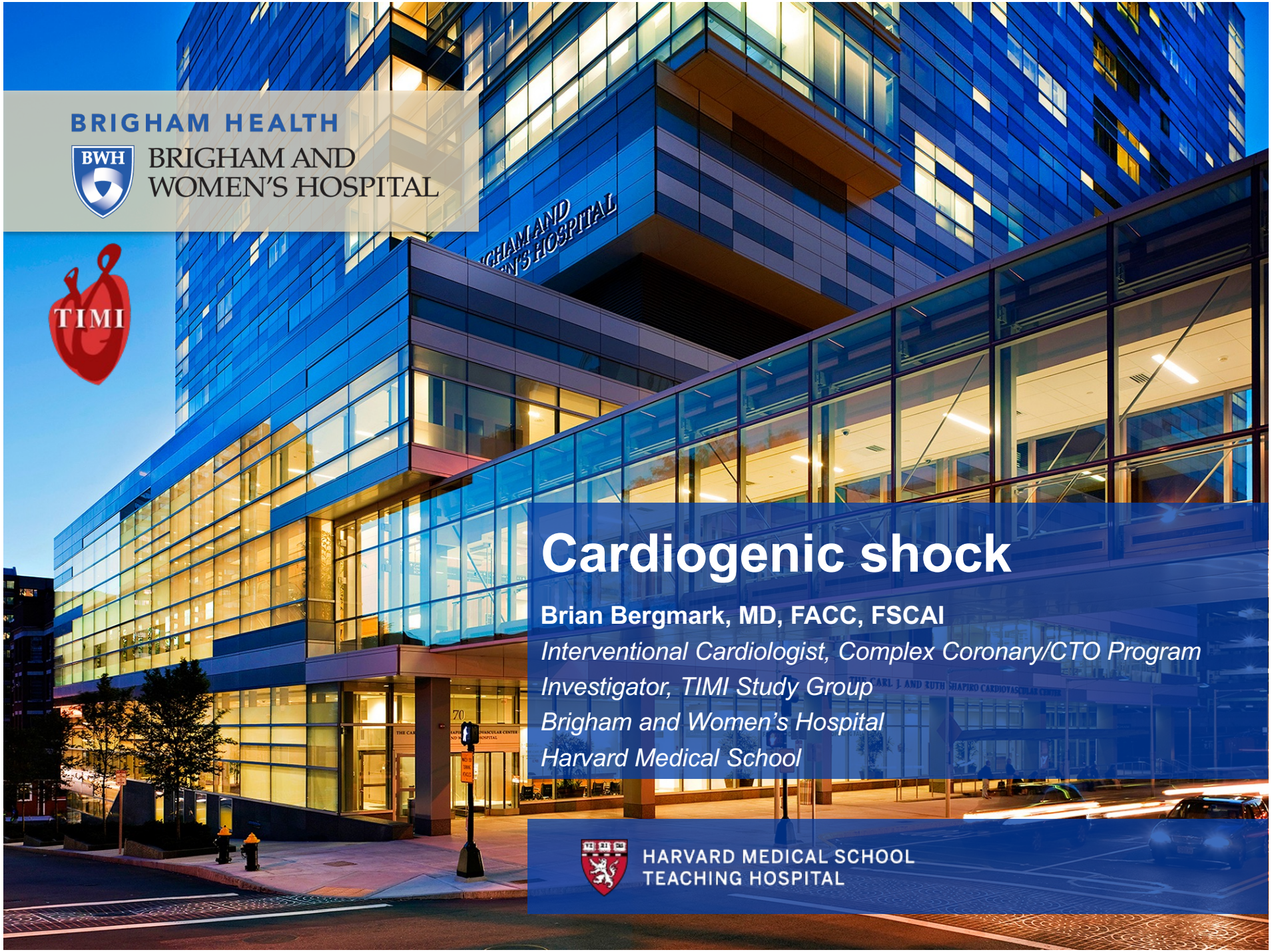
BRIGHAM HEALTH
BWH
BRIGHAM AND
WOMEN'S HOSPITAL
TIMI
Cardiogenic shock
Brian Bergmark, MD, FACC, FSCAI
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Harvard Medical School
HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL

Disclosures

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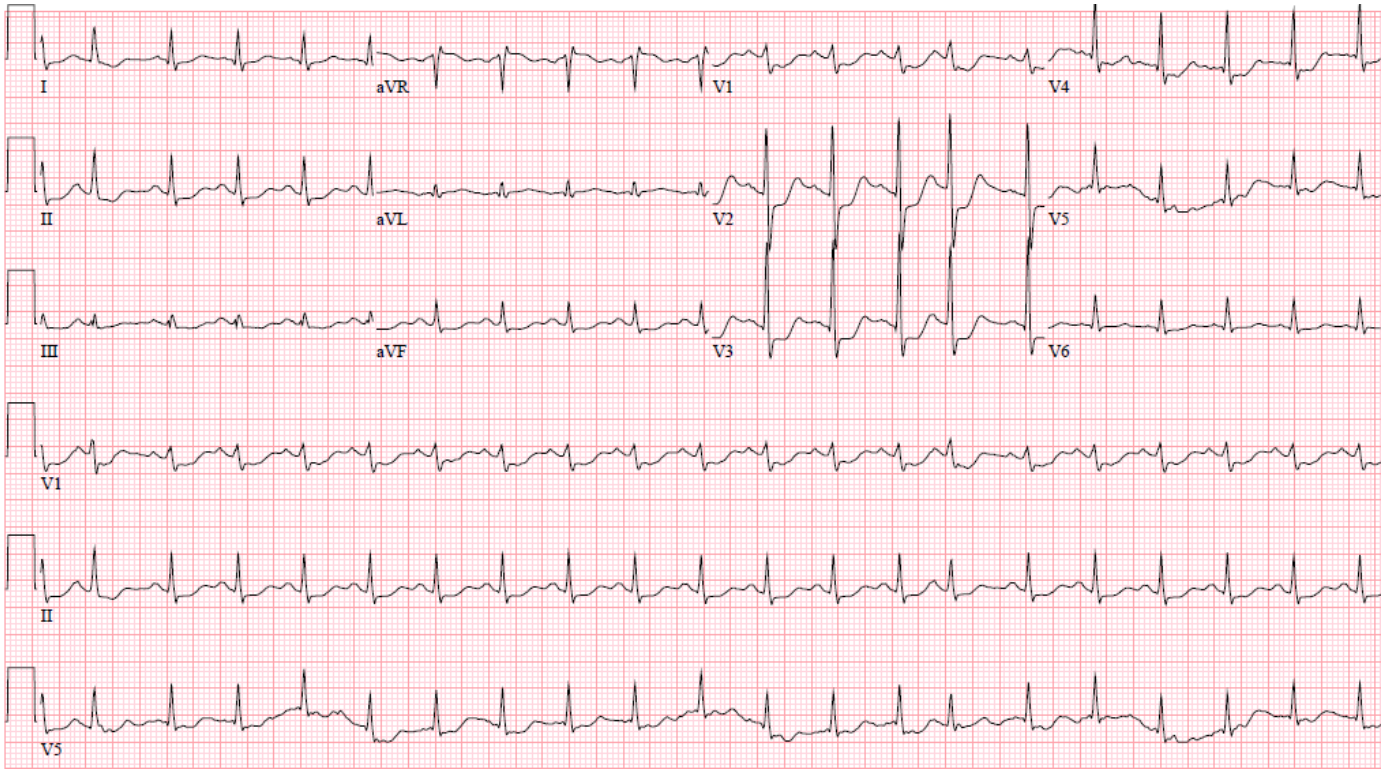
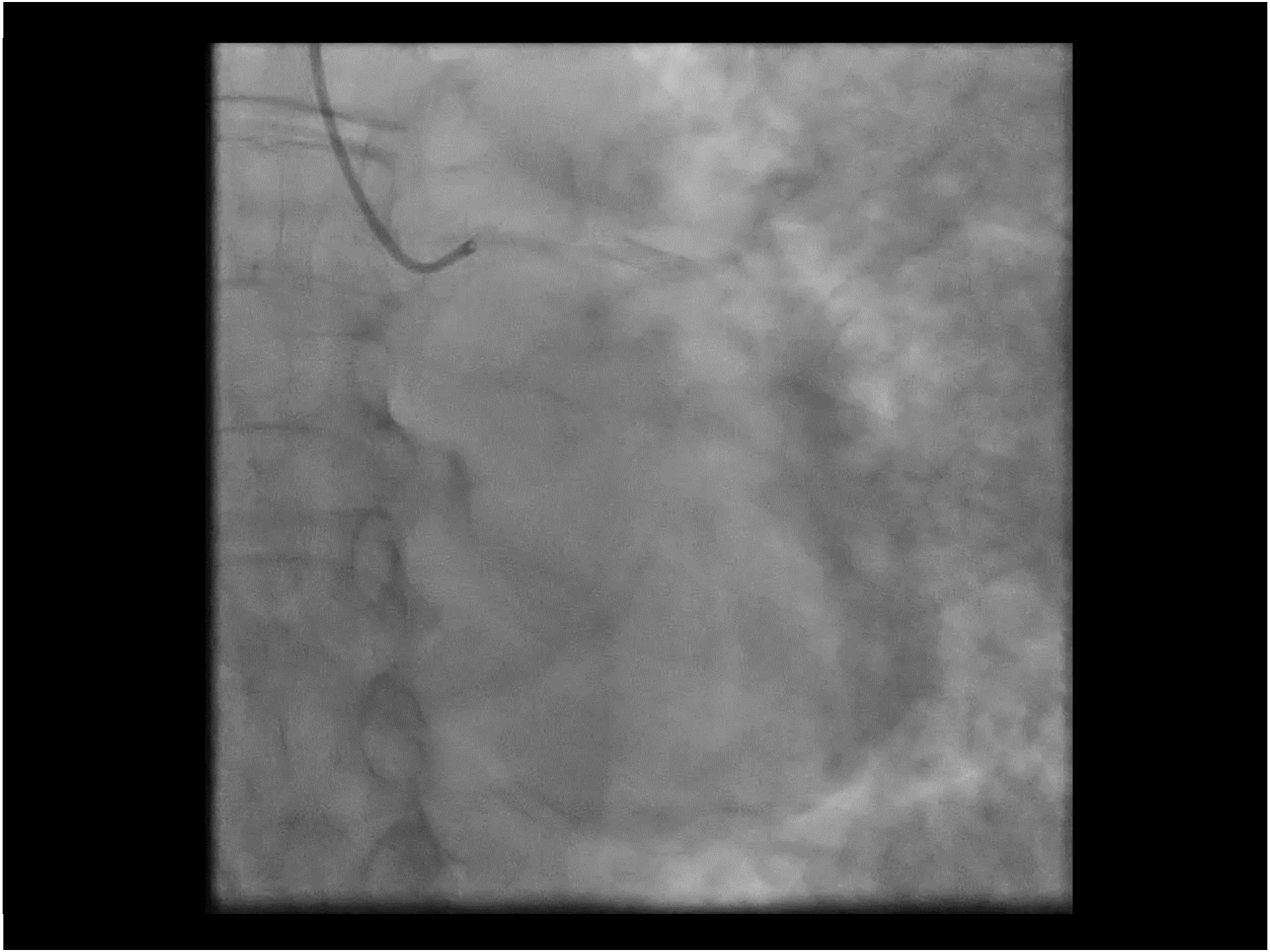
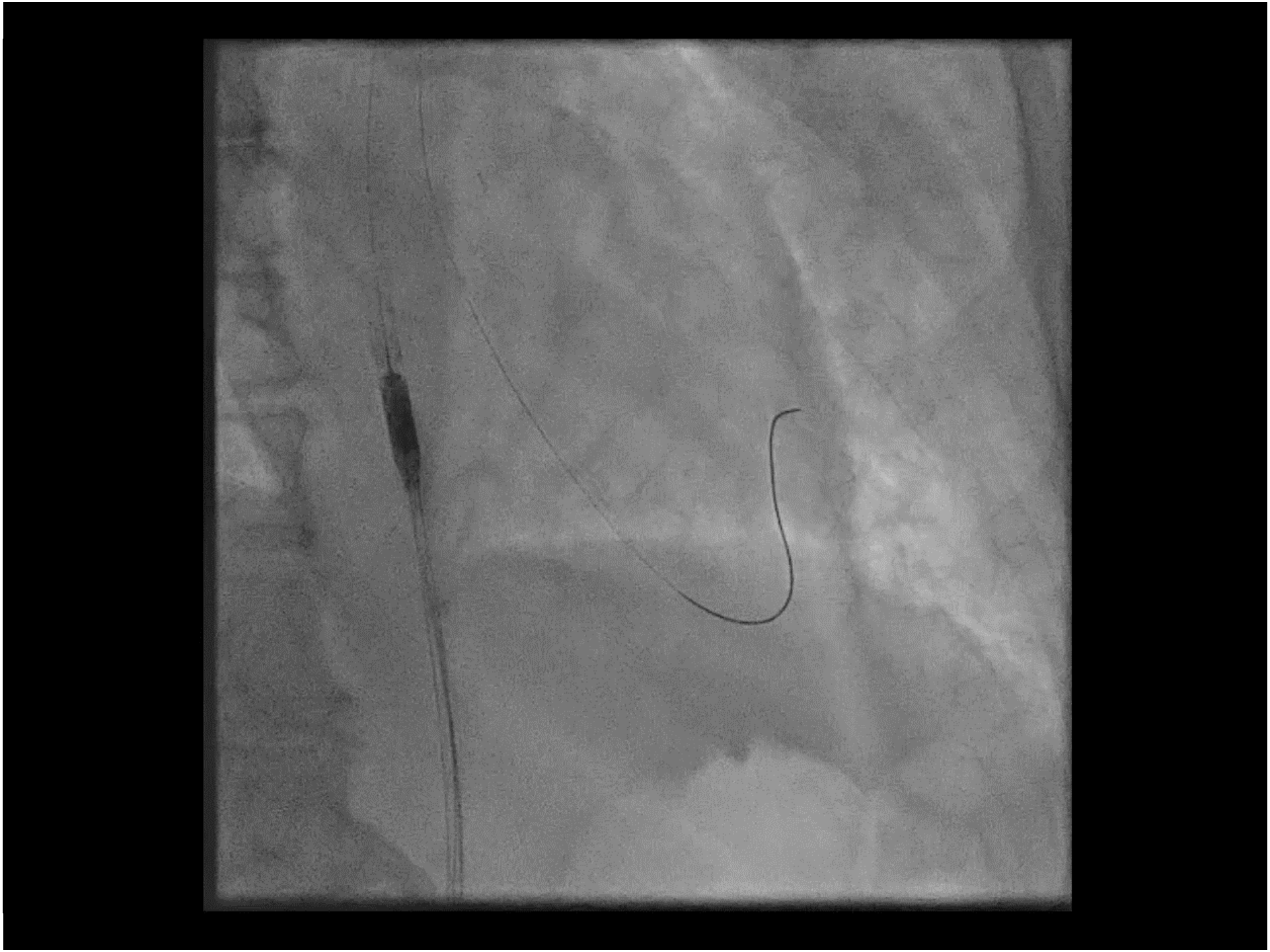
Case

