Left Ventricular Failure in the Cath Lab

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Overview

- Etiology
- Treatment/Device selection

Etiology

- Acute coronary syndrome
- Acute on chronic HF
- Post-cardiotomy syndrome
- Valvular disease
- Complications of MI (VSD, MR, cardiac rupture)
- Arrhythmia
- Myocarditis
- Complex PCI/Iatrogenic

AMI

- Early Invasive Reperfusion Therapy

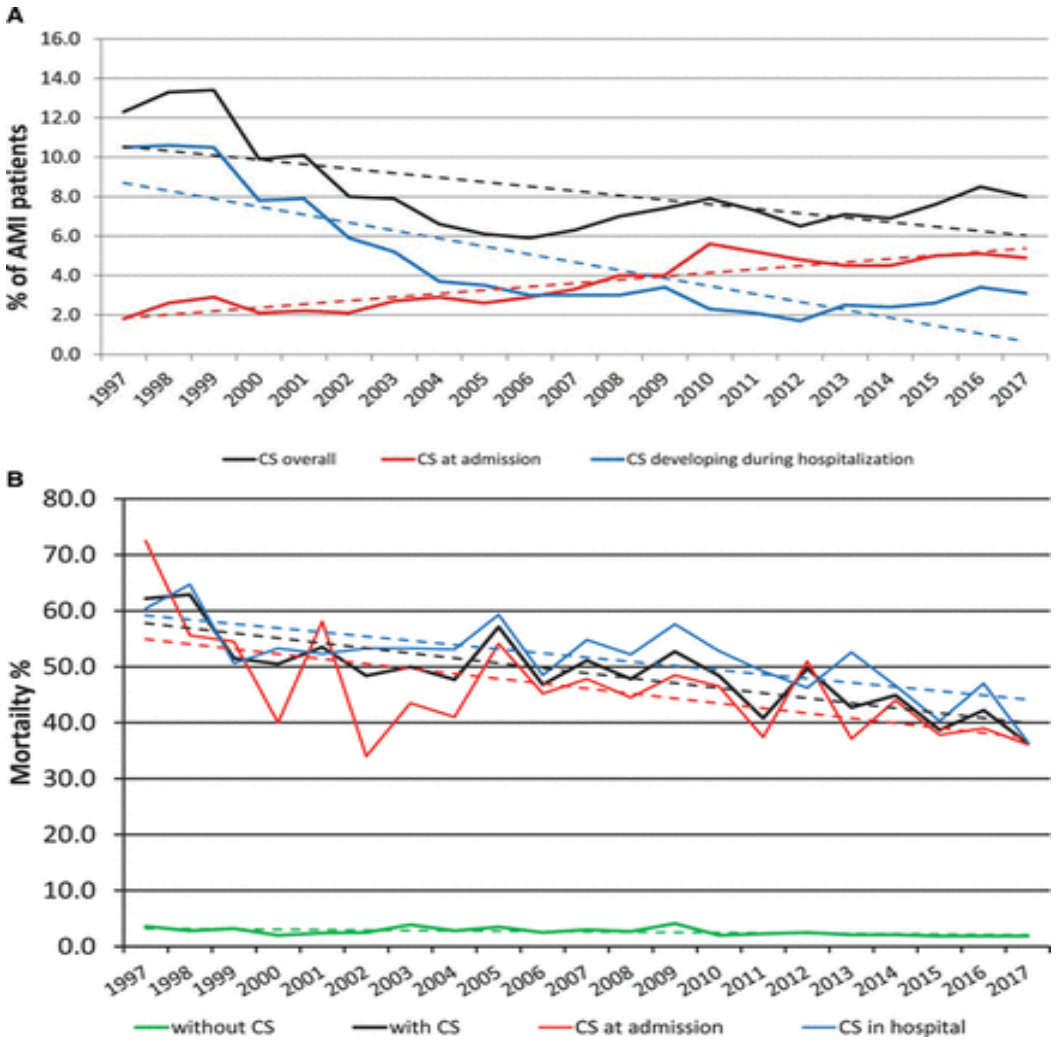
PCI: Culprit vs Multi-vessel

CABG

- SMASH
- SHOCK

CULPRIT-SHOCK

AMI: Cardiogenic Shock



Mortality 70% to 36%

Early Revascularization

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Timothy D. Henry. Circulation. Invasive Management of Acute Myocardial Infarction Complicated by Cardiogenic Shock: A Scientific Statement From the American Heart Association, Volume: 143, Issue: 15, Pages: e815-e829, DOI: (10.1161/CIR.0000000000000959)

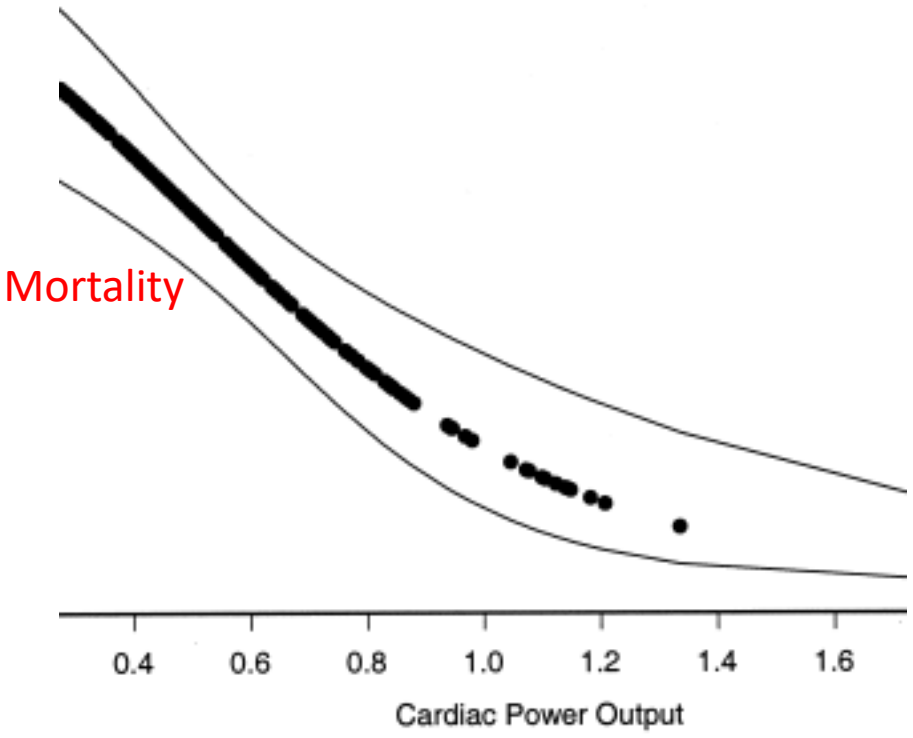
Medical Optimization

- Levophed vs Dopamine
- Vasopressin
- ?RHC
- Check LVEDP and decrease contrast use
- Low threshold to intubate(watch for RV decompensation)
- Hypoxia & metabolic acidosis

Role of Percutaneous MCS

- Maintain end organ perfusion
- Reduces intra-cardiac filling pressure
- Reduce ventricular volumes
- Reduce wall stress
- Reduce myocardial O2 consumption
- Augment coronary perfusion

CPO : MAP x CO/ 451



Cardiac power is the strongest hemodynamic correlate of mortality in cardiogenic shock: a report from the SHOCK trial registry.
Fincke R[1], Hochman JS, Lowe AM, Menon V, Slater JN, Webb JG, LeJemtel TH, Cotter G; SHOCK Investigators.

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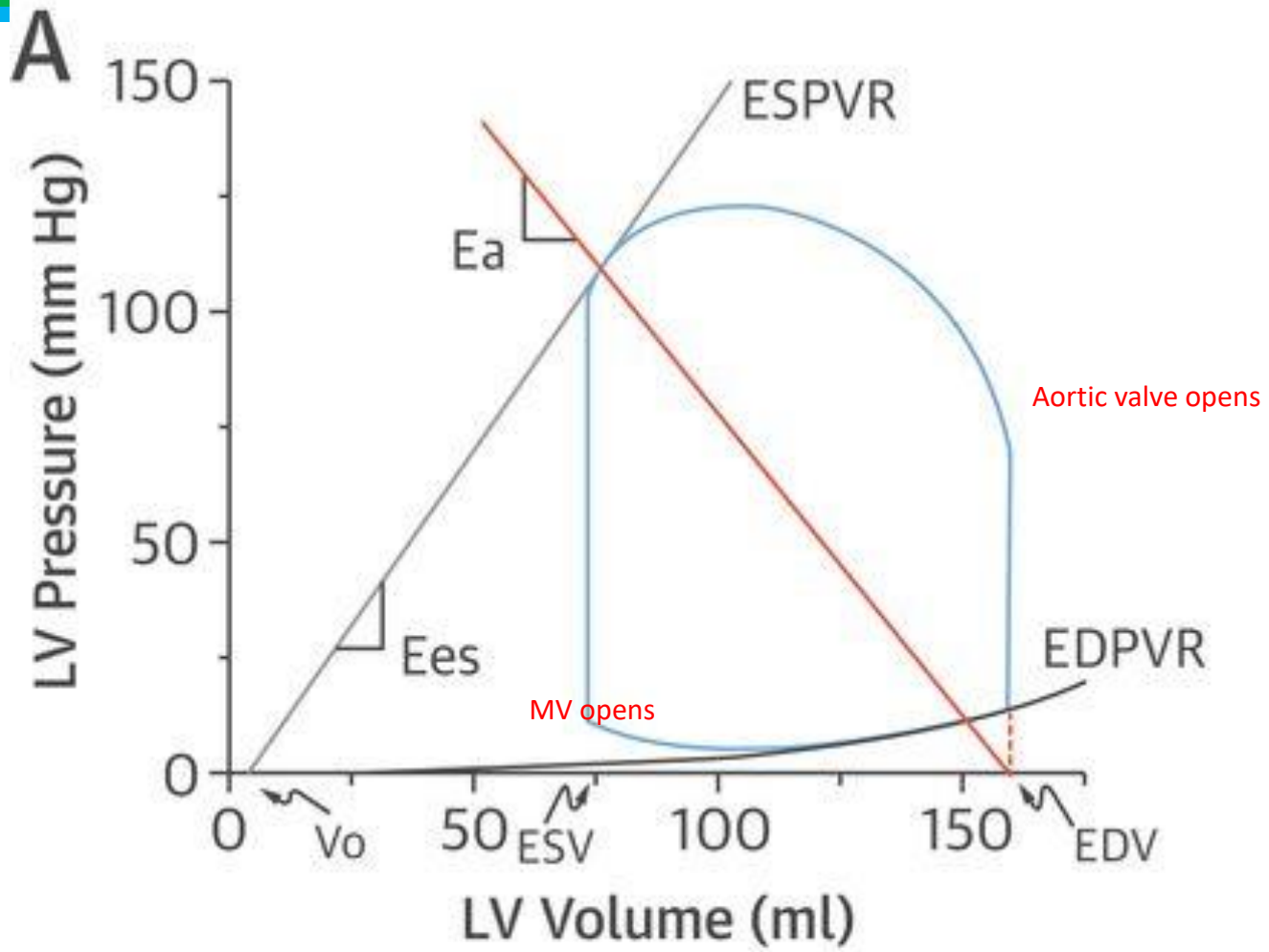


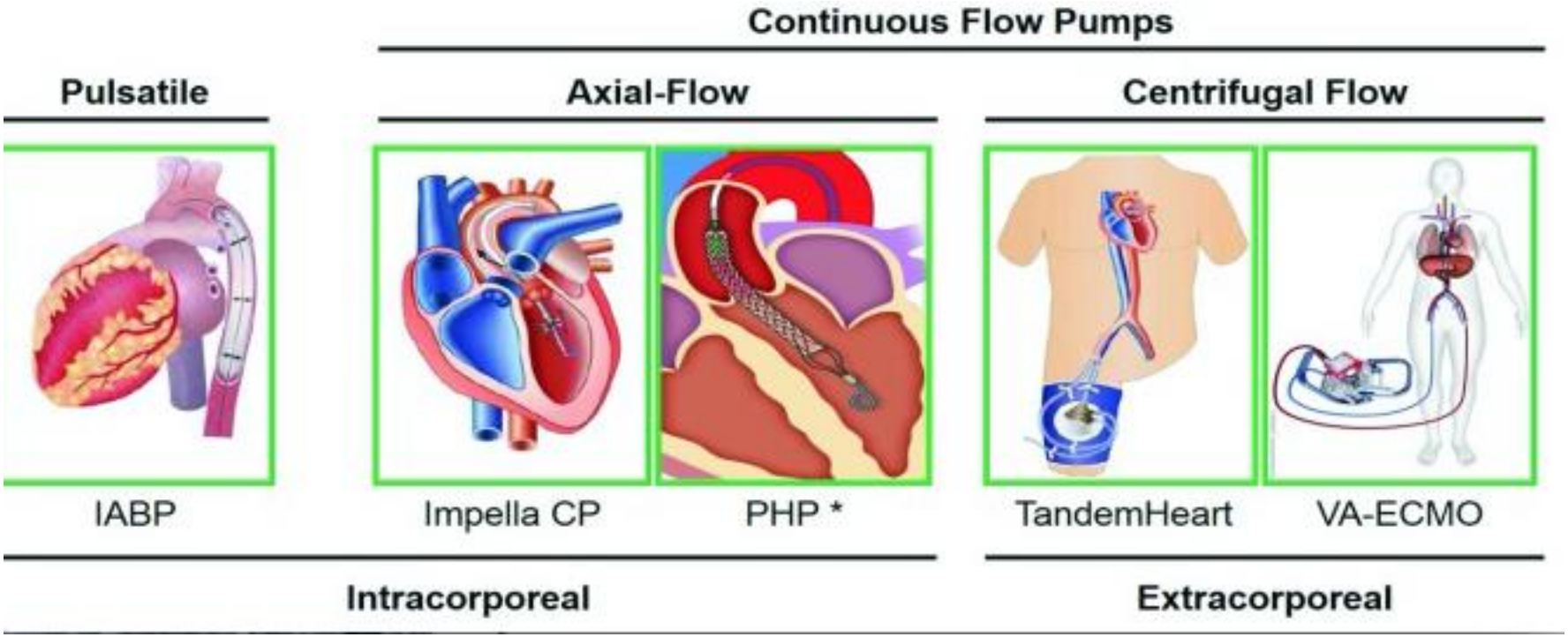
- (Normal pressure–volume loop (PVL), is bounded by the end-systolic pressure–volume relationship (ESPVR) and end-diastolic pressure–volume relationship (EDPVR). ESPVR is approximately linear with slope end-systolic elastance (Ees) and volume–axis intercept (Vo). Effective arterial elastance (Ea) is the slope of the line extending from the end-diastolic volume (EDV) point on the volume axis through the end-systolic pressure–volume point of the loop.

Burkhoff, D., G. Sayer, D. Doshi and N. Uriel (2015). "Hemodynamics of Mechanical Circulatory Support." J Am Coll Cardiol **66**(23): 2663-2674.

“Mechanical Circulatory Support”

In addition to providing optimization of hemodynamics, the devices must have a desirable risk/benefit ratio with demonstrable safety and efficacy. Additionally, they should be feasible and economical, with relative ease of insertion and availability

LEFT VENTRICULAR SUPPORT DEVICES



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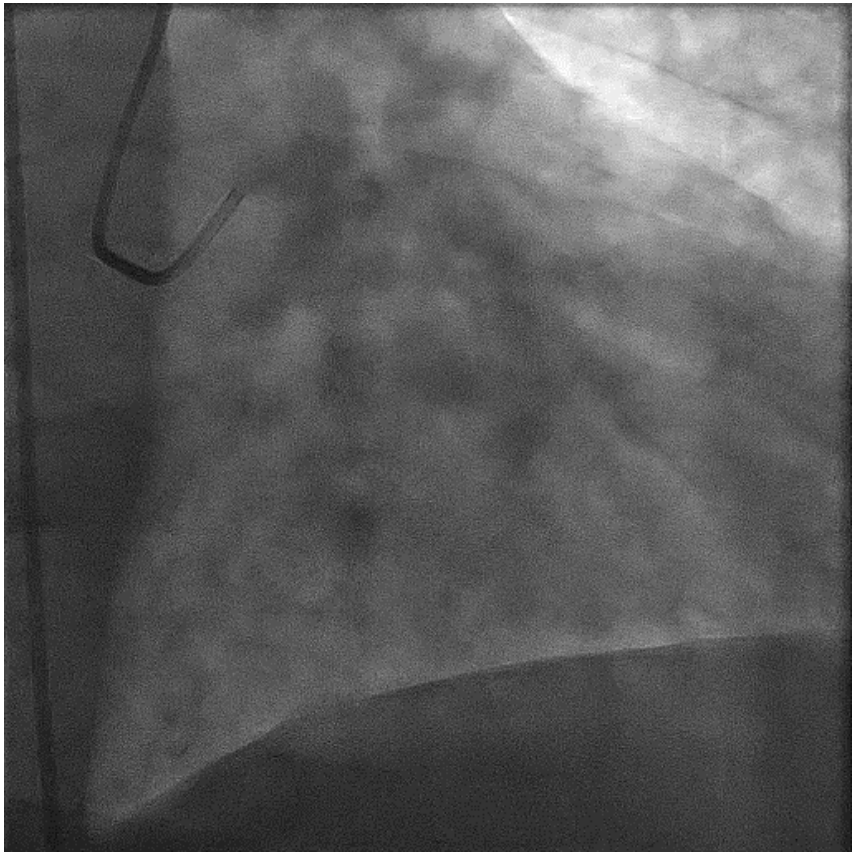

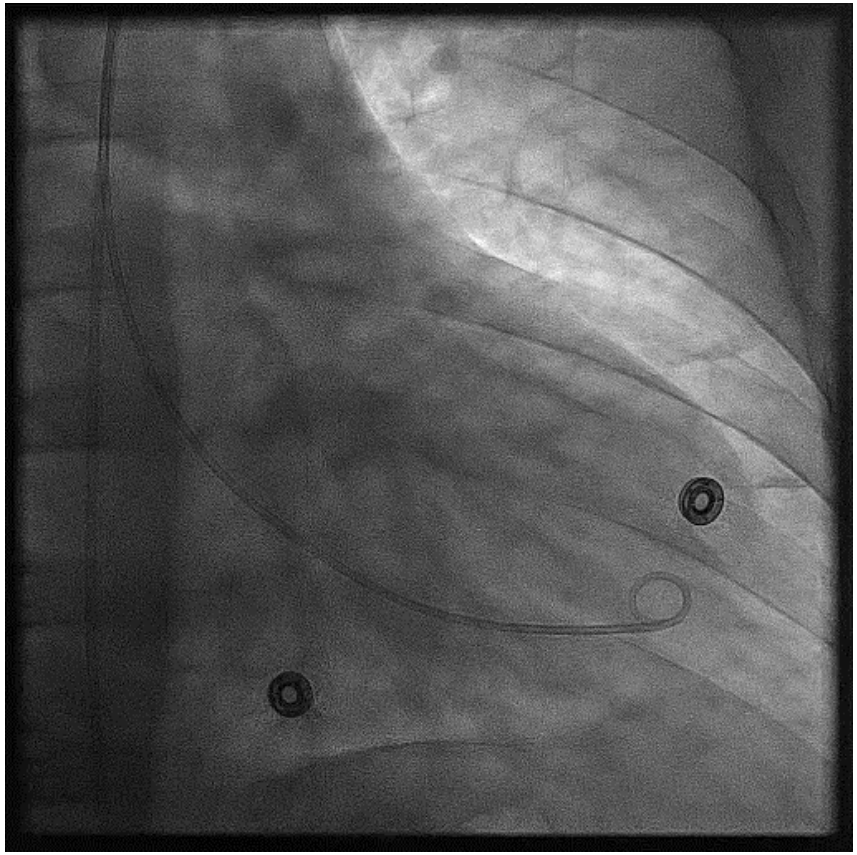

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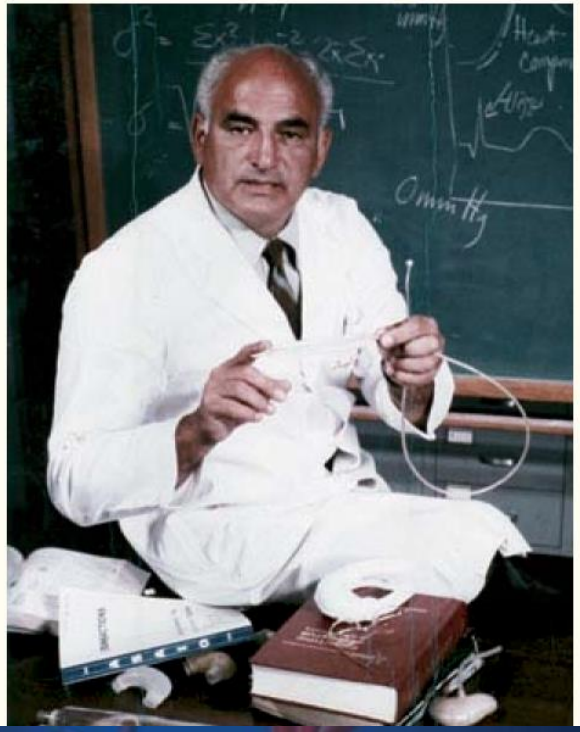
IABP

- Most commonly used
- Kantrowitz 1968
- Unloads the LV
- Decrease myocardial oxygen demand
- Increases coronary perfusion



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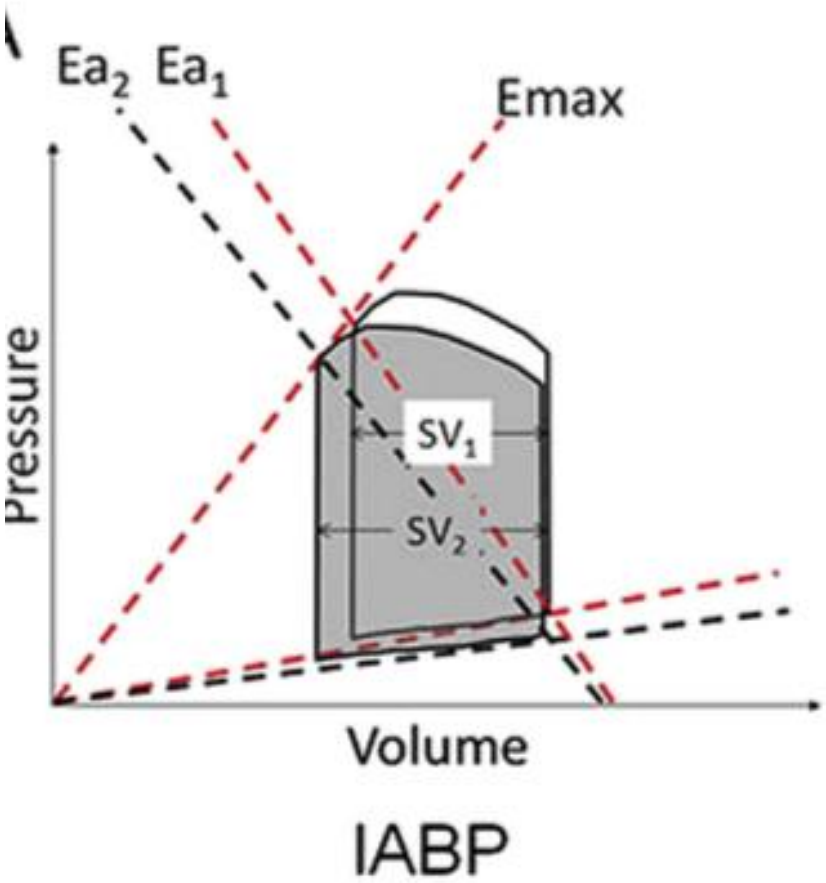
IABP

