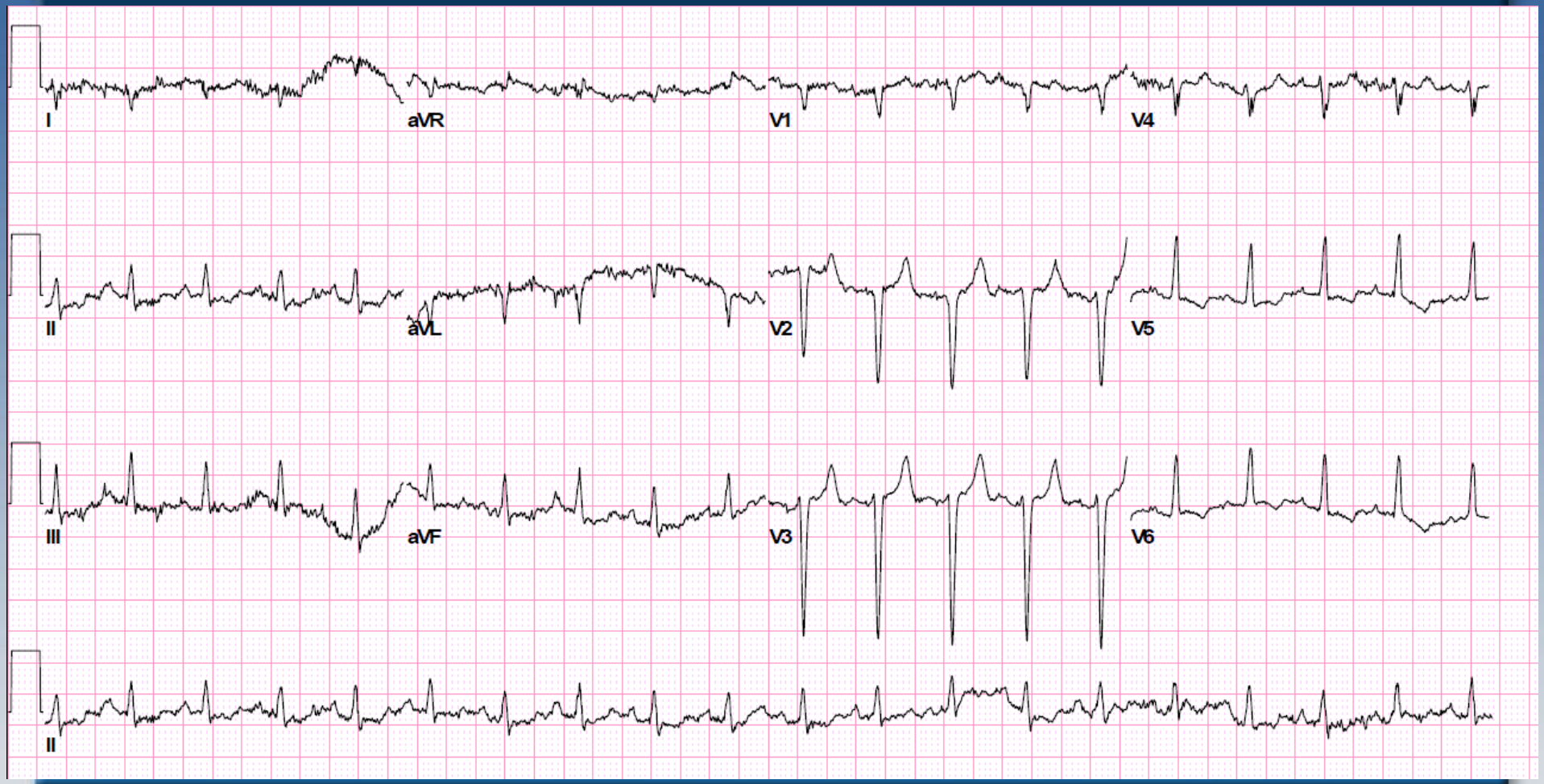
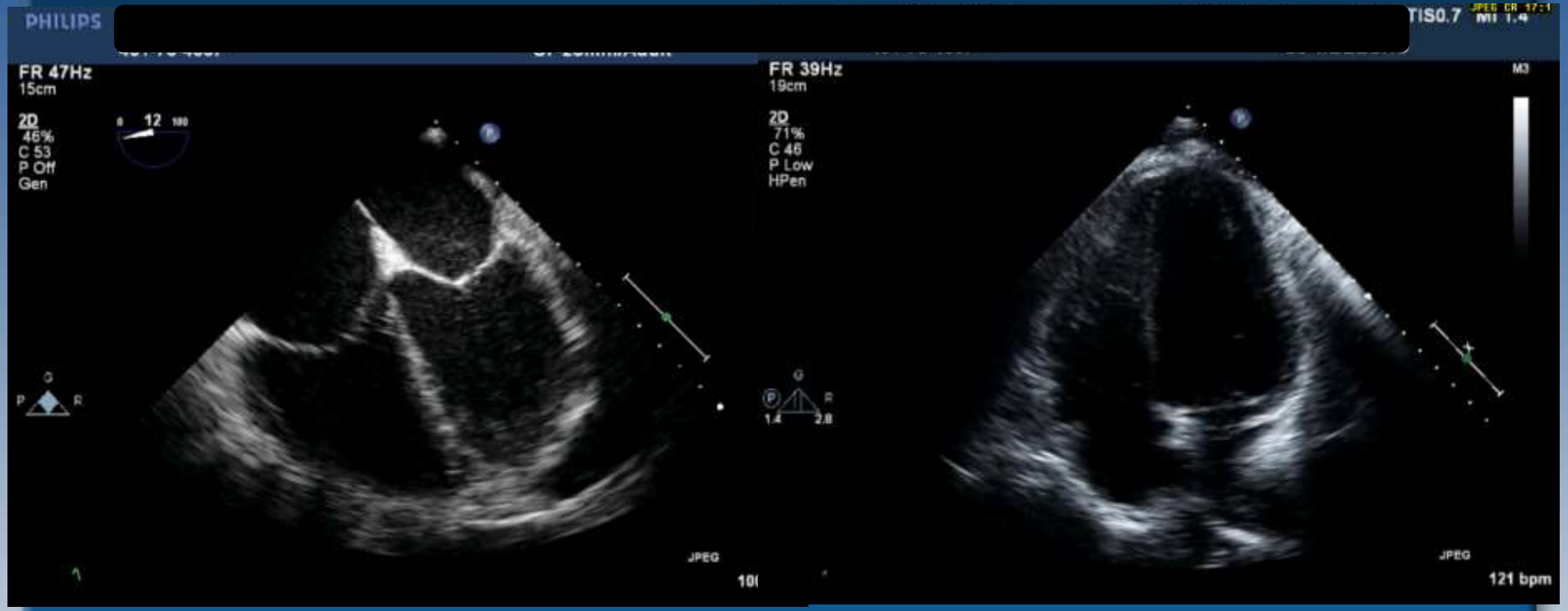
67 male, DM, smoker, PAD, prior stroke, LVEF=20%, anginal chest pain, referred for PCI following an elective coronary angiogram



Echocardiogram



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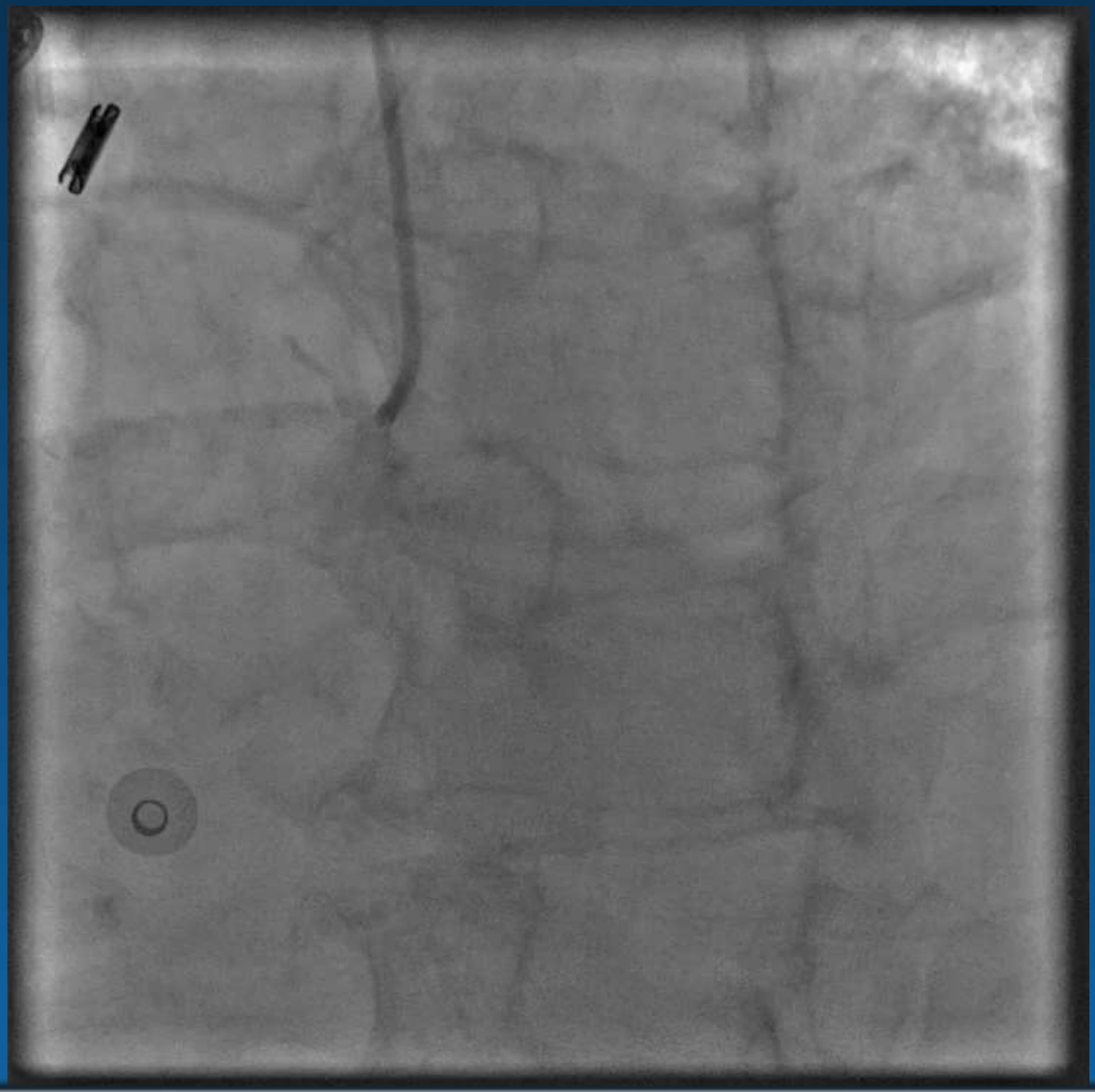
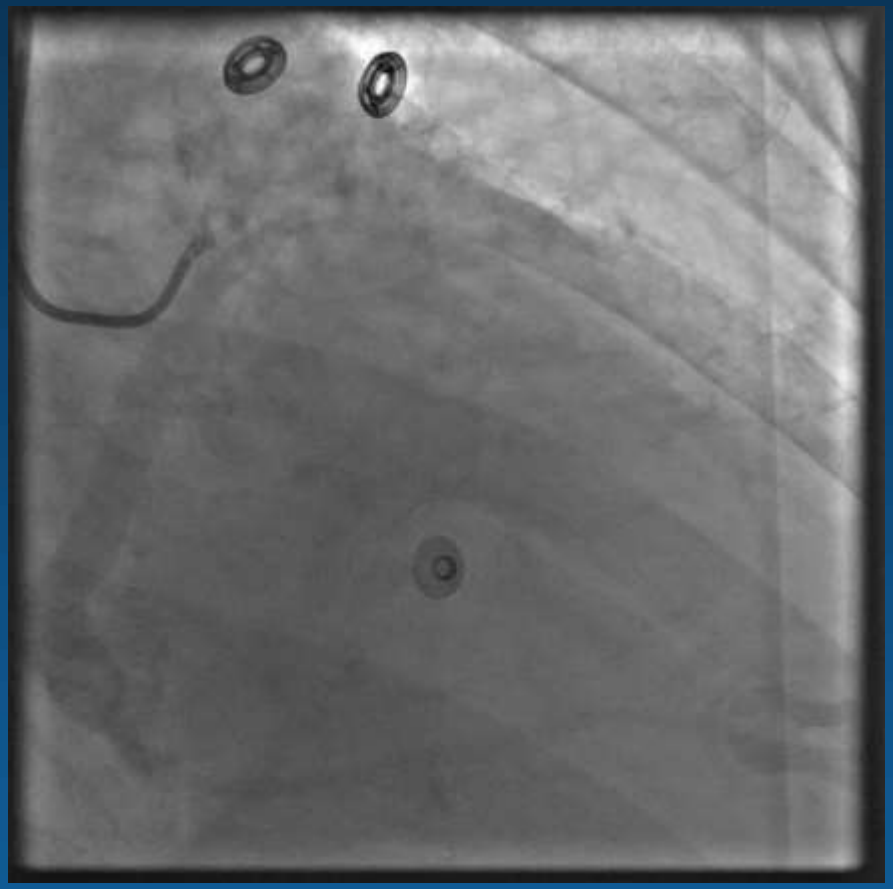
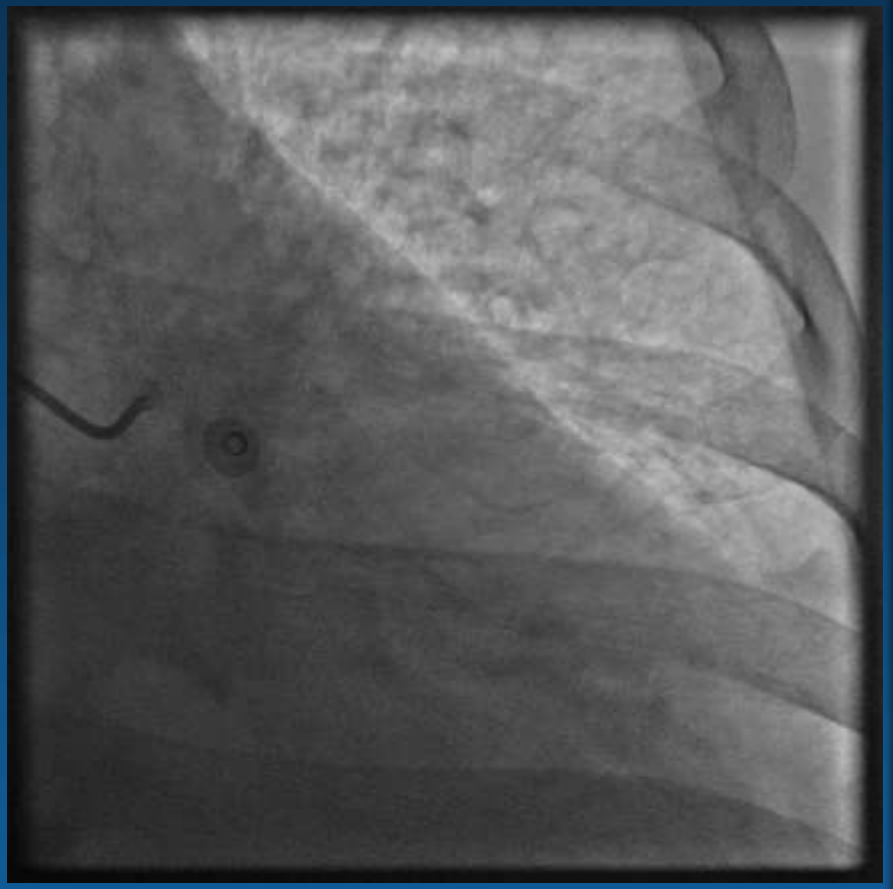
RCA Angiogram



Left Coronary Angiogram





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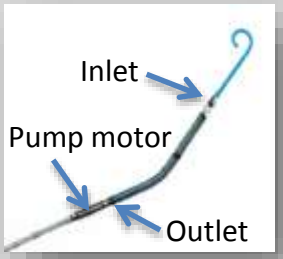
Question 4

Which of the following revascularization strategies would you recommend? Choose one of the following:

A. CABG
B. PCI with IABP support
C. PCI with Impella 2.5 support
D. PCI with TandemHeart
E. PCI with an additional arterial access for IABP, if needed

Impella™ Hemodynamic Support Catheters

Impella 2.5	Impella CP	Impella 5.0	Impella LD
			
9F catheter 2.5 L/min 12F pump motor	9F catheter 2.5 L/min 14F pump motor	9F catheter 5.0 L/min 21F pump motor	9F catheter 5.0 L/min 21F pump motor

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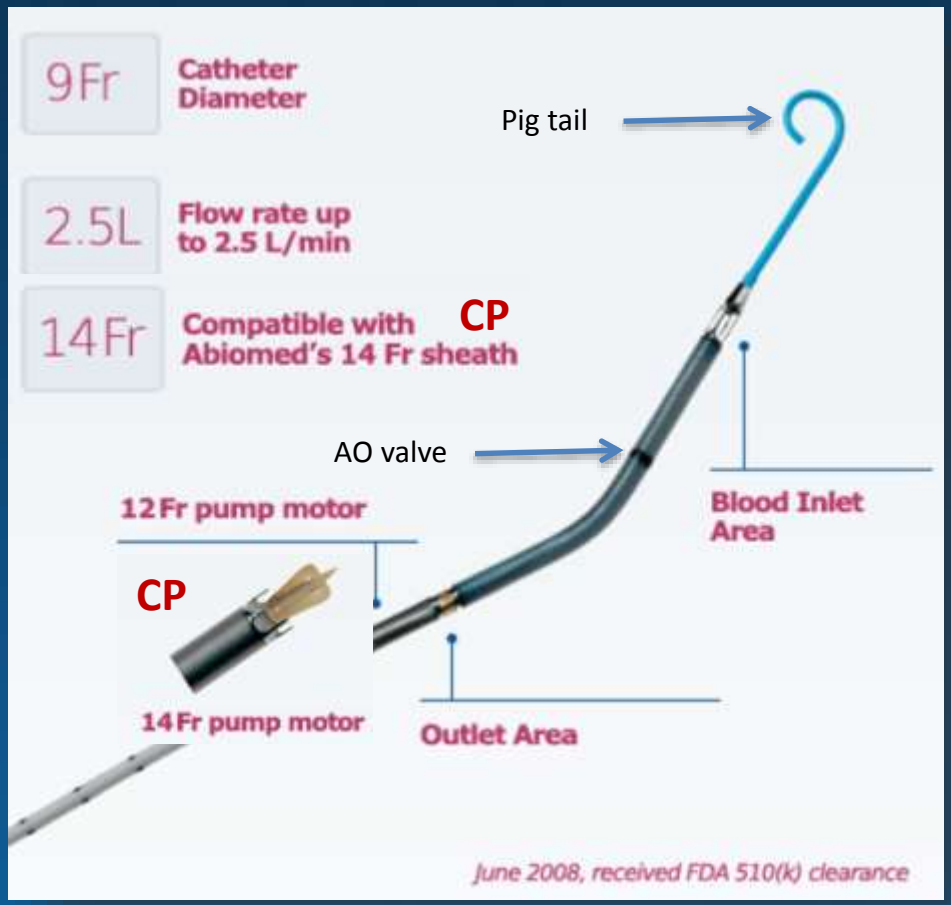
Impella™ 2.5/CP



Migration of Impella CP catheter

- The Impella 2.5 catheter is an intravascular microaxial blood pump that delivers up to 2.5 L/min of forward flow blood from the left ventricle (LV) to the aorta (AO)
- Reduces LV end-diastolic volume
- Reduces LV end diastolic pressure
- Increases mean AO pressure & flow