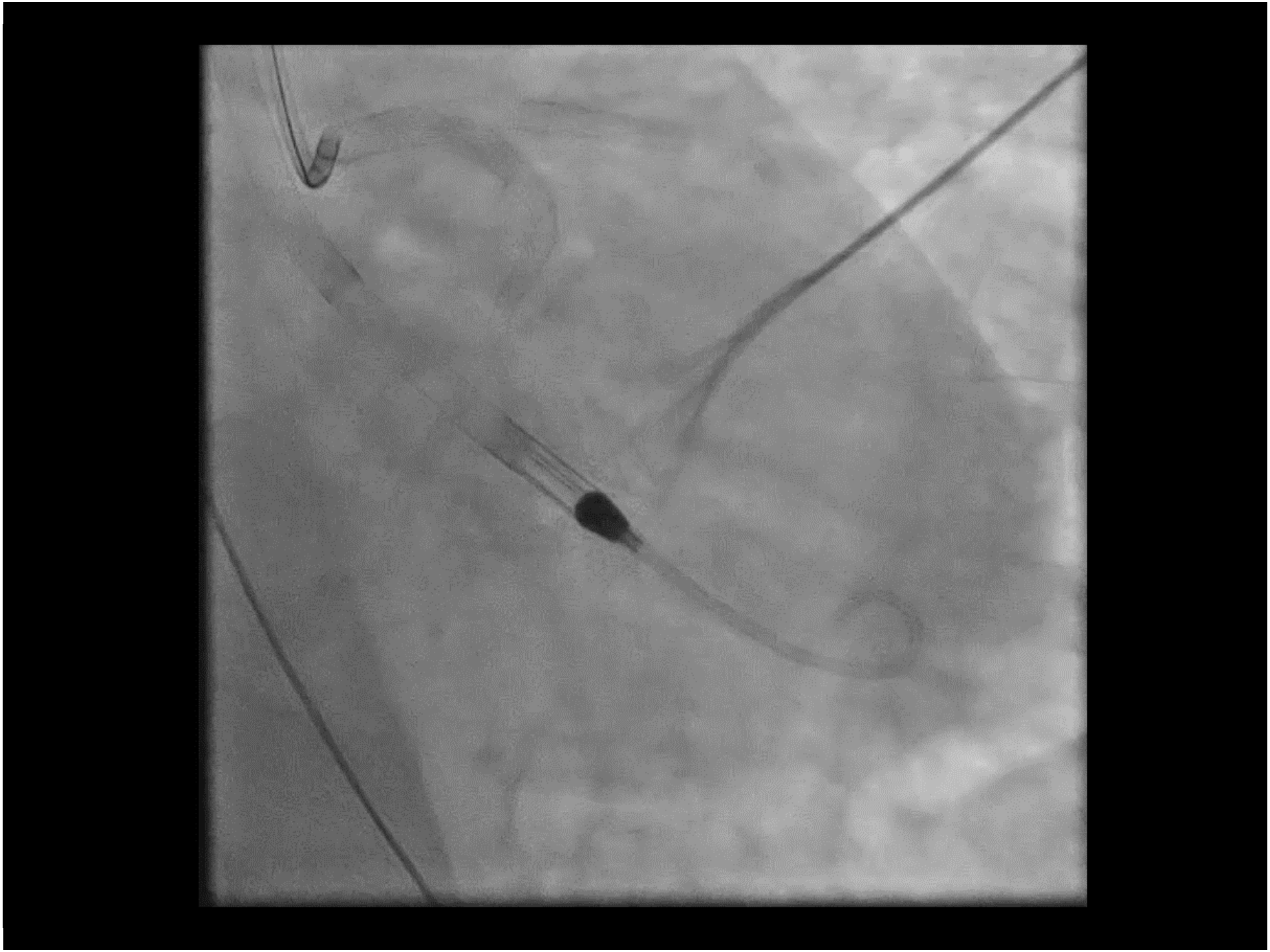
67-year-old man

Cardiac arrest, defibrillated
Recurrent episodes of VT
Hypotensive









Outline

Epidemiology

Definition and diagnosis

Management

- General supportive measures
- Etiologies with specific therapies
  - Acute MI
  - PE
- Mechanical circulatory support

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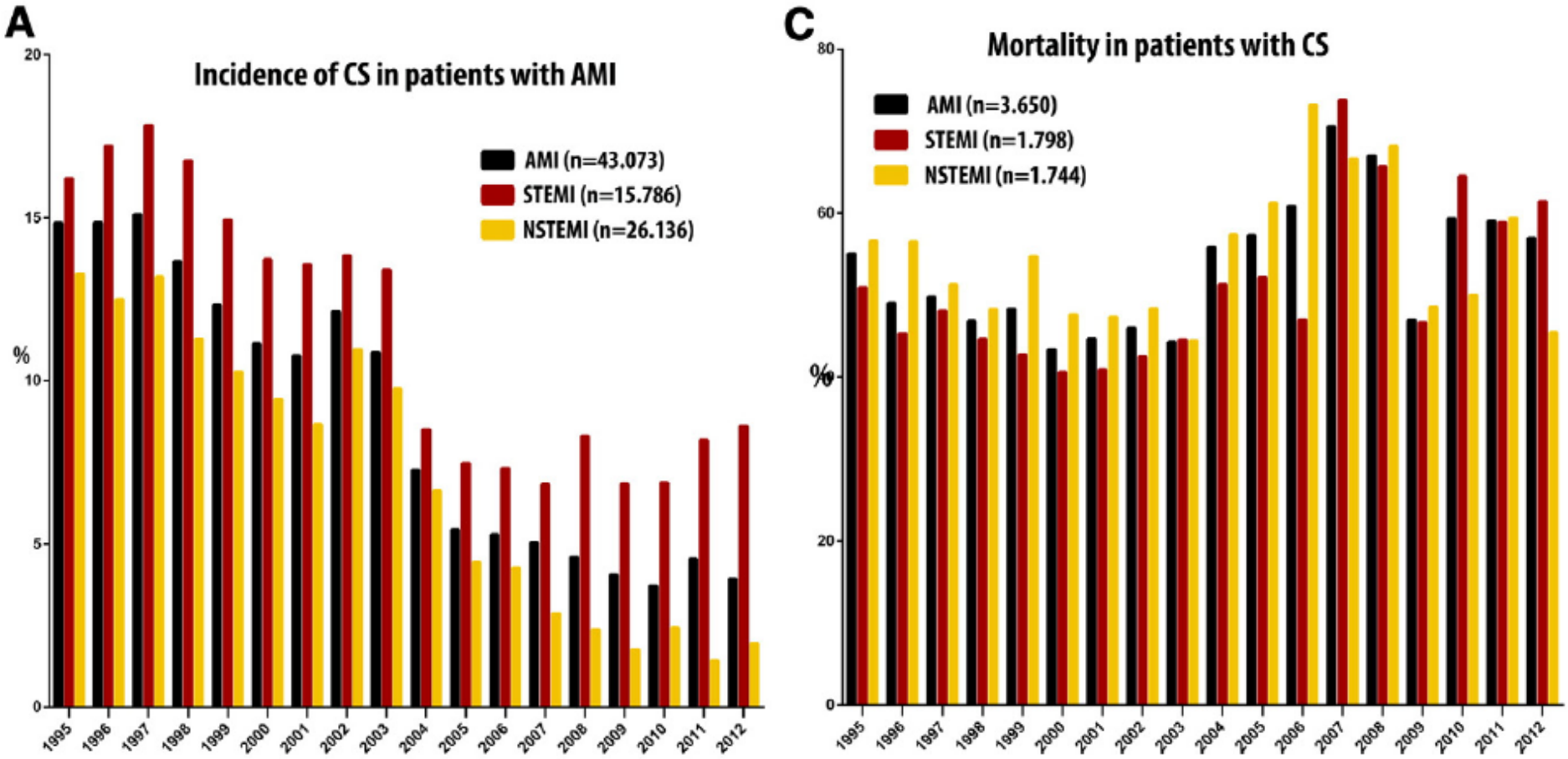
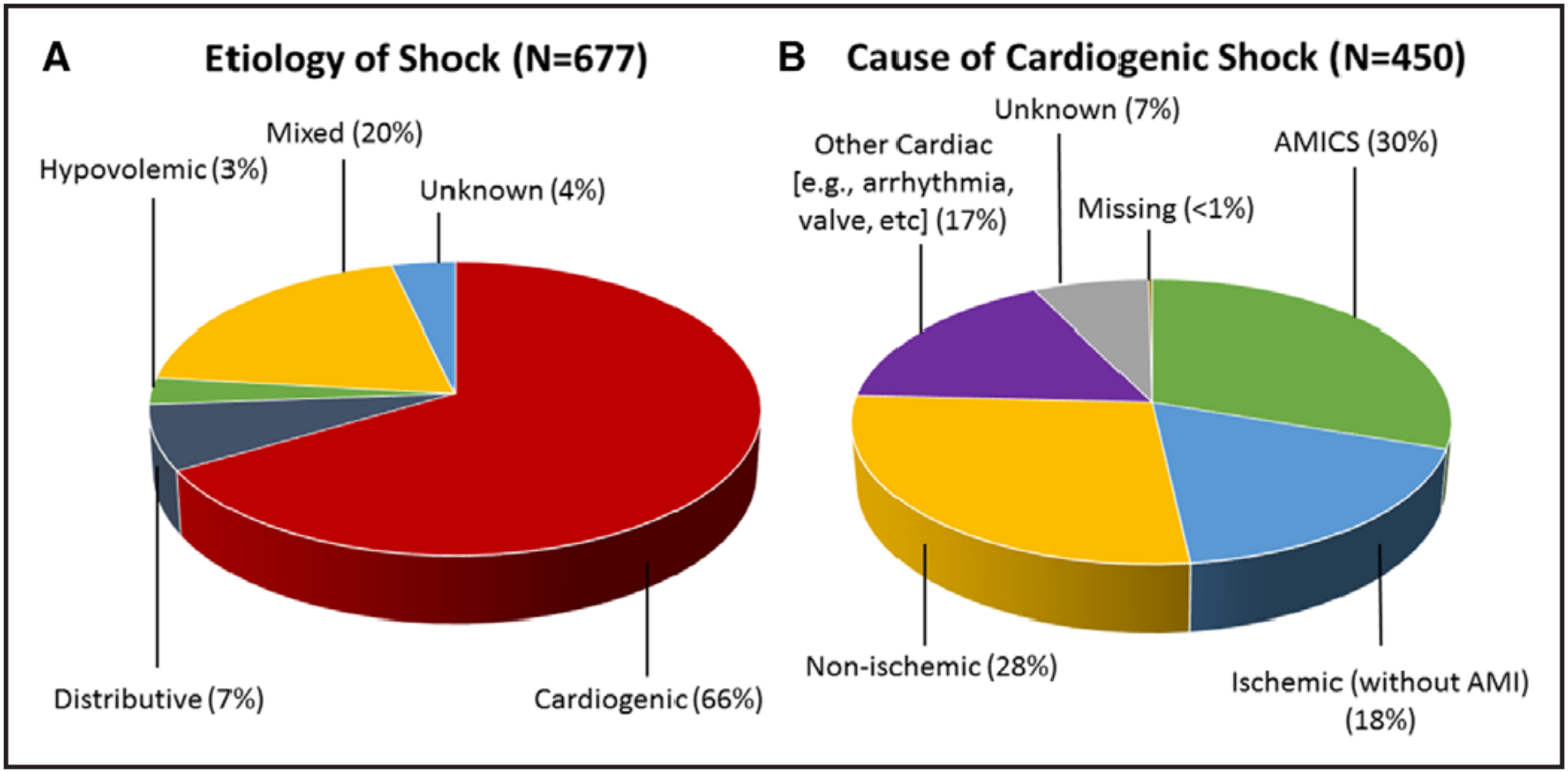
Epidemiology



Patients are older and with more comorbidities

Redfors. Int J Cardiol. 2015.

Epidemiology



Berg. Circ Cardiovasc Qual/Outcomes. 2019.

Go to www.menti.com and use the code 8340 3513

Care setting

At my hospital:

A) There is no separate CICU

B) There is a CICU and they manage all patient care independently (vent, pressors, etc.)

C) There is a CICU but they have no idea what they're doing with critically ill patients (Pulm/Crit Care co-manages)

D) Other

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- General supportive measures
- Etiologies with specific therapies
  - Acute MI
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Cardiogenic Shock

Clinical Definition	SHOCK Trial[9]*	IABP-SHOCK II[1]†	ESC HF Guidelines[15]
Cardiac disorder that results in both clinical and biochemical evidence of tissue hypoperfusion	Clinical criteria: SBP <90 mm Hg for ≥30 min OR Support to maintain SBP ≥90 mm Hg AND End-organ hypoperfusion (urine output <30 mL/h or cool extremities) Hemodynamic criteria: CI of ≤2.2 L·min^{-1}·m^{-2} AND PCWP ≥15 mm Hg	Clinical criteria: SBP <90 mm Hg for ≥30 min OR Catecholamines to maintain SBP >90 mm Hg AND Clinical pulmonary congestion AND Impaired end-organ perfusion (altered mental status, cold/clammy skin and extremities, urine output <30 mL/h, or lactate >2.0 mmol/L)	SBP <90 mm Hg with adequate volume and clinical or laboratory signs of hypoperfusion Clinical hypoperfusion: Cold extremities, oliguria, mental confusion, dizziness, narrow pulse pressure Laboratory hypoperfusion: Metabolic acidosis, elevated serum lactate, elevated serum creatinine

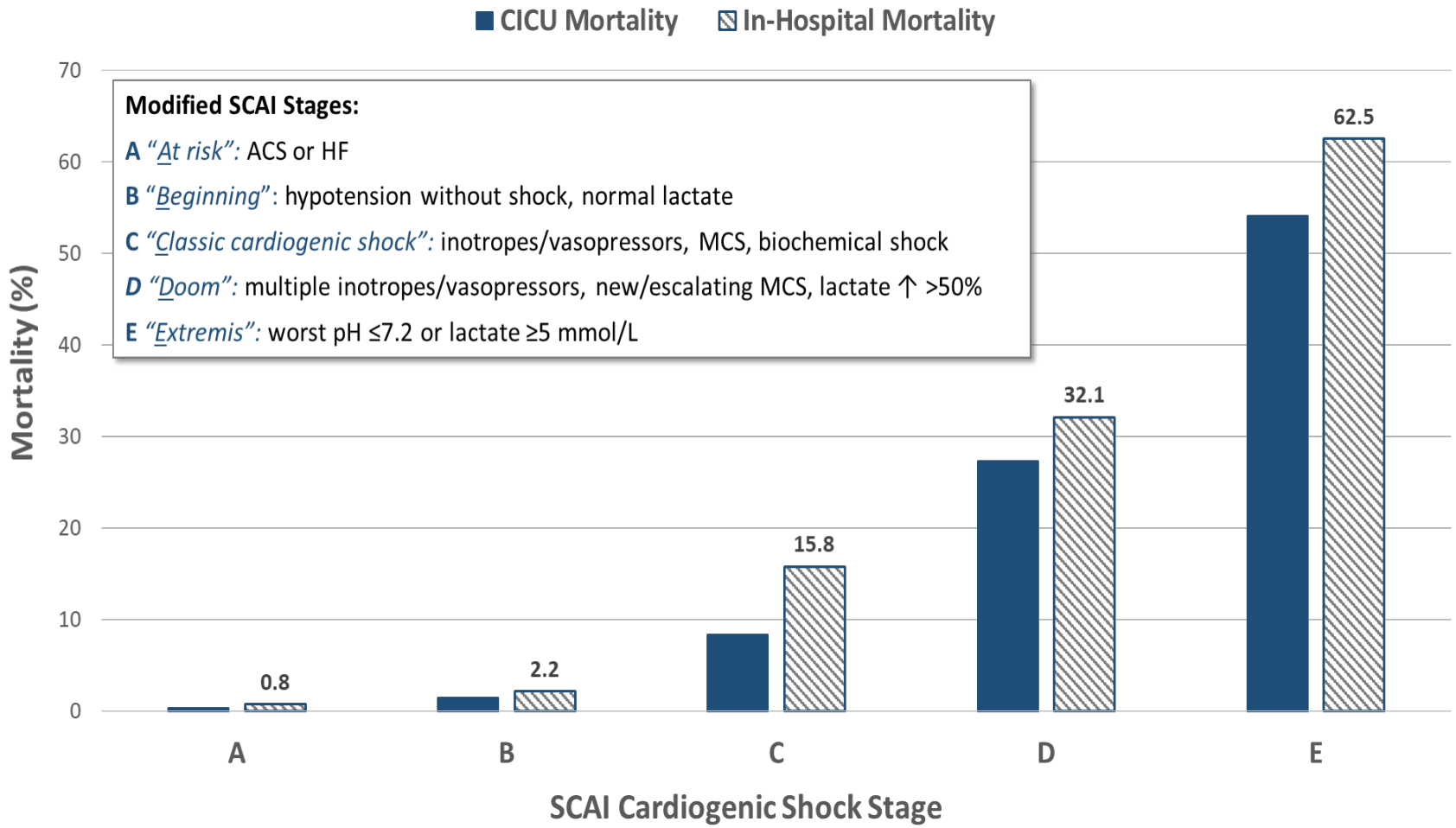
1) Blood pressure threshold

2) Clinical/laboratory evidence of hypoperfusion/congestion

3) +/- Hemodynamic evidence of low flow/congestion

Van Diepen. Circulation. 2017.