- Minimal effect on CO & CPO
- Decreases SVR and improves pulsatility
- Readily available
- Easy to use
- Can be used with VA-ECMO

- Bleeding
- Limb ischemia
- Infection
- Thrombocytopenia
- Bowel/renal ischemia



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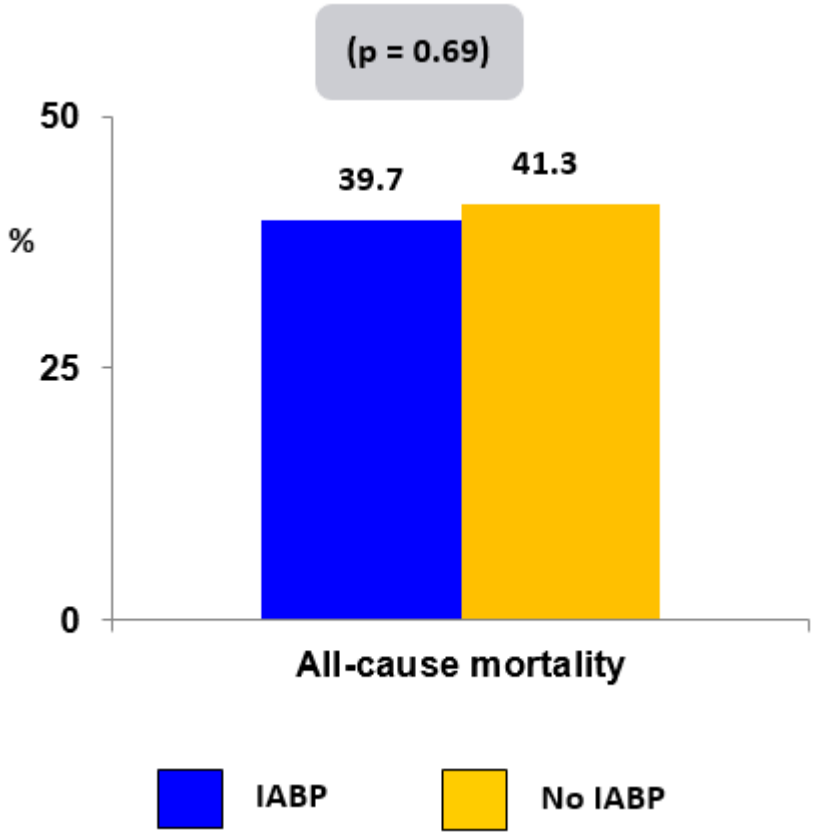
- Early observational data
- Shock trial
- CRISP-AMI trial
- NCDR registry
- BCIS-1 study (high risk PCI)
- IABP-SHOCK 2



Thiele H, et al. N Engl J Med 2012;367:1287-96

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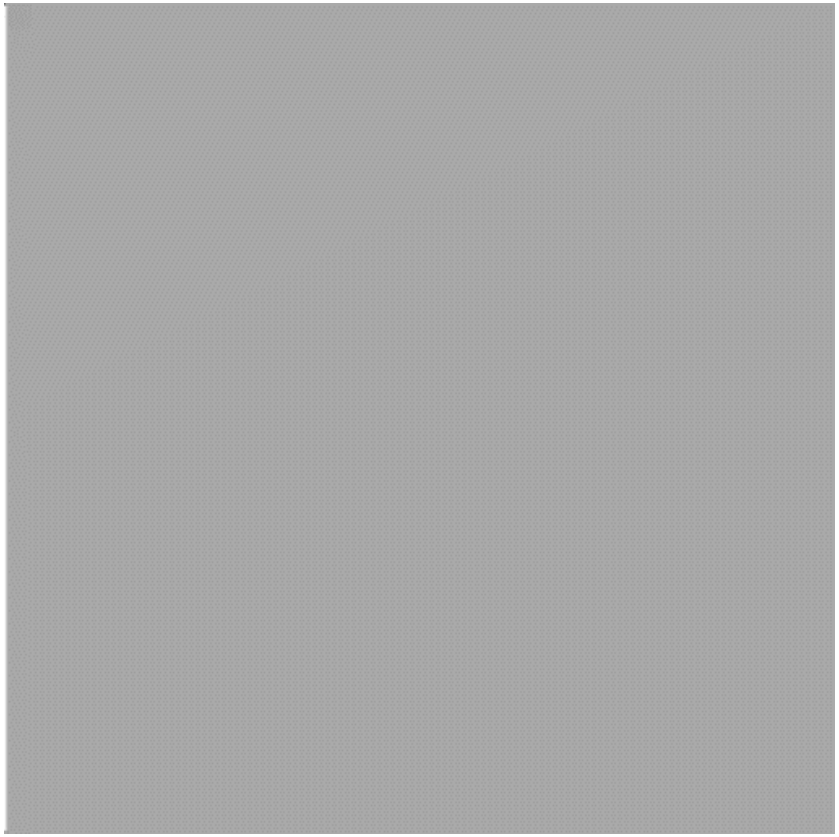
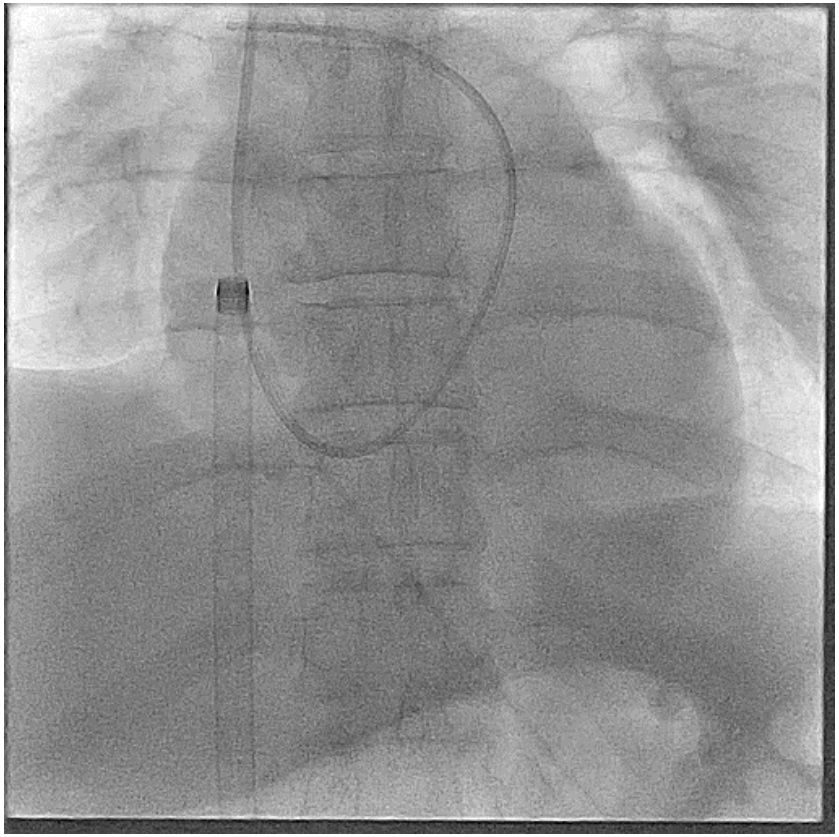
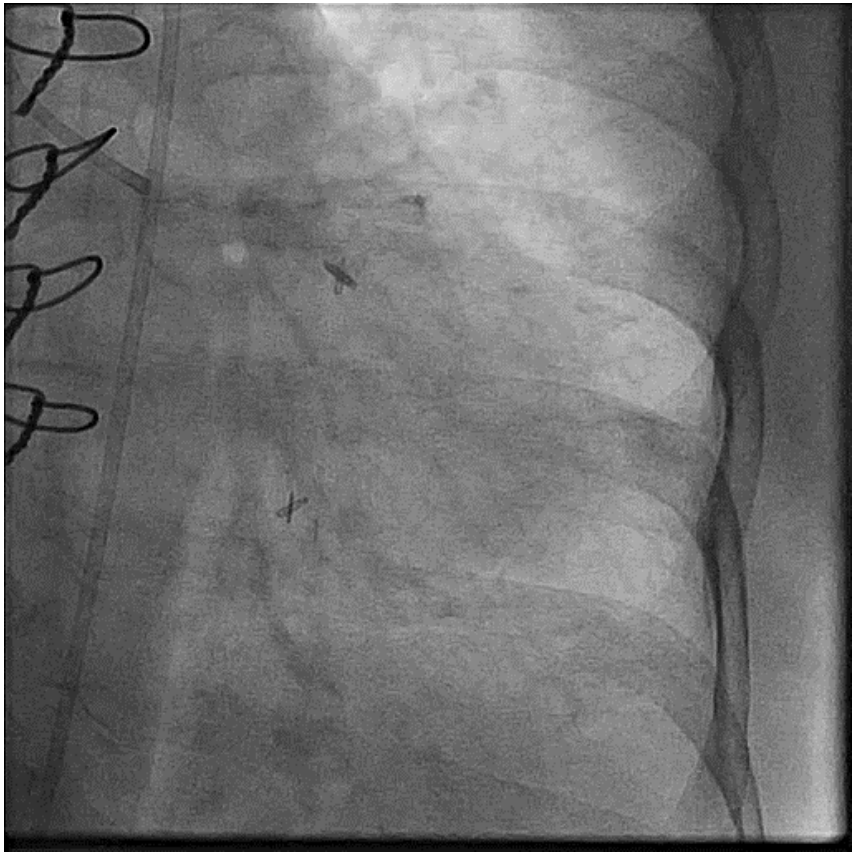
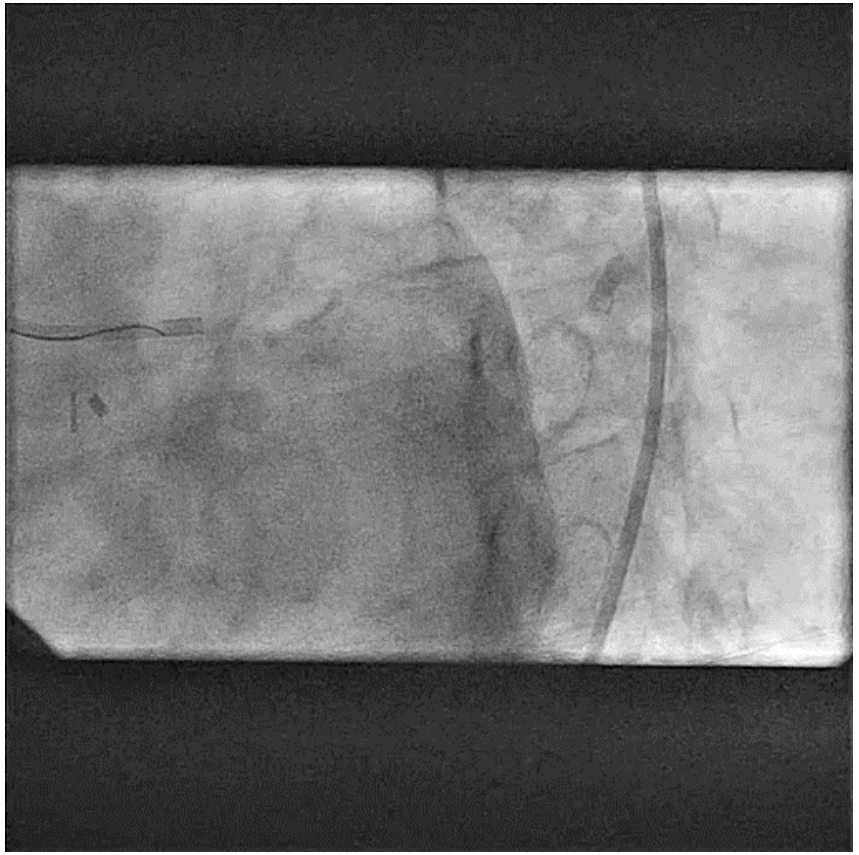
- Works well in acute MR and VSD
- Chronic heart failure





Complex PCI





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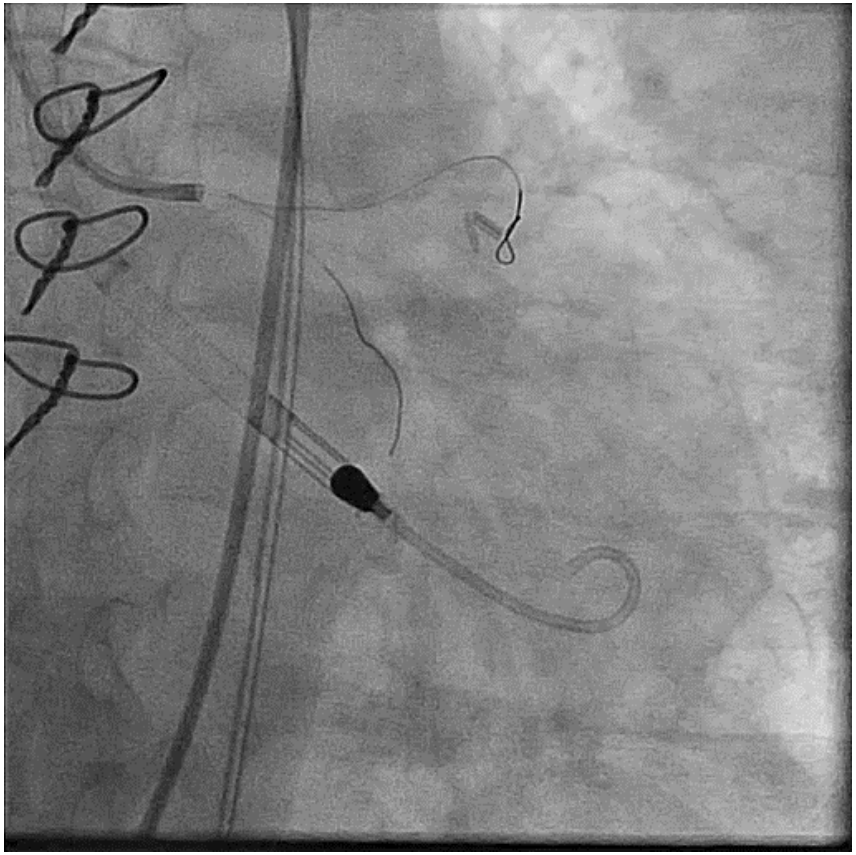
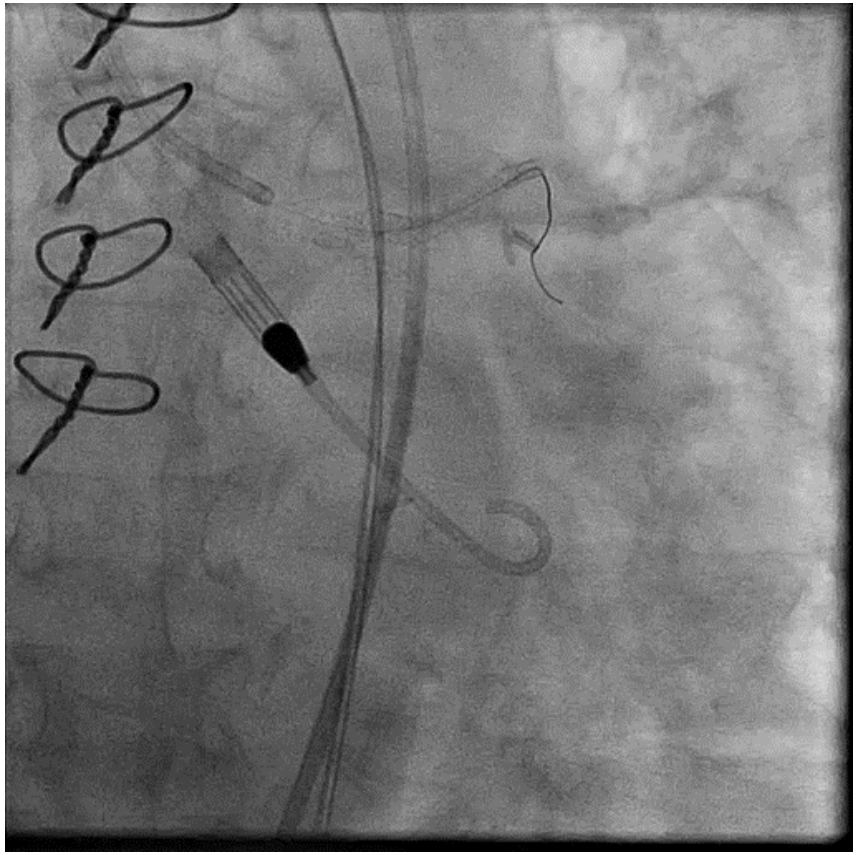
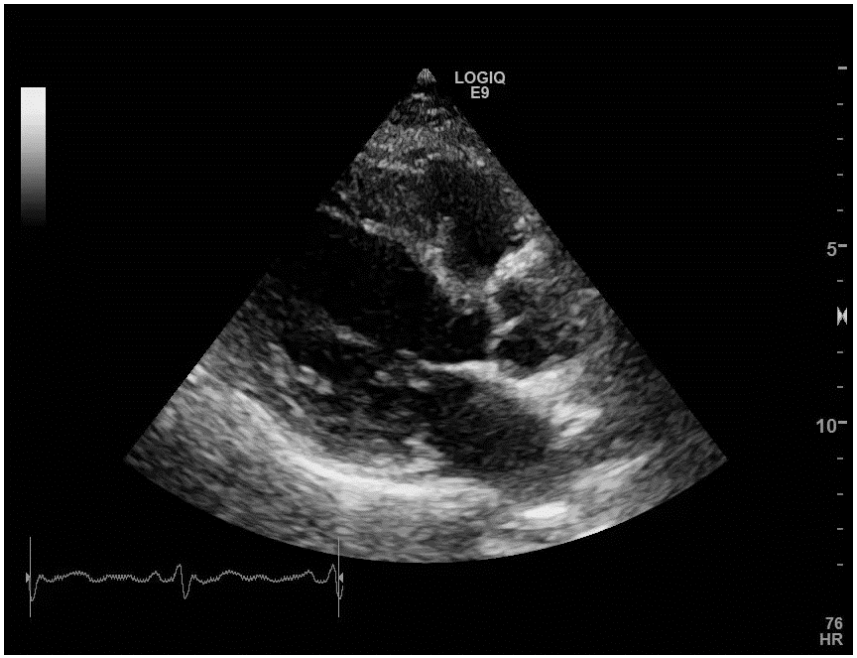
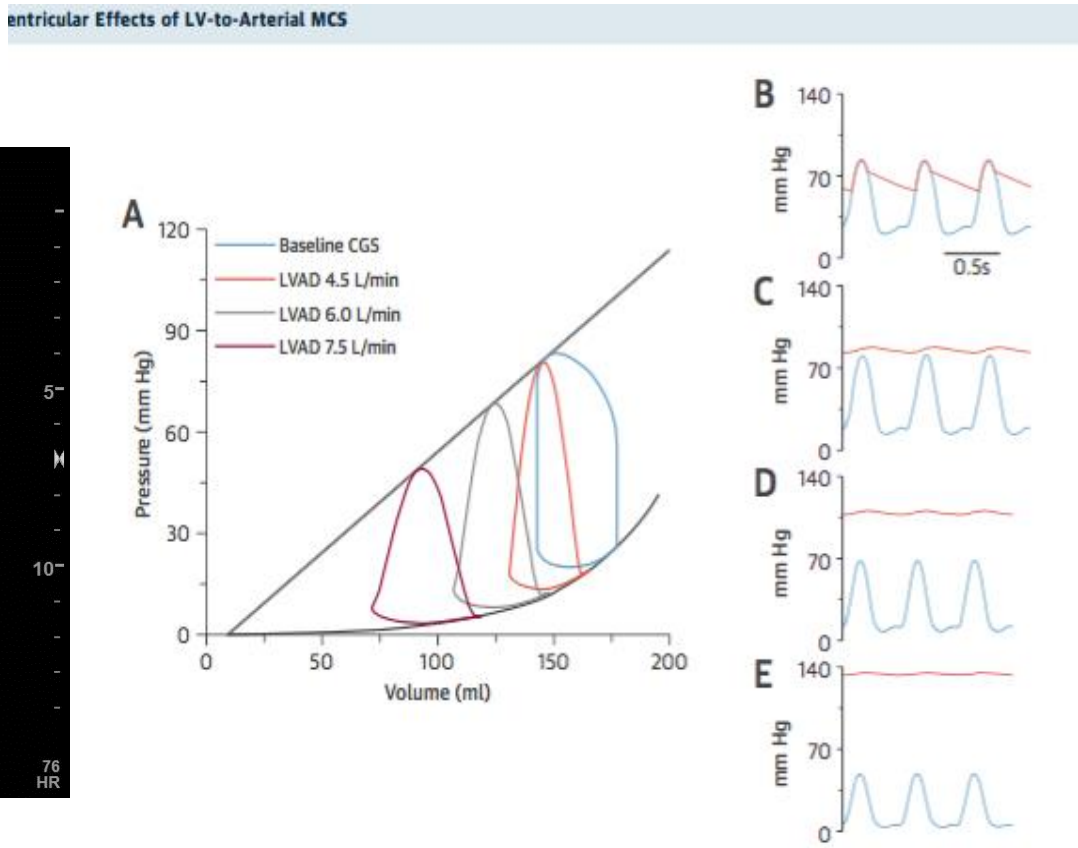




Allegheny
Health Network





- Loop becomes triangular and shifts progressively leftward (indicating increasing degrees of unloading)

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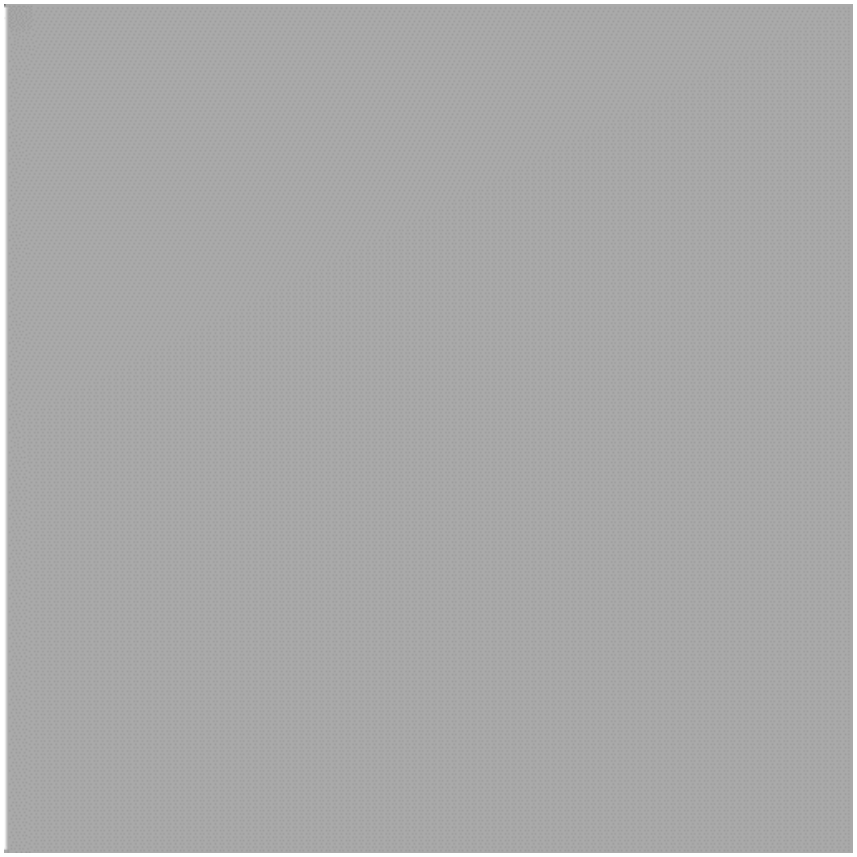
Burkhoff, D., G. Sayer, D. Doshi and N. Uriel (2015). "Hemodynamics of Mechanical Circulatory Support." J Am Coll Cardiol **66**(23): 2663-2674.