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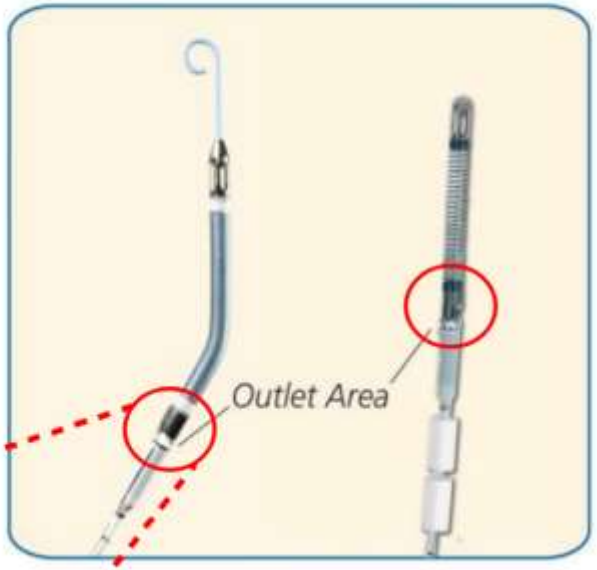
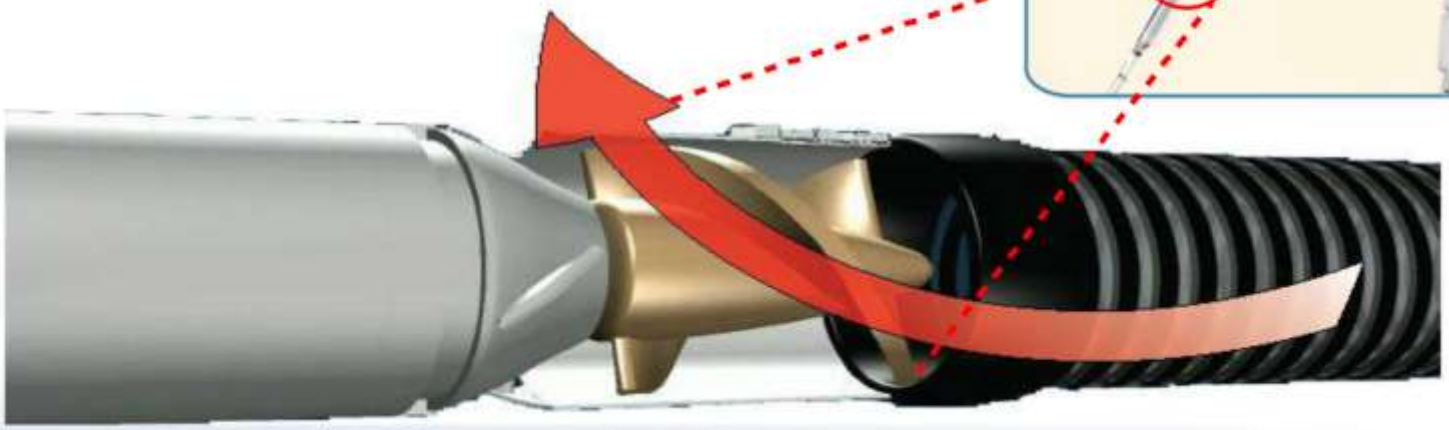
Impella™ Rotating Pump

Moving the Blood

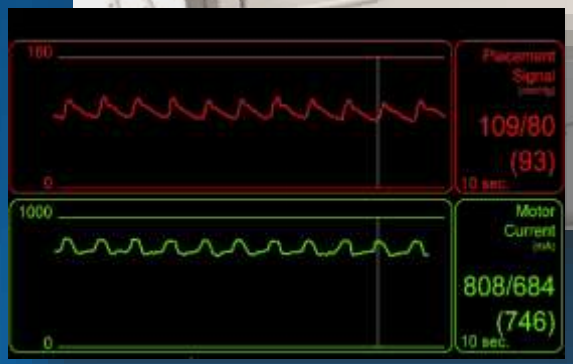
Rotating impeller pulls blood through the cannula

Faster rotation= Higher flow





Impella™ Controller



- Interface for monitoring & controlling the Impella catheter & purge system
- Purge system prevents blood from entering the catheter motor
- Hands-on demonstration

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Question 5

When correctly inserted and placed in the LV, Impella catheters reduce? Choose one of the following:

A. Aortic diastolic pressure
B. Left ventricular end diastolic volume
C. Left ventricular end diastolic pressure
D. All of the above
E. Only B and C

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Target Hemodynamics

- Low CVP could precipitate a suction alarm
- Controller may reduce motor speed if a low volume state exists
- Rapid infusion of appropriate crystalloid or colloid solution may resolve the alarm
- Is Swan in place: SG CO = Impella flow + LV ejection
- Native LV will be in competition for volume with Impella & will normally be reduced (unloaded)

Impella Management

- Identify controller alarms
- Echocardiography to assess positioning in addition to controller placement indicators
- Purge pressure & flow alarms
- CPR
- Removal & access site management
- Hemolysis, HIT, vascular complications

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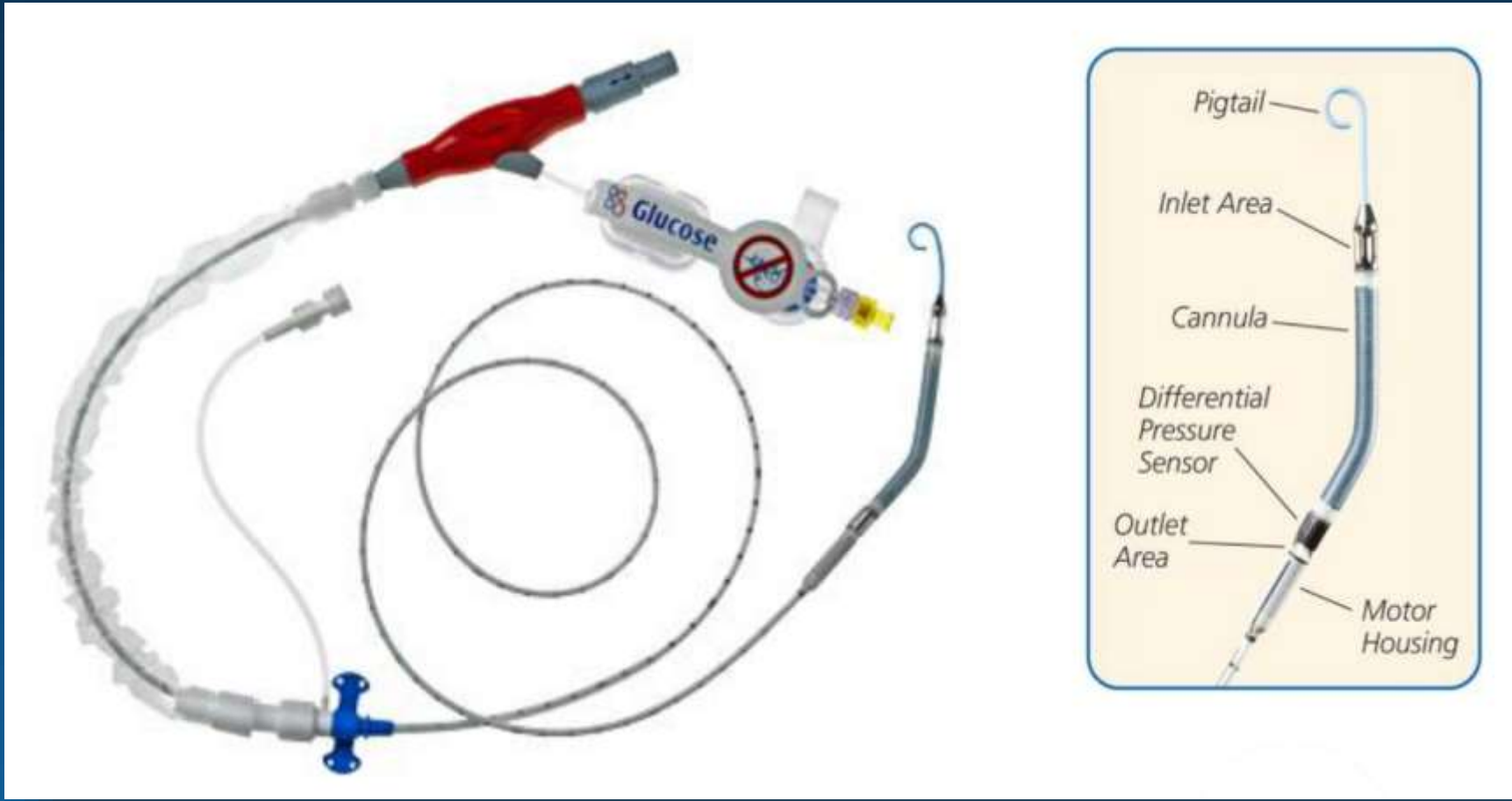
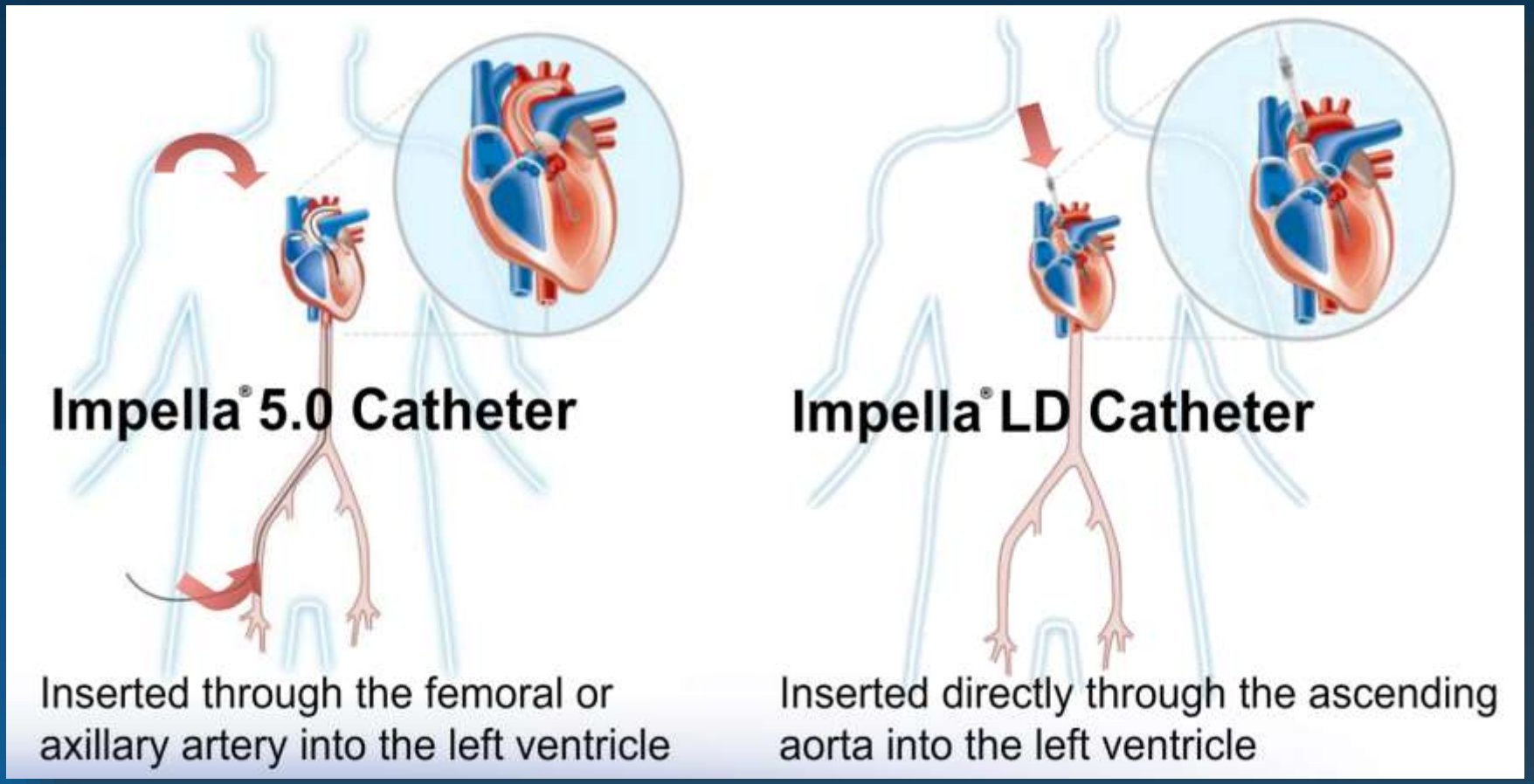
Impella™ 5.0



Impella™ 5.0 and LD Technology



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Question 6

Which one of the Impella catheters is correctly matched with its insertion description? Choose one of the following:

A. Impella 2.5 – percutaneous femoral artery
B. Impella 2.5 – only surgical cut down of femoral or axillary artery
C. Impella 5.0 – direct aortic insertion
D. Impella LD catheter – exclusively via femoral artery cut down

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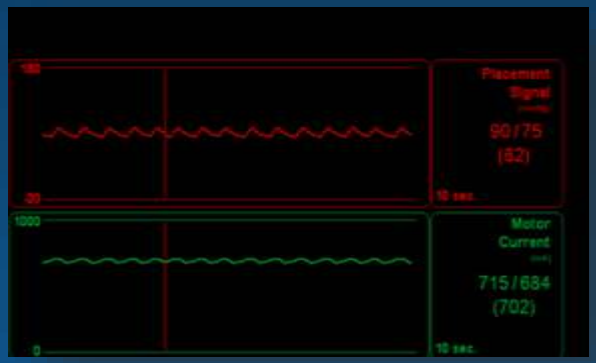
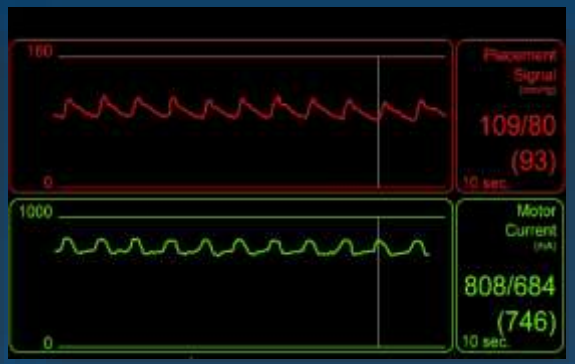
Question 7

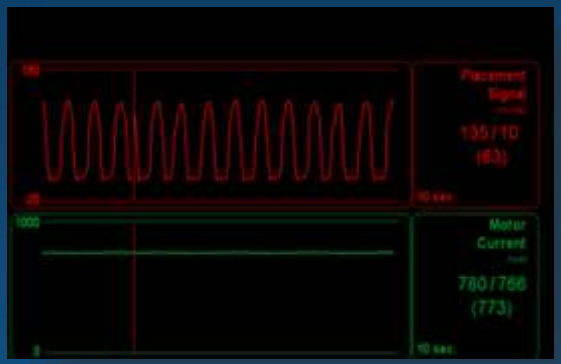
Which one of the Impella controller placement screens indicate that the Impella cannula is too far into the LV?



A



B



C

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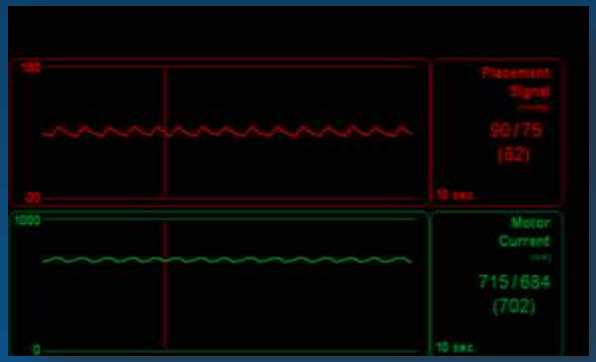
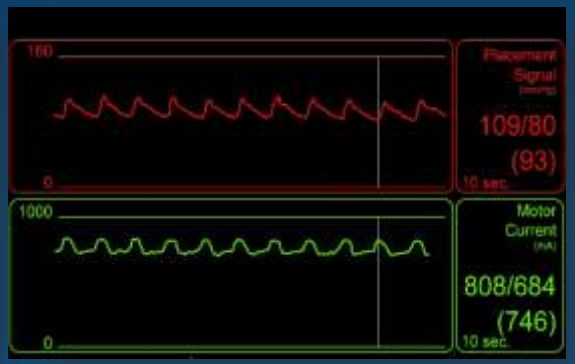
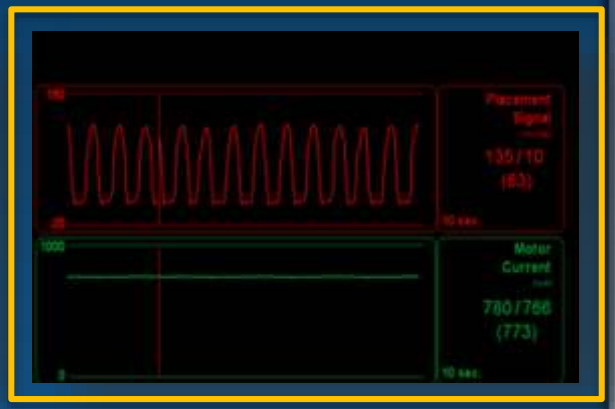


A

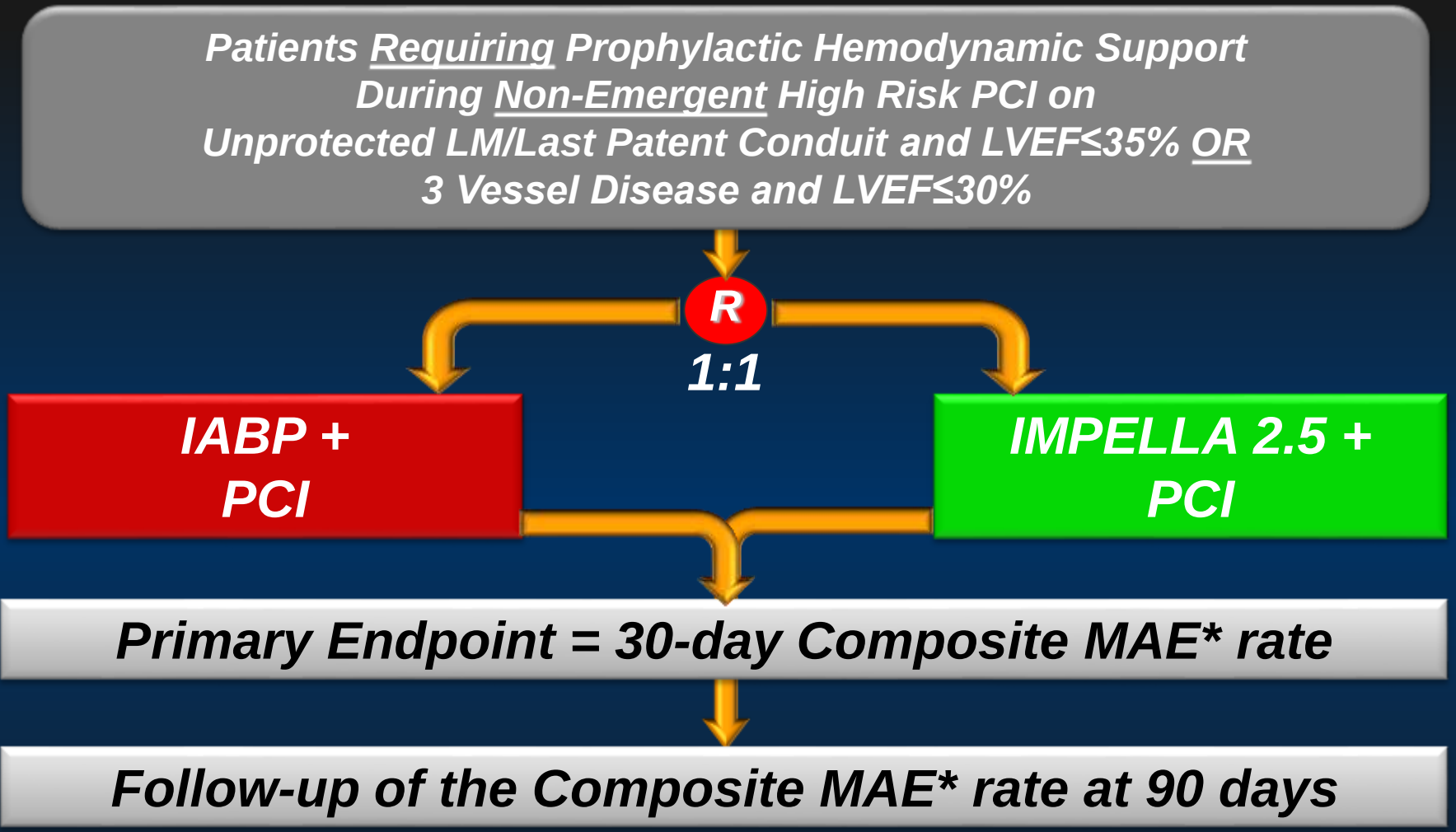


B



C

PROTECT II Trial Design



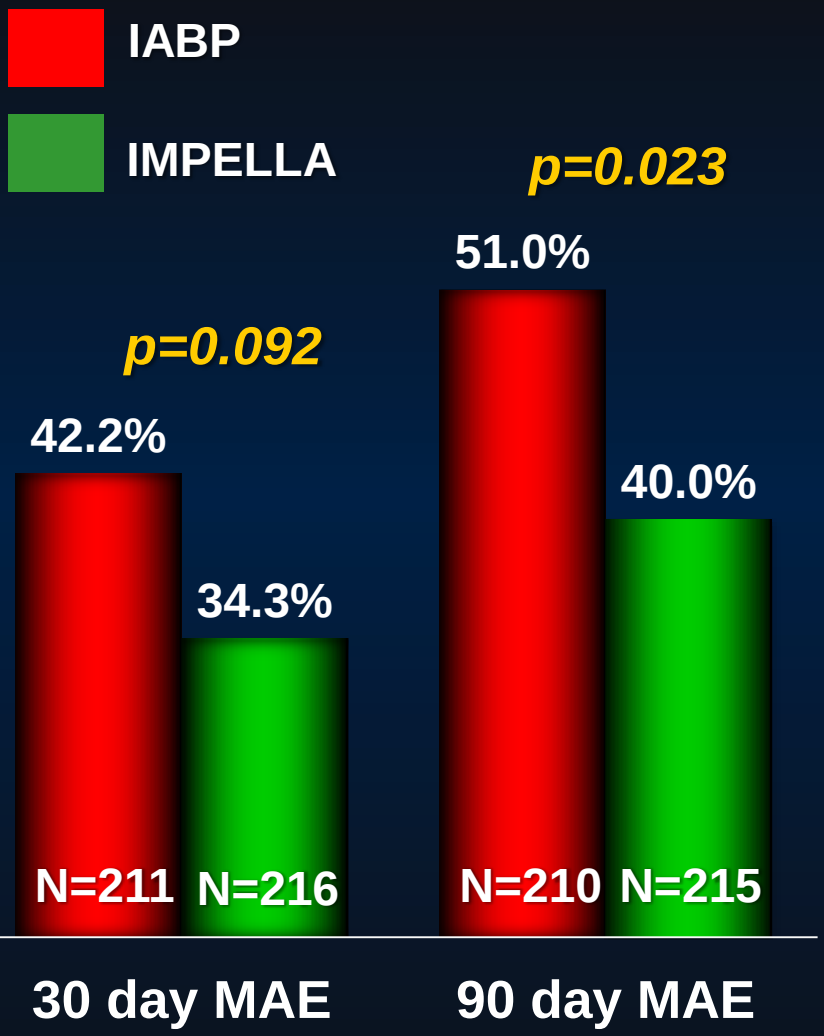
*Major Adverse Events (MAE) :
Death, MI (>3xULN CK-MB or Troponin) , Stroke/TIA, Repeat Revasc, Cardiac or Vascular Operation or Vasc. Operation for limb ischemia, Acute Renal Dysfunction, Increase in Aortic insufficiency, Severe Hypotension, CPR/VT, Angio Failure