Mortality by SCAI Classification



Slide courtesy of Dr. Erin Bohula

Lawler et al. Critical Care Med. 2021

Outline

Epidemiology

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<u>Management</u>

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  - Acute MI
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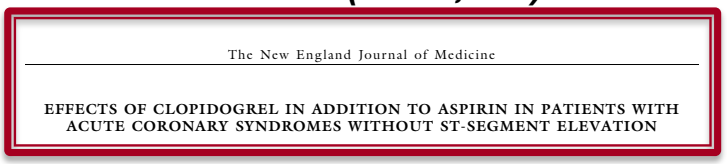
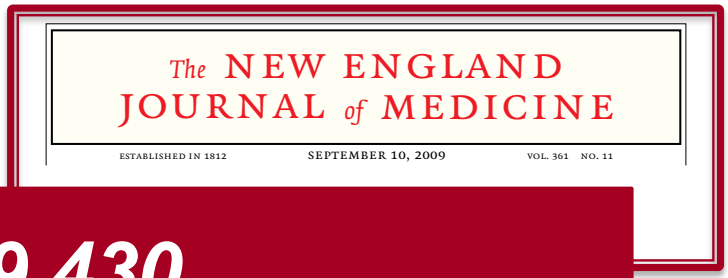
RCTs for P2Y12 inhibition in ACS/PCI

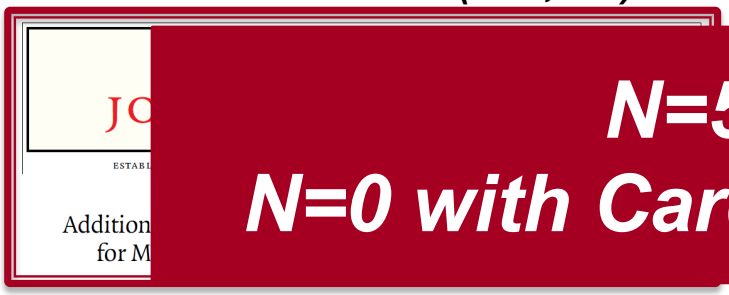
CURE (N=12,562)



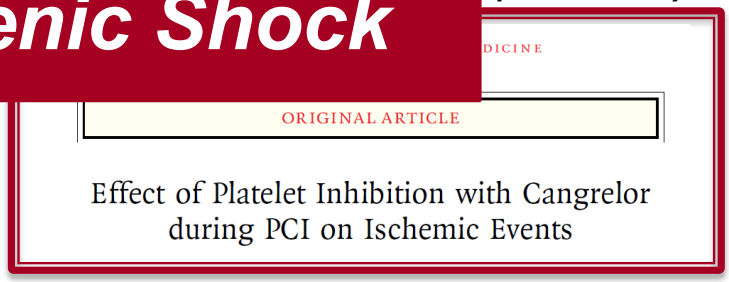
PLATO (N=18,624)



CLARITY-TIMI 28 (N=3,491)

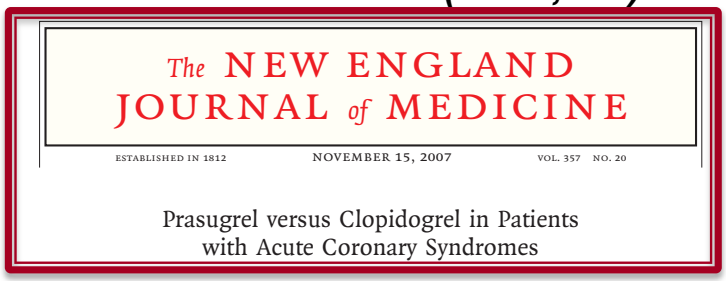


(N=11,145)



N=59,430
N=0 with Cardiogenic Shock

TRITON-TIMI 38 (N=13,608)



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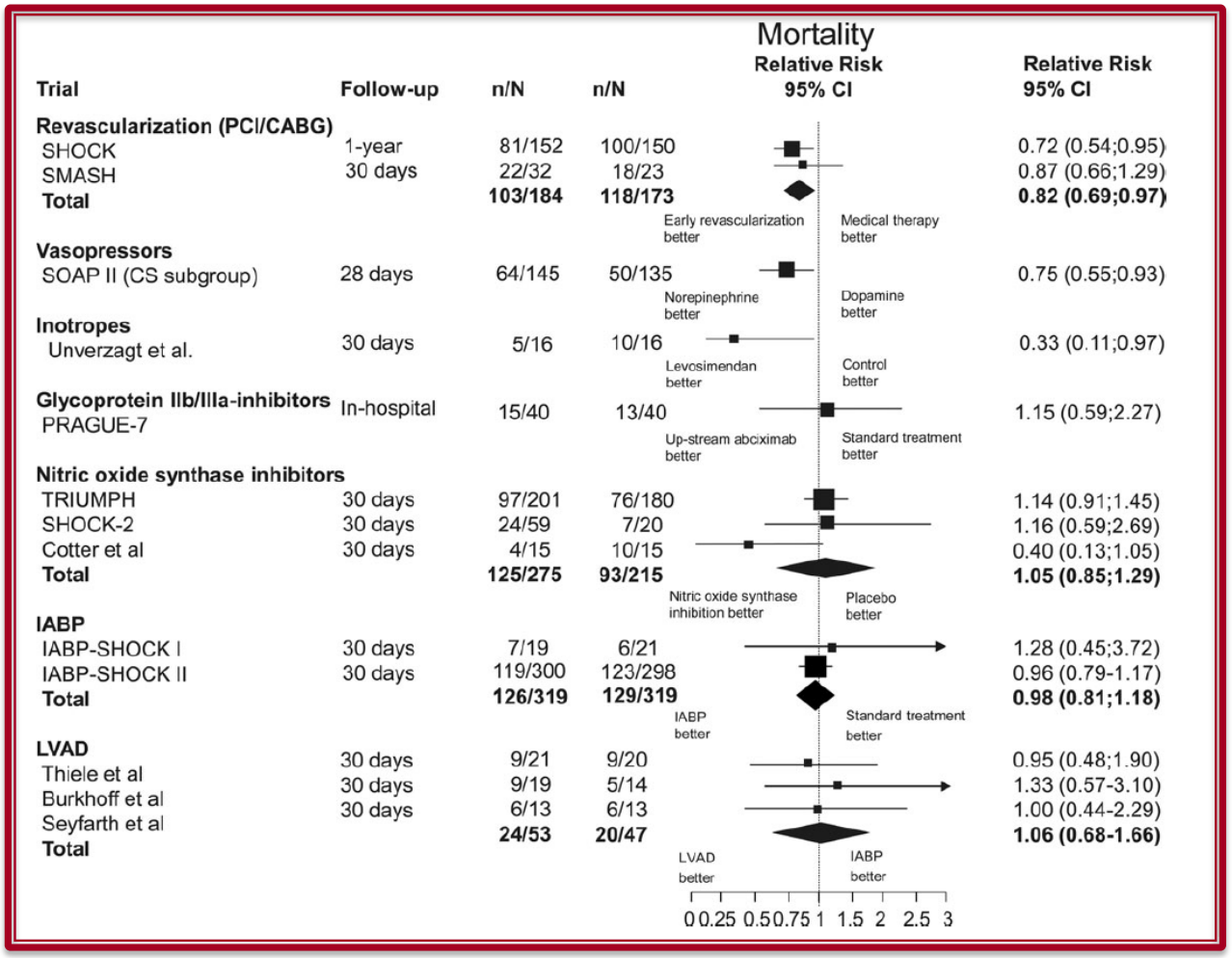
RCTs in Cardiogenic Shock

Total N~2,000



Slide courtesy of Dr. Erin Bohula

Thiele et al. EHJ. 2015

Etiologies

- Acute MI
- Mechanical complication of MI (VSD, MR, free wall rupture)
- Valvular heart disease
- NICMP with ADHF
- Arrhythmia
- PE
- Tamponade
- Myocarditis
- Congenital heart disease with ADHF
- Pulmonary hypertension
- RV failure
- *Et cetera*…

Uni- or Bi-Ventricular Failure?

Hemodynamic Profiles of Various Forms of Shock						
Type of shock	**RAP**	**PCWP**	**CO**	**SVR**	**CPO**	**PAPi**
1° L-sided	nl or ↑	↑	↓	↑	≤0.6	>0.9
1° R-sided	↑	nl or ↓	↓	↑	> or < 0.6	≤0.9
Biventricular	↑	↑	↓	↑	≤0.6	≤0.9

- Cardiac power output (**CPO**) (W) = MAP × CO/451
- Pulmonary artery pulsatility index (**PAPi**) = (PA systolic - PA diastolic) / RA mean

Slide courtesy of Dr. Erin Bohula

For mild to moderate shock

↑ Cardiac output

↓ **Resistance**

↓ **Filling pressures**

Inotrope

Vasodilator + Diuretic

Vasoactive therapies

Pure vasopressors – Incr SVR

Inopressors – Incr CO, Incr SVR

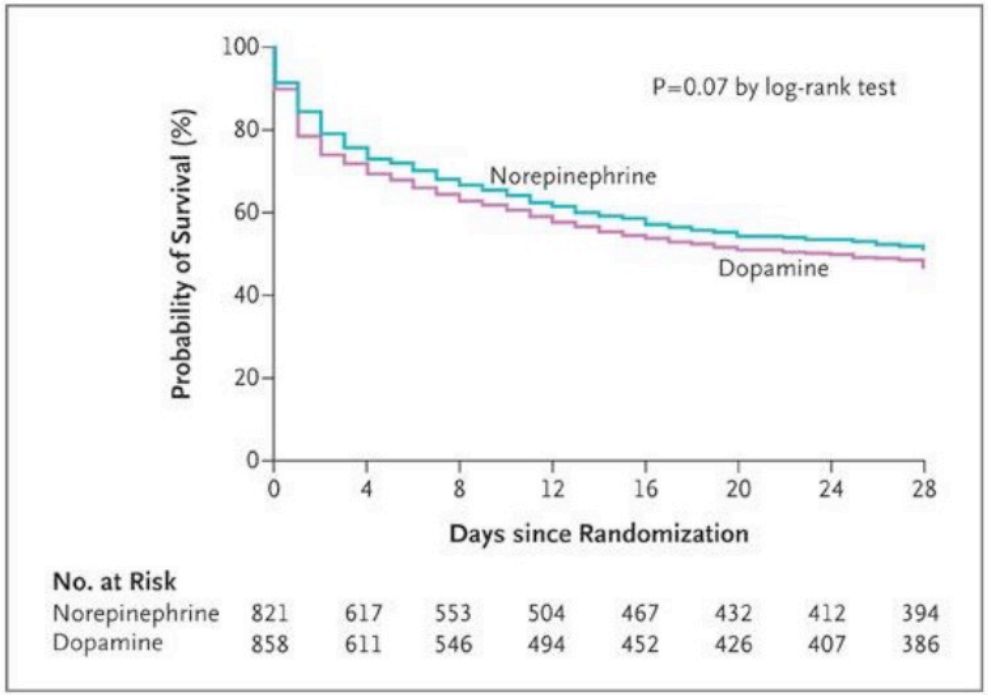
Inodilators – Incr CO, decr SVR

Vasoactive Drugs							
Drug	**Receptors**	**MAP**	**HR**	**CO**	**SVR**	**PVR**	**Comment**
Pure vasopressors							
Phenylephrine	Pure α_1	↑↑	↓↓[a]	↓[a]	↑↑↑	↑↑	
Vasopressin	V_1 & V_2	↑↑	↓↓[a]	↓[a]	↑↑↑	↔	Consider if refractory to catechols. Attractive if RV dysfxn or PHT.
Inopressors *(relative pressor vs. inotropy depends on drug & dose)*							
Norepinephrine	$\alpha >> \beta_1$	↑↑	↔/↑	↔/↑	↑↑↑	↔/↑	More pressor than inotrope. Fewer tachyarrhythmias than w/ dopa and mortality at least as good if not better.
Epinephrine							
Low-dose	β_1 & $\beta_2 > \alpha$	↑	↑↑	↑↑	↓	↔	Inotrope
High-dose	$\alpha > \beta$	↑↑	↑↑	↑↑	↑↑	↑	Inotrope+pressor
Dopamine[b]							
Low-dose	D	↔	↔/↑	↔/↑	↔/↓	↔	
Medium-dose	$\beta_1 >$ D, α	↔/↑	↑	↑↑	↔	↔	
High-dose	$\alpha > \beta_1$, D	↑↑	↑↑	↑	↑↑	↑	
Inodilators							
Dobutamine	$\beta_1 >>> \beta_2, \alpha_1$	↔/↓	↑↑	↑↑	↓	↓	↓ PCWP. Fast onset. Tachyphylaxis.
Milrinone	PDE_3 inhib	↓↓	↑	↑↑↑	↓↓	↓↓	↓↓ PCWP; ↓ PVR; ∴ attractive if RV dysfxn or PHT. Slow onset. Renally cleared.
Isoproterenol	β_1 & β_2	↓	↑↑↑	↑↑	↓↓	↓	⊕ chronotrope
Pure vasodilators							
Nitroglycerin	NO → sGC	↓	↑	↔	↓	↓	Venodilator >> arteriolar dilator
Nitroprusside[c]	NO → sGC	↓↓↓	↑	↑↑c	↓↓↓	↓↓	Arteriolar dilator ≥ venodilator

Slide courtesy of Dr. Erin Bohula

SOAP II: Dopamine vs Norepinephrine

1679 patients with shock

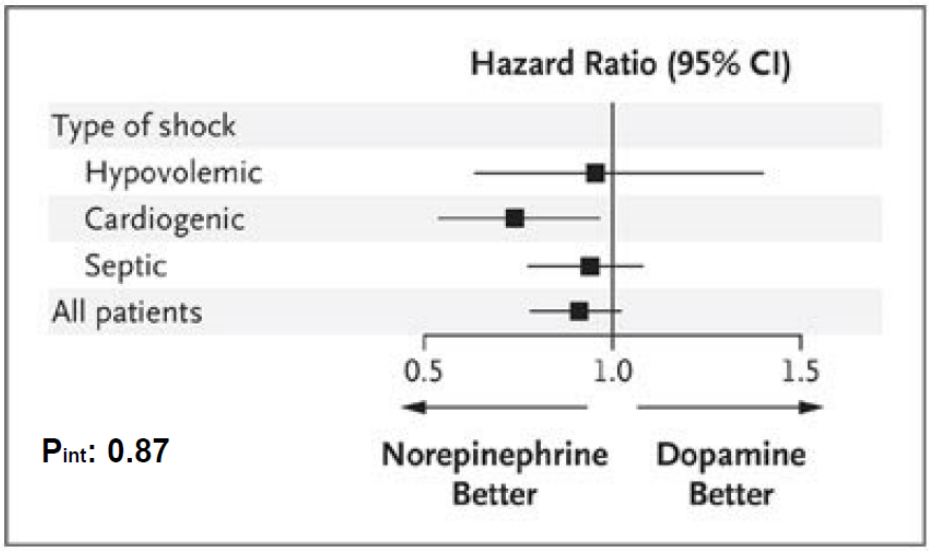


De Backer et al. NEJM 2010;362:779.

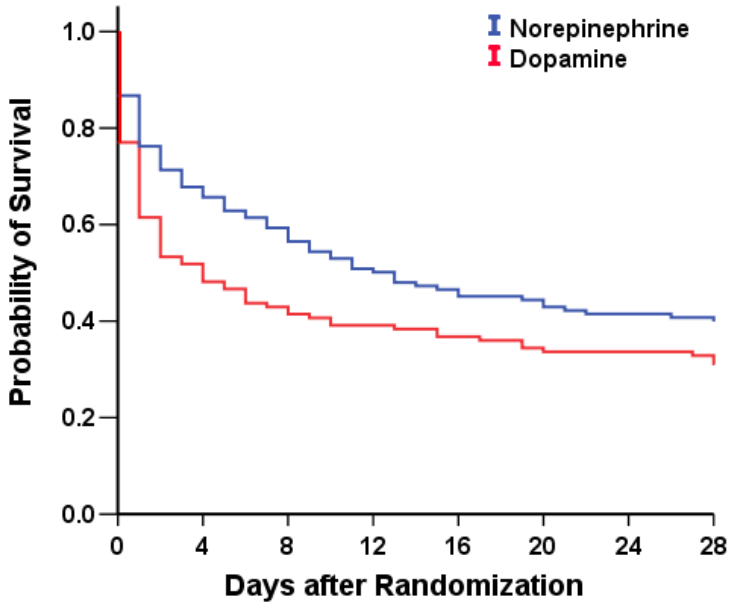
- ***28d mortality:***
  - ***52.5% for DA vs 48.5% for norepi***
  - ***OR 1.17 (0.97-1.42), p=0.10***
- ***Arrhythmias: 24.1% vs 12.4%***

Slide courtesy of Dr. Erin Bohula

SOAP II: Dopamine vs Norepinephrine



Cardiogenic Shock (N=280)



Signal of harm with dopamine?

