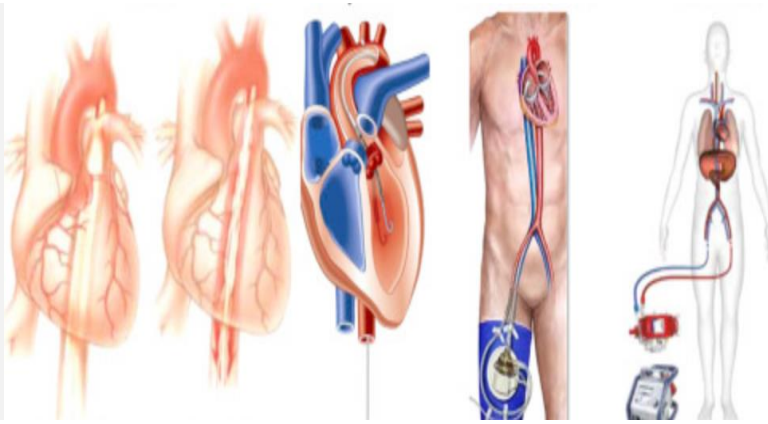
Cardiogenic Shock
Heart Team Approach to Management



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Disclosures

- Consultant: Medtronic, Abiomed

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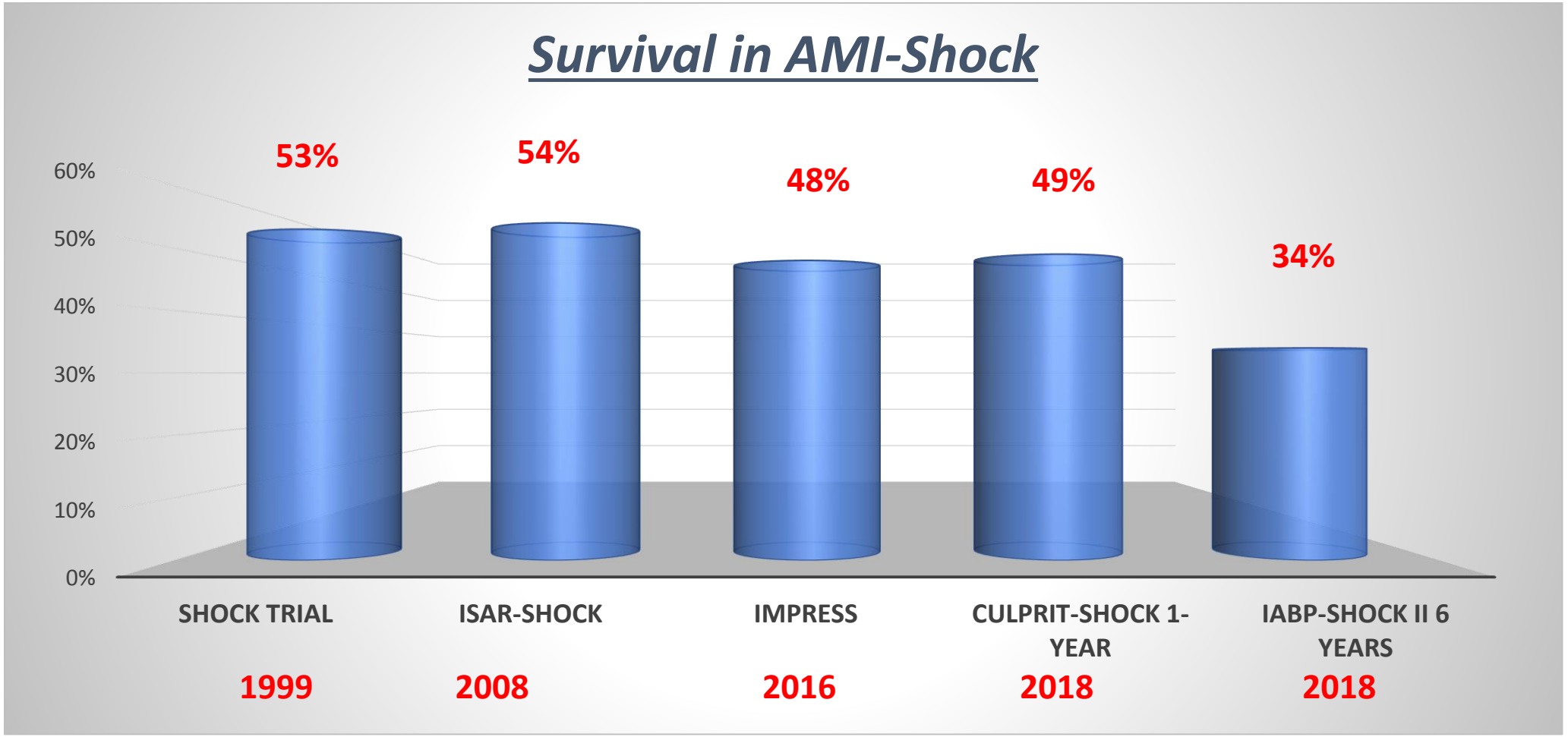
Overview – Nearly Two Decades of Poor Outcomes



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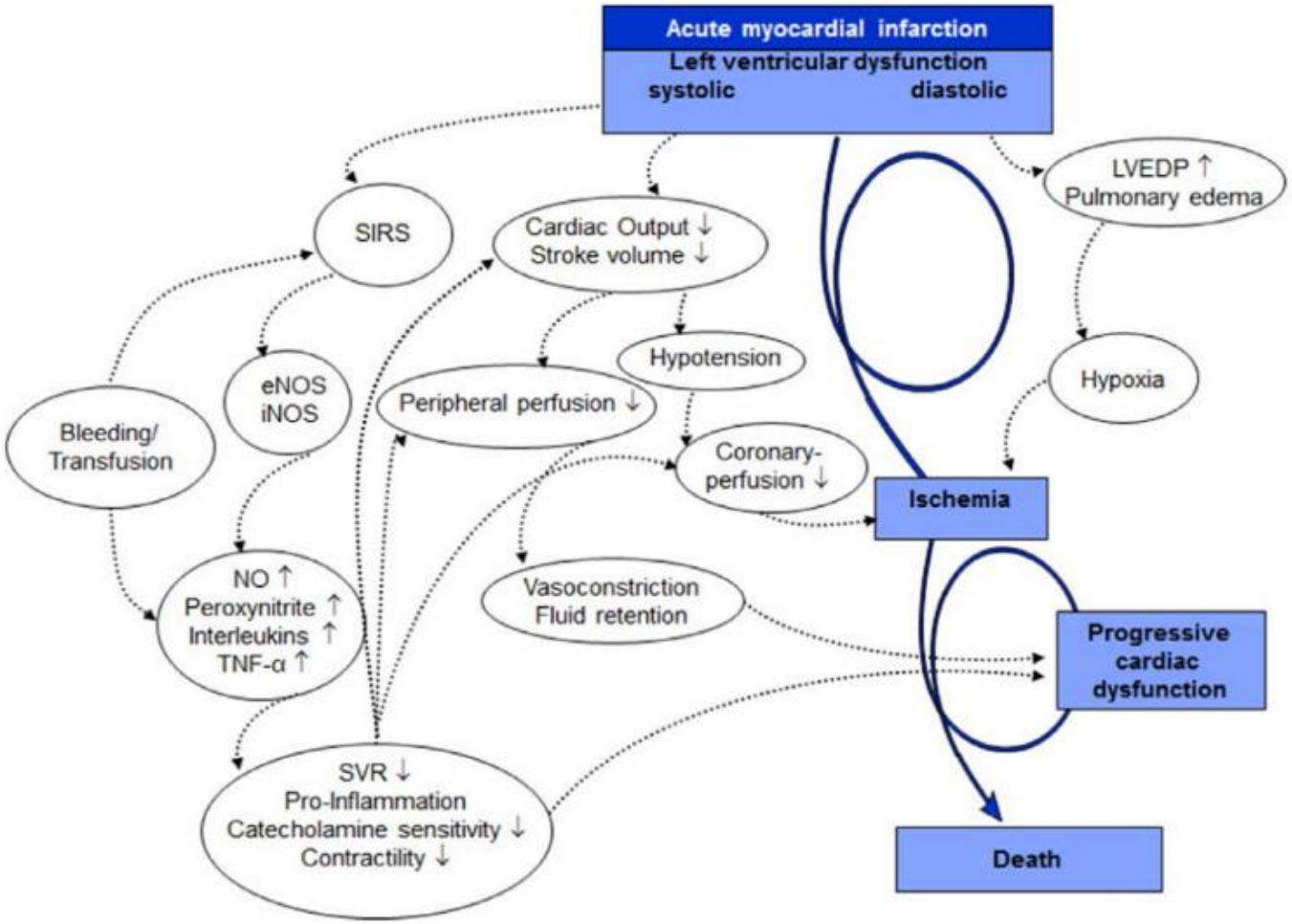
Proverbial “Death Spiral” of CS

Coronary Problem

Ventricular Failure

Vascular Response



Van Diepen et al. *Circulation* 2017;136:e232-e268

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Scope of Problem - High Morbidity and Mortality

Lifeline STEMI Systems Accelerator Project

TABLE 2 In-Hospital Outcomes Stratified by CS

	No-CS	CS	p Value
Post-admission reinfarction	0.9 (184)	1.3 (25)	<0.001
Heart failure at discharge	5.4 (1,184)	15.3 (303)	<0.001
Bleeding event	3.7 (802)	11.0 (218)	<0.001
Stroke	0.6 (137)	2.5 (49)	<0.001
Mortality	3.5 (754)	34.4 (686)	<0.001

Values are % (n).

CS = cardiogenic shock.

Kochar A et al. *JACC Cardiovascular Interventions* 2018; 11(18):1824-1833

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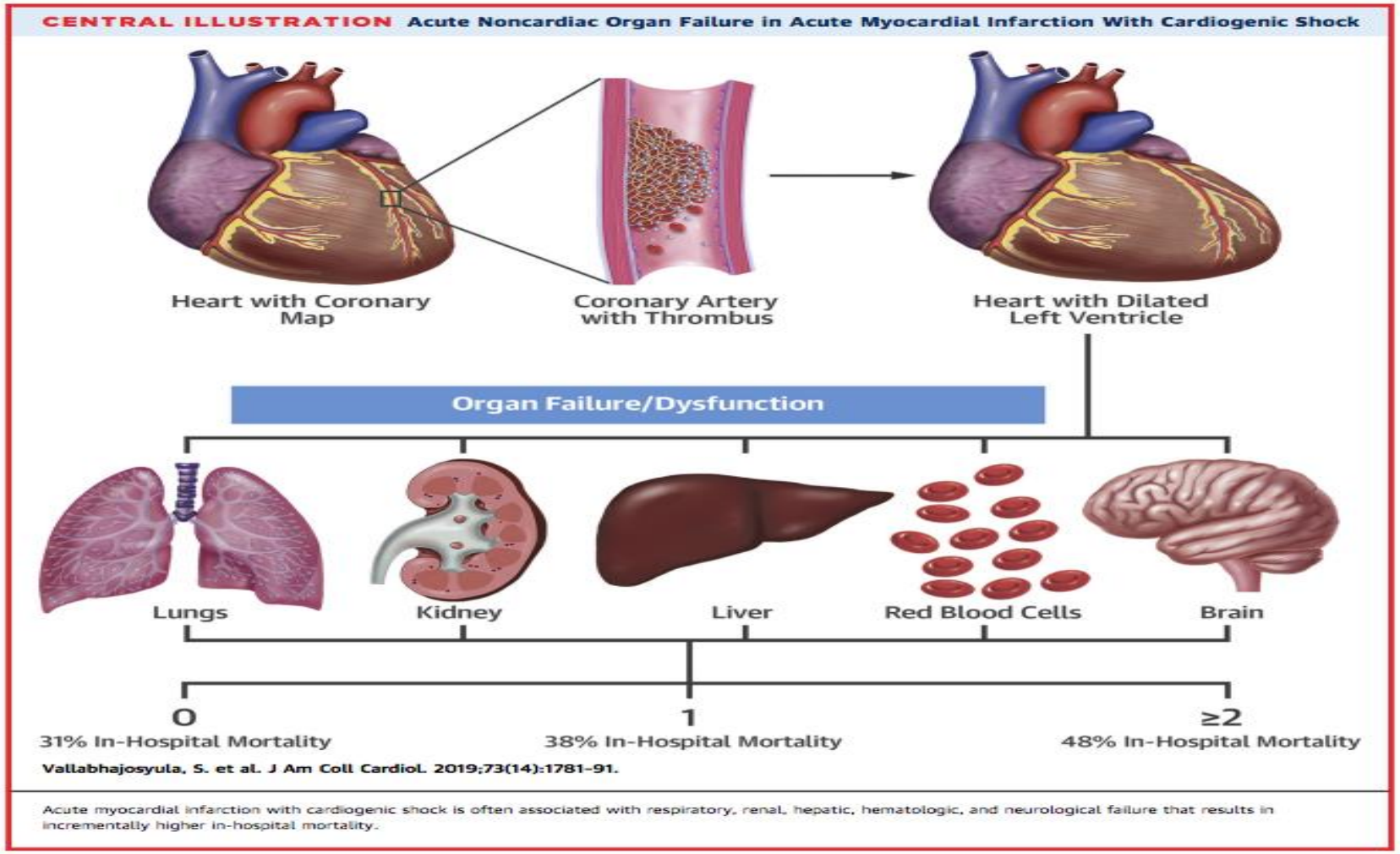
Scope of Problem: End-Organ Failure



Vallabhajosyula S et al. JACC 2019;73:1781-91

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Scope of Problem – Practice Variations

Procedure	Quartile 1 (N=937)	Quartile 2 (N=3328)	Quartile 3 (N=3284)	Quartile 4 (N=1580)	*P* Value*
Coronary angiography—n (%)	440 (47.0)	1852 (55.6)	2132 (65.0)	1165 (73.7)	<0.001
Percutaneous coronary intervention—n (%)	335 (35.8)	1256 (37.8)	1448 (44.1)	822 (52.0)	<0.001
Coronary artery bypass grafting—n (%)	38 (4.1)	446 (13.4)	545 (16.6)	309 (19.6)	<0.001
Total revascularization—n (%)	373 (39.8)	1702 (51.1)	1993 (60.7)	1131 (71.6)	<0.001
Right heart catheterization—n (%)	13 (1.4)	126 (3.8)	143 (4.4)	93 (5.9)	<0.001

Procedure	Quartile 1 (N=937)	Quartile 2 (N=3328)	Quartile 3 (N=3284)	Quartile 4 (N=1580)	*P* Value*
ND-MCS (percutaneous)—n (%)	0.0 (0.0)	82 (2.5)	160 (4.9)	110 (6.7)	< 0.001
ND-MCS (nonpercutaneous)—n (%)	0 (0.0)	†	†	†	0.51
IABP—n (%)	0 (0.0)	628 (18.9)	1234 (37.6)	946 (59.9)	< 0.001
ECMO—n (%)	0 (0.0)	48 (1.4)	50 (1.5)	35 (2.2)	< 0.001
PCPS—n (%)	0 (0.0)	†	†	†	0.72

Strom JB et al. Circulation Cardiovascular Interventions 2019

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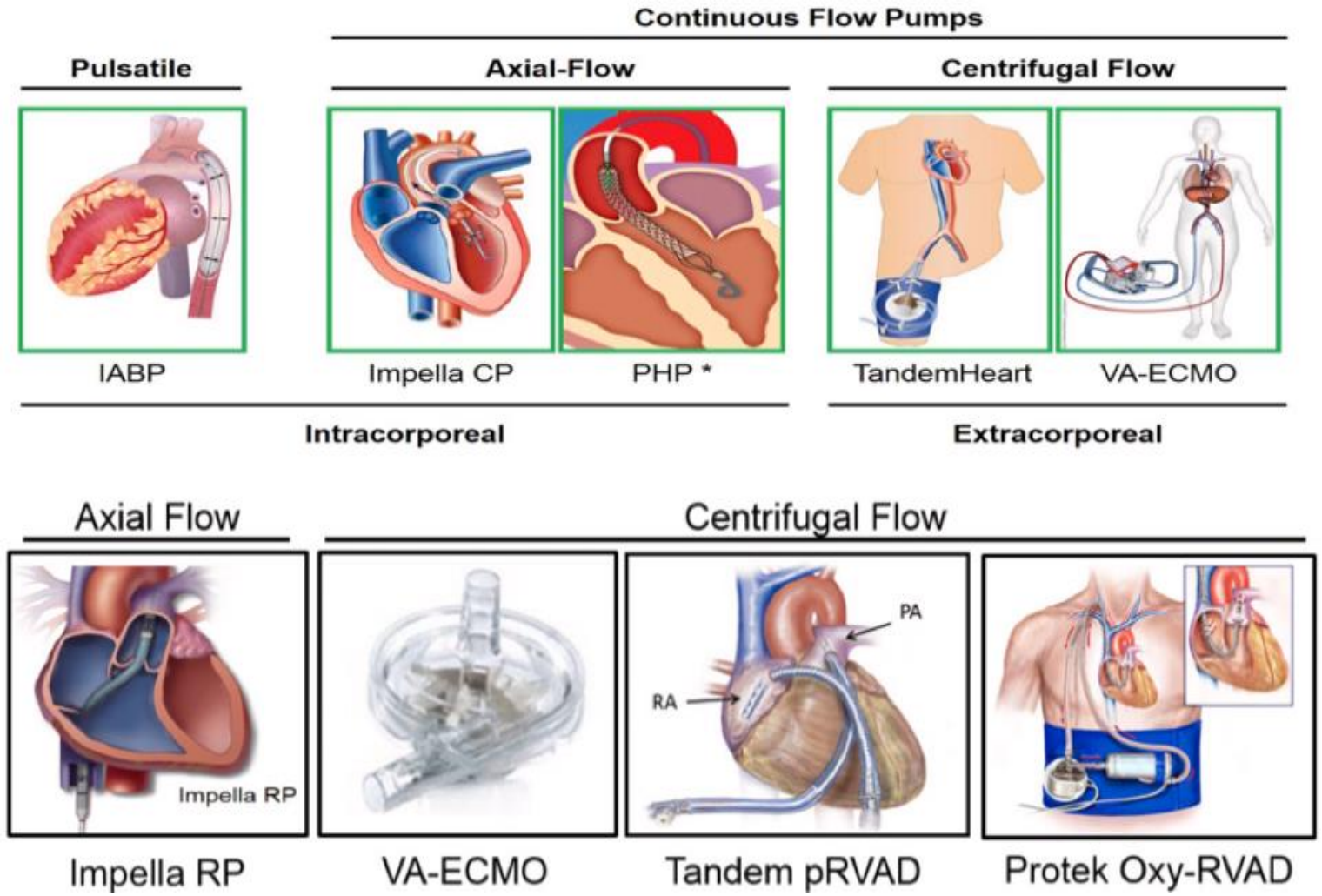
Current State: Spectrum of Acute MCS



Kapur et al F1000 Research 2017

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IABP– Minimal Hemodynamic & No Mortality Benefit

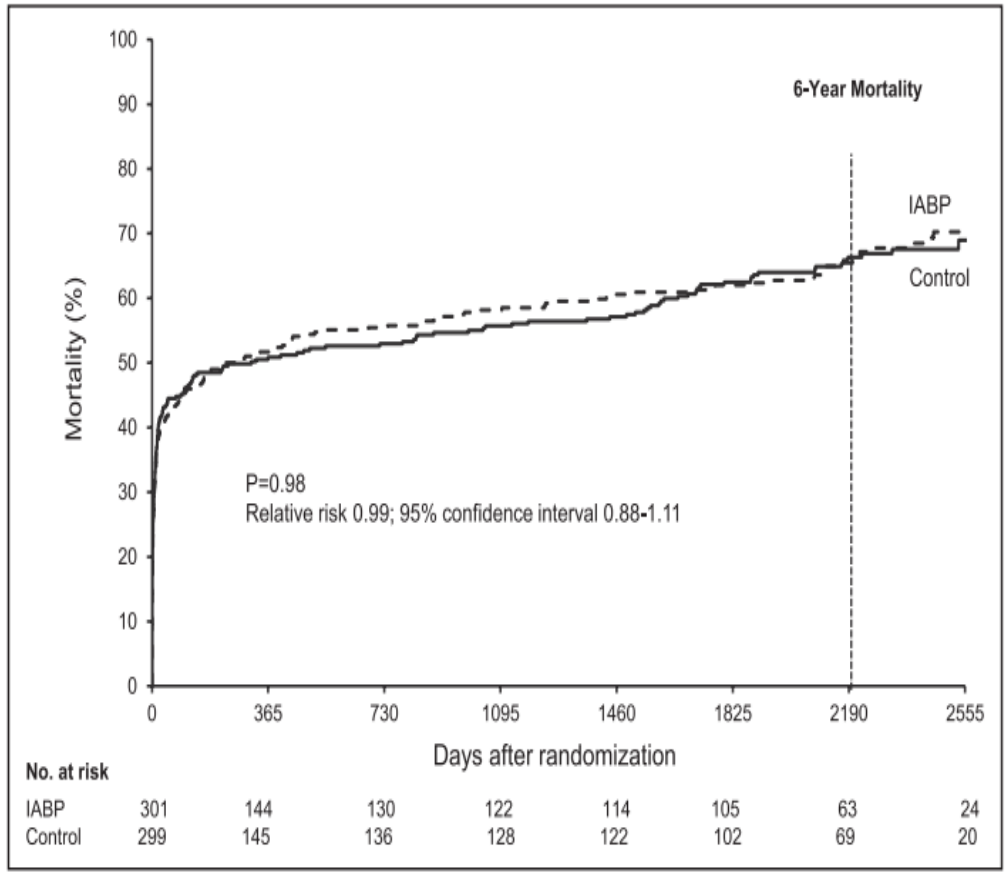

Table 1. Clinical Outcomes at 6 Years

Variable	Intraaortic Balloon Pump (n=297)	Control (n=294)	Relative Risk (95% CI)	*P* Value
All-cause mortality	197/297 (66.3)	197/294 (67.0)	0.99 (0.88–1.11)	0.98
Events in 6-year survivors				
Reinfarction	9/100 (9.0)	7/97 (7.2)	1.25 (0.48–3.22)	0.65
Stroke	1/100 (1.0)	6/97 (6.2)	0.16 (0.02–1.32)	0.06
Recurrent revascularization	26/100 (26.0)	31/97 (32.0)	0.81 (0.52–1.26)	0.36
Repeat percutaneous coronary intervention	18/100 (18.0)	26/97 (26.8)	0.67 (0.39–1.14)	0.14
Additional coronary artery bypass grafting	8/100 (8.0)	7/97 (7.2)	1.11 (0.42–2.94)	0.84
Implantable cardioverter defibrillator implantation	13/100 (13.0)	15/97 (15.5)	0.84 (0.42–1.67)	0.62

Thiele H et al. *Circulation* 2018

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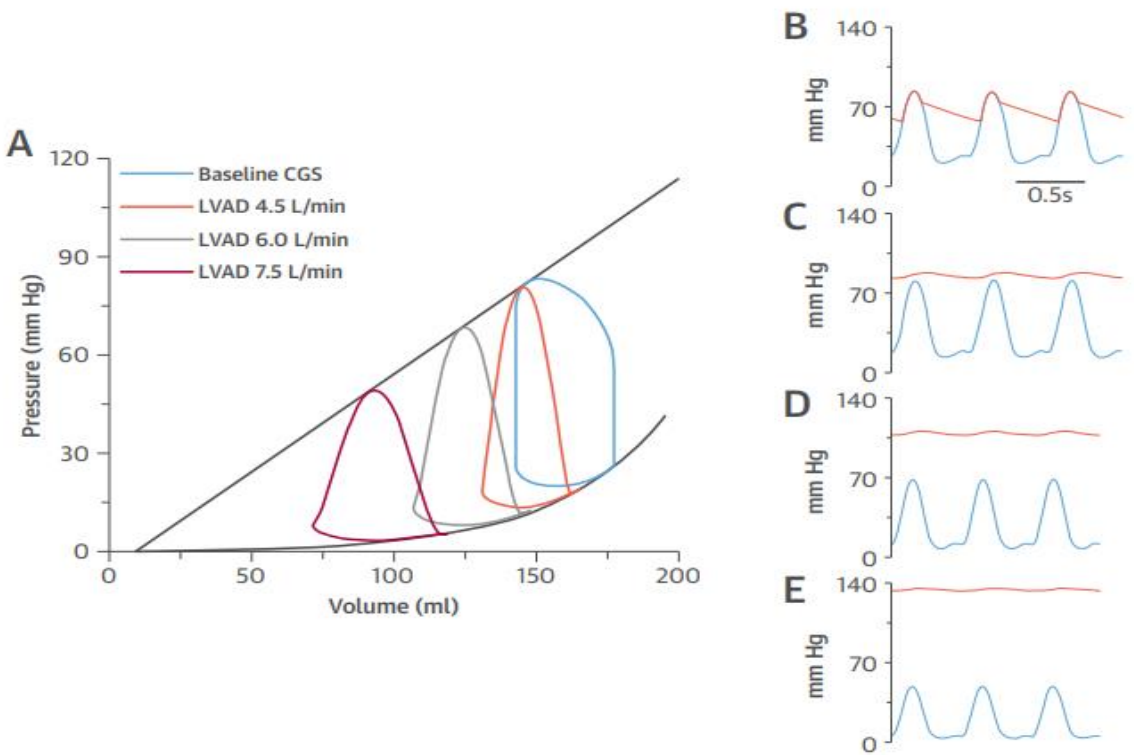
LV-Aortic Axial Flow: Impella

FIGURE 6 Ventricular Effects of LV-to-Arterial MCS



(A) Flow-dependent changes of the pressure-volume loop with LV-to-aortic pumping. The loop becomes triangular and shifts progressively leftward (indicating increasing degrees of LV unloading). Corresponding LV and aortic pressure waveforms at baseline **(B)**, 4.5 l/min **(C)**, 6.0 l/min **(D)** and 7.5 l/min **(E)**. With increased flow, there are greater degrees of LV unloading and uncoupling between aortic and peak LV pressure generation. LVAD = left ventricular assist device; other abbreviations as in Figures 1, 4, and 5.

Burkhoff et al. JACC 2015; 66(23): 2664-74

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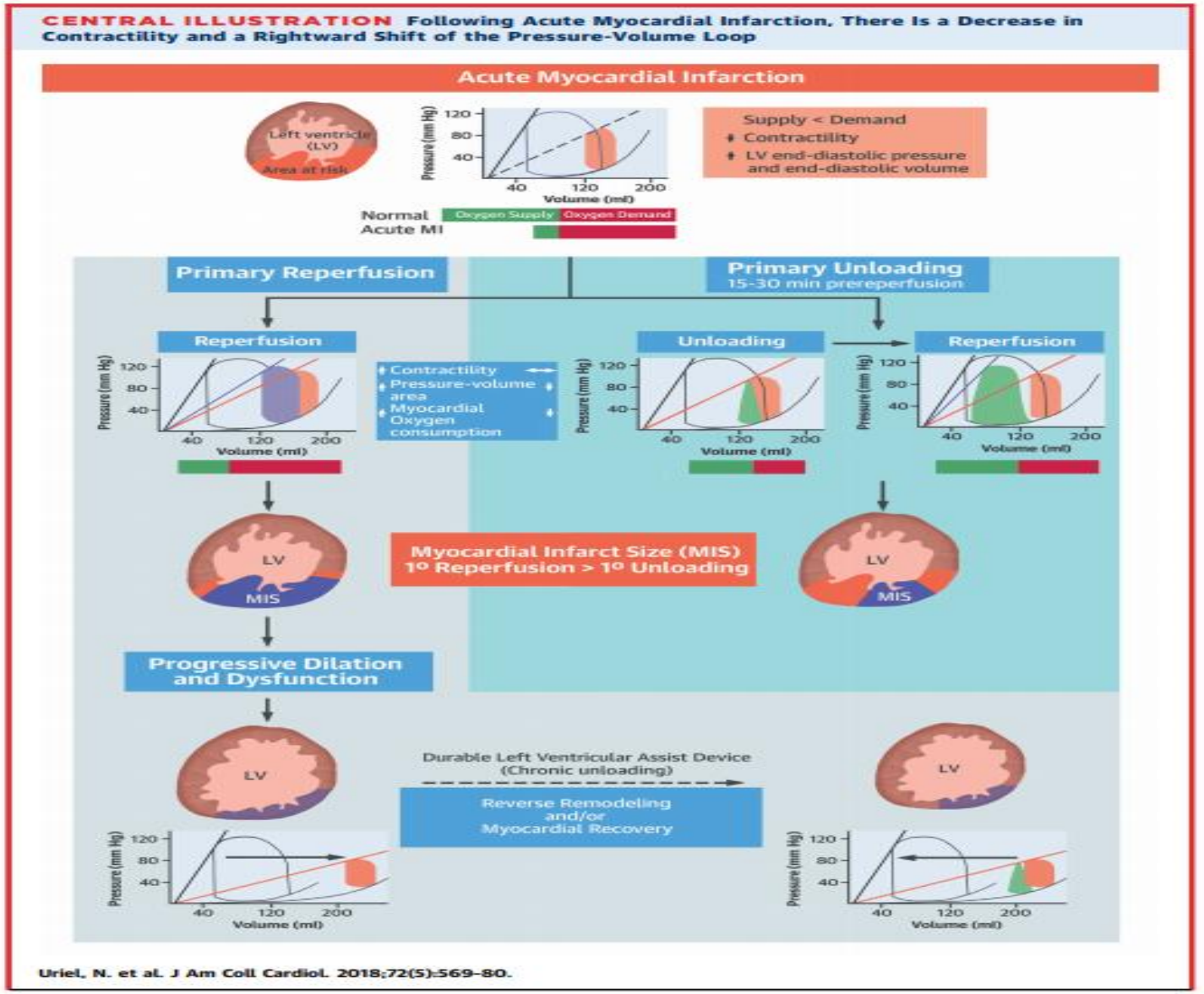
D2U vs D2B



Uriel, N. et al. J Am Coll Cardiol. 2018;72(5):569-80.

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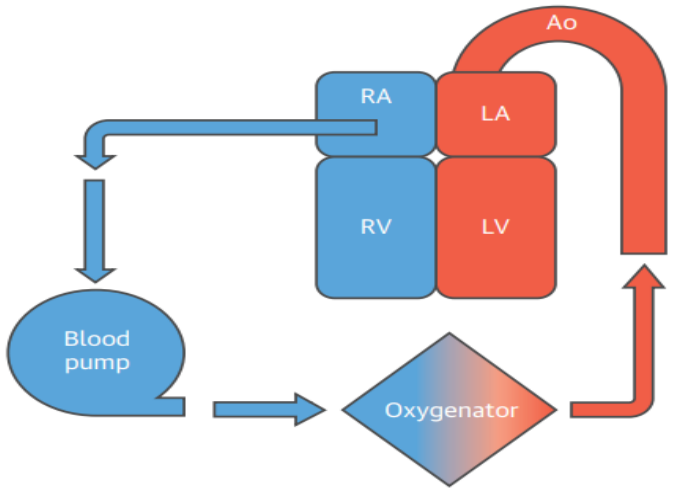
VA-ECMO

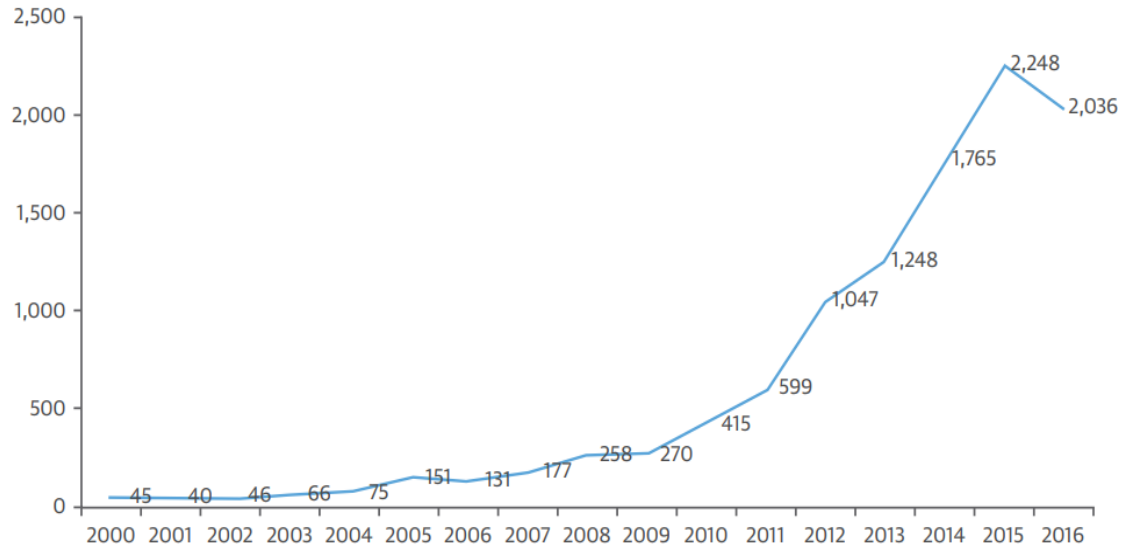
- Implemenation of 2018 UNOS donor allocation system : priority determined primarily by hemodynamic status – priority given to pts on ECMO.

FIGURE 2 Venoarterial Extracorporeal Membrane Oxygenation Circuit



A centrifugal pump withdraws desaturated blood from the right atrium with nonpulsatile pump outflow directed toward the membrane oxygenator then guided via an outflow cannula to a systemic artery. Reprinted with permission from Kapur and Zisa (7). Ao = aorta; LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

FIGURE 1 Growth of Adult Cardiac Extracorporeal Membrane Oxygenation Runs



Graph depicting the increase the number of adult cardiac extracorporeal membrane oxygenation runs. There was an increase of 1,180% in the last decade. There were <200 runs/year between 1997 and 2007, increasing to >2,000 runs/year in 2014 to 2016. Data are from the Extracorporeal Life Support Organization (2).

Guglin M et al. JACC 2019;73(6):698-716

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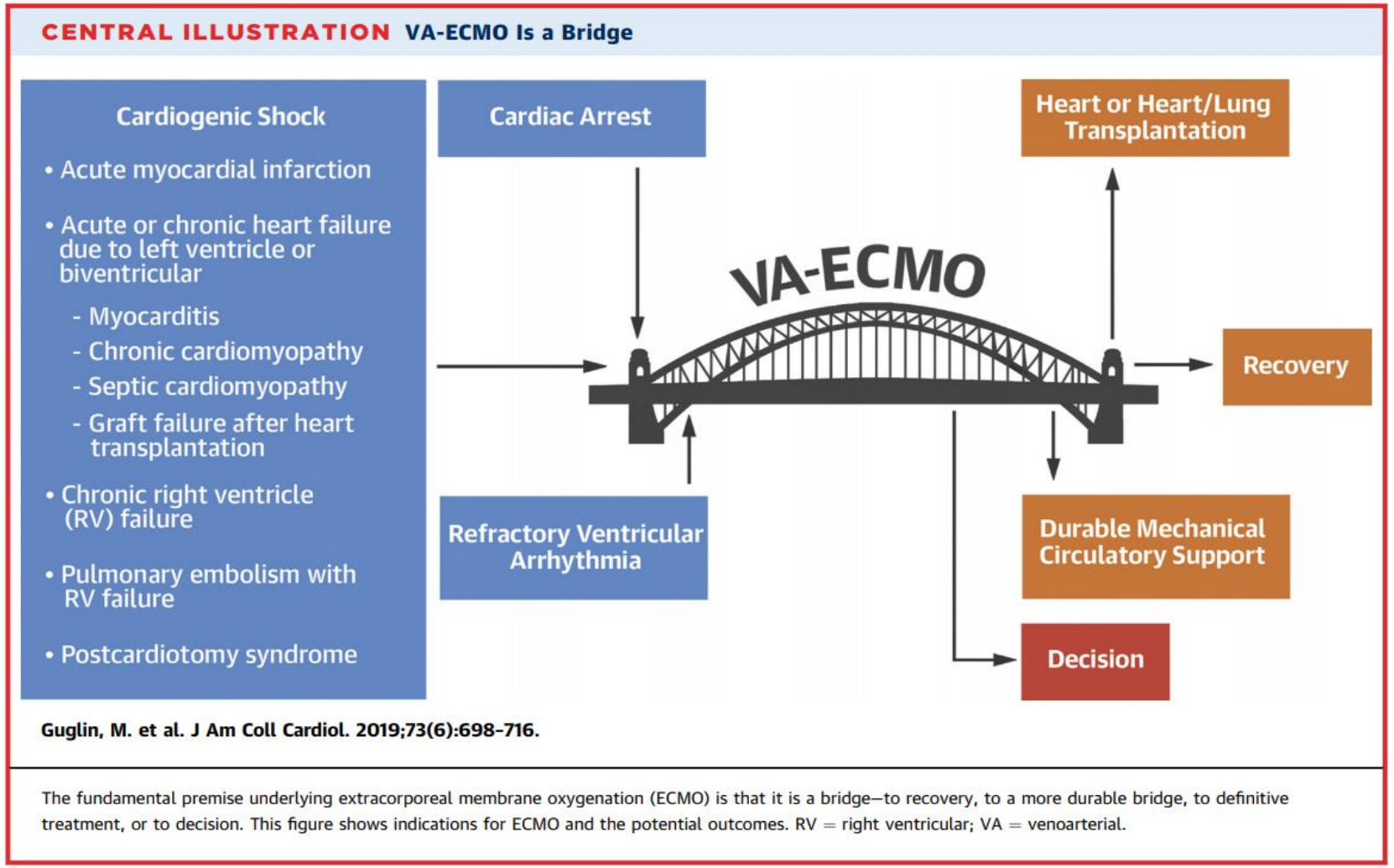
VA-ECMO



Guglin M et al. JACC 2019;73(6):698-716

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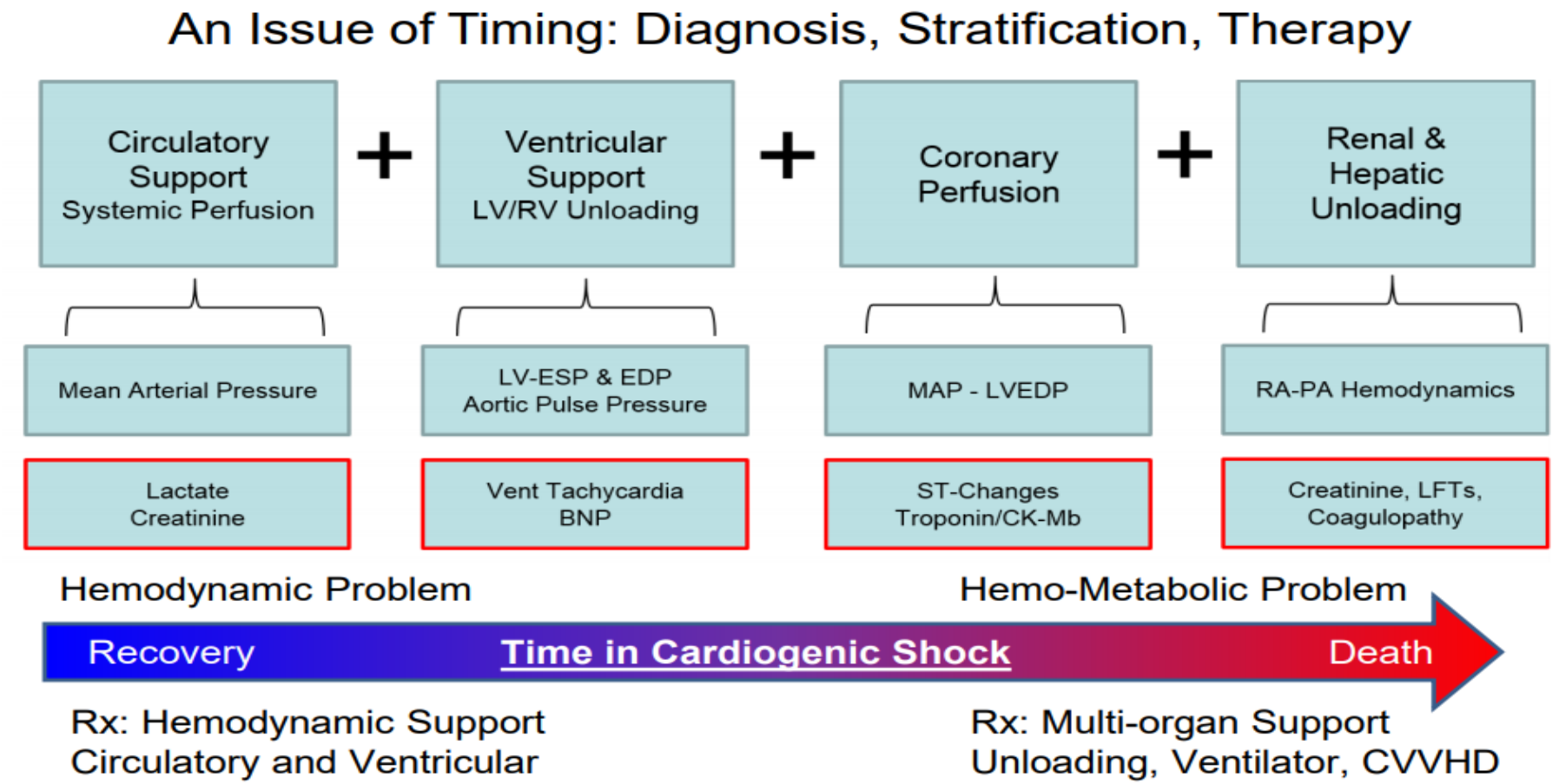
Hemodynamic Support Equation



Kapur and Esposito Curr Cardio Risk 2016

Kapur and Esposito F1000 2017

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VA-ECMO - LV Venting

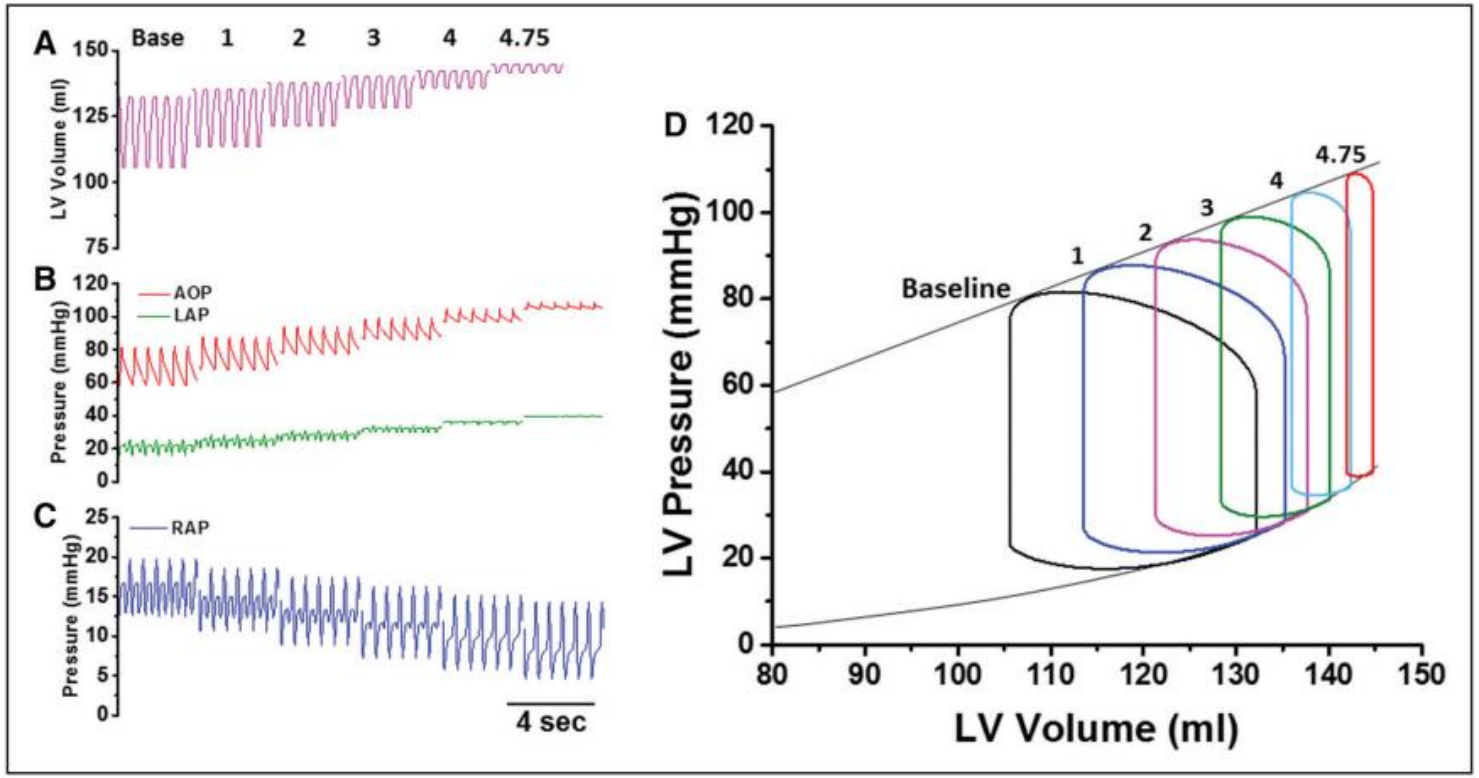

Figure 4. Hemodynamic changes that occur during acute cardiogenic shock and peripheral venoarterial extracorporeal membrane oxygenation (VA-ECMO) at increasing flow rates (1, 2, 3, 4, 4.75 L/min) with an unvented left ventricle (LV).

A, LV volume and pressure increases. **B**, Aortic pressure (AOP) and left atrial pressure (LAP) increase. **C**, Right atrial pressure (RAP) decreases. **D**, Pressure-volume loops generated during acute cardiogenic shock and VA-ECMO at increasing flow rates. With increasing ECMO flow rates, aortic pressure and afterload (slope of the arterial elastance and end-systolic pressure increase). There is a concomitant decrease in stroke volume (represented by the width of the pressure-volume loop) and an increase in LV volume (LV distention) and LAP. As stroke volume approaches zero, this would clinically correspond to the aortic valve remaining closed throughout the cardiac cycle.

Rao P et al. Circ Heart Fail 2018;11:e004905

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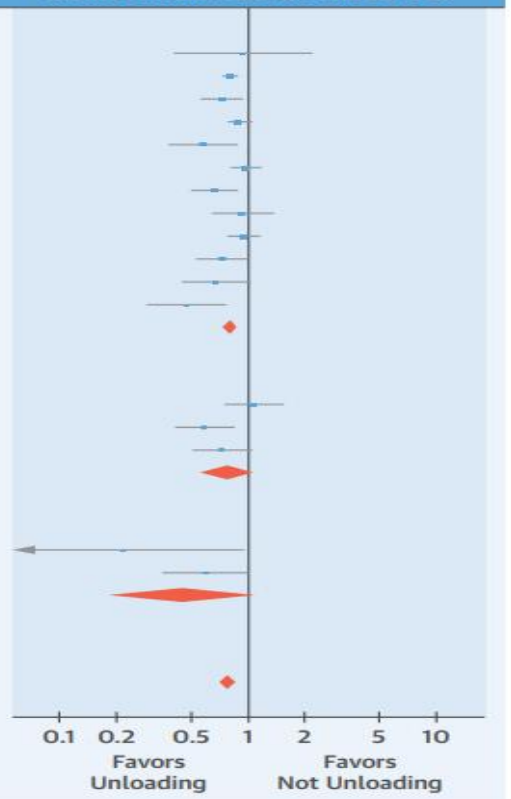
VA-ECMO - LV Venting

CENTRAL ILLUSTRATION Left Ventricular Unloading During Venoarterial Extracorporeal Membrane Oxygenation

Study or Subgroup	Unloading Events	Unloading Total	No Unloading Events	No Unloading Total	Weight
1.1.1 Intra-Aortic Balloon Pump					
Aoyama, 2014	22	35	2	3	1.2%
Aso, 2016	330	604	708	1,046	14.3%
Brechot, 2018	45	104	92	155	7.5%
Doll, 2004	105	143	62	76	11.7%
Kai Chen, 2018	17	38	17	22	3.9%
Lin, 2016	144	302	110	227	10.3%
Overtchouk, 2018	33	63	34	43	6.7%
Park, 2014	21	41	30	55	4.5%
Ro, 2014	41	60	139	193	9.7%
Sakamoto, 2012	62	94	4	4	5.6%
Tepper, 2018	15	30	22	30	3.9%
Wang, 2013	13	41	31	46	3.0%
Subtotal (95% CI)		**1,555**		**1,900**	**82.3%**
Total events	848		1,251		
1.1.2 Percutaneous Left-Ventricular Support					
Akanni, 2018	16	29	100	196	5.0%
Pappalardo, 2017	16	34	98	123	4.7%
Patel, 2018	17	30	28	36	4.9%
Subtotal (95% CI)		**93**		**355**	**14.6%**
Total events	49		226		
1.1.3 Right Upper Pulmonary Vein or Transseptal Left Atrial Cannula					
Poptsov, 2014	2	28	6	18	0.4%
Shmack, 2017	9	20	21	28	2.7%
Subtotal (95% CI)		**48**		**46**	**3.1%**
Total events	11		27		
Total (95% CI)		**1,696**		**2,301**	**100.0%**
Total events	908		1,504		



Russo, J.J. et al. J Am Coll Cardiol. 2019;73(6):654–62.

The association between left ventricular unloading during VA-ECMO for cardiogenic shock and all-cause mortality was assessed before and after stratification by left ventricular unloading strategy (IABP, pVAD, or RUPV or trans-septal left atrial cannula). The Mantel-Haenszel method was used to examine the overall risk ratio associated with left ventricular unloading during VA-ECMO using a random effects model. Left ventricular unloading during VA-ECMO for cardiogenic shock was associated with reduced mortality (RR: 0.79; 95% CI: 0.72 to 0.87; $p < 0.00001$). There was no heterogeneity in this association in relation to the specific left ventricular unloading strategy used ($p = 0.47$). CI = confidence interval; IABP = intra-aortic balloon pump; LA = left atrial; pVAD = percutaneous ventricular assist device; RR = relative risk; RUPV = right upper pulmonary vein; VA-ECMO = venoarterial extracorporeal membrane oxygenation.

Mortality: 54% (LV vent) vs 65% (no LV vent)

HR 0.79, 95% CI (0.72-0.87)

p < 0.00001

Russo JJ et al. JACC 2019;73:654-62

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Shock Algorithms

- ***A) Rationale***
  - Complexity of care
  - Too much practice variation.
  - No RCT's to guide management
  - Clinical Precedent

- ***B) Actions to Develop Shock Team***
  - Team Members
  - Standardized Protocol
  - Hub-and-Spoke Model

- ***C) Improve Outcomes***
  - Enhanced Disease Recognition
  - Appropriate revascularization and utilization of MCS


CATHETERIZATION & CARDIOVASCULAR INTERVENTIONS

Explore this journal >

Coronary Artery Disease

A team-based approach to patients in cardiogenic shock

Jacob A. Doll MD, E. Magnus Ohman MD, Manesh R. Patel MD, Carmelo A. Milano MD, Joseph G. Rogers MD, David H. Wohns MD, Navin K. Kapur MD, Sunil V. Rao MD

First published: 3 November 2015 Full publication history

Doll J et al. Catheterization & Cardiovascular Intervention 2015;88:424-33

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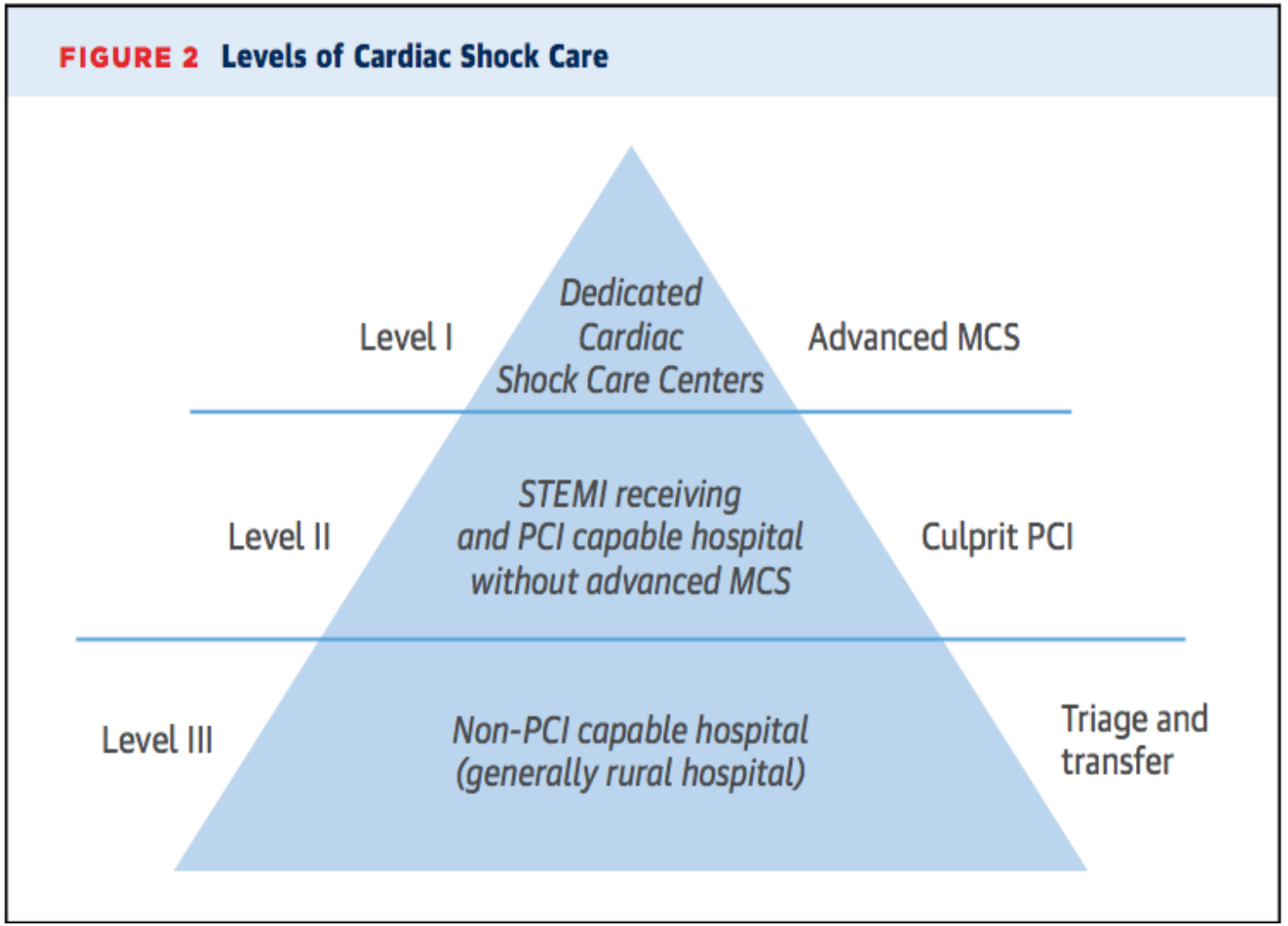
Cardiac Shock Care Centers



Rab T et al. JACC 2018; 72(16):1972-80

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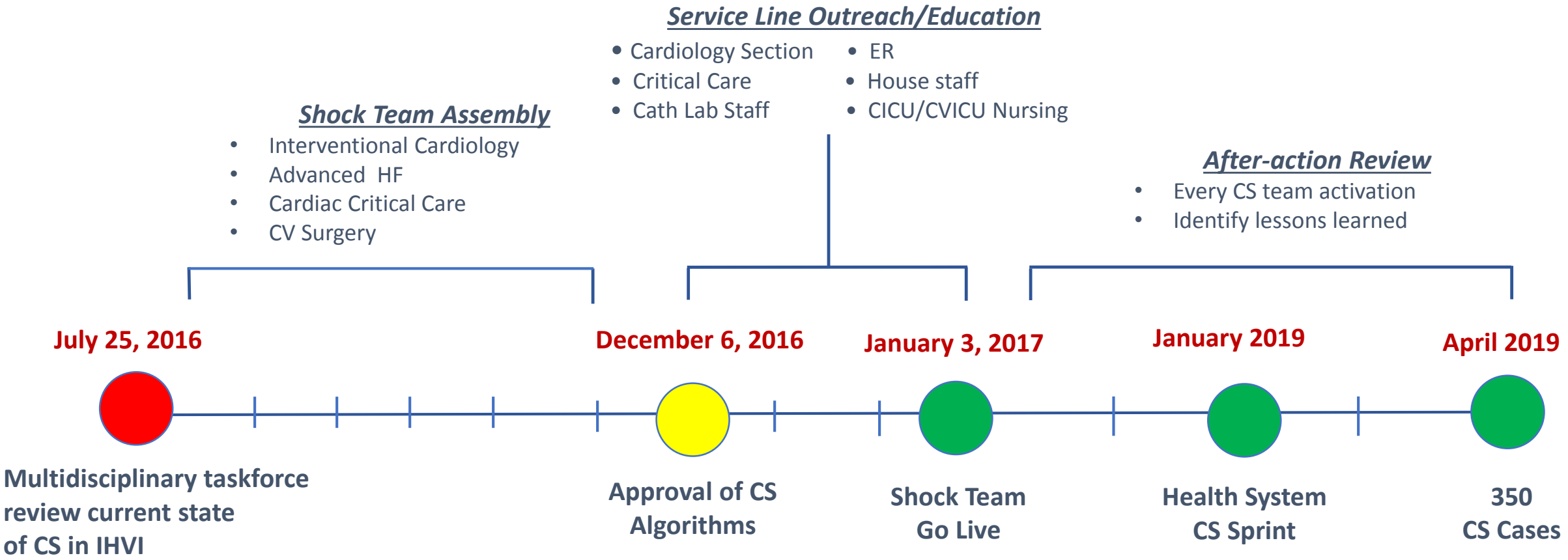
Timeline of IHVI Heart Recovery Initiative



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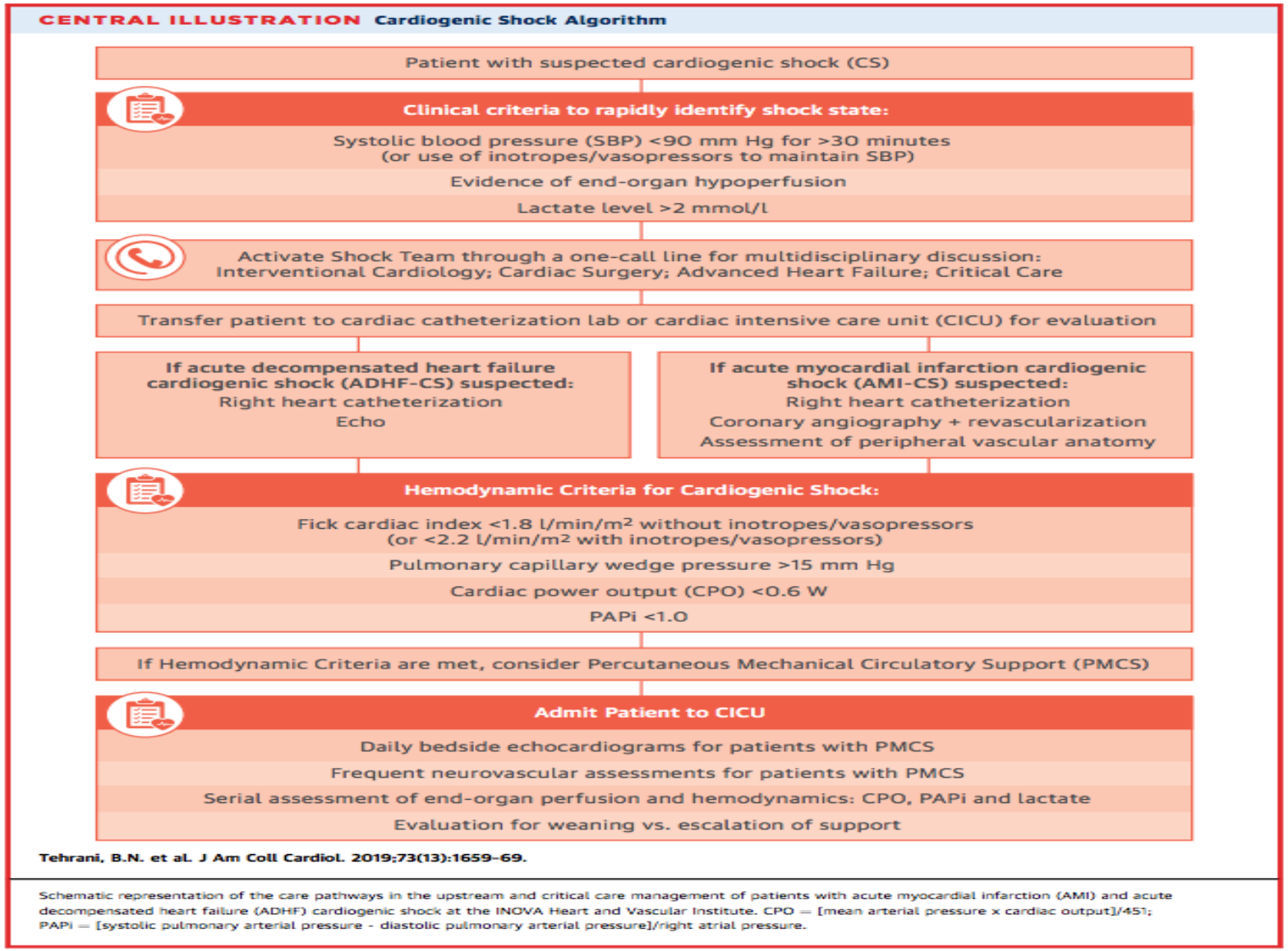
INOVA Heