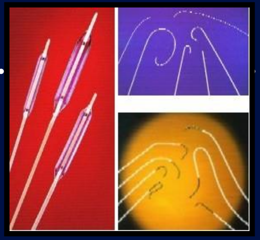
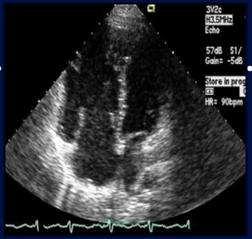
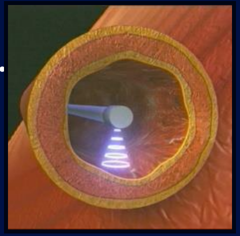
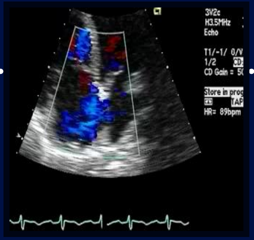
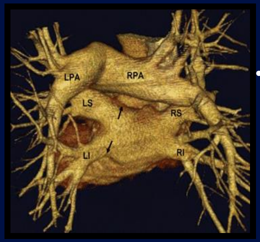
Cath Lab Essentials : LV Assist Devices for Hemodynamic Support (LABP, Impella, Tandem Heart, ECMO)

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Disclosures

- I have no financial or other conflicts of interest to report.

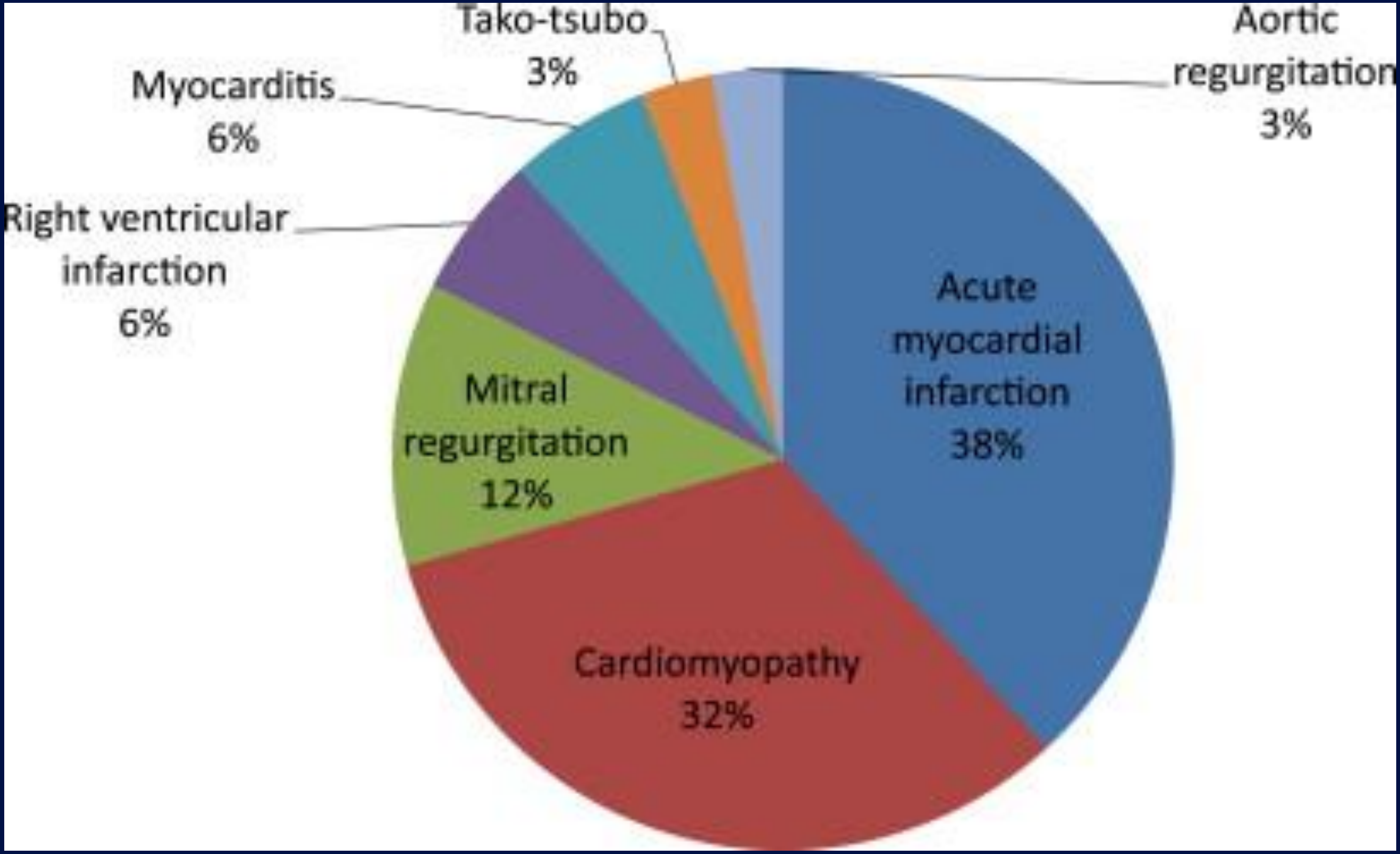
Cardiogenic Shock

Inadequate end organ perfusion due to a reduced cardiac output despite adequate circulatory volume

- AMS; Cold, clammy skin; Oliguria;
- Increased serum lactate

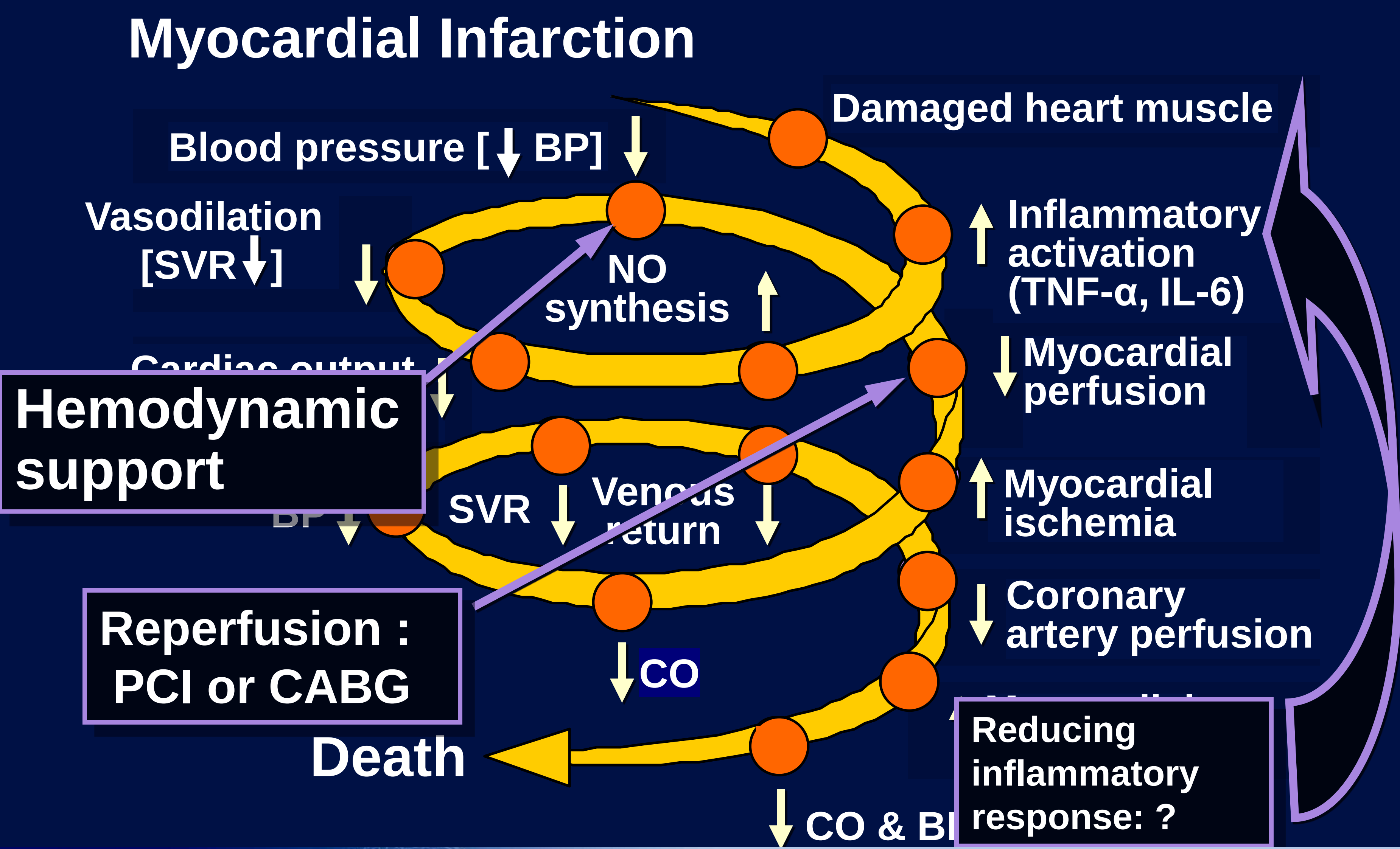
1. Cardiac Index (CI)
   - CI < 1.8 L/min/m^2
   - CI < 2.2 L/min/m^2 with inotropic/pressor support
2. PCWP > 15 mmHg or LVEDP >18
3. Systolic Blood Pressure (SBP)
   - SBP < 90 mmHg for at least 30 mins
   - SBP > 90 mmHg with inotropic/pressor support

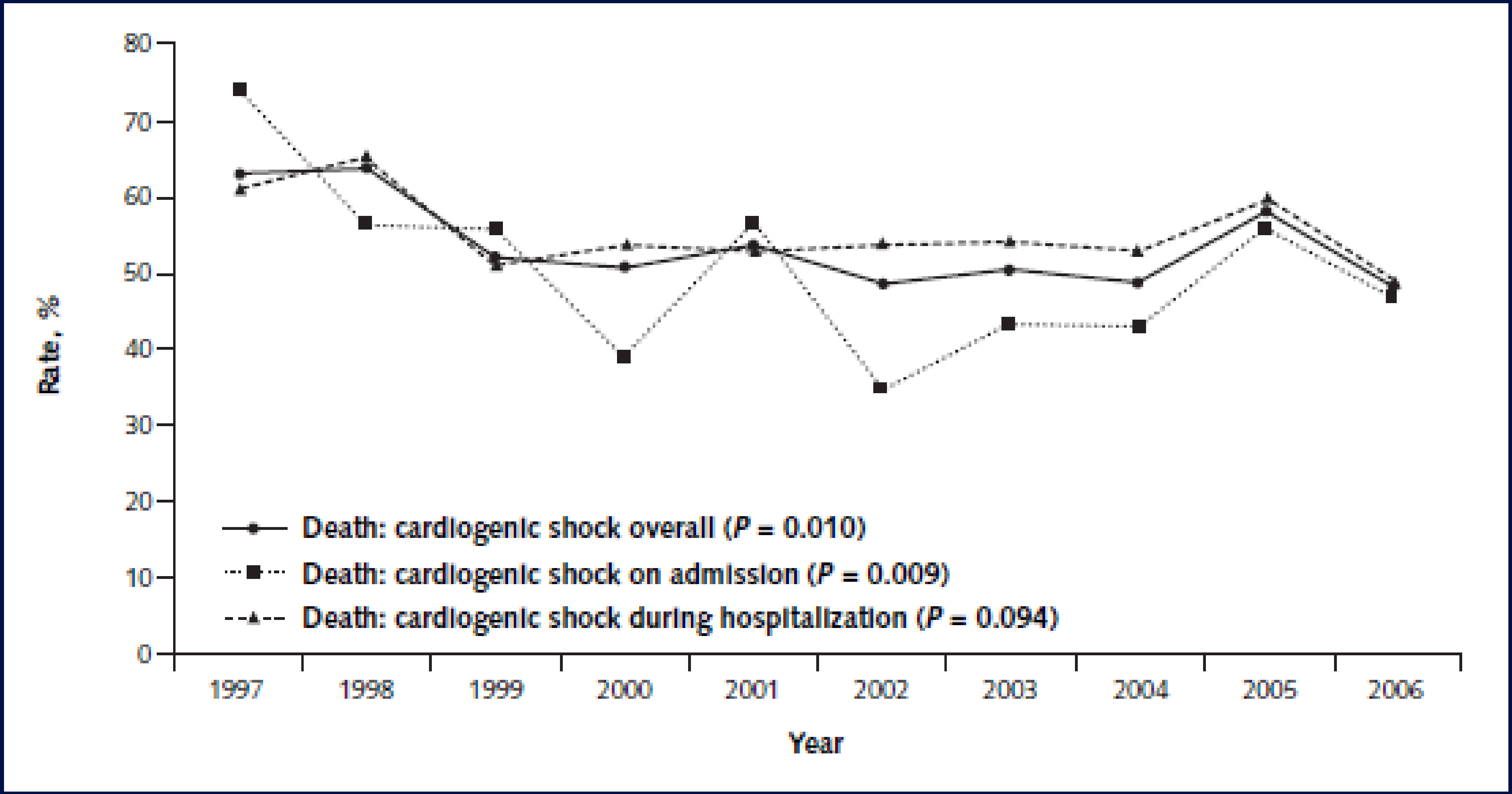
Causes of Cardiogenic Shock



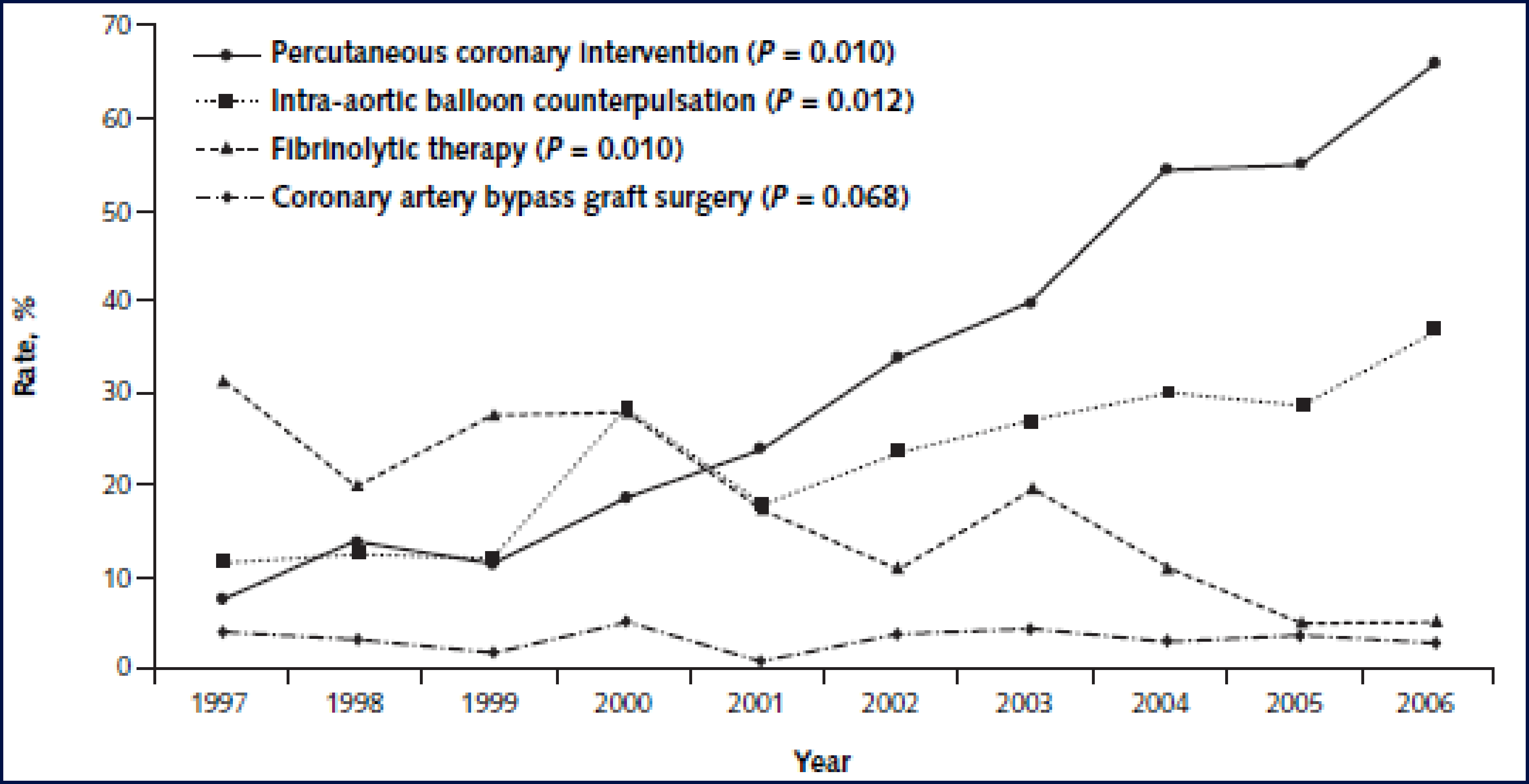
Cardiology Clinics, 2013; 31(4): 567-580,

Physiology of Cardiogenic Shock: A Downward Spiral



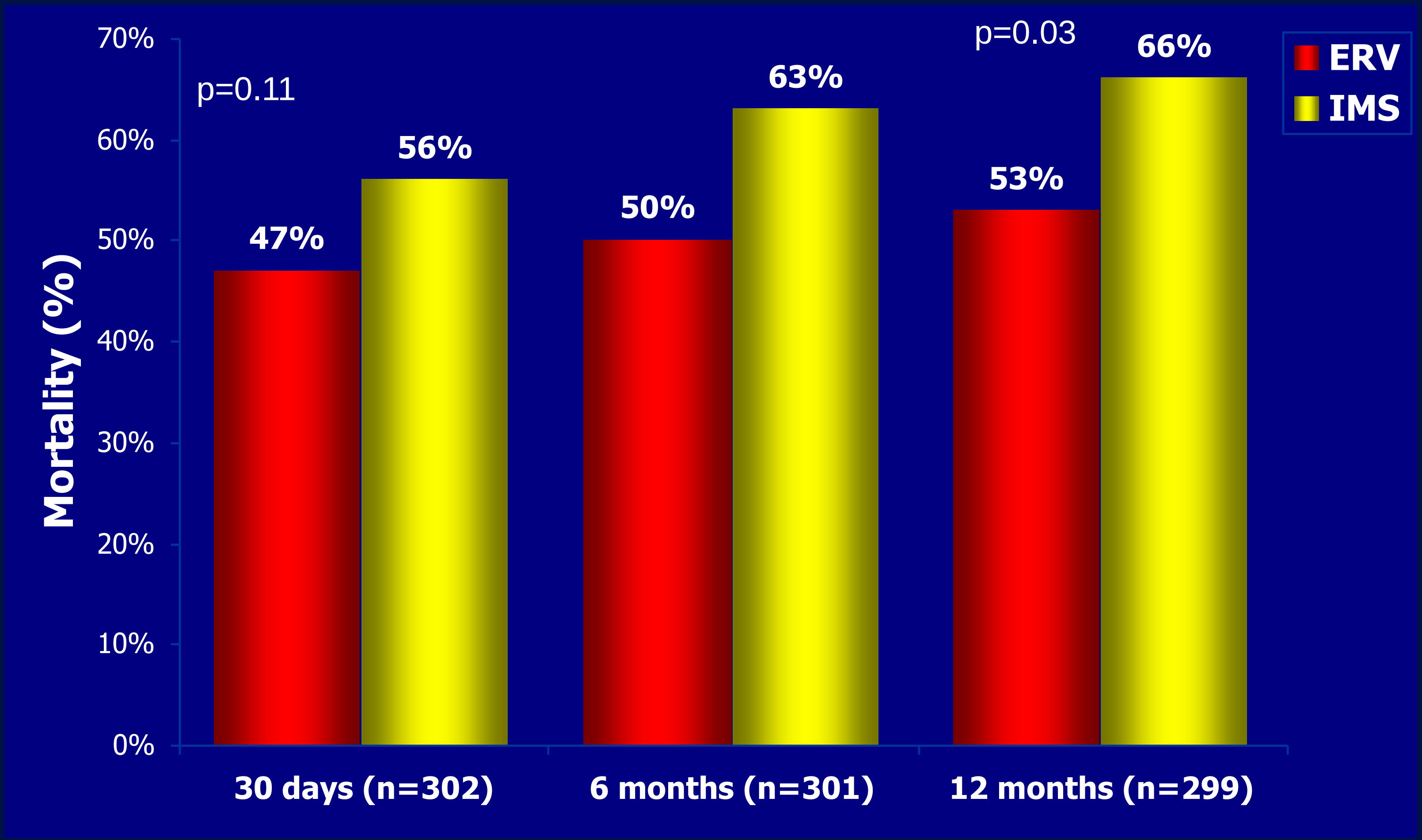


80
70
60
50
40
30
20
10
0
Rate, %
Death: cardiogenic shock overall (P = 0.010)
Death: cardiogenic shock on admission (P = 0.009)
Death: cardiogenic shock during hospitalization (P = 0.094)
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year