Slide courtesy of Dr. Erin Bohula

Epinephrine vs Norepinephrine

57 pts with CS due to AMI s/p PCI and with PA line in place

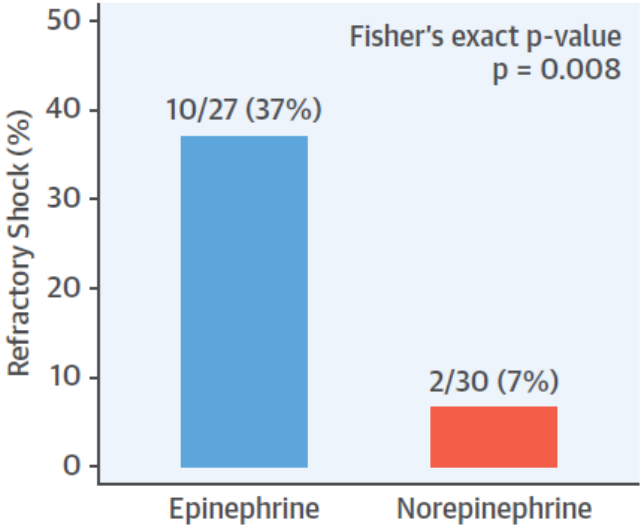


TABLE 2 Serious Adverse Events and Outcomes

	Epinephrine (n = 27)	Norepinephrine (n = 30)	p Value*	Odds Ratio (95% Confidence Interval)	p Value†
Refractory shock	10 (37)	2 (7)	0.008	8.24 (1.61-42.18)	0.011
Arrhythmia	11 (41)	10 (33)	0.59	1.37 (0.47-4.05)	0.56
ECLS	3 (11)	1 (3)	0.34	3.62 (0.35-37.14)	0.28
Death	14 (52)	11 (37)	0.29	1.86 (0.65-5.36)	0.25
Death within 7 days	8 (30)	3 (10)	0.093	3.79 (0.89-16.17)	0.072
Death within 28 days	13 (48)	8 (27)	0.11	2.55 (0.84-7.72)	0.097

Values are n (%) unless otherwise indicated. Odds ratios were expressed by using the norepinephrine group as reference. *p value from the Fisher exact test. †p value from the Wald test.

ECLS = extracorporeal life support.

Refractory Shock: Sustained hypotension, end-organ hypoperf, incr LA, high inotrope or vasopressor doses

Levy et al. JACC 2018;72:173-82.

Milrinone vs Dobutamine

SCAI B,C,D, or E

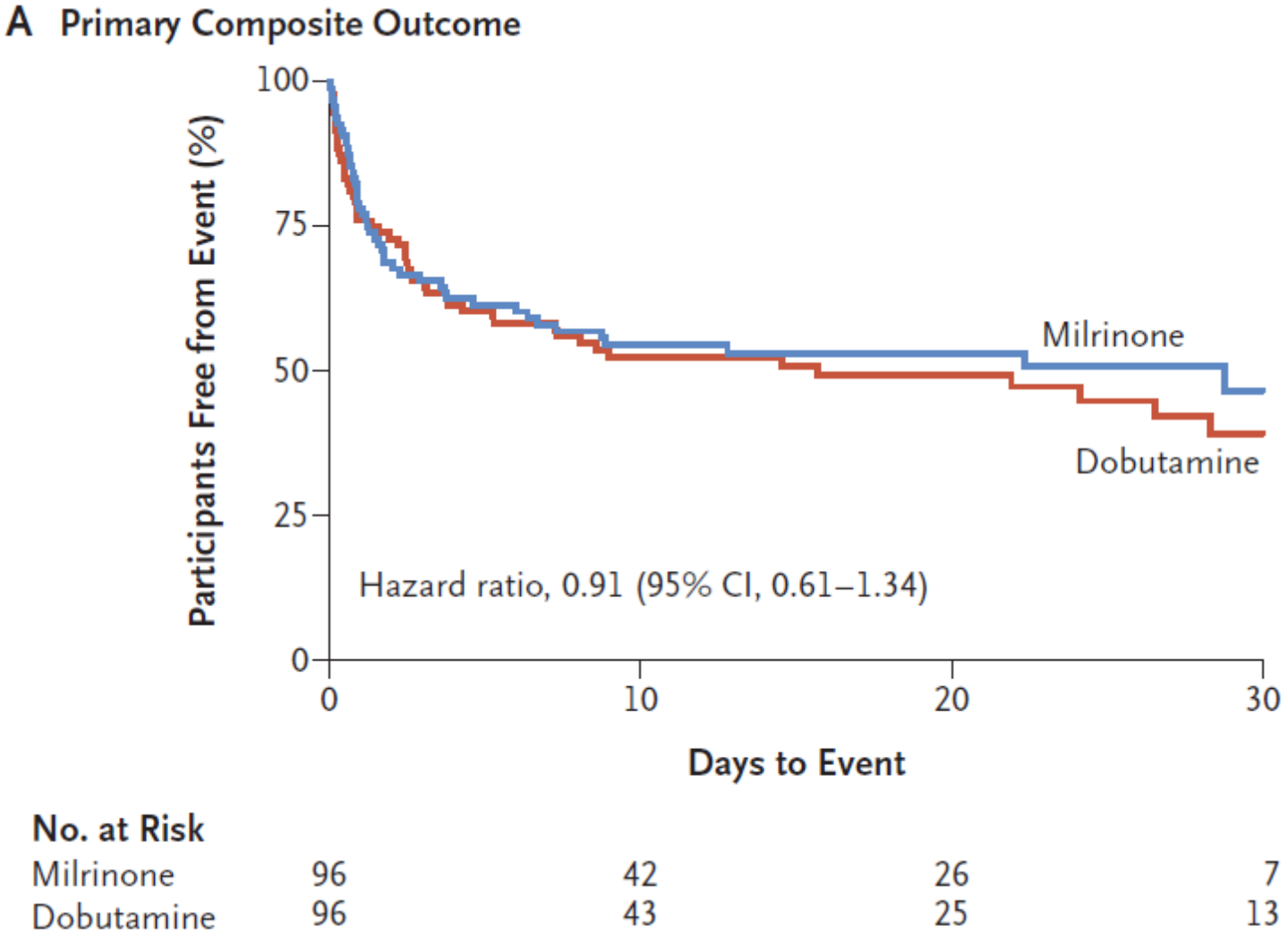
***PEP**: In-hospital death, resuscitated cardiac arrest, cardiac transplant/MCS, MI, TIA/stroke, or RRT*

Table 1. Baseline Characteristics of the Participants.*

Characteristic	Milrinone (N=96)	Dobutamine (N=96)
Age — yr	68.9±13.8	72.0±11.3
Female sex — no. (%)	36 (38)	34 (35)
Median body-mass index (IQR)†	26.4 (23.7–31.0)	26.0 (22.5–30.5)
Race — no. (%)‡		
White	86 (90)	79 (82)
Non-White	10 (10)	17 (18)
Left ventricular function		
Median left ventricular ejection fraction (IQR) — %	25 (20–40)	25 (20–40)
Cause of ventricular dysfunction — no. (%)		
Ischemic	66 (69)	62 (65)
Nonischemic	30 (31)	33 (34)
Coexisting conditions — no. (%)		
Previous myocardial infarction	39 (41)	29 (30)
Previous percutaneous coronary intervention	30 (31)	19 (20)
Previous coronary-artery bypass grafting	20 (21)	19 (20)
Previous stroke or transient ischemic attack	13 (14)	15 (16)
Atrial fibrillation	49 (51)	46 (48)
Chronic kidney disease§	38 (40)	40 (42)
Chronic liver disease	6 (6)	7 (7)
Chronic obstructive pulmonary disease	11 (11)	14 (15)
SCAI cardiogenic shock class — no. (%)¶		
A	0	0
B	6 (6)	5 (5)
C	77 (80)	78 (81)
D	10 (10)	12 (12)
E	3 (3)	1 (1)
Time from admission to the cardiac ICU to randomization — hr	23.4±92.6	17.9±50.6

Mathew R. NEJM. 2021.

Milrinone vs Dobutamine



Mathew R. NEJM. 2021.

Vasopressor summary

- **Limited evidence base**
- **Catecholamines have not demonstrated improved survival**
- **But, data suggest norepinephrine may be better than dopamine or epinephrine**

Step-Wise Approach to CS Management

- **Correct hypotension (MAP goal ≥65 mmHg), typically with inopressor initially (often norepinephrine)**
- **Assess degree of congestion (preload) & adequacy of perfusion (CO)**
- **Assess and treat reversible causes of cardiogenic shock:**
  - Acute ischemia, etc
  - Other potential contributors: dysrhythmias, acid/base disturbances, negative inotropes (bB, CCB) and antihypertensives
- **Optimize hemodynamics, often with PAC to guide therapy**

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Etiologies

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- Mechanical complication of MI (VSD, MR, free wall rupture)
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- PE
- Tamponade
- Myocarditis
- Congenital heart disease with ADHF
- Pulmonary hypertension
- RV failure
- *Et cetera*…

Acute MI complicated by shock

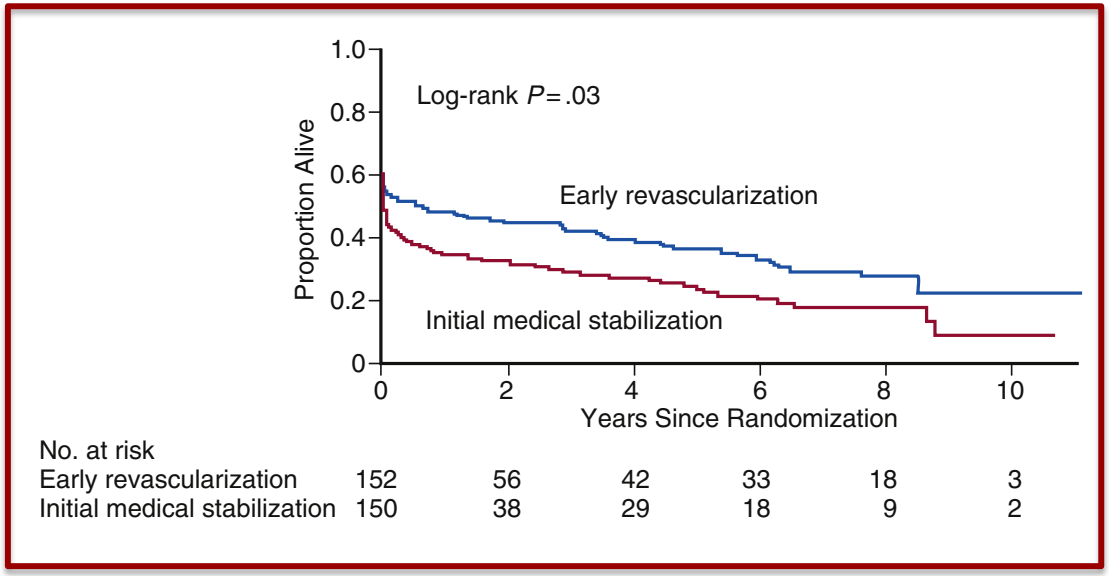
Early revascularization

General supportive measures

Mechanical circulatory support as needed

Recognition and mgmt of mechanical complications

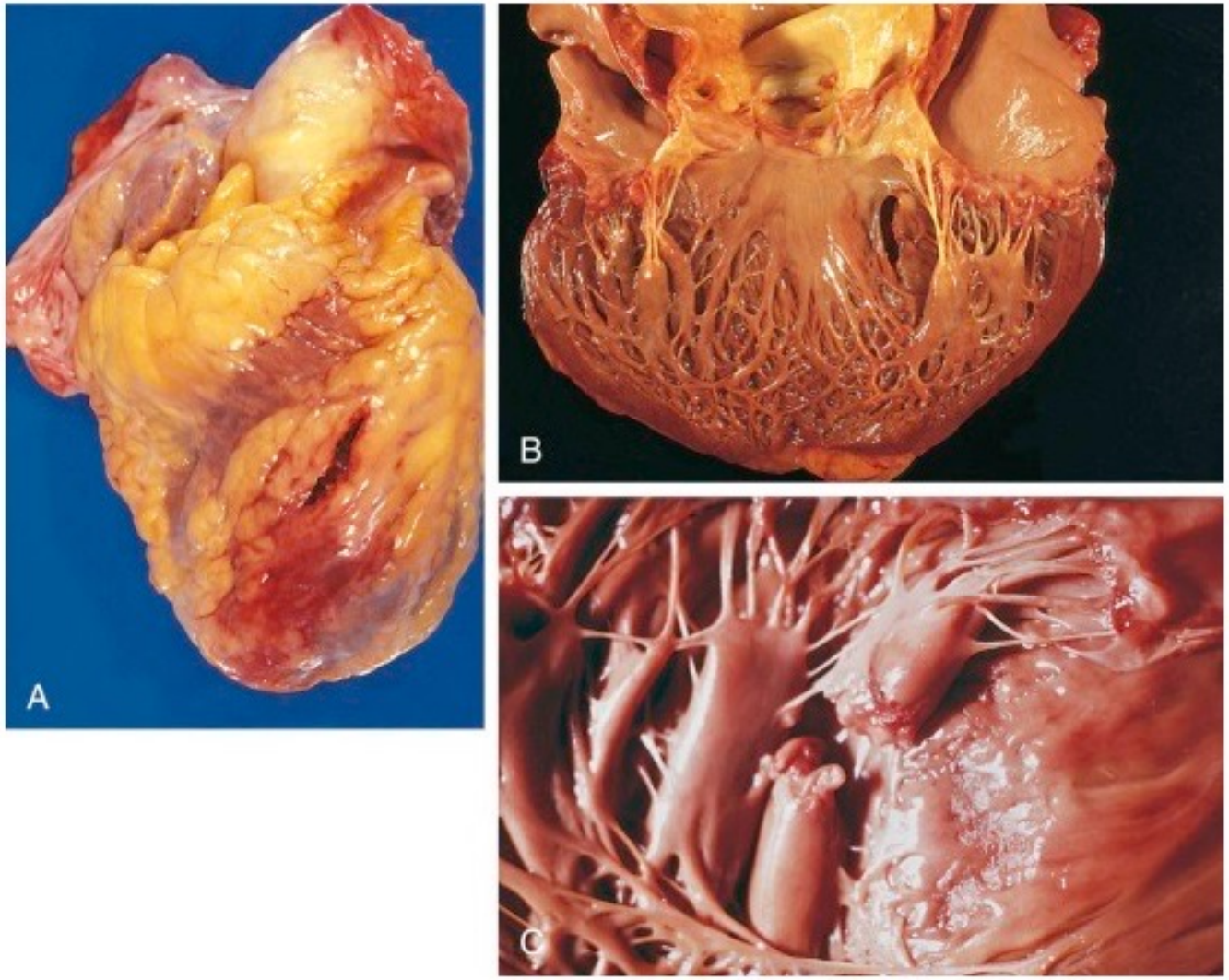
Mortality Benefit with Early Revascularization



- **302 pts with STEMI and CS**
- **Early revasc w/in 6 hrs vs med Rx followed by prn revasc**
- **Survival**
  - 30 d: 53.3% vs 44.0% (p=0.11)
  - 1 yr: 46.7% vs 33.6% (p<0.03)
  - 6 yr: 32.8% vs 19.6% (p=0.03)