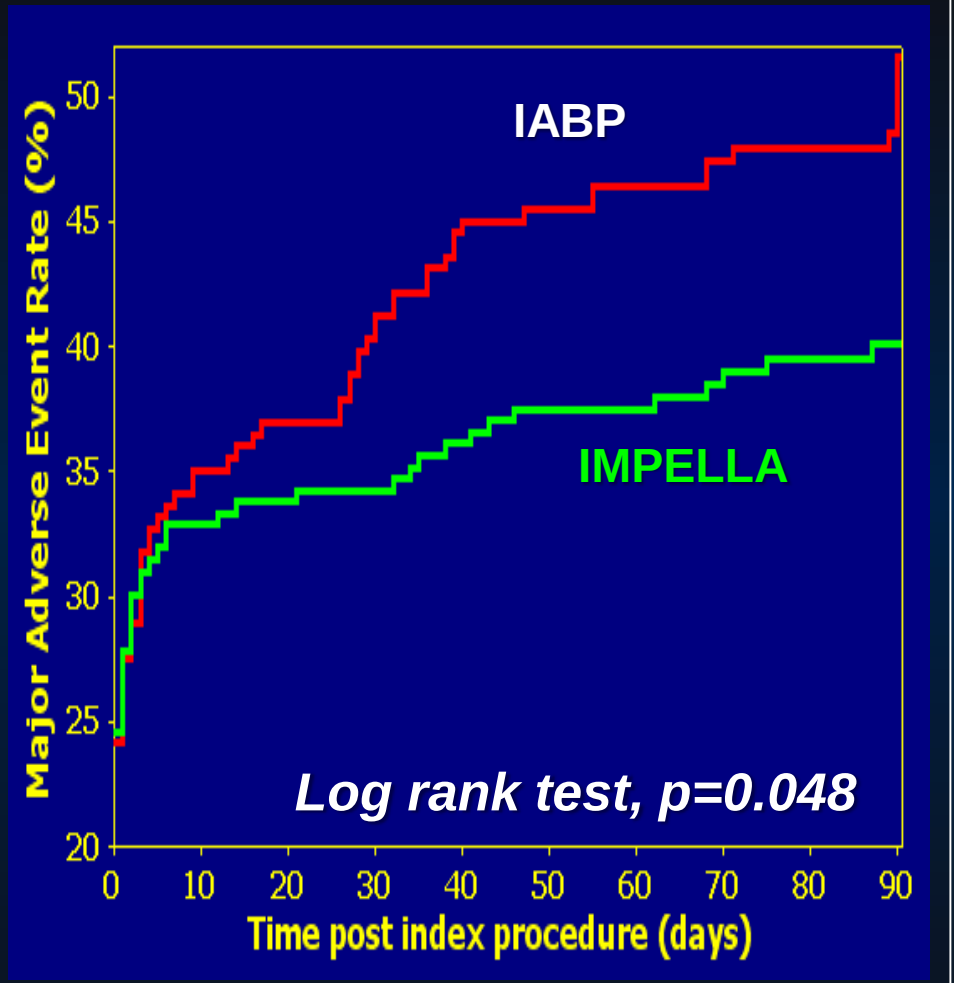
O'Neill et al, Circulation. 2012;126(14):1717-27

PROTECT II: Results

- Final cohort 452 patients
  - 3 withdrew consent (IABP arm)
  - 1 died (Impella 2.5 arm) before PCI
  - Full cohort included all 448 ITT patients randomly assigned to either Impella 2.5 (n=225) or IABP (n=223)
  - Pre-specified PP population: 427 –met eligibility criteria (216 for Impella 2.5 and 211 for IABP).

PROTECT II: Per Protocol MAE (N=427)



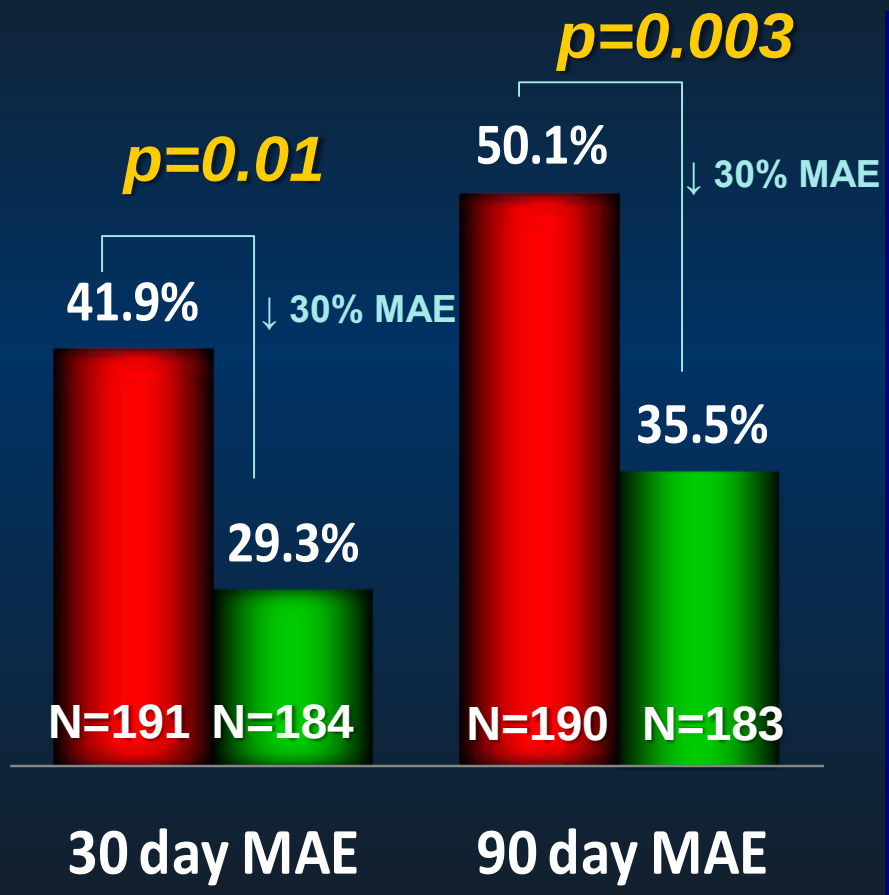


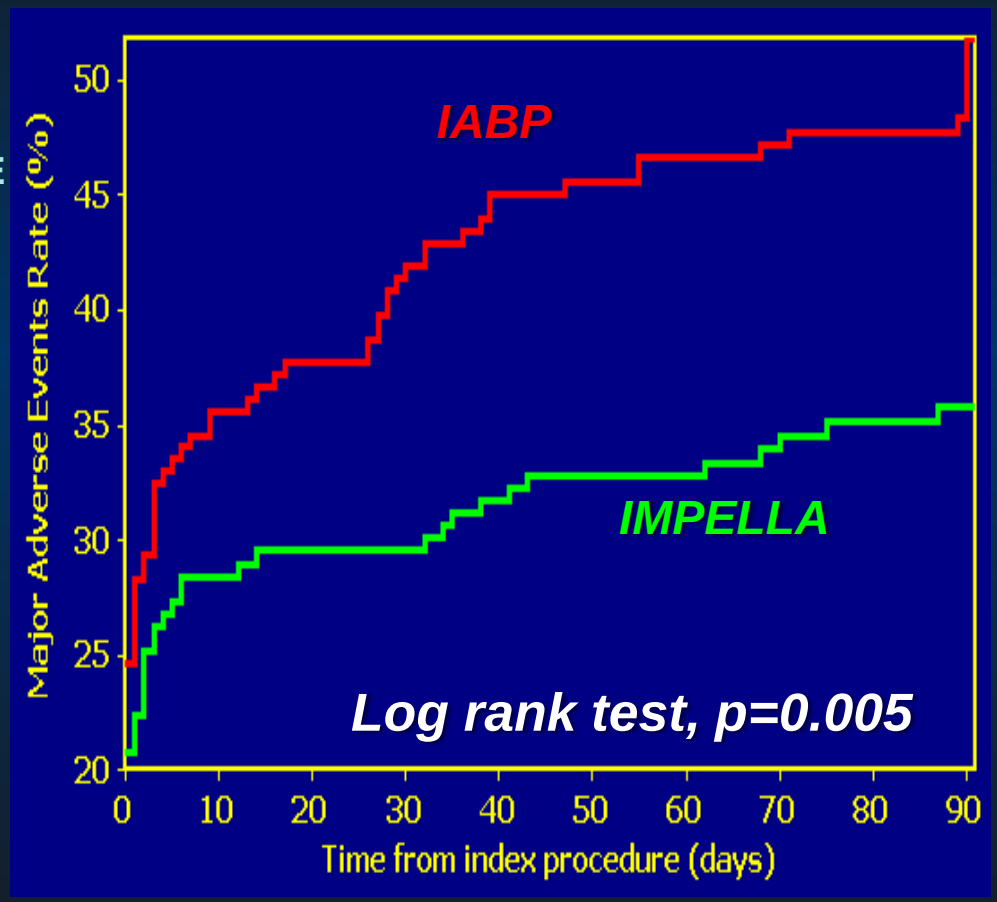
O'Neill et al, Circulation. 2012;126(14):1717-27

PROTECT II MAE Outcome

Pre-specified High Risk PCI Without Atherectomy Group

Per Protocol (N=374)

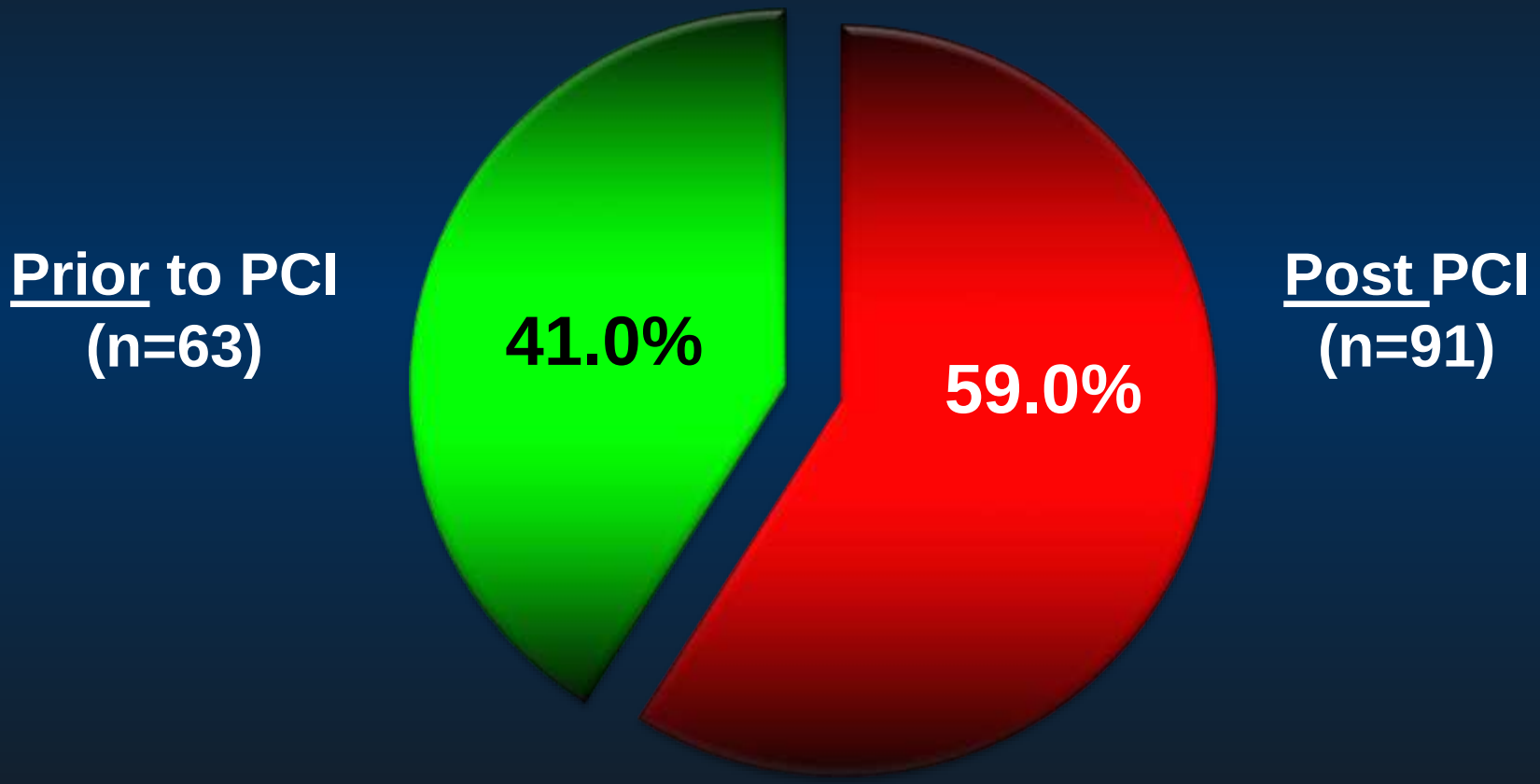




Cohen et al, Catheter Cardiovasc Interv. 2013 (In press)

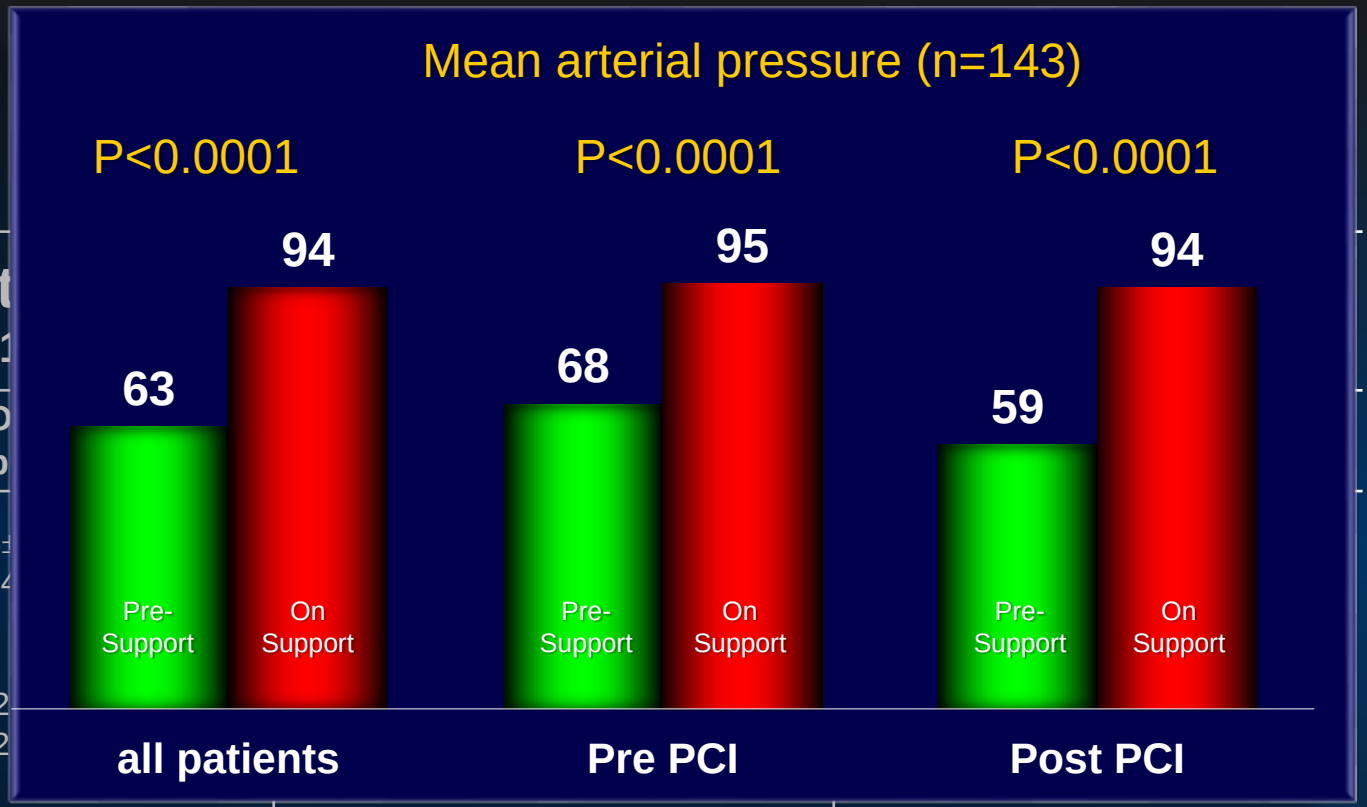
MAE= Major Adverse Event Rate

Impella® Insertion Timing (N= 154)