Percutaneous coronary intervention (P = 0.010)
Intra-aortic balloon counterpulsation (P = 0.012)
Fibrinolytic therapy (P = 0.010)
Coronary artery bypass graft surgery (P = 0.068)
Rate, %
0
10
20
30
40
50
60
70
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year

Emergency revascularisation - SHOCK Trial

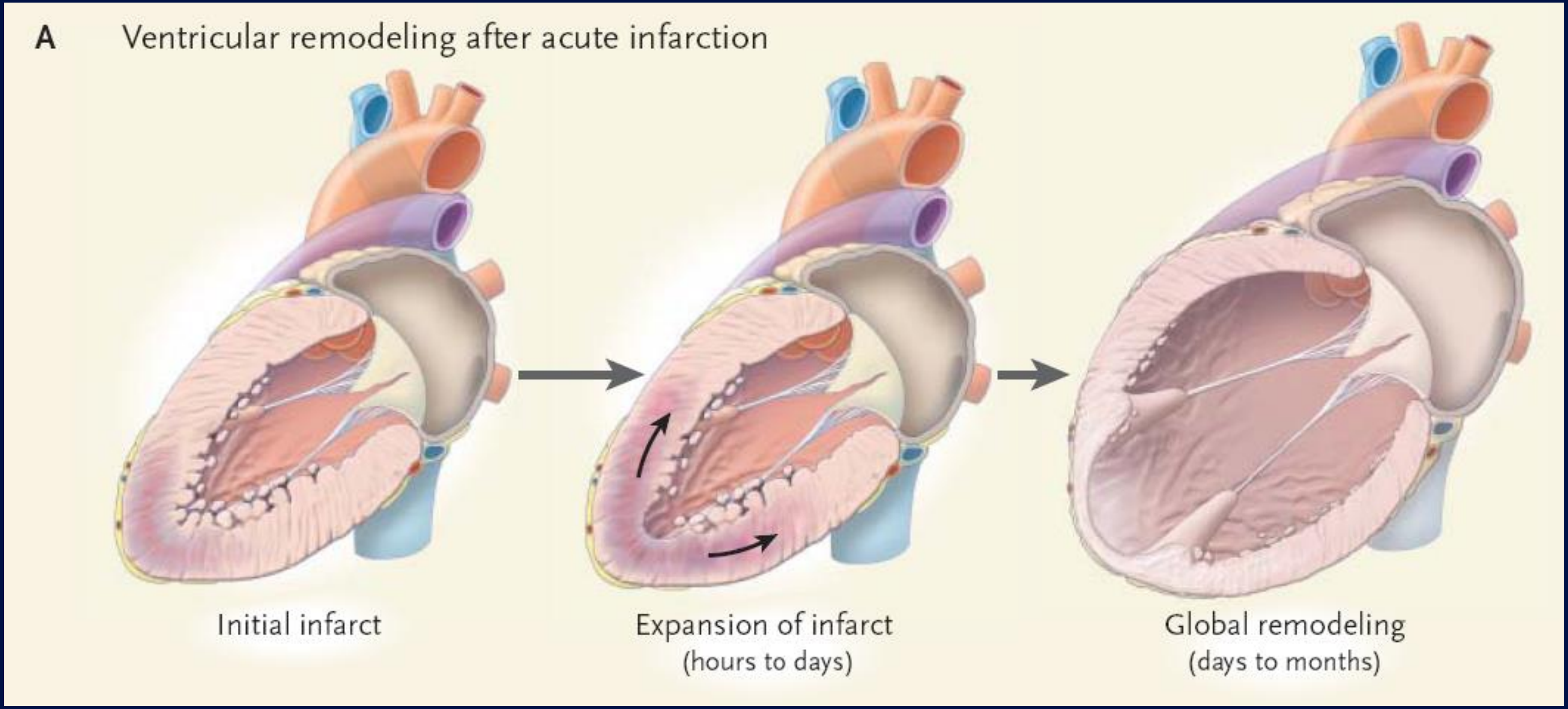


85% of survivors NYHA Class I/II at 12 months after early revascularization or initial medical stabilization

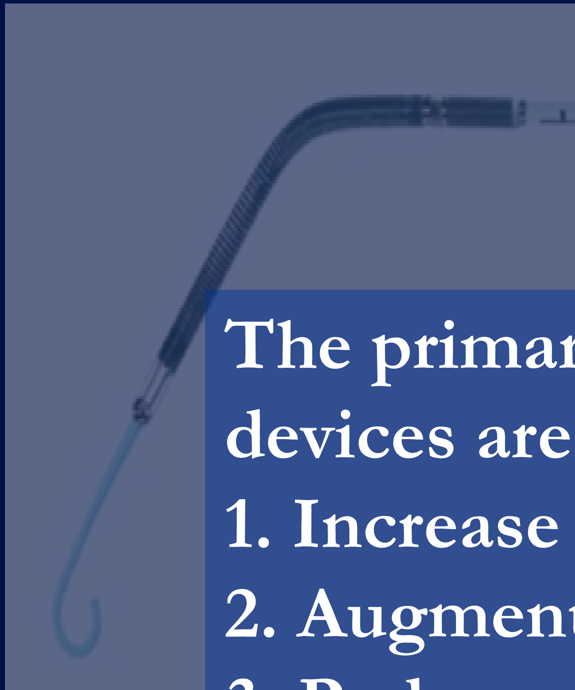
Hochman JAMA 2000;285:190

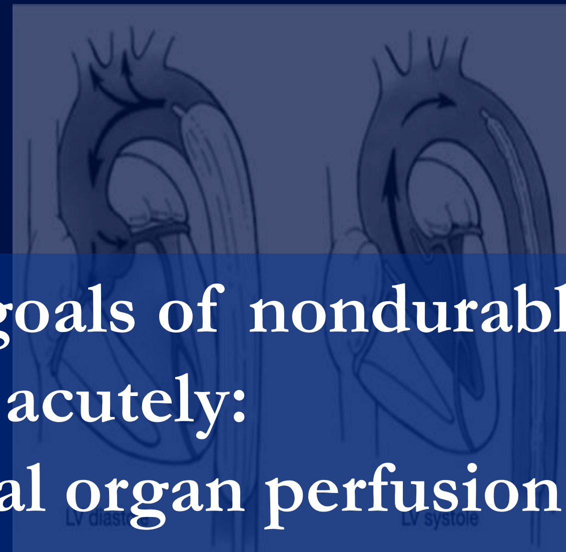
Heart muscle can recover with support

High Potential of heart muscle recovery, Gain in Ejection Fraction → **Low Potential of heart muscle recovery, Loss in Ejection Fraction**



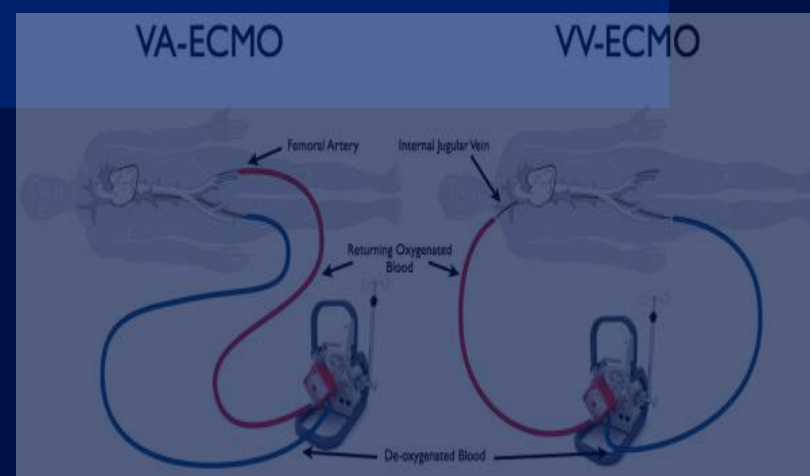
New England Journal of Medicine: 2003; 348:2007-18





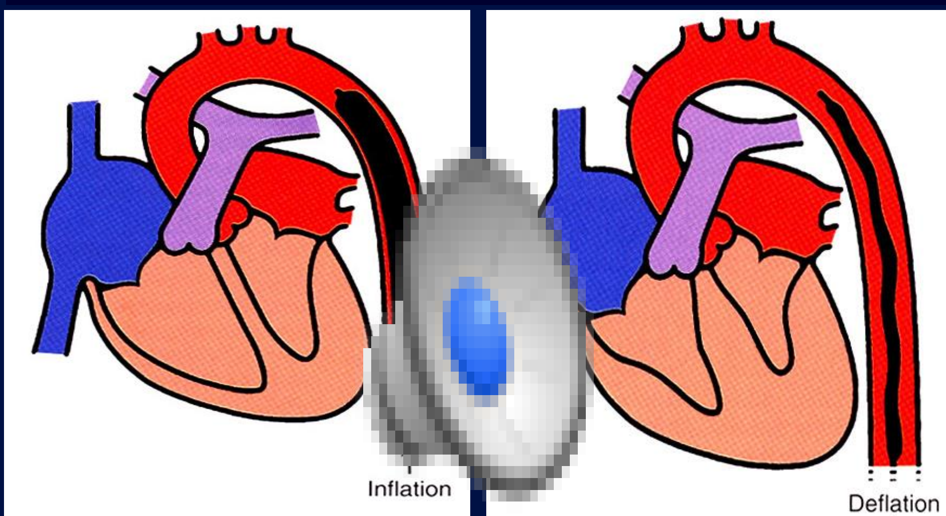
The primary goals of nondurable MCS devices are to acutely:

1. Increase vital organ perfusion
2. Augment coronary perfusion
3. Reduce ventricular volume and filling pressures, thereby reducing wall stress, stroke work, and myocardial oxygen consumption



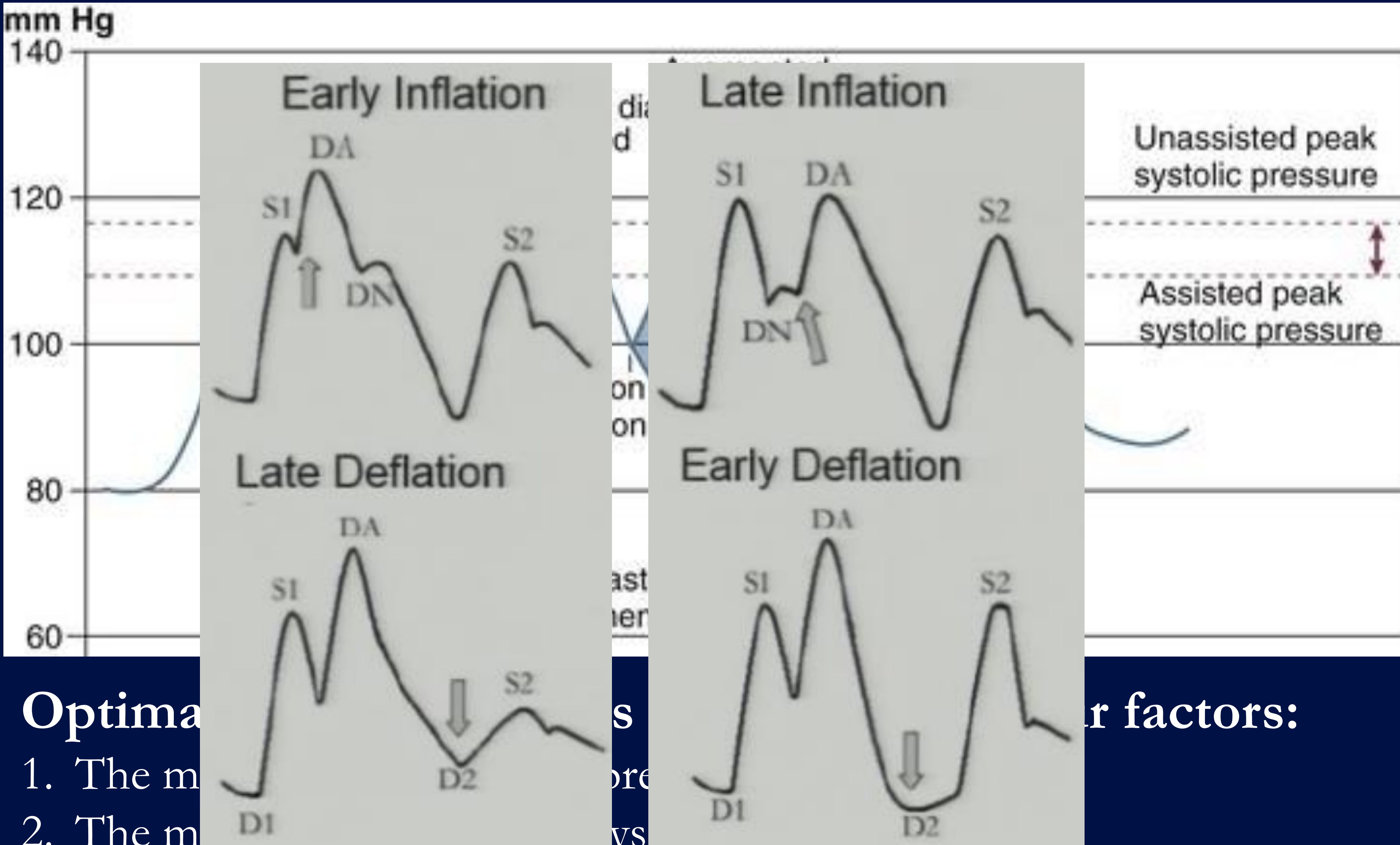
Intra-Aortic Balloon Pump

- Introduced in 1968 (Kantrowitz)
- First "true percutaneous" support device
- Cheapest, most common (20% of all cardiogenic shock cases), CO 0.5L/min
- Stabilize pt, but not full support
- No outcome benefit



Hemodynamic Effects

Diastolic pressure	↑↑
CO/cardiac workload	↑
MAP	↑
LV Wall Tension	↓↓
PCWP	↓↓
Oxygen Demand	↓
LV Volume	↓
Coronary Blood Flow	←→



Optima… s … r factors:

1. The m… pre…
2. The m… ystolic pressure
3. The magnitude of volume displacement
4. The timing of balloon inflation and deflation

Curr Cardiol Rep. 2015; 17:40

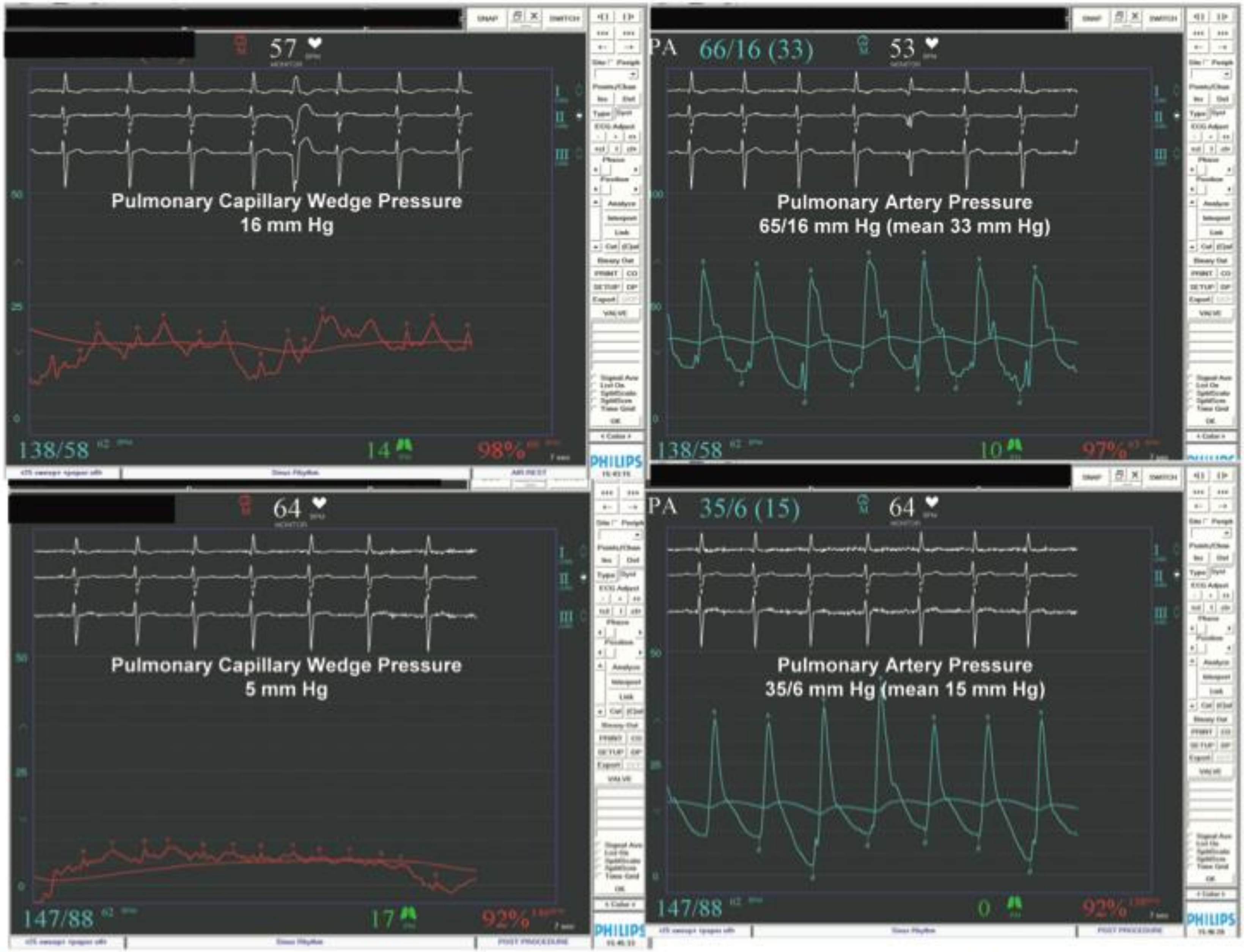
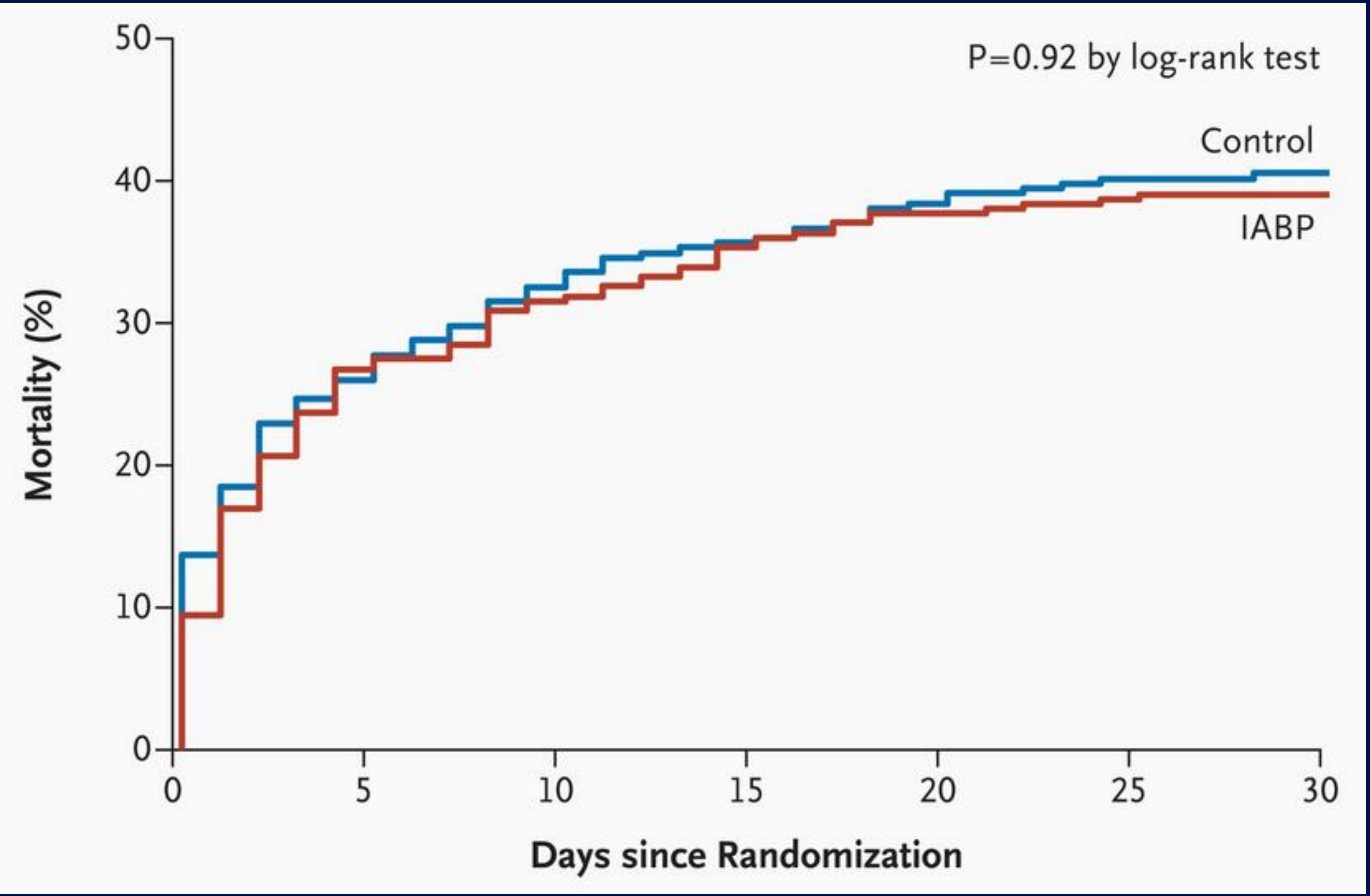