Hochman JS, Sleeper LA, Webb JG, et al: JAMA *295(21):2511, 2006*

Mechanical Complications



Mechanical Complications

CHARACTERISTIC	VENTRICULAR SEPTAL RUPTURE	RUPTURE OF THE VENTRICULAR FREE WALL	PAPILLARY MUSCLE RUPTURE
Incidence	1-3% without reperfusion therapy, 0.2-0.34% with fibrinolytic therapy, 3.9% in patients with cardiogenic shock	0.8-6.2%; fibrinolytic therapy does not reduce risk; primary PTCA seems to reduce risk	≈1% (the posteromedial more frequent than the anterolateral papillary muscle)
Time course	Bimodal peak; within 24 hr and 3-5 days; range, 1-14 days	Bimodal peak; within 24 hr and 3-5 days; range, 1-14 days	Bimodal peak; within 24 hr and 3-5 days; range, 1-14 days
Clinical manifestations	Chest pain, shortness of breath, hypotension	Anginal, pleuritic, or pericardial chest pain; syncope; hypotension; arrhythmia; nausea; restlessness; hypotension; sudden death	Abrupt onset of shortness of breath and pulmonary edema; hypotension
Physical findings	Harsh holosystolic murmur, thrill (+), S_3, accentuated second heart sound, pulmonary edema, RV and LV failure, cardiogenic shock	Jugular venous distention (29% of patients), pulsus paradoxus (47%), electromechanical dissociation, cardiogenic shock	A soft murmur in some cases, no thrill, variable signs of RV overload, severe pulmonary edema, cardiogenic shock
Echocardiographic findings	Ventricular septal rupture, left-to-right shunt on color flow Doppler echocardiography through the ventricular septum, pattern of RV overload	>5 mm pericardial effusion not visualized in all cases; layered, high-acoustic echoes within the pericardium (blood clot); direct visualization of tear; signs of tamponade	Hypercontractile LV, torn papillary muscle or chordae tendineae, flail leaflet, severe mitral regurgitation on color flow Doppler echocardiography
Right-heart catheterization	Increase in oxygen saturation from the RA to RV, large *v* waves	Ventriculography insensitive, classic signs of tamponade not always present (equalization of diastolic pressures in the cardiac chambers)	No increase in oxygen saturation from the RA to RV, large *v* waves, * very high pulmonary capillary wedge pressure

Acute shock after MI:

- Think of mechanical complications
- They can happen whenever they want to
- Immediate ultrasound
- Typically a surgical emergency

Other etiologies of cardiogenic shock requiring specific therapy

Pulmonary embolism
Valvular disease
Arrhythmia
Tamponade
Myocarditis
Pulmonary hypertension

Other etiologies of cardiogenic shock requiring specific therapy

Pulmonary embolism
Valvular disease
Arrhythmia
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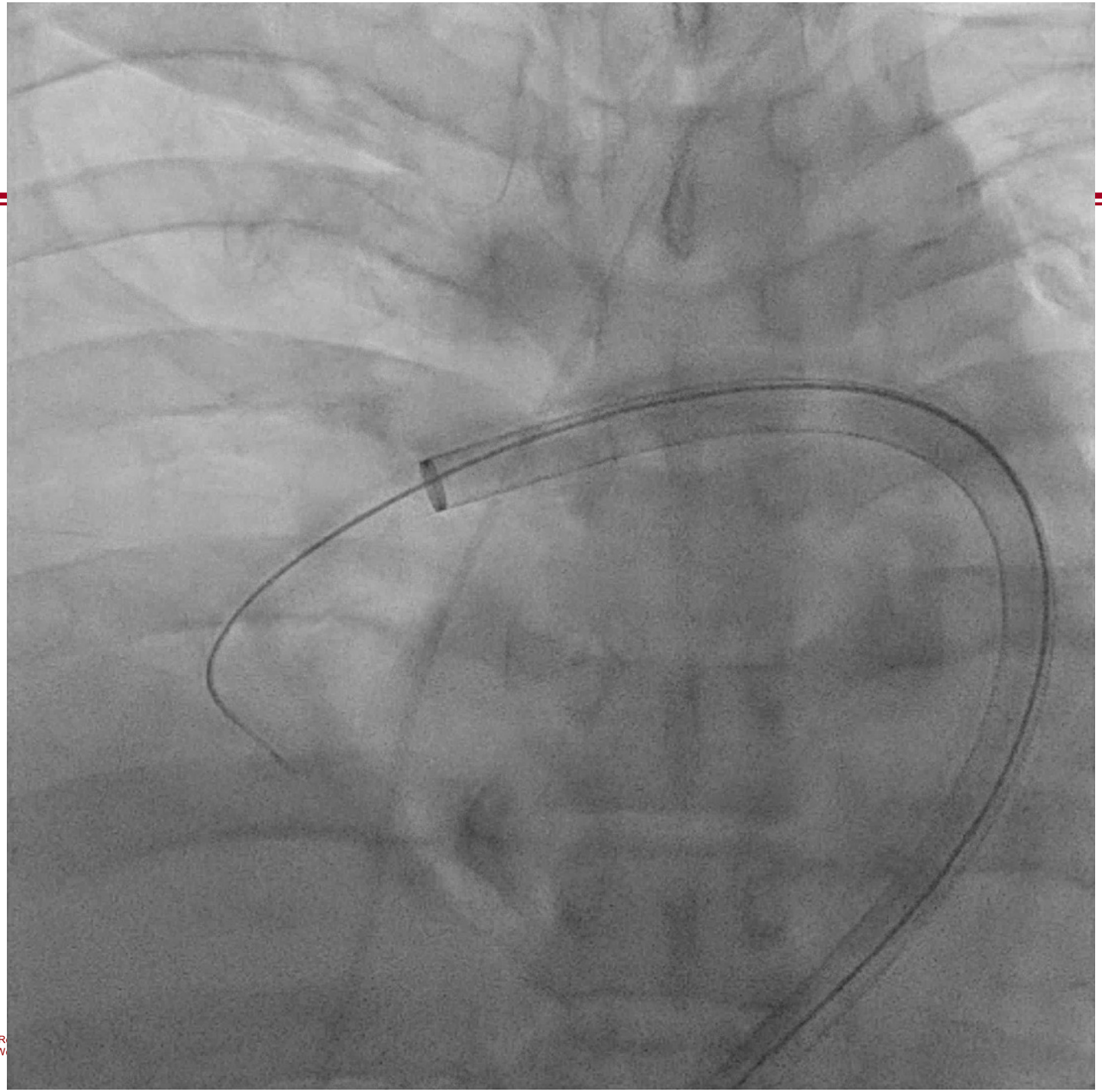
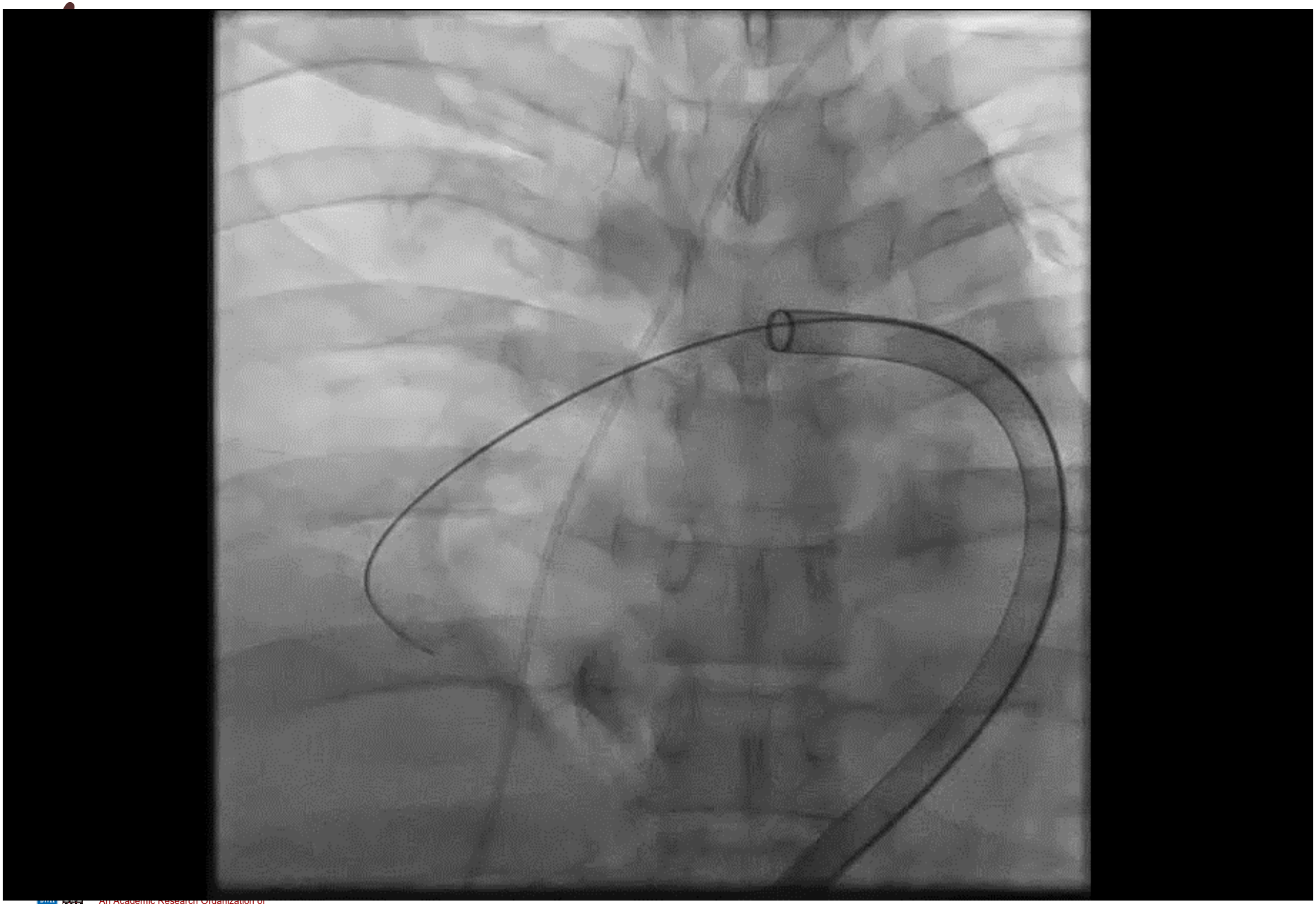
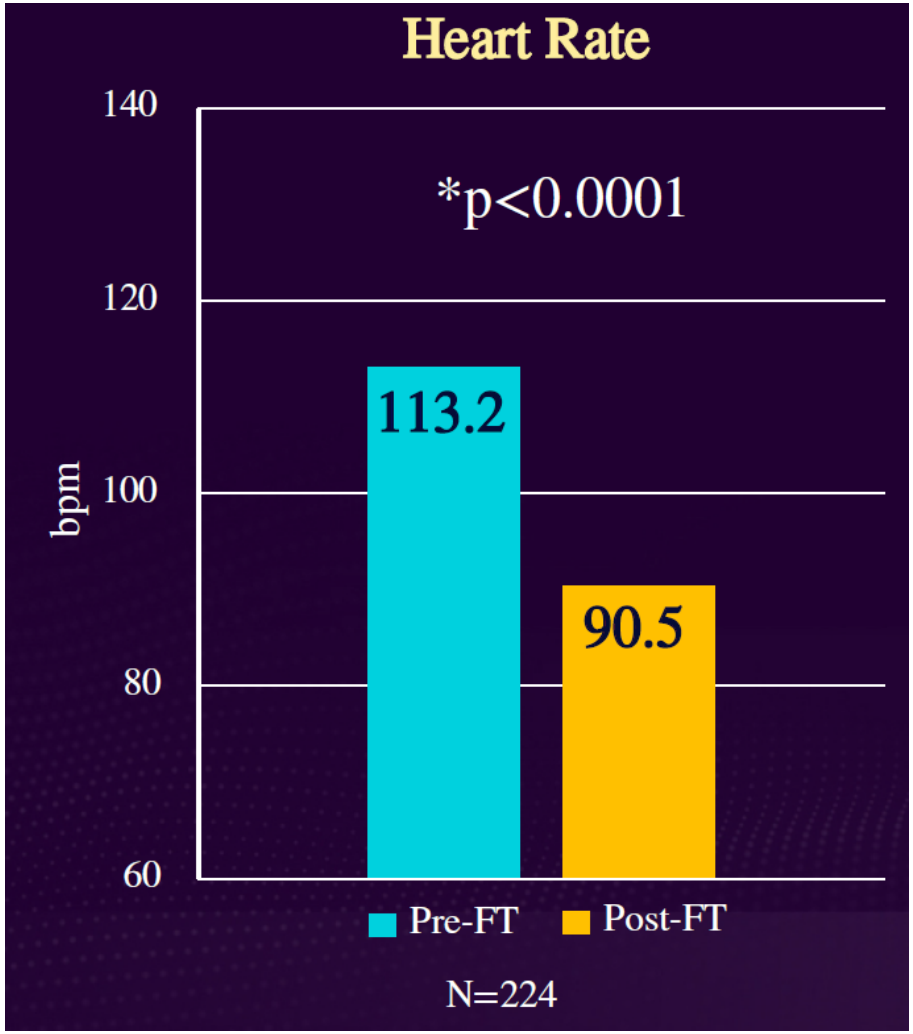
Myocarditis
Pulmonary hypertension