O'Neill et al, J Interven Cardiol 2013;9999:1-11

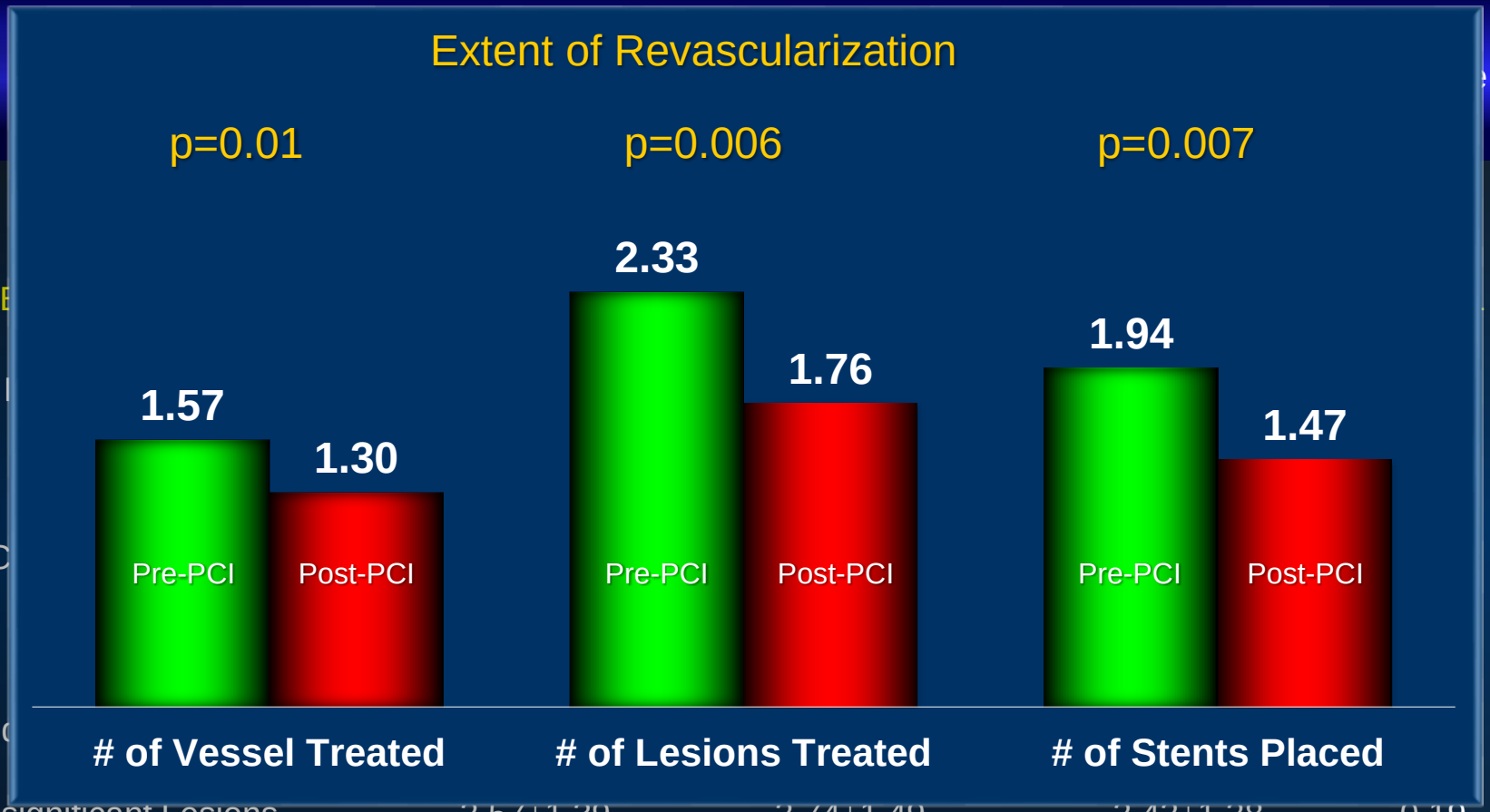
Hemodynamics



	All pat N = 1								
	Pre Support	O Sup							
MAP, mmHg	62.7±19.2 (143)	94.4± (14							
PCWP, mmHg	31.9±11.1 (25)	19.2 (2							
Cardiac Index, L/min/m^2	1.9±0.7 (23)	2.7±0.7 (23)	<0.0001	1.9±0.9 (7)	2.3±0.8 (7)	0.055	1.9±0.6 (16)	2.9±0.6 (16)	<0.0001
Cardiac Power Output, Watt	0.48±0.17 (23)	1.06±0.48 (23)	<0.0001	0.54±0.2 (7)	0.83±0.4 (7)	0.035	0.46±0.1 (16)	1.2±0.5 (16)	<0.0001

O'Neill et al, J Interven Cardiol 2013;9999:1-11

Procedural Characteristics

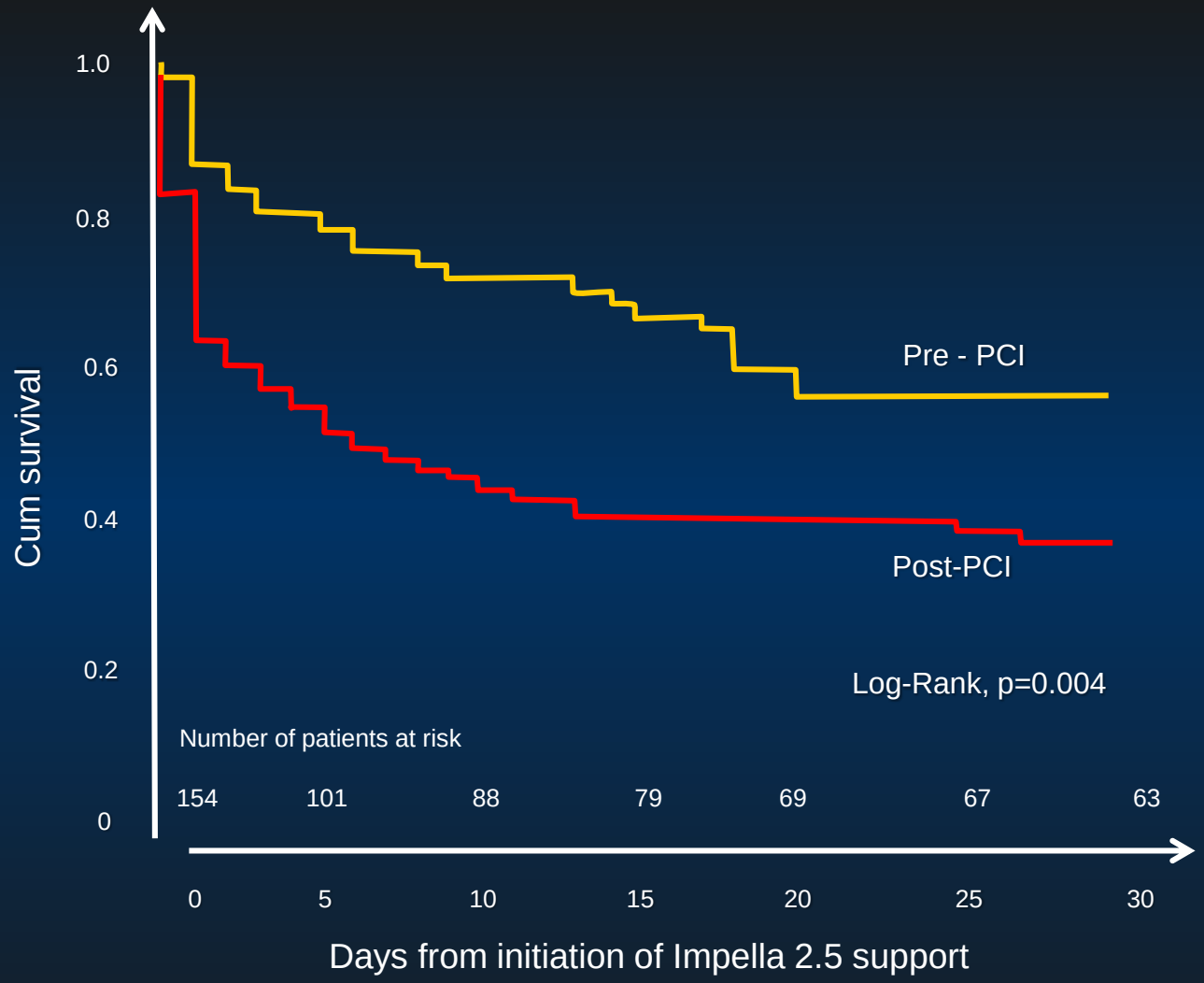


Duration of				
Median DTB				
Suspected I				
LM				
LAD				
Left C				
RCA				
Graft				
Number of				
Number of significant Lesions	2.57±1.39	2.74±1.49	2.42±1.28	0.19
Number of vessel treated	1.42±0.63	1.57±0.67	1.30±0.57	0.01
TIMI Flow [0-1] Prior to PCI	80.2%	71.9%	84.8%	0.14
TIMI Flow [0-1] Post PCI	8.7%	4.6%	11.9%	0.19

*: DTB time for patients admitted for STEMI

O'Neill et al, J Interven Cardiol 2013;9999:1-11

Outcome: Impella Pre or Post PCI



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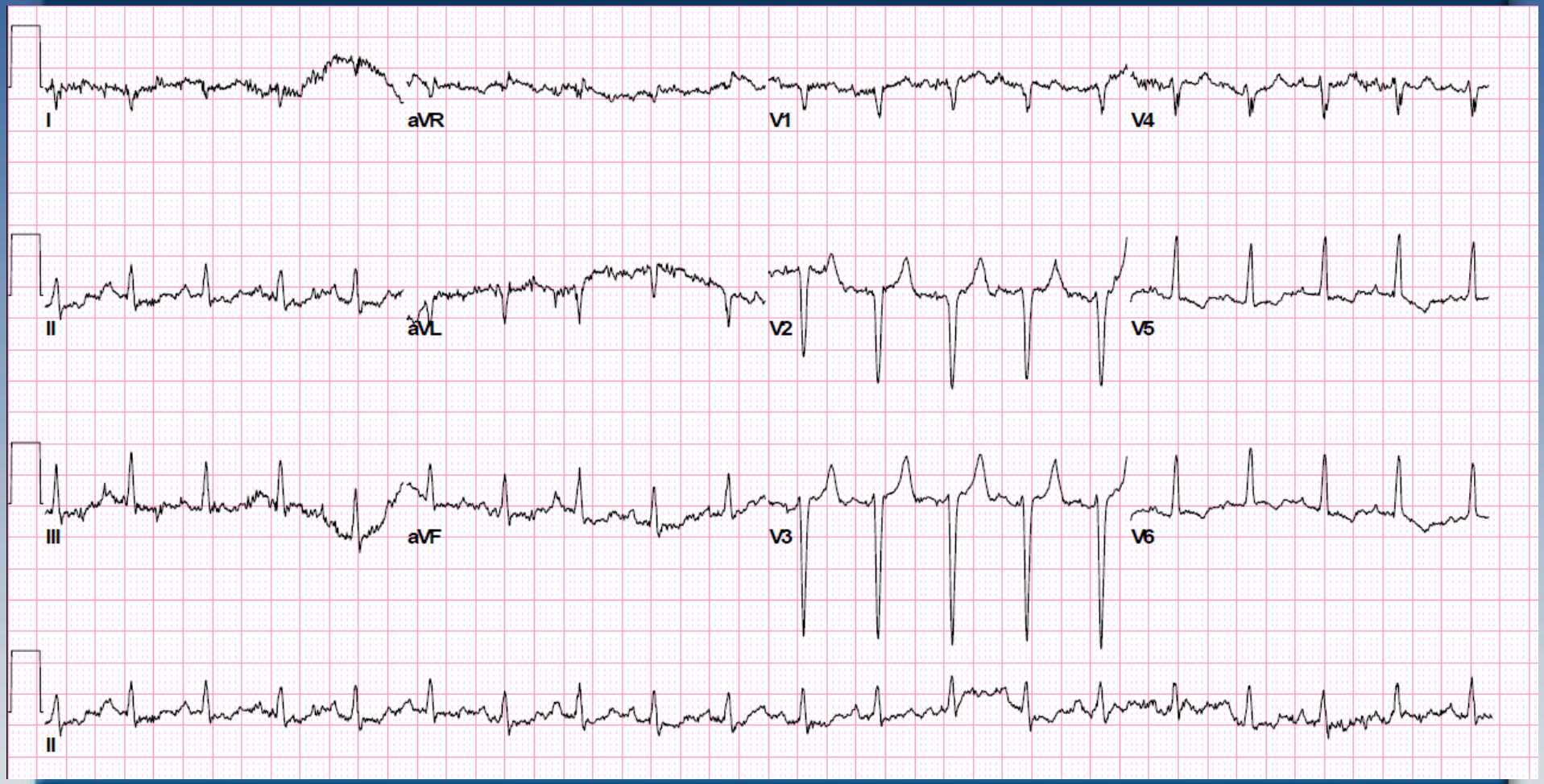
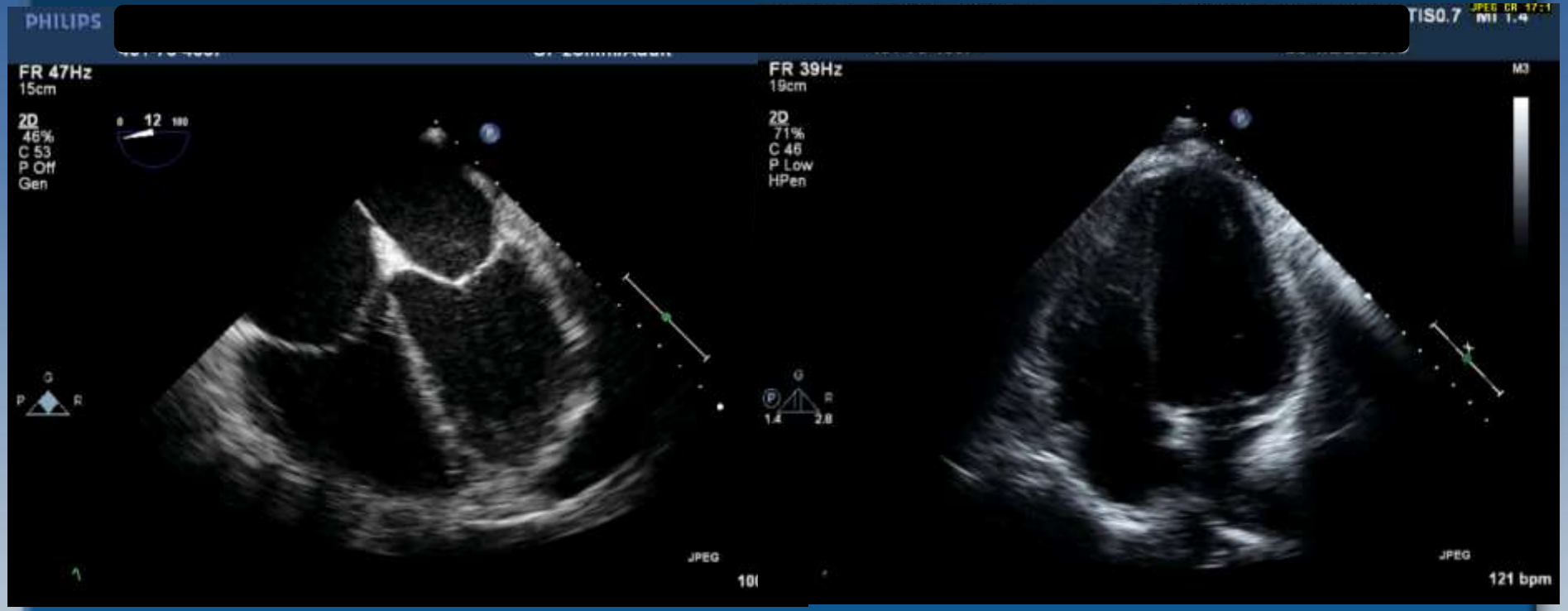


Echocardiogram



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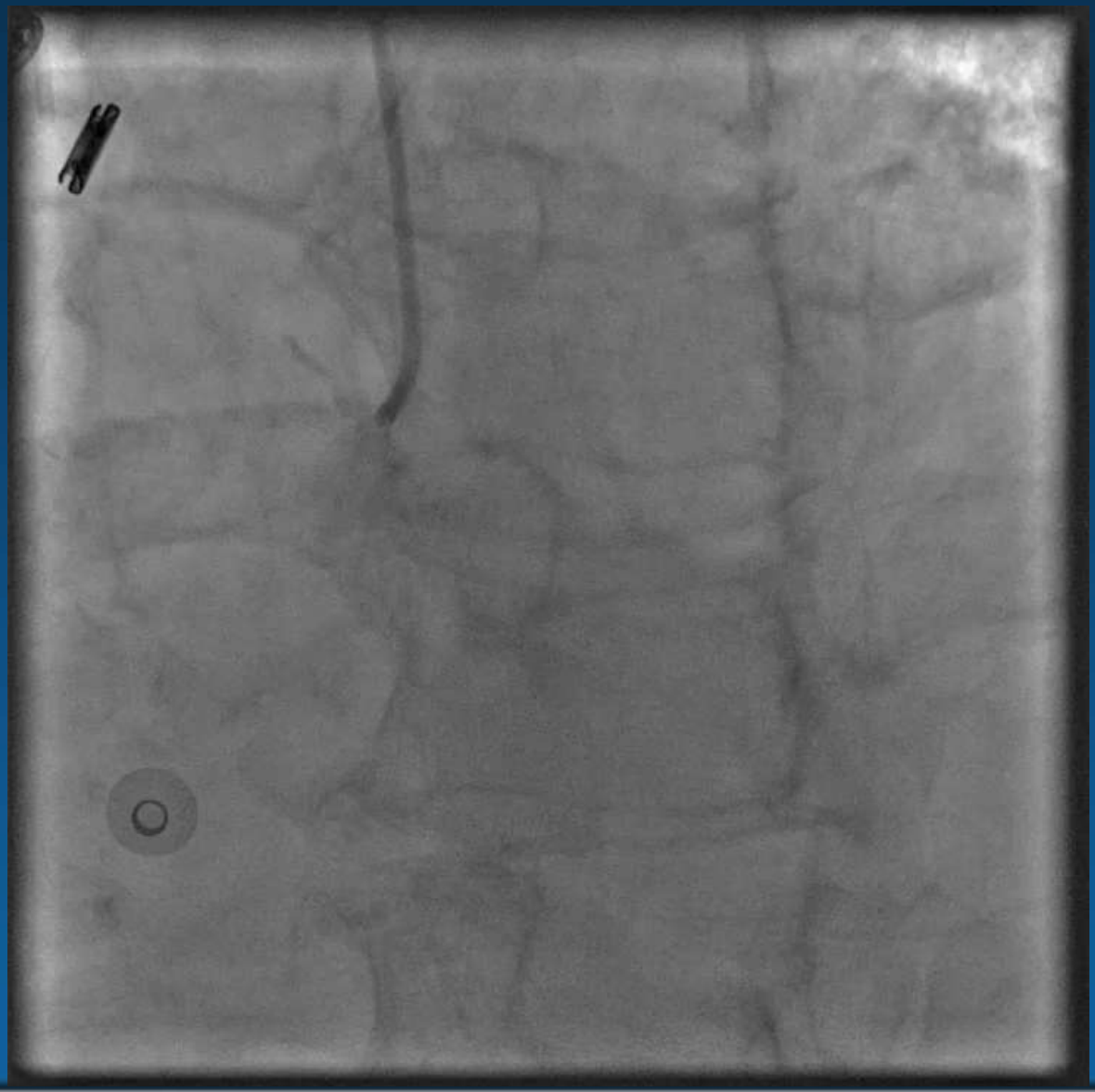
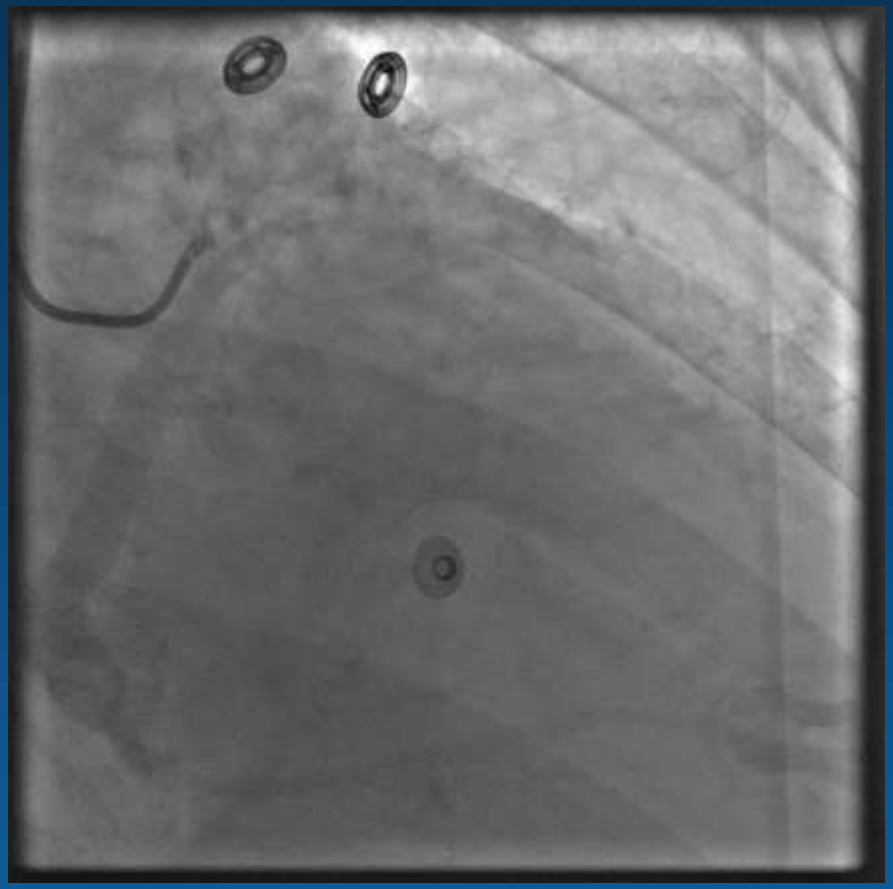
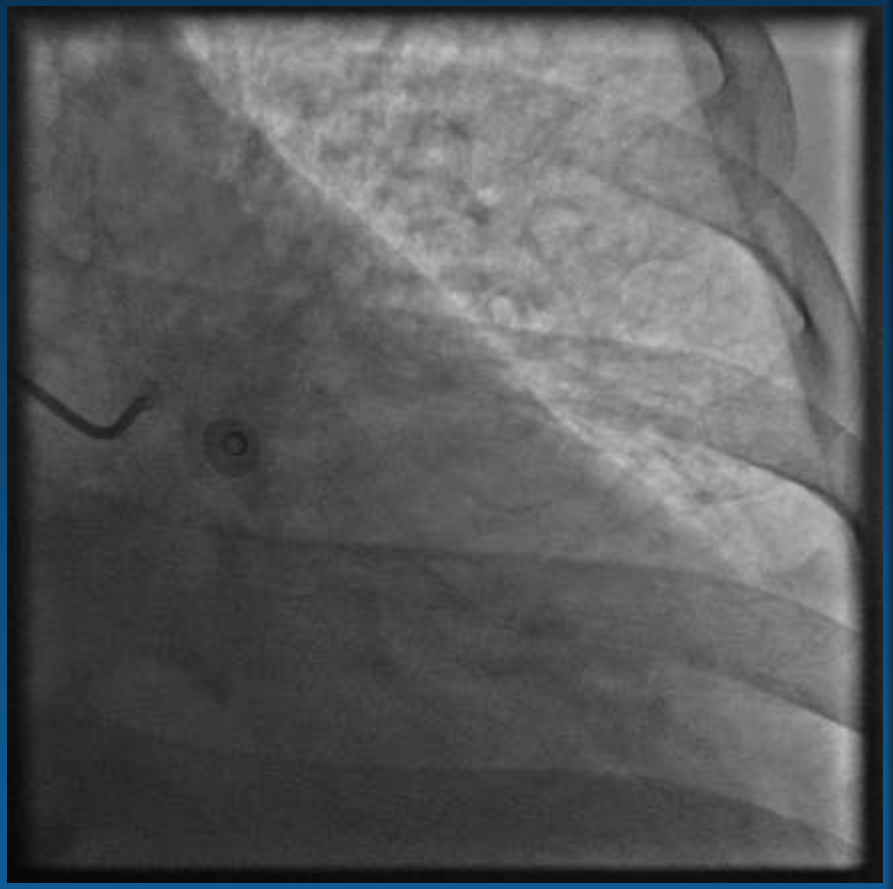
RCA Angiogram