Figure 4. *Pulmonary capillary wedge pressure (left) and pulmonary artery pressure (right) before (top) and after (bottom) insertion of the intra-aortic balloon pump.*

Nair et al Journal of Invasive Cardiology 2011

IABP-Shock II Trial: Results Primary Study Endpoint: 30-day Mortality

(IABP in Cardiogenic Shock and Primary PCI)



Thiele H et al. NEJM 2012;367:1287

Indications for IABP

- High Risk PCI
- Cardiogenic Shock
- Refractory Ischemia
  - Left Main
  - 3 Vessel CAD
  - VT/VFib
- MR or VSD after MI
- Severe CHF? Bridge to Transplant
- Pre-operative stabilization

Contraindication to IABP

- Severe Peripheral vascular disease
- Aortic regurgitation
- Aortic Dissection
- PDA
- HOCM
- Heparin intolerance
- Bleeding Diathesis
- Sepsis

Complications of IABP

- Vascular access bleeding/complications
- Limb ischemia
- Infection
- Thrombocytopenia
- Migration and aortic arch trauma
- Other non-vascular (CVA, embolization of cholesterol, balloon rupture)
- Air embolism risk (reduced by using helium gas)

Hemodynamic Advantage of pVAD vs. IABP

	pVAD	IABP
► Directly unload the left ventricle	+++	-
► Reduce myocardial workload and oxygen consumption	+++	++
► Increase cardiac output and coronary and end-organ perfusion	+++	+

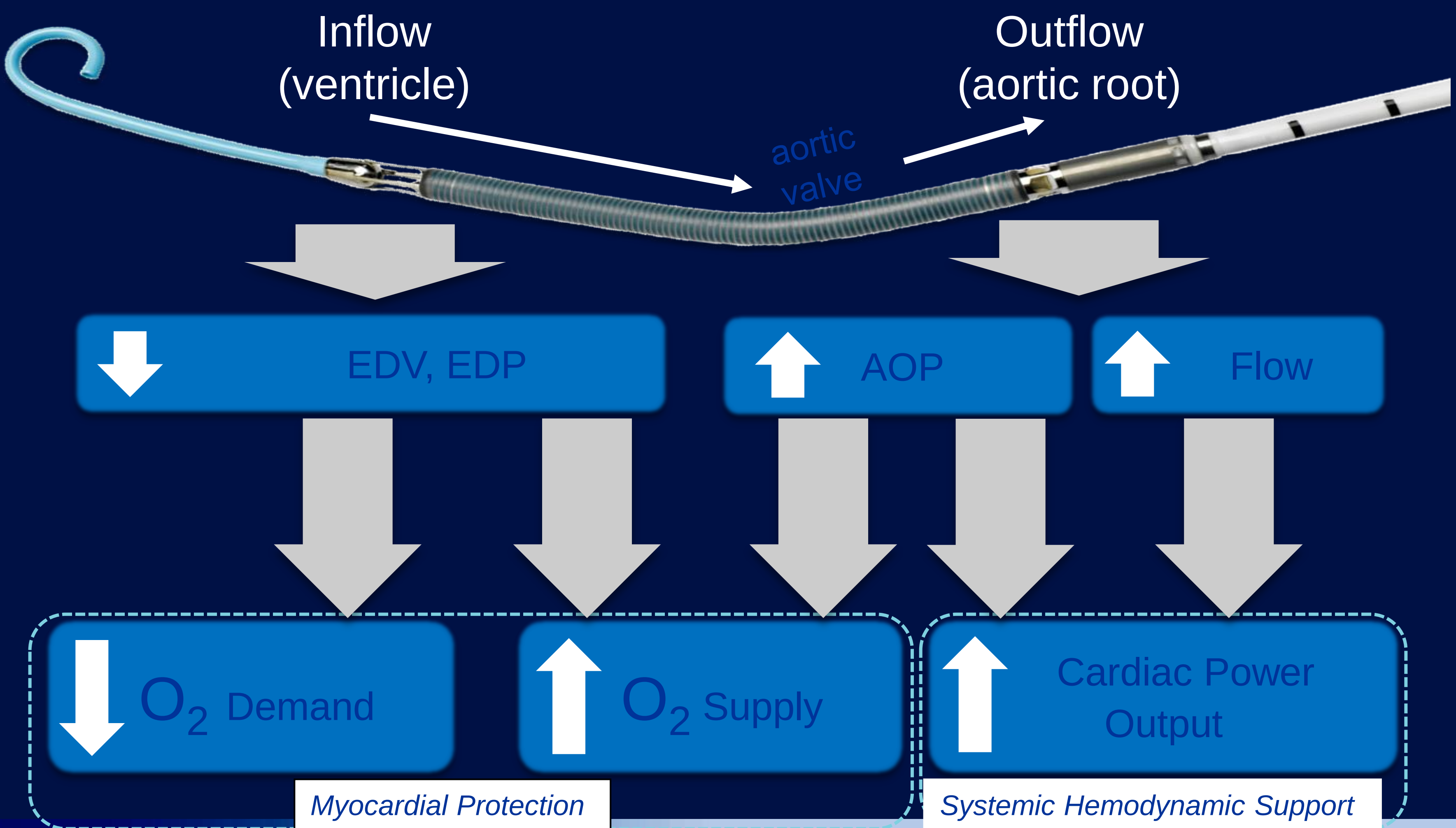
Impella

- Continuous axial flow pump
- Simple insertion
- Increases cardiac output & unloads LV
- LP 2.5 – CO 2.5 L/min
- CP 4.0 L/min
  - 14 F percutaneous
- LP 5.0
  - 21 F surgical cutdown; Maximum 5L flow