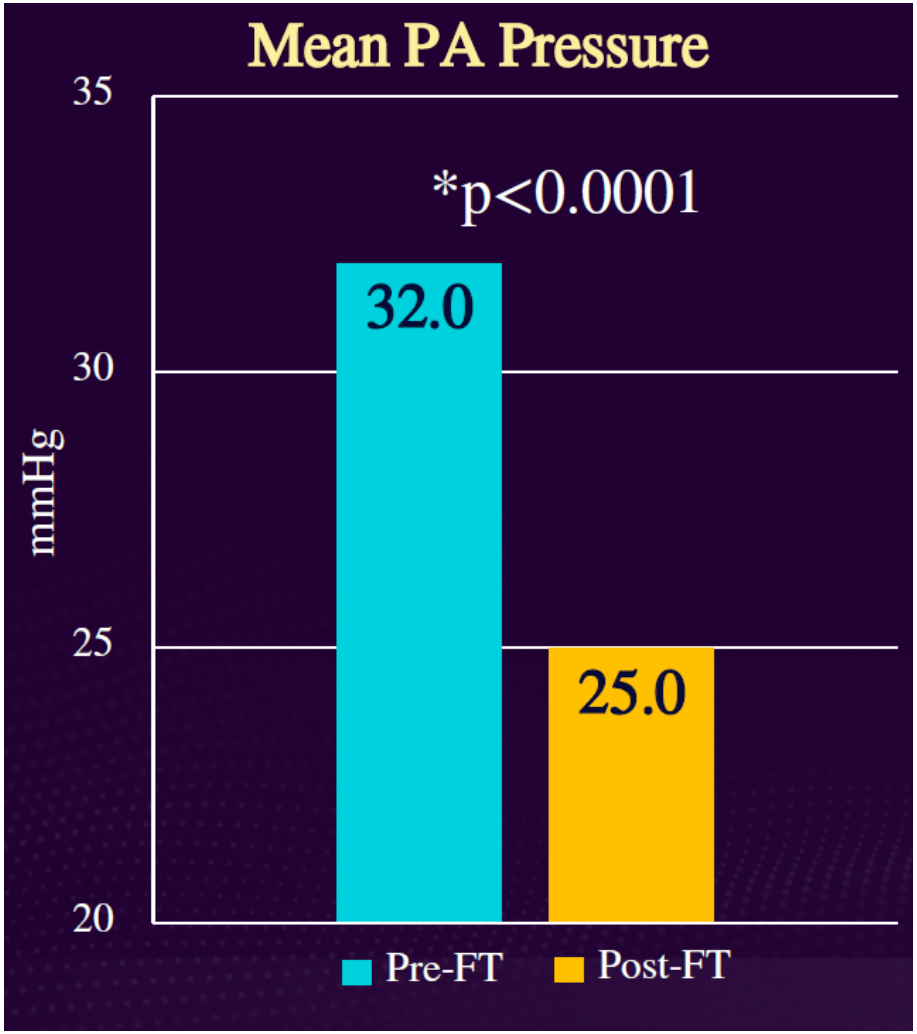



LEFT
Right



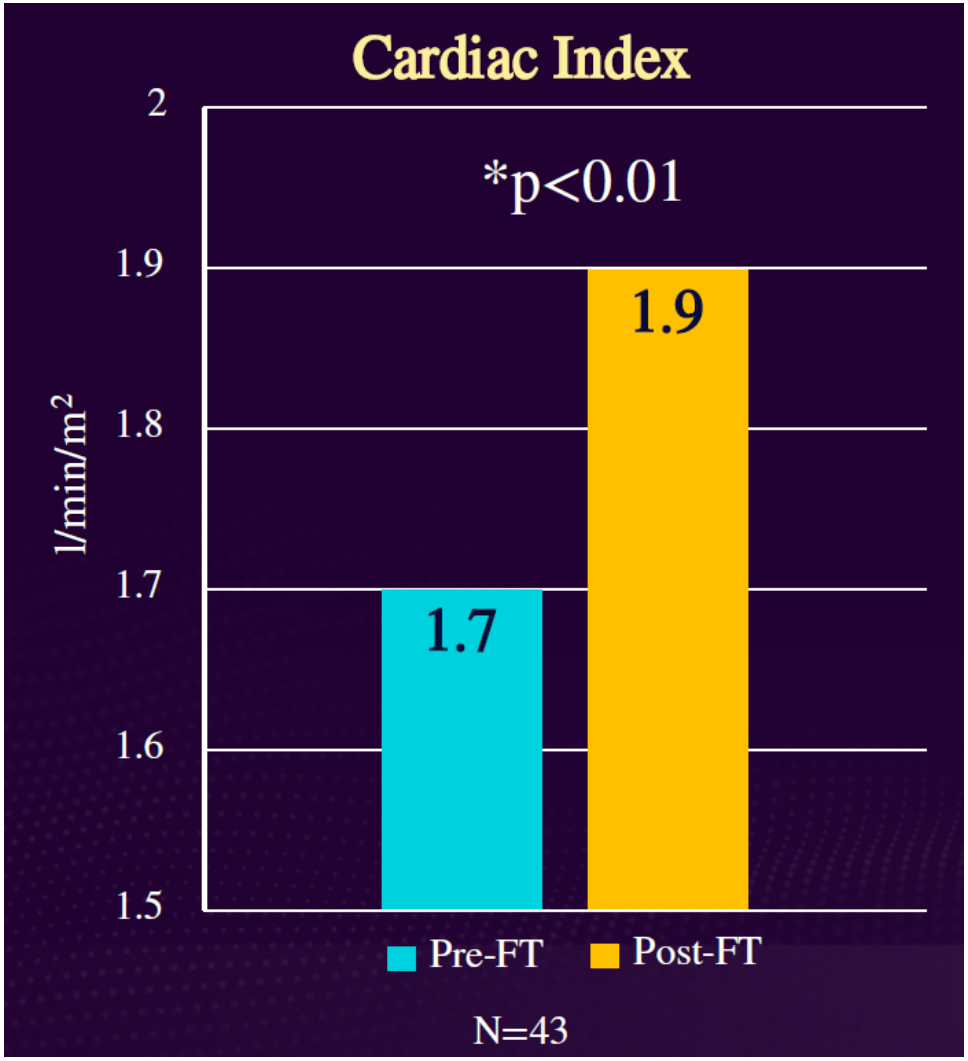
FLASH Registry





Toma C. TCT. 2020.

FLASH Registry



Toma C. TCT. 2020.

Go to www.menti.com and use the code 8340 3513

PE Revascularization

At my hospital:

A) There are no percutaneous or surgical options for PE revascularization

B) There are percutaneous revascularization options only

C) There is surgical revascularization only

D) There are both percutaneous and surgical options

E) Other

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  - Acute MI
  - PE
- Mechanical circulatory support

Complex Decisions

Shock Team

Chambers needing support (LV, RV, both)
Degree of support needed
Need for gas exchange
Vascular access considerations
Other anatomic considerations
Timing
Candidacy for long term therapies (VAD, transplant)

LV Support

Go to www.menti.com and use the code 8340 3513

LV Support

For a patient with SCAI C/D cardiogenic shock from LV failure, the typical first line MCS at my hospital is:

A) There are no MCS options

B) IABP

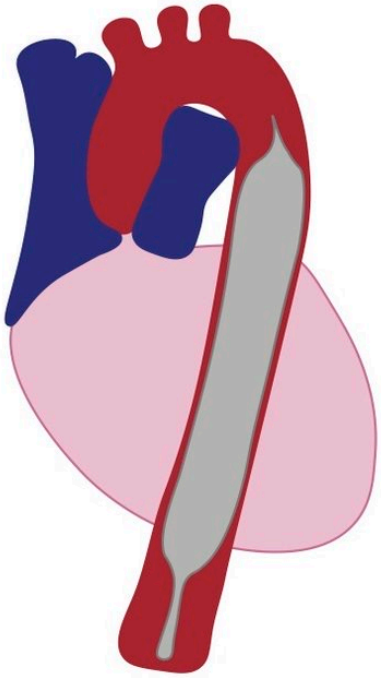
C) Impella CP

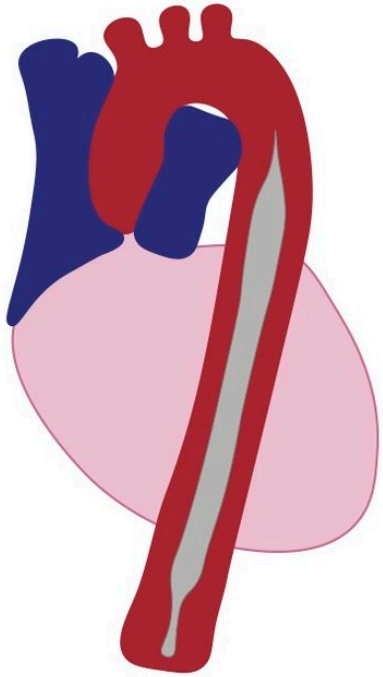
D) TandemHeart

E) ECMO

F) Other

Intra-aortic balloon pump (IABP)

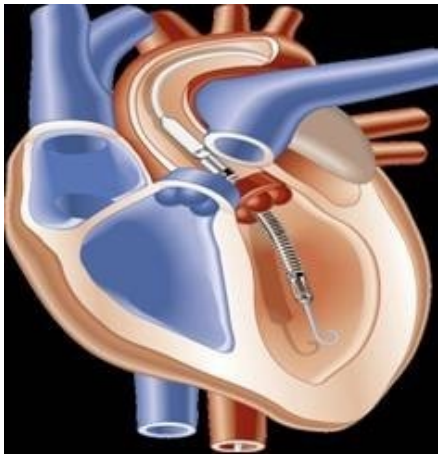


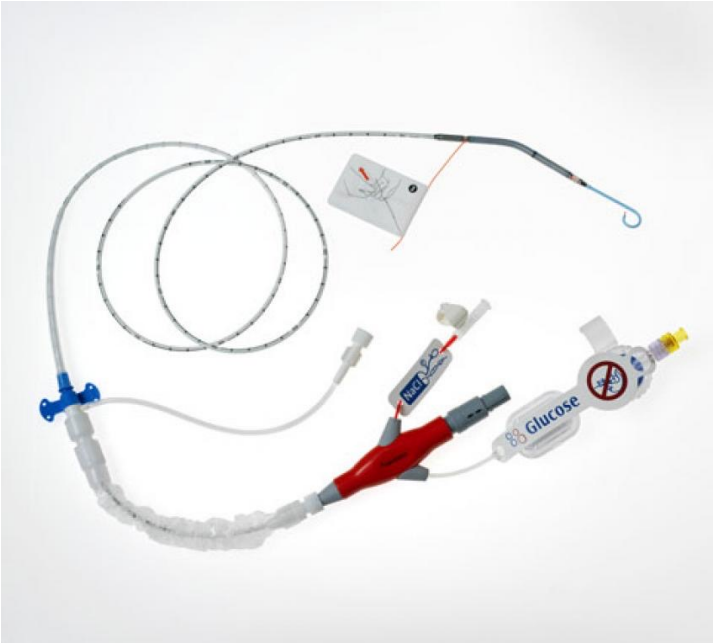


(+)
Rapid placement
Lower profile than other MCS options
Axillary possible

(-)
Minimal support

Impella CP





(+)

Good support (3.5 L/min)

Typically rapid placement

Unloads LV

Axillary/transcaval possible

(-)

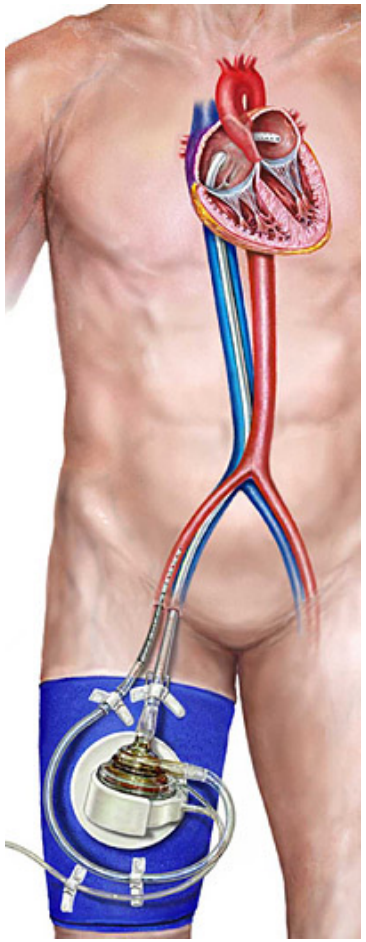
Migrates

Thrombocytopenia/hemolysis

Vascular injury

Note: Impella 5.5 also available (ax/transAo)

TandemHeart



(+)

Robust support (4-5 L/min)

Possible to add gas exchange to circuit

Migration is unusual

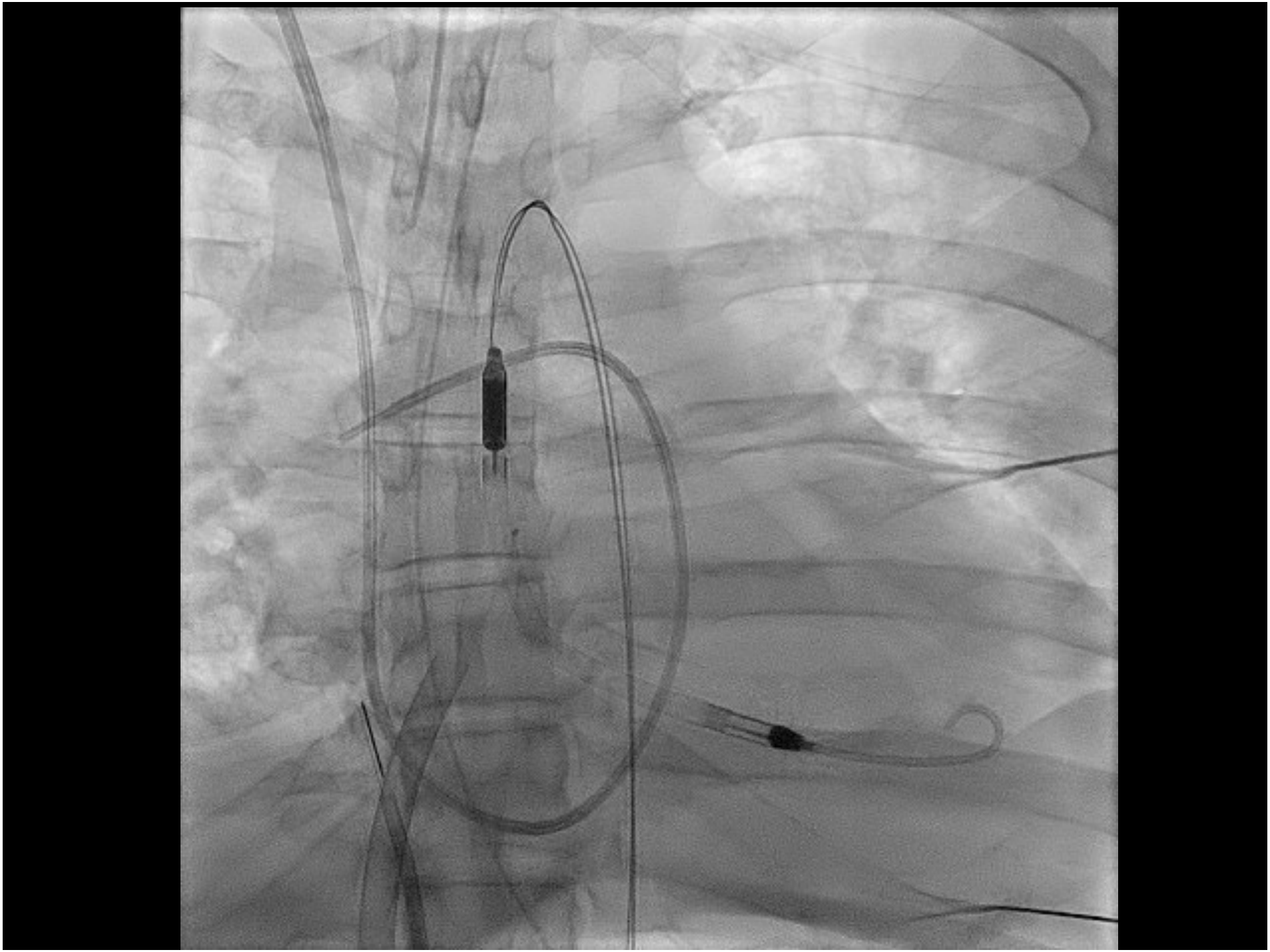
(-)