USPella (30)	Prophylactic HR-PCI	Severe 3VD, UPLMN, last patent vessel, low EF No STEMI or shock, mean SYNTAX score 36	175	Impella 2.5	12-month survival: 88%	MACE: 8%
EuroPella (52)	Prophylactic HR-PCI	Severe 3VD, UPLMN, last patent vessel, EF <30% No STEMI or shock	144	Impella 2.5	30-day survival: 94.5%	MI: 0%, stroke 0.7%, bleeding 6.2%, vascular complication 4%
Protect I (7)	HR-PCI	Last patent vessel, UPLMN, EF <35% No STEMI or shock	20	Impella 2.5		MACE 20%
PROTECT-II (23)	HR-PCI	UPLMN, last patent vessel, EF <35%, 3VD, and EF <30%	452	IABP (226) versus IMPELLA 2.5 (226)	Superior hemodynamics with Impella (CPO) No statistical difference in MAE	MAE: MAE 30 & 90 days: (ITT) Impella: 35.1%, 40.6% IABP: 40.1%, 49.3%

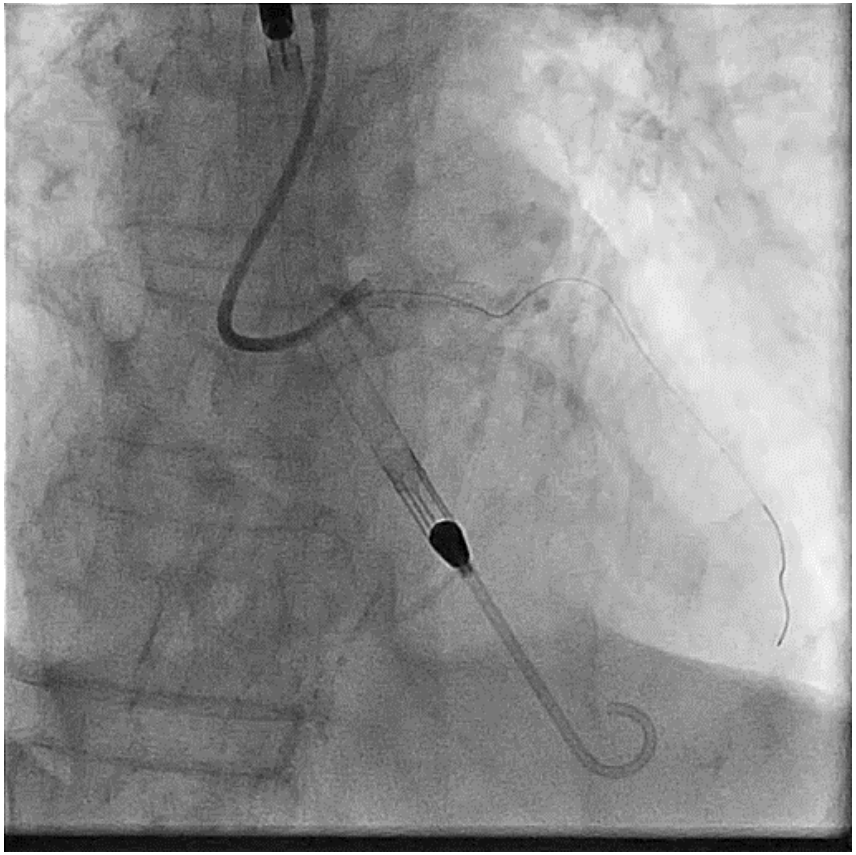
Atkinson, T. M., E. M. Ohman, W. W. O'Neill, T. Rab and J. E. Cigarroa (2016). "A Practical Approach to Mechanical Circulatory Support in Patients Undergoing Percutaneous Coronary Intervention: An Interventional Perspective." JACC Cardiovasc Interv **9**(9): 871-883.

- Device thrombosis
- Vascular injury
- Hemolysis

- LV thrombus
- Mechanical aortic valve
- Severe PVD
- Moderate to severe AI



Ongoing Impella Trials



PROTECT IV

High risk PCI

Impella vs IABP

DanGer Shock

Impella vs standard of care

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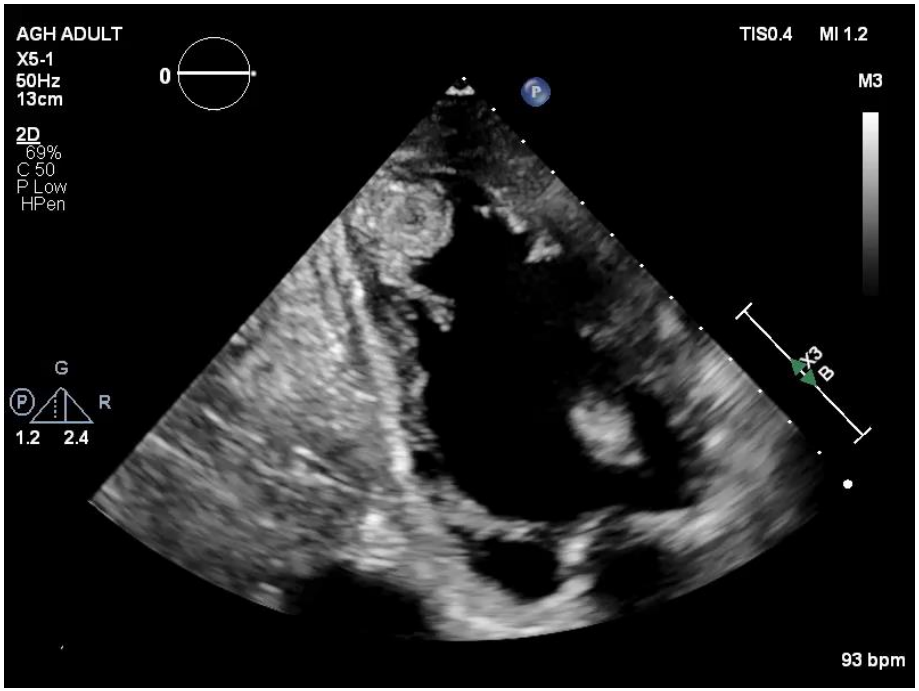

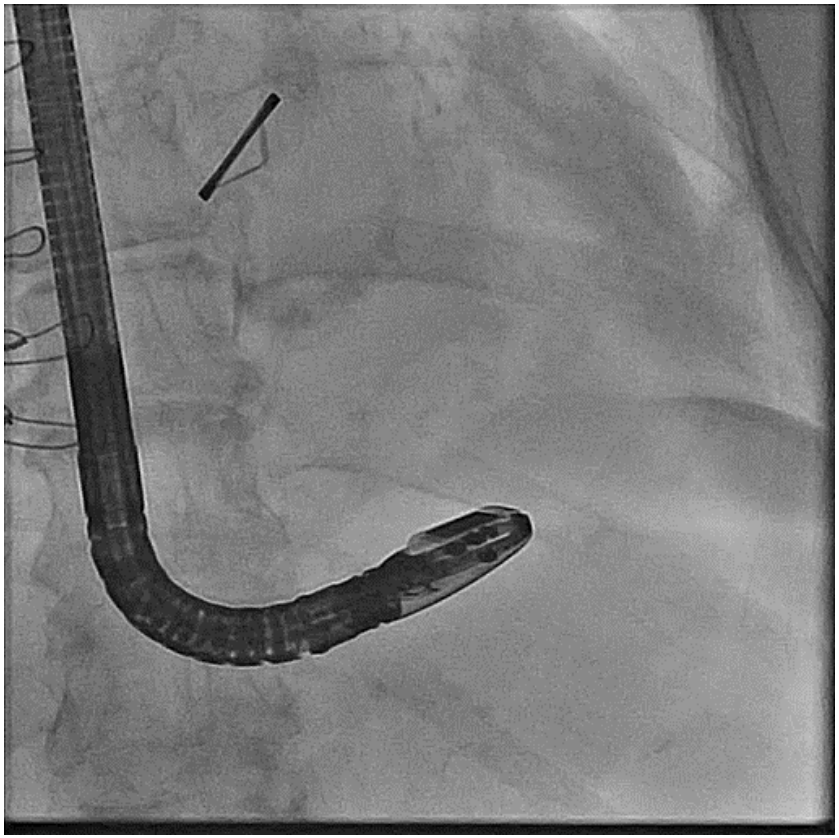

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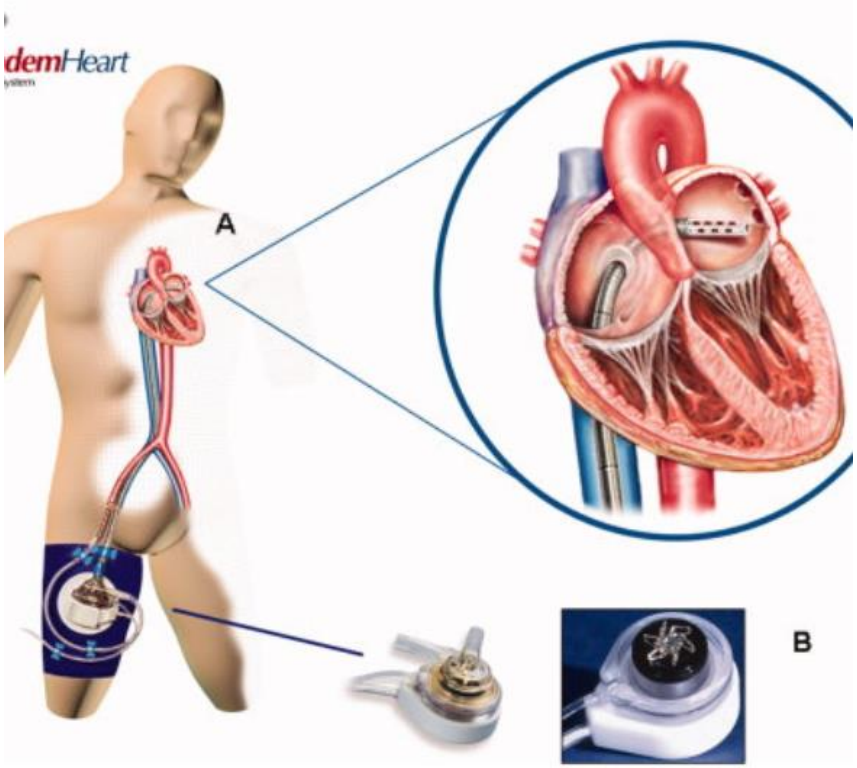

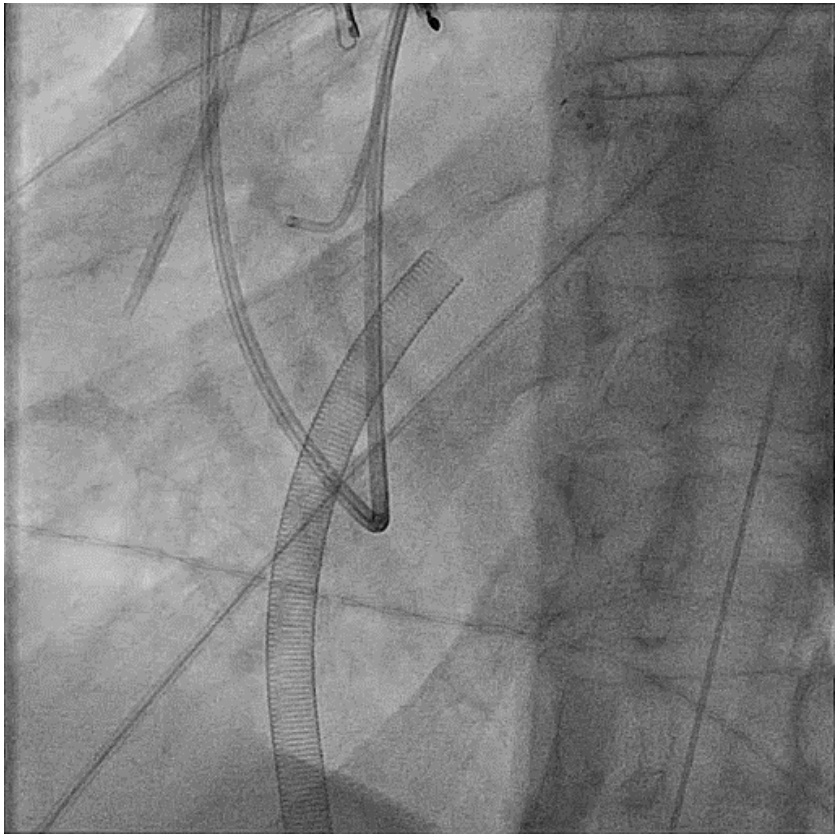

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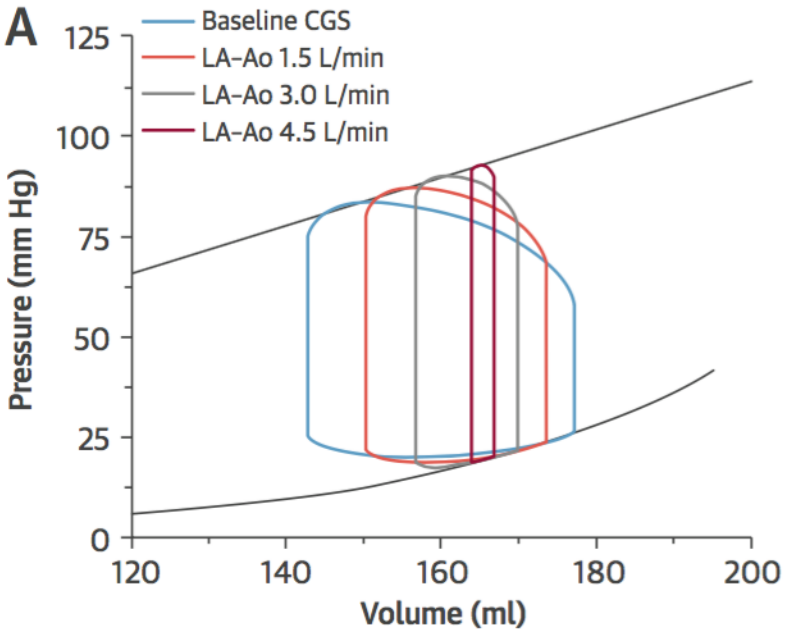
Tandem Heart



- LV thrombus
- Critical aortic stenosis
- Severe AI
- Severe aortic/iliac disease

Burkhoff, D., G. Sayer, D. Doshi and N. Uriel (2015). "Hemodynamics of Mechanical Circulatory Support." J Am Coll Cardiol **66**(23): 2663-2674.

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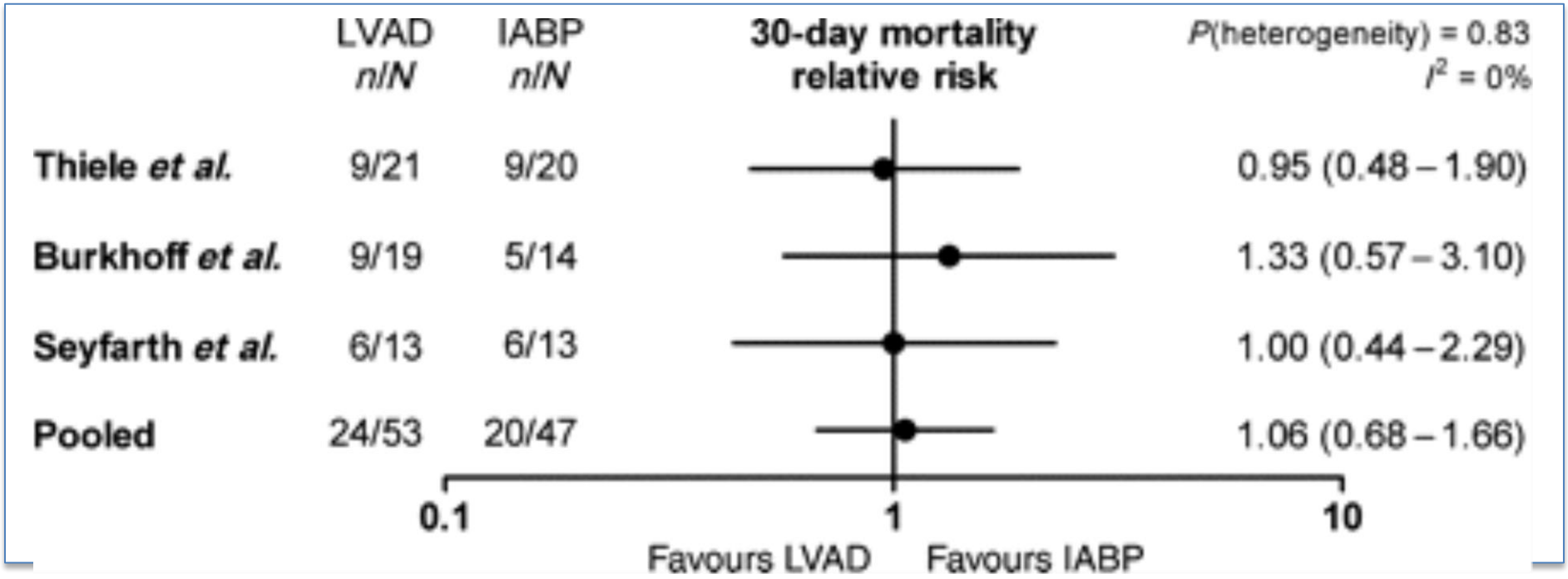
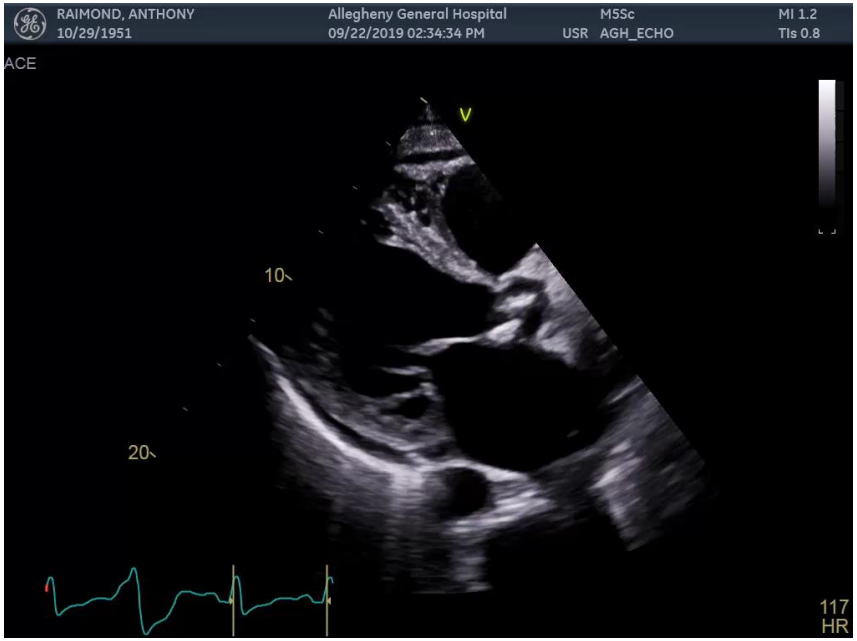
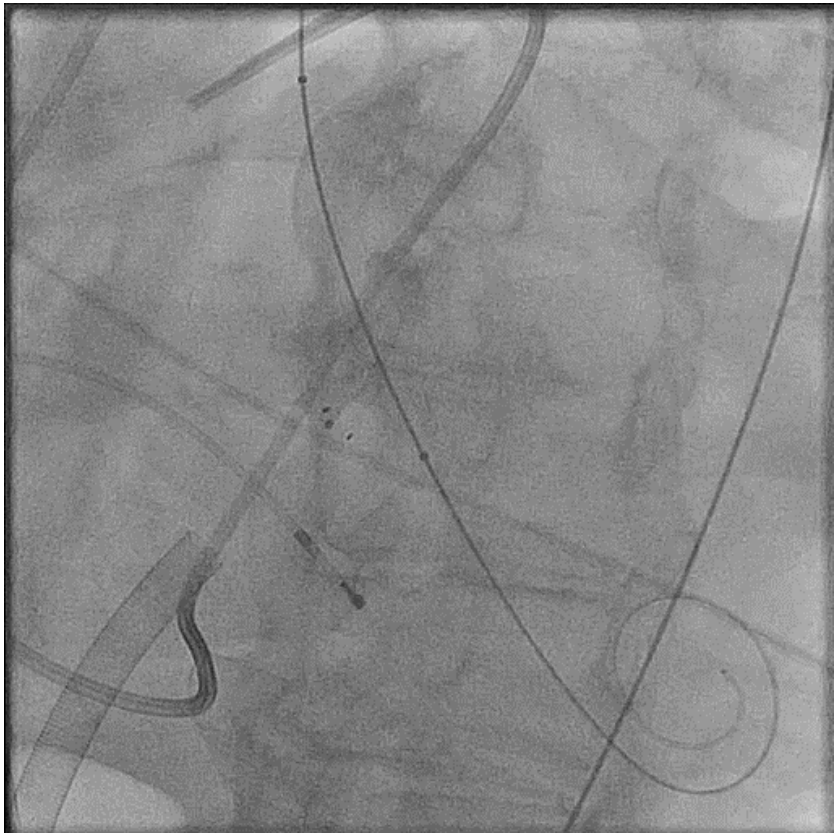
	Thiele *et al.*[16]	Burkhoff *et al.*[17]	Seyfarth *et al.*[18]
Percutaneous LVAD used	TandemHeart	TandemHeart	Impella LP2.5
Control	IABP	IABP	IABP
Total number of patients	41	33	26
Setting	Single-centre	Multi-centre	Two-centre
Inclusion period	2000–2003	2002–2004	2004–2007



Percutaneous left ventricular assist devices vs. intra-aortic balloon pump counterpulsation for treatment of cardiogenic shock: a meta-