Impella Insertion

Principles of Impella Design

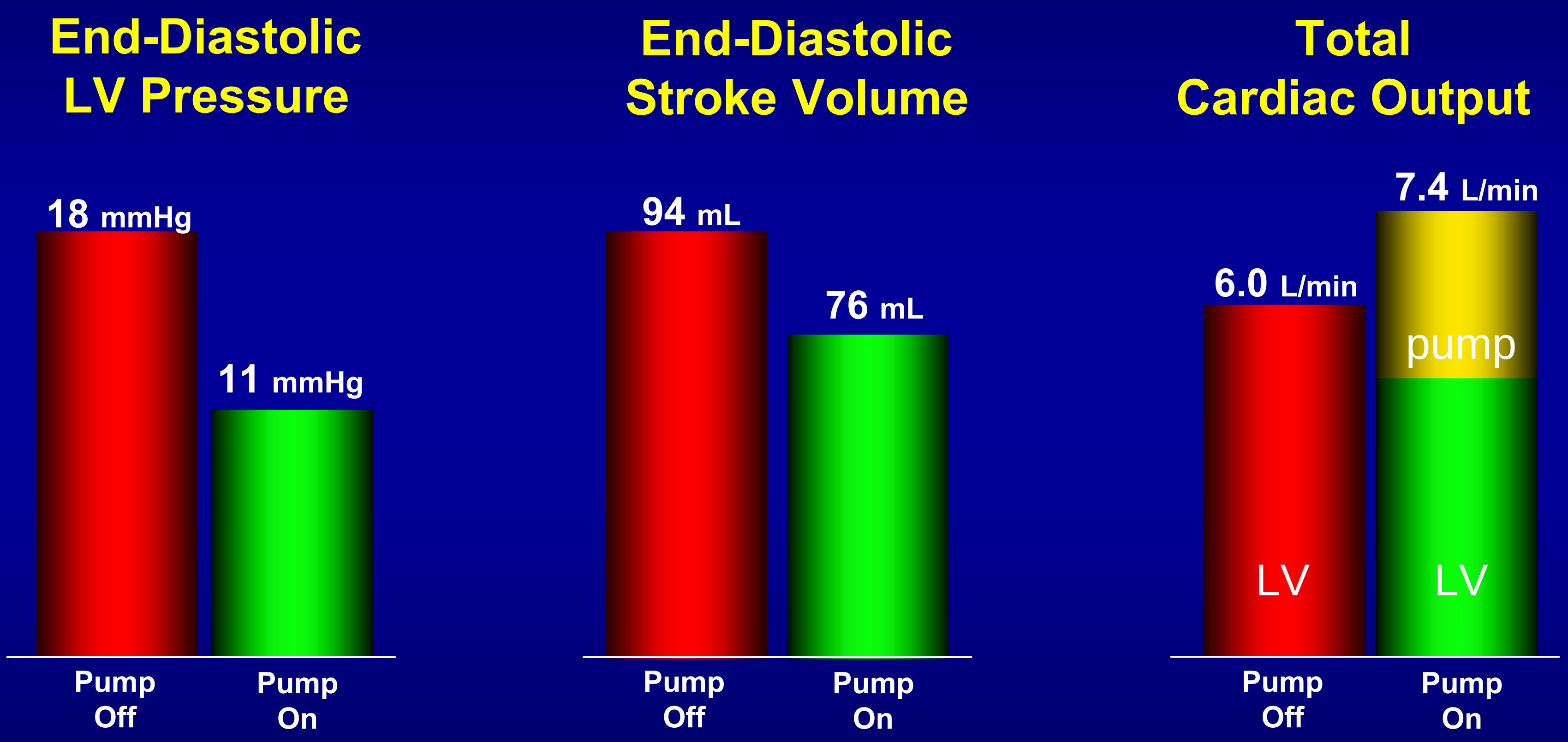
Mimic Heart's Natural Function



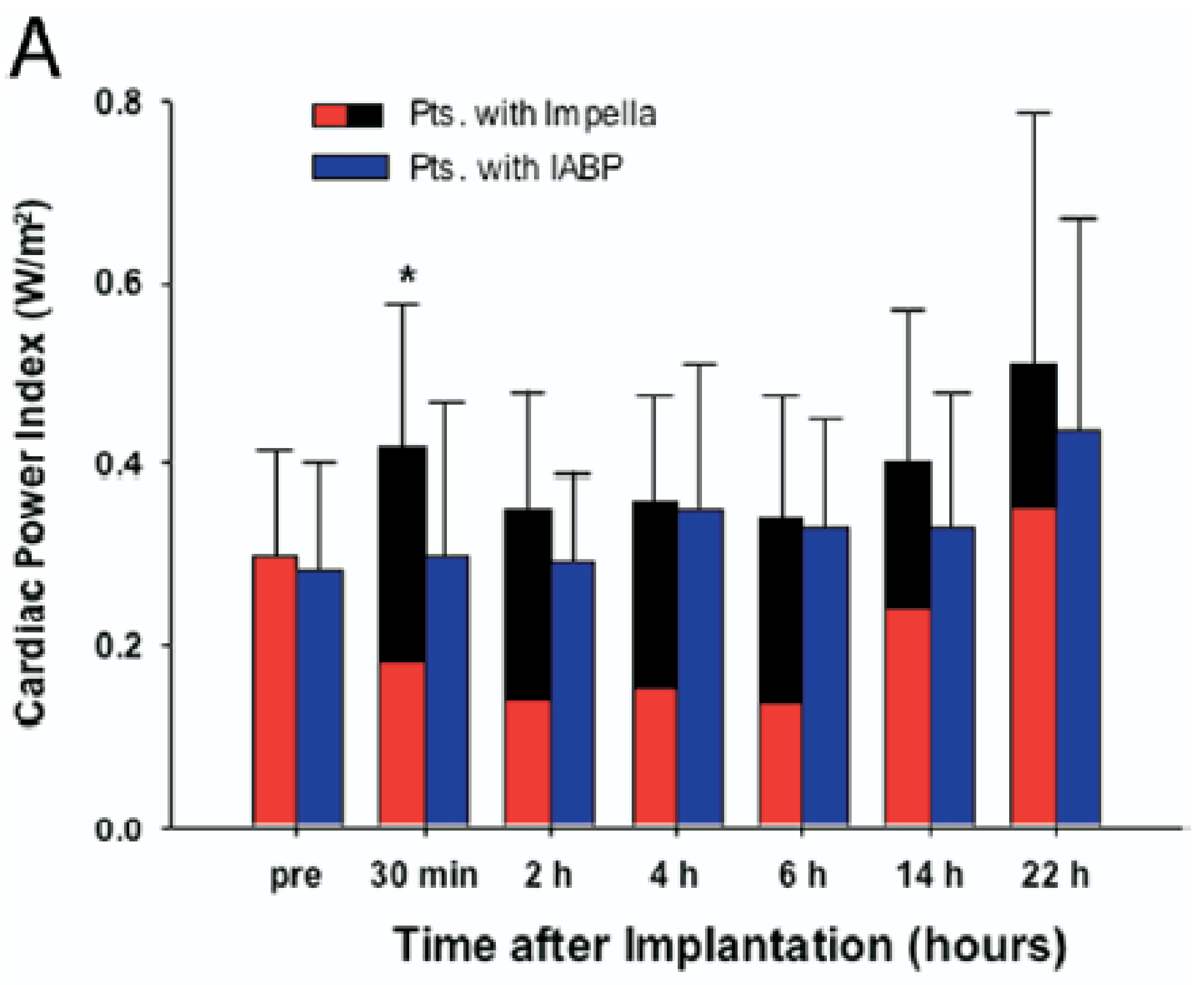
UCIrvine | University of California

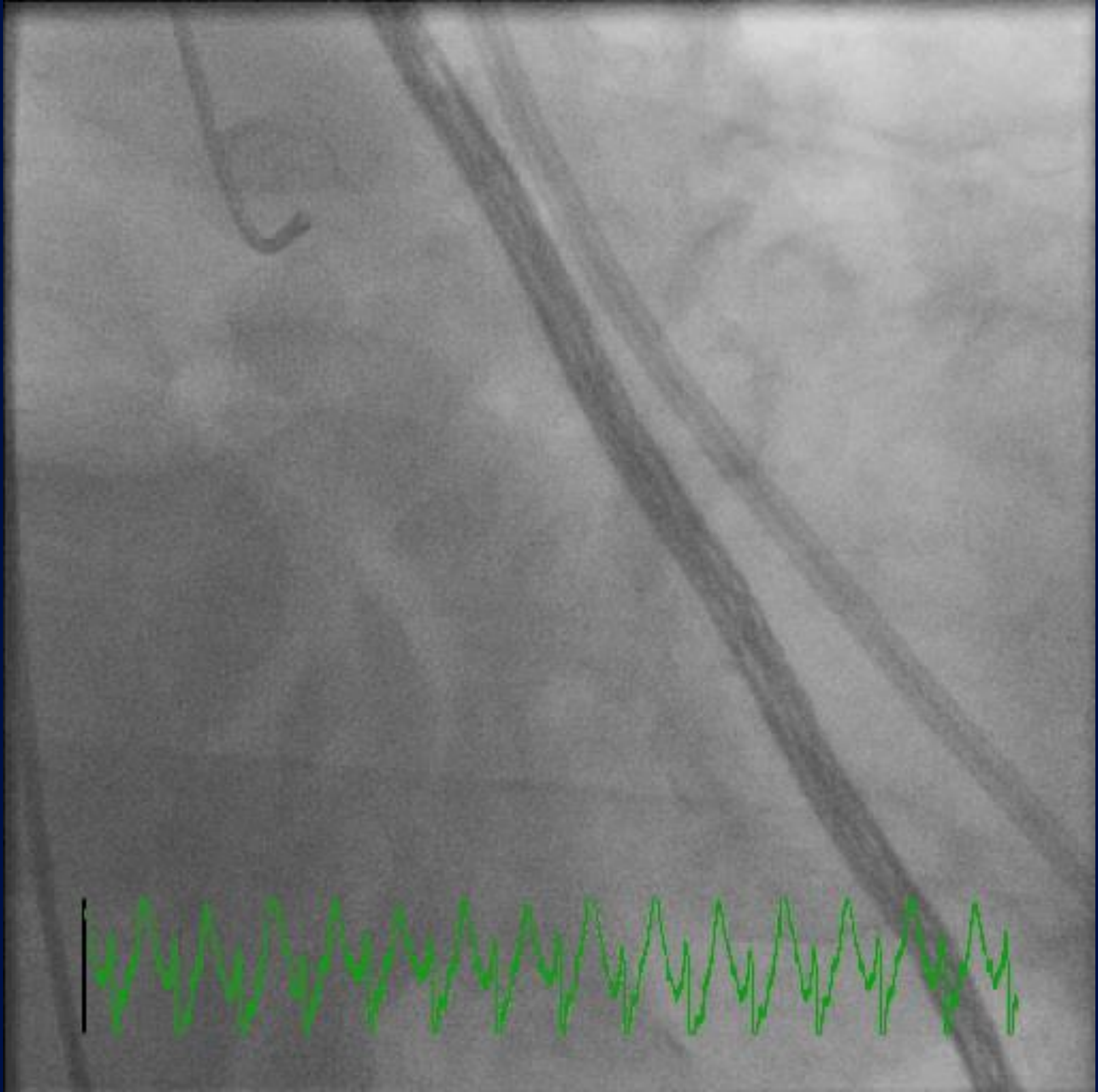
Naidu S S Circulation 2011;123:533-543

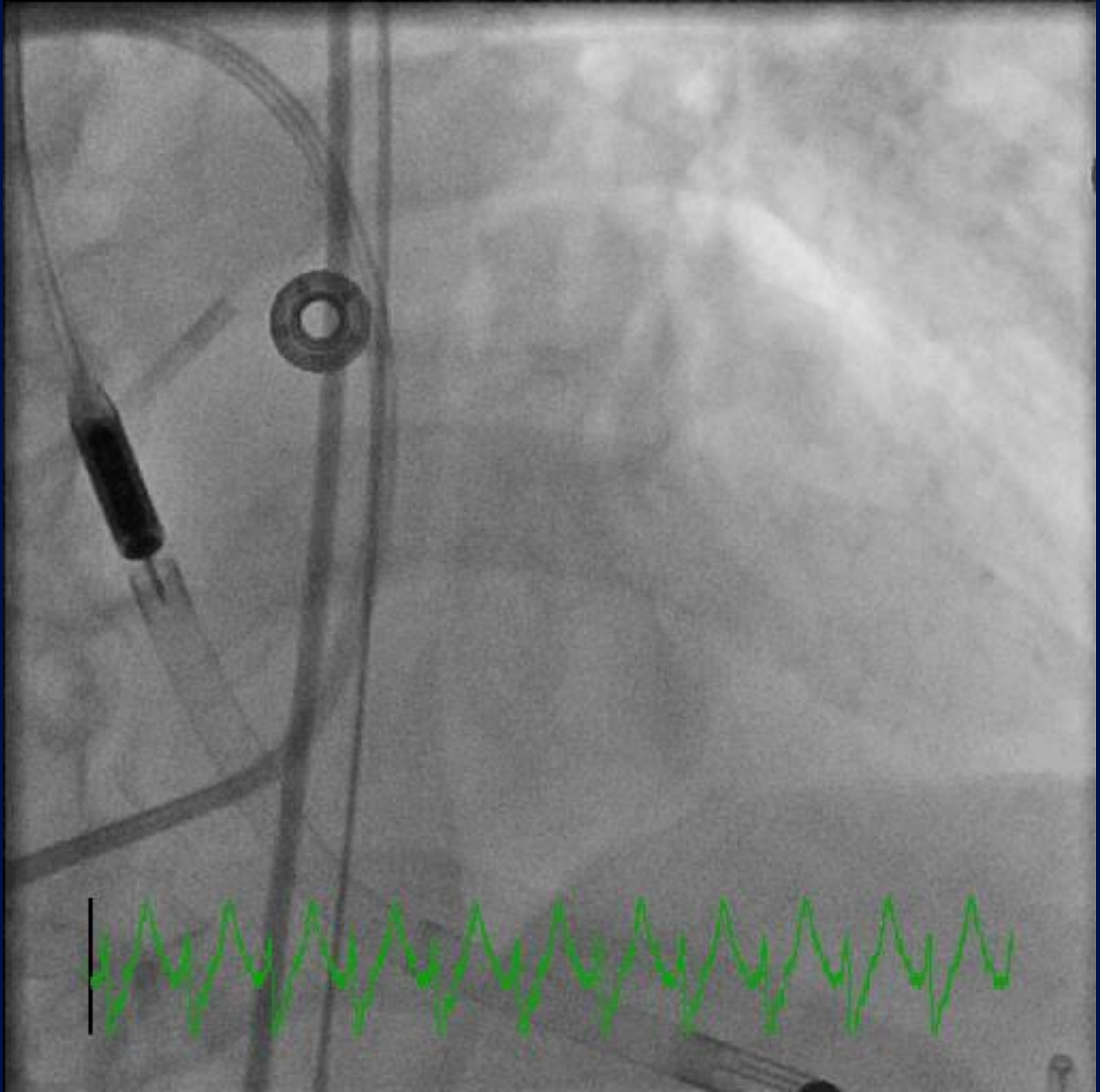
IMPELLA Unloads Actively the Ventricle, Reduces Work Loads and Increases Cardiac Output



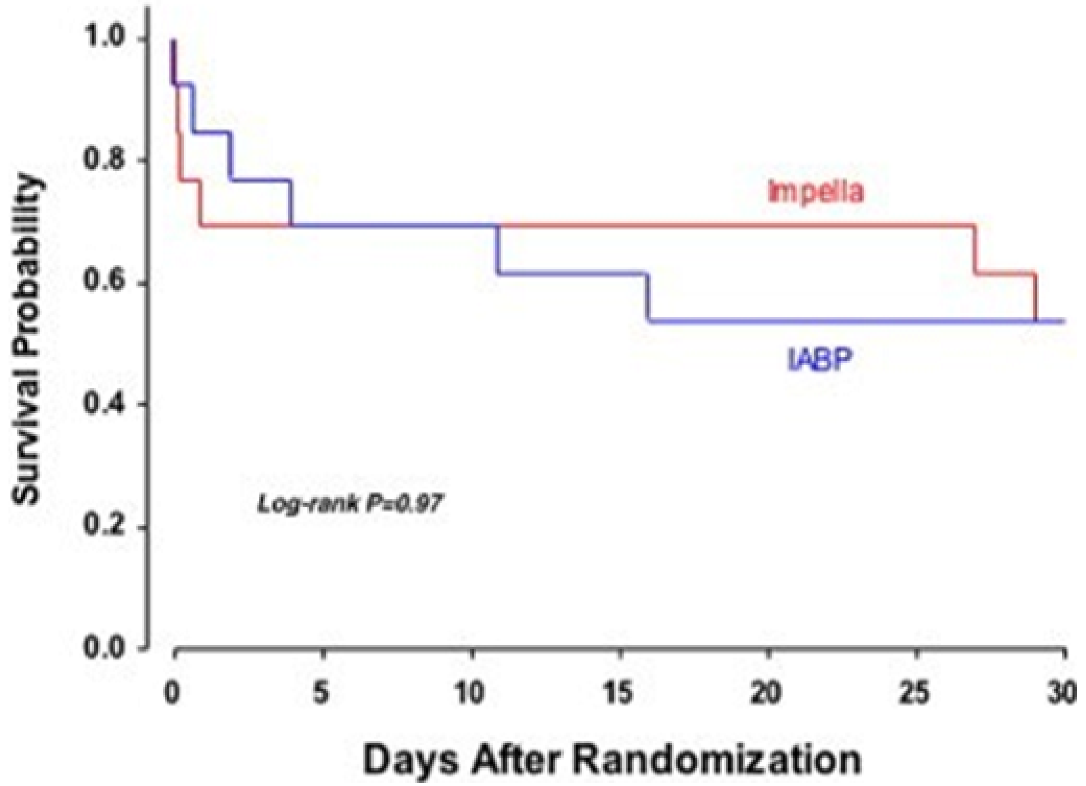
M.Valgimigli et al.,Catheterization & Cardiovascular Interventions 65:263–267 (2005)


A
Pts. with Impella
Pts. with IABP
Cardiac Power Index (W/m²)
0.8
0.6
0.4
0.2
0.0
*
pre
30 min
2 h
4 h
6 h
14 h
22 h
Time after Implantation (hours)





ISAR Shock: A Randomized Clinical Trial to Evaluate the Safety and Efficacy of a Percutaneous LV Assist Device Versus IABP in Cardiogenic Shock



Overall 30 day mortality was 46% in both groups

Contraindications

- Mural thrombus in the LV
- Presence of a mechanical aortic valve
- Aortic valve stenosis (AVA $\leq$ 0.6cm2)
- Moderate to severe aortic insufficiency
- Severe PAD
- VSD

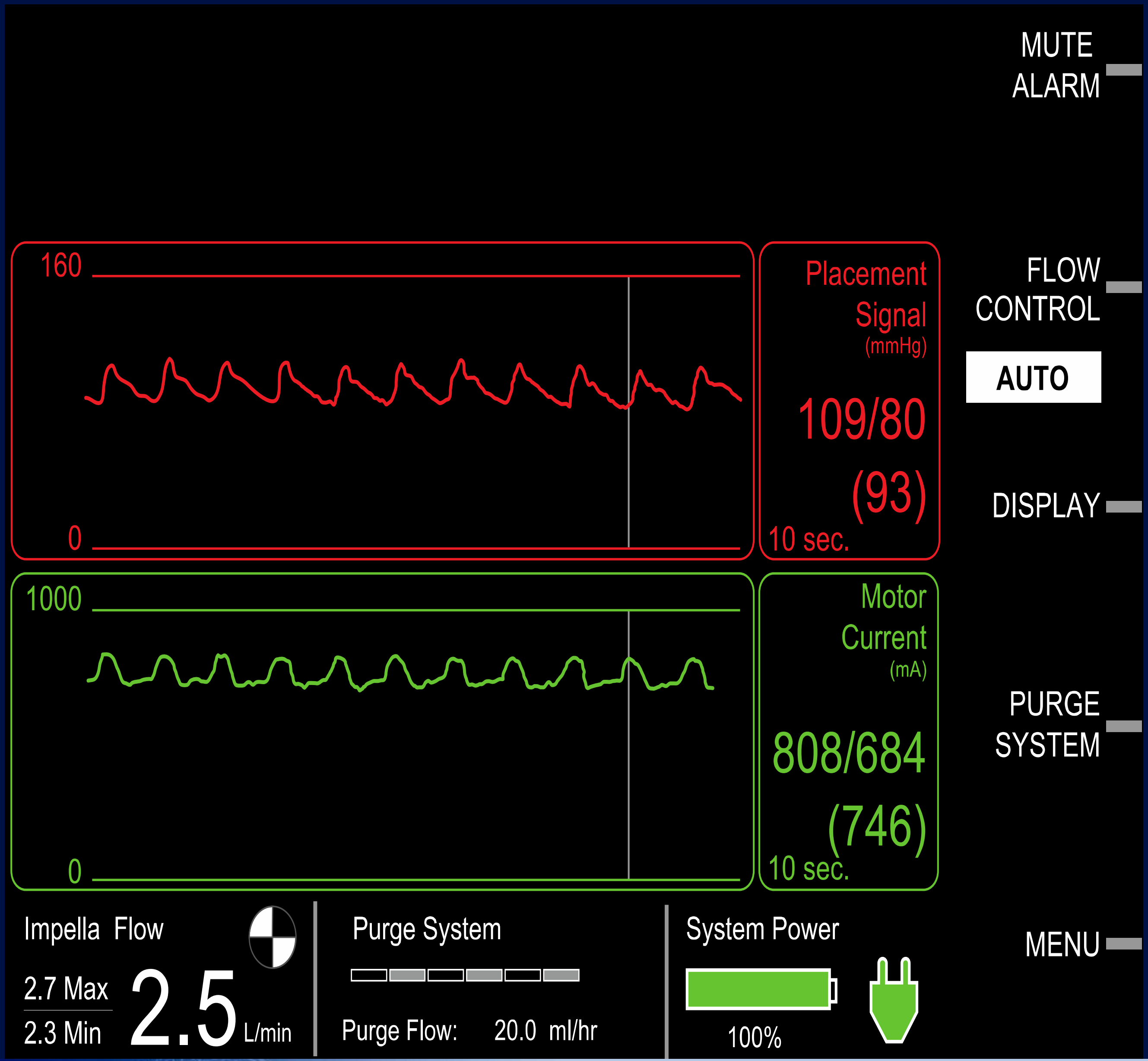
Complications

- Hemolysis
  - May respond to repositioning the device
- Persistent hemolysis associated with acute kidney injury
- Bleeding
- Limb ischemia/vascular injury
- Stroke

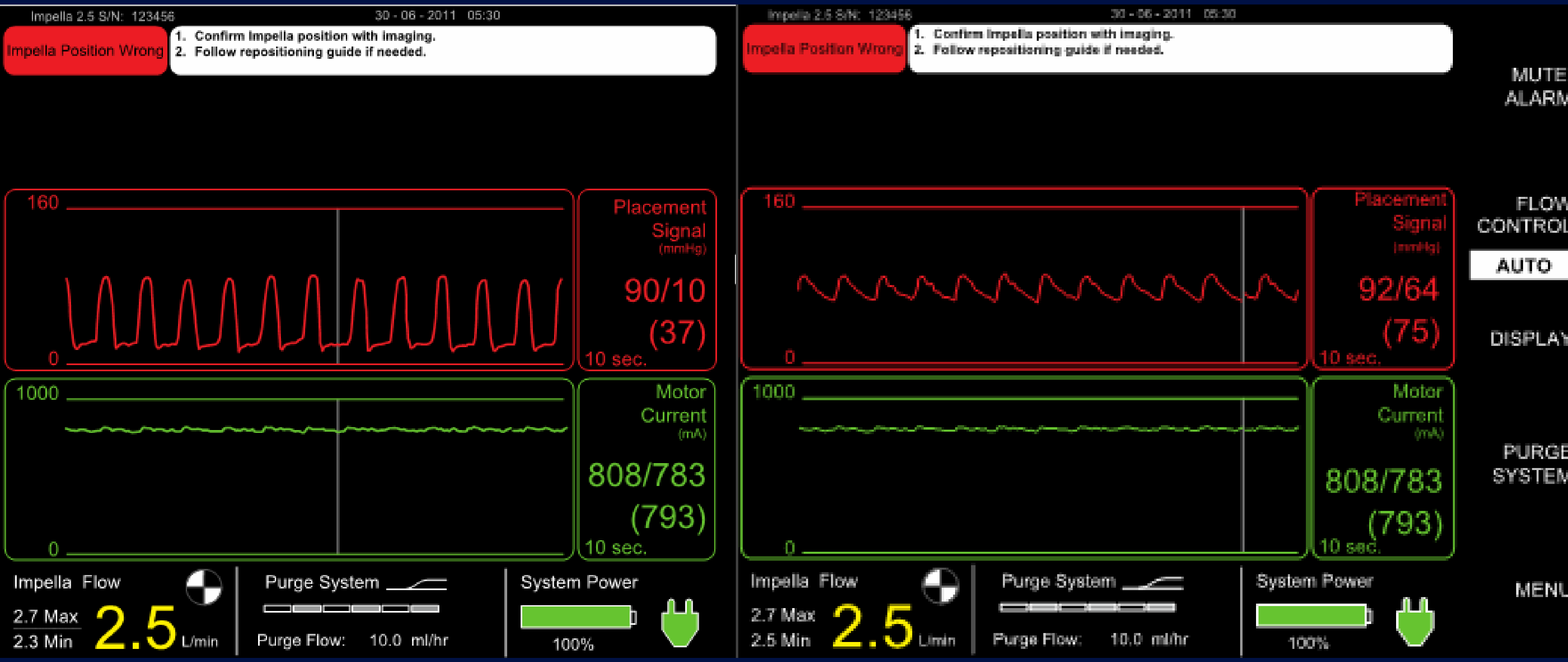
Table 5.2 Performance Level Flow Rates

Performance Level		*Flow Rate (L/min)	Revolutions Per Minute (rpm)
P0	Impella® Catheter motor is stopped	0.0 – 0.0	0
P1	Flow rate increases as the performance level increases	0.0 – 0.5	25,000
P2		0.4 – 1.0	35,000
P3		0.7 – 1.3	38,000
P4		0.9 – 1.5	40,000
P5		1.2 – 1.8	43,000
P6		1.4 – 2.0	45,000
P7		1.6 – 2.2	47,000
P8	Recommended maximum performance level for continuous use	1.9 – 2.5	50,000
P9	Used to confirm stable position after placement; can be used to provide maximum flow for up to 5 minutes. After 5 minutes, the Automated Impella® Controller will automatically default to P8.	2.1 – 2.6	51,000