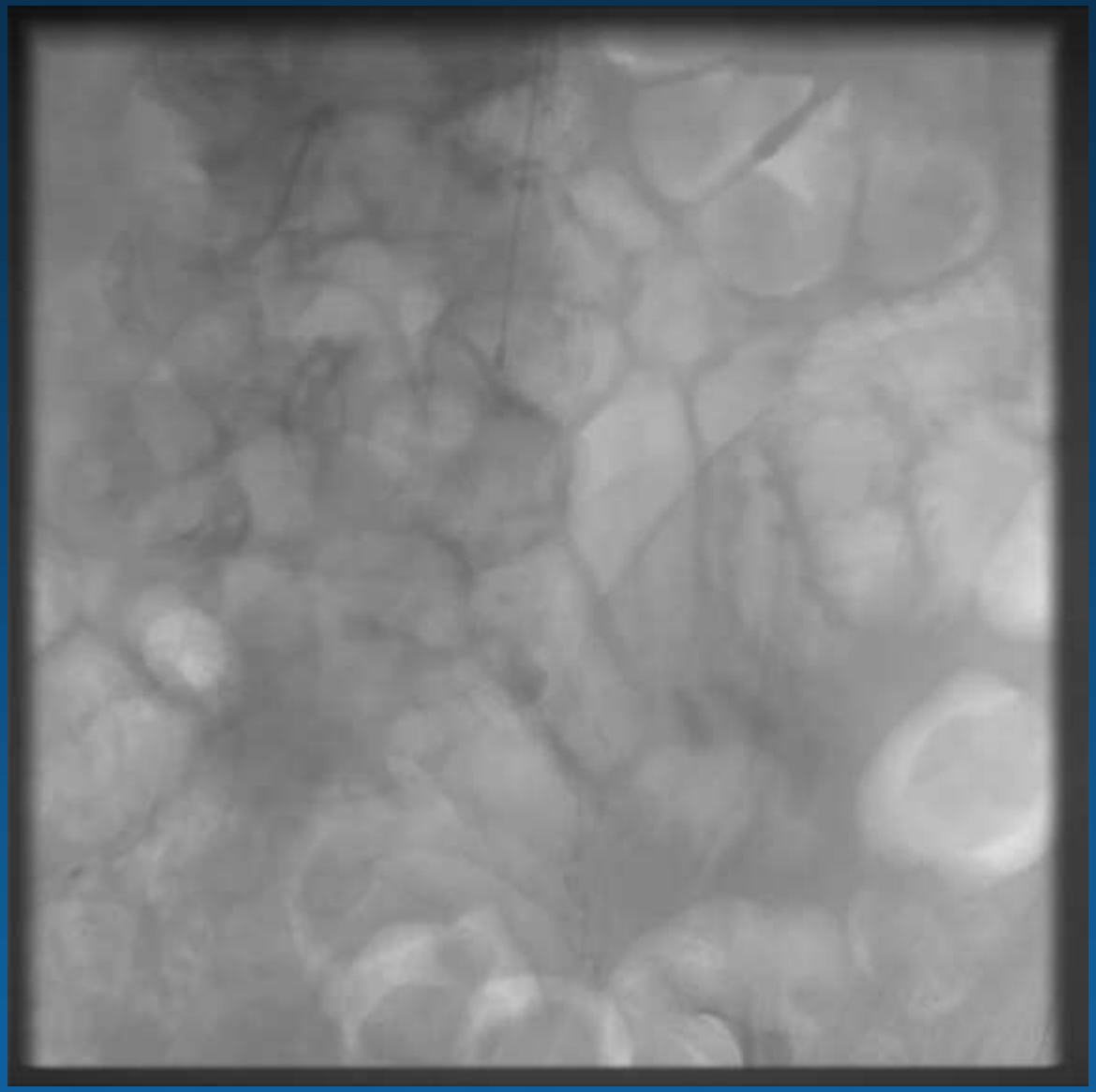


Left Coronary Angiogram

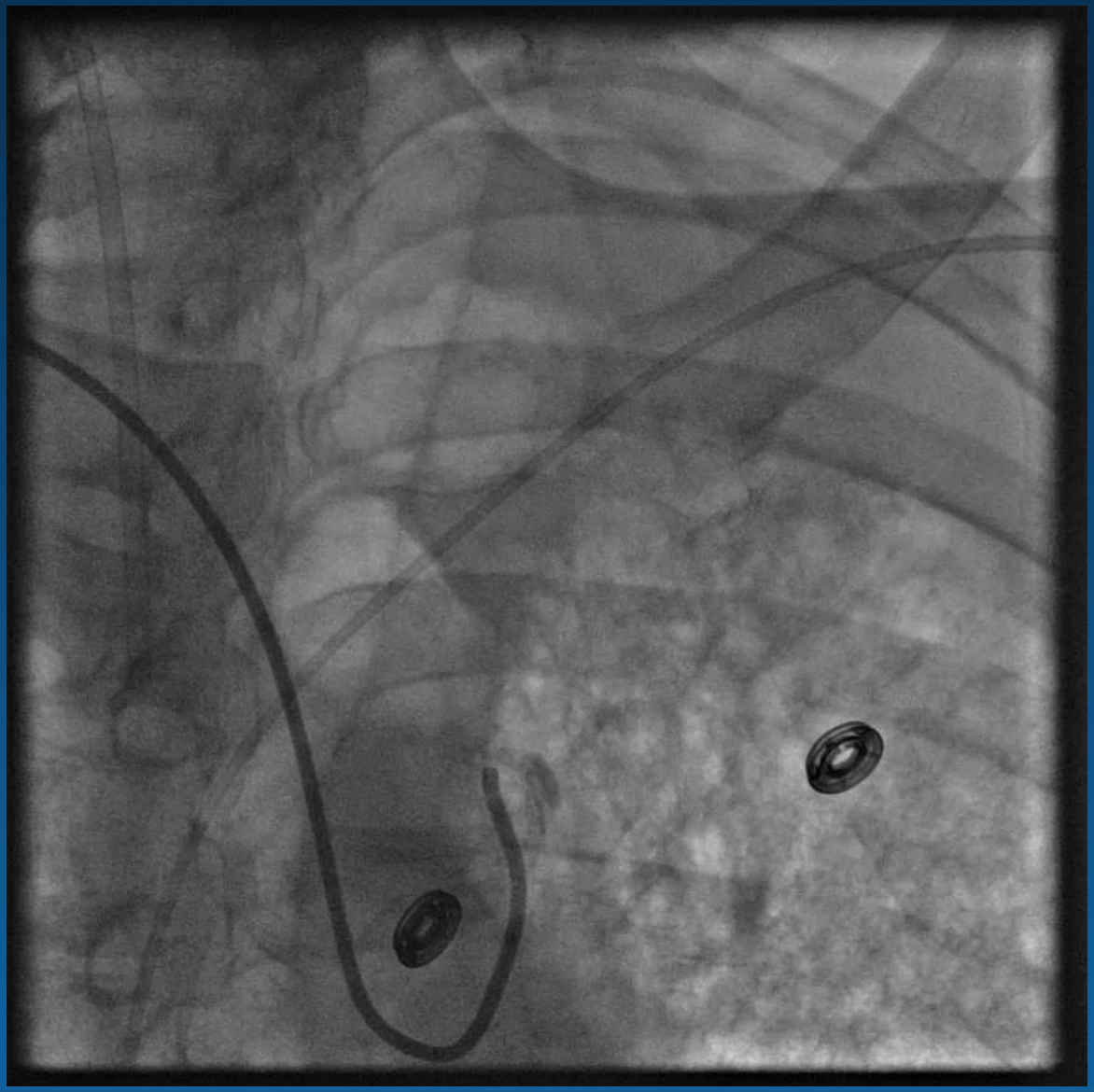




Distal Aortogram



Left Subclavian Artery Angiogram



Left Axillary Artery Percutaneous Access with Pre-closure

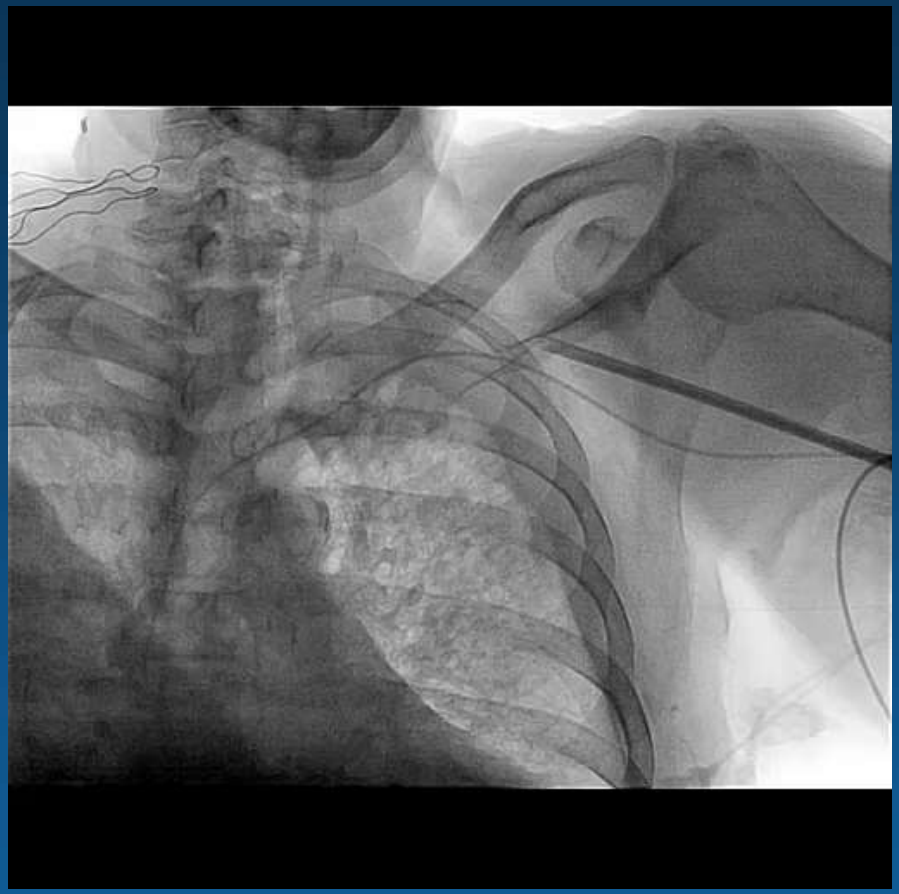
Left Axillary Artery Percutaneous Access with Pre-closure

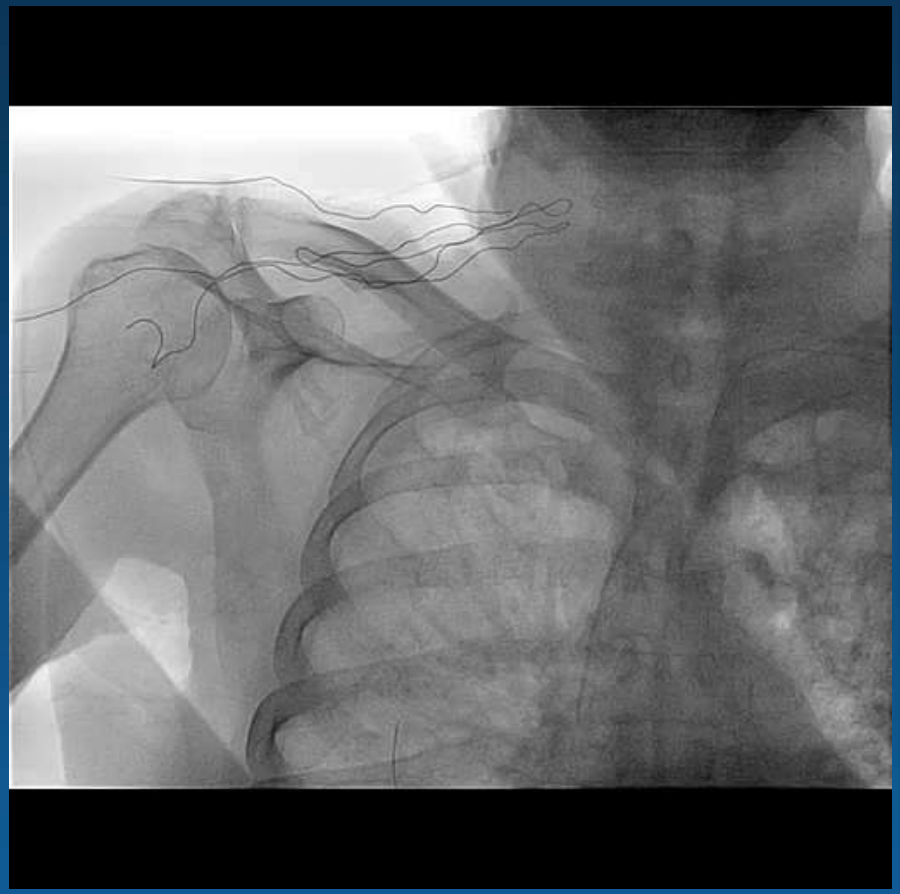
Left Axillary Artery Percutaneous Access with Pre-closure

Left Axillary Artery Percutaneous Access with Pre-closure

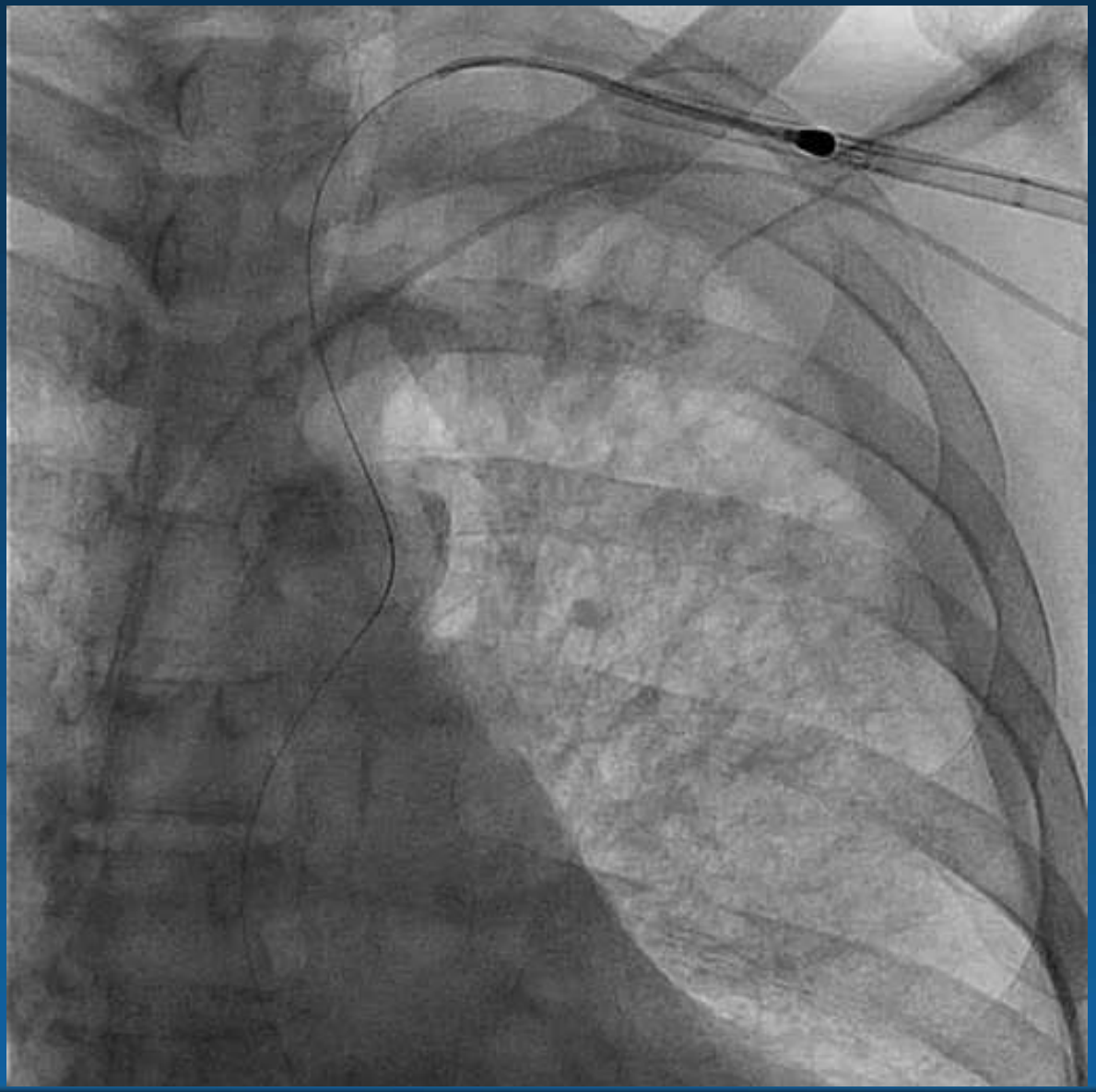
Left Axillary Artery Percutaneous Access with Pre-closure