Critical AS





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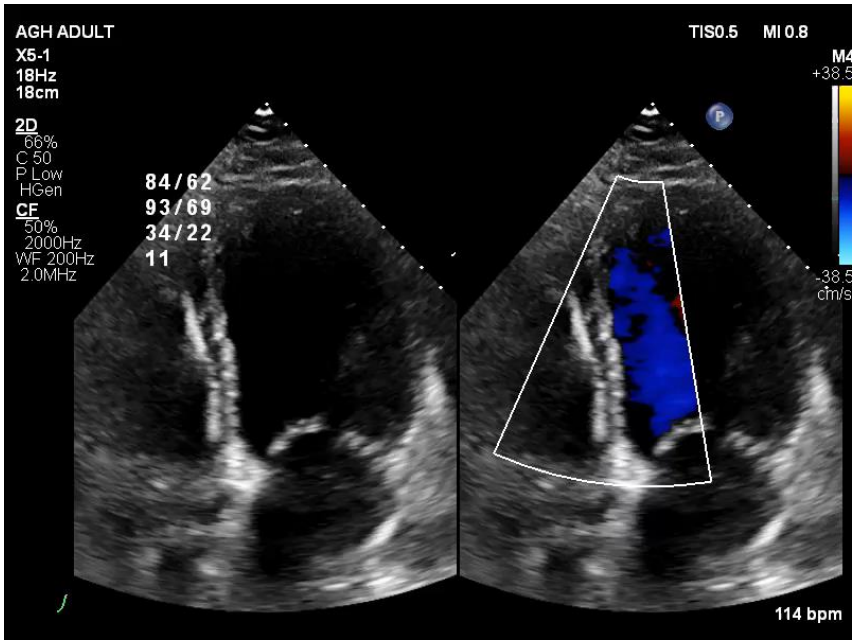
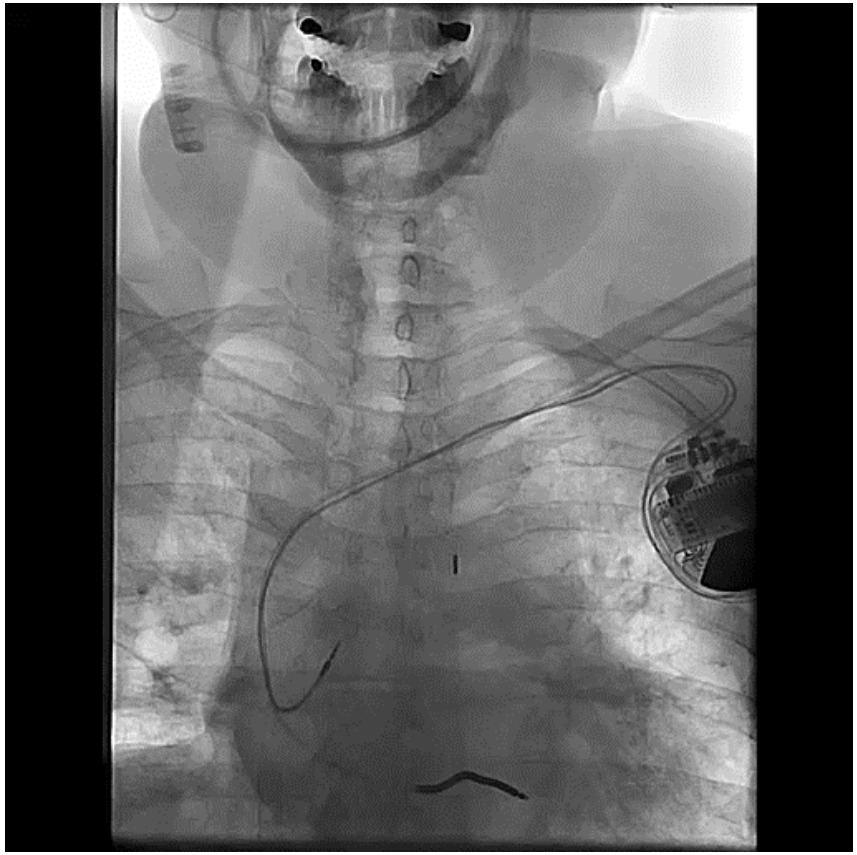
- Severe PAD
- Ventricular septal defect
- Bleeding diathesis and LA thrombus.

- Local vascular injury, limb ischemia
- Air embolism, tamponade, and thromboembolism
- Left atrial cannula can migrate into the RA causing hemodynamic collapse and profound hypoxia.

Acute BiV Failure





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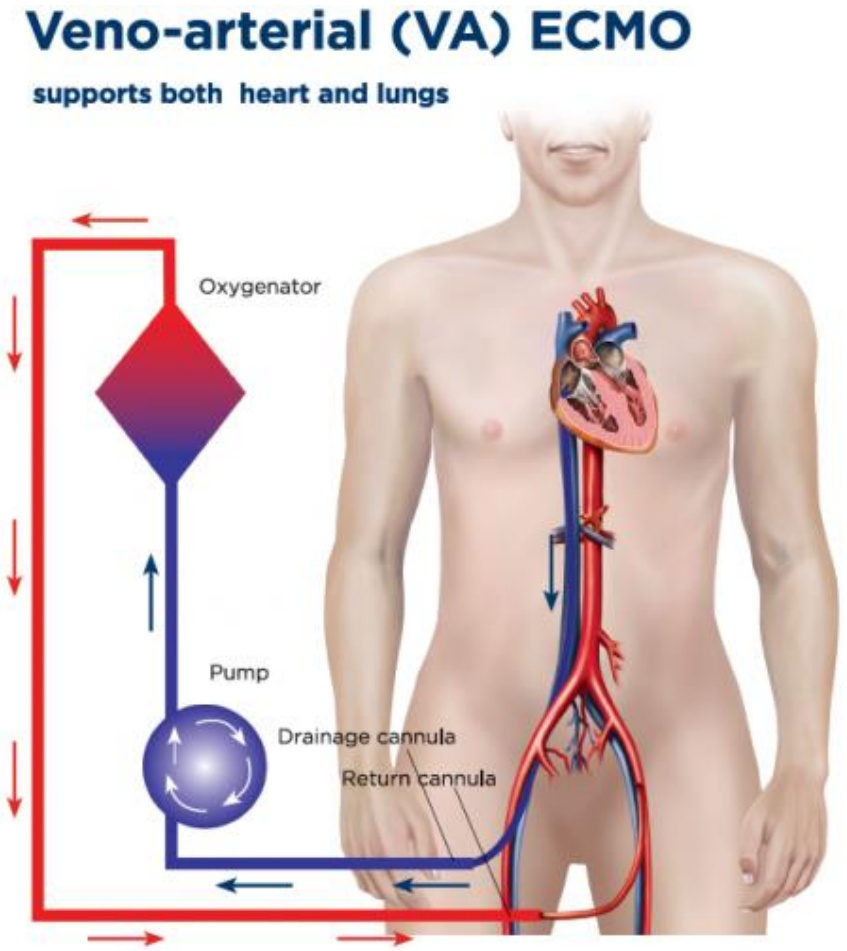
VA ECMO

- Cardiac arrest
- Profound shock
- Hemo-metabolic stage
- Respiratory failure



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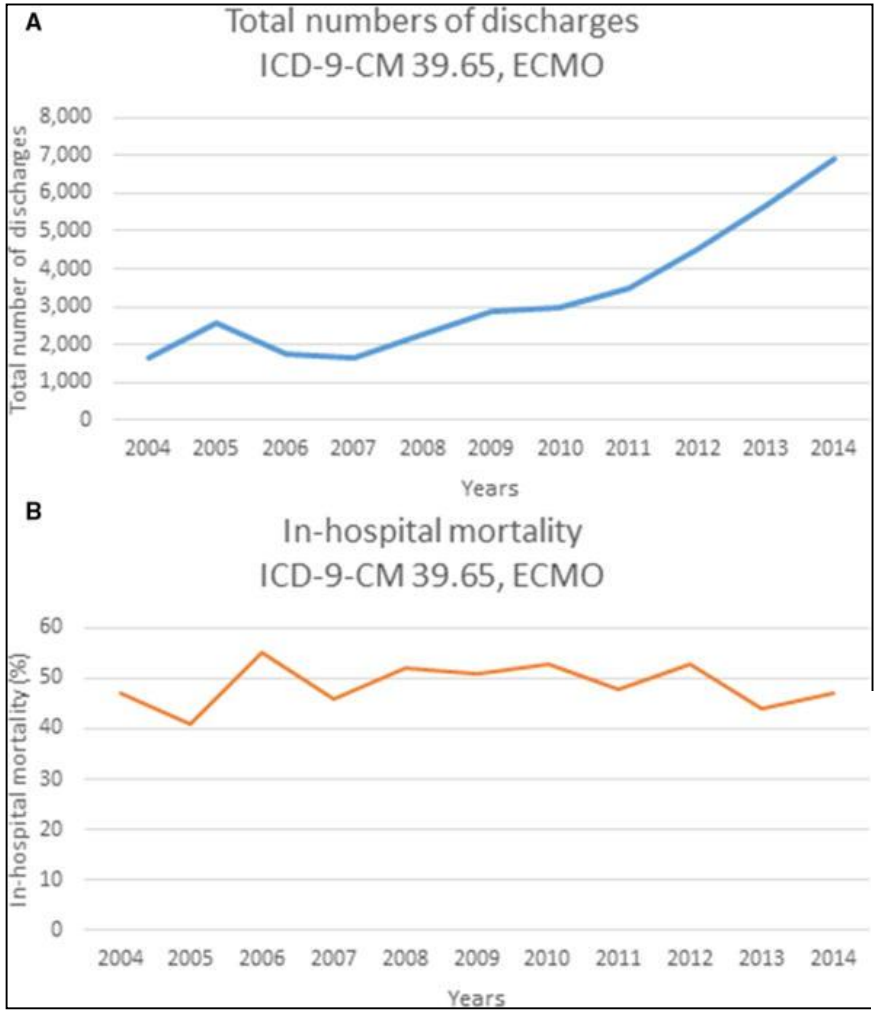

Percutaneous Mechanical Circulatory Support Devices in Cardiogenic Shock.
Mandawat, Aditya; Rao, Sunil

Circulation: Cardiovascular Interventions. 10(5):e004337, May 2017.
DOI: 10.1161/CIRCINTERVENTIONS.116.004337

2004 to 2014 Nationwide Inpatient Sample databases to identify all patients undergoing extracorporeal membrane oxygenation (ECMO; International Classification of Diseases-Ninth Revision [ICD-9] CM 39.65). The Mantel-Haenszel X2 test was used to analyze trends. A, ECMO was used in 1653 patients in 2004 and 6890 patients in 2014 (Ptrend=0.005). B, In-hospital mortality was stable between 2004 and 2014 at 47% (Ptrend=0.80).

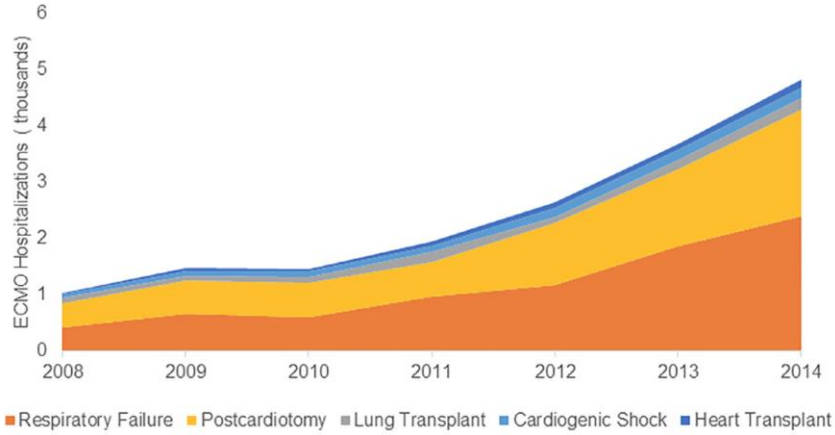

Fig. 1. Temporal trends by indication for ECMO in the United States, 2008–2014.

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Extracorporeal Membrane Oxygenation Use Has Increased by 433% in Adults in the United States from 2006 to 2011.

Sauer, Christopher; Yuh, David; Bonde, Pramod

ASAIO Journal. 61(1):31-36, January/February 2015.
DOI: 10.1097/MAT.0000000000000160

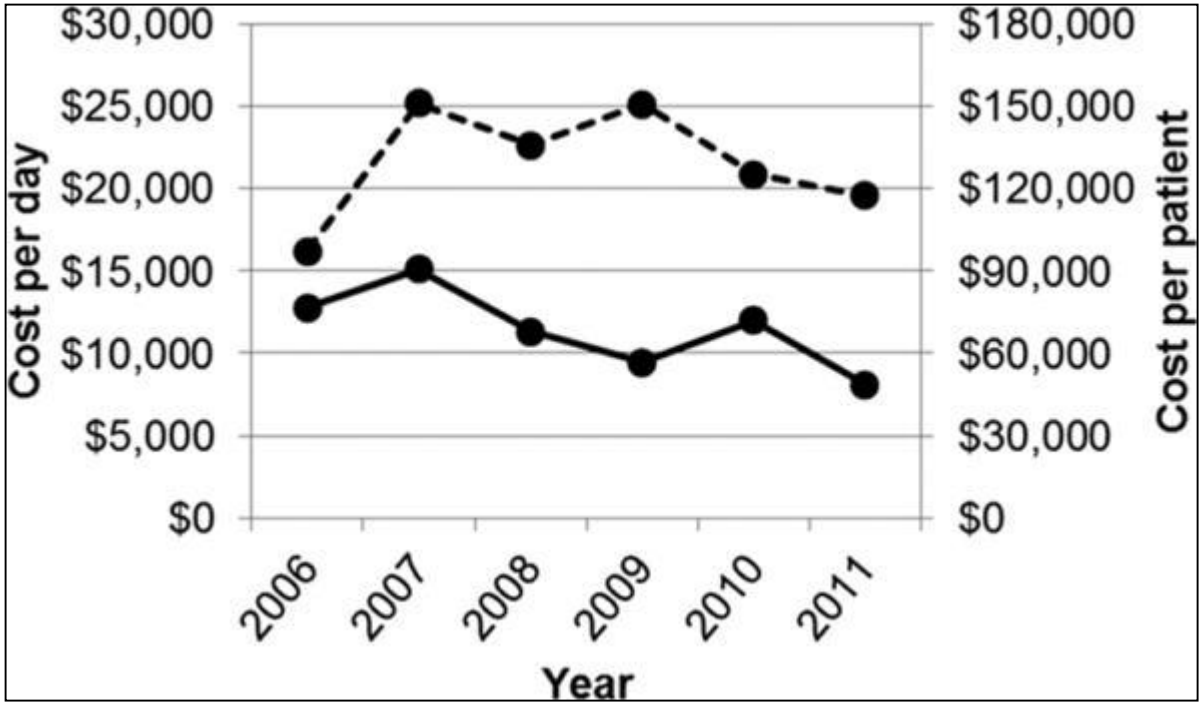

Figure 5 . Median costs per day of hospitalization (solid line) and median total hospitalization costs per patient (dotted line) for adults who received ECMO in the United States from 2006 to 2011. All amounts adjusted to 2011 US dollars using the Consumer Price Index Inpatient Hospital Services inflation multiplier.

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TABLE 1 Common Indications, Contraindications, and Considerations for VA-ECMO Deployment

Indications	Contraindications
Refractory CS in the setting of	Absolute
Acute coronary syndrome	Disseminated malignancy
Acute heart failure	Unwitnessed cardiac arrest
Post-cardiotomy, unable to wean from bypass	Severe irreversible brain injury
Myocarditis	Severe aortic incompetence
Primary graft failure after heart transplantation	Low likelihood of myocardial recovery, unless a candidate for durable MCS or heart transplantation
Refractory ventricular arrhythmias	Severe, irreversible multiorgan failure
Severe infection or drug intoxication complicated by cardiac depression	Severe peripheral arterial disease (for peripheral cannulation)
Severe hypothermia (<28°C) with cardiac instability	Relative
	Advanced age
	Bleeding diathesis

Venoarterial Extracorporeal Membrane Oxygenation in Cardiogenic Shock
Mary E. Keebler, Elias V. Haddad, Chun W. Choi, Stuart McGrane, Sandip Zalawadiya, Kelly H. Schlendorf, D. Marshall Brinkley, Matthew R. Danter, Mark Wigger, Jonathan N. Menachem, Ashish Shah and JoAnn Lindenfeld
JACC: Heart Failure
Volume 6, Issue 6, June 2018 DOI: 10.1016/j.jchf.2017.11.017

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TABLE 3 SAVE Score Parameters, Risk Classifications, and Predicted Survival

Parameter	Score
Diagnosis	
Myocarditis	3
Refractory VT/VF	2
Graft failure post-heart or lung transplant	3
Congenital heart disease	−3
Other diagnosis	0
Age (yrs)	
18-38	7
39-52	4
53-62	3
≥63	0
Weight (kg)	
≤65	1
65-89	2
≥90	0
Acute pre-ECMO organ failure (include all that apply)	
Liver failure	−3
CNS dysfunction	−3
Renal failure	−3
Chronic kidney disease (eGFR <60 ml/min/1.73 m^2 for ≥3 months)	−6
Duration of intubation pre-ECMO (h)	
≤10	0
11-29	−2
≥30	−4
Peak inspiratory pressure ≤20 cm H_2O	3
Pre-ECMO cardiac arrest	−2
Diastolic blood pressure before ECMO ≥40 mm Hg	3
Pulse pressure before ECMO ≥20 mm Hg	−2
HCO_3 before ECMO ≤15 mmol/l	−3
Constant value to add to all calculations	−6
Total	−35 to 17

Hospital Survival Classification by SAVE Score	Risk Class	Survival
>5	I	75
1 to 5	II	58
−4 to 0	III	42
−9 to −5	IV	30
≤−10	V	18

Venoarterial Extracorporeal Membrane Oxygenation in Cardiogenic Shock
Mary E. Keebler, Elias V. Haddad, Chun W. Choi, Stuart McGrane, Sandip Zalawadiya, Kelly H. Schlendorf, D. Marshall Brinkley, Matthew R. Danter, Mark Wigger, Jonathan N. Menachem, Ashish Shah and JoAnn Lindenfeld
JACC: Heart Failure
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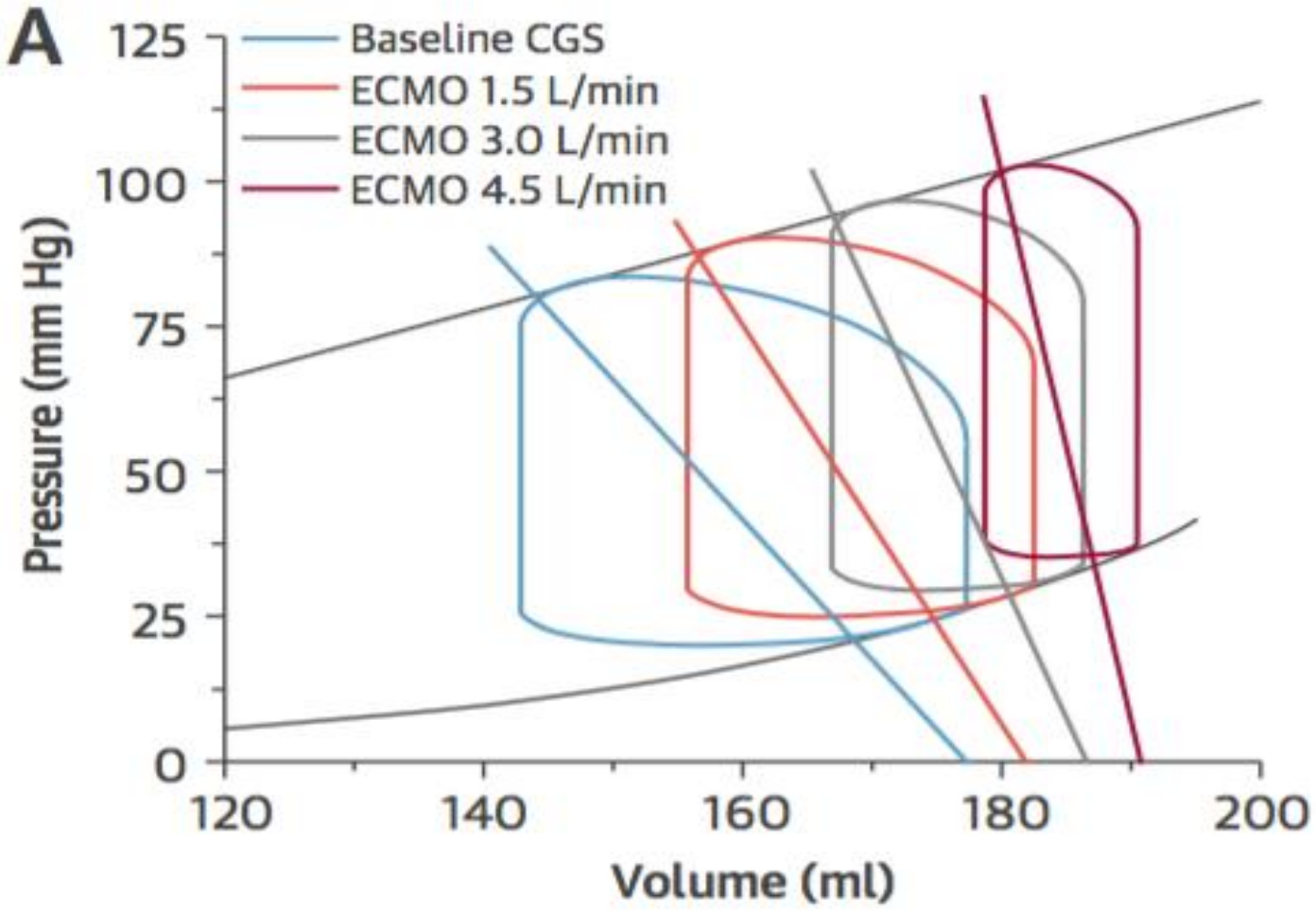
VA ECMO



Burkhoff, D., G. Sayer, D. Doshi and N. Uriel (2015). "Hemodynamics of Mechanical Circulatory Support." J Am Coll Cardiol 66(23): 2663-2674.

