Cardiogenic Shock and Acute Mechanical Circulatory Support

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- I have no disclosures

Overview

- Cardiogenic shock (CS)
  - Definition
  - Etiology
  - Risk of mortality
  - Clinical, hemodynamic, & laboratory parameters
  - Classification scheme
  - General Management

Overview

- Acute Mechanical Circulatory Support
  - Rationale for use
  - Intra-aortic Balloon Pump
  - Impella (left, right, and biventricular)
  - TandemHeart
  - VA ECMO
  - Centrimag

Cardiogenic Shock

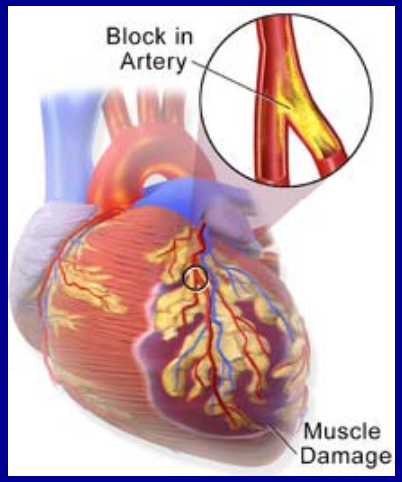
- State of end-organ hypoperfusion due to cardiac failure
- MI remains the most common cause of CS
  - Complicates 8.6% of STEMIs
  - Complicates 2.5% of NSTEMIs
  - 40,000-50,000 cases/yr in the US
  - 70-80% of pts develop CS in hospital as opposed to presenting to ER

Babaev A, et al. *JAMA*. 2005;294:448.

Hasdai D, et al. *J Am Coll Cardiol*. 2000;36:685.

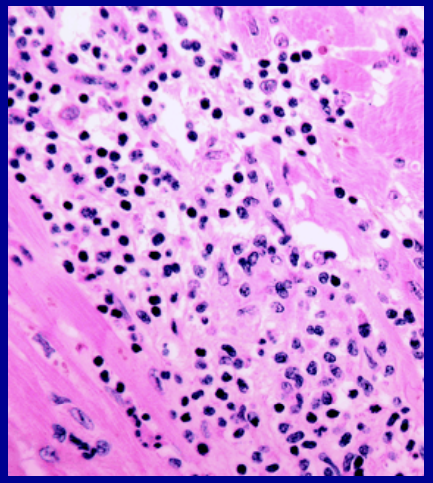
Thom T, et al. *Circulation*. 2006;113:e85.

Common Causes of Cardiogenic Shock

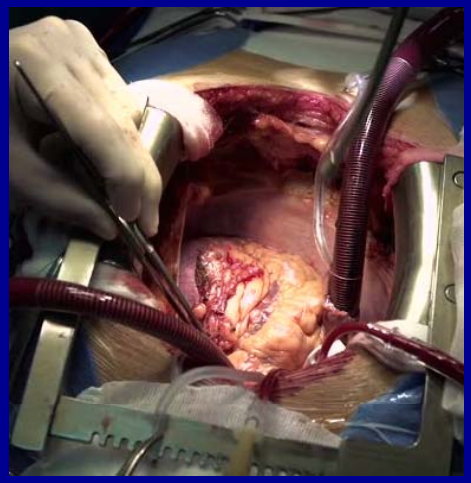


Acute MI and mechanical complications

Acute decompensated HF



Myocarditis

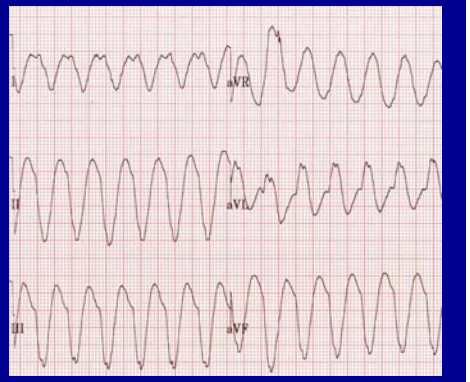


Postcardiotomy

Postpartum Cardiomyopathy

Valvular

Cardiac Tamponade



Arrhythmias

Kar B, et al. *Circulation*.2012;125:1809.

What is the approximate in-house mortality for cardiogenic shock?

A) 5%

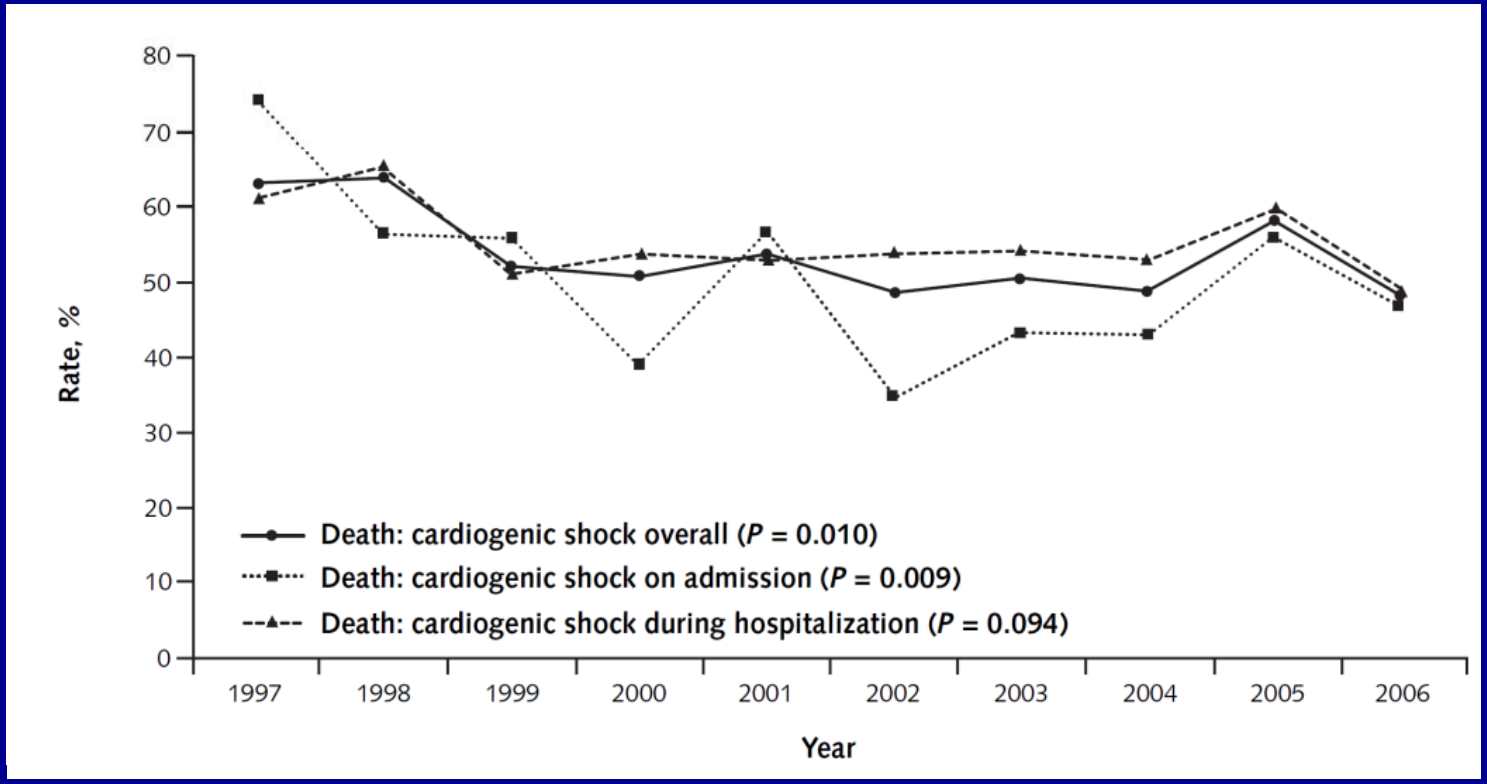
B) 25%

C) 50%

D) 80%

Mortality in AMI and CS

AMIS Registry (All ACS)
1997-2006



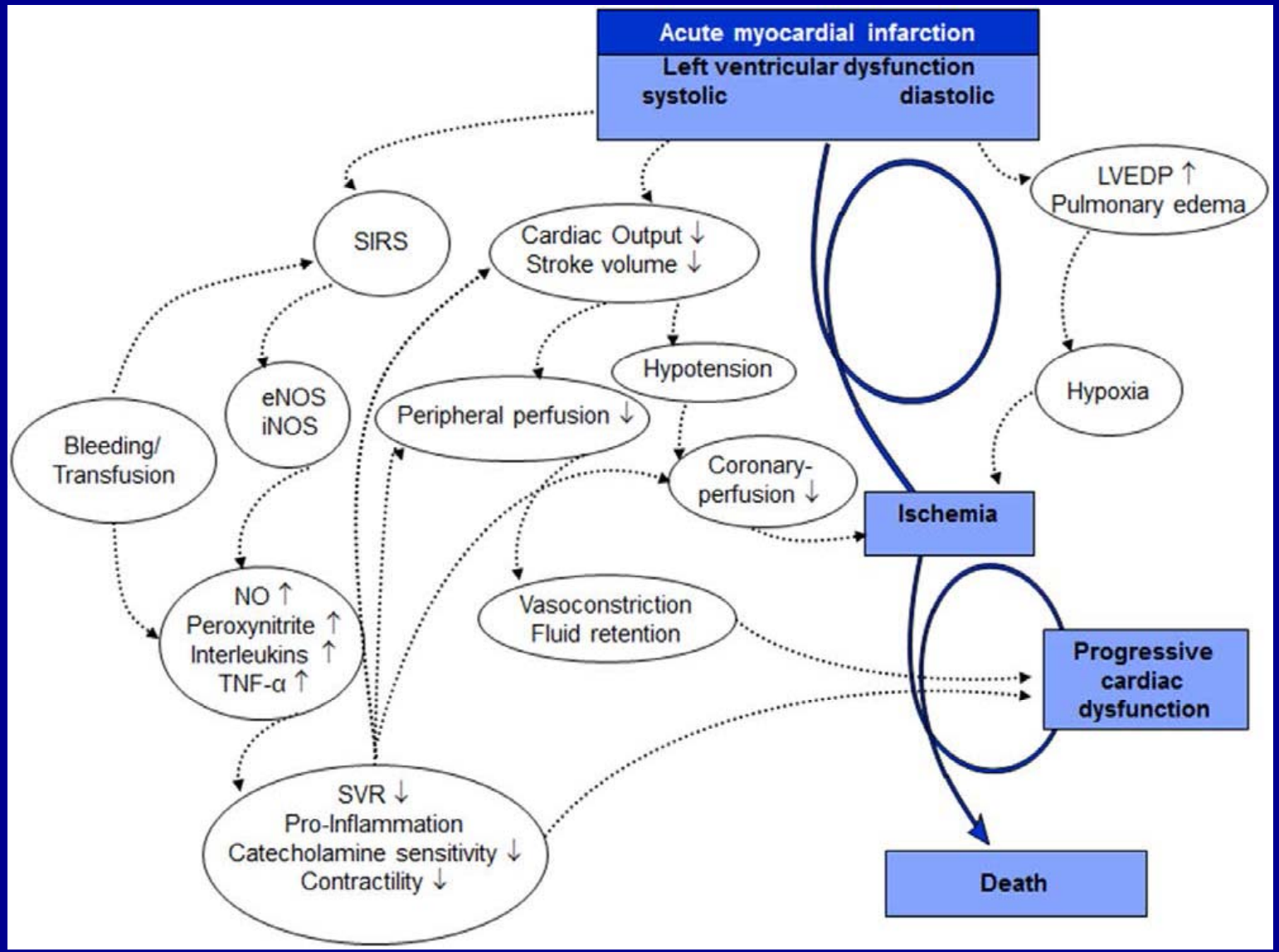
Jeger RV, et al. *Ann Intern Med*.2008;149:618.

Risk Factors for Mortality

- In-hospital mortality at 30 days in SHOCK trial was 57%
- Independent risk factors in this cohort
  - Age
  - Shock on admission
  - Clinical evidence of end-organ hypoperfusion
  - Anoxic brain injury
  - Systolic BP
  - Prior CABG
  - Non-inferior wall MI
  - Creatinine ≥1.9 mg/dL

Sleeper LA, et al. *Am Heart J*.2010;160:443.

Pathophysiology of shock is complex



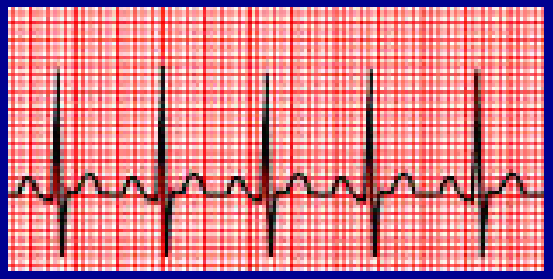
Hochman JS. *Circulation*.2003;107:2998.

van Diepen S, et al. *Circulation*. 2017;136:e232–e268.

Hollenberg SM, et al. *Ann Intern Med*.1999;131:47.

Early recognition of cardiogenic shock is extremely important for patient outcomes

Clinical Parameters of Shock



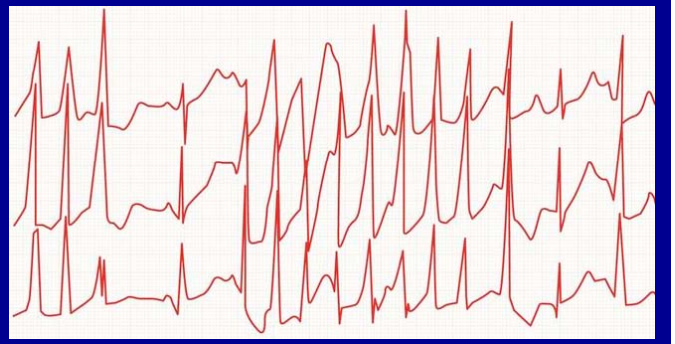
Tachycardia

Cool Extremities

Decreased urine output

Pulmonary congestion

Altered Mental Status



Arrhythmias

Classifying Shock

		Volume Status	
		Wet	**Dry**
Peripheral Circulation	**Cold**	Classic Cardiogenic Shock (↓CI; ↑SVRI; ↑PCWP)	Euvolemic Cardiogenic Shock (↓CI; ↑SVRI; ↔PCWP)
	Warm	Vasodilatory Cardiogenic Shock or Mixed Shock (↓CI; ↓/↔SVRI; ↑PCWP)	Vasodilatory Shock (Not Cardiogenic Shock) (↑CI; ↓SVRI; ↓PCWP)

van Diepen S, et al. *Circulation*. 2017;136:e232–e268.