LSCA Access

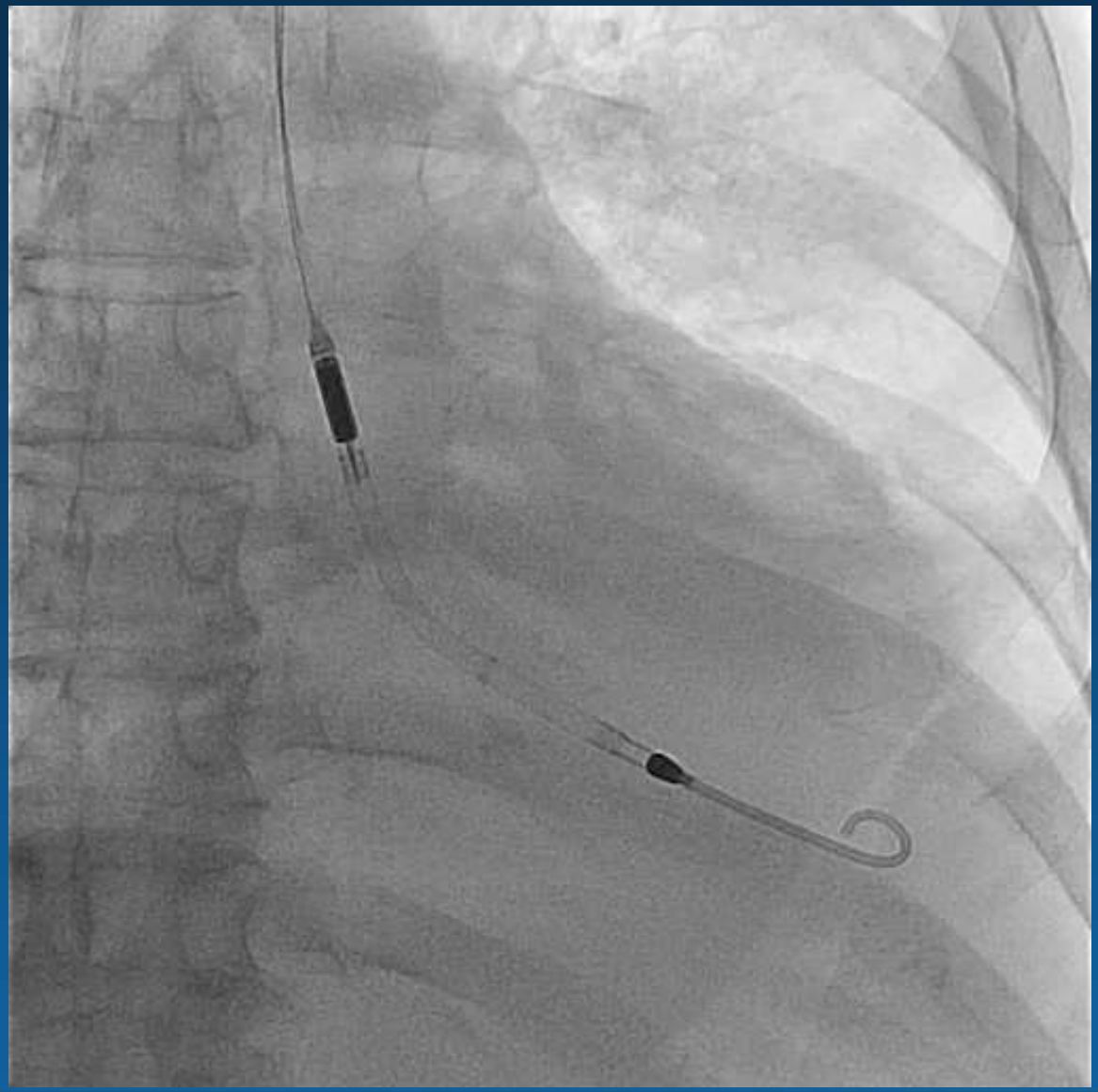




Impella 2.5 Insertion

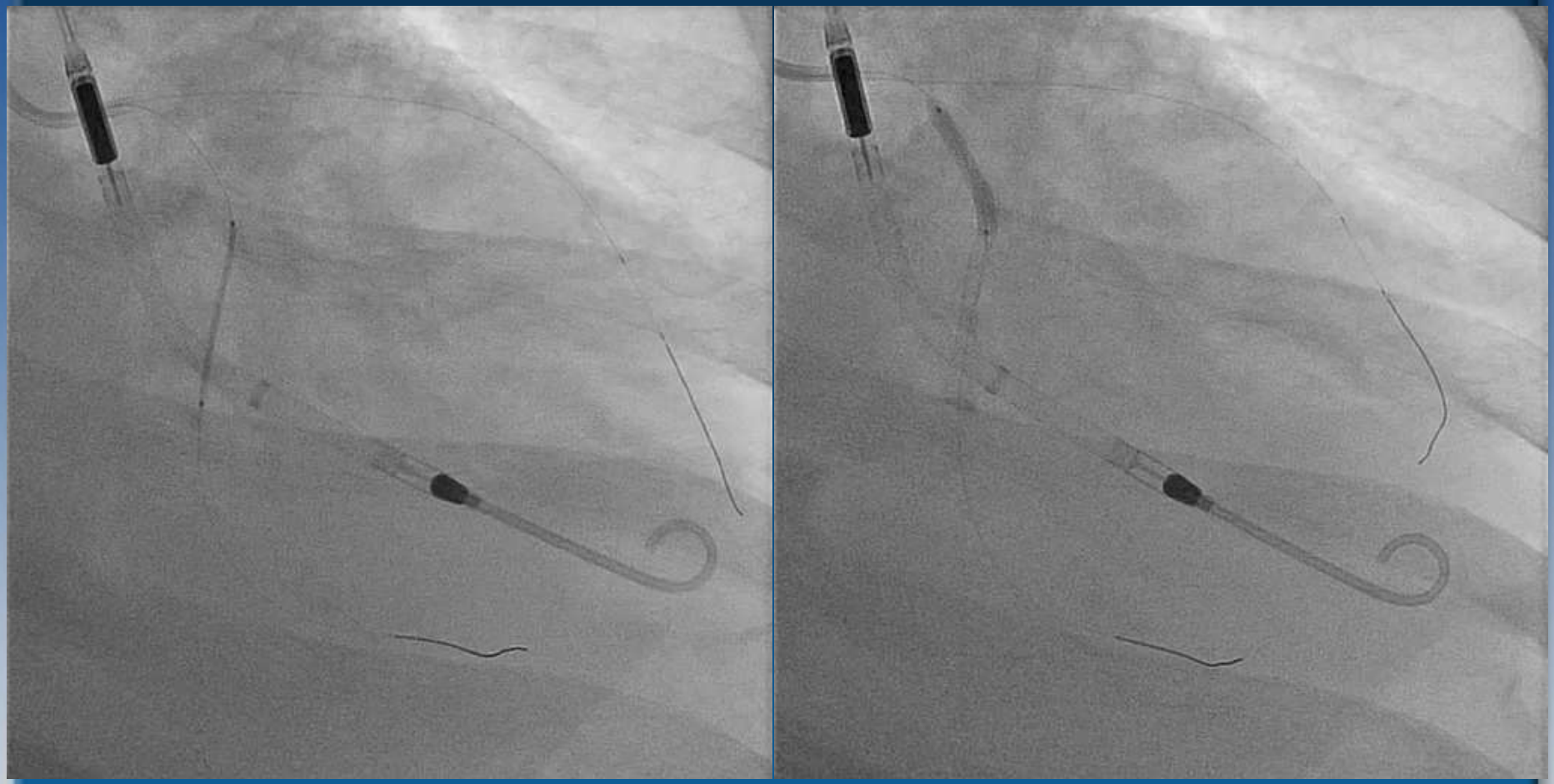


Impella 2.5 Insertion

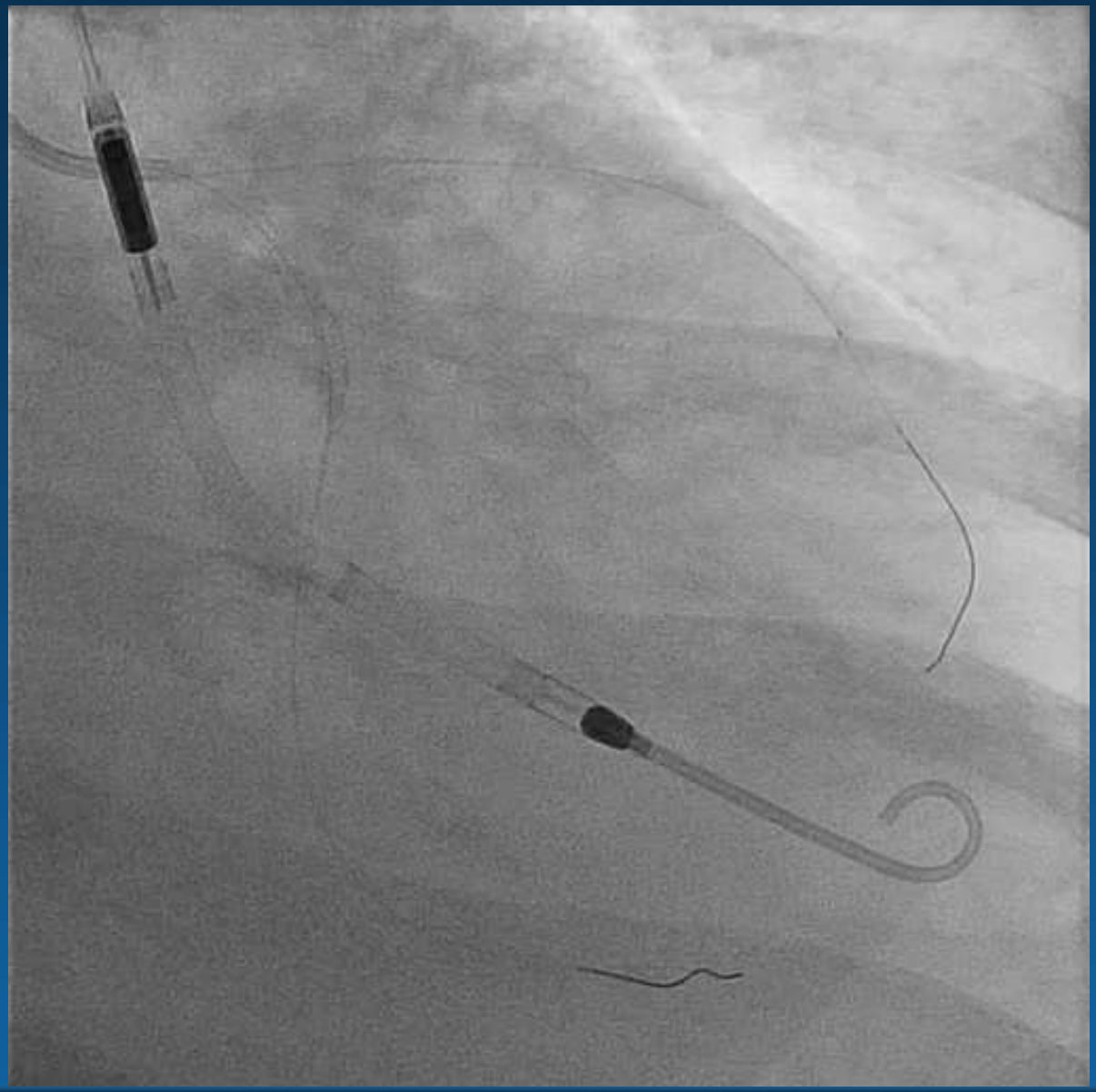


LM Guide Injection

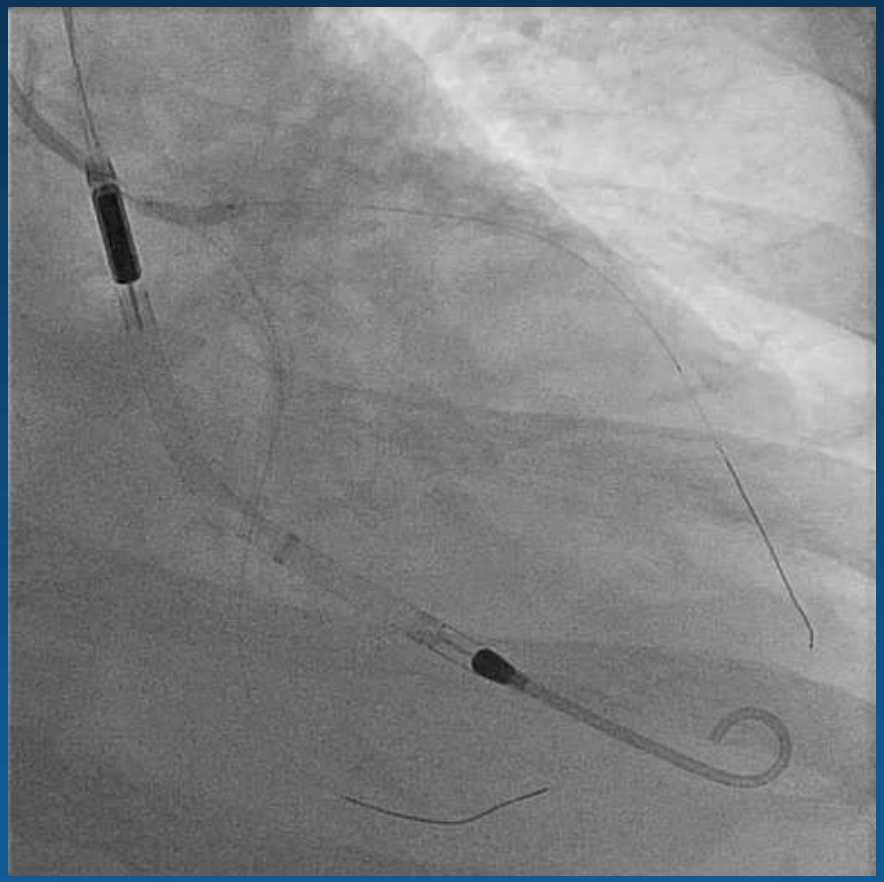
Left Circumflex Artery DES

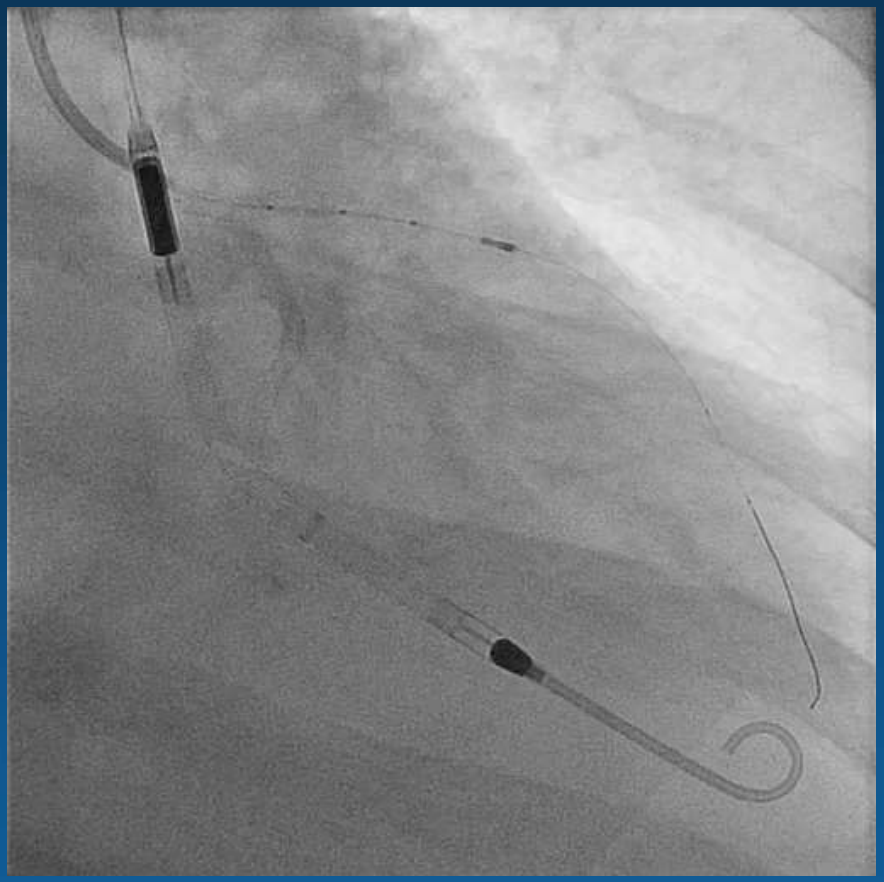


Post-LCX DES Implantation

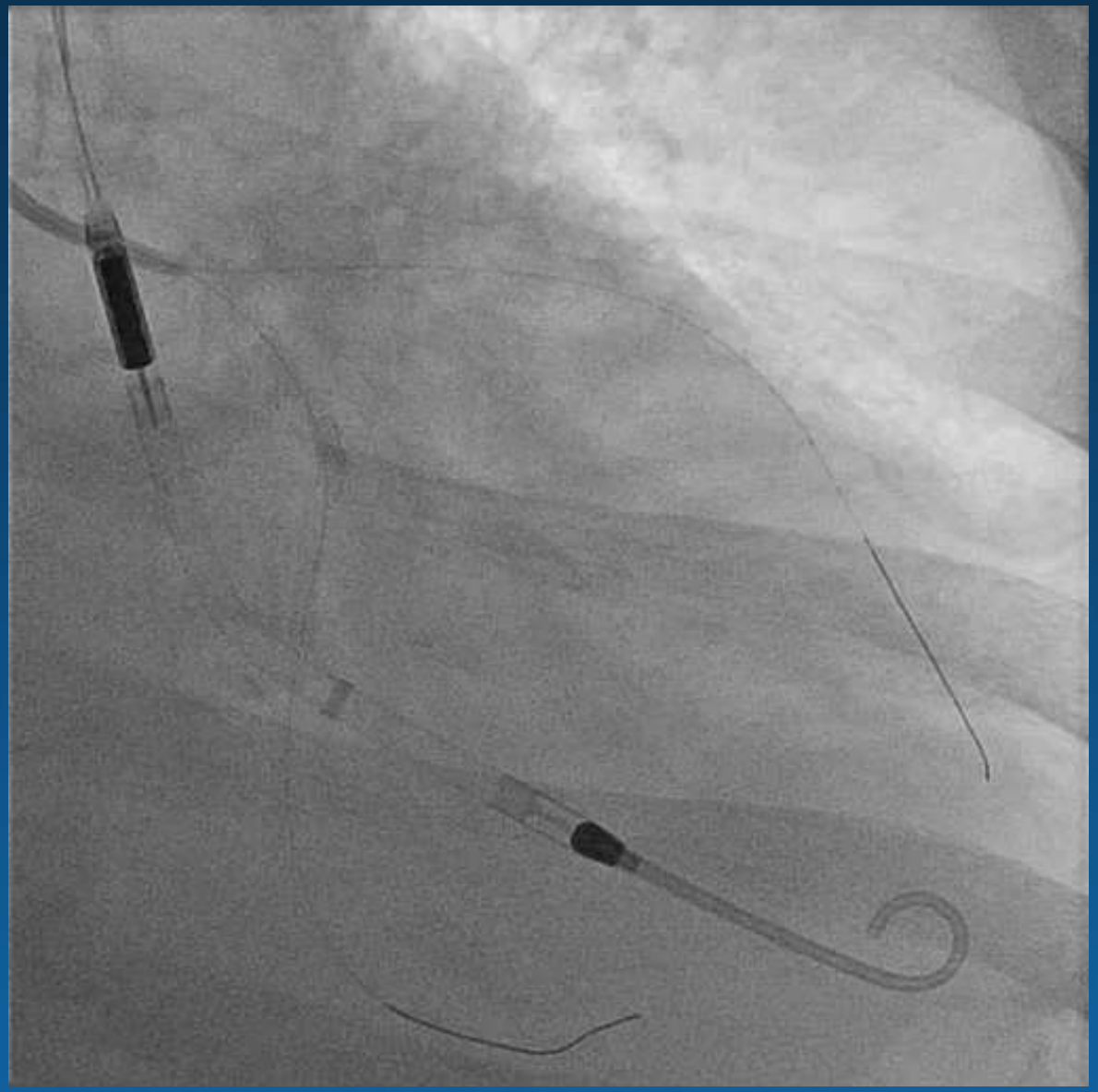


LM PTCA & IVUS

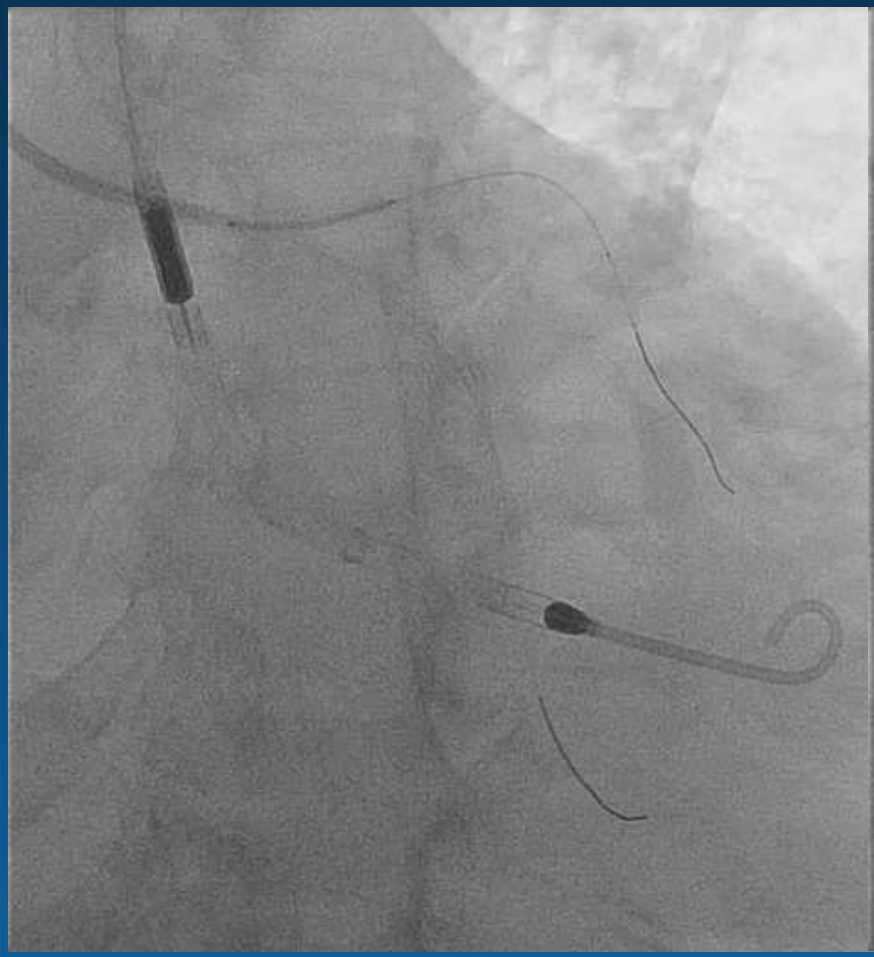


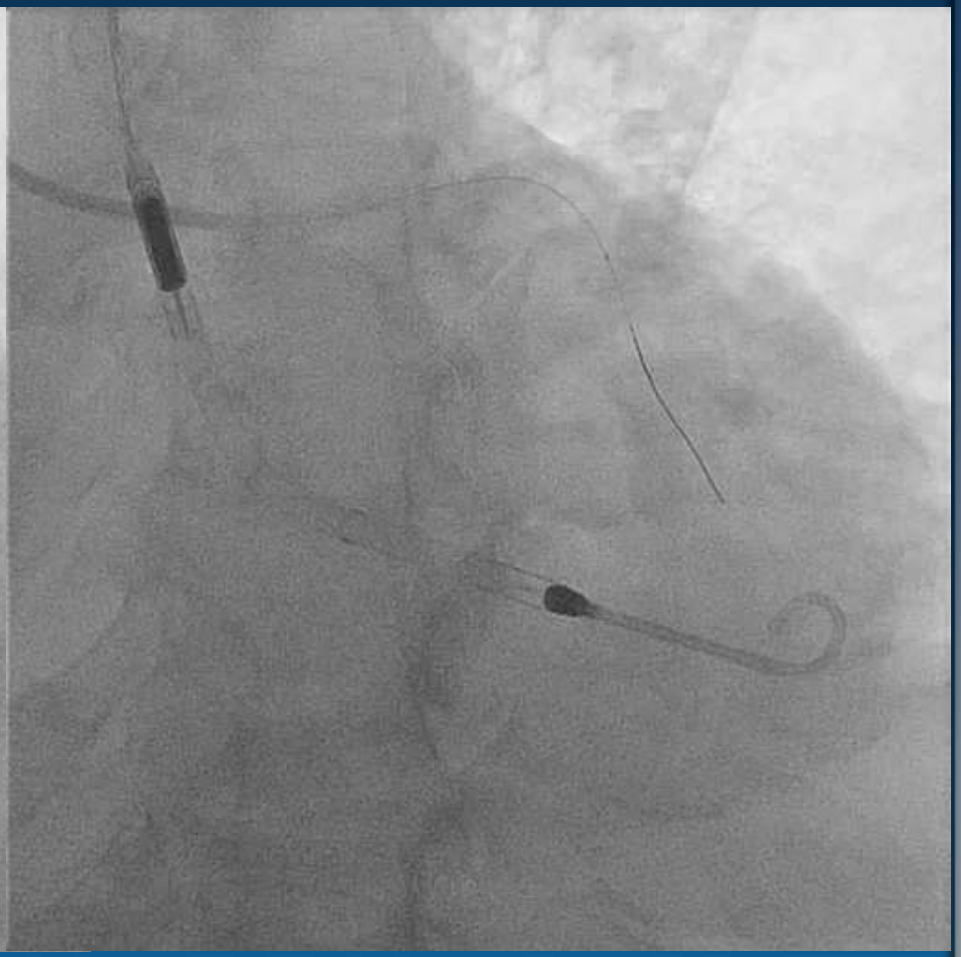


Post-LM PTCA