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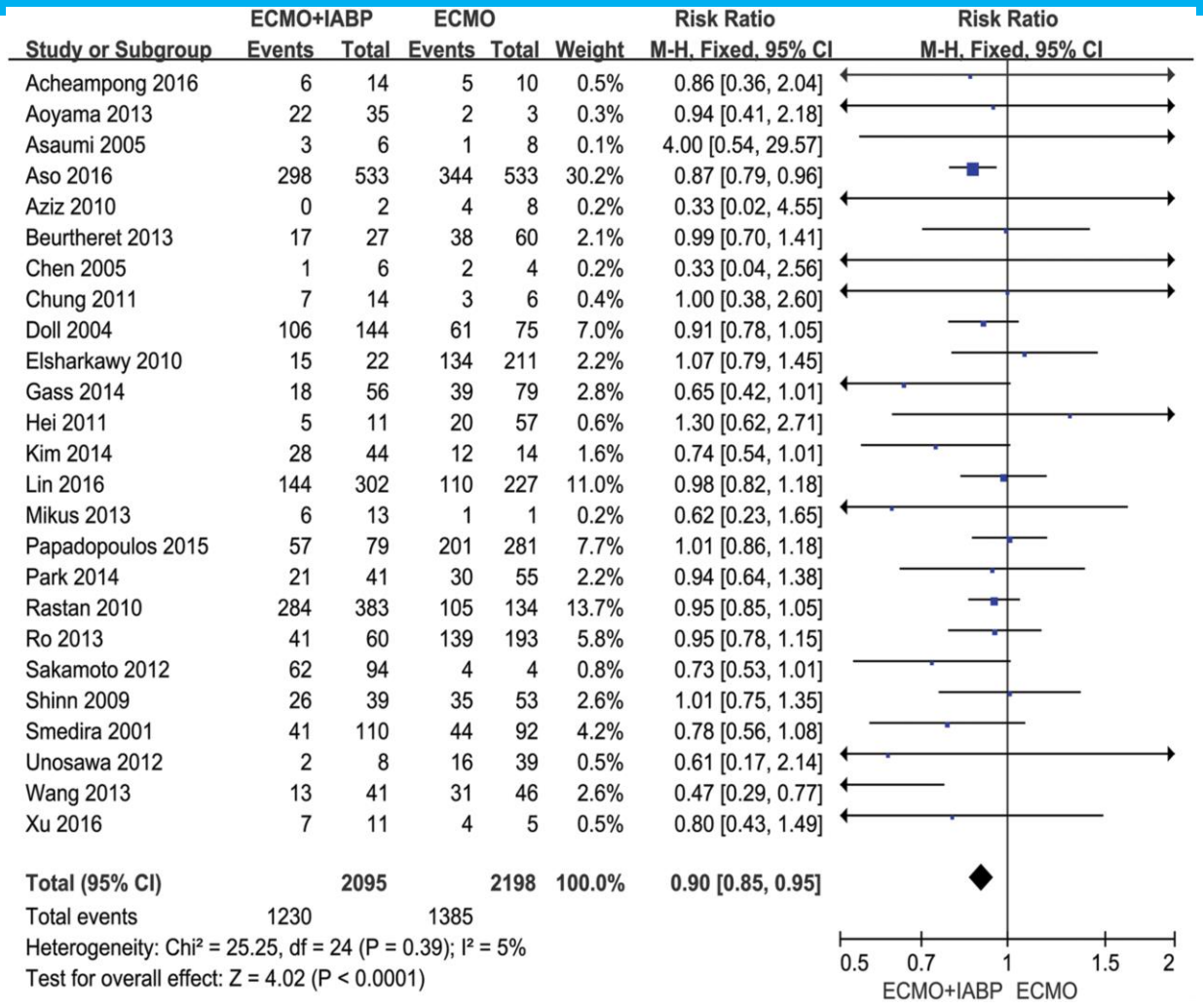

From: Effect of an intra-aortic balloon pump with venoarterial extracorporeal membrane oxygenation on mortality of patients with cardiogenic shock: a systematic review and meta-analysis†

Eur J Cardiothorac Surg. Published online September 24, 2018. doi:10.1093/ejcts/ezy304

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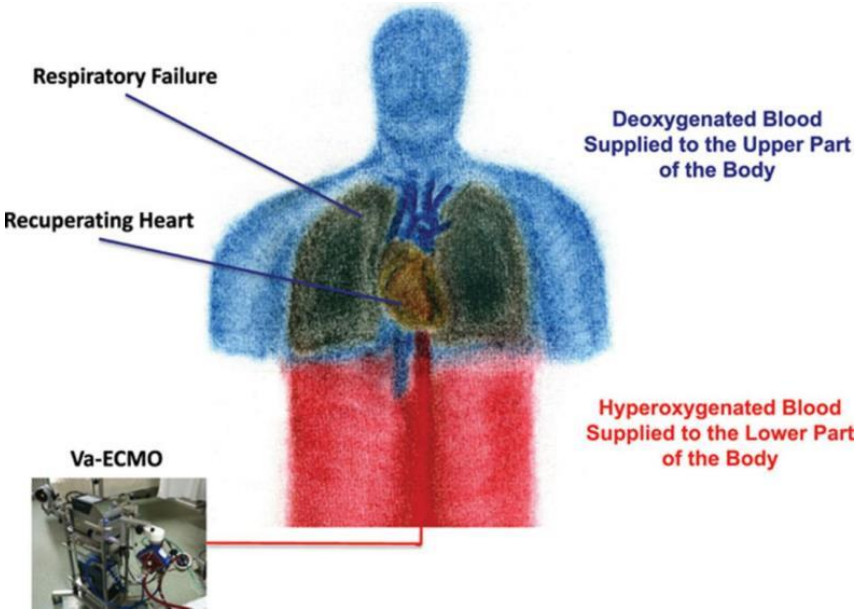
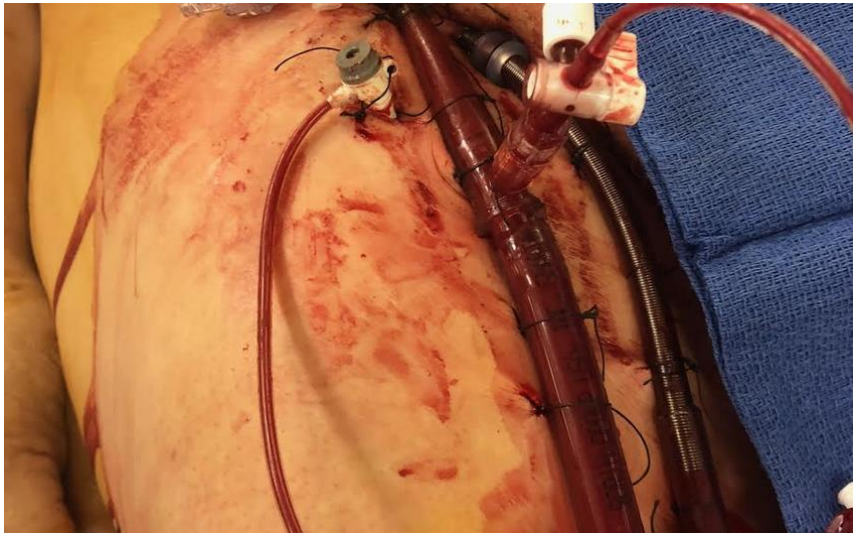
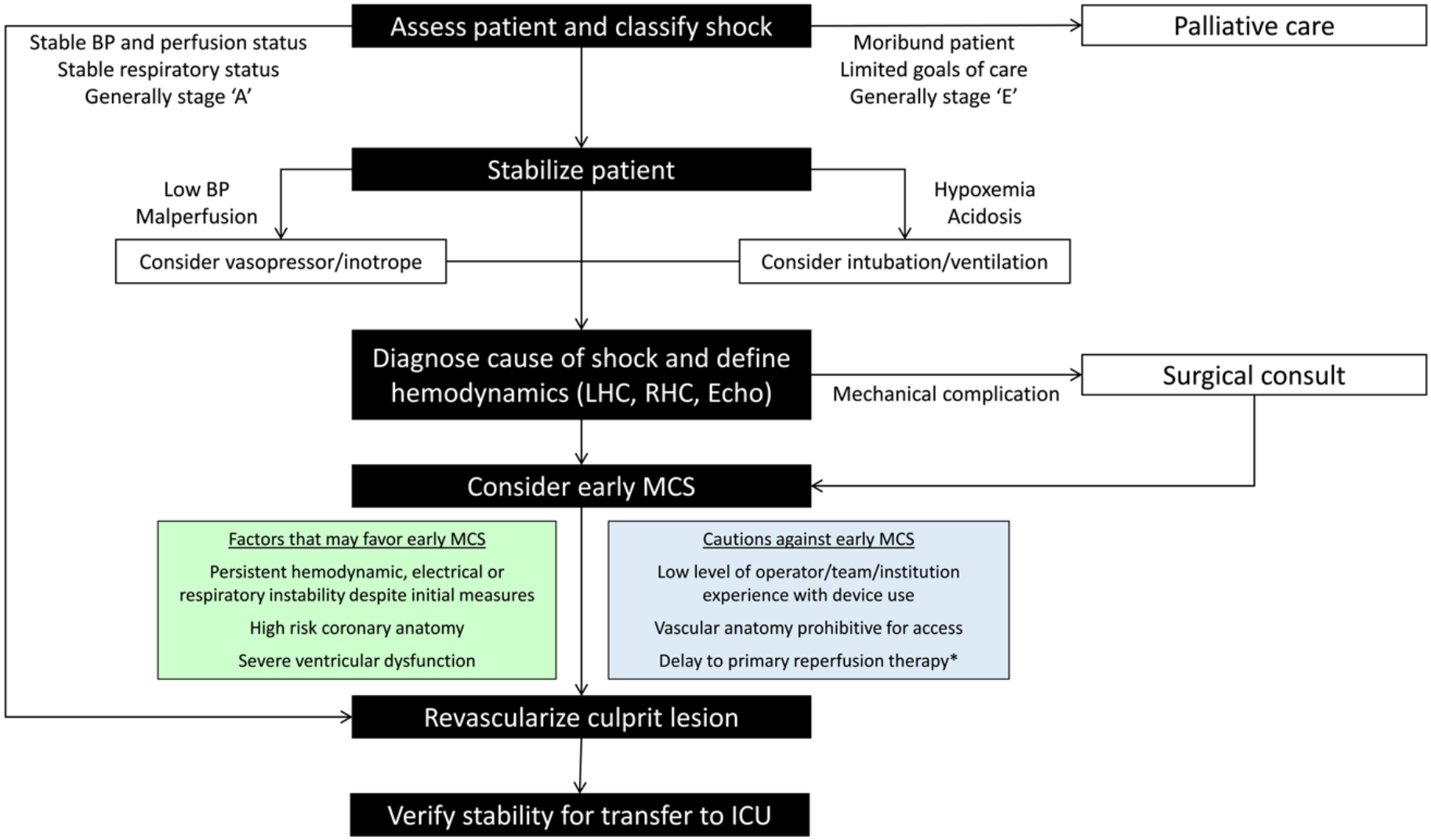




Allegheny Health Network



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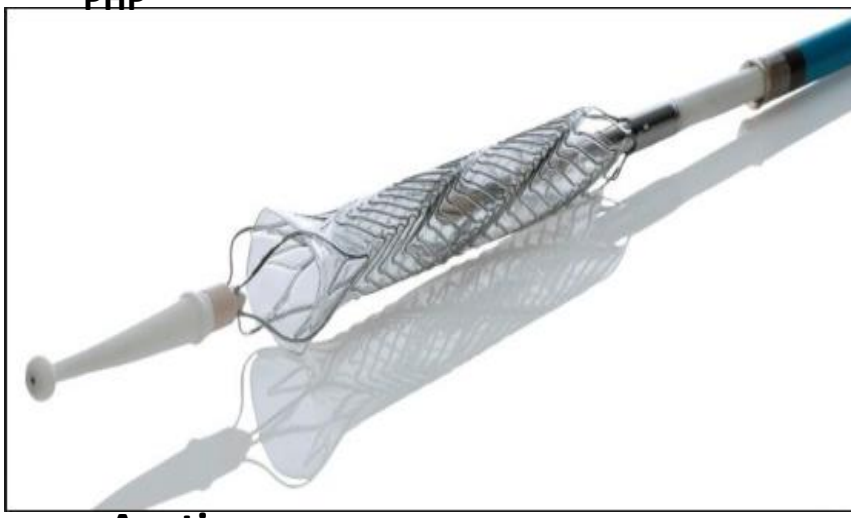
Circulation. 2021;143:e815–e829.

Thank you

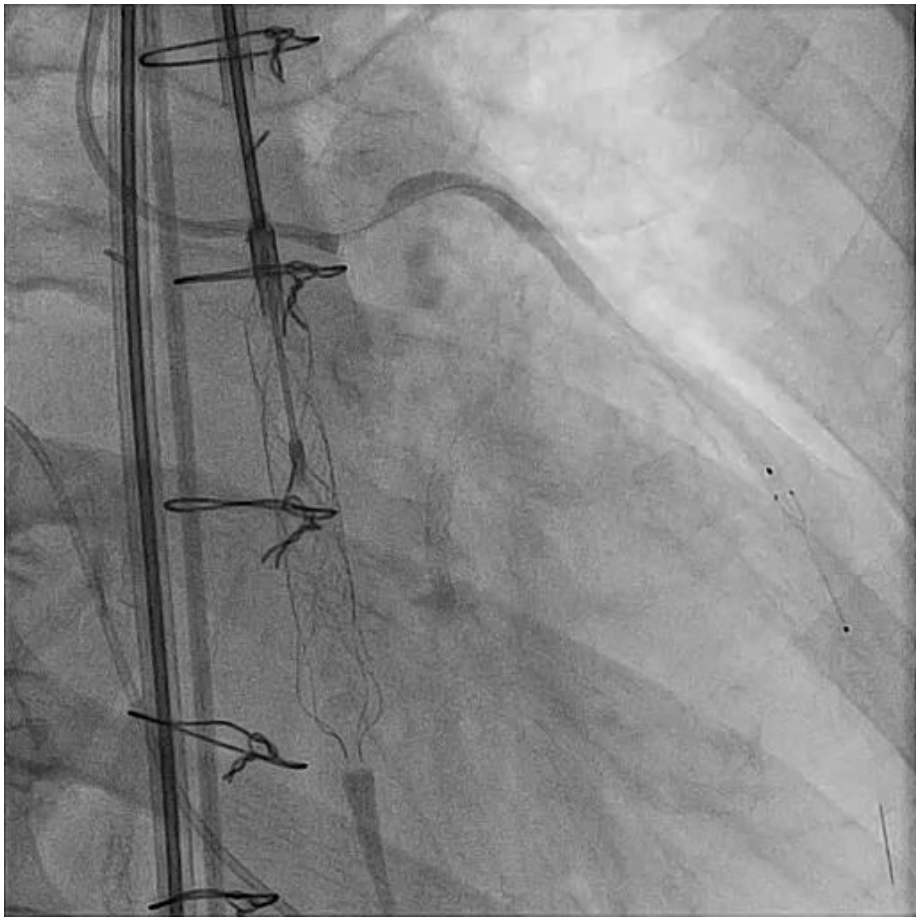
Allegheny Health Network

Investigational devices

PHP

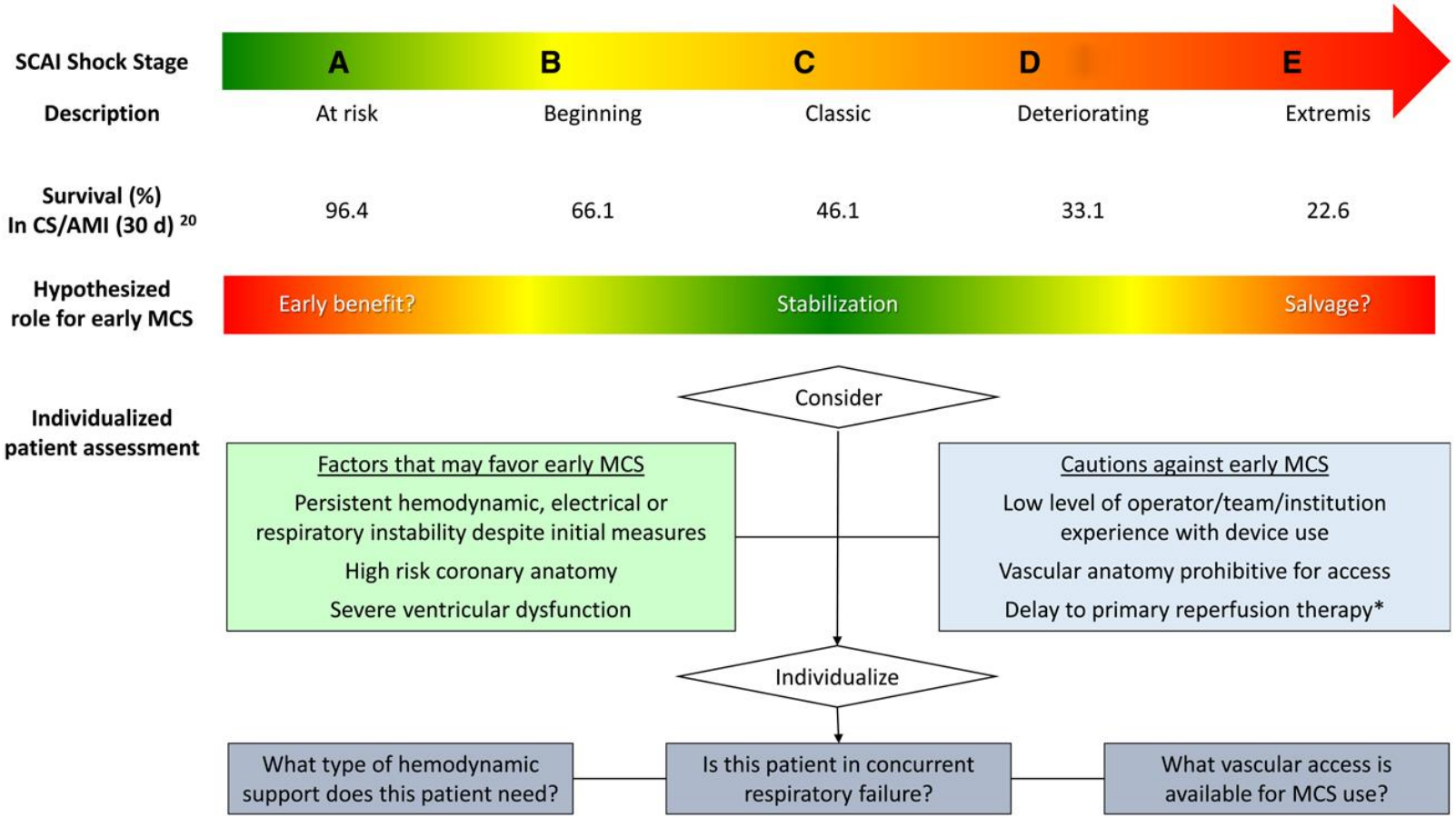


Aortix



Allegheny Health Network

Conclusions



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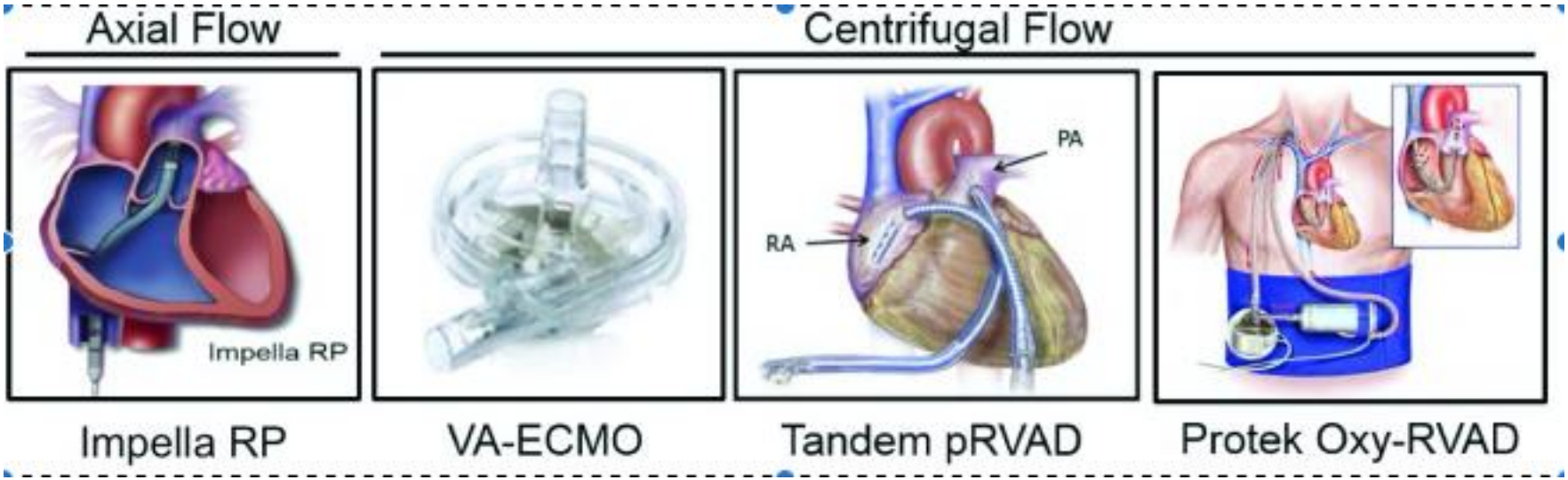
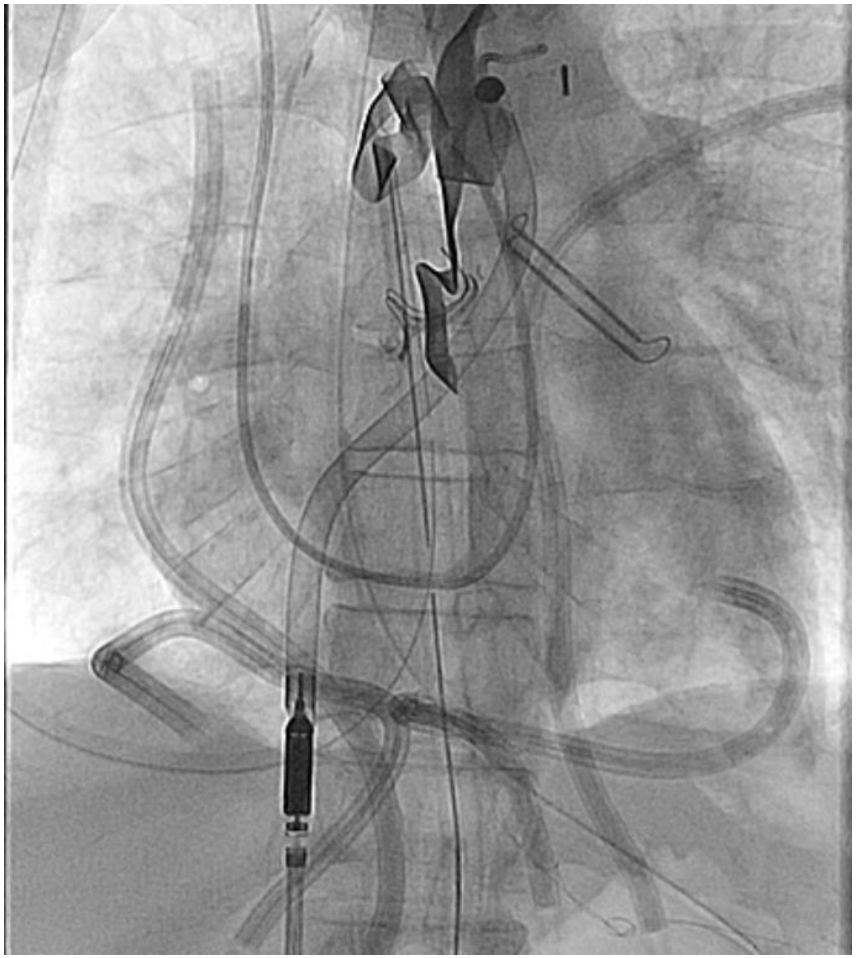
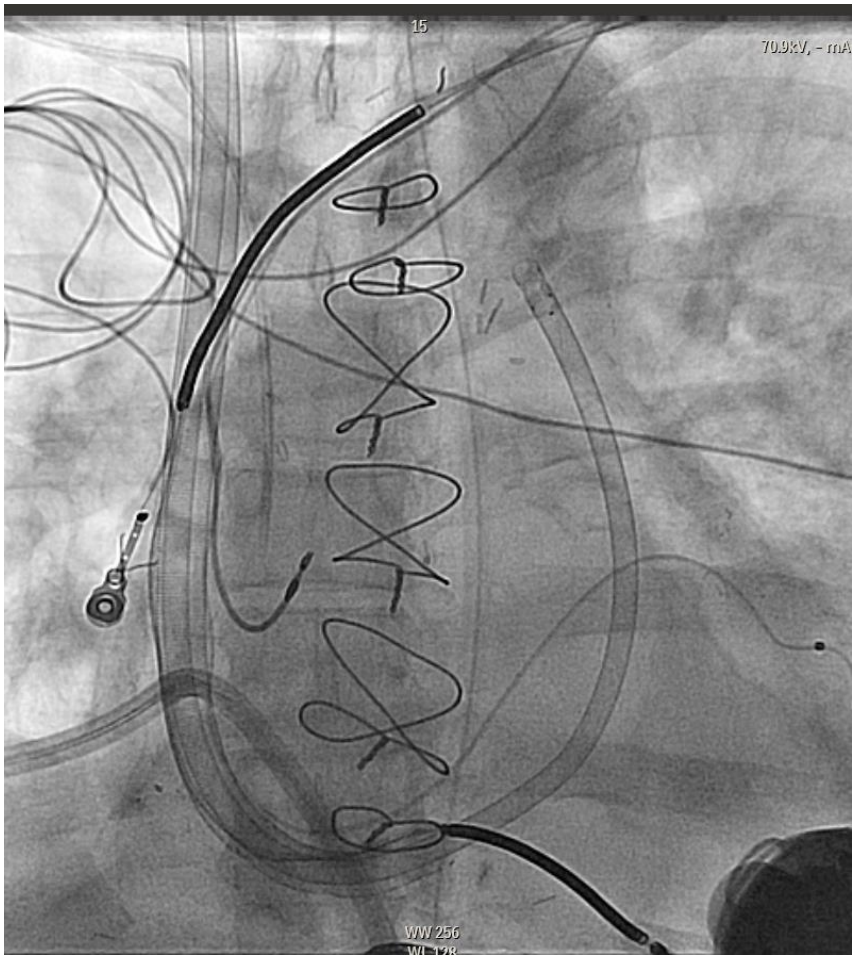
RIGHT VENTRICULAR SUPPORT DEVICES