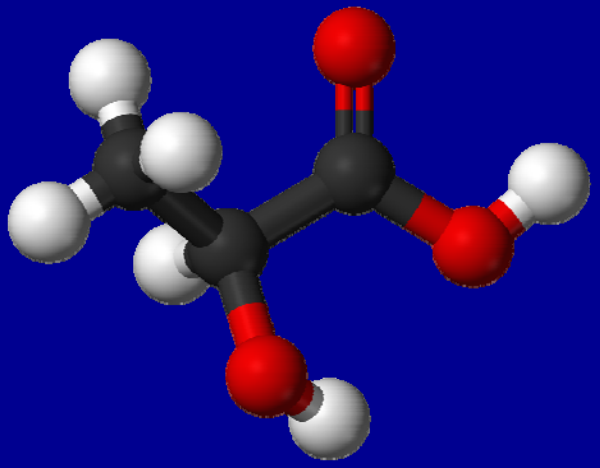
Hemodynamic Parameters

- Persistent hypotension
  - SBP <80-90 mmHg or MAP 30 mmHg lower than baseline
- Severe reduction in cardiac index
  - <1.8 L/min without support
  - <2.0-2.2 L/min with support
- Elevated filling pressure
  - LVEDP >18 mmHg OR
  - RVEDP >10-15 mmHg

Other Hemodynamic Parameters

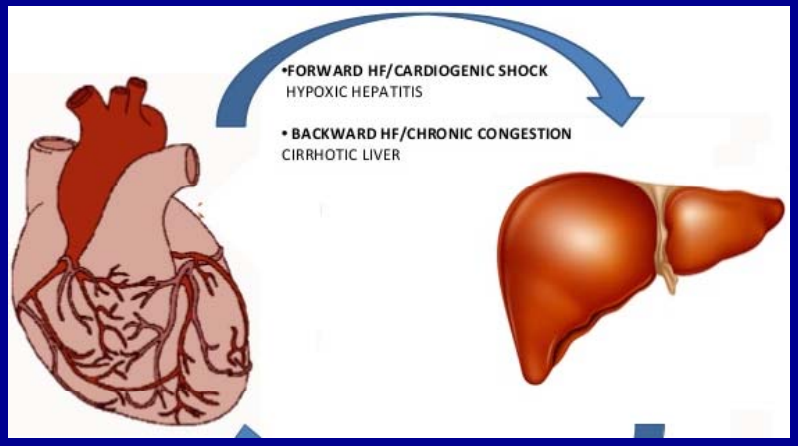
- RA pressure
  - Reflects volume overload
  - Reflects RV function
- PA pressure
  - Degree of pulmonary hypertension
  - Mean PAP ≤25 mmHg can signify RV failure
- PA saturation
  - Reflection of cardiac output

Laboratory Parameters

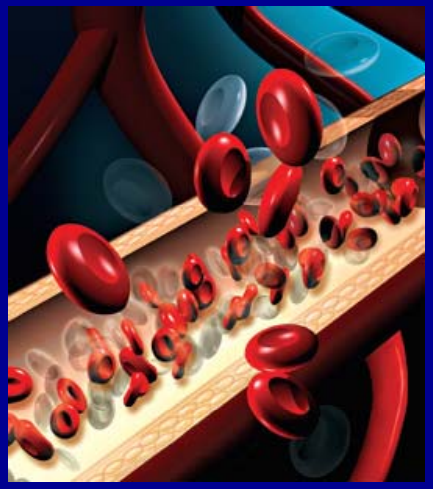


Lactic acidosis

Acute renal failure



Liver dysfunction



Coagulopathy

Clinical Spectrum of CS

Preshock	At significant risk for developing CS
Mild	Responsive to low-dose inotropes/vasopressors
Profound	Responsive to high-dose inotropes/vasopressors
Severe refractory	Unresponsive to high-dose intropes/vasopressors and IABP

INTERMACS Levels

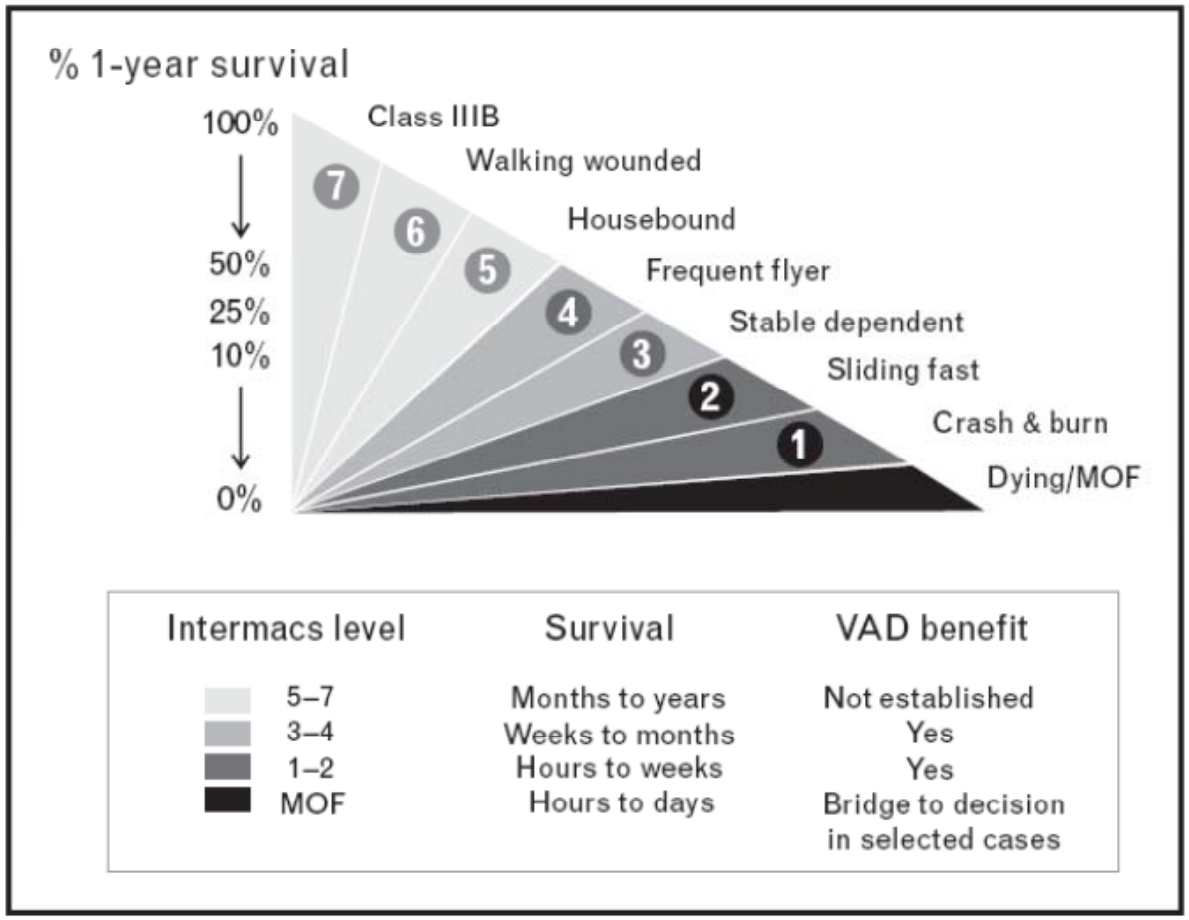
Table 4. INTERMACS: Patient Selection

Patient profile/status: INTERMACS levels	
1. Critical cardiogenic shock	
2. Progressive decline	
3. Stable but inotrope dependent	← Degrees of Class IV
4. Recurrent advanced HF	
5. Exertion intolerant	
6. Exertion limited–NYHA IIIb	
7. Advanced NYHA III	

Kirklin JK, et al. *J Heart Lung Transplant*.2008;27:1065.

INTERMACS Levels

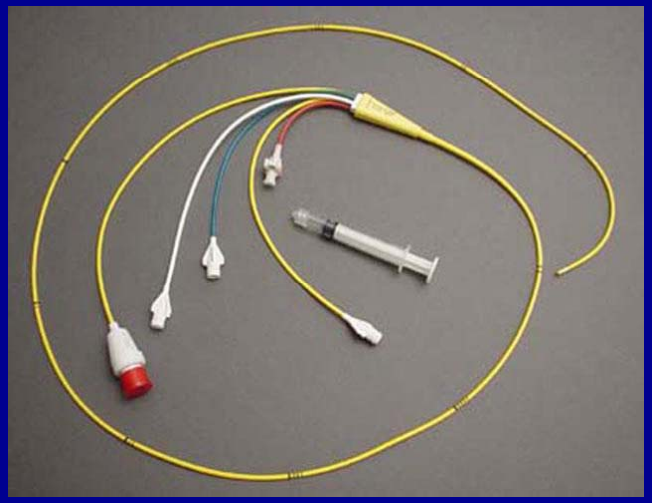
Figure 1 Clinical severity of end-stage heart failure defined by the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) levels



Kirklin JK, et al. *J Heart Lung Transplant*.2008;27:1065.

General Management of CS

- Adequate oxygenation
- Hemodynamic monitoring
  - Intra-arterial BP monitoring
  - PA catheter
    - Establish diagnosis
    - Guide changes in therapy



- Pharmacologic/inotropic support
  - Dopamine -Norepinephrine
  - Dobutamine -Epinephrine
  - Milrinone

Revascularization in ACS in setting of cardiogenic shock

- Timing is important
- Earlier is better
- Increased survival

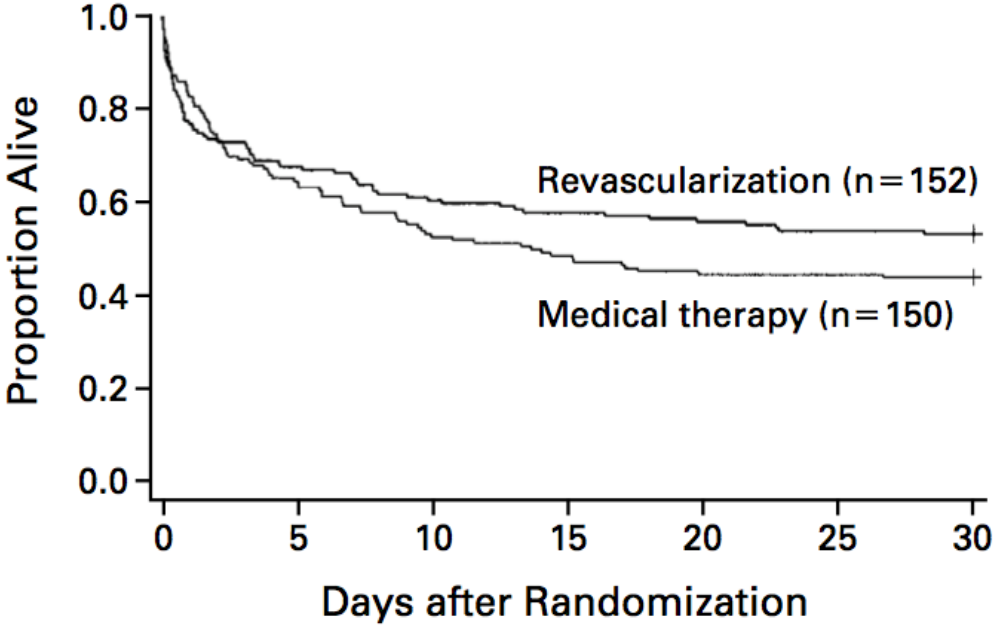
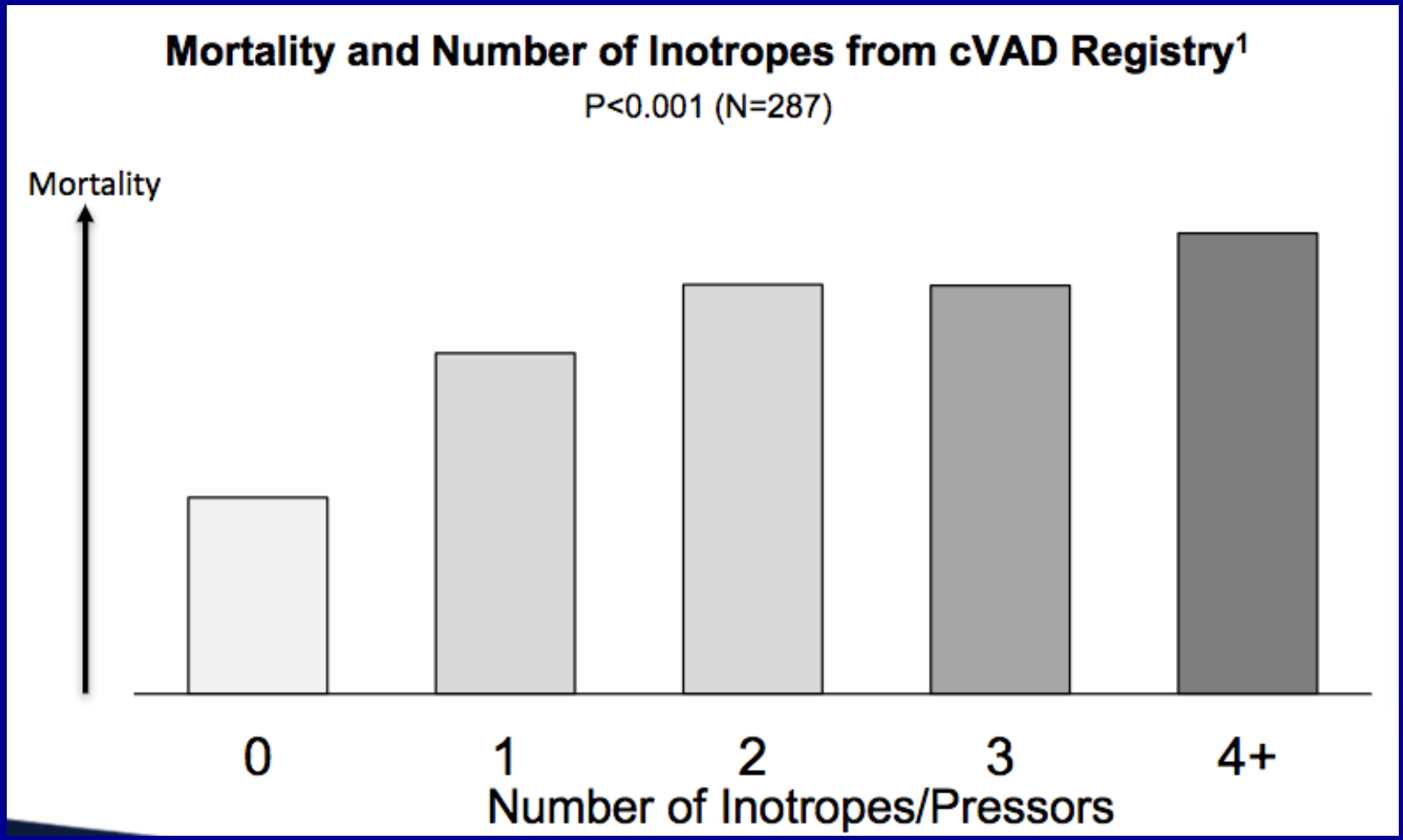


Figure 1. Overall 30-Day Survival in the Study.
The 30-day survival rate was 53.3 percent for patients assigned to revascularization and 44.0 percent for those assigned to medical therapy.

Hochman JS, et al. *N Engl J Med*.1999;341:625.

Increased Inotrope Exposure is Associated with Mortality in AMI/CGS



Basir M, et al. *Am. J Cardiol*. 2016.

Rationale for Mechanical Circulatory Support

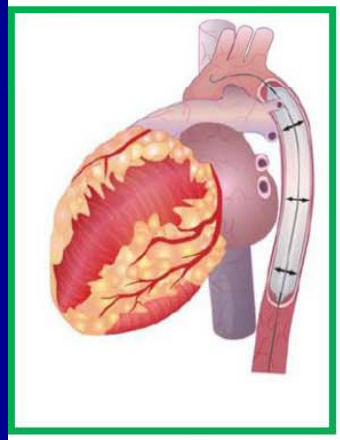
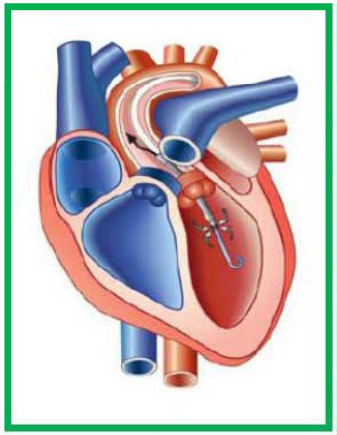
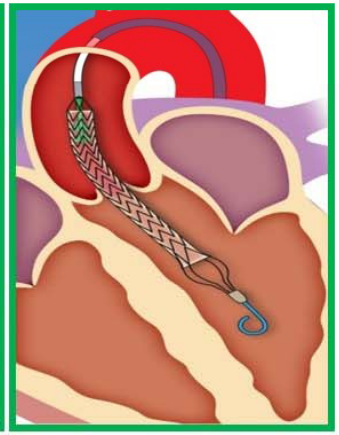
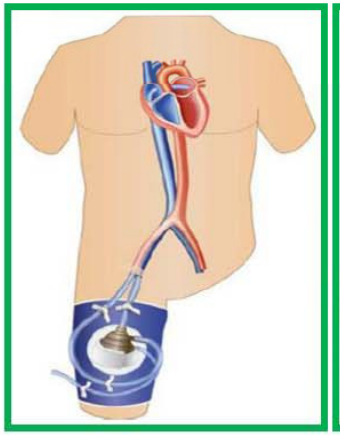
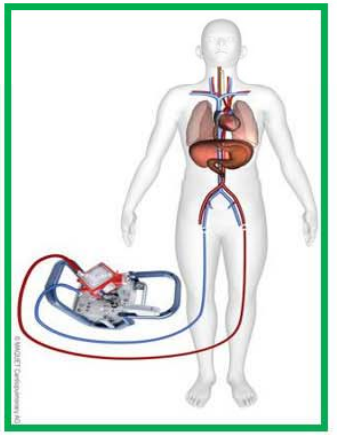
- Break downward spiral by restoring adequate systemic perfusion pressure
- Allow time to address underlying etiology of myocardial pump failure
- Allow for myocardial recovery

What form of mechanical circulatory support cannot be placed percutaneously?

A) Impella CP
B) ECMO
C) Centrimag Biventricular VAD
D) Impella RP
E) Intra-aortic balloon pump

Acute Mechanical Circulatory Support Options for the LV

Continuous Flow Pumps

Pulsatile	Axial-Flow		Centrifugal Flow	
				
IABP	Impella CP	PHP *	TandemHeart	VA-ECMO
Intracorporeal			**Extracorporeal**	

* Investigational

Kapur NK, Esposito M. *J Am Coll Cardiol* 2016.