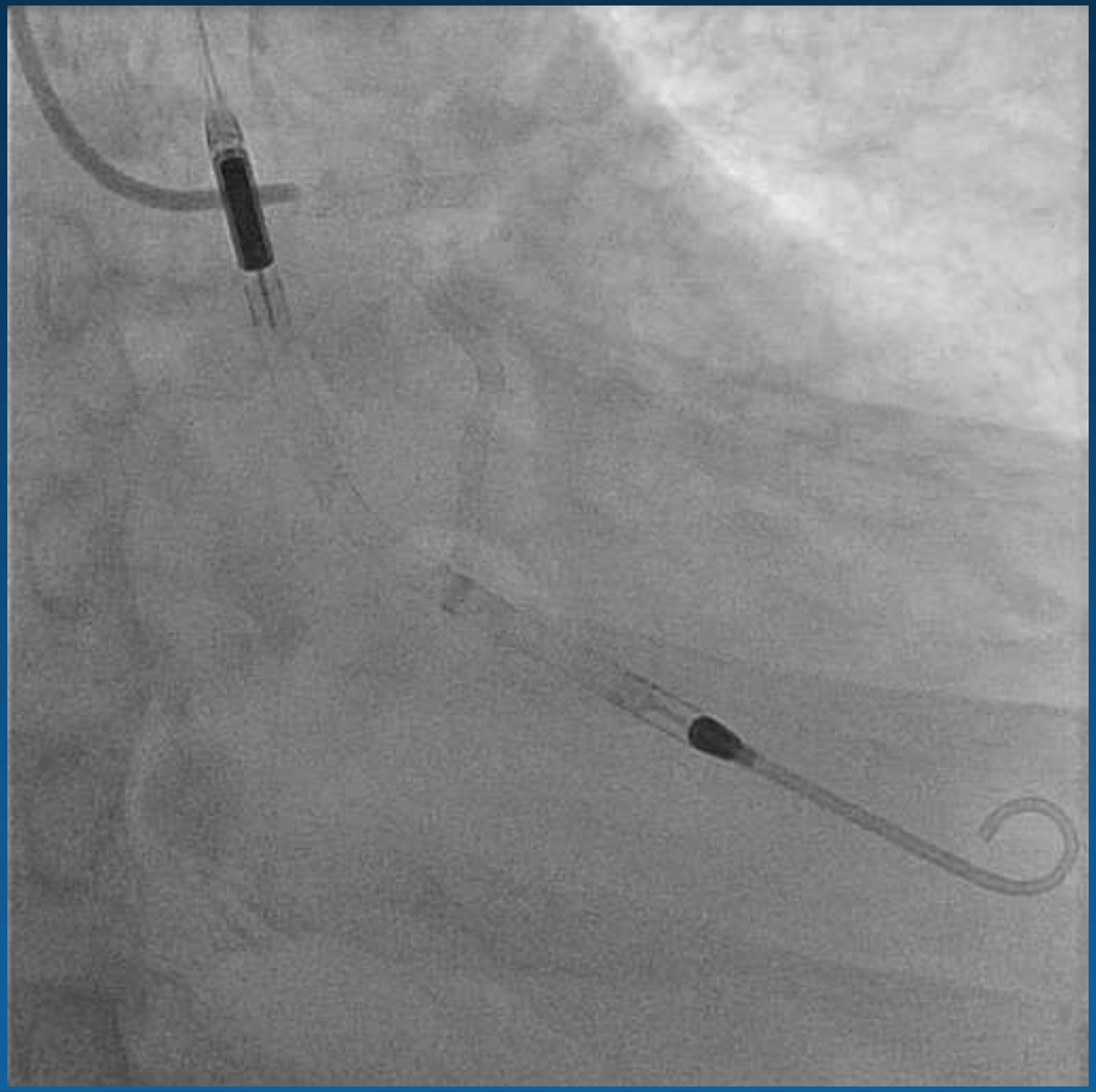


LAD DES

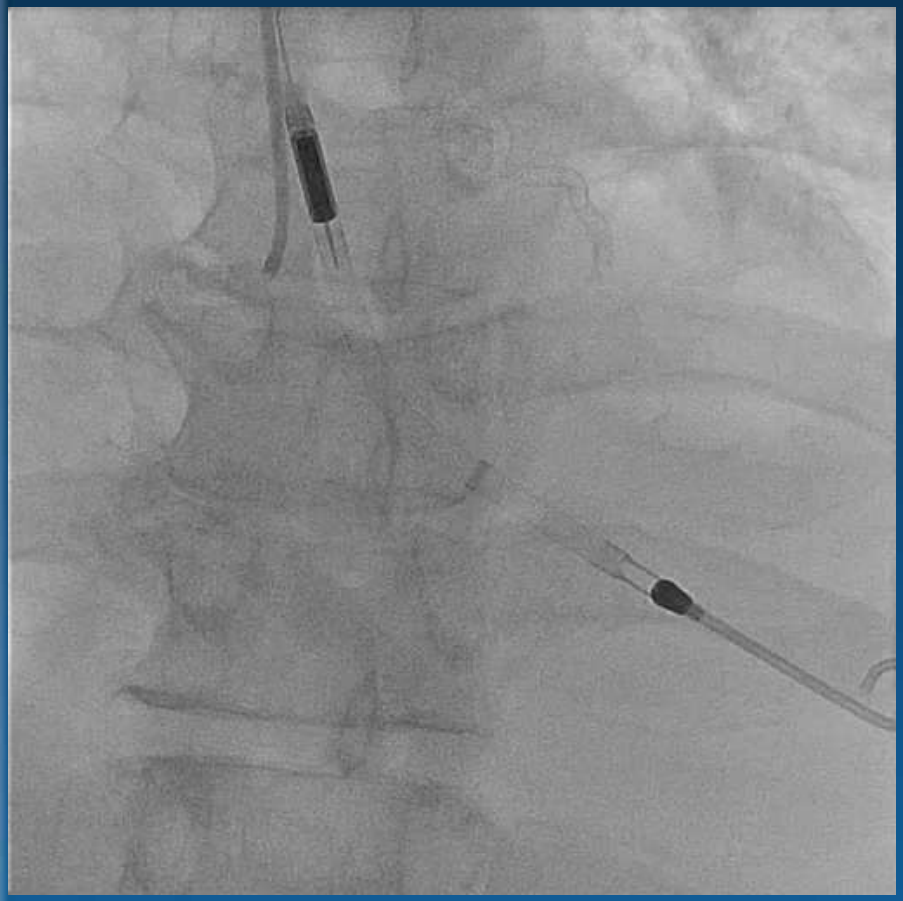


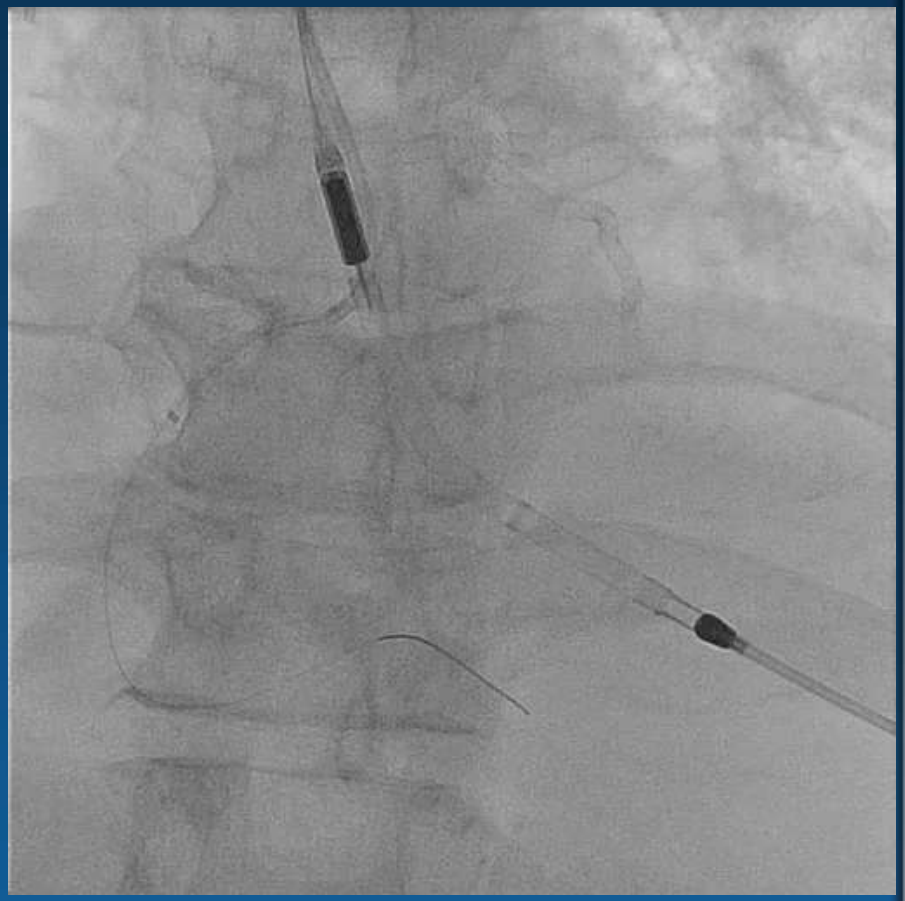


Final LAD Angiogram

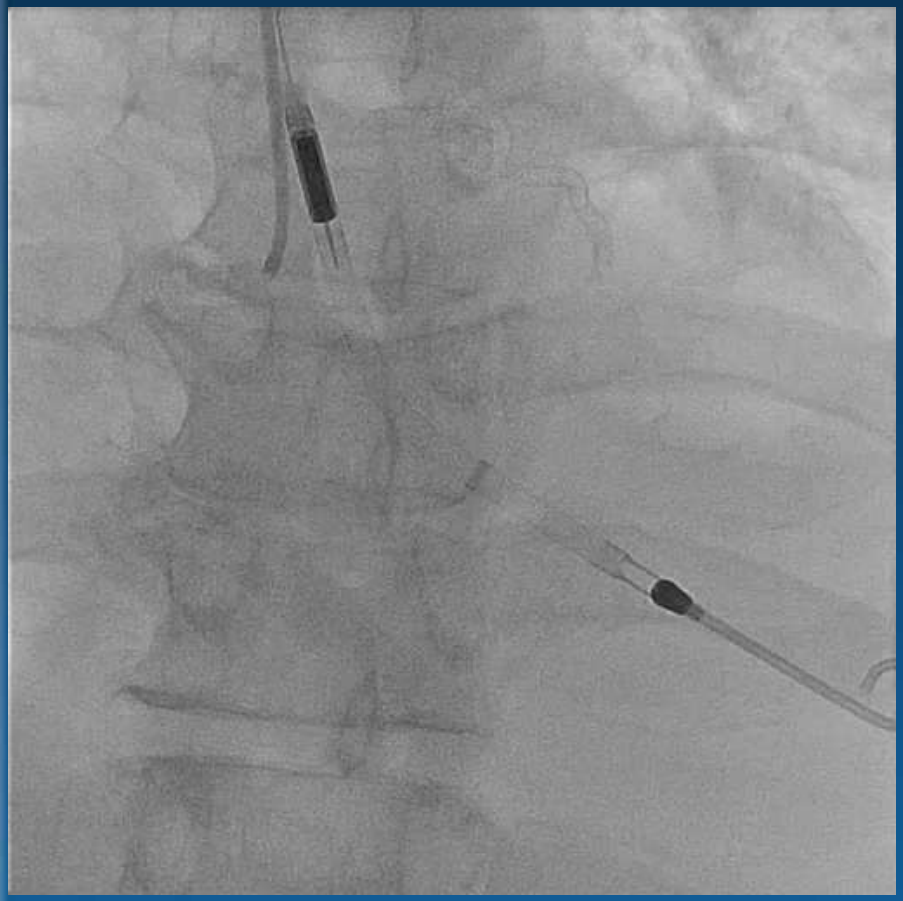


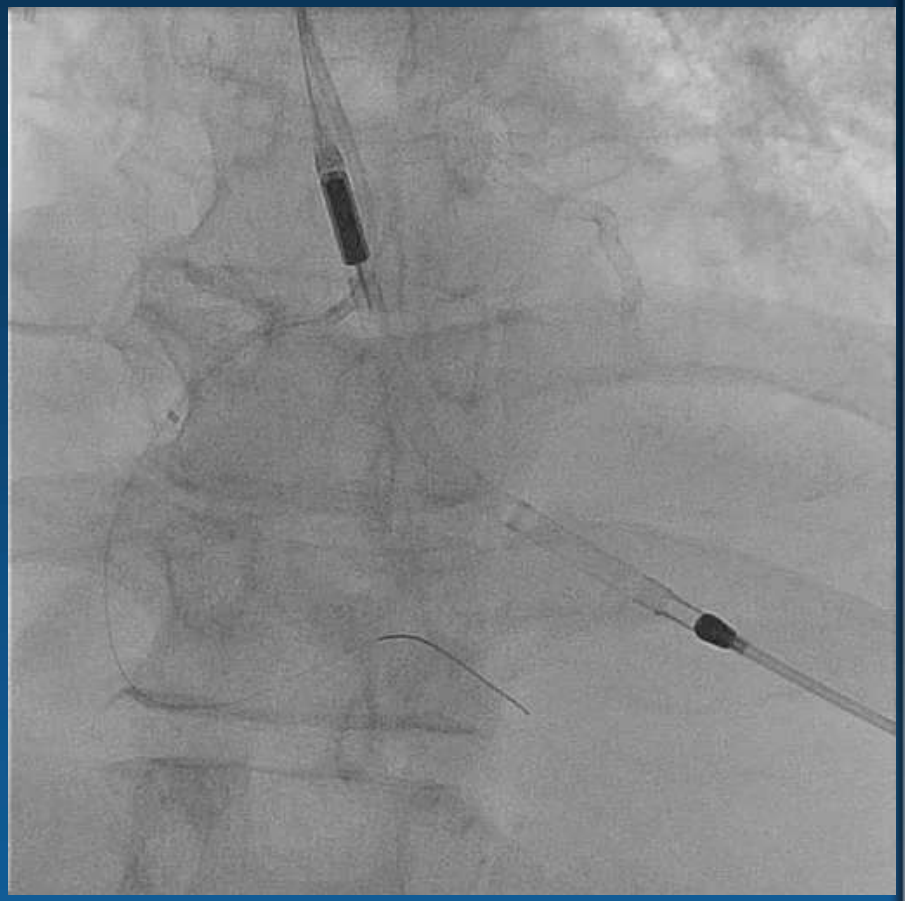
RCA PCI



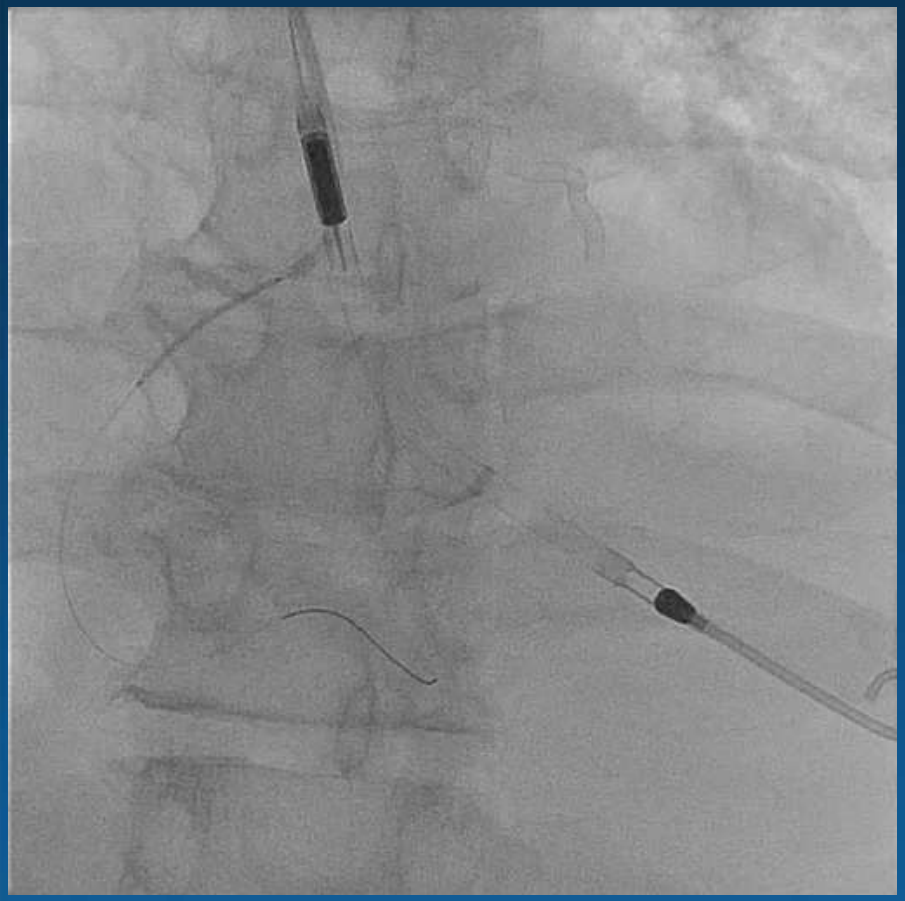


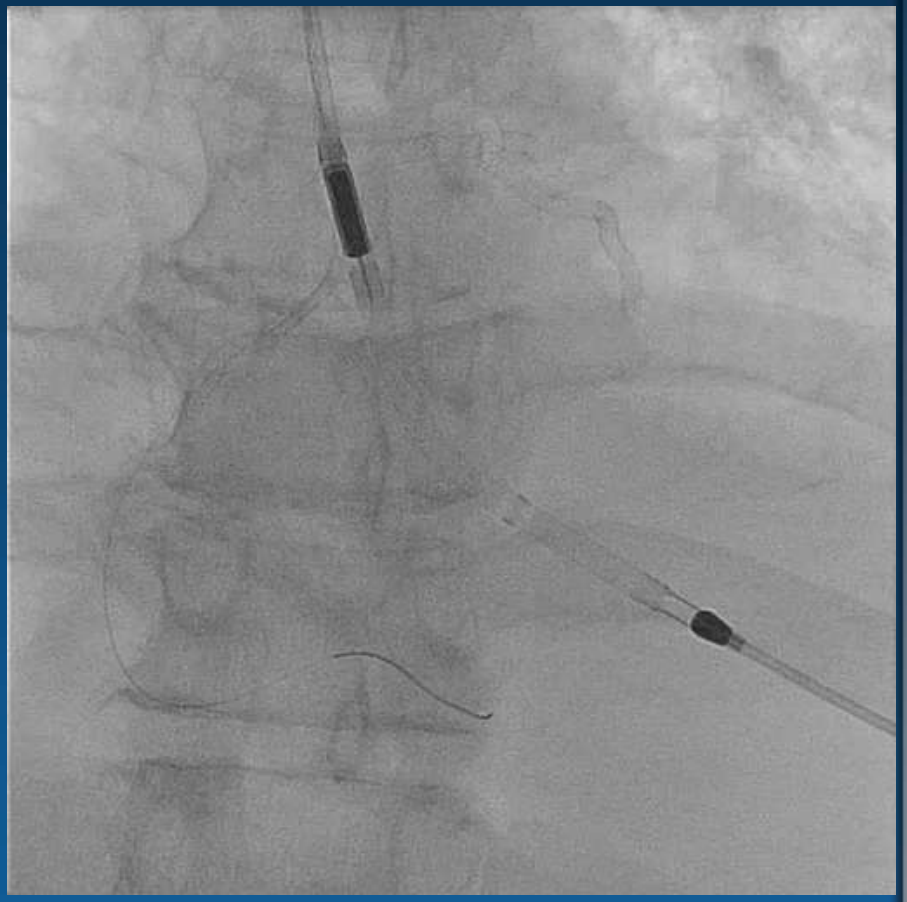
RCA PCI-Guideliner



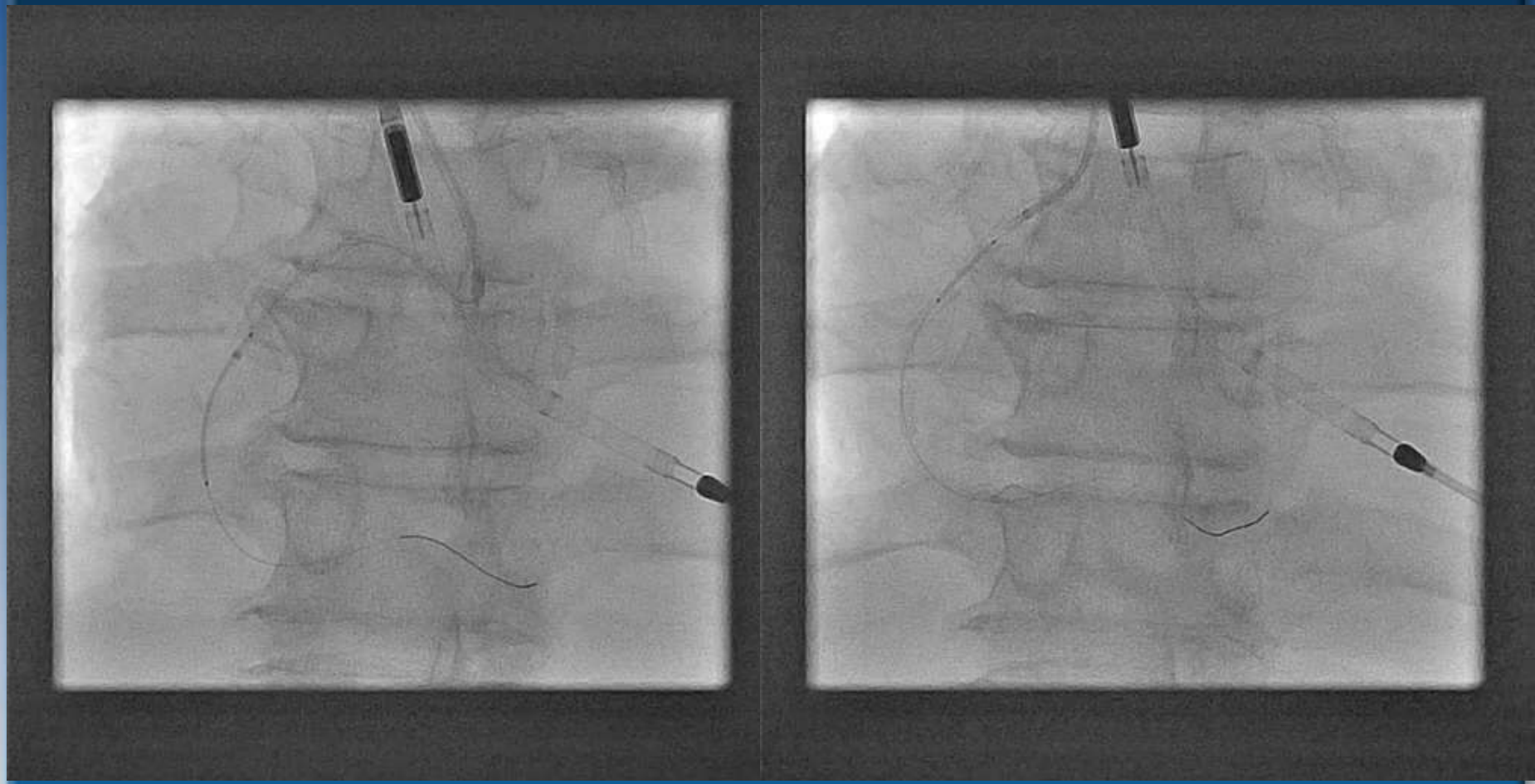


RCA PCI-Proximal DES

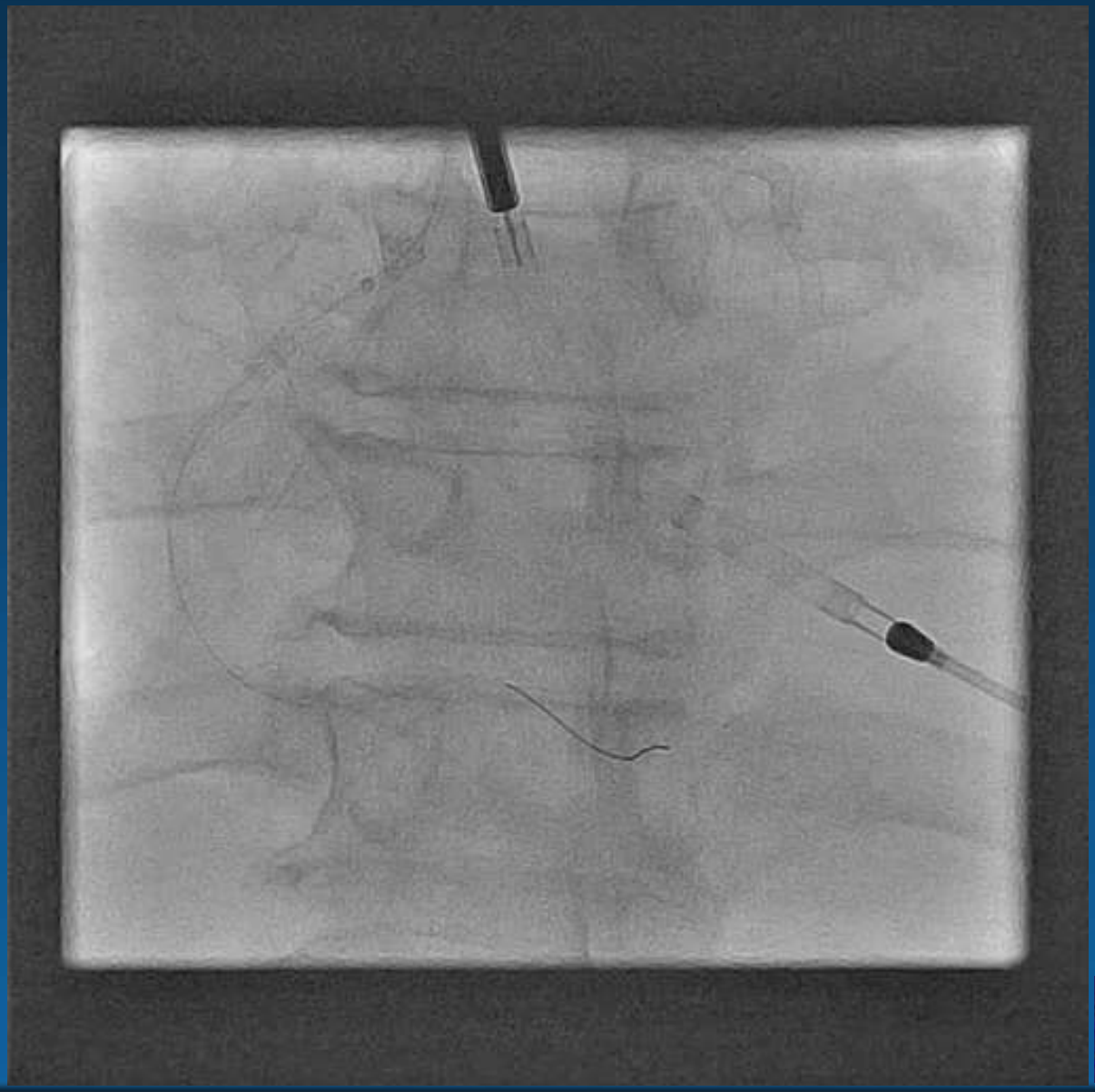




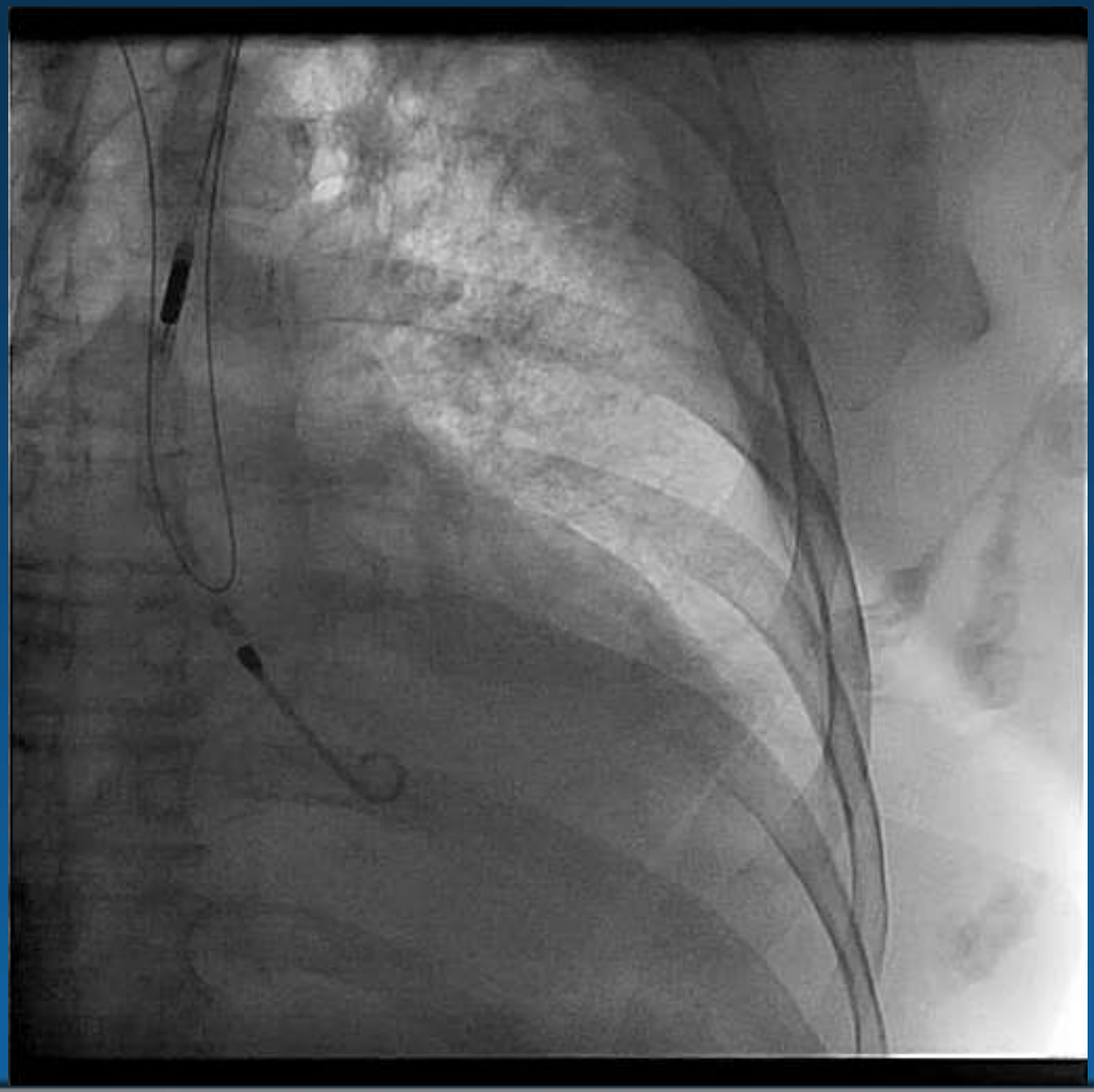
RCA PCI-Proximal DES