Circulation. 2017;136:314–326. DOI: 10.1161/CIRCULATIONAHA.116.025290

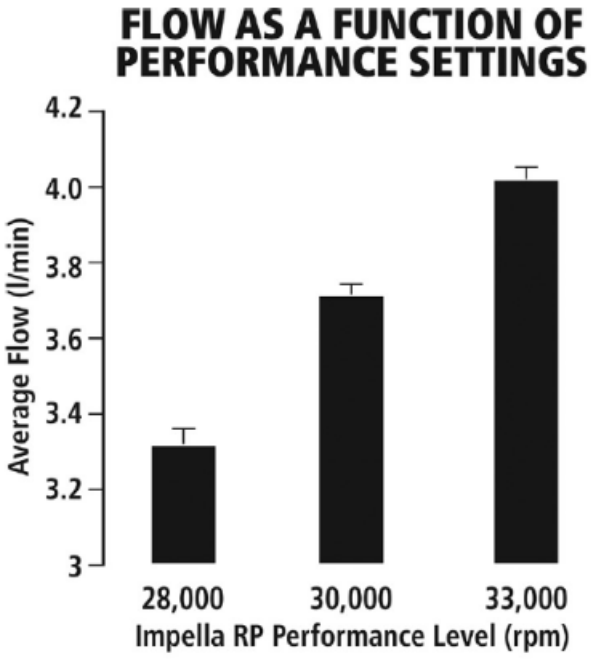
Allegheny Health Network

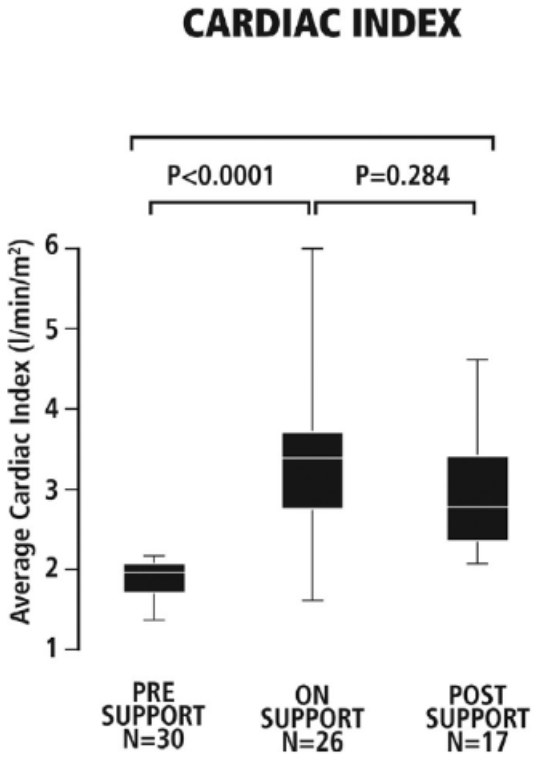


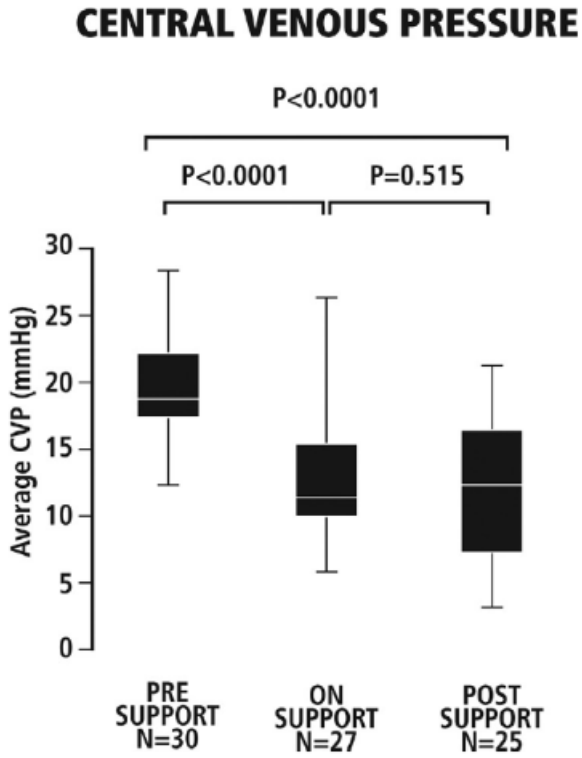


Allegheny
Health Network

Benefits of a novel percutaneous ventricular assist device for right heart failure: The prospective RECOVER RIGHT study of the Impella RP device





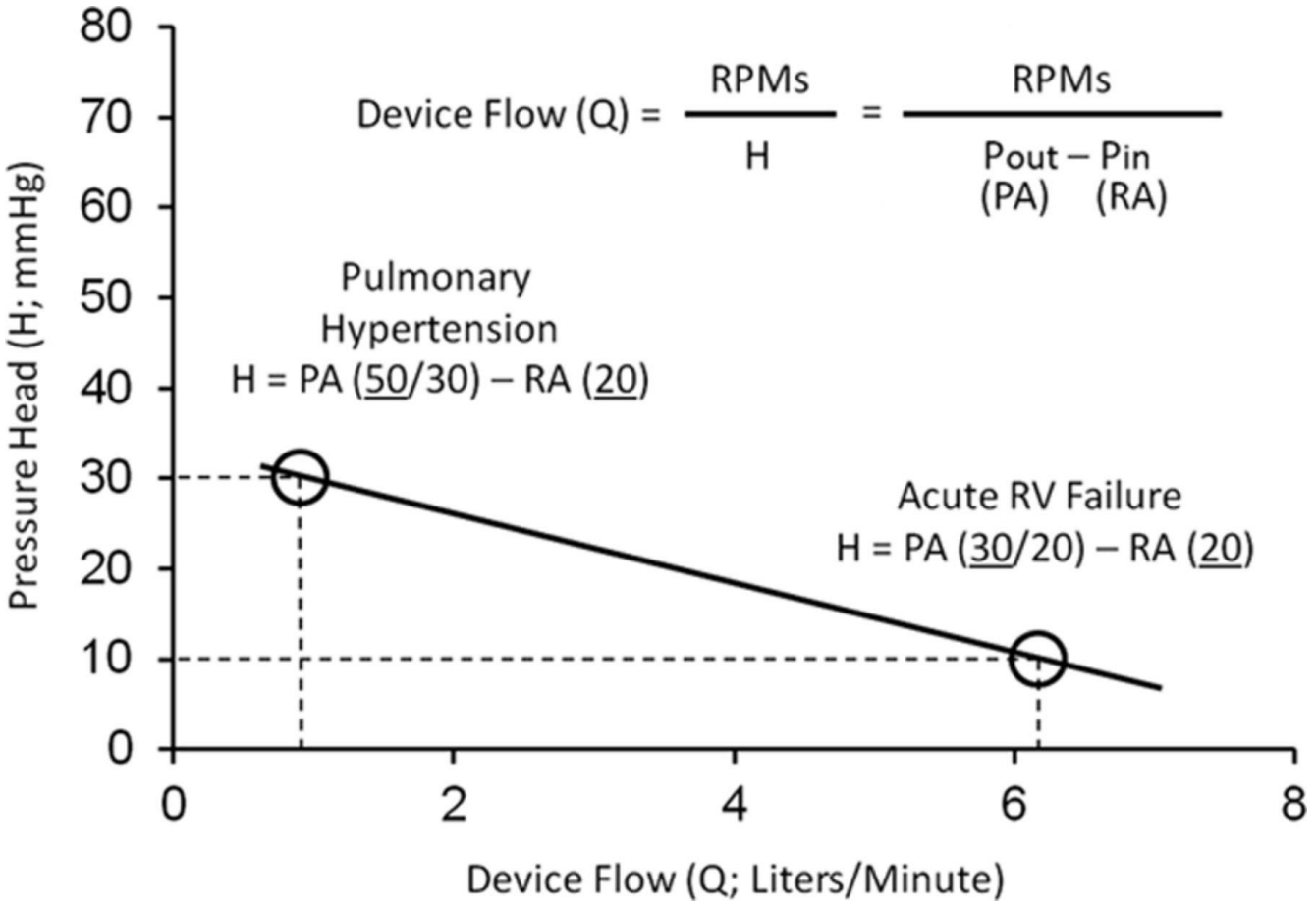


Anderson M et al. JHLT 2015

TABLE IV. Predictive Value of Invasive Hemodynamic Indices Using Specific ROC Derived Cut-points as Determinants of Severe RVD as Defined by In-hospital Mortality and/or the Need for a pRVSD in Acute IWMI

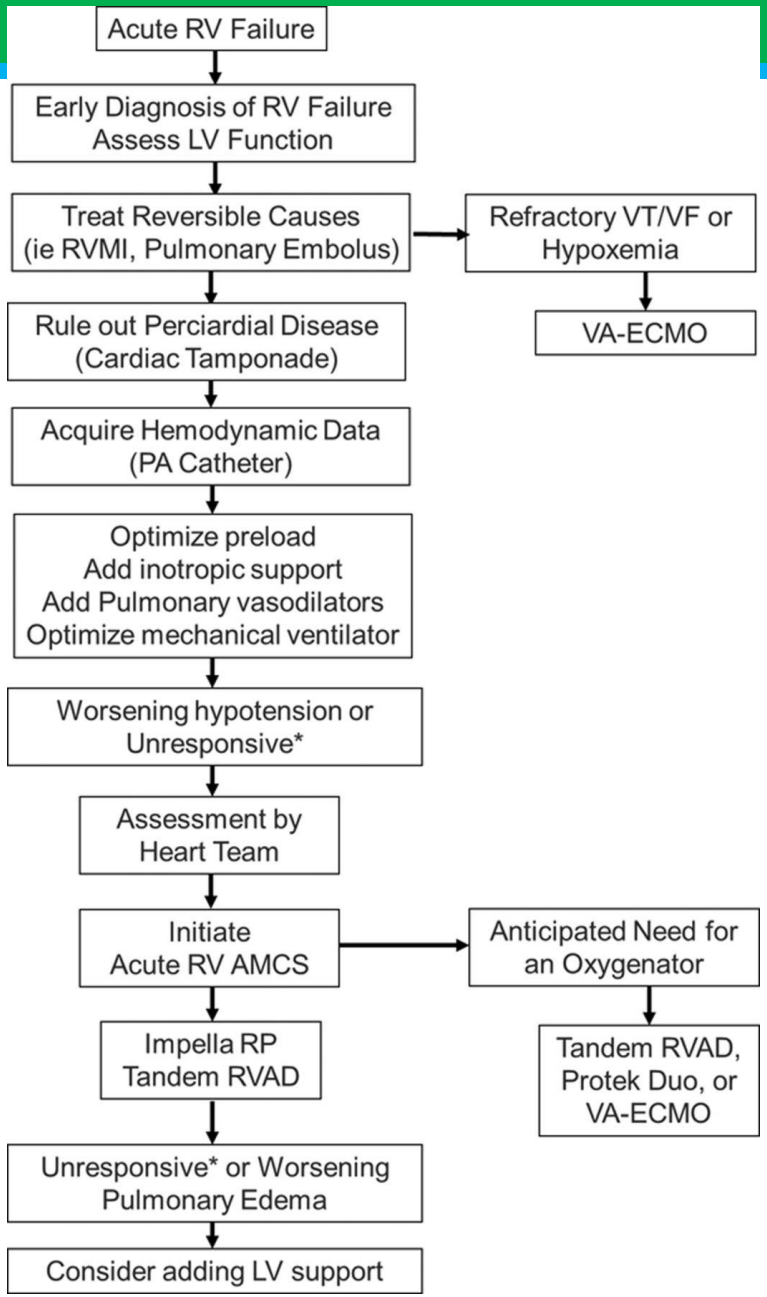
	Sensitivity	Specificity	NPV	PPV	Accuracy	C-Statistic
Severe RVD						
PAPi $\leq$ 0.9	100.0	98.3	100.0	90.0	98.6	0.998
RA:PCWP $\geq$ 0.86	75.0	93.2	96.5	60.0	91.0	0.841
RVSW $\leq$ 8.6	0.0	100.0	88.2	0.0	88.2	0.900

The pulmonary artery pulsatility index identifies severe right ventricular dysfunction in acute inferior myocardial infarction.
Ravi Korabathina;Kevin S Heffernan;Vikram Paruchuri;Ayan R Patel;James O Mudd;Jordan M Prutkin;Nicole M Orr;Andrew Weintraub;Carey D Kimmelstiel;Navin K Kapur



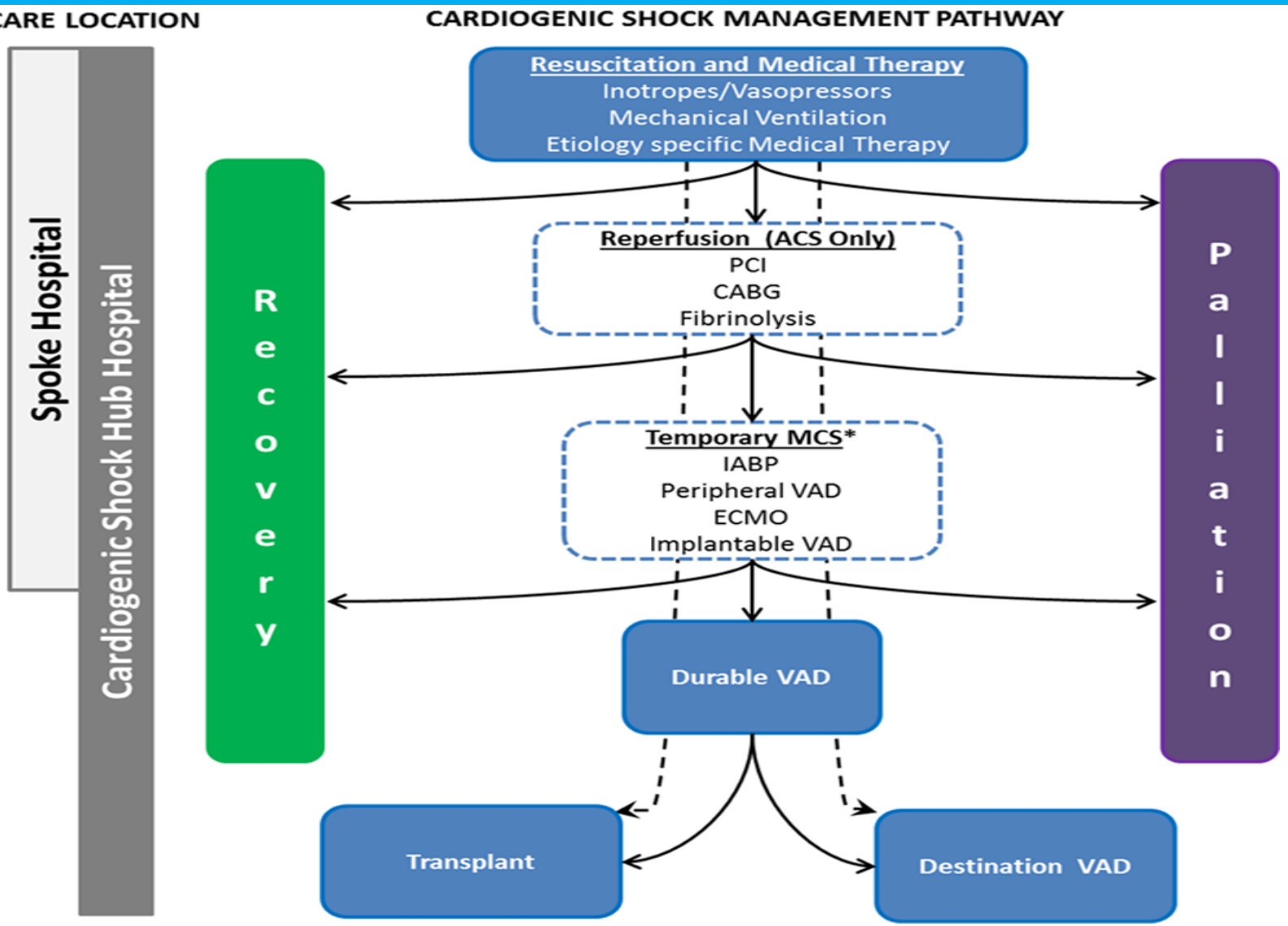
Mechanical Circulatory Support Devices for Acute Right Ventricular Failure, Volume: 136, Issue: 3, Pages: 314-326, DOI: (10.1161/CIRCULATIONAHA.116.025290)

Allegheny Health Network



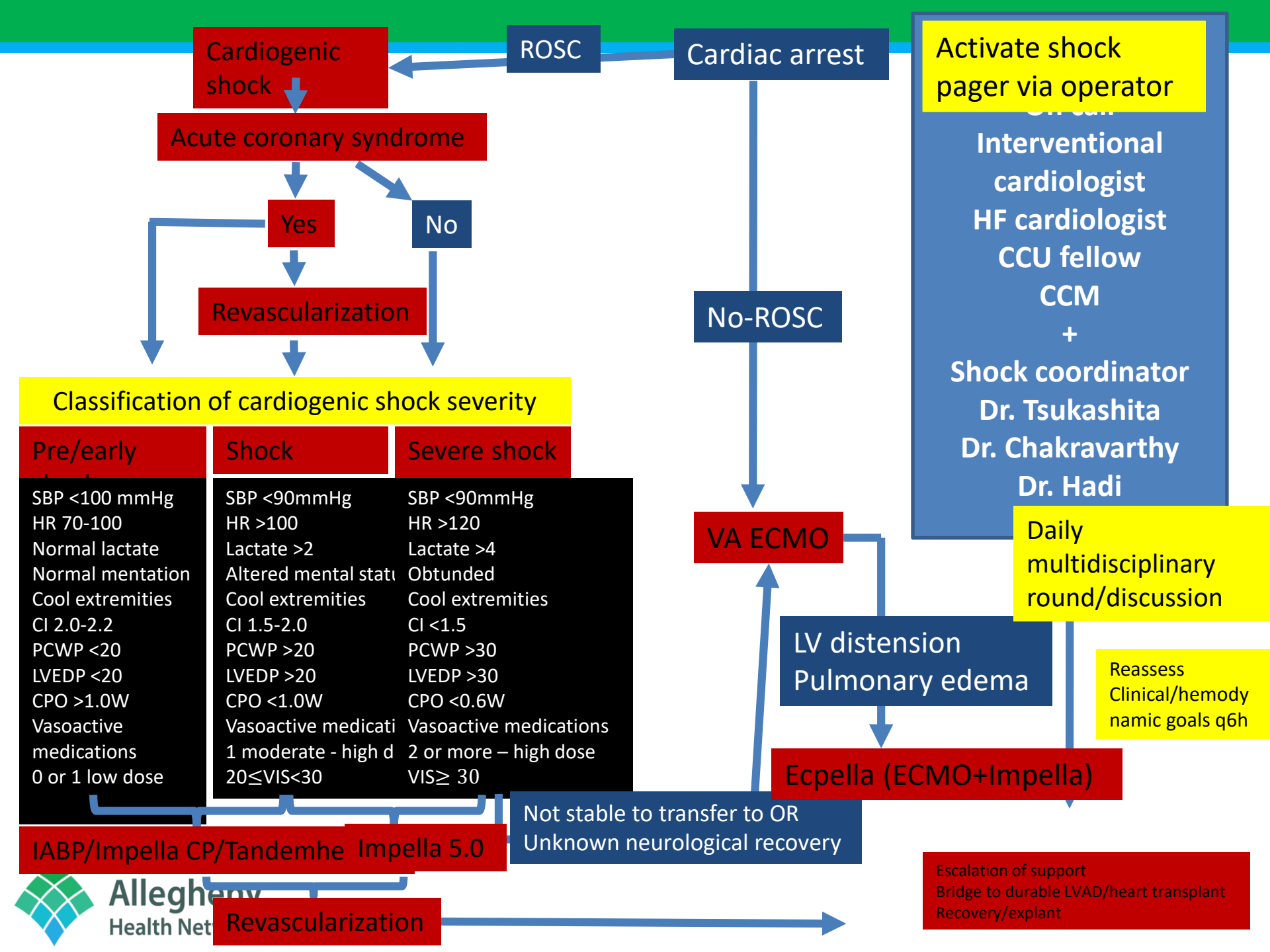
Mechanical Circulatory Support Devices for Acute Right Ventricular Failure, Volume: 136, Issue: 3, Pages: 314-326, DOI: (10.1161/CIRCULATIONAHA.116.025290)

Allegheny
Health Network



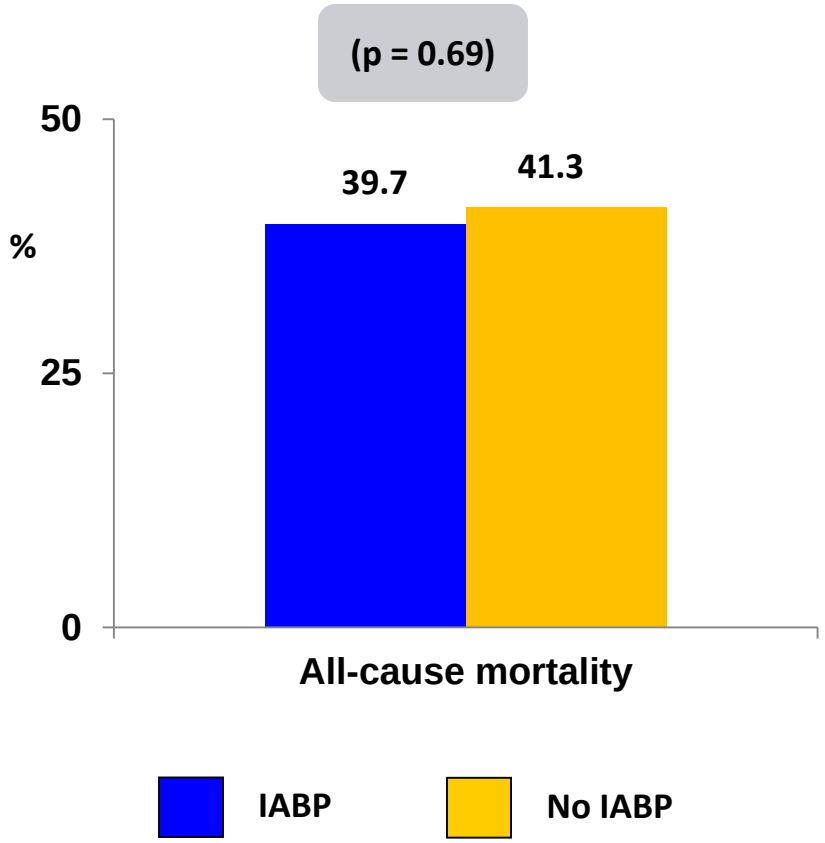
Contemporary Management of Cardiogenic Shock: A Scientific Statement From the American Heart Association, Volume: 136, Issue: 16, Pages: e232-e268, DOI: (10.1161/CIR.0000000000000525)

Allegheny Health Network


Cardiogenic shock
ROSC
Cardiac arrest
Activate shock pager via operator
Acute coronary syndrome
Interventional cardiologist
HF cardiologist
CCU fellow
CCM
+
Shock coordinator
Dr. Tsukashita
Dr. Chakravarthy
Dr. Hadi
Yes
No
Revascularization
No-ROSC
Classification of cardiogenic shock severity
Pre/early
Shock
Severe shock
SBP <100 mmHg
HR 70-100
Normal lactate
Normal mentation
Cool extremities
CI 2.0-2.2
PCWP <20
LVEDP <20
CPO >1.0W
Vasoactive medications
0 or 1 low dose
SBP <90mmHg
HR >100
Lactate >2
Altered mental stat
Cool extremities
CI 1.5-2.0
PCWP >20
LVEDP >20
CPO <1.0W
Vasoactive medicati
1 moderate - high d
20≤VIS<30
SBP <90mmHg
HR >120
Lactate >4
Obtunded
Cool extremities
CI <1.5
PCWP >30
LVEDP >30
CPO <0.6W
Vasoactive medications
2 or more – high dose
VIS≥ 30
VA ECMO
Daily multidisciplinary round/discussion
LV distension
Pulmonary edema
Reassess Clinical/hemodynamic goals q6h
Ecpella (ECMO+Impella)
Not stable to transfer to OR
Unknown neurological recovery
IABP/Impella CP/Tandemhe
Impella 5.0
Revascularization
Escalation of support
Bridge to durable LVAD/heart transplant
Recovery/explant

IABP-SHOCK II

Trial design: Patients with acute myocardial infarction (AMI) and cardiogenic shock were randomized to IABP (n = 301) versus no IABP (n = 299). All patients received early revascularization and best available medical therapy.



Results

- At 30 days, all-cause mortality: 39.7% of the IABP group vs. 41.3% of the no IABP group (p = 0.69)
- Reinfarction: 3.0% vs. 1.3% (p = 0.16)
- Stent thrombosis: 1.3% vs. 1.0% (p = 0.71)
- Major bleeding: 3.3% vs. 4.4% (p = 0.51)
- Peripheral ischemic complications requiring intervention: 4.3% vs. 3.4% (p = 0.53)

Conclusions

- Among patients with AMI and cardiogenic shock, the use of IABP did not reduce mortality
- Overall mortality was slightly lower than expected, which could have contributed to the null finding

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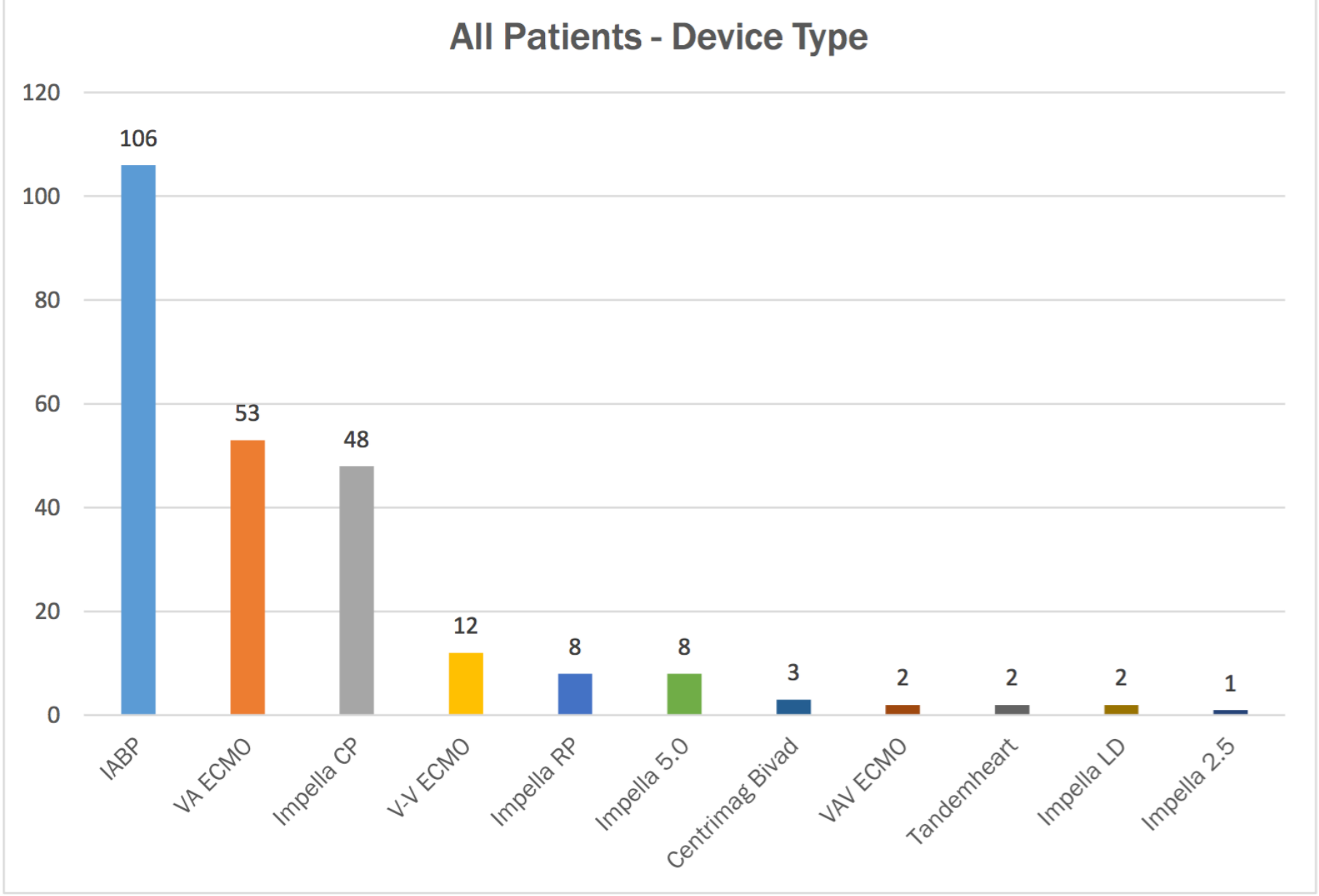
Thiele H, et al. N Engl J Med 2012;367:1287-96



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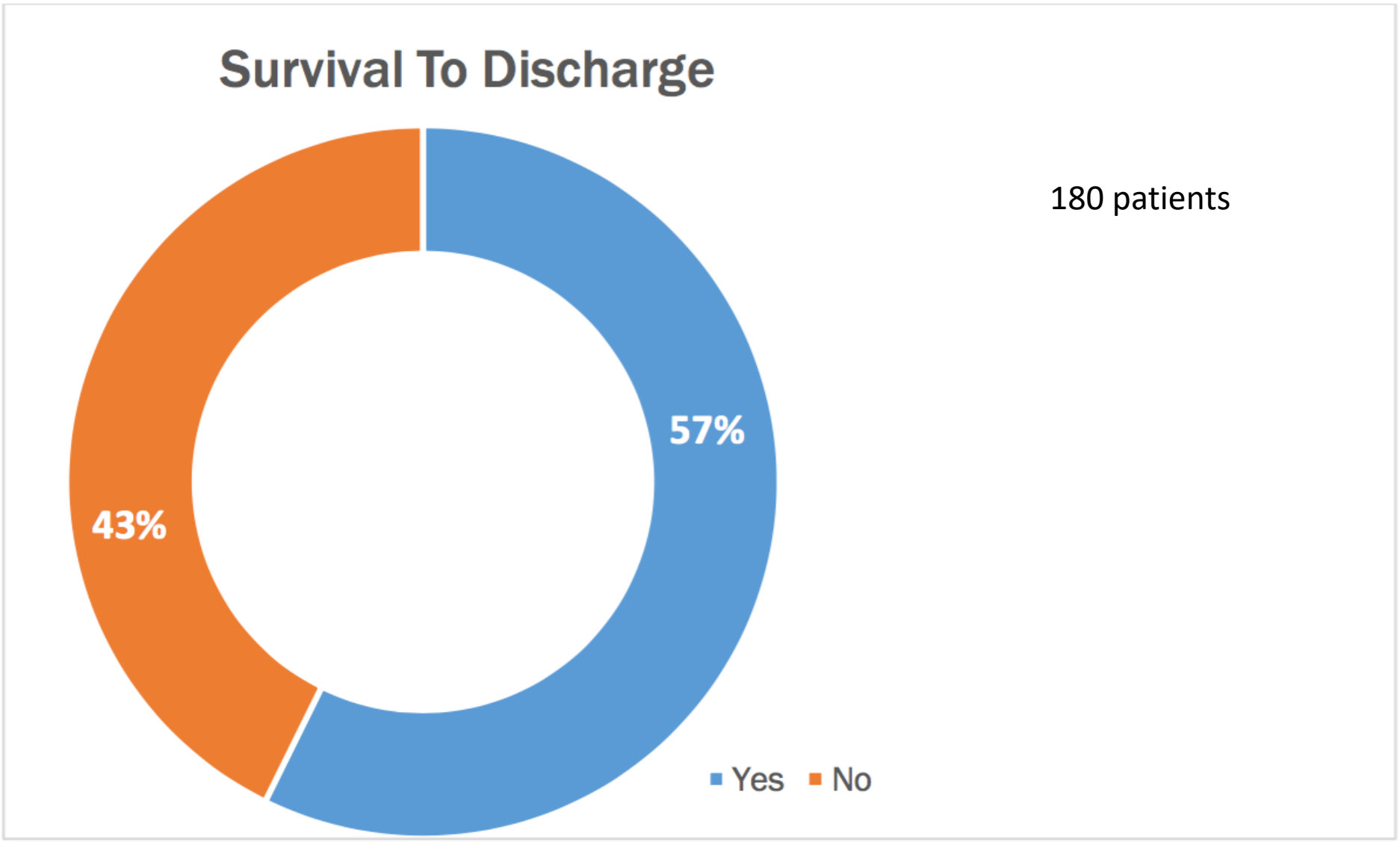
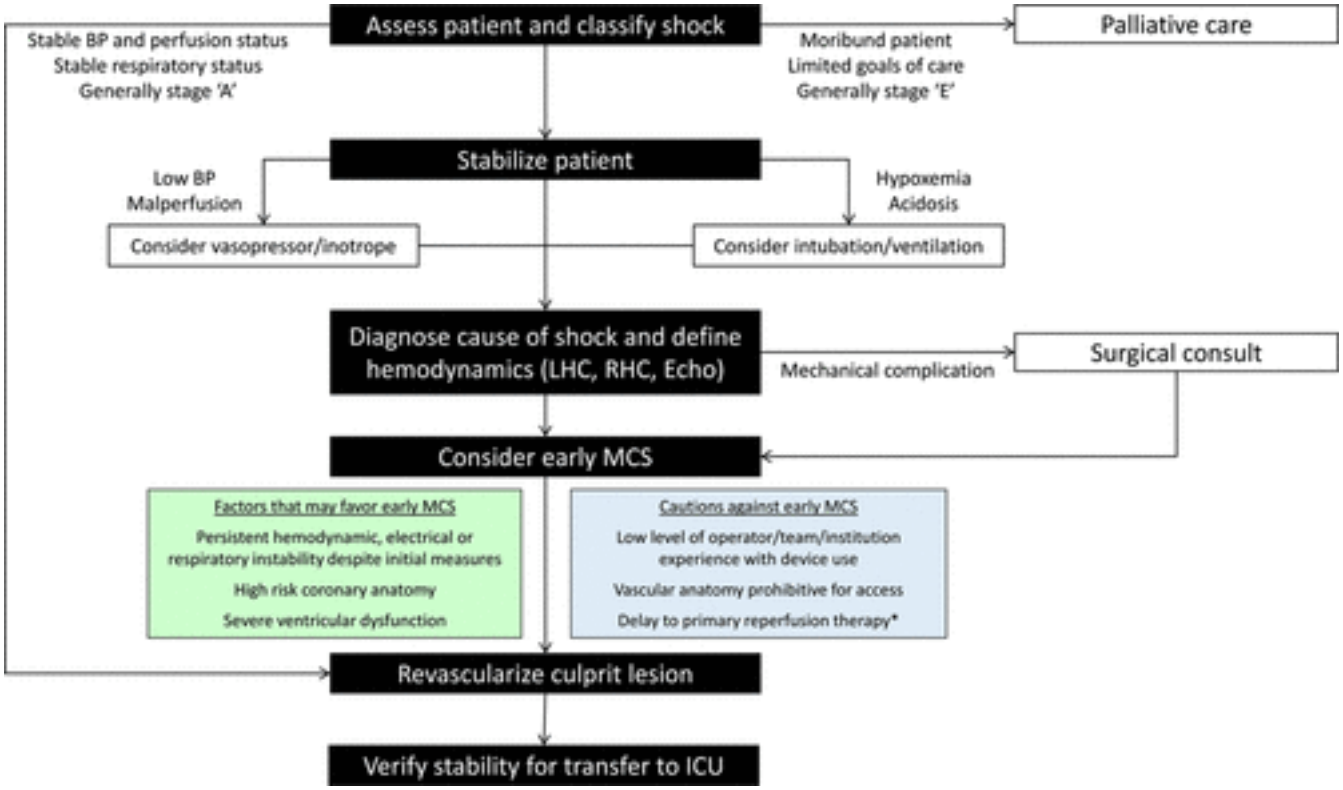
180 patients in 14 months; 64 pts had more than one device

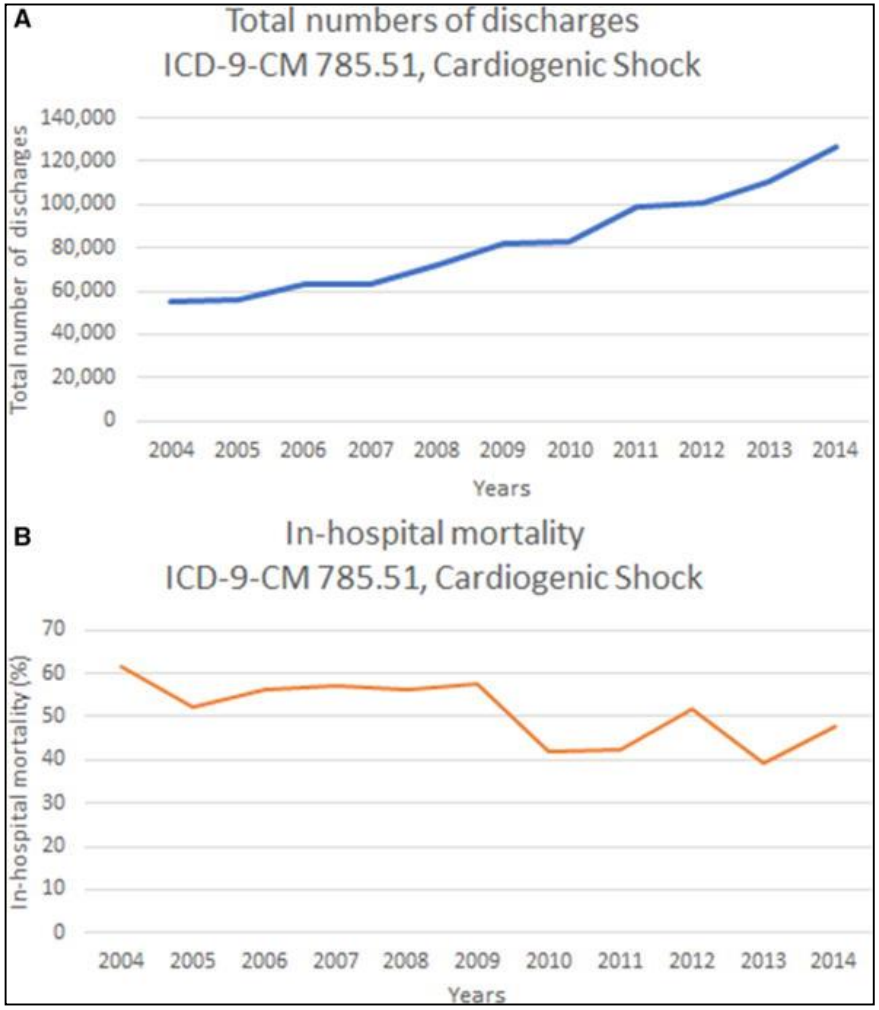


180 patients

Allegheny Health Network



Allegheny Health Network



Percutaneous Mechanical Circulatory Support Devices in Cardiogenic Shock.
Mandawat, Aditya; Rao, Sunil

Circulation: Cardiovascular Interventions. 10(5):e004337, May 2017.
DOI: 10.1161/CIRCINTERVENTIONS.116.004337

2004 to 2014 Nationwide Inpatient Sample databases to identify all patients with cardiogenic shock (CS; International Classification of Diseases-Ninth Revision [ICD-9] CM 785.51). The Mantel-Haenszel X2 test to analyze trends. A, The overall incidence of CS increased from 55 123 discharges in 2004 to 126 555 discharges in 2014 (Ptrend=0.002). B, In-hospital mortality decreased from 62% in 2004 to 48% in 2014 (Ptrend=0.02).

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- PROTECT I
- PROTECT II
- ISAR-SHOCK
- REGISTRY DATA

  (EuroPella & USPella)

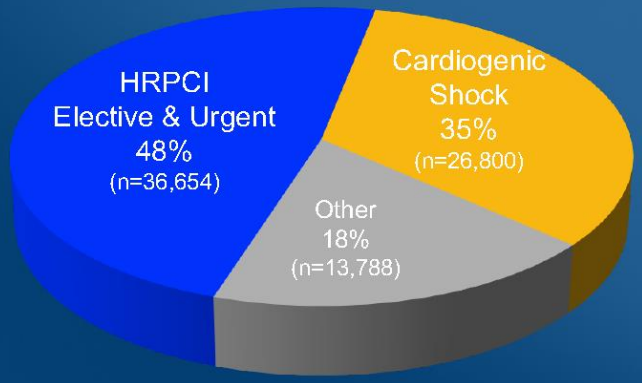
- Did not show survival benefit
- More hemodynamic support

ABIOMED IQ PROGRAM: REAL-WORLD CLINICAL EVIDENCE

MENU

Reported Usage in IQ Database[1]

N=77,242

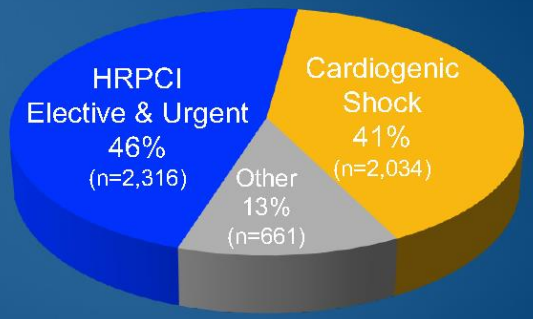


Observational Quality Assurance Database

- IRB Exempt / HIPAA Compliant
- 1,307 US Impella® Centers; 2009-2018
- Reviewed by Abiomed heart team physicians
- All devices, all indications

cVAD Study Data[2]

N=5,011



FDA Pre/Post Market Study

- Prospective study; one year follow-up; academic core labs
- FDA validated/audited for Pre-Market Approval (PMA) & Post-Approval Studies (PAS)
- Used for expansion of FDA indications for device use
- Used to assess best practices adoption & outcomes, and confirm appropriate use of the Impella

1. Abiomed Impella Quality (IQ) Database, Danvers MA
2. cVAD Study Data of Patients Undergoing PCI for Acute Myocardial Infarction Complicated by Cardiogenic Shock as of August 2018

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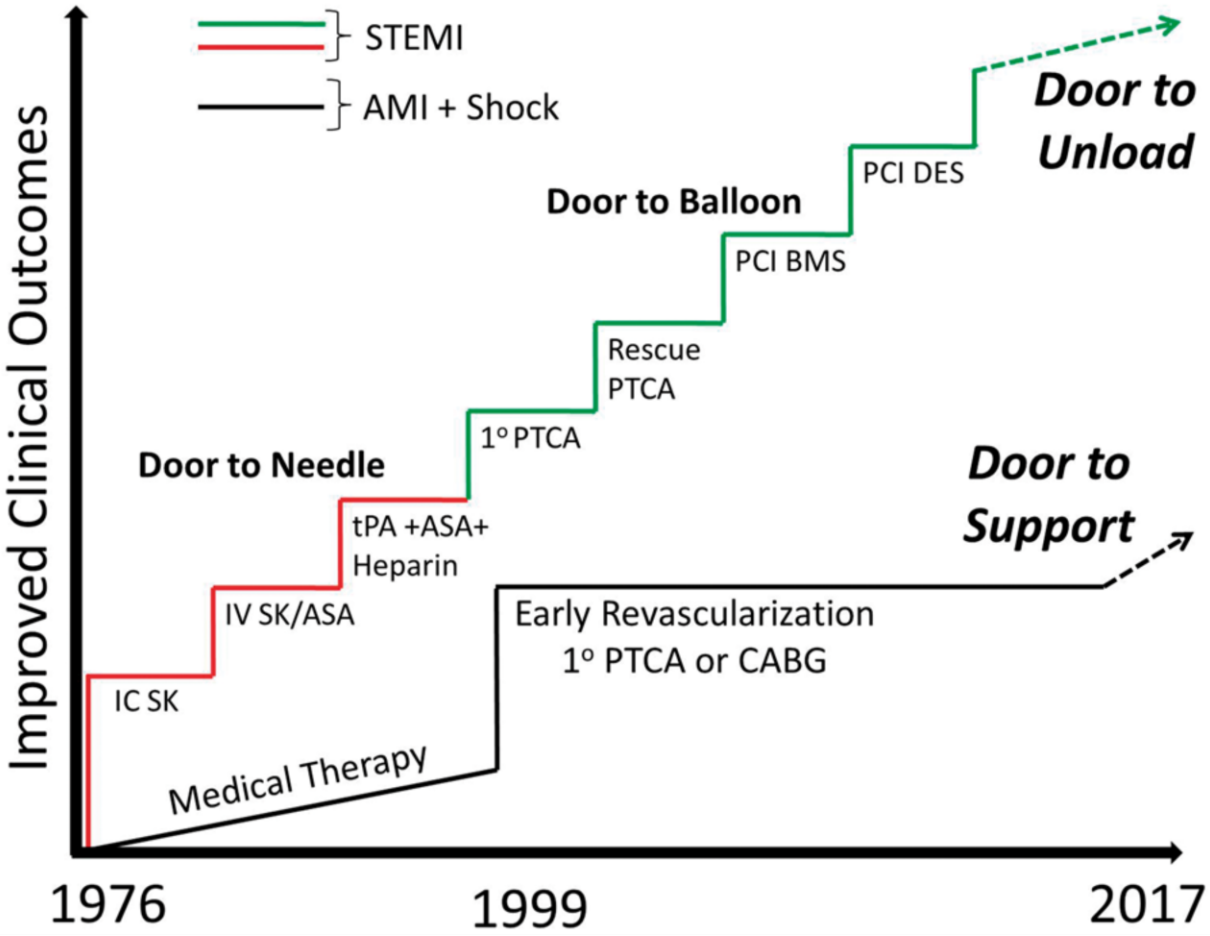

From: Timing, timing, timing: the emerging concept of the 'door to support' time for cardiogenic shock

Eur Heart J. 2017;38(47):3532-3534. doi:10.1093/eurheartj/ehx406

Eur Heart J | Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2017. For permissions, please email: journals.permissions@oup.com.