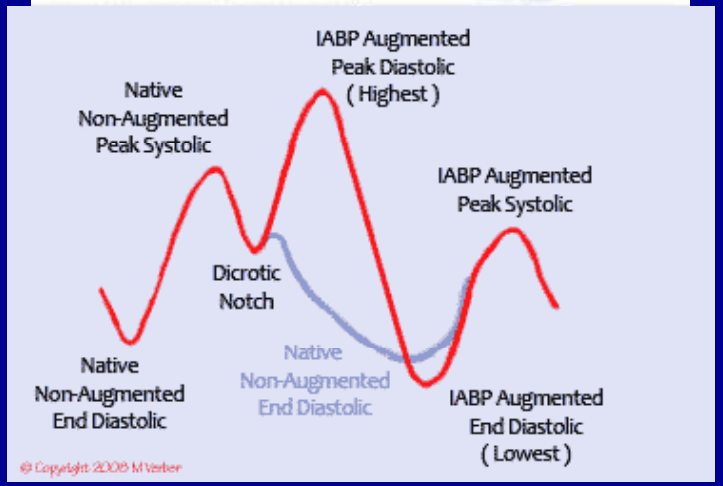
Intra-aortic balloon pumps have been shown to improve survival in cardiogenic shock?

A) True

B) False

Intra-aortic Balloon Pump

- Inflates during diastole
- Deflates during systole
- Improves coronary perfusion
- Decreases afterload
- Augments CO ~0.5 L/min
- Complications
  - Balloon migration
  - Bleeding
  - Leg ischemia
  - Thrombocytopenia



http://www.rocaredondapress.com/IABP/iabp-0.htm

Intra-aortic Balloon Pump

- ACC/AHA Class IB recommendation for CS in the setting of AMI
- Observational studies have shown mixed benefits in terms of mortality
- Improvements in hemodynamic profiles have been shown (CO, CI, PCWP)
- Recent randomized controlled trials have not shown 30-day mortality benefit

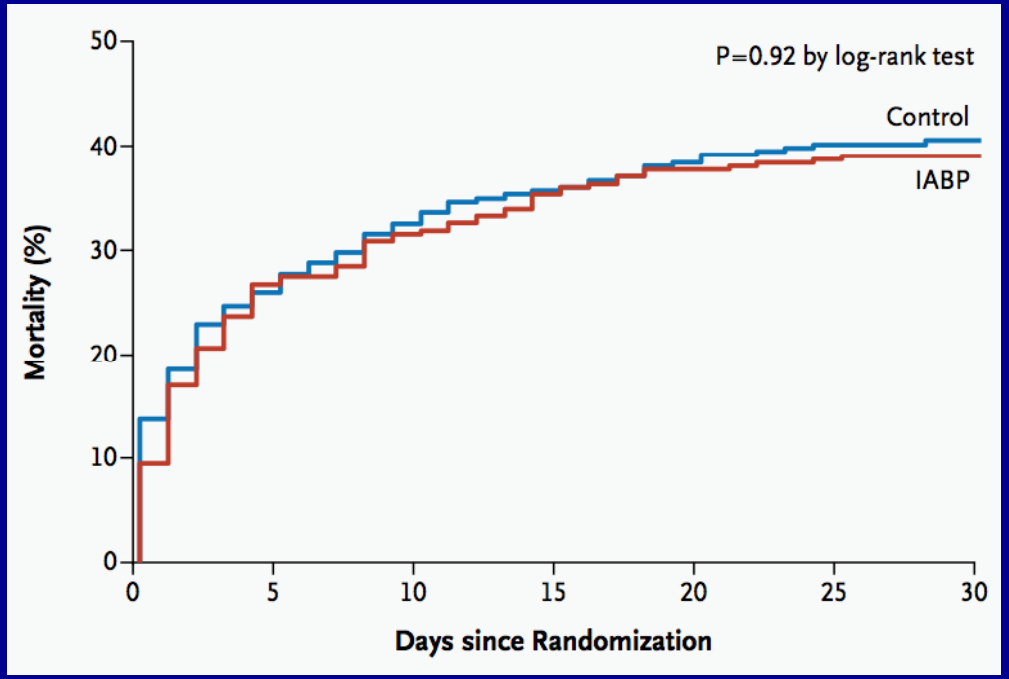
Prondzinsky P, et al. *Crit Care Med*.2010;83:152.

Unverzgat S, et al. *Cochrane Database Syst Rev*.2011;7.CD007398.

Sjauw KD, et al. *Eur Heart J*.2009;30:459.

IABP-SHOCK II Trial

- Randomized, prospective, open-label trial
- AMI c/b CS
- 600 pts
- Early revasc strategy
- No sig diff in mortality or secondary endpoints

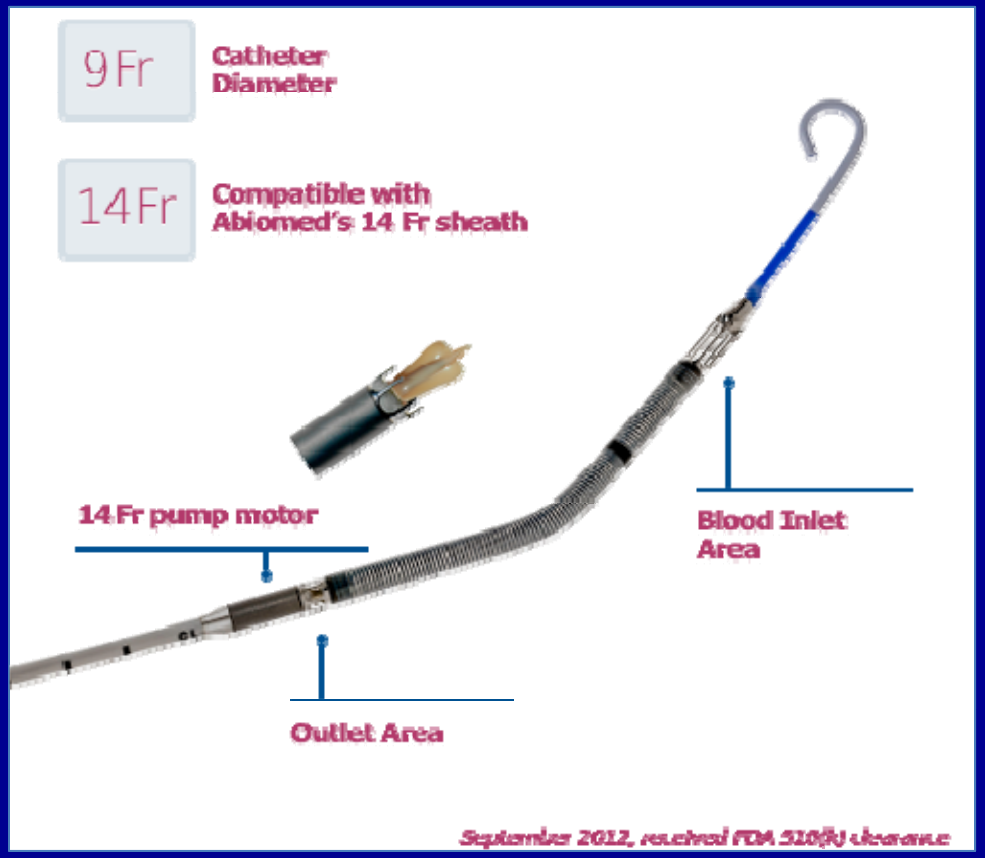


- 6 year f/u also no difference in mortality (66.3% vs 67.0%; RR 0.99; 95% CI, 0.88–1.11), recurrent MI, stroke, revasc, readmission

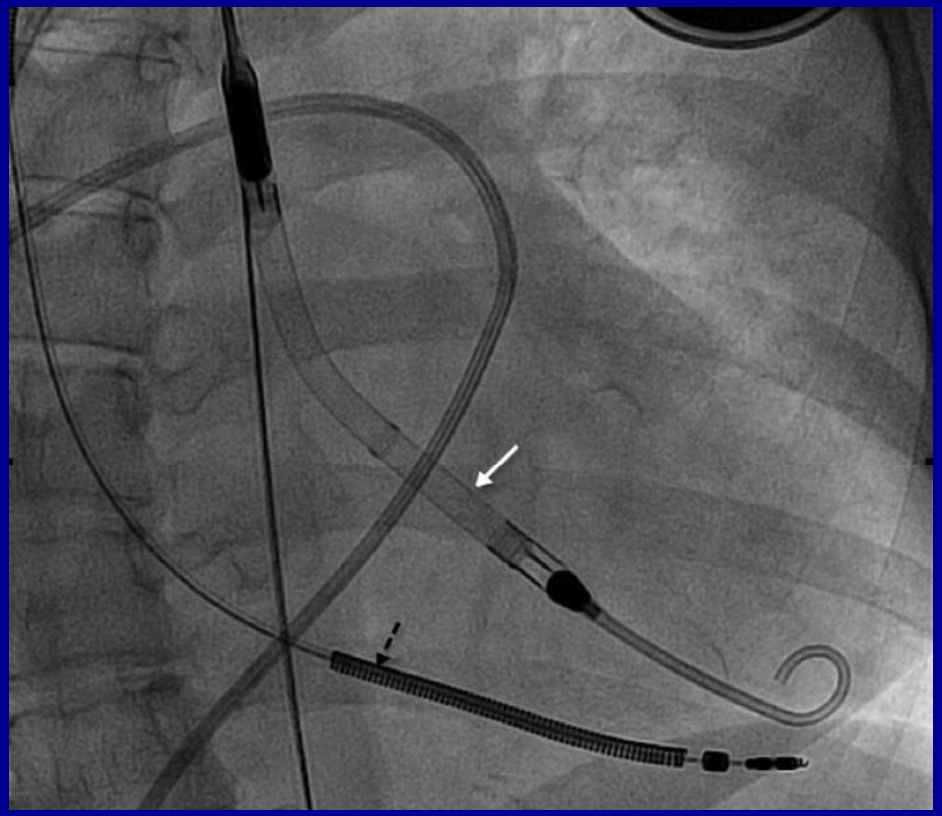
Thiele H, et al. *N Engl J Med*.2012;367:1287.
Thiele H, et al. *Circulation*. 2018;139:395.

Impella CP

- Catheter-mounted microaxial rotary pump inserted into LV across AV via femoral artery access
- Can increases CO by 3.5 L/min
- Complications
  - Migration of device
  - Bleeding
  - Limb ischemia
  - Hemolysis

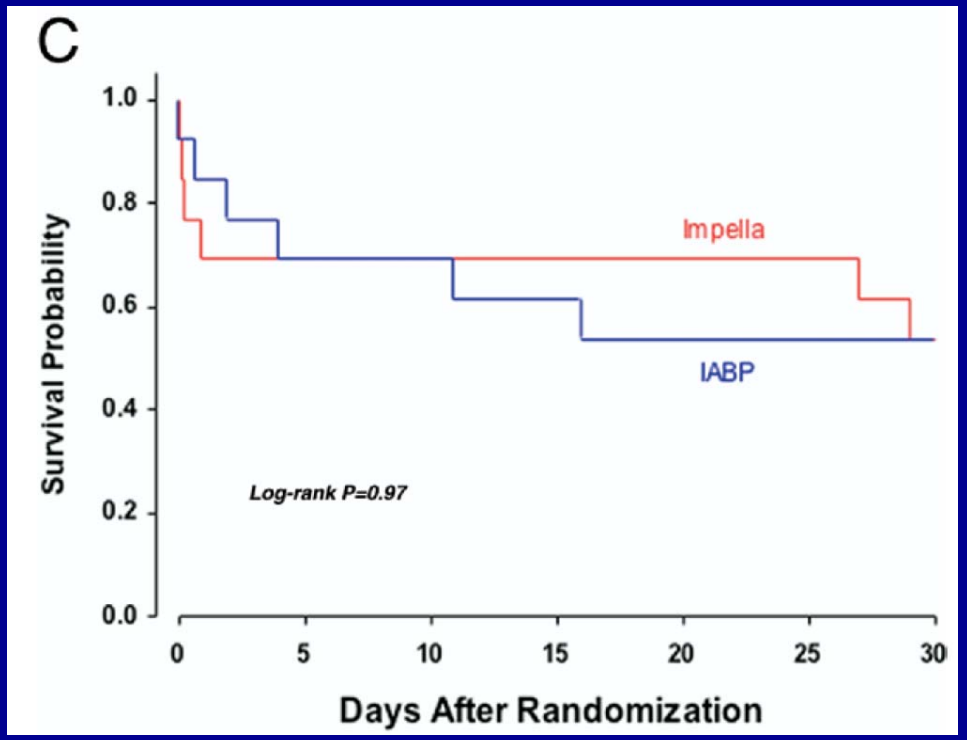


Impella CP



ISAR-SHOCK Trial

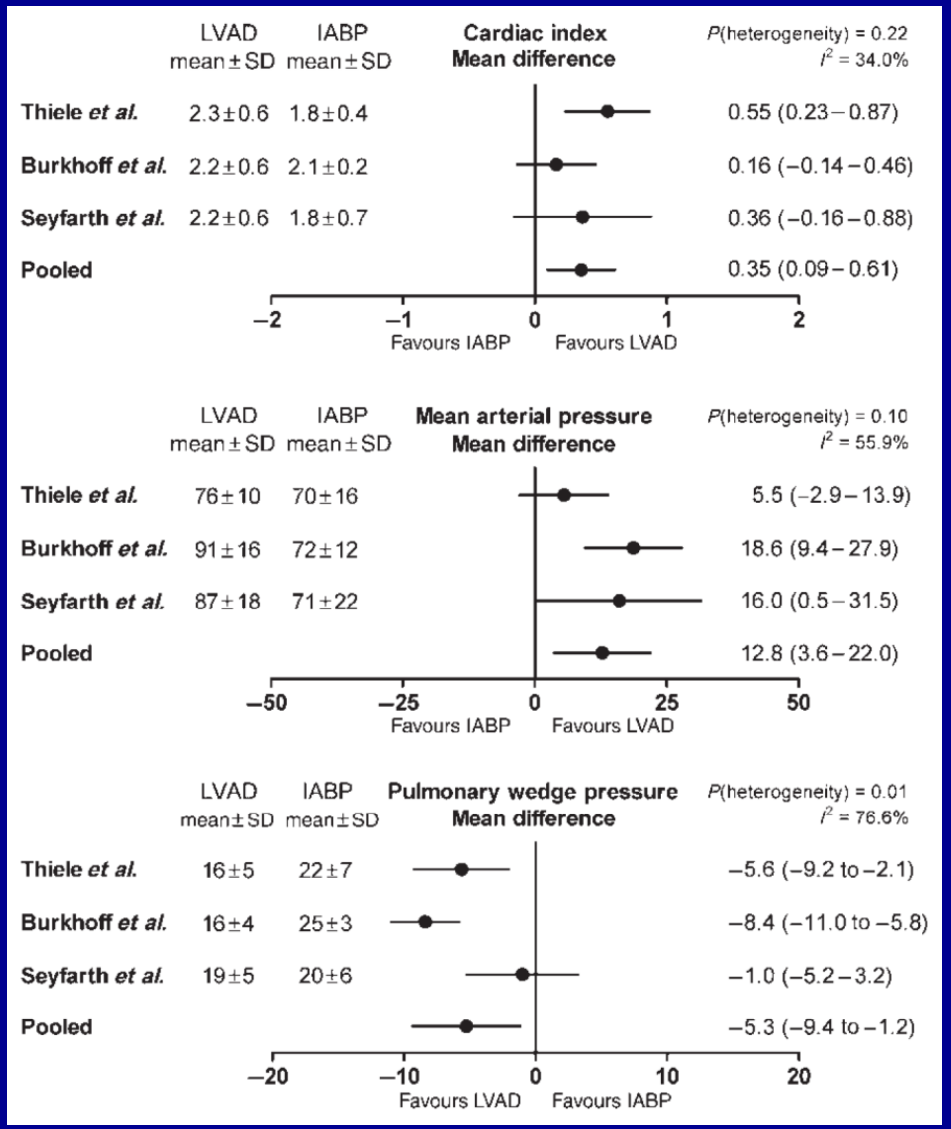
- Randomized trial of 26 pts with AMI c/b CS
- IABP vs Impella
- Sig improved hemodynamics in Impella group
- Median duration of support ~24 hrs
- No sig diff in survival
- 30 day mortality 46%
- Increased adverse events in Impella group



Seyfarth M, et al. *J Am Coll Cardiol*.2008;52:1584.

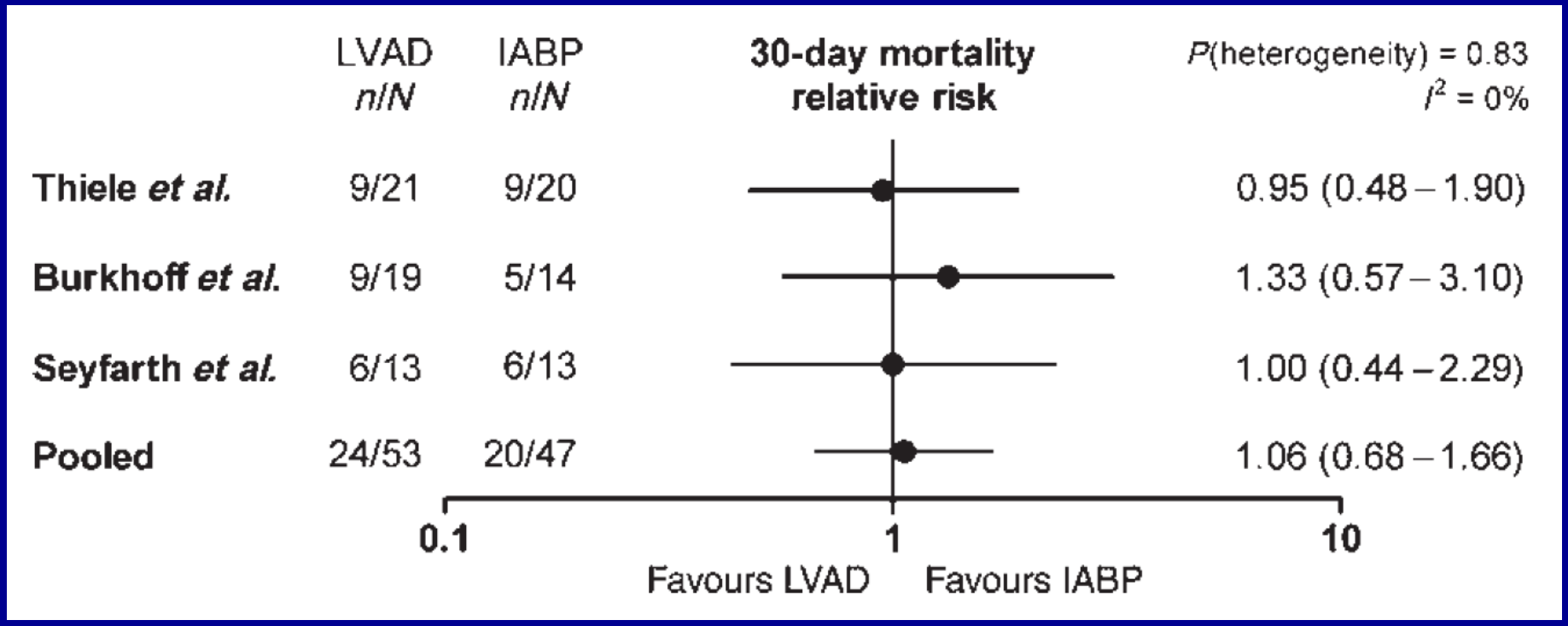
Comparison of IABP vs PVAD

- Meta-analysis
- Majority of pts had CS 2/2 AMI
- PVAD pts had higher CI and MAP and lower PCWP compared to IABP pts



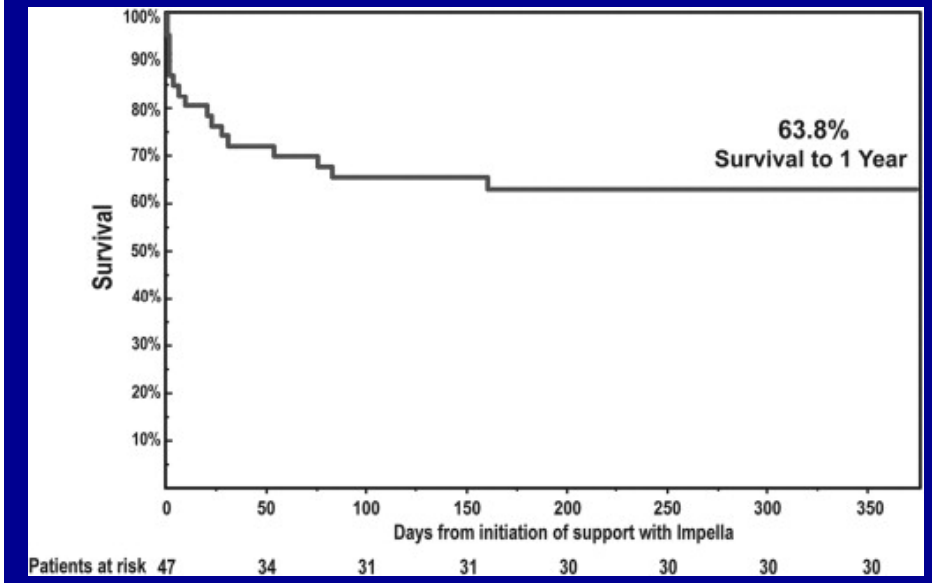
Cheng JM, et al. *Eur Heart J*.2009;30:2102.

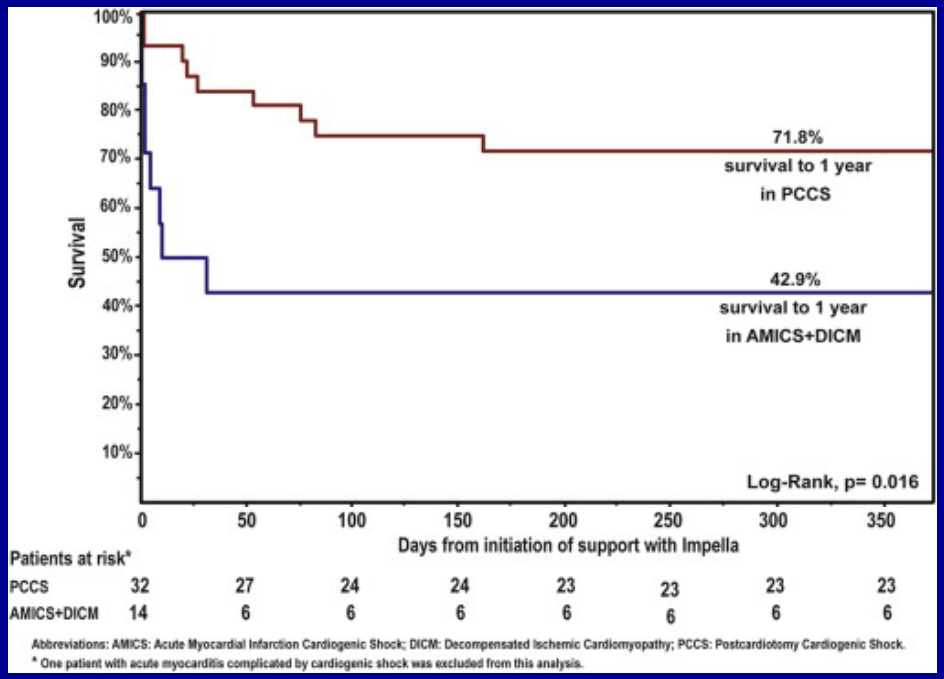
Comparison of IABP vs PVAD



Cheng JM, et al. *Eur Heart J*.2009;30:2012.

Retrospective Data for Impella in CS





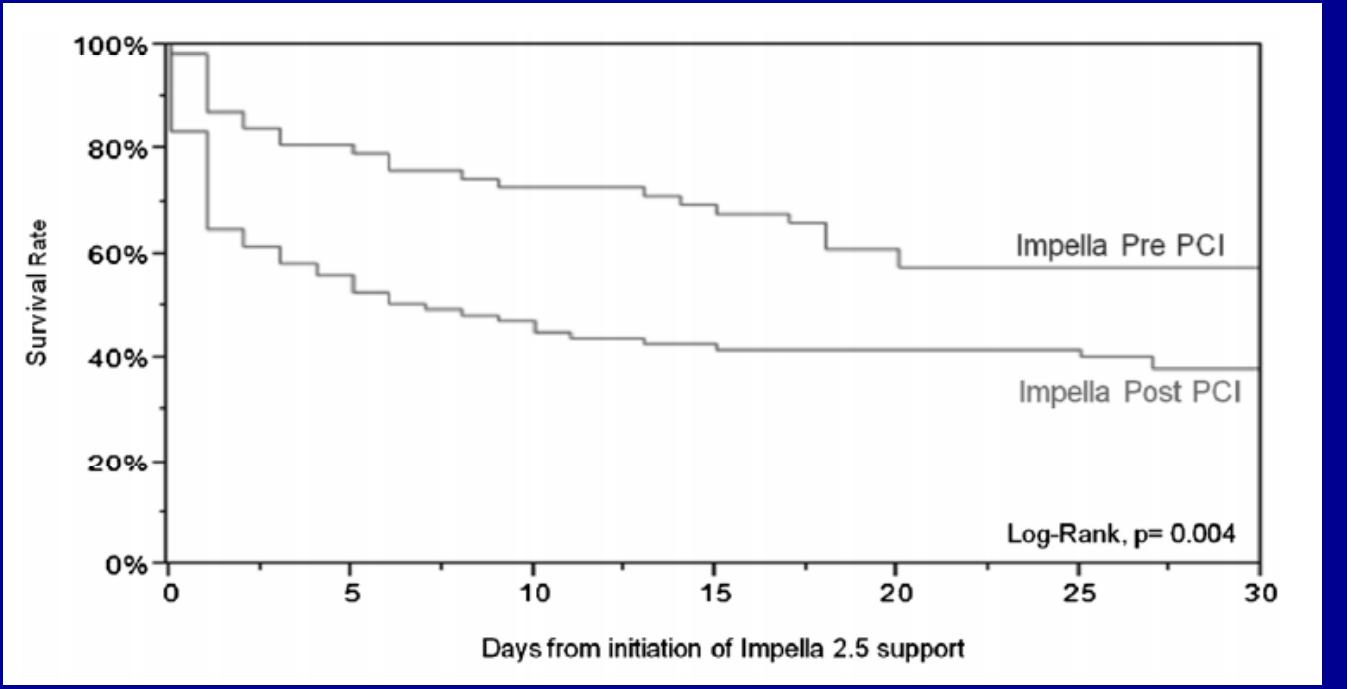
- Retrospective analysis of 47 patients with CS who received Impella 2.5 (20%) or 5.0 (80%)
- Indications: AMI/ADHF in 15 pts (32%) and postcardiotomy CS in 32 (68%)
- Complications occurred in 14 pts (30%): device malfunction, high purge pressures, tube fracture, and groin hematoma

Lemaire A, et al. *Ann Thorac Surg*. 2014;97:133-8.

Early Mechanical Support May Improve Outcomes in CS and AMI

USPella Registry

154 patients with CS complicating AMI who received Impella 2.5, comparison between Impella pre-PCI and Impella post-PCI



- Mortality: Pre-PCI (40.7%), Post-PCI (65.1%)
- Door to Balloon Time: Pre-PCI (112 mins), Post-PCI (52 mins)
- Pre-PCI Group with more lesions and vessels treated

J Interv Cardiol. 2014. 27(1): 1–11.

What device does not provide mechanical right ventricular support?

A) ECMO

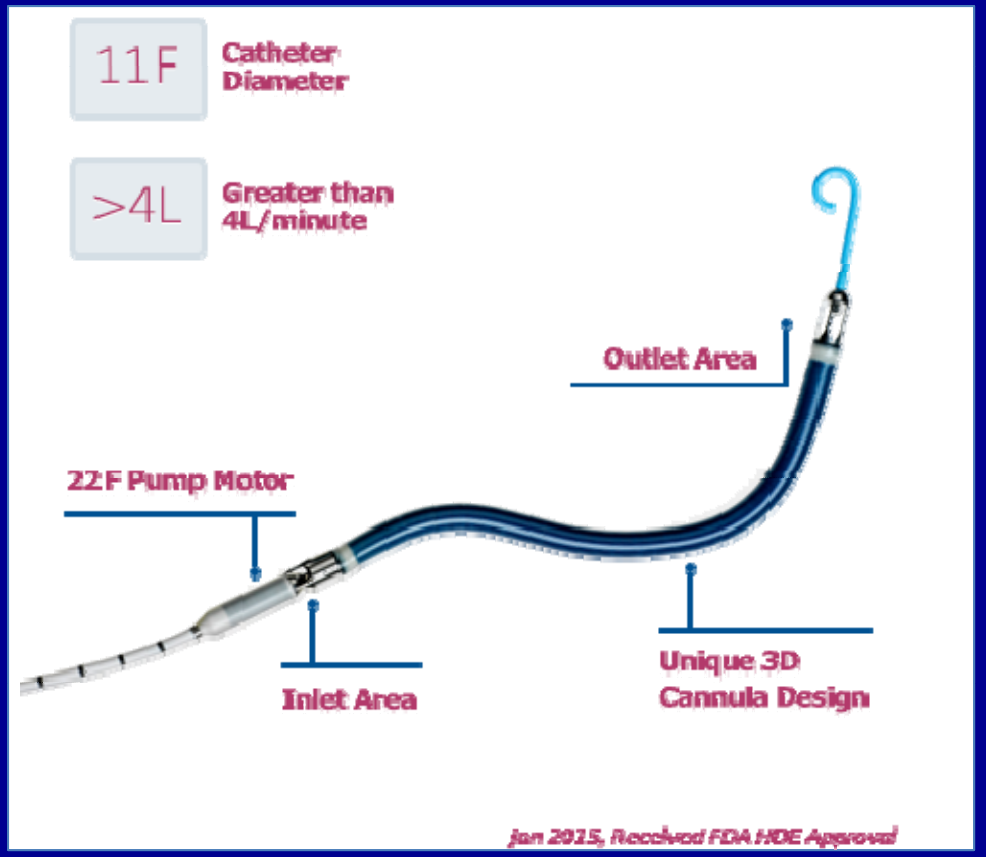
B) Impella CP

C) Impella RP

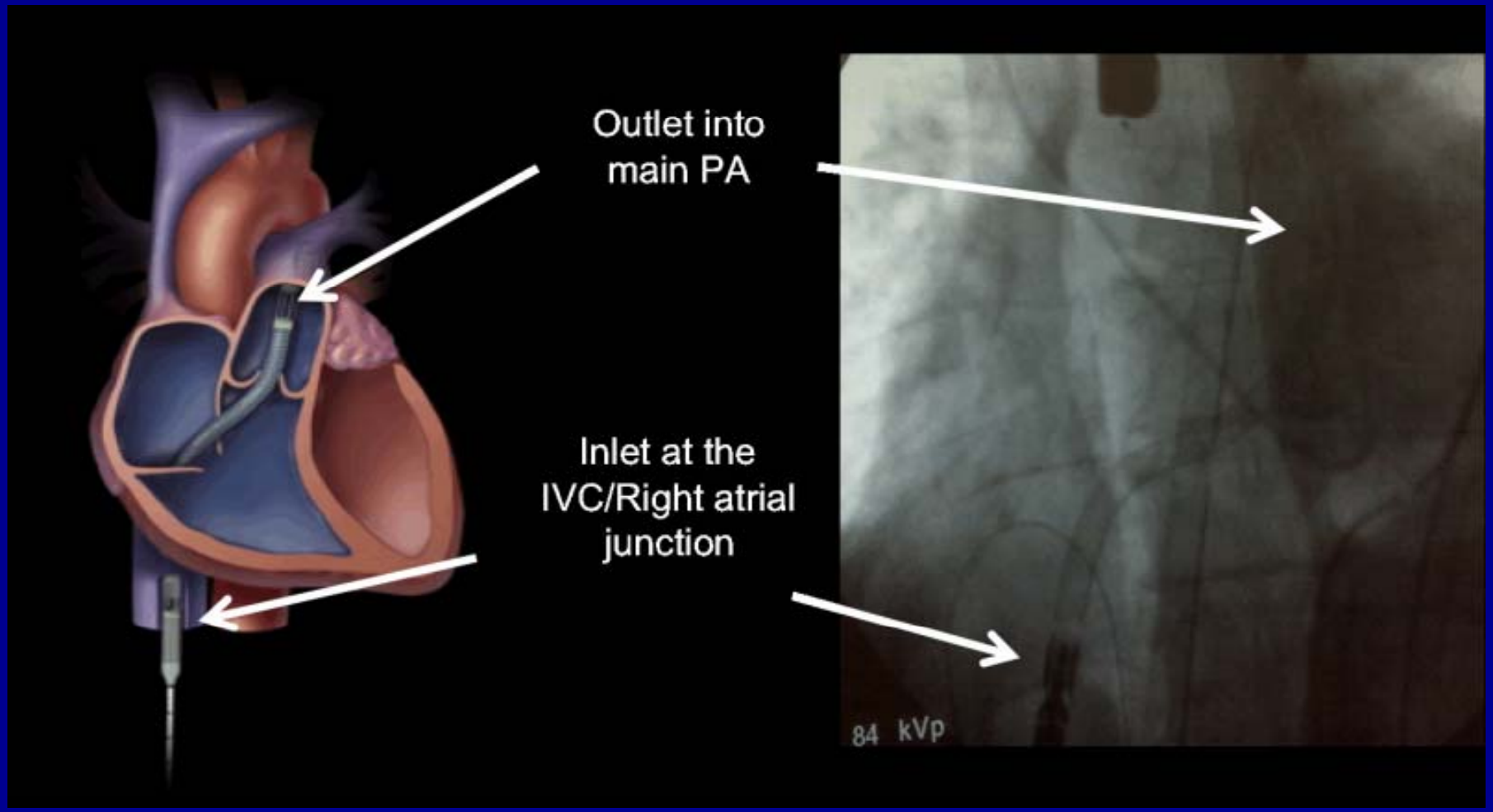
D) Protek Duo

Impella RP

- Catheter-mounted microaxial rotary pump inserted via the femoral vein, into the RA, across the tricuspid and pulmonic valves, and into the PA
- Inlet sits in the IVC and the outlet is in the PA
- Approved for acute right heart failure/decompensation following LVAD implantation, MI, heart transplant, or cardiac surgery



Impella RP



http://www.complexcardiac.com/acute-mechanical-cardiac-supportrvad-abiomed-impella-rp-rd.html

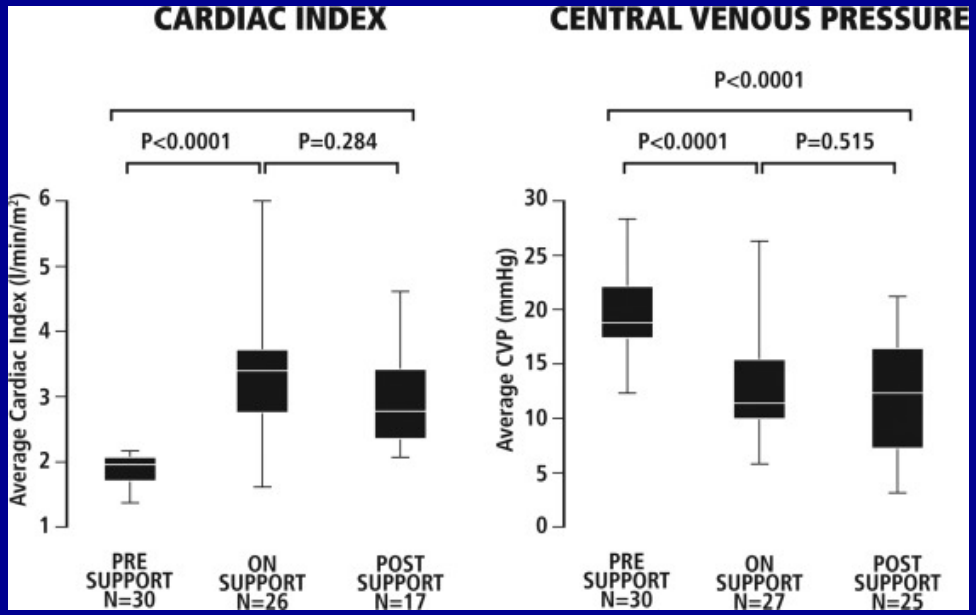
PROTECT RIGHT Study

- 30 patients with RVF refractory to medical treatment received Impella RP
- Cohort A: 18 patients with RVF after LVAD
- Cohort B: 12 patients with RVF after cardiotomy or myocardial infarction
- Primary end point: survival to 30 days or hospital discharge
- Secondary end points: safety and efficacy

Anderson MB, et al. *J Heart Lung Transplant*. 2015;34:1549-60.

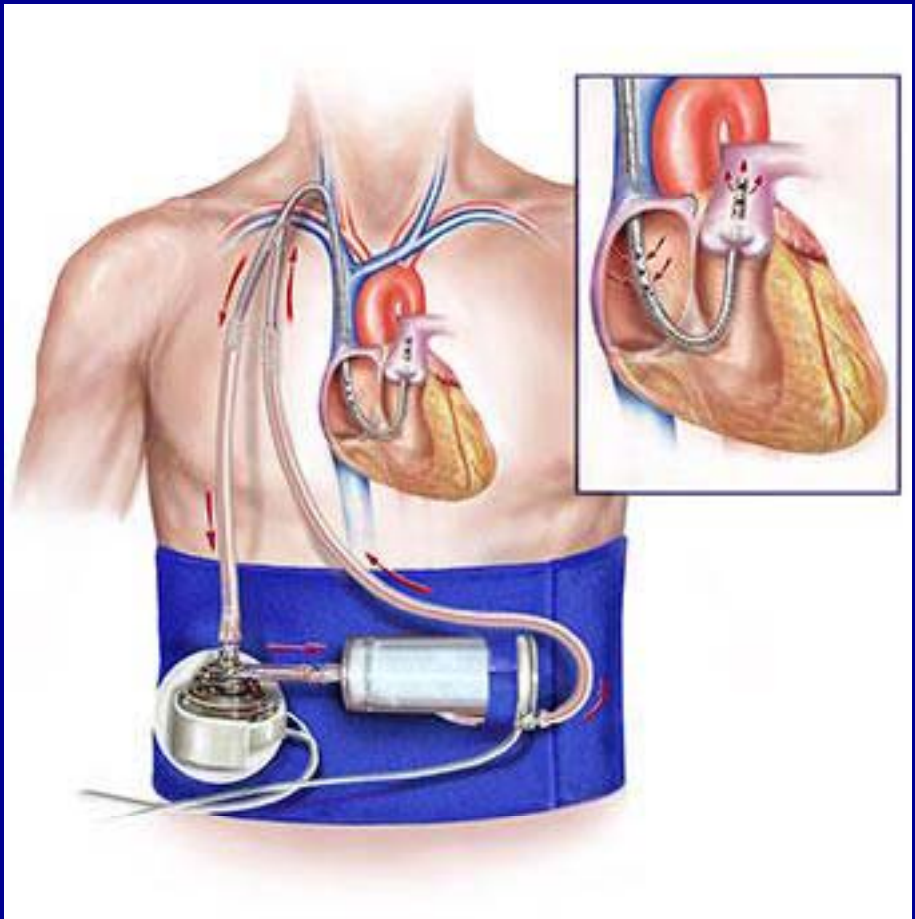
PROTECT RIGHT Study

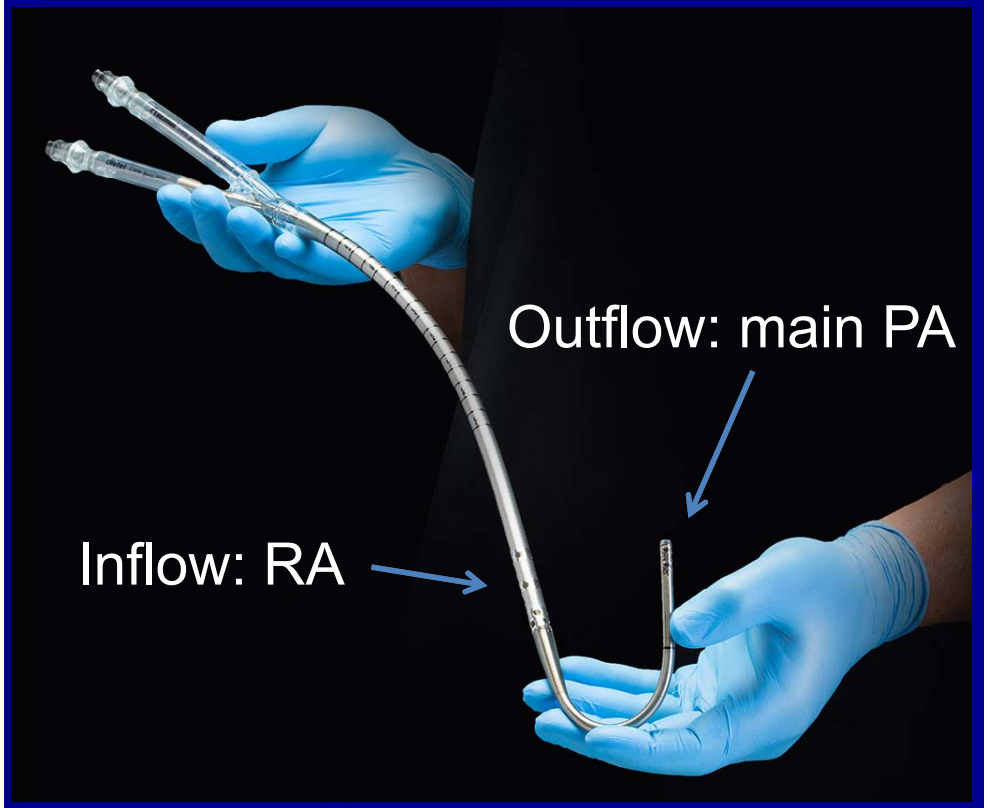
	All patients	Cohort A	Cohort B	
	(N = 30)	(n = 18)	(n = 12)	
Event	% (No.)	% (No.)	% (No.)	p-value
Alive at				
30 Days	73.3 (22)	83.3 (15)	58.3 (7)	0.129
Discharge	70.0 (21)	77.8 (14)	58.3 (7)	0.255
180 days	70.0 (21)	77.8 (14)	58.3 (7)	0.255



Anderson MB, et al. *J Heart Lung Transplant*. 2015;34:1549-60.

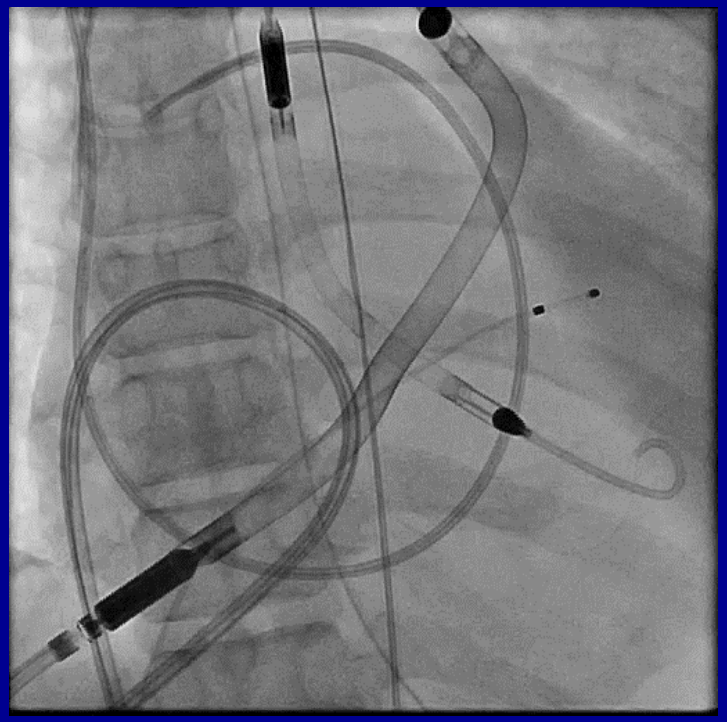
ProtekDuo

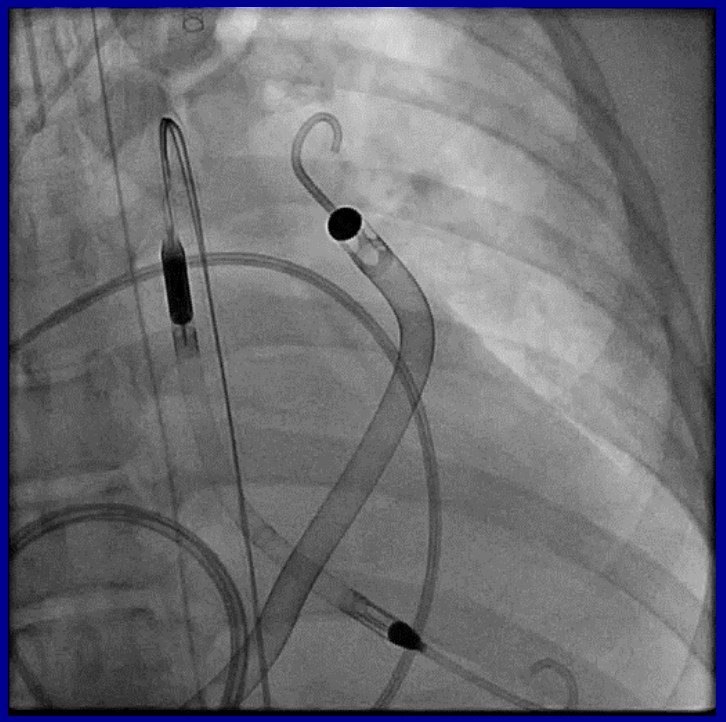




- Dual lumen cannula (29F or 31F) inserted percutaneously via IJ venous access connected to a para-corporeal pump
- Oxygenator can also be introduced into the circuit if needed

Bipella



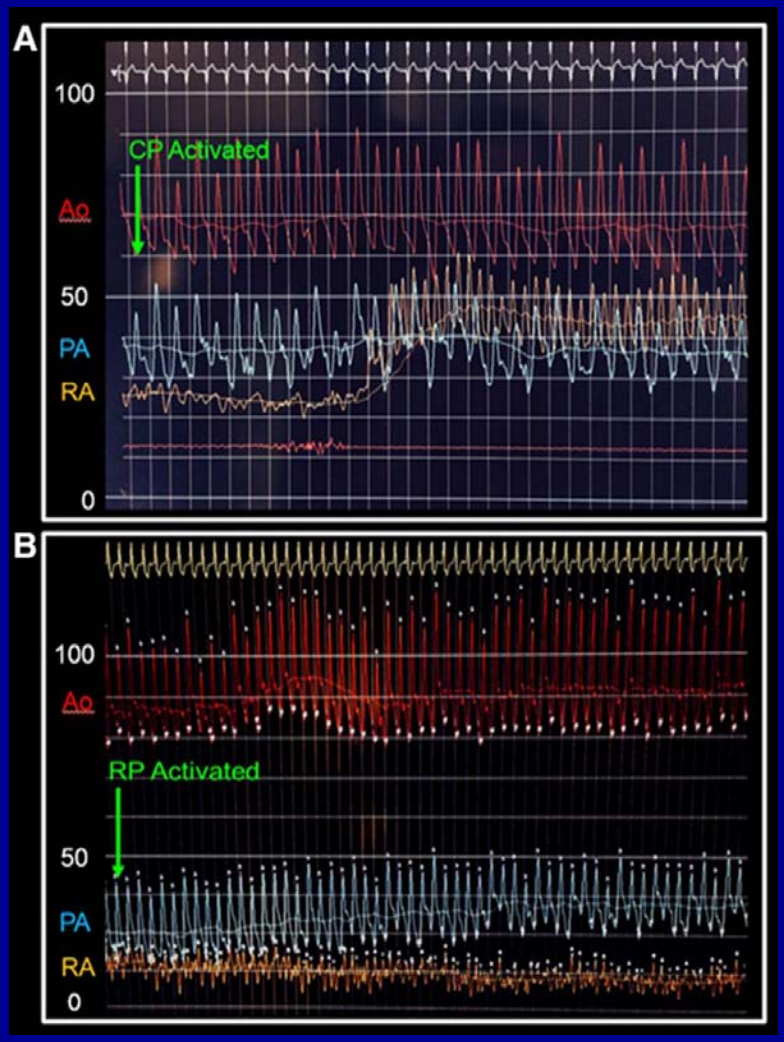


Combined use of Impella CP/5.0 with Impella RP for biventricular support

BiPella Support

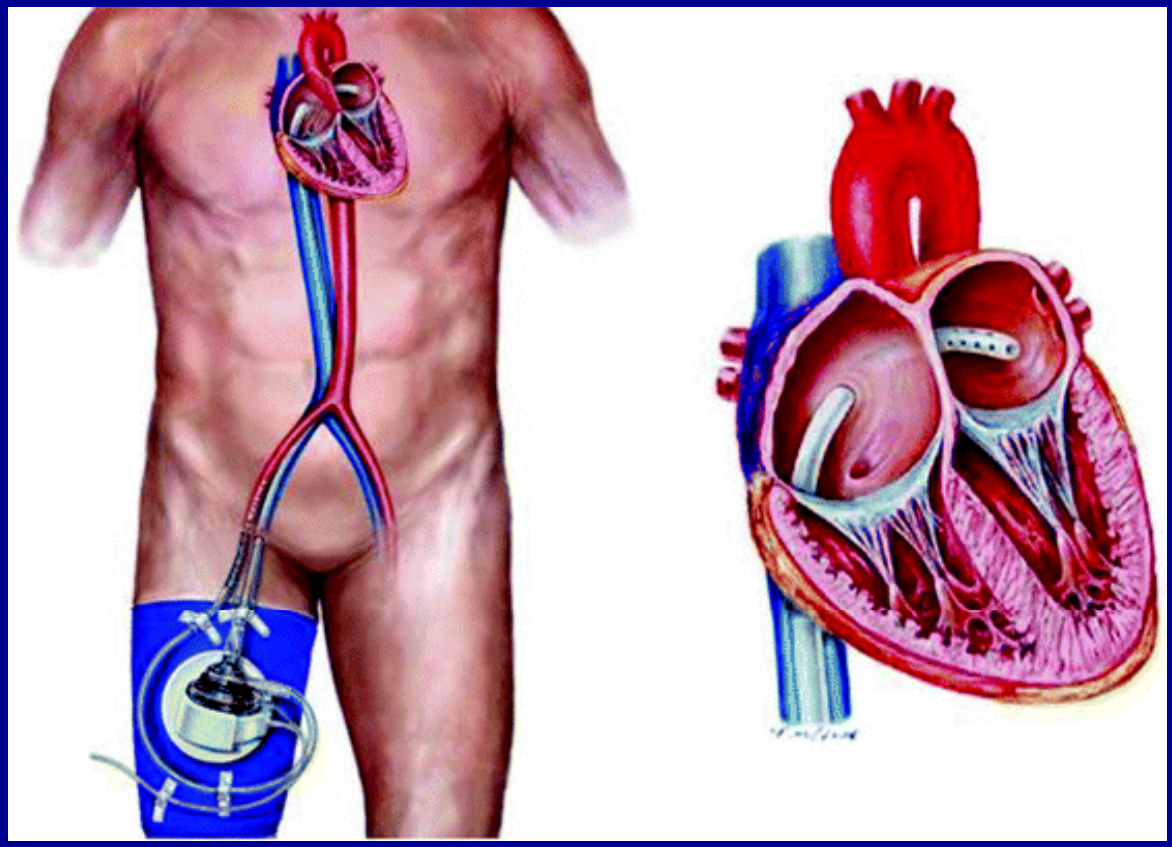
Impella CP activated
- RA pressure rising
- PA pressure slowly declining

Impella RP activated in addition to Impella CP
- RA pressure decreasing
- PA pressure increasing



Nima Aghili et al. *Circ Cardiovasc Interv*. 2016;9:e003636

TandemHeart



- 21F venous cannula inserted percutaneously into the left atrium by transseptal puncture
- Blood returned by a para-corporeal pump to the iliac artery through an arterial cannula
- Circuit can be connected to an oxygenator if needed

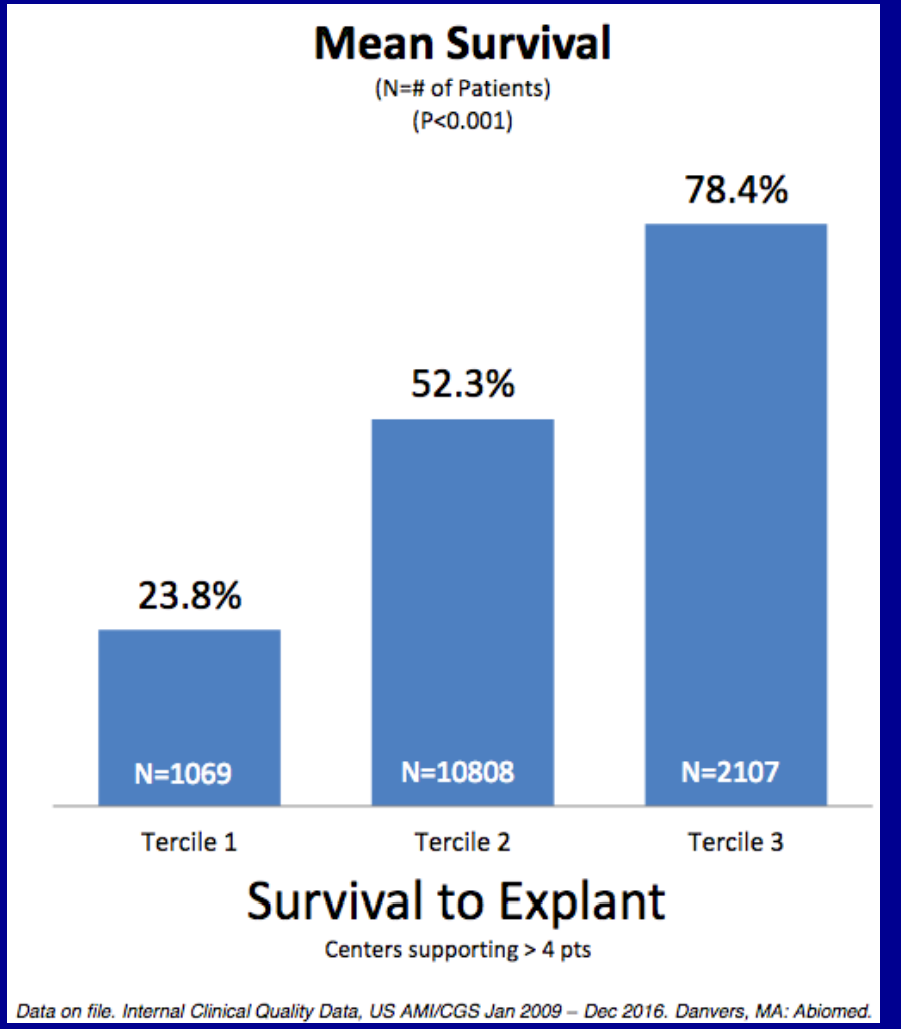
Does pulmonary artery catheter monitor help in the management of cardiogenic shock?

A) Yes

B) No

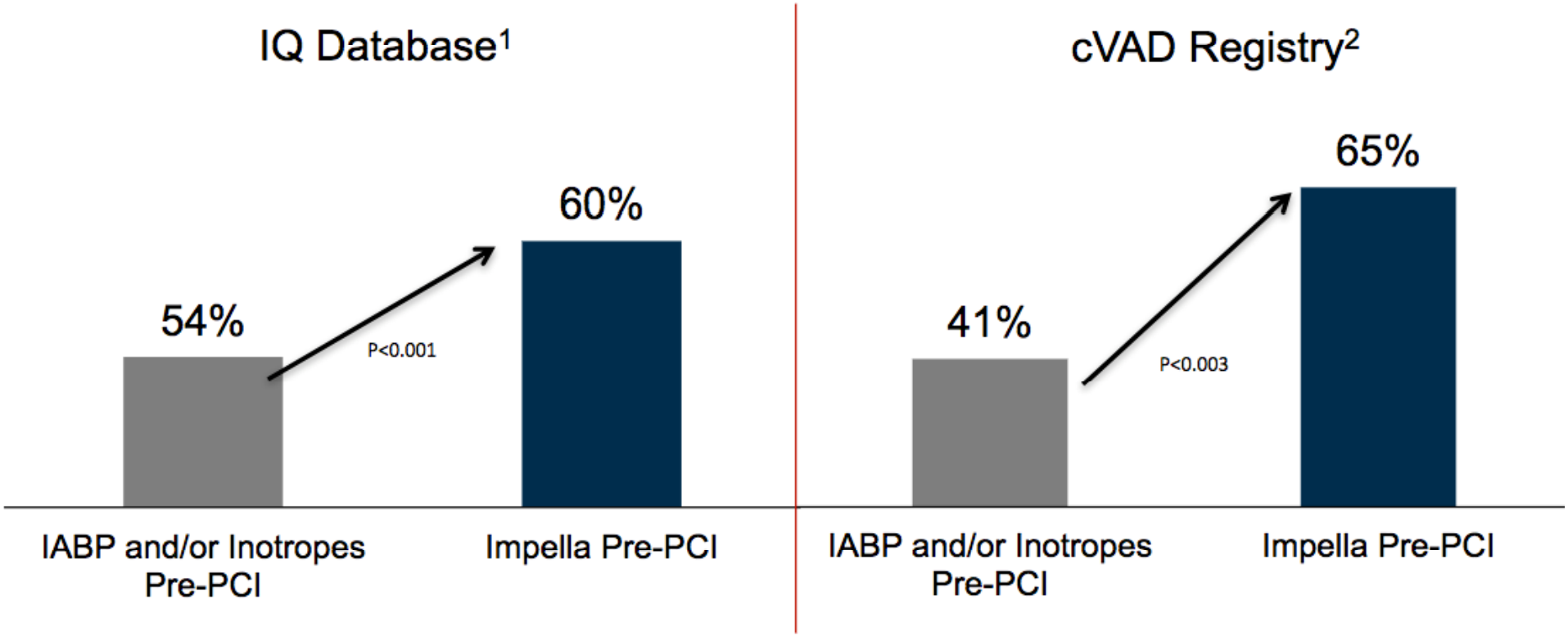
Practices Associated with Improved Survival in AMI and CS

- 15,259 patients with AMI and CS treated with Impella CP between 2009-2016
  - Impella PrePCI
  - Use of Hemodynamic Monitoring
  - Use of Impella CP



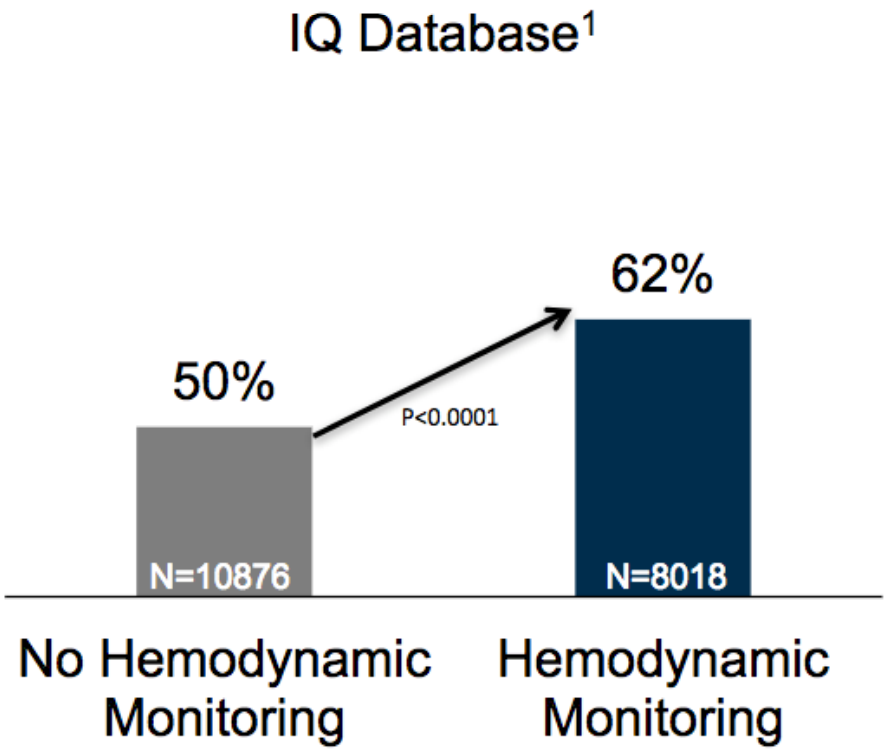
O'Neill WW, et al. *Am Heart J*. 2018;202:33-38.

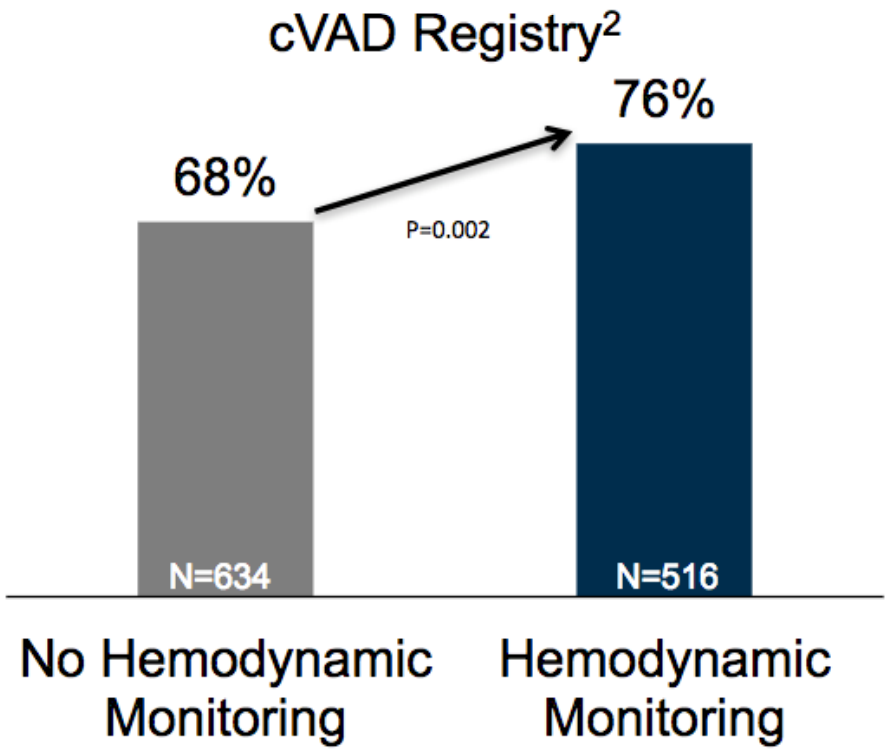
Impella Pre-PCI associated with Improved Survival in AMI/CGS



1. *Abiomed Impella Quality (IQ) Database, US AMI/CGS Apr 2009– Oct 2017. Survival to Explant. Danvers, MA: Abiomed.*
2. *O'Neill et al., J Int Cardiol 2014;27:1-11. Survival to hospital discharge*

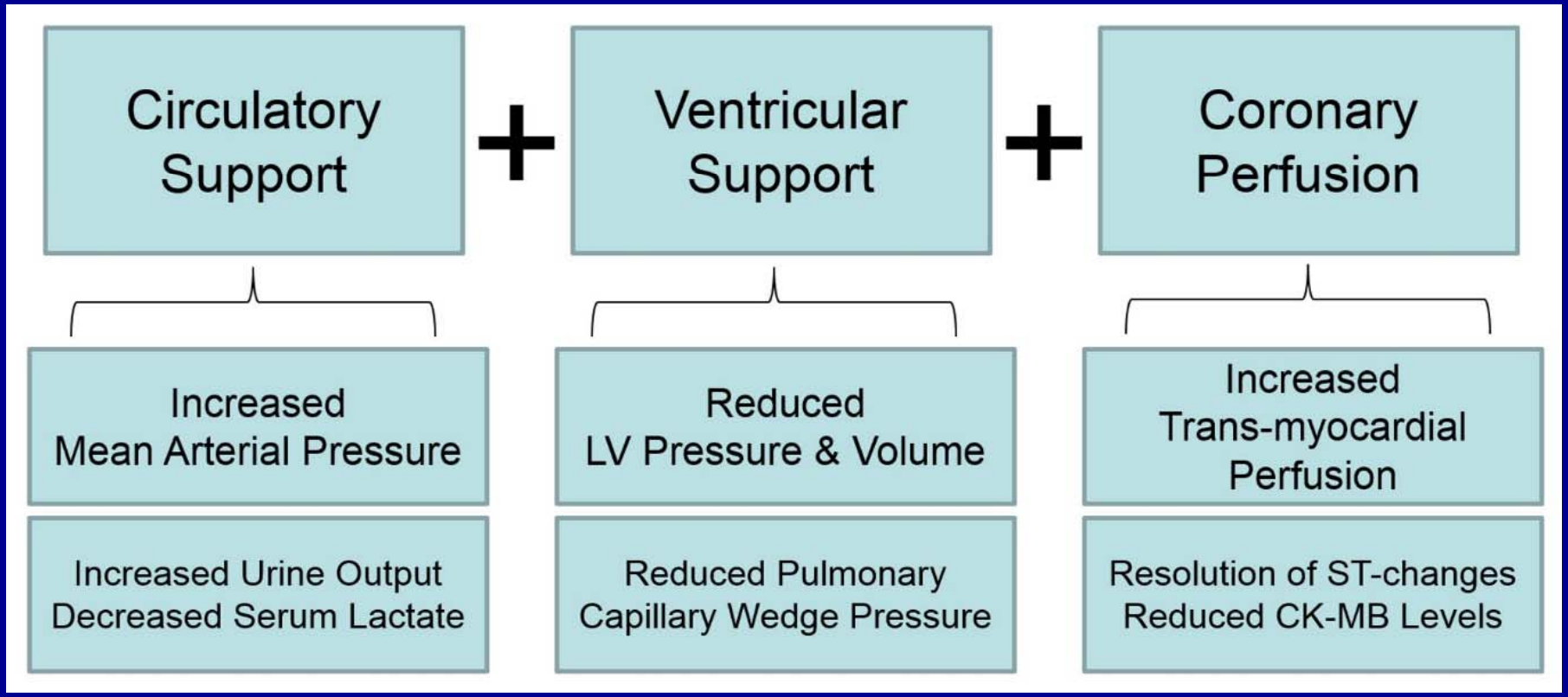
Hemodynamic Monitoring associated with Improved Survival in AMI/CGS





1. *Abiomed Impella Quality (IQ) Database, US AMI/CGS Apr 2009– Oct 2017. Survival to Explant. Danvers, MA: Abiomed.*
2. *cVAD survival to explant 2009-2016*

Solving the Hemodynamic Support Equation in CS



Kapur NK, Esposito M. *J Am Coll Cardiol* 2016.

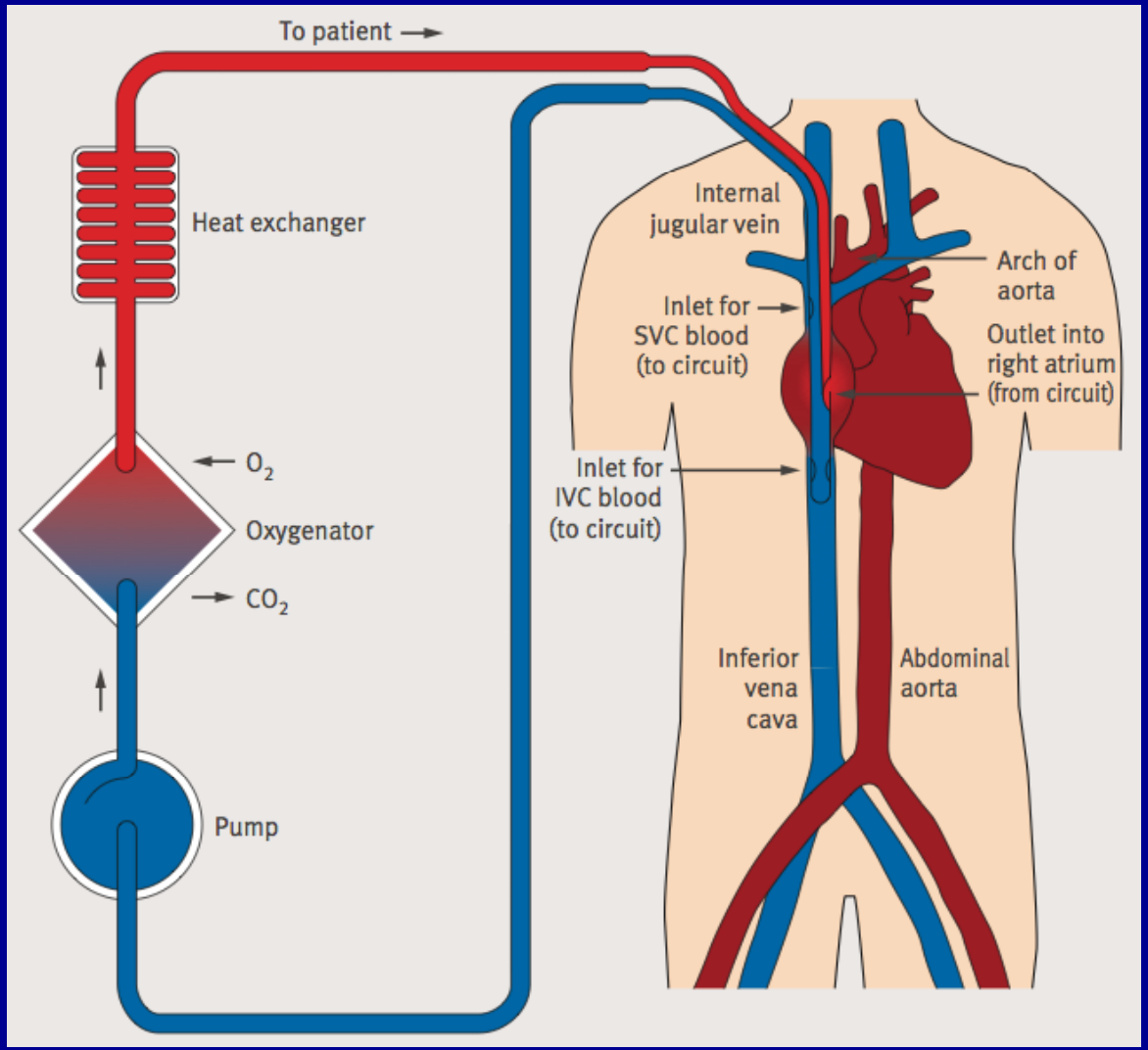
Extracorporeal Membrane Oxygenation (ECMO)

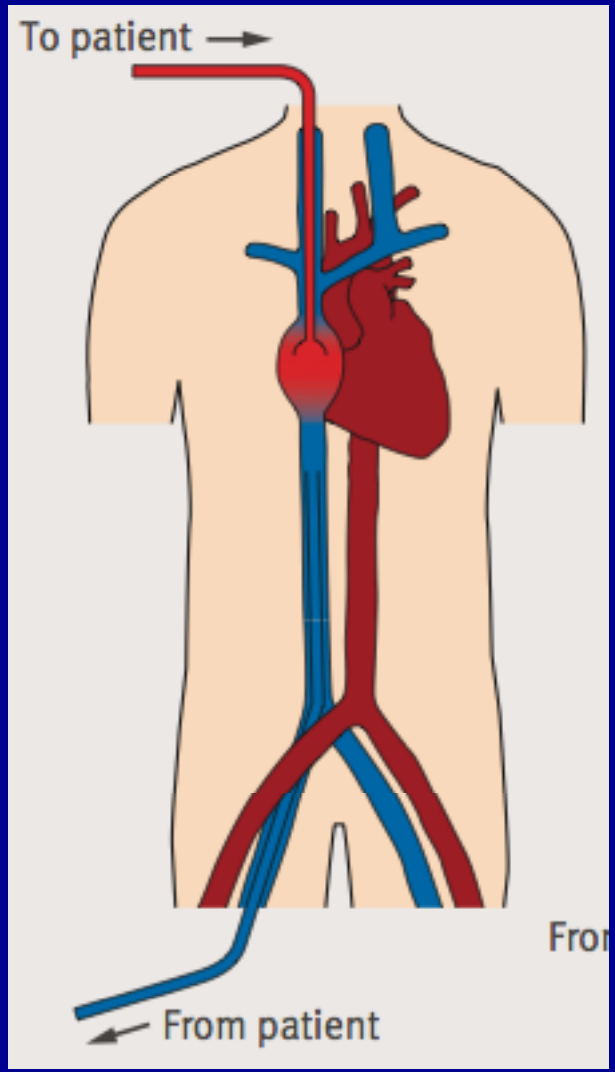
- Variation of cardiopulmonary bypass
- Circuit of a centrifugal blood pump, membrane oxygenator and heparin-coated tubing
- Can provide ≥ 4.5 L/min of support

ECMO

- Two possible configurations
  - Veno-venous for pulmonary support
  - Veno-arterial for cardiac and pulmonary support
- Can be placed at the bedside
- Indications
  - Hypoxemic respiratory failure
  - Refractory cardiogenic shock
  - Failure to wean from cardiopulmonary bypass
  - Cardiac arrest (adjunct to CPR)

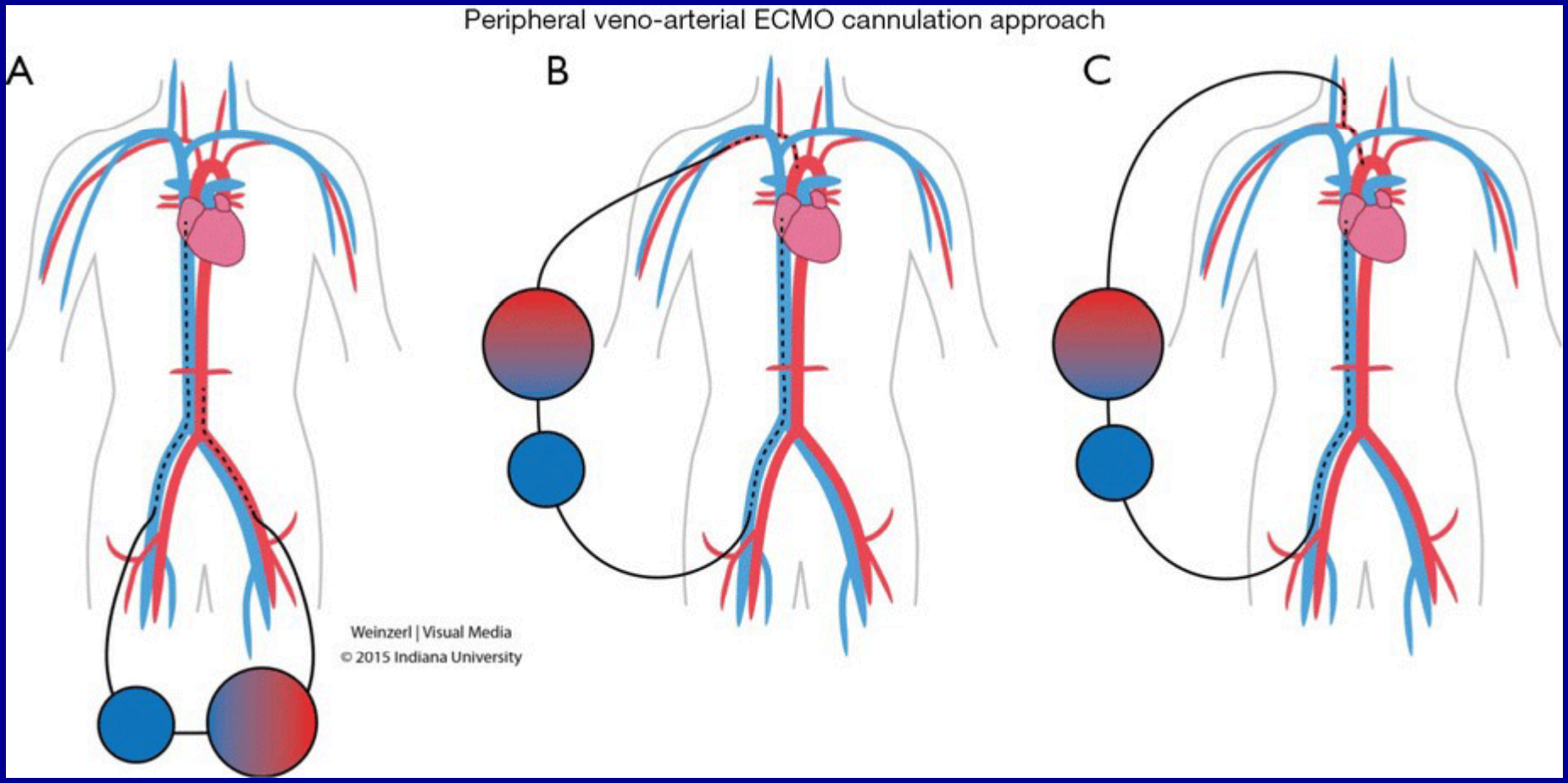
VV ECMO Configurations





Gaffney AM, et al. *BMJ*.2010;341:c5317.

VA ECMO Configurations

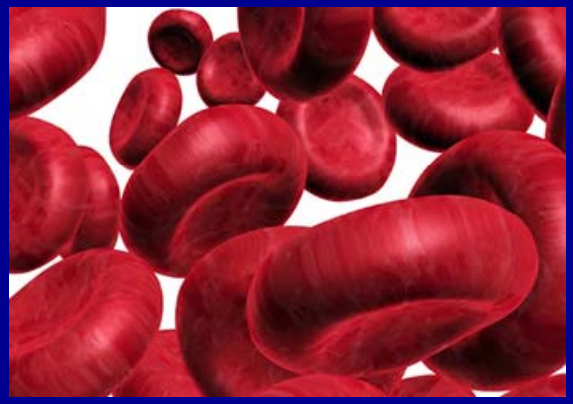


Makdisi G, Wang I. *J Thorac Dis*. 2015:7.

Relative Contraindications to ECMO

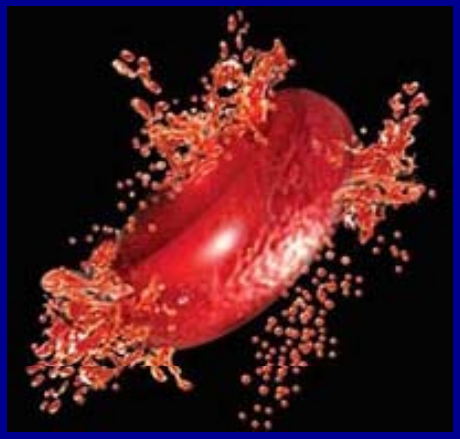
- Contraindication to anticoagulation
- Advanced age
- Morbid obesity
- Poor neurologic prognosis
- Terminal malignancy
- Prolonged cardiac arrest
- Irreversible cardiac failure
- Not candidate for durable MCS or OHT

ECMO Complications



Bleeding

Infection



Hemolysis

Limb Ischemia

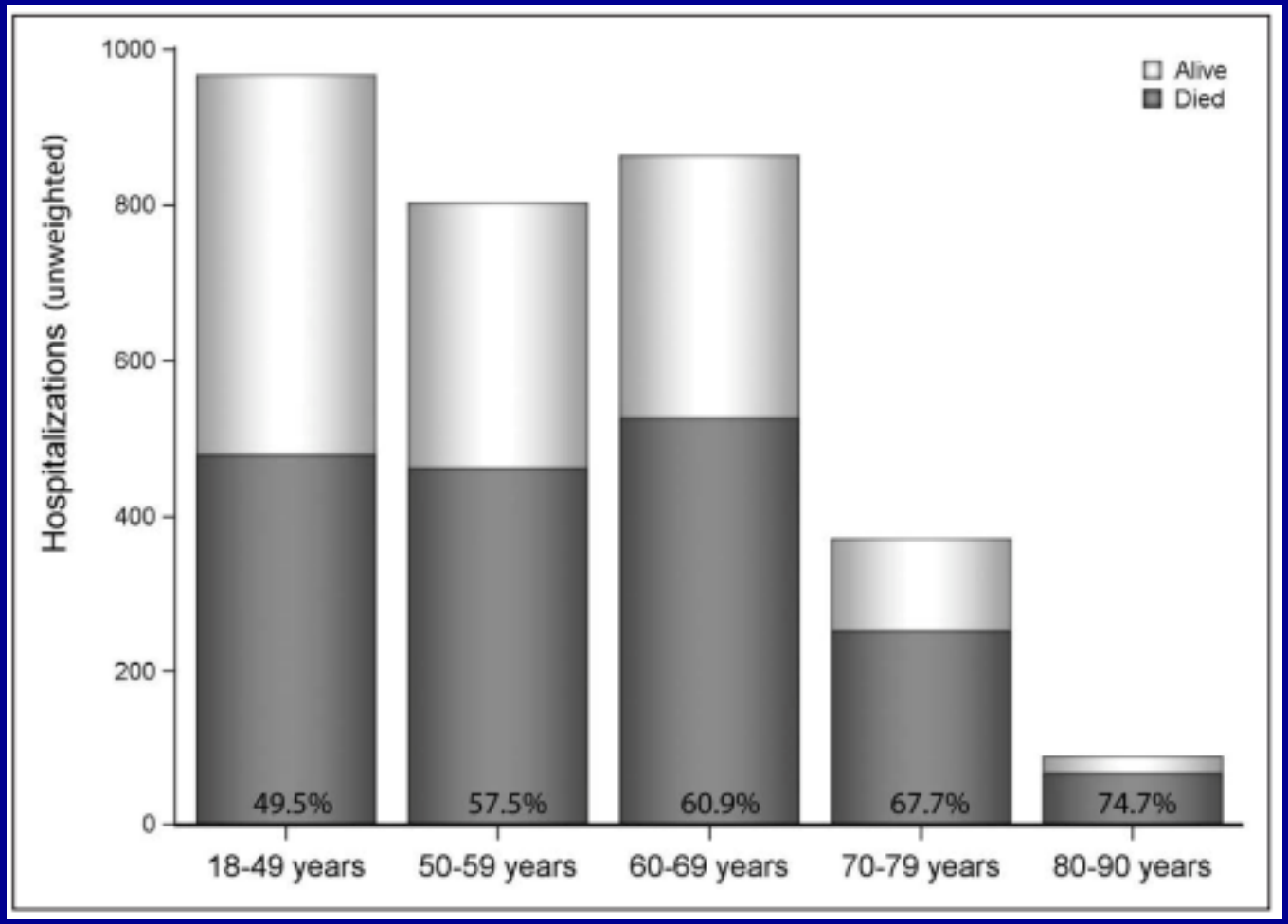
Stroke

ECMO Outcomes

- Retrospective review of 131 ECMO pts 1995-2005 at single center
  - ECMO used for CS of various etiologies
  - Mean support 2.9 days
  - Mean f/u 39 months
  - 50% long-term survivors
  - 46 pts weaned, 5 pts transplanted, 28 pts implanted with durable VAD

Hoefer D, et al. *Ann Thorac Surg*.2006;82:28.

ECMO Outcomes by Age



National Inpatient Sample 2004-2016

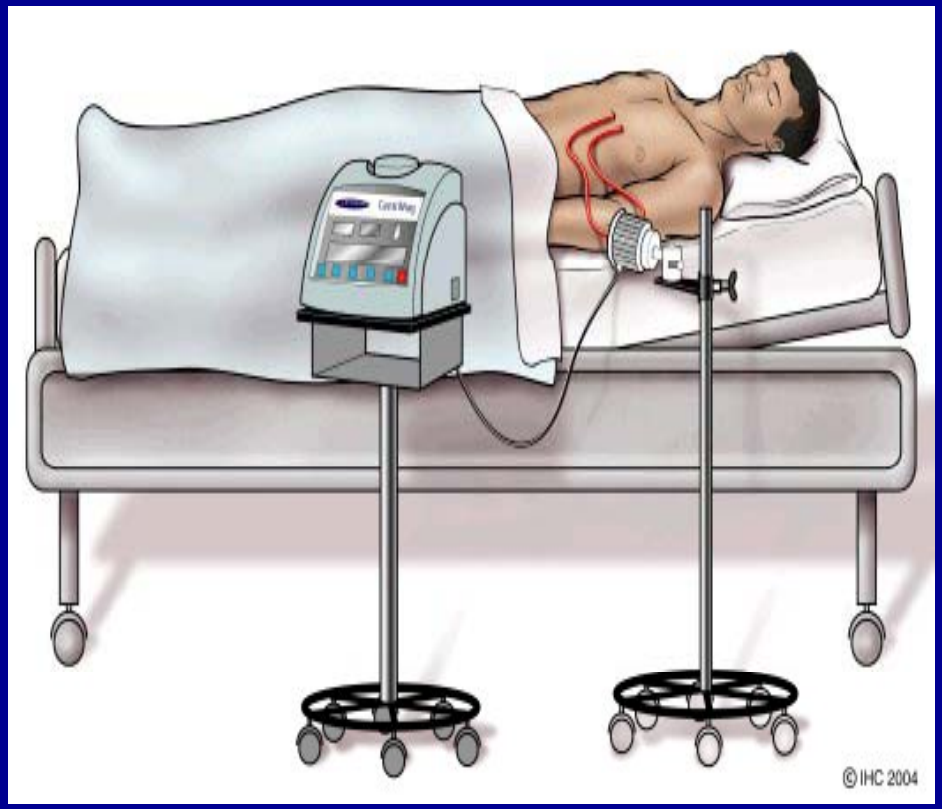
Chung M, et al. *Crit Care Med.* 2019; 47:e214.

Surgically Implanted MCS

- Short-term
  - Centrimag : external centrifugal blood pump with intrathoracic canulation
  - Can be used as LVAD, RVAD or BiVAD
- Long-term
  - Abbott Heartmate II: continuous flow LVAD
  - Abbott Heartmate 3: continuous flow LVAD
  - Heartware VAD: continuous flow LVAD
- Can provide up to 10 L/min of support

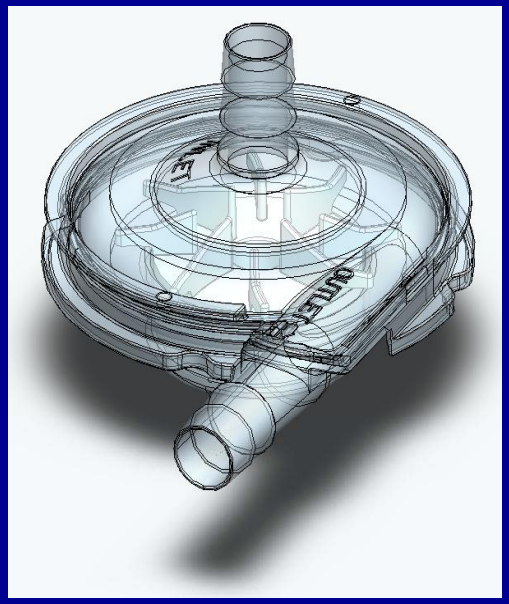
Centrimag

Temporary Continuous Flow



LVAD configuration: Inflow canula in LV, Outflow canula in Ao
RVAD configuration: Inflow canula in RA, Outflow canula in PA

Centrimag

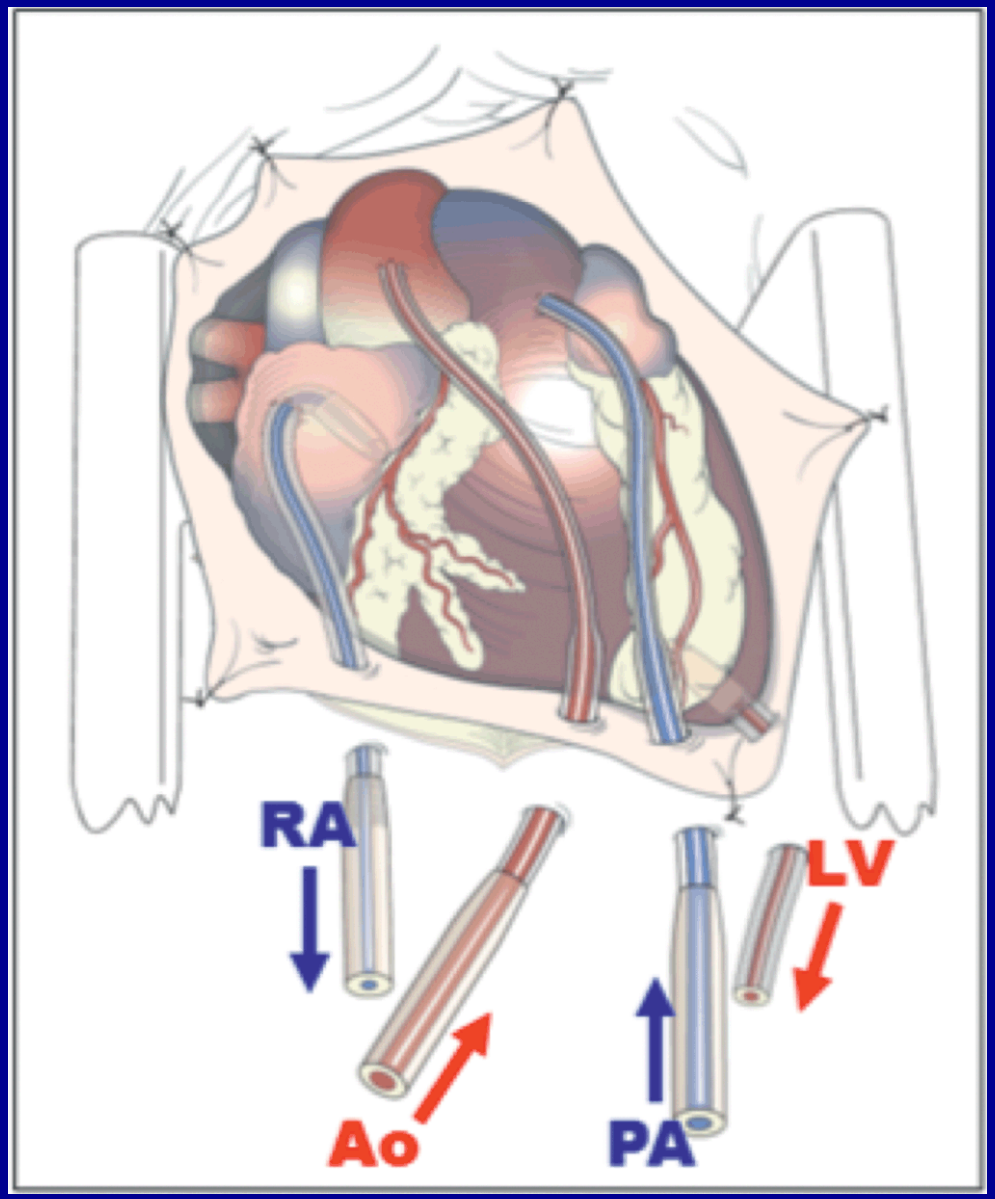


Pump

Motor

Console

BiVAD Centrimag Configuration

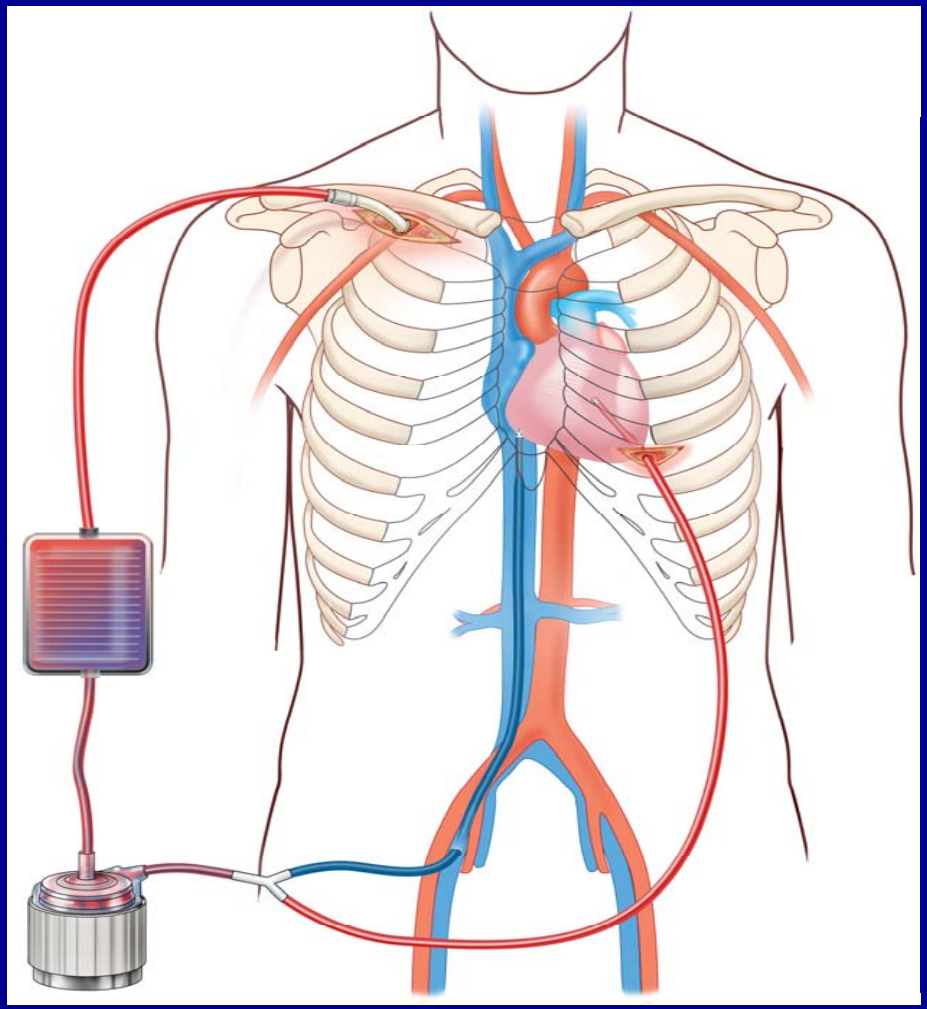


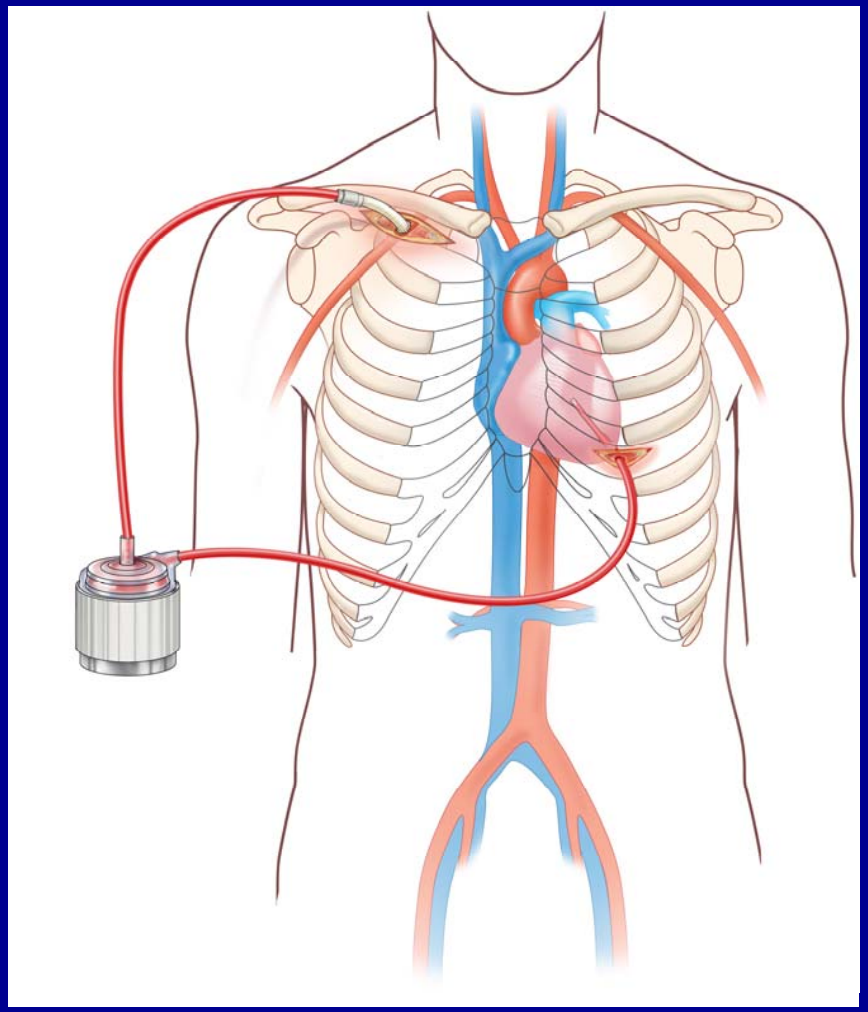
Centrimag Outcomes

- Retrospective study pts implanted with Centrimag at CUMC 1/2007-8/2009
- 27 pts with acute refractory CS
  - 17 ICM, 7 DCM, 3 other
  - Mean age 47.1 yrs
  - 85% with IABP, 70% on vasopressors, 44% on more than 1 inotrope
- 24 of 27 survived to explant
- 20 of 27 survived to discharge
- 1-year survival 68%
- 10 pts with thromboembolic complications

Worku B, et al. *J Heart Lung Transplant*.2012;31:611.

Koji VAD





Courtesty of Koji Takeda, MD, PhD

Patient Selection

- Refractory cardiogenic shock
- Use when it will improve survival instead of prolonging the dying process
- Should be withheld if no foreseeable exit strategy for removal
  - Bridge to revascularization
  - Bridge to surgically-implanted MCS
  - Bridge to transplantation
  - Bridge to decision

Tallaj JA, Cadeiras M. *J Am Coll Cardiol*.2011;57:697.

Kar B, et al. *Circulation*.2012;125:1809.

Device Selection

- Degree of mechanical support needed to adequately restore circulation and provide adequate oxygenation
- Presence of RV dysfunction
- Severity of end-organ dysfunction
- Presence of PAD
  - Femoral arterial access and sheath/cannula size

Timing of Implantation

- Vasopressor/inotropic support increases oxygen demand and myocardial ATP consumption
- Narrow window of opportunity
- Strongly consider MCS when there is continued escalation of medical therapy due to worsening hemodynamic and laboratory parameters

Multi-disciplinary Team at NYPH/Cornell

- Cardiology
  - Dr. Evelyn Horn, Dr. Irina Sobol, Dr. Maria Karas, Dr. Udhay Krishnan, Dr. Parag Goyal
  - NPs/RN: Neshama Avrahami, Rosemarie Gadioma, Cecilie Gjerde, Meghan Ward, Abby Donde
- CT Surgery
  - Dr. Arash Salemi
- Social Work, Psychiatry, Nutrition, Physical Therapy, Occupational Therapy

Take Home Points

- Importance of early recognition of refractory cardiogenic shock
- Determine patient eligibility for mechanical circulatory support
- Understand different options for hemodynamic support
- Involve multi-disciplinary team early for evaluation and intervention