RCA DES-Final Angiogram

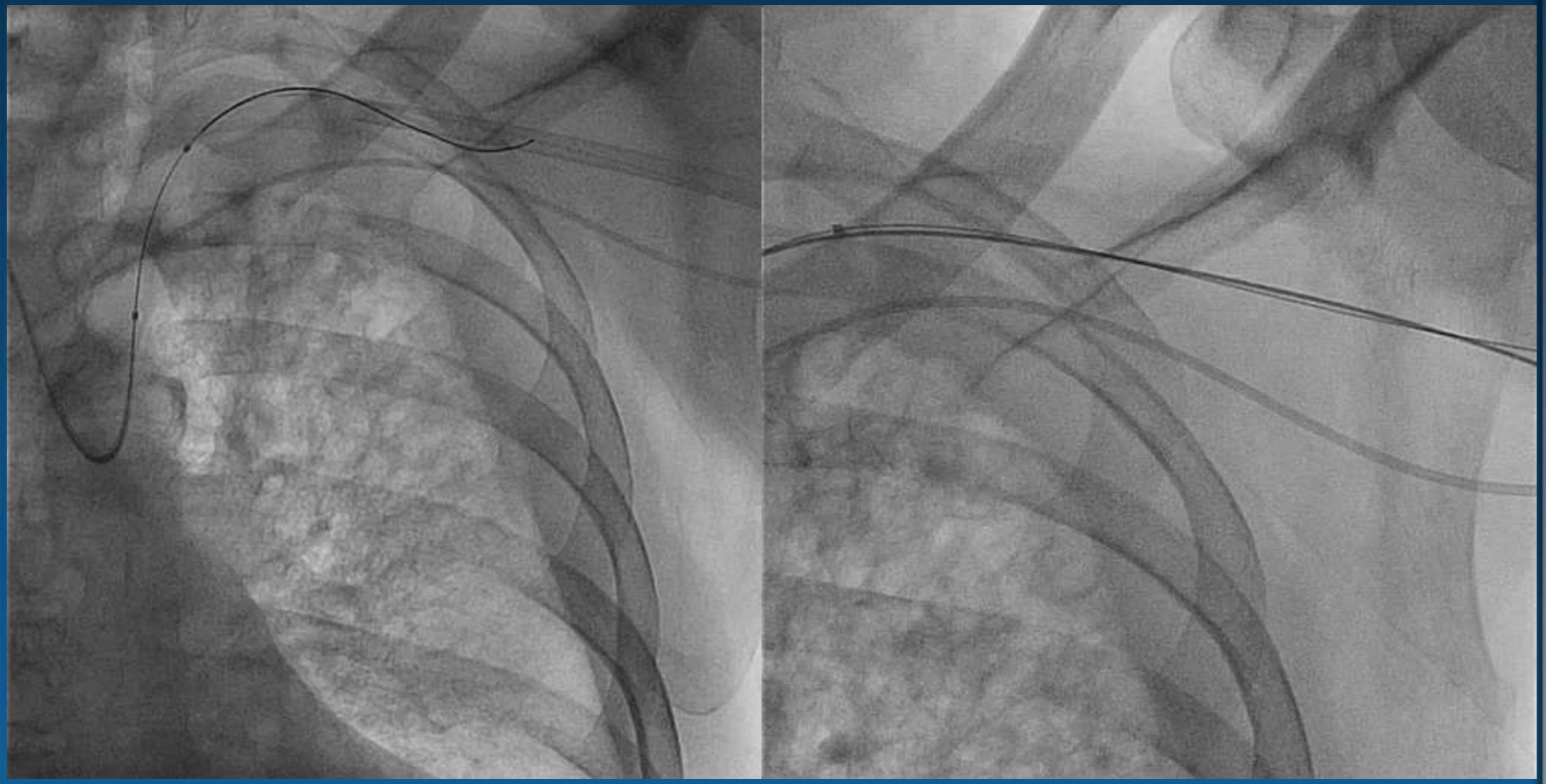


Impella Removal



LSCA Guidewire Placement

Left Axillary Artery Sheath Removal



Conclusions

- Hemodynamic support may be readily delivered during high-risk PCI or PCI in cardiogenic shock with Impella, IABP & TandemHeart
- Impella provides the highest level of hemodynamic support, facilitating more complete revascularization, with no additional harm

Dallas CARDIOVASCULAR INNOVATIONS 2015

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