PLACEMENT SCREEN

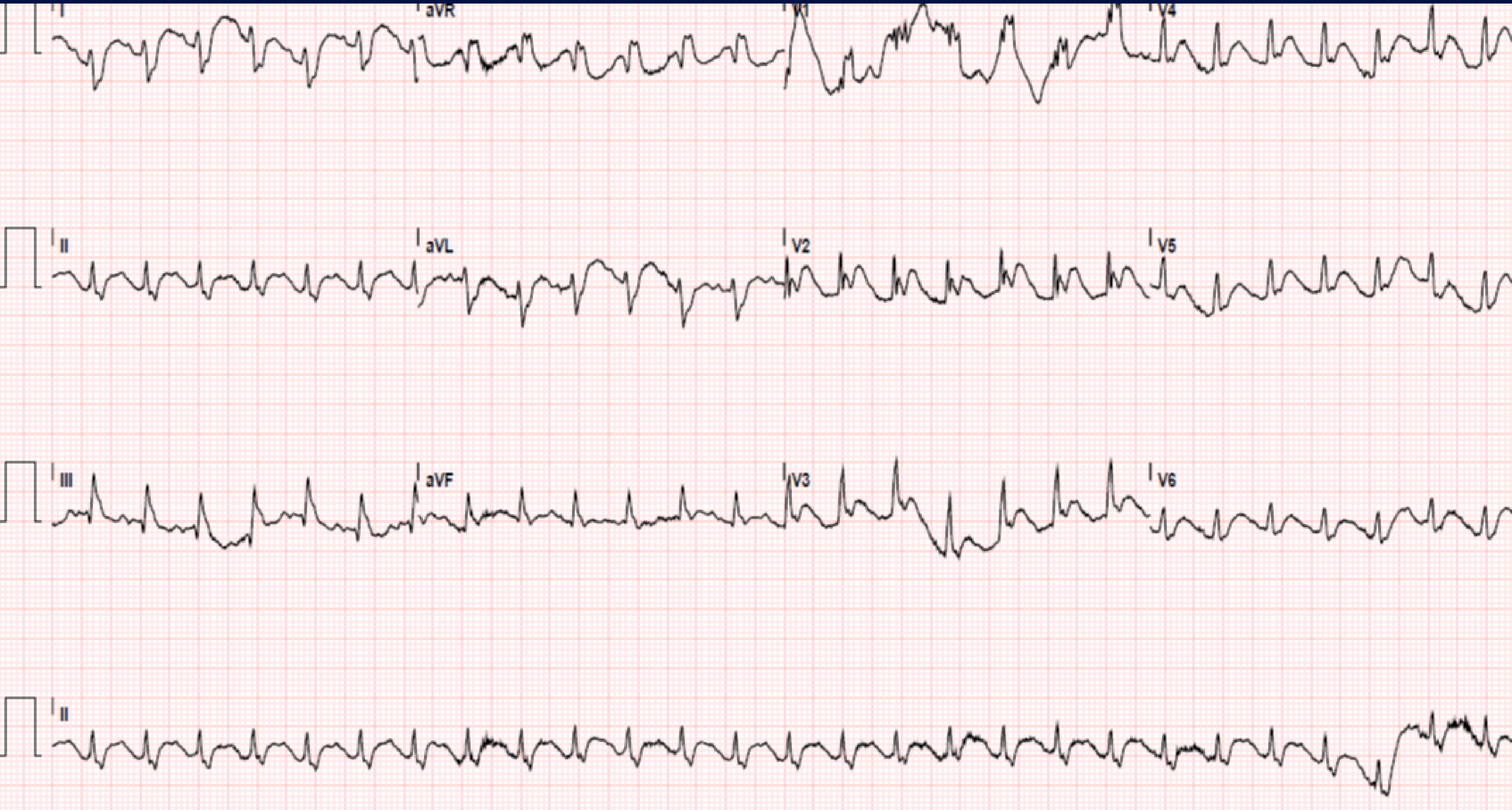


PLACEMENT SCREEN

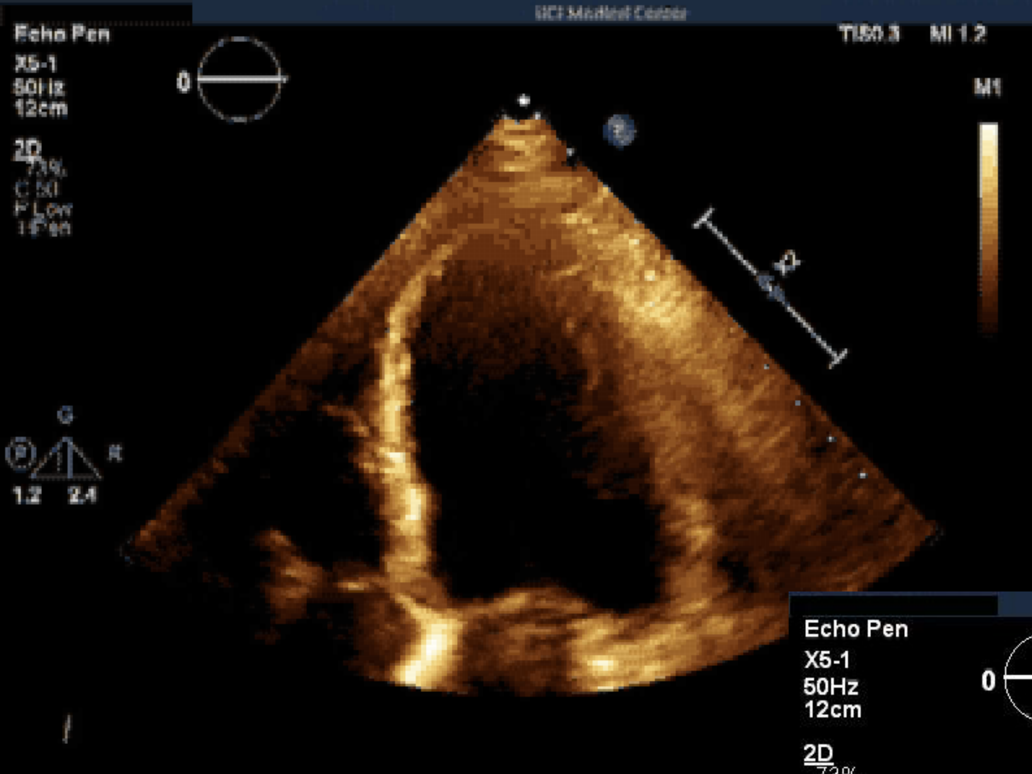


Case

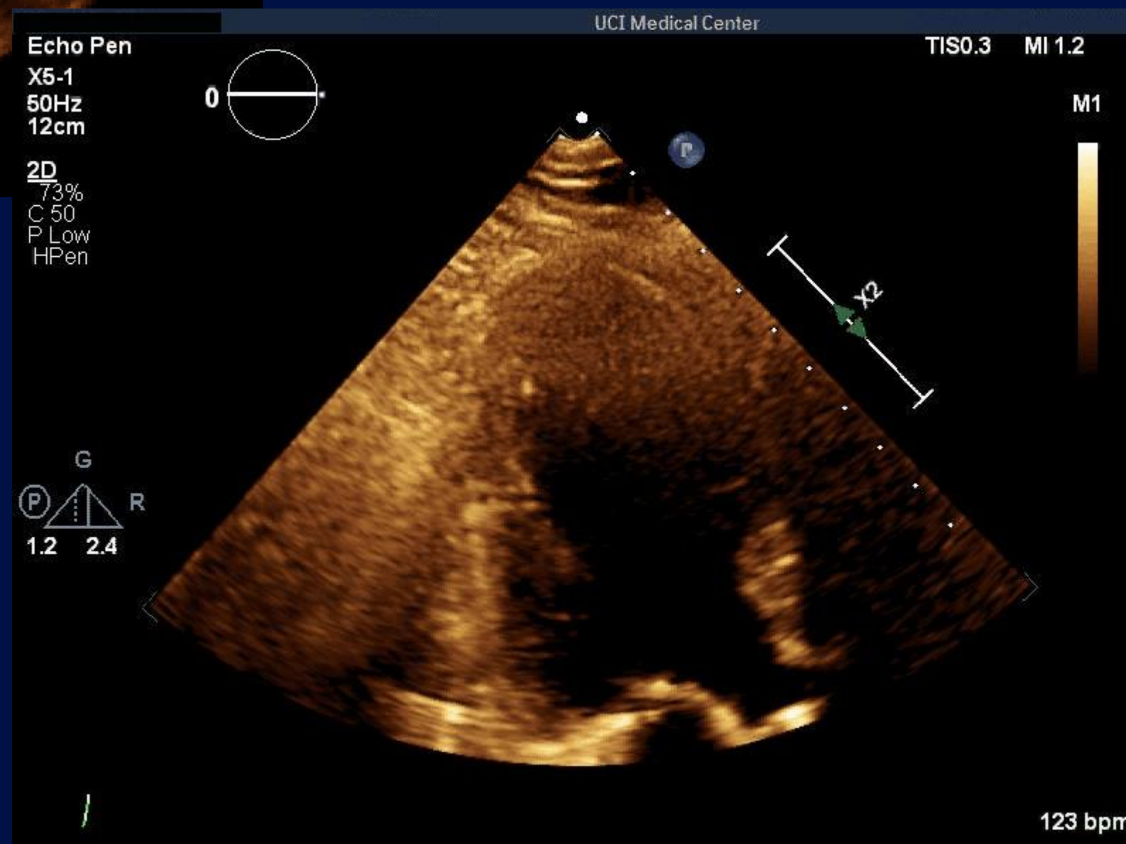
- 52 year old female lap cholecystectomy complicated by injury to the common bile duct and sepsis.
- Patient become acutely tachycardic to 160s and hypoxic.



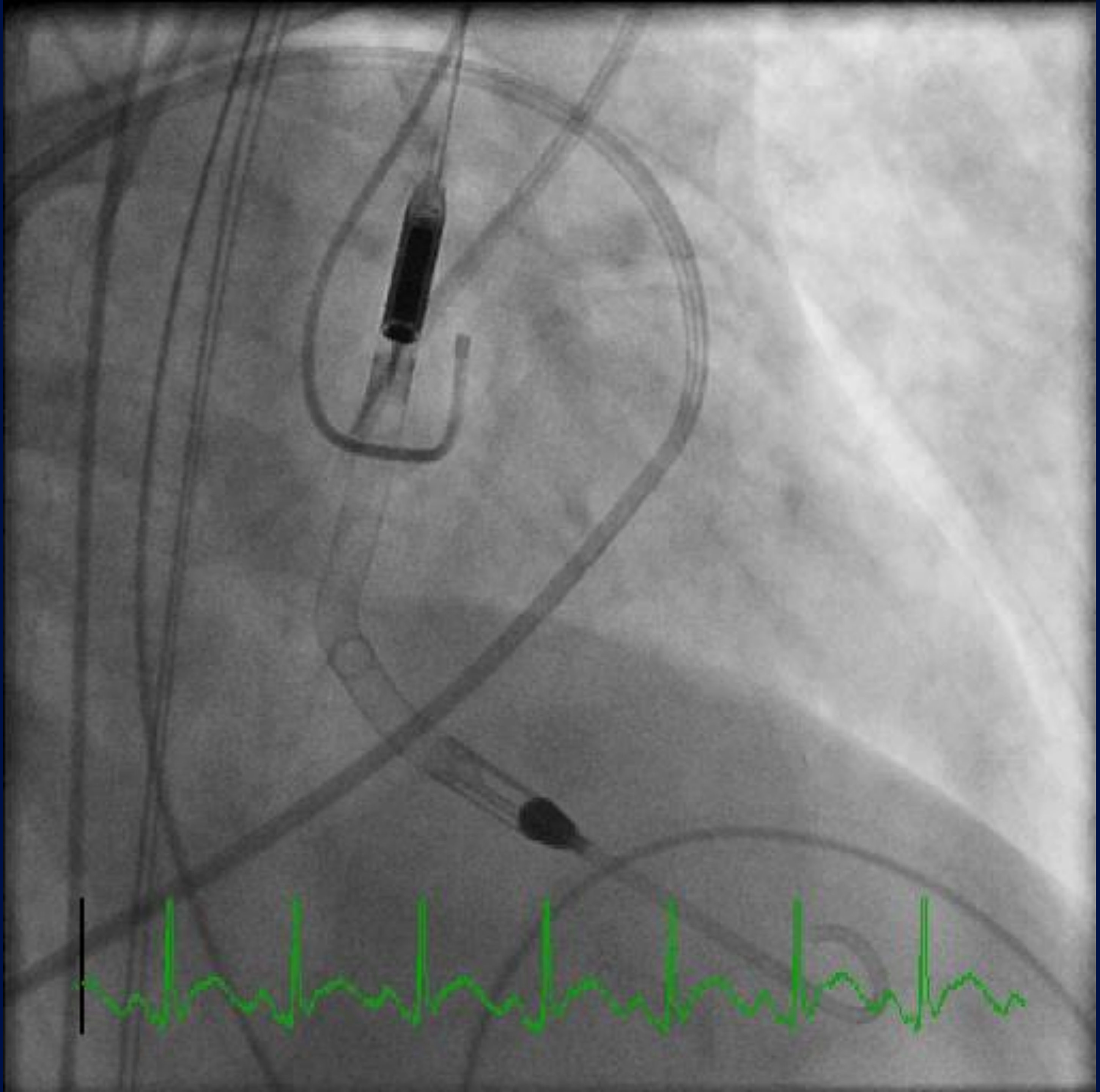
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

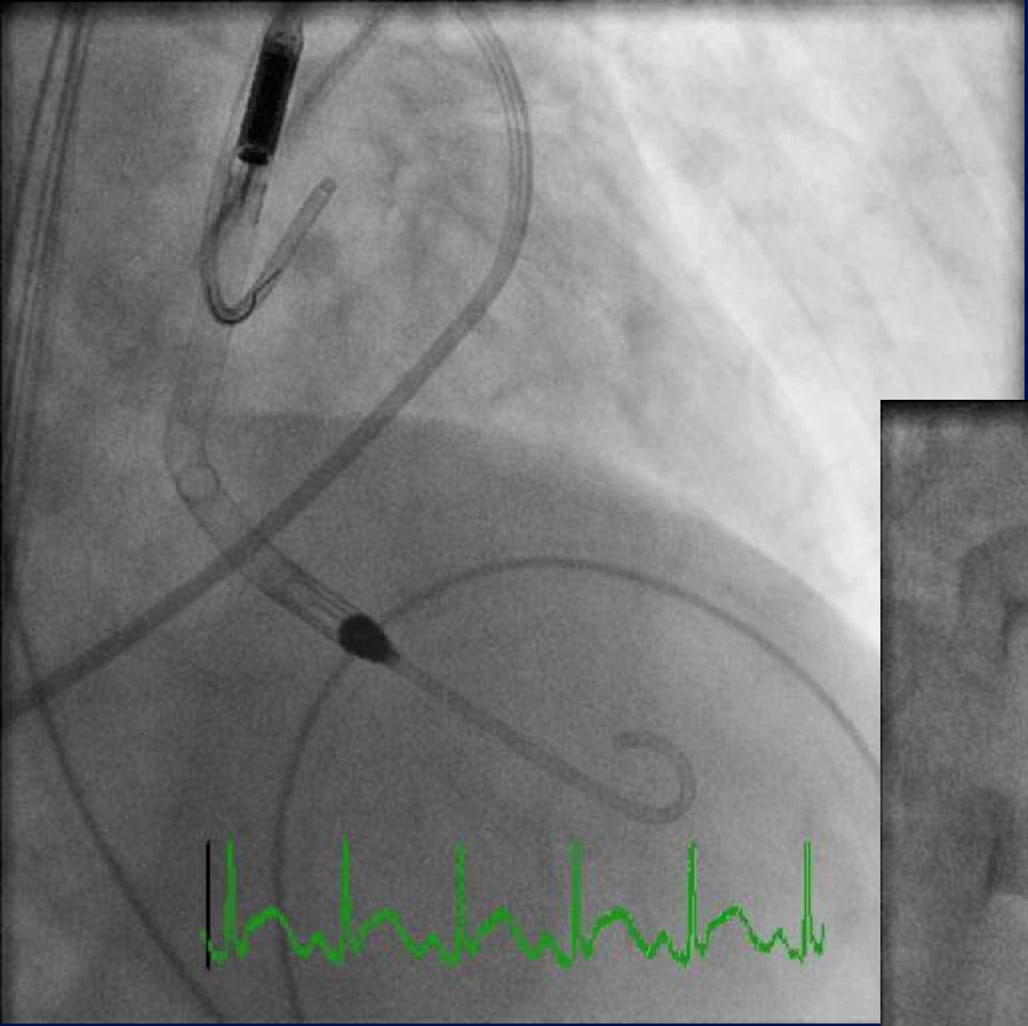


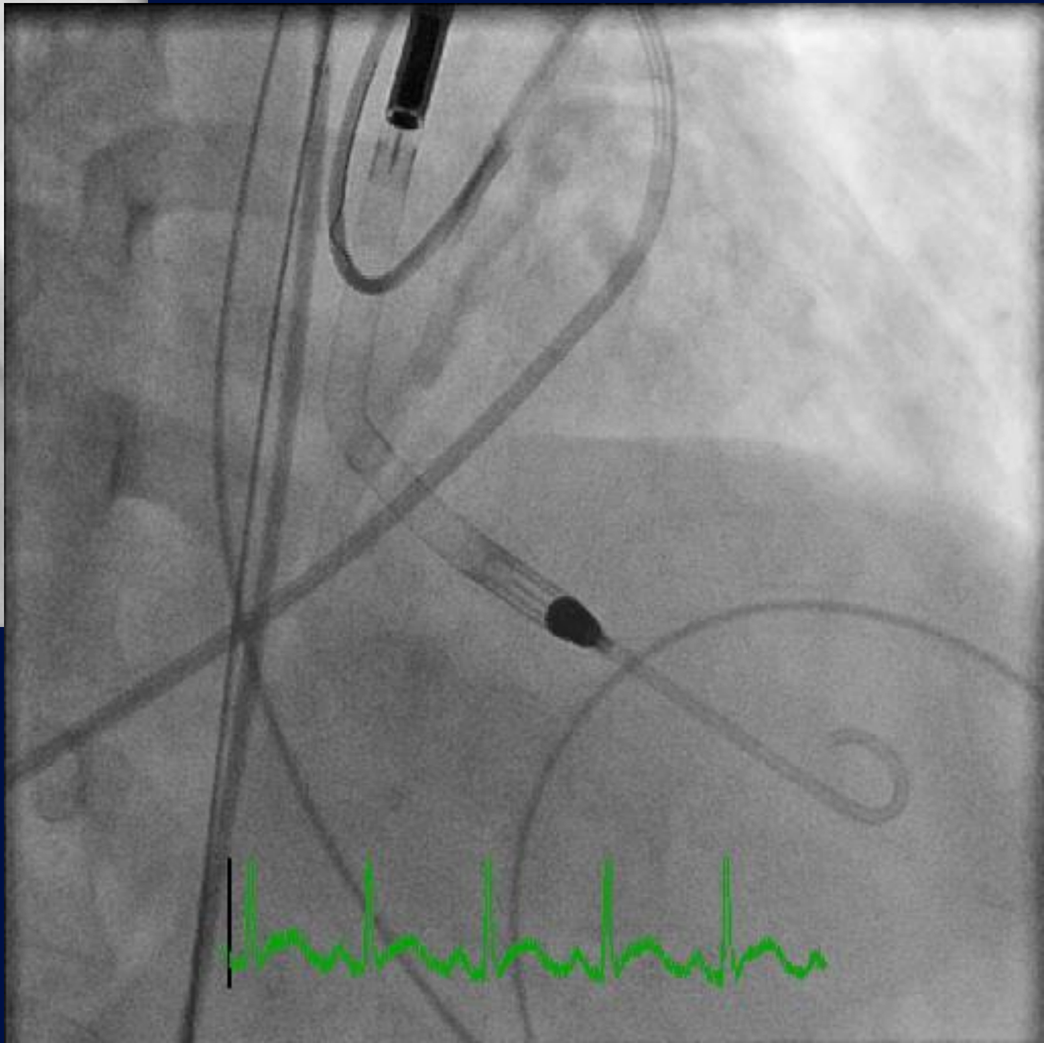
Echo Pen
X5-1
12cm
2D
TIS0.3
MI 1.2
M1
0
X2
1.2
2.4

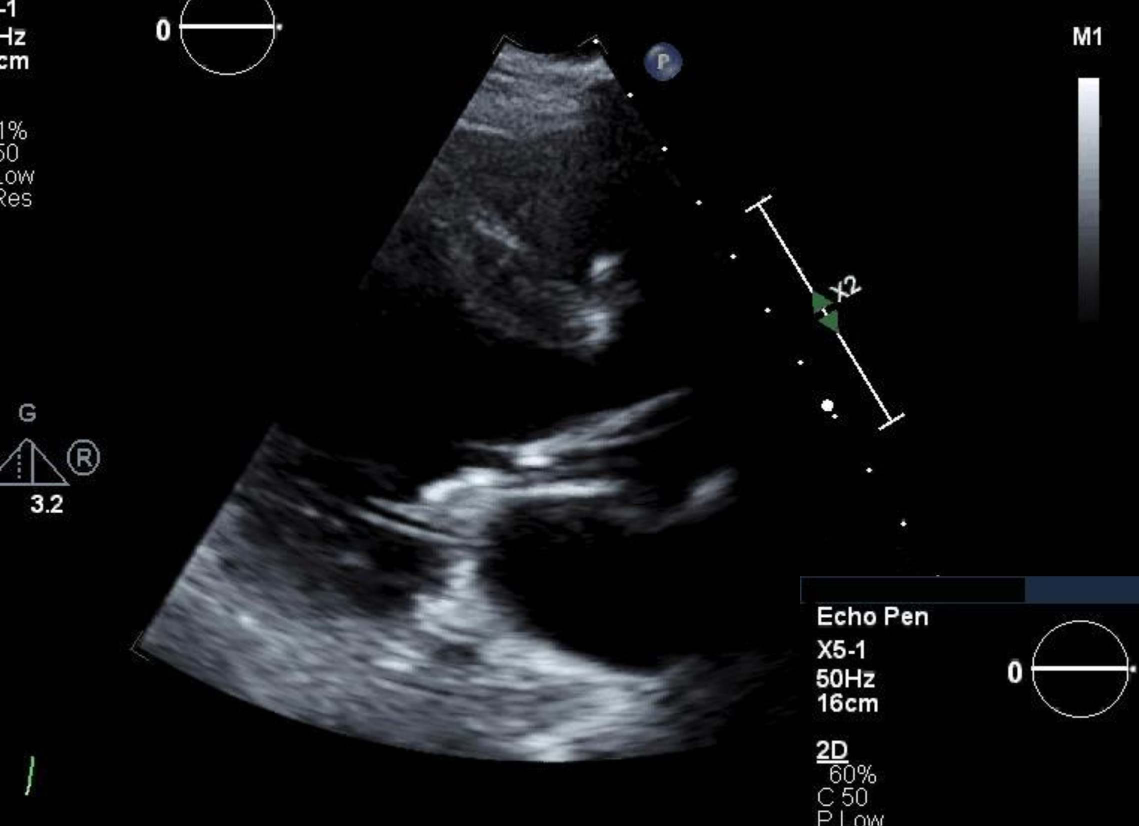


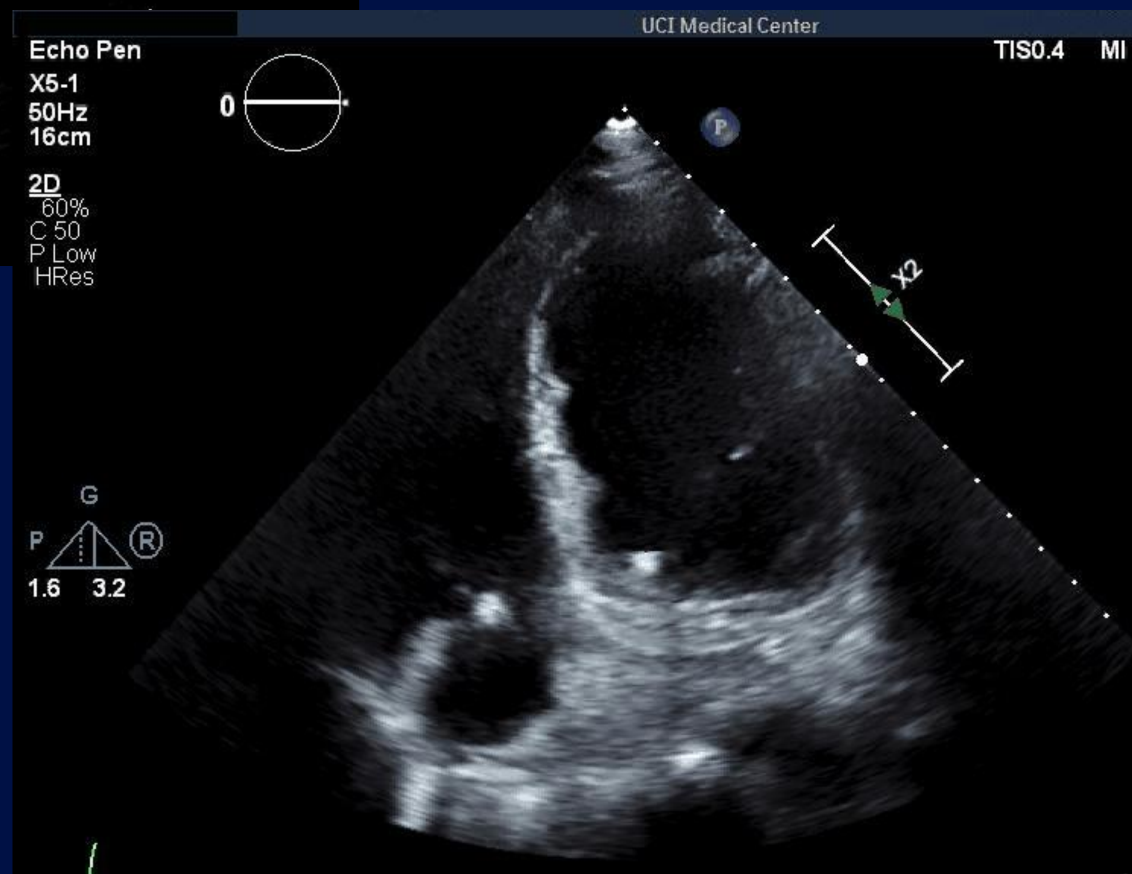
UCI Medical Center
Echo Pen
X5-1
50Hz
12cm
2D
73%
C 50
P Low
HPen
TIS0.3
MI 1.2
M1
0
X2
G
P
R
1.2
2.4
123 bpm