Limited availability

Requires transeptal puncture

Imperfect LV unloading

Vascular injury

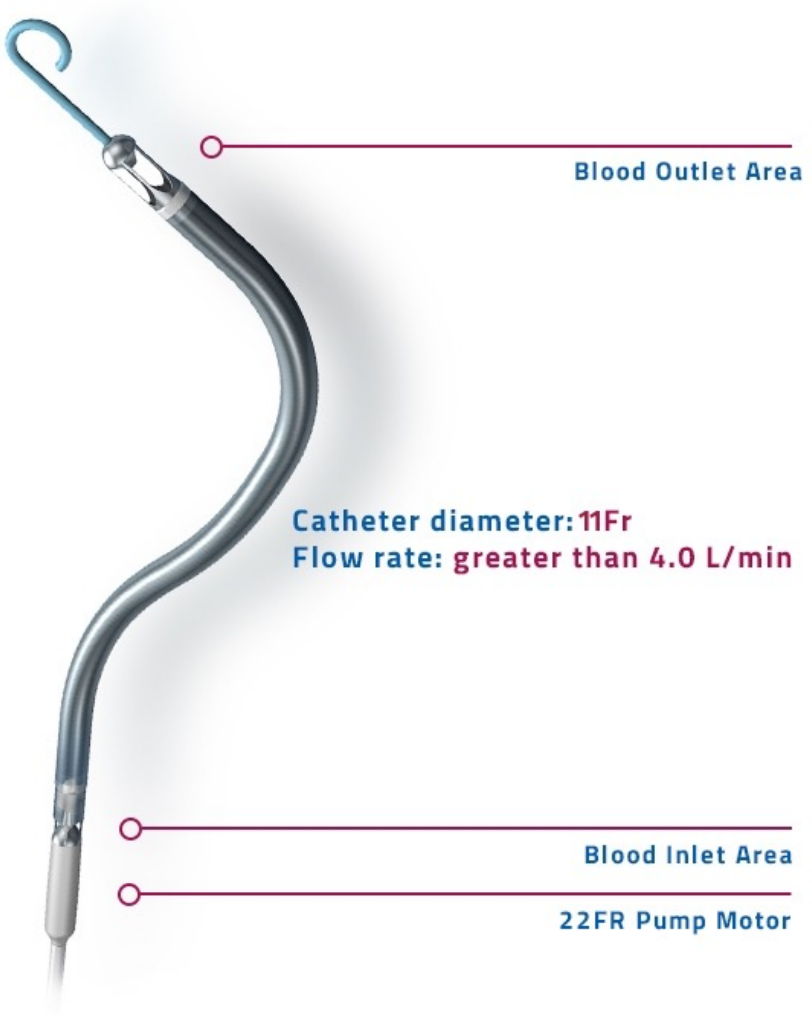


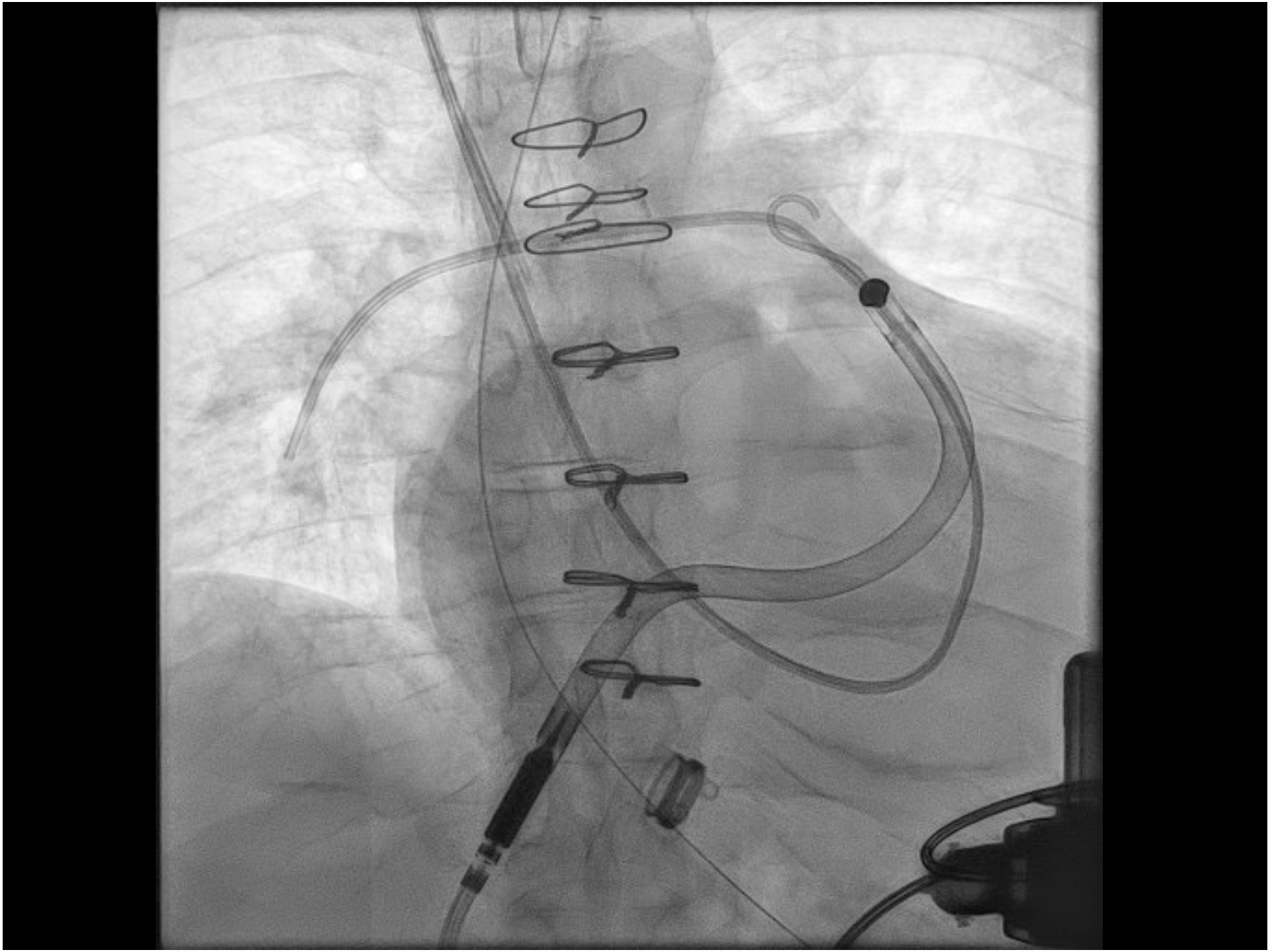
RV Support

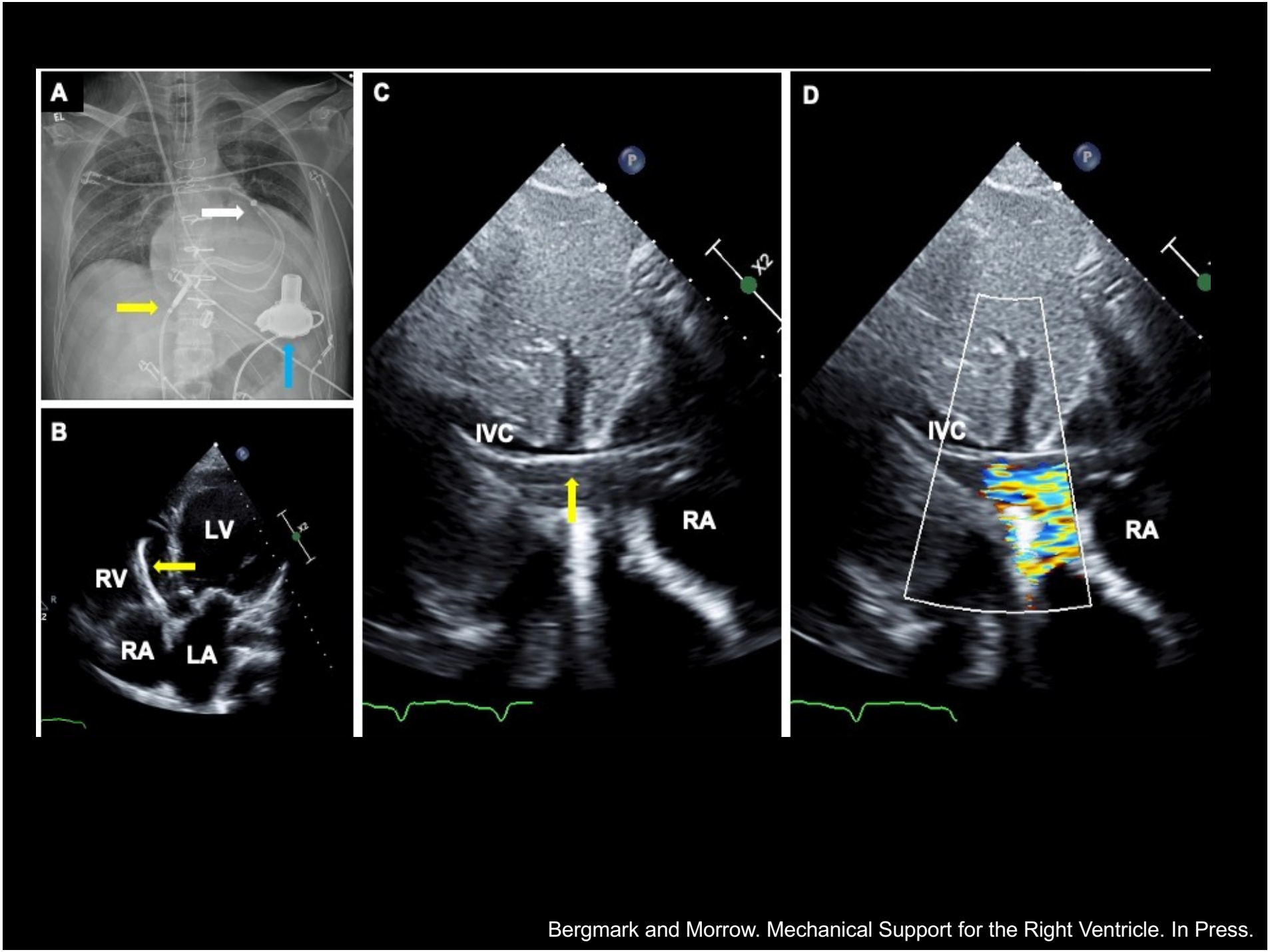
Impella RP

(+)
4 L/min
Typically fast placement

(-)
Femoral only
Migrates
Thrombocytopenia /hemolysis





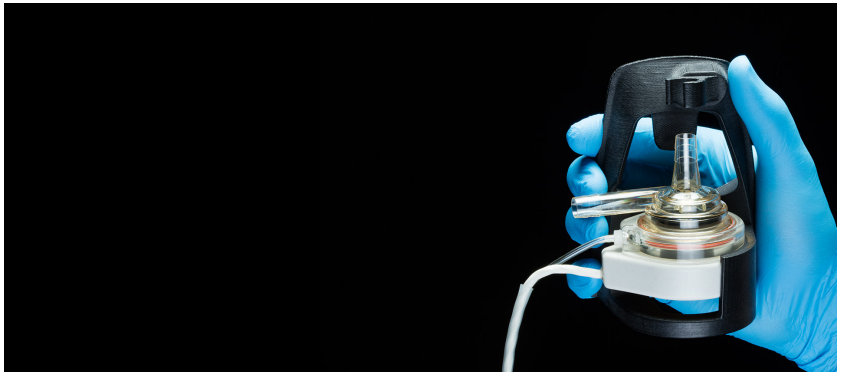


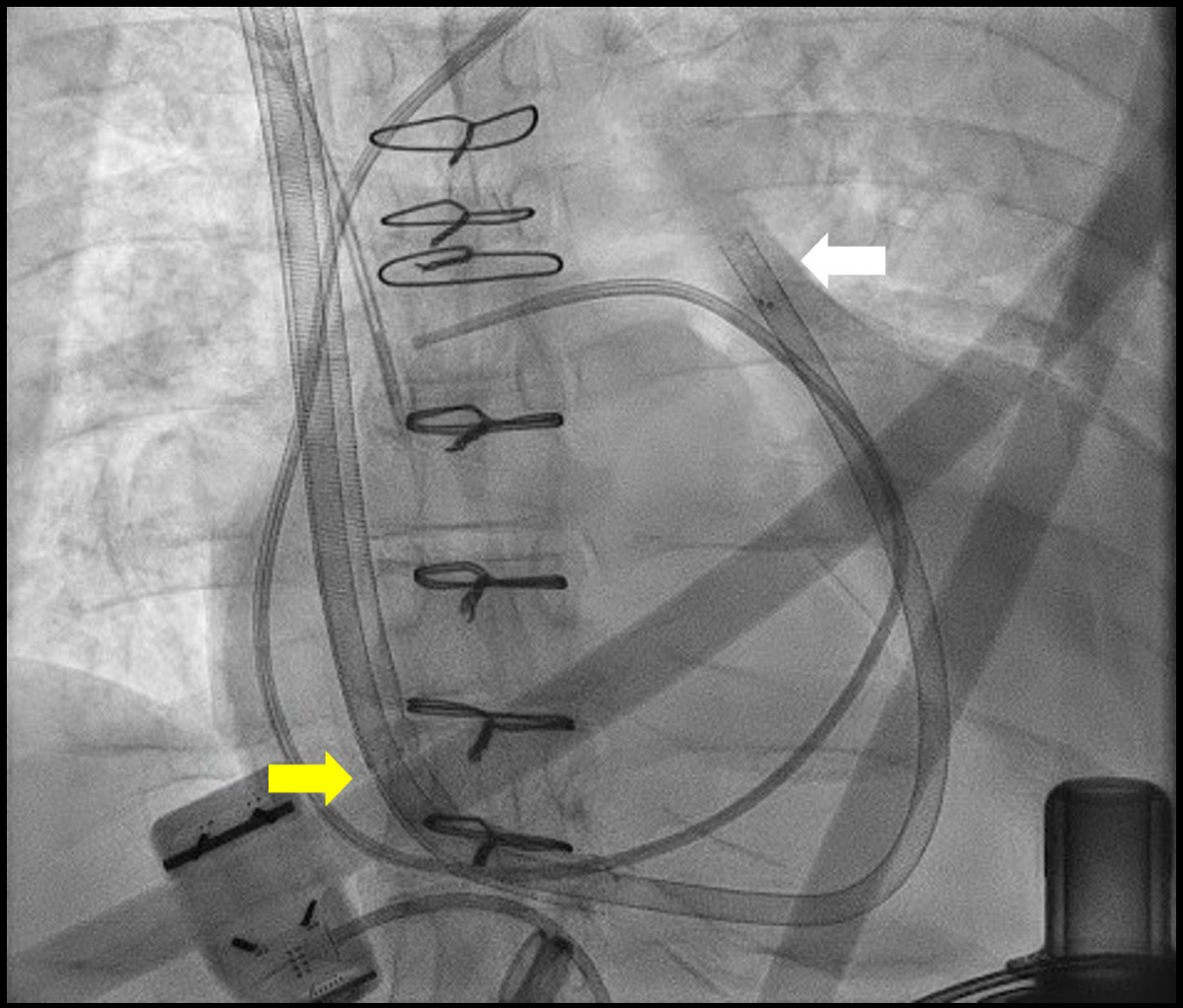
Bergmark and Morrow. Mechanical Support for the Right Ventricle. In Press.

Tandem RVAD

(+)
- 5+ L/min
- Typically fast placement
- Can add oxygenator
- If pair with TandemHeart LVAD and gas exchanger, have full ECLS in place
- Flexible access

(-)
- Larger access (28-31 Fr)
- Need to de-air circuit

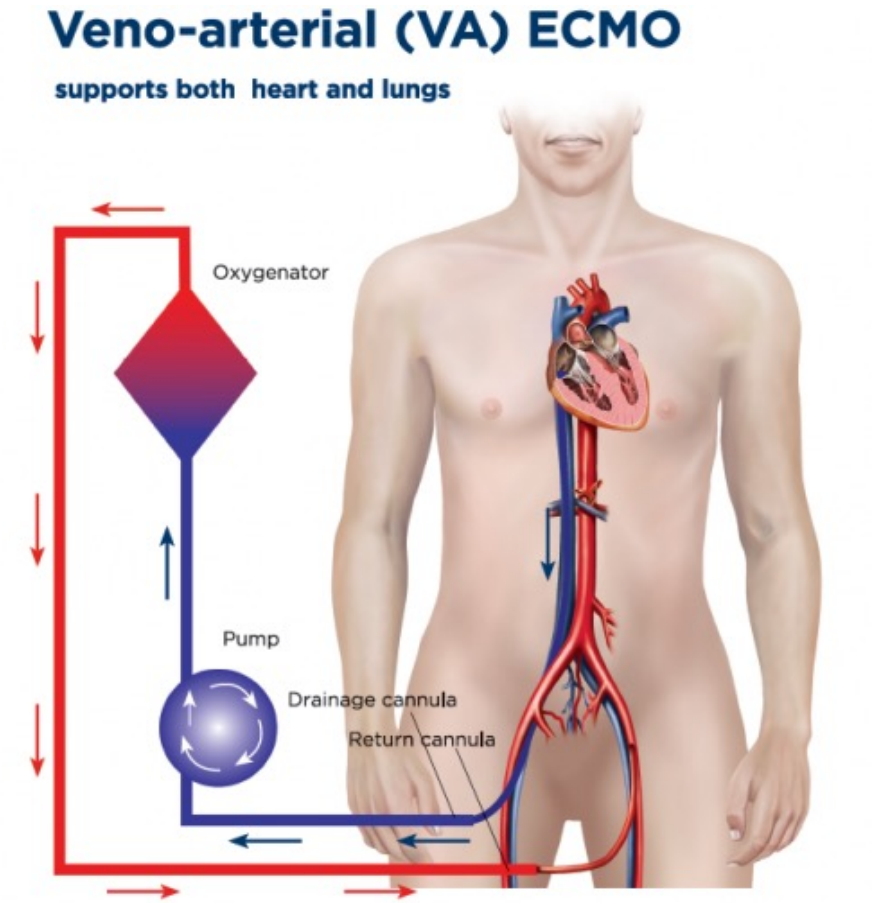




Bergmark and Morrow. Mechanical Support for the Right Ventricle. In Press.