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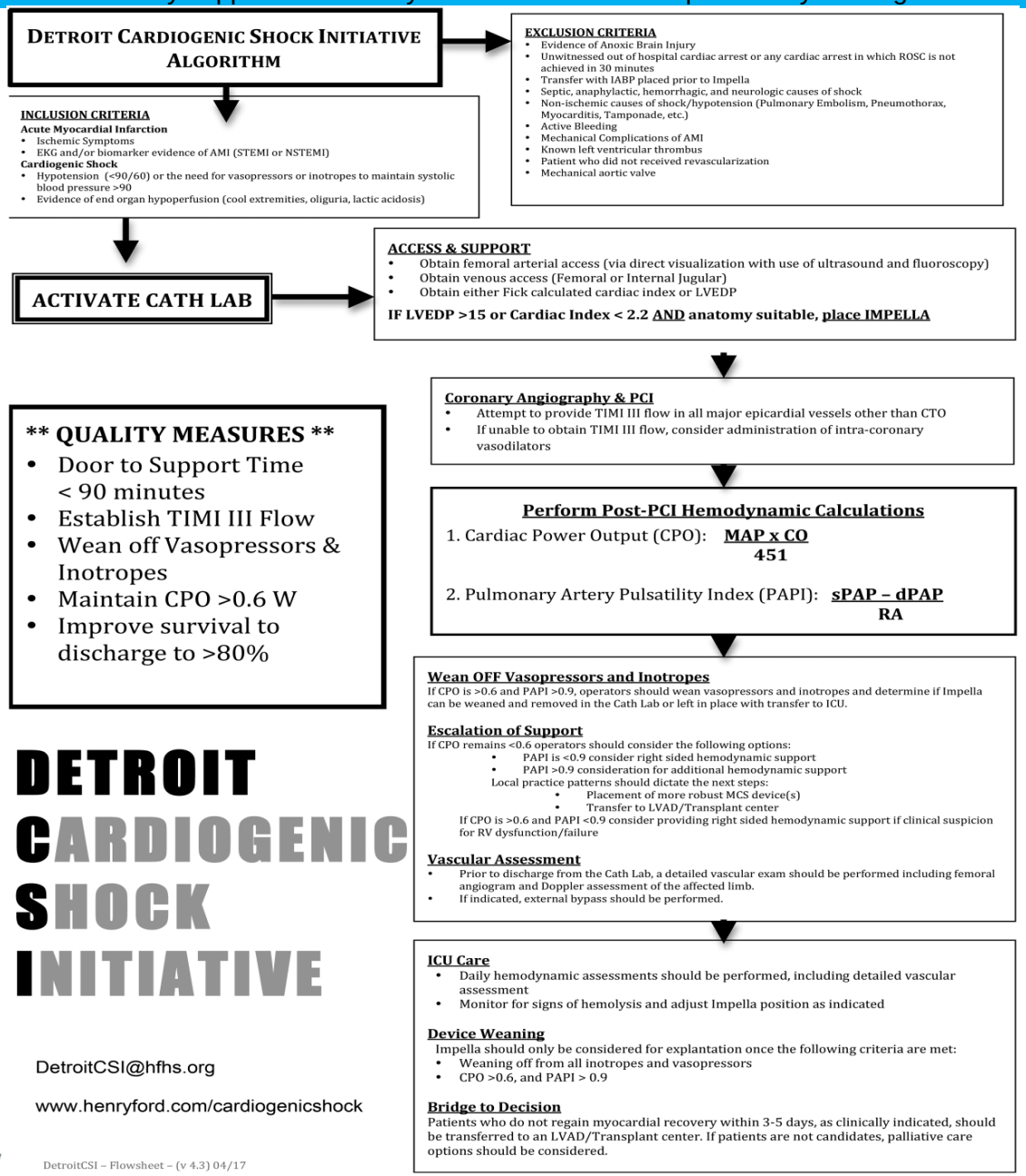
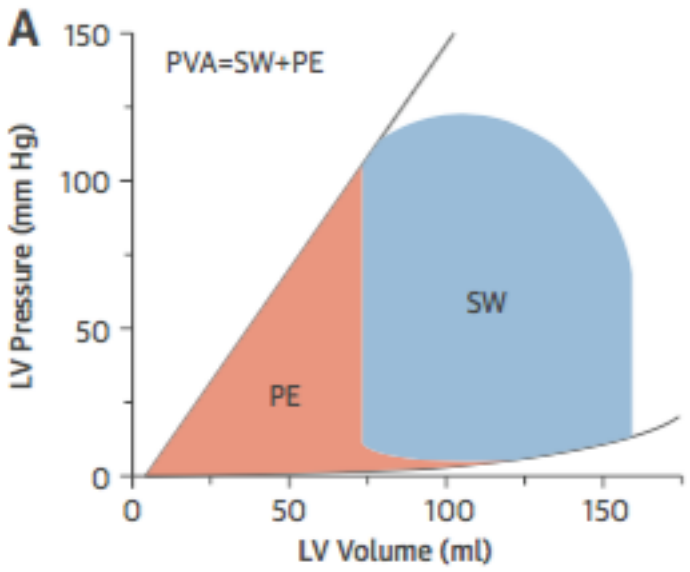
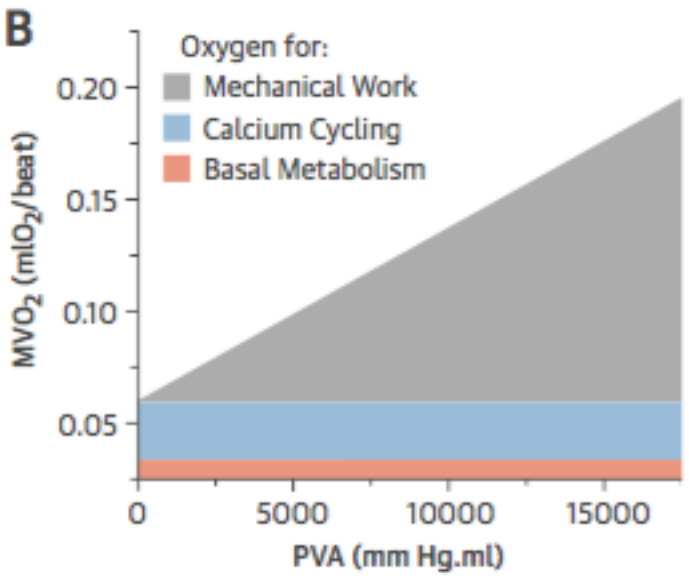
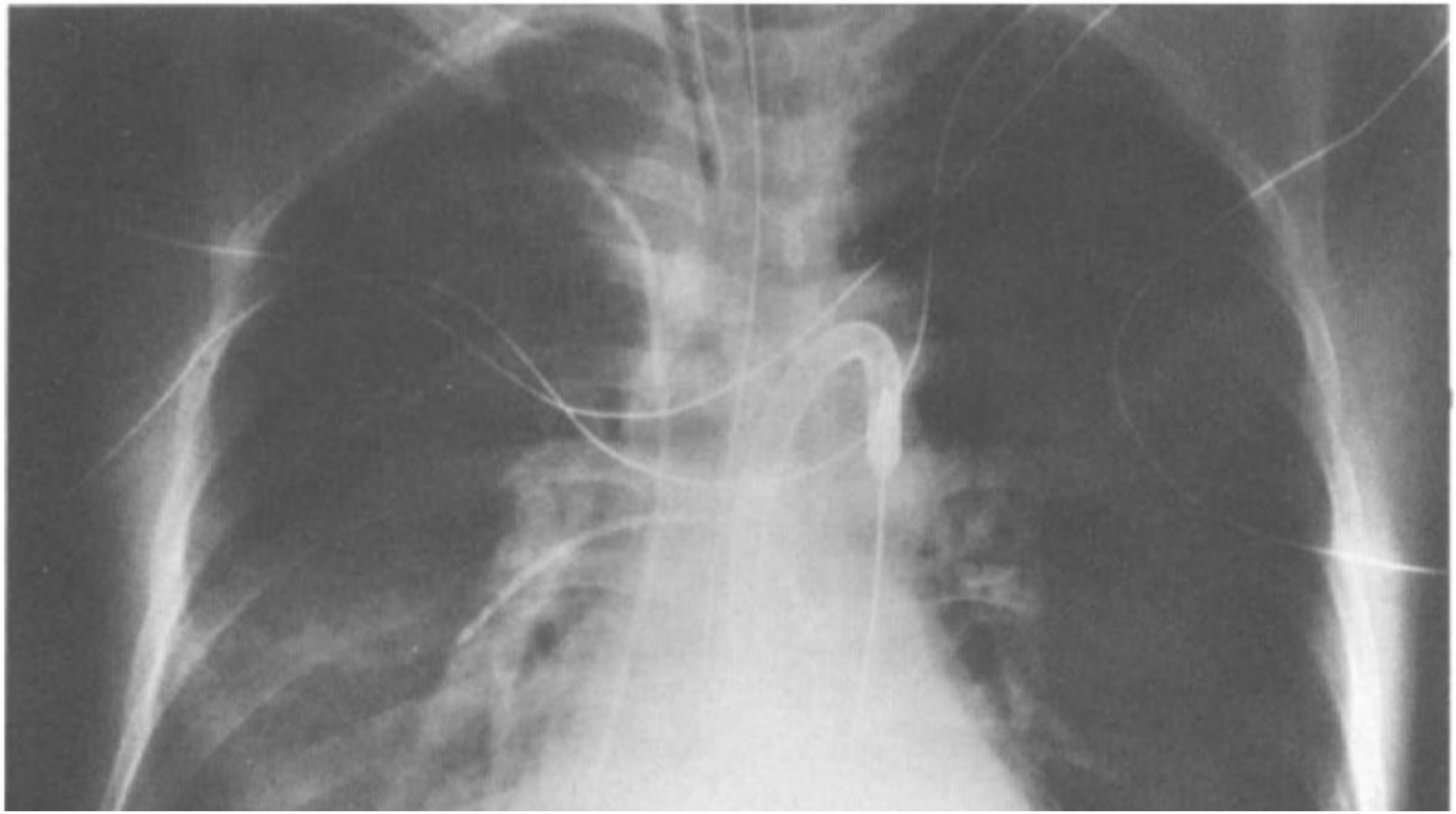

DETROIT CARDIOGENIC SHOCK INITIATIVE ALGORITHM
EXCLUSION CRITERIA
Evidence of Anoxic Brain Injury
Unwitnessed out of hospital cardiac arrest or any cardiac arrest in which ROSC is not achieved in 30 minutes
Transfer with IABP placed prior to Impella
Septic, anaphylactic, hemorrhagic, and neurologic causes of shock
Non-ischemic causes of shock/hypotension (Pulmonary Embolism, Pneumothorax, Myocarditis, Tamponade, etc.)
Active Bleeding
Mechanical Complications of AMI
Known left ventricular thrombus
Patient who did not received revascularization
Mechanical aortic valve
INCLUSION CRITERIA
Acute Myocardial Infarction
Ischemic Symptoms
EKG and/or biomarker evidence of AMI (STEMI or NSTEMI)
Cardiogenic Shock
Hypotension (<90/60) or the need for vasopressors or inotropes to maintain systolic blood pressure >90
Evidence of end organ hypoperfusion (cool extremities, oliguria, lactic acidosis)
ACTIVATE CATH LAB
ACCESS & SUPPORT
Obtain femoral arterial access (via direct visualization with use of ultrasound and fluoroscopy)
Obtain venous access (Femoral or Internal Jugular)
Obtain either Fick calculated cardiac index or LVEDP
IF LVEDP >15 or Cardiac Index < 2.2 AND anatomy suitable, place IMPELLA
** QUALITY MEASURES **
Door to Support Time < 90 minutes
Establish TIMI III Flow
Wean off Vasopressors & Inotropes
Maintain CPO >0.6 W
Improve survival to discharge to >80%
Coronary Angiography & PCI
Attempt to provide TIMI III flow in all major epicardial vessels other than CTO
If unable to obtain TIMI III flow, consider administration of intra-coronary vasodilators
Perform Post-PCI Hemodynamic Calculations
1. Cardiac Power Output (CPO): MAP x CO / 451
2. Pulmonary Artery Pulsatility Index (PAPI): sPAP – dPAP / RA
Wean OFF Vasopressors and Inotropes
If CPO is >0.6 and PAPI >0.9, operators should wean vasopressors and inotropes and determine if Impella can be weaned and removed in the Cath Lab or left in place with transfer to ICU.
Escalation of Support
If CPO remains <0.6 operators should consider the following options:
PAPI is <0.9 consider right sided hemodynamic support
PAPI >0.9 consideration for additional hemodynamic support
Local practice patterns should dictate the next steps:
Placement of more robust MCS device(s)
Transfer to LVAD/Transplant center
If CPO is >0.6 and PAPI <0.9 consider providing right sided hemodynamic support if clinical suspicion for RV dysfunction/failure
Vascular Assessment
Prior to discharge from the Cath Lab, a detailed vascular exam should be performed including femoral angiogram and Doppler assessment of the affected limb.
If indicated, external bypass should be performed.
DETROIT CARDIOGENIC SHOCK INITIATIVE
DetroitCSI@hfhs.org
www.henryford.com/cardiogenicshock
ICU Care
Daily hemodynamic assessments should be performed, including detailed vascular assessment
Monitor for signs of hemolysis and adjust Impella position as indicated
Device Weaning
Impella should only be considered for explantation once the following criteria are met:
Weaning off from all inotropes and vasopressors
CPO >0.6, and PAPI > 0.9
Bridge to Decision
Patients who do not regain myocardial recovery within 3-5 days, as clinically indicated, should be transferred to an LVAD/Transplant center. If patients are not candidates, palliative care options should be considered.
DetroitCSI – Flowsheet – (v 4.3) 04/17





(A) Pressure-volume area (PVA) is the sum of the stroke work (SW) and potential energy (PE). **(B)** Myocardial oxygen consumption (MVO_2) is linearly correlated with PVA and is divided into 3 major components, as indicated in the figure. LV = left ventricular.

Burkhoff, D., G. Sayer, D. Doshi and N. Uriel (2015). "Hemodynamics of Mechanical Circulatory Support." J Am Coll Cardiol **66**(23): 2663-2674.



First Human Use of the Hemopump, a Catheter-Mounted Ventricular Assist Device

O. H. Frazier, MD, Richard K. Wampler, MD, J. Michael Duncan, MD,
Wayne E. Dear, MD, Michael P. Macris, MD, Steven M. Parnis, and John M. Fuqua, BS

Cullen Cardiovascular Surgical Research Laboratories and the Cardiac Catheterization Laboratory, Texas Heart Institute/St. Luke's Episcopal Hospital, Houston, Texas, and Nimbus Medical, Inc, Rancho Cordova, California

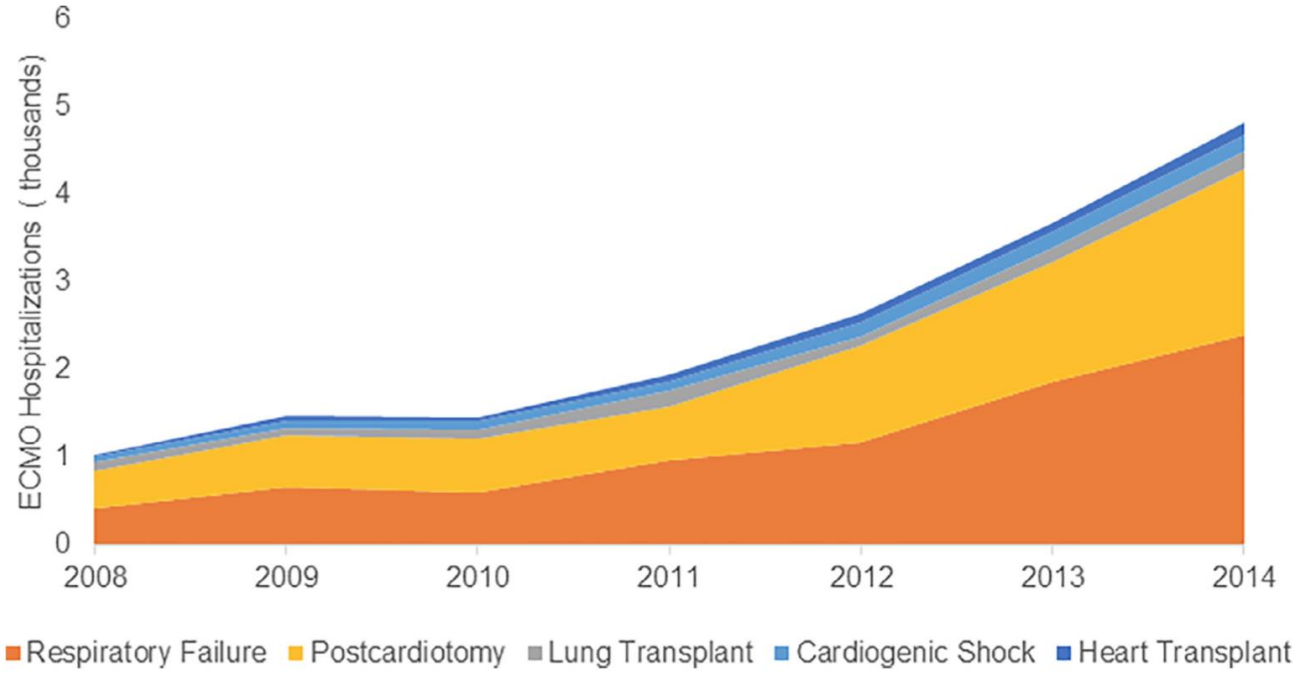
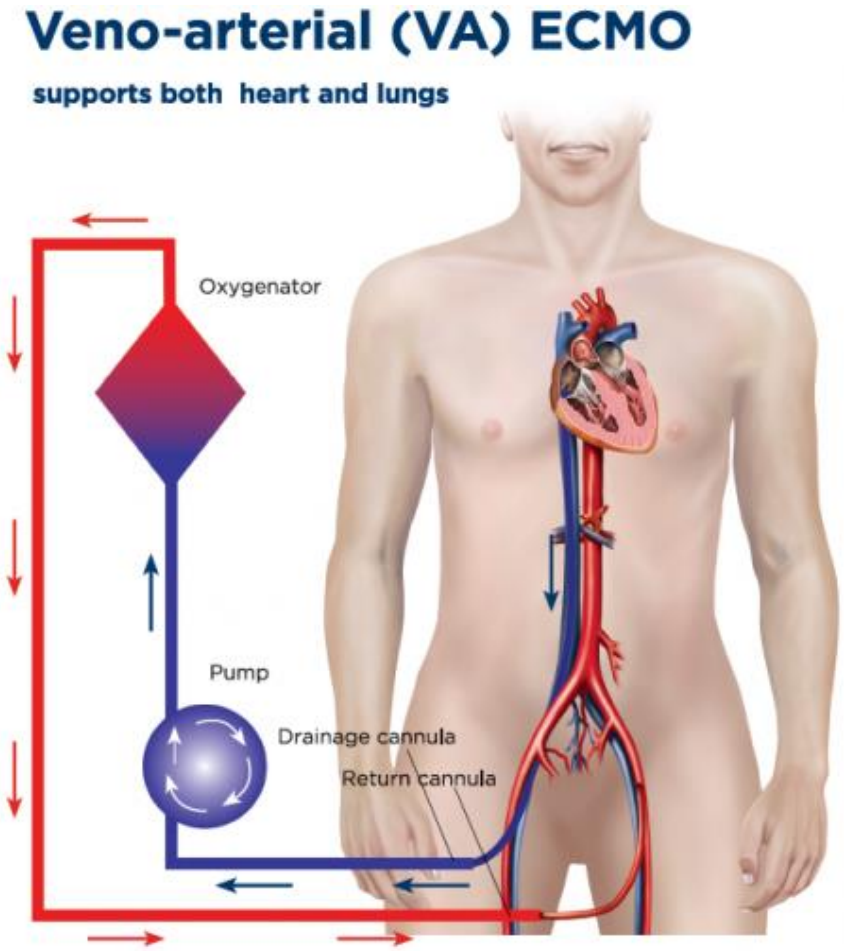


Fig. 1. Temporal trends by indication for ECMO in the United States, 2008–2014.

ECMO



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Acute hemodynamic compromise/cardiogenic shock

- SBP <90mm Hg
- Drop in MAP 30 mm Hg below baseline
- CI <1.8 L/min/m2 without hemodynamic support
- CI <2.2 L/min/m2 with hemodynamic support
- PCWP >15

Circulatory support during procedures

- High risk PCI
- High risk ablation