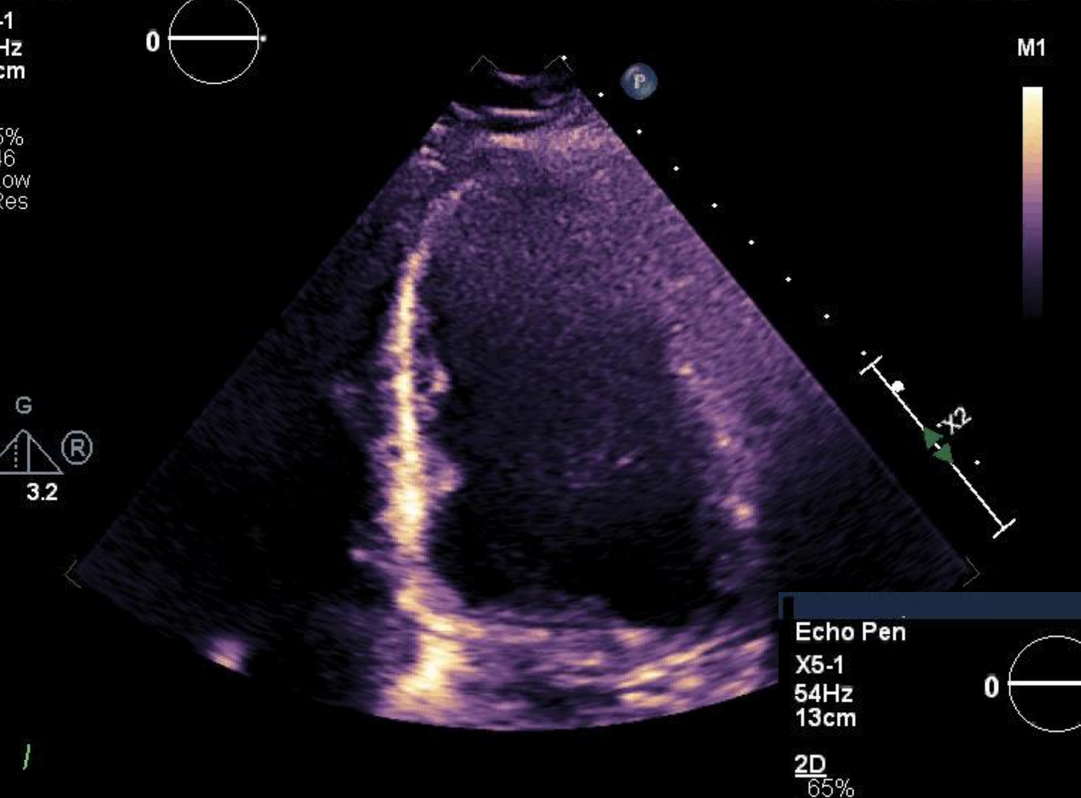




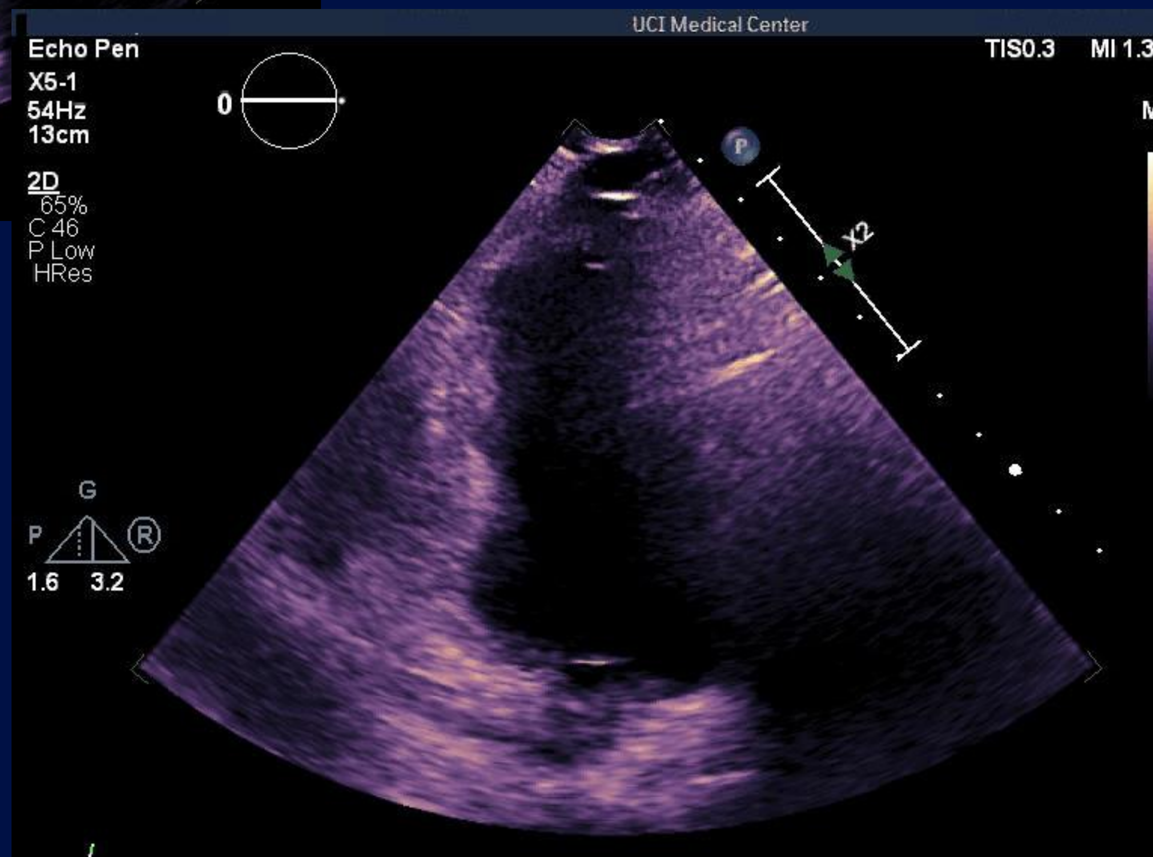



0
M1
X2
G
3.2


UCI Medical Center
Echo Pen
X5-1
50Hz
16cm
2D
60%
C 50
P Low
HRes
TIS0.4
MI
0
X2
G
P
1.6
3.2

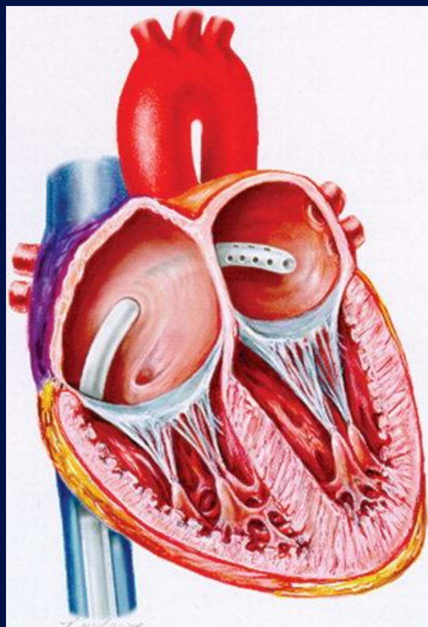


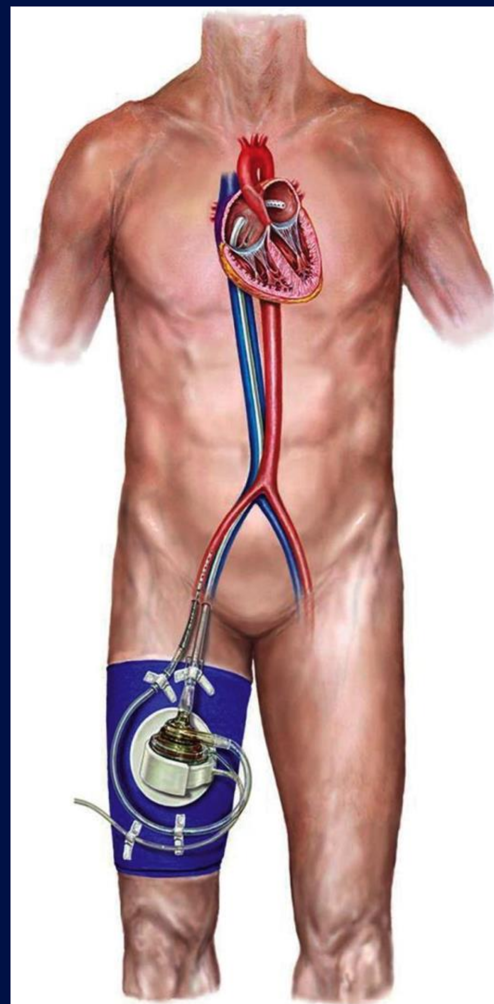
0
M1
X2
G
3.2



UCI Medical Center
Echo Pen
TIS0.3
MI 1.3
X5-1
54Hz
13cm
0
2D
65%
C 46
P Low
HRes
X2
G
P
1.6
3.2

TandemHeart

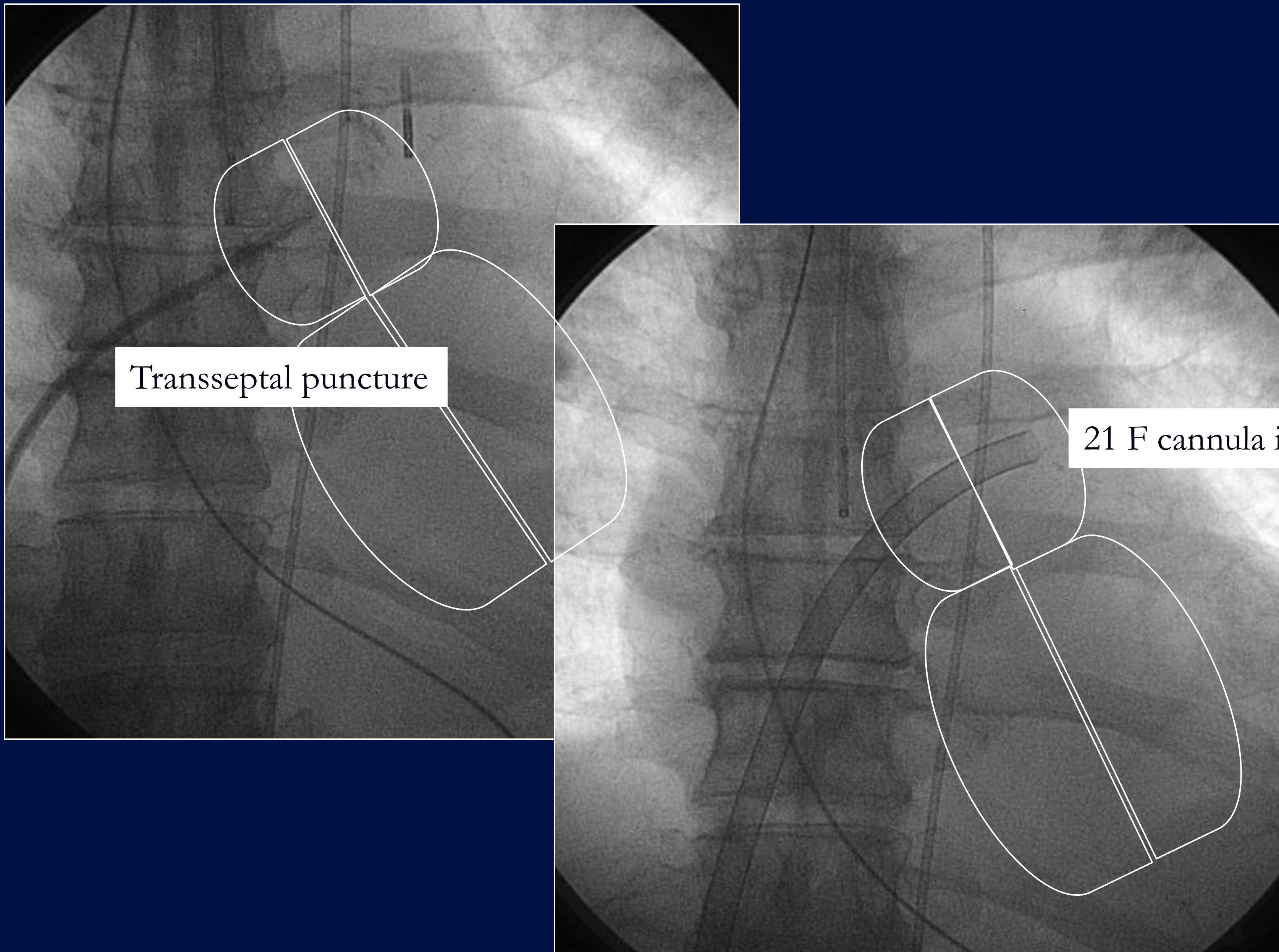




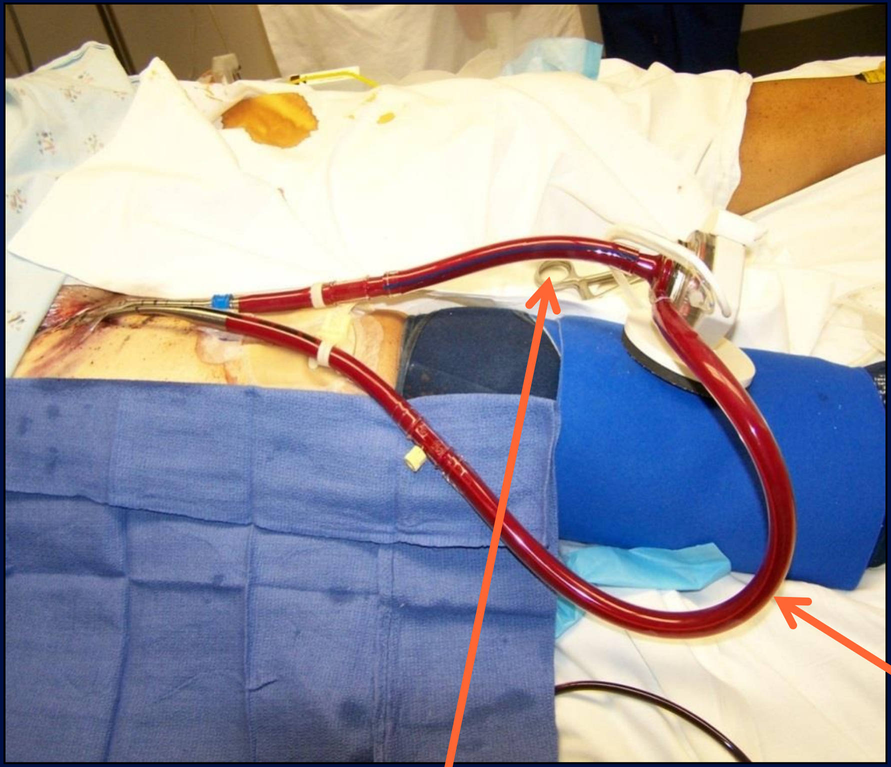
- Left atrial-to-femoral arterial LVAD
- 21F venous transseptal cannula
- 17F arterial cannula
- Maximum flow 4L/min