Biventricular Support

Extracorporeal Membrane Oxygenation (ECMO)



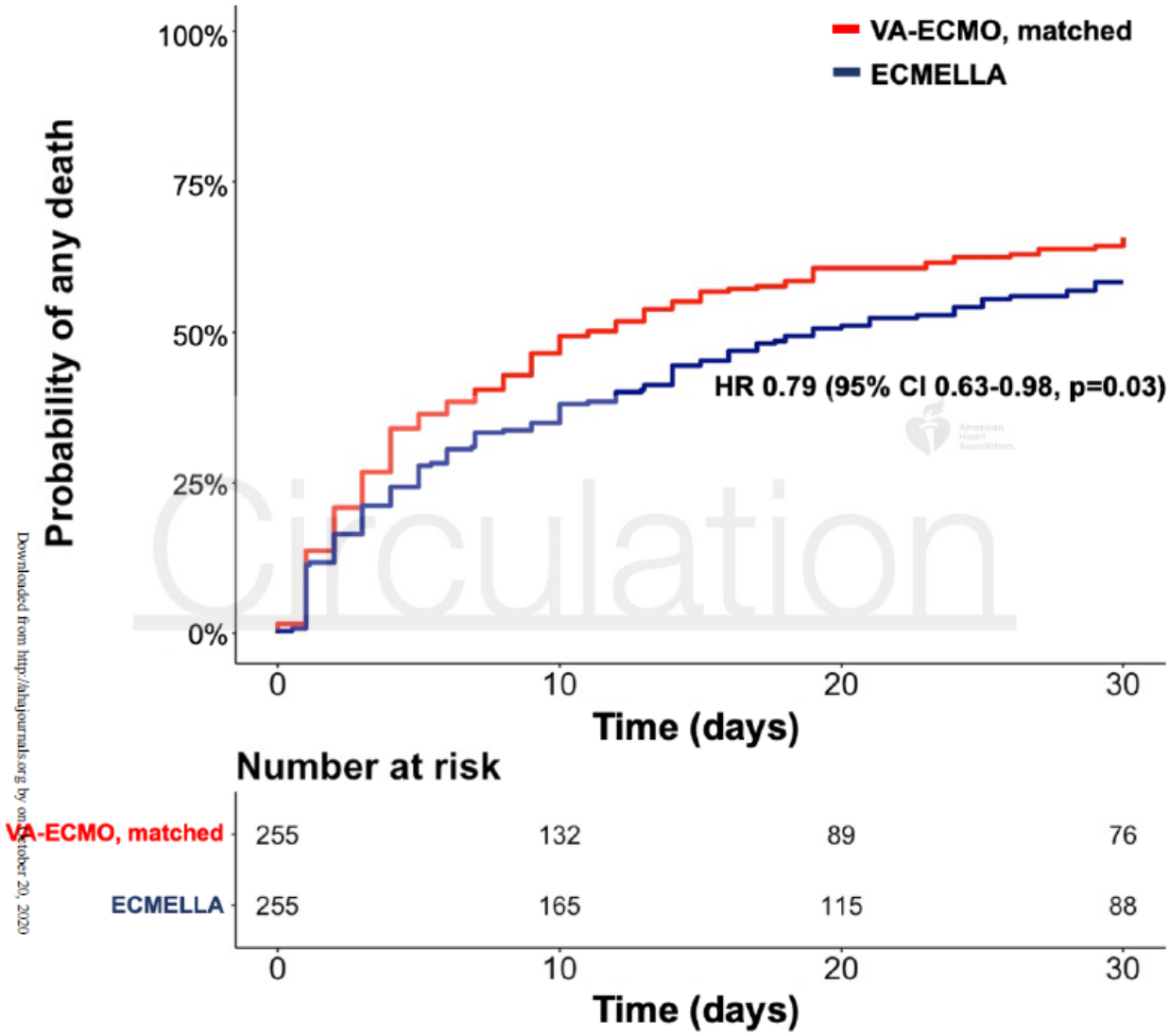
(+)

Full cardiopulmonary bypass
(Up to 6 L/min)
RV support
VT/VF tolerated

(-)

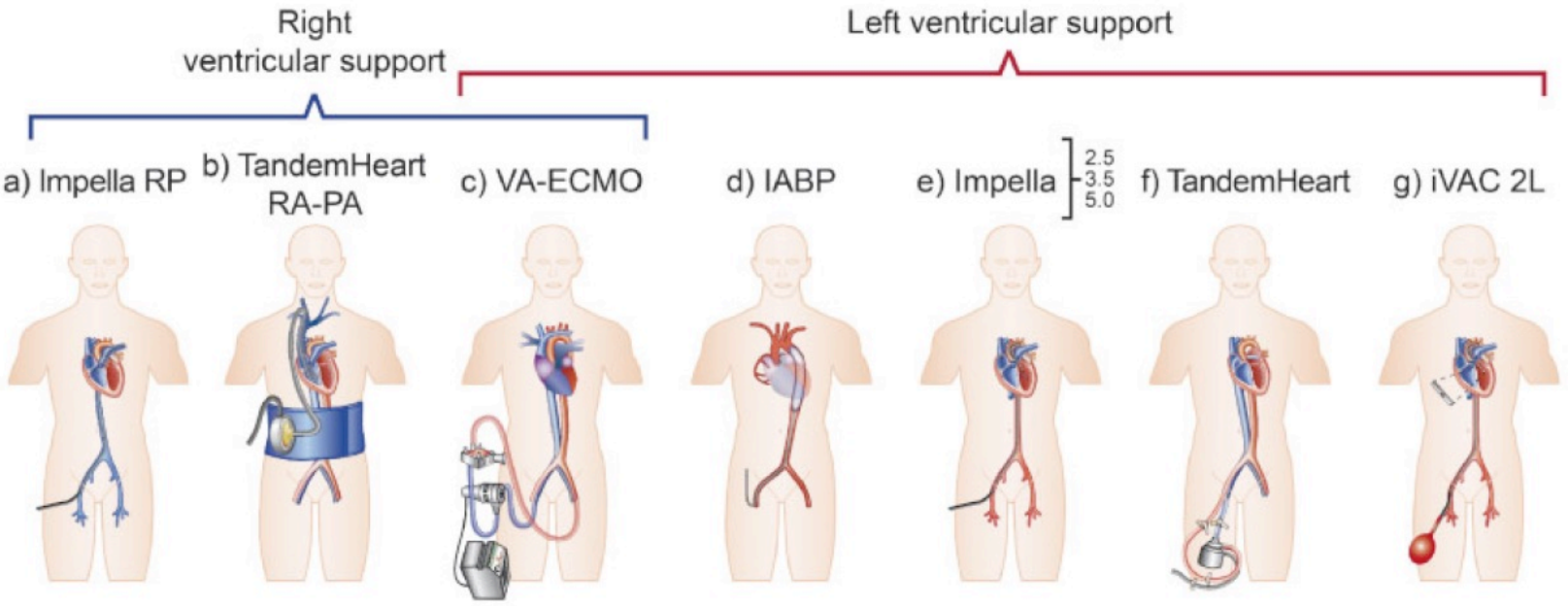
May require LV vent
Vascular injury
Limited availability

LV Unloading? (trending on twitter…)



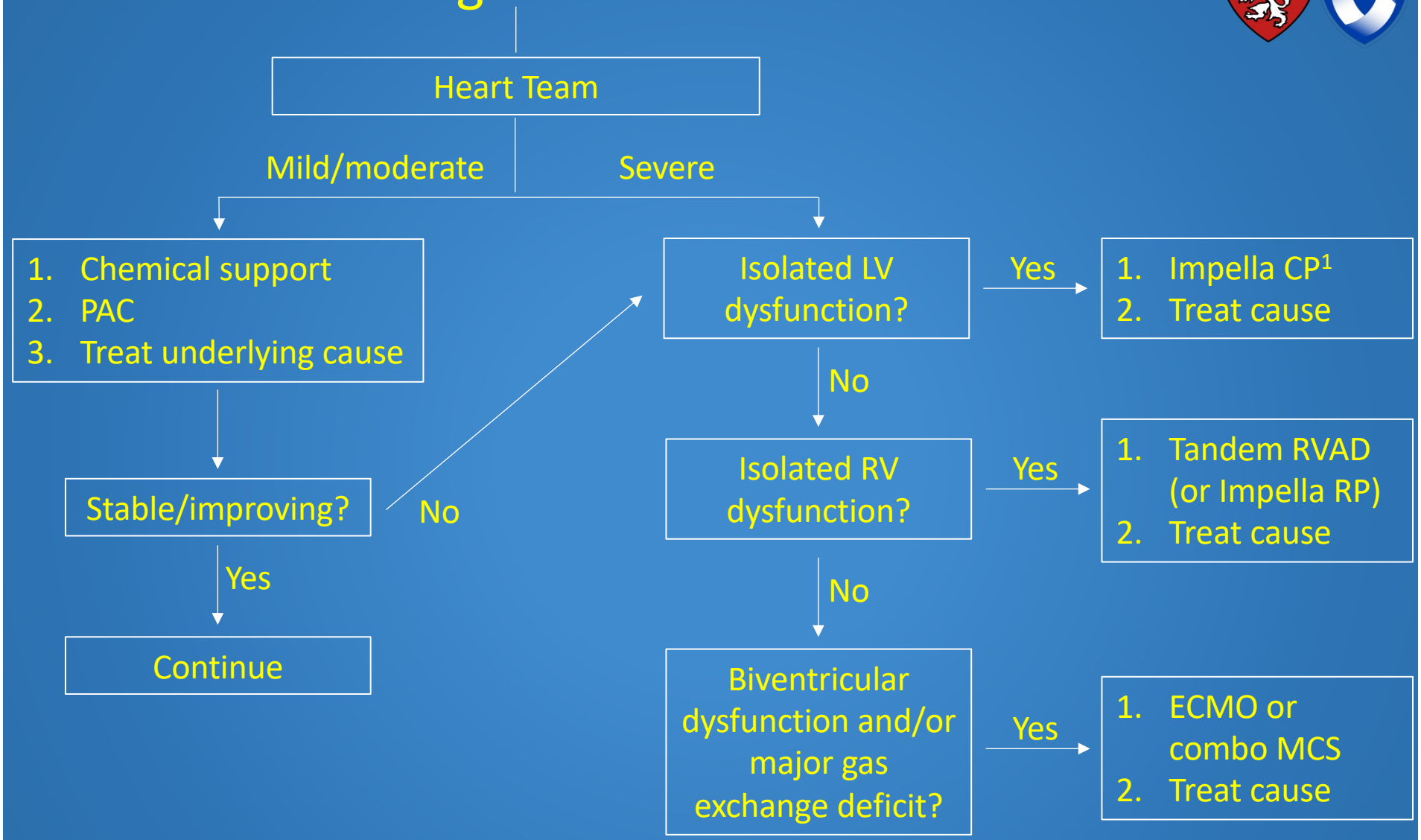
- 16 centers in 4 countries
- 686 consecutive patients
- NOT RANDOMIZED
- 1:1 PSM
- Patients with CS on ECMO in whom team decided to place Impella:
  - Had more complications
  - Had lower rates of death at 30 days
- Hypothesis-generating, needs RCT

MCS Overview



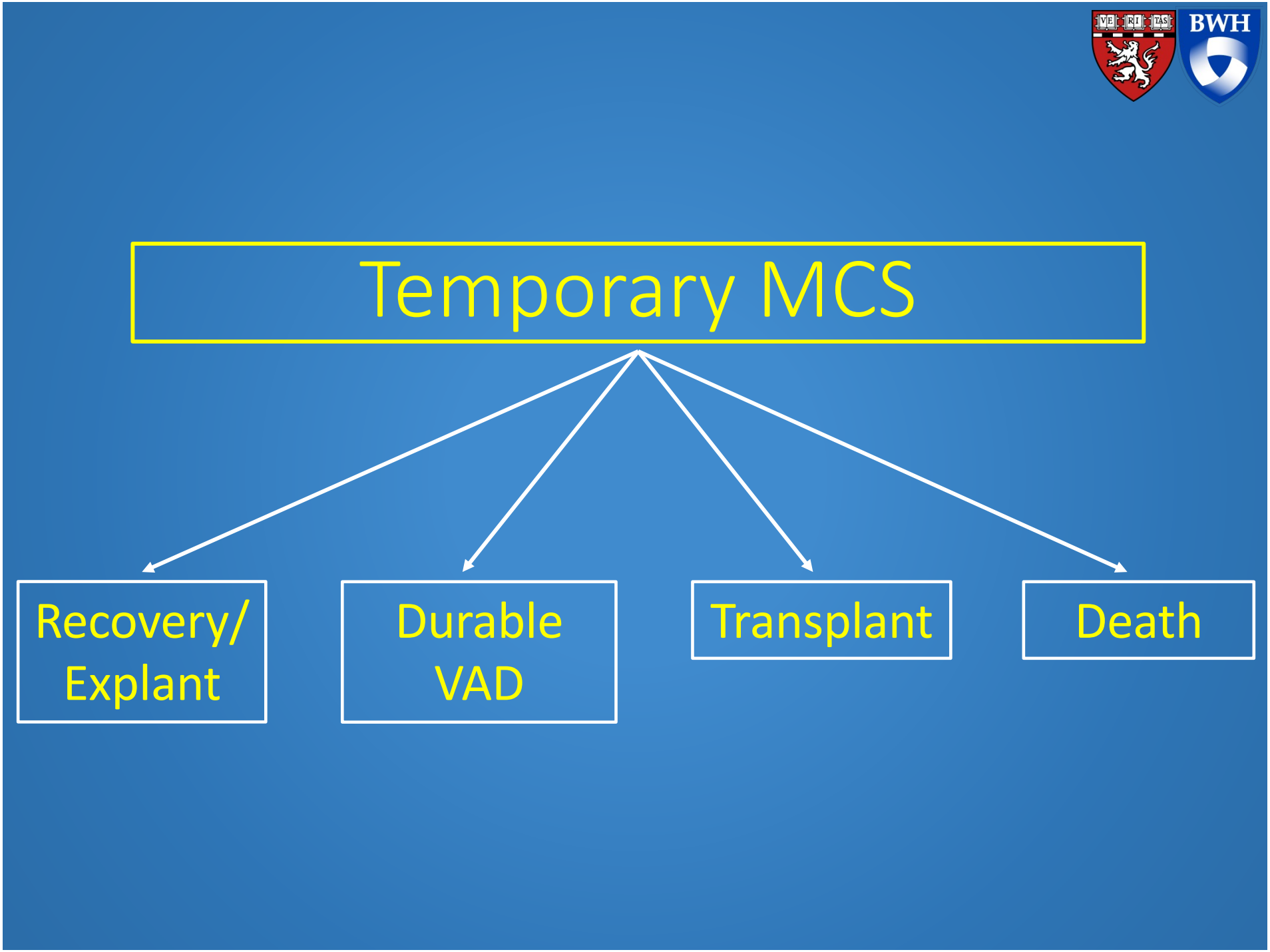
	a) Impella RP	b) TandemHeart RA-PA	c) VA-ECMO	d) IABP	e) Impella 2.5 / 3.5 / 5.0	f) TandemHeart	g) iVAC 2L
Flow:	max. 4.0 L	max. 4.0 L	max. 7.0 L		2.5-5.0 L	max. 4.0 L	max. 2.8 L
Pump speed:	33.000 rpm	max. 7.500 rpm	max. 5000 rpm		max. 51.000 rpm	max. 7.500 rpm	40 ml/beat
Cannula size:	22 F	29 F	14-19 F arterial 17-21F venous	7-8 F	12-14 F	12-19 F arterial 21F venous	17 F
Insertion/ Placement	Femoral vein	Internal jugular vein	Femoral artery Femoral vein	Femoral artery	Femoral artery	Femoral artery Femoral vein for LA access	Femoral artery
LV Unloading	-	-	-	(+)	+ - ++	++	+
RV Unloading	+	+	++	-	-	-	-

Cardiogenic Shock



[1]ECMO or TandemHeart if contraindication to Impella such as mechanical aortic valve or if Impella CP inadequate (may consider Impella 5.5)

Where are we going with this?


Temporary MCS
Recovery/ Explant
Durable VAD
Transplant
Death

Boards-Style Question

A 67-year-old woman presented with anterior STEMI 18 hours after symptom onset. Given ongoing chest discomfort and resuscitated VT in the Emergency Department she underwent emergent LAD PCI with TIMI 2 flow at the end of the procedure. On day 3 she develops acute chest pain, hypotension, and dyspnea. Physical exam reveals tachypnea and cool extremities as well as a harsh systolic murmur which was not previously present.

What is the next best step in this patient's care?

A) Place pulmonary artery catheter to measure RA and RV SpO2
B) Emergent coronary angiography for suspected stent thrombosis
C) Emergent transthoracic echocardiogram with simultaneous consultation of Cardiac Surgery and Cardiac Catheterization Laboratory
D) CT-PE

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D) CT-PE

Take Home Points

Cardiogenic shock is associated with high mortality

Recognizing and classifying cardiogenic shock can be challenging, but is essential

Prompt revascularization is the critical therapy for acute MI with shock

Diverse causes of cardiogenic shock exist beyond acute MI, but are much less studied

Take Home Points

For cardiogenic shock caused by a treatable etiology, prompt etiology-specific therapy is essential

Supportive measures include inotropes, vasodilators, diuretics and mechanical circulatory support

Multidisciplinary decision-making facilitates rapid and appropriate initiation of directed supportive therapy

Thank you

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