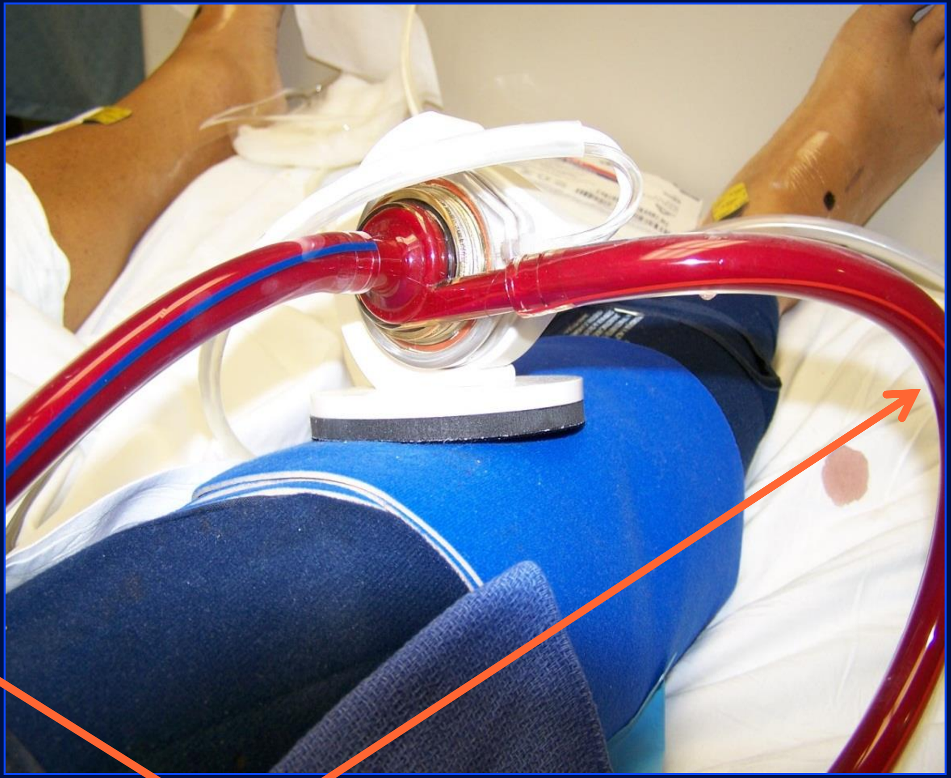
Hemodynamic Effects

CO	↑↑
MAP	↑
PCWP	↓↓


Transseptal puncture
21 F cannula in LA

TandemHeart Cannula



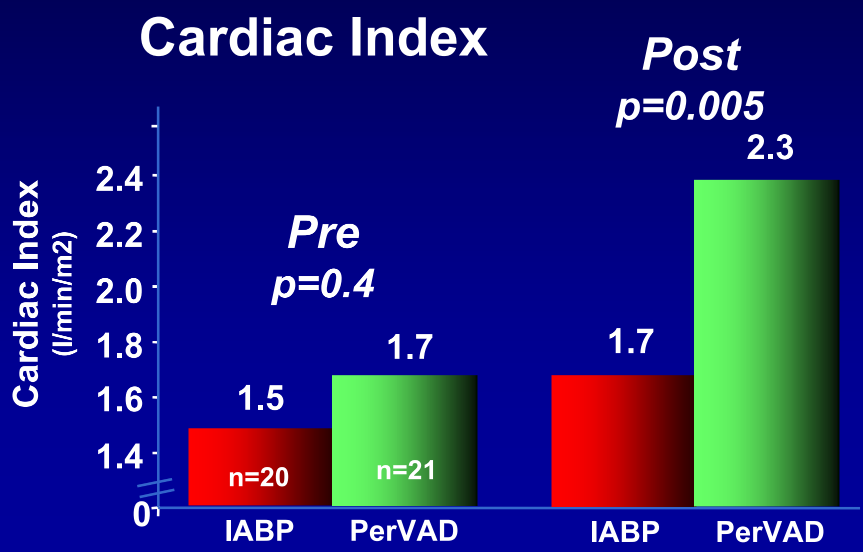


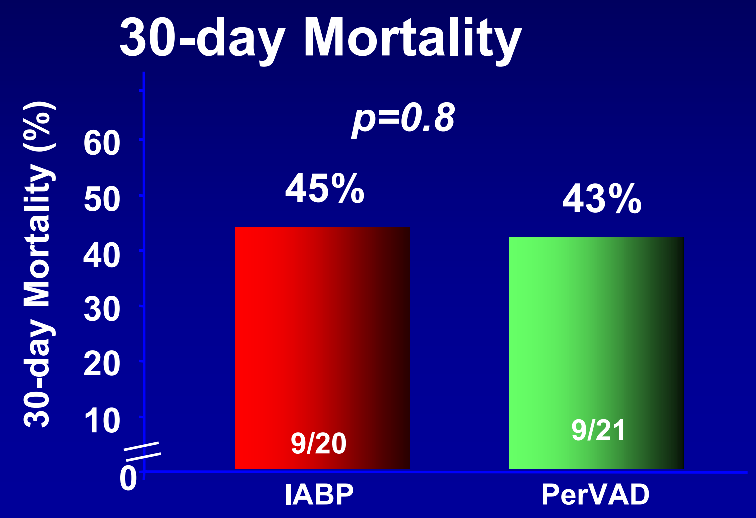
Venous cannula

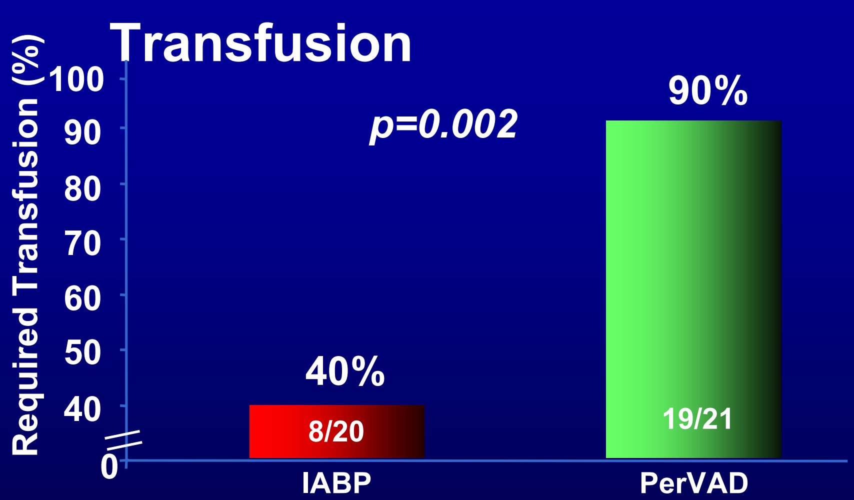
arterial return cannula

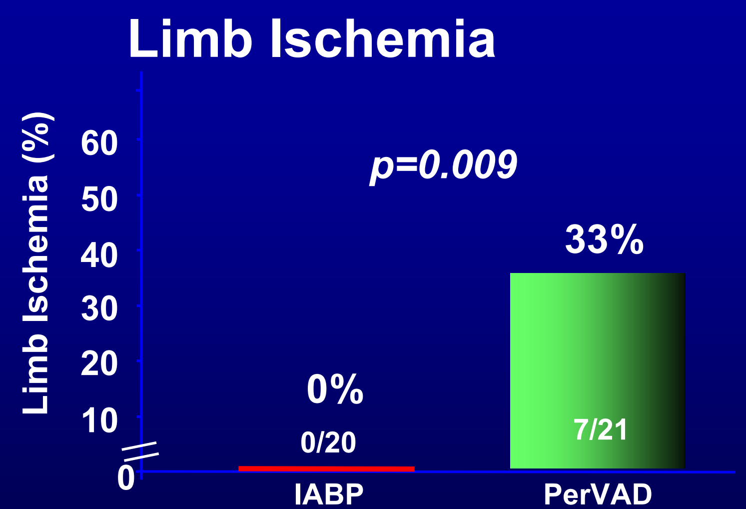

PUMP STOPPED
Flow (LPM)
0.0
Speed (RPM)
6900
3500
7500
Pressure
Flow
Pump
TandemHeart
Property of
CardiacAssist, Inc.

TandemHeart Shock Study

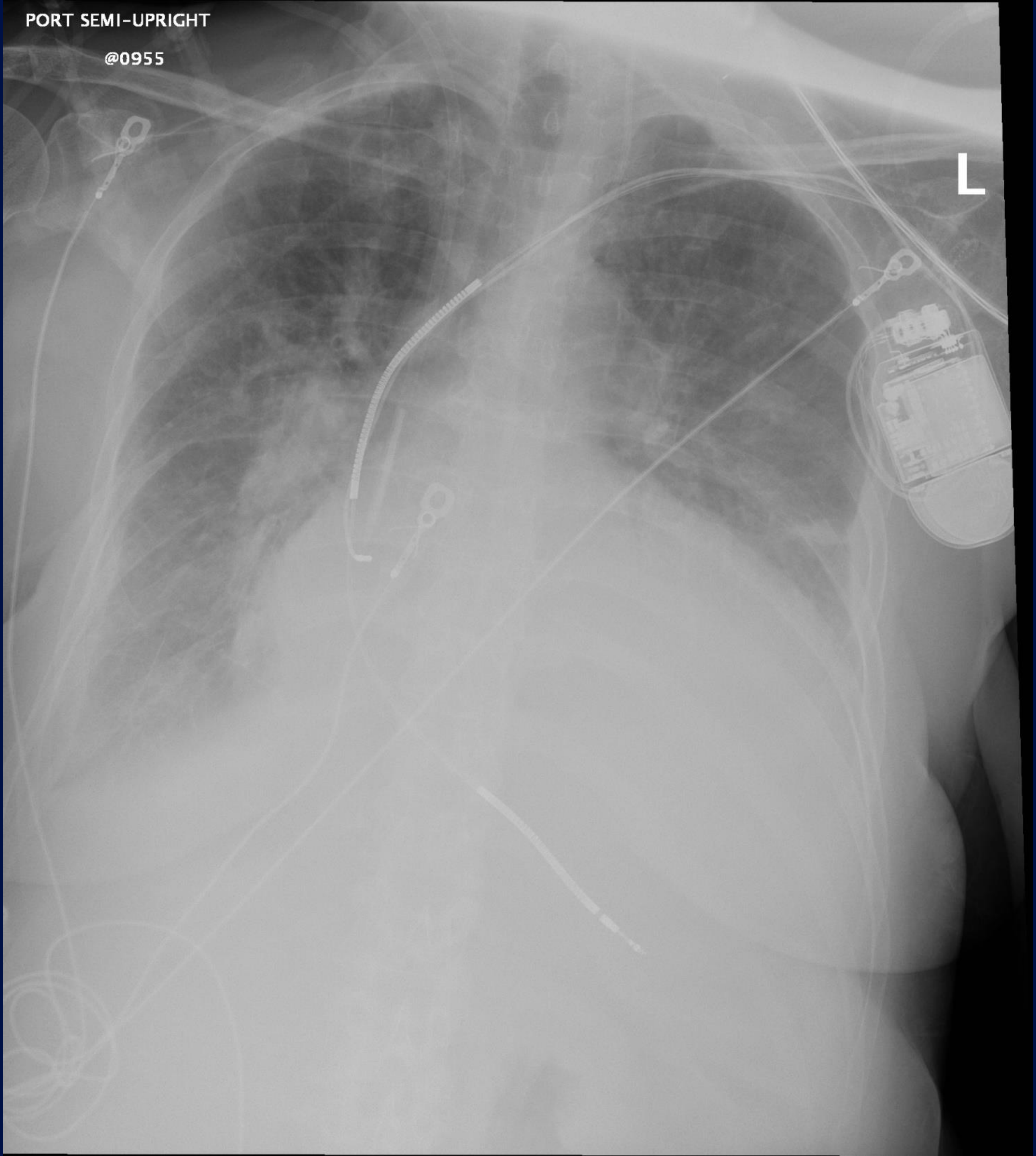


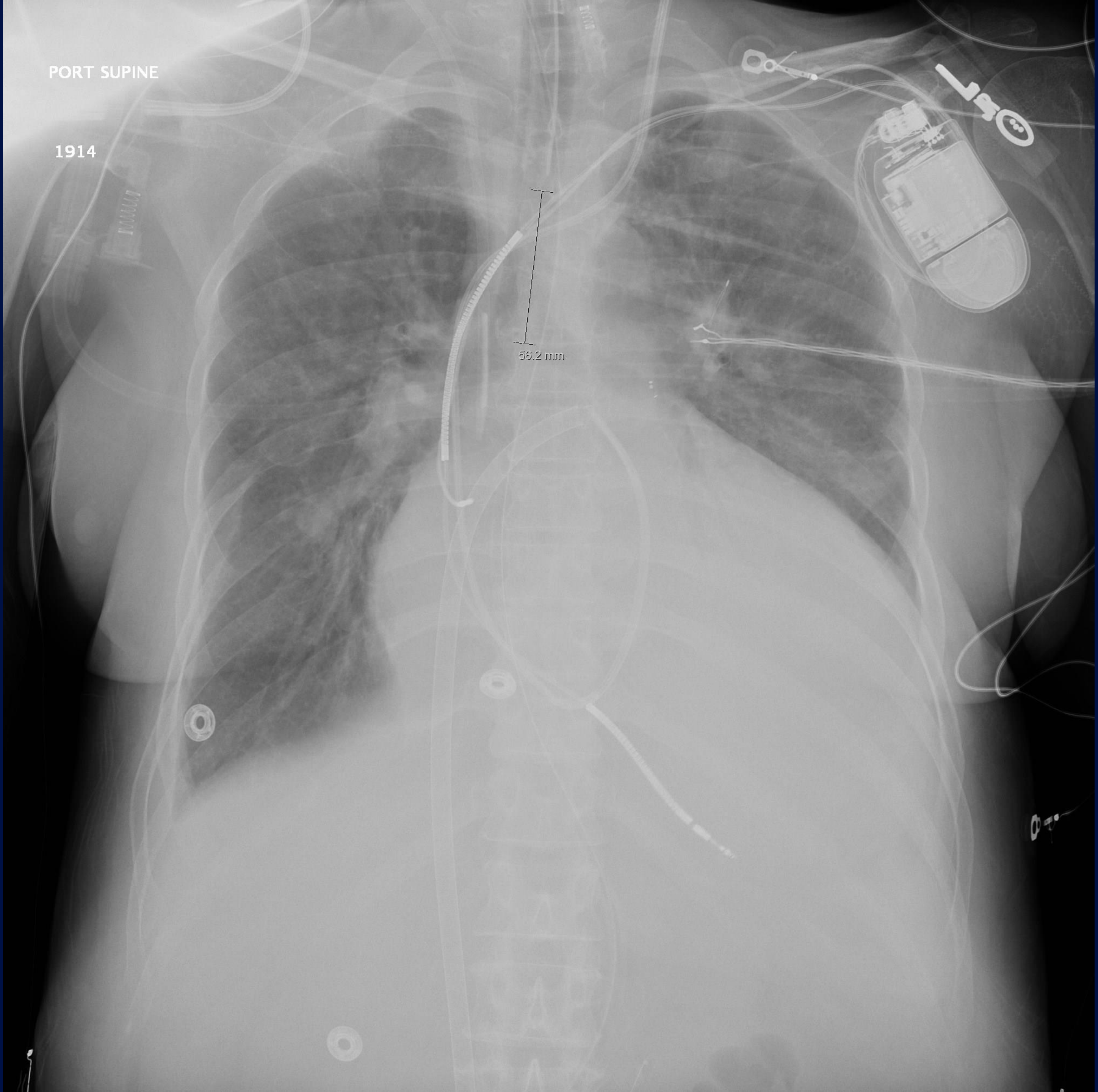




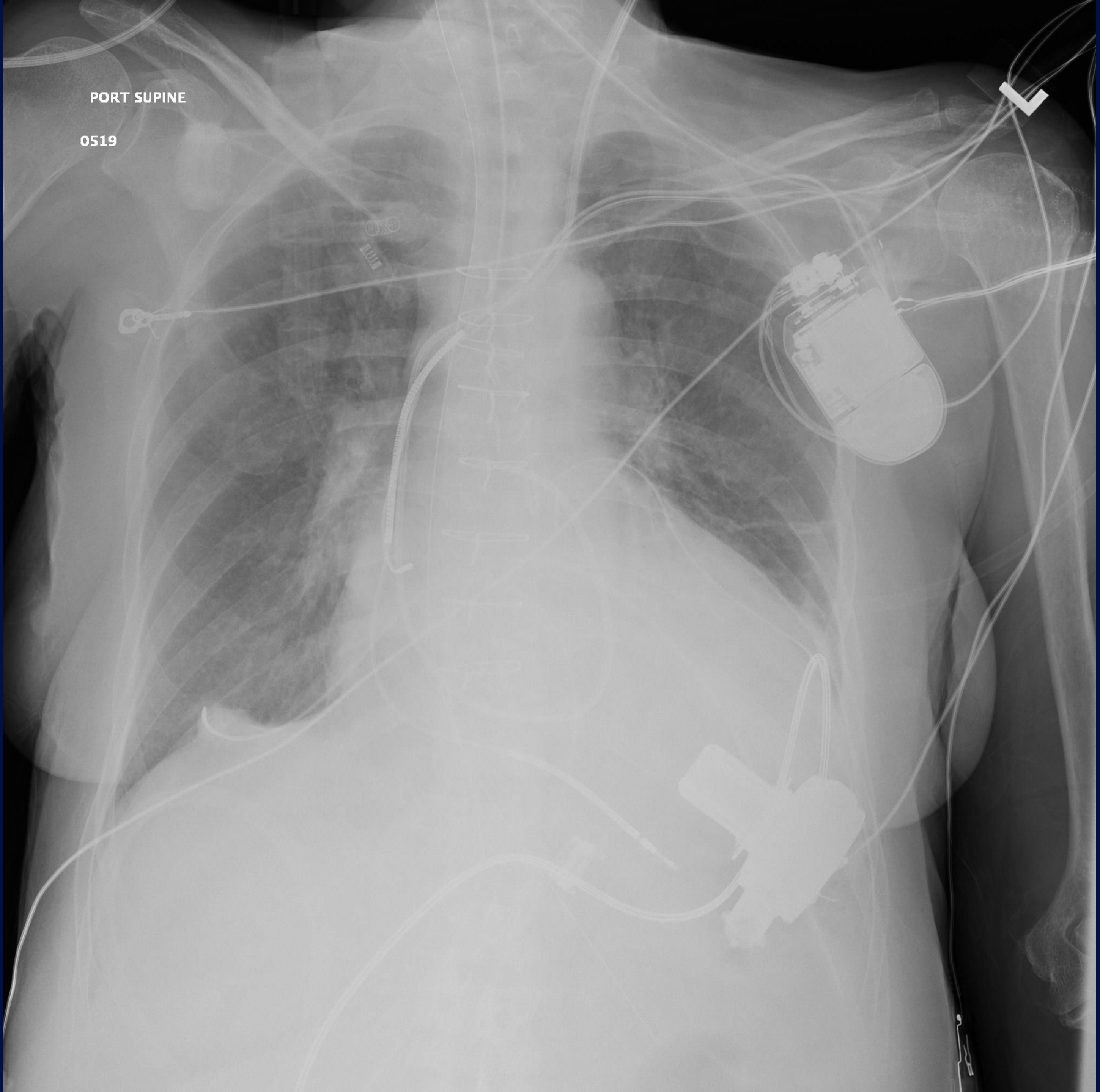


Thiele and al. Eur. Heart Journal 2005 Jul;26(13):1276-83


PORT SEMI-UPRIGHT
@0955
L

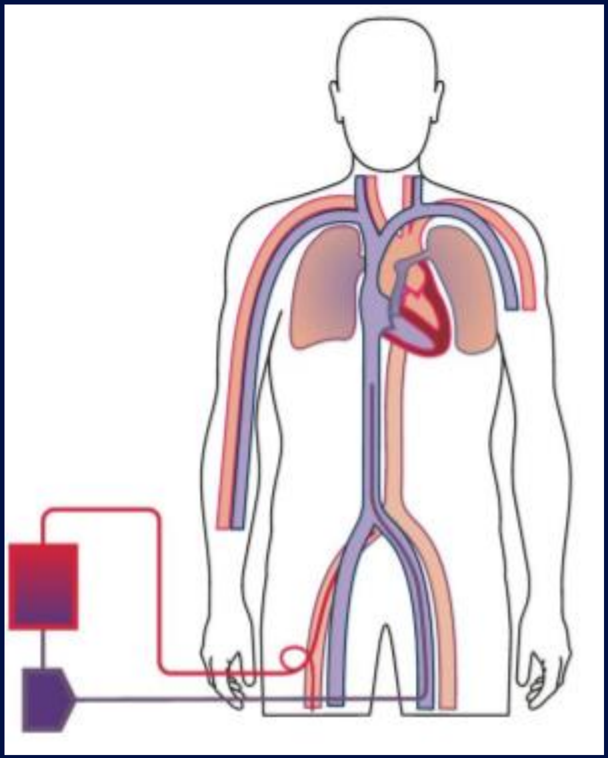


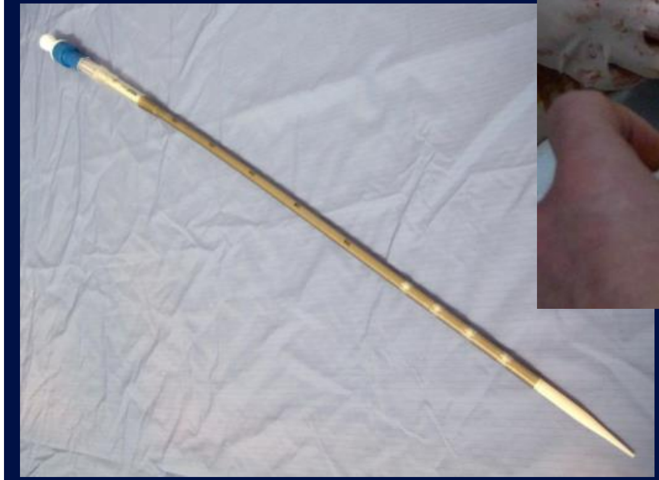
PORT SUPINE
1914
56.2 mm


PORT SUPINE
0519

Extracorporeal Membrane Oxygenation (ECMO)

Cannulation

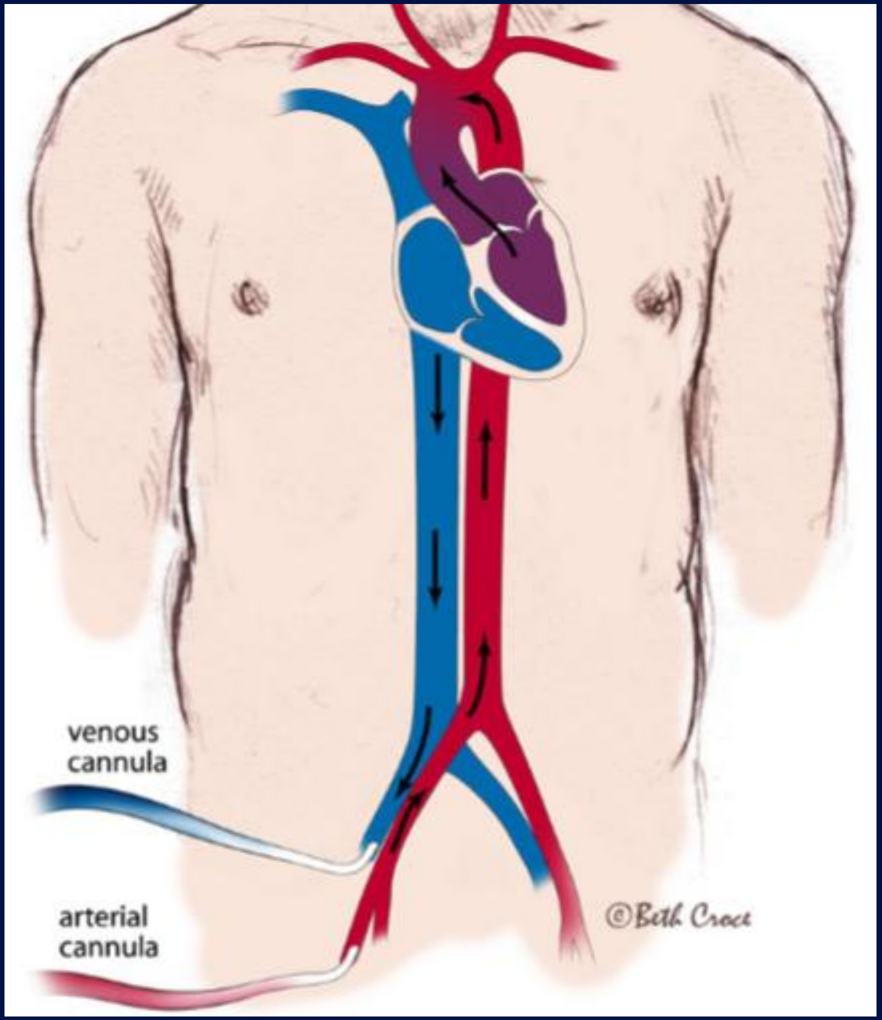




- Femoral vein cannulated with 21-25Fr catheter tip in the right atrium.
- Femoral artery cannula 17-21 Fr inserted to the taper with the tip at the common iliac artery or lower aorta.
- Distal antegrade perfusion cannula inserted into common femoral artery to prevent distal limb ischemia. Usual size 5-9 Fr

Peripheral Cannulation

- Retrograde peripheral flow leads to admixing in the arch
- If there is respiratory insufficiency, the heart will pump poorly oxygenated blood to the coronaries and proximal arch vessels while ECMO supplies oxygenated blood to the rest of the body.



Advantages and Disadvantages

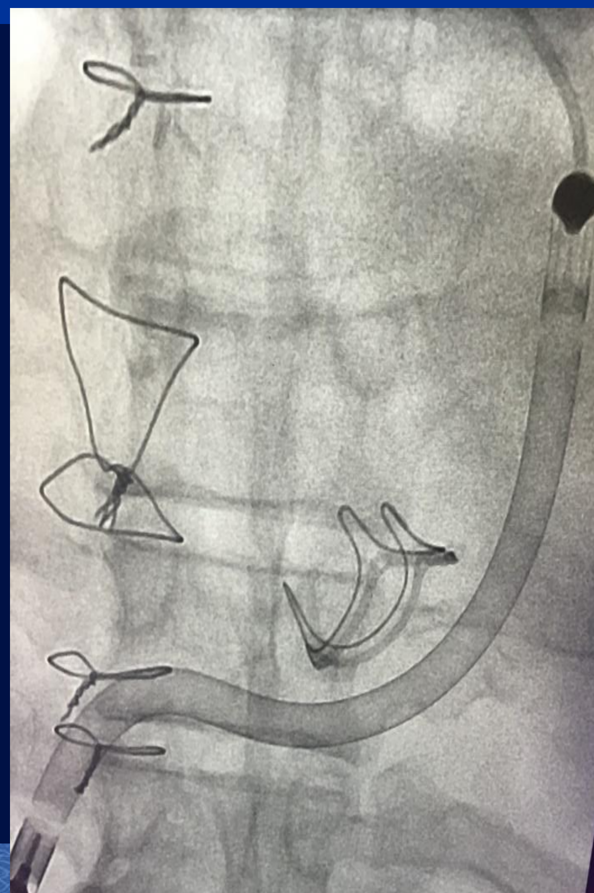
- Relatively Inexpensive (as compared to Impella/TandemHeart)
  - Double the cost of conventionally treated patients ($65K)
  - Favorable lifetime predicted cost-utility
- Minimally invasive (peripheral cannulation)
- Bedside deployment
- Biventricular support
- Pulmonary support

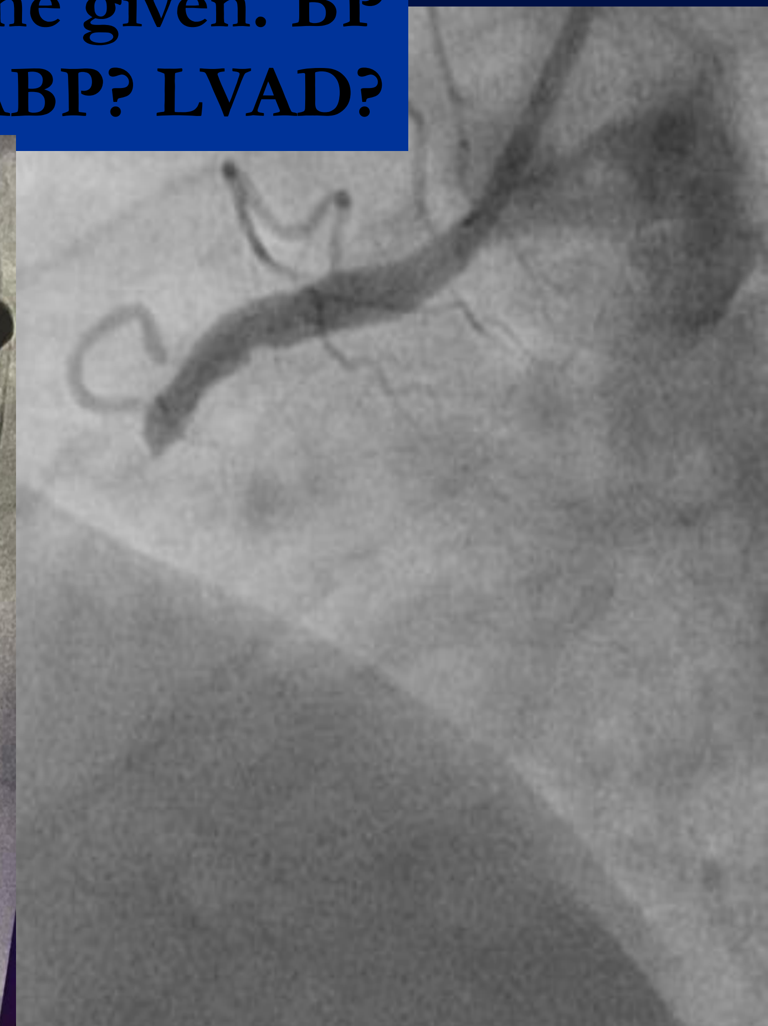
- Labor intensive (ACT monitoring, bedside monitoring, management)
- Patient is immobilized
- LV distention
- High complication risk (57%)

Bridge to Nowhere

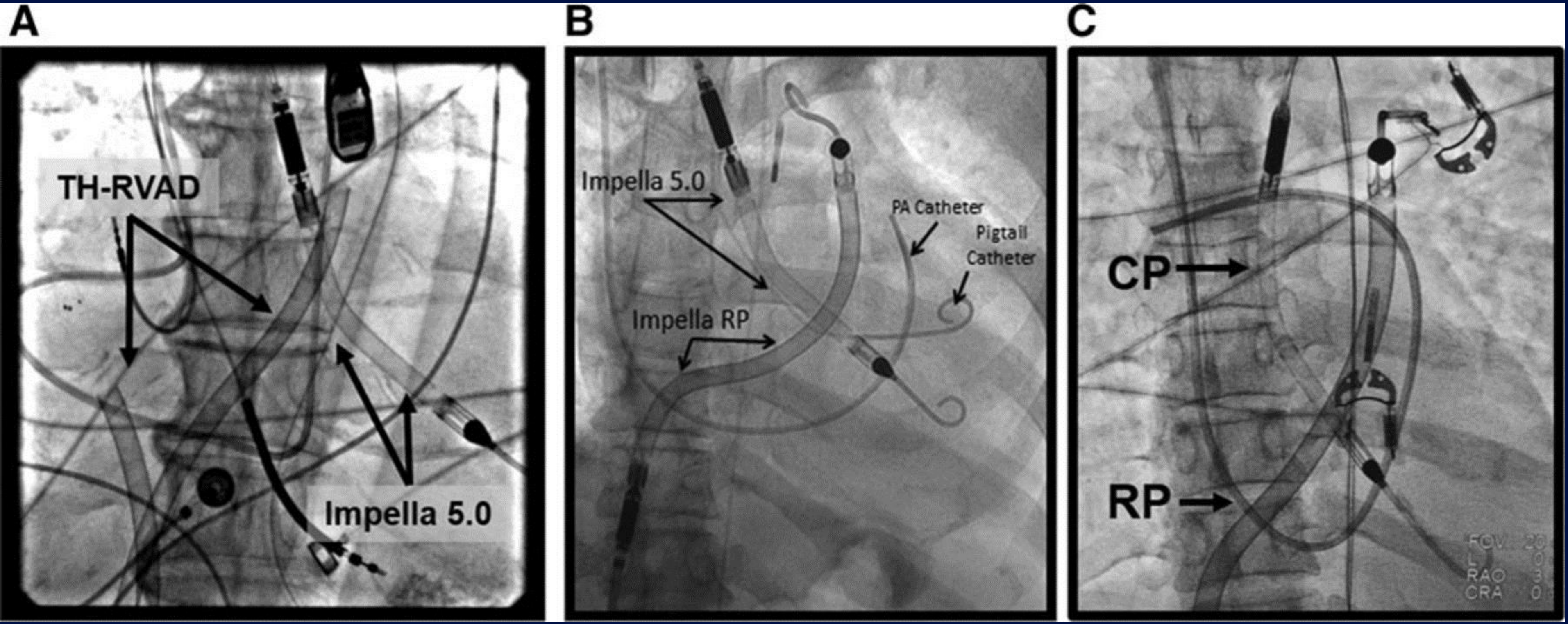
- Absolute
  - Unrecoverable heart and not a candidate for transplant or VAD
  - Presence of severe chronic organ failure
  - Severe brain injury OR Prolonged CPR
  - Severe peripheral vascular disease
  - Severe aortic insufficiency
- Relative
  - Obesity
  - Malignancy
  - Contraindication to anticoagulation
  - Advanced age >75
  - Compliance (financial, cognitive, psychiatric, or social limitations)

71 yo M 4h intermittent chest pain, light headedness, pallor, sweating. Inferior STEMI. Left Coronary System has mild CAD. RCA is 100%. JVD 12cm. Fluids, Dopamine given. BP 72/55, HR 68bpm. What now? IABP? LVAD?



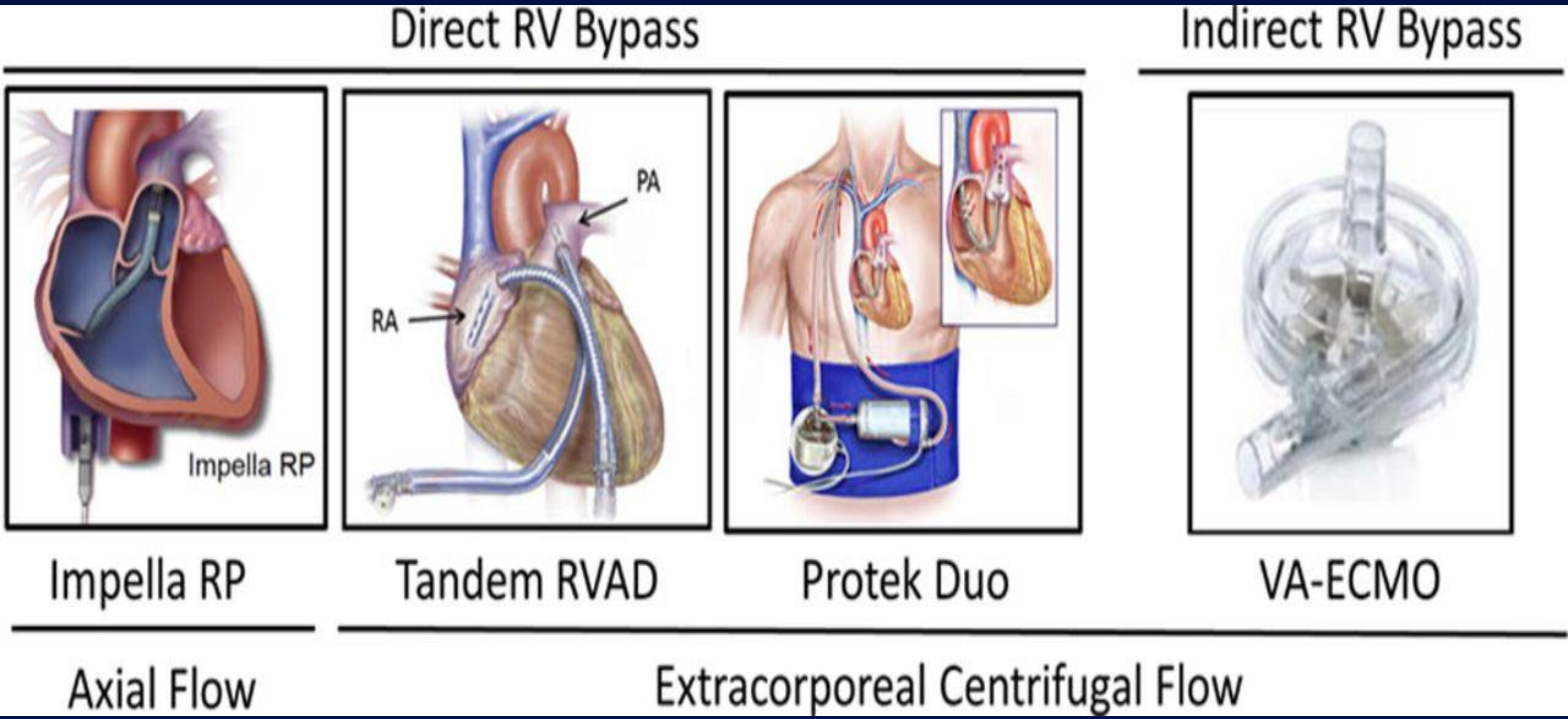


Percutaneous Biventricular Acute MCS Support Configuration



Kapur et al. Circ. 2017;136:314-326

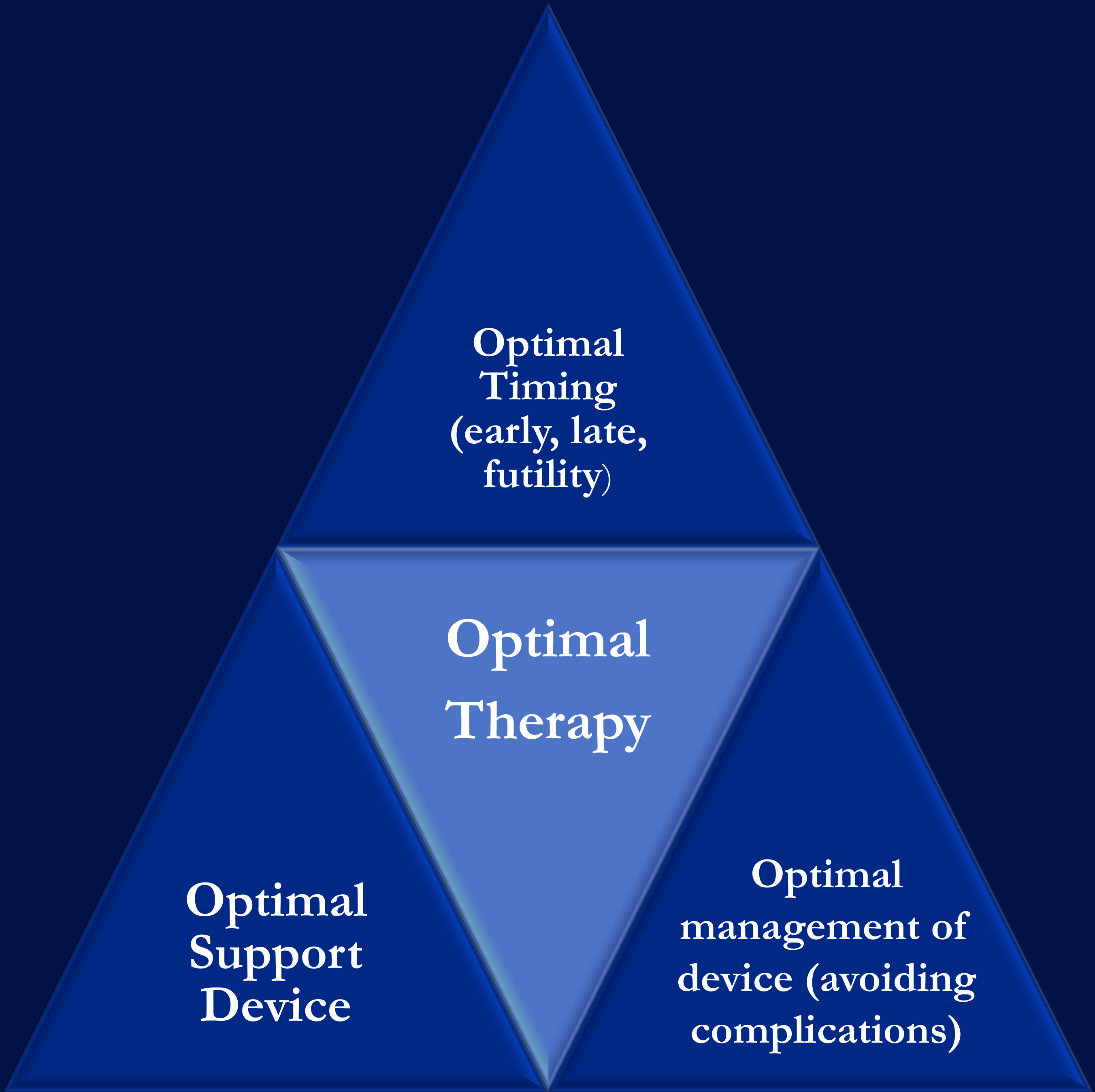
Mechanical circulatory support for RV failure



Kapur et al. Circ. 2017;136:314-326

Approach to Cardiogenic Shock

- Consider IABP in:
  - Cardiogenic shock (mild)
- Moderate to severe cardiogenic shock, on inotropes and vasopressors:
  - Consider Impella (CP, 5.0L), TandemHeart, ECMO
- Biventricular cardiogenic shock:
  - Consider ECMO or combined percutaneous LVAD/RVAD



Euro Heart J(2015) 36, 1223–1230

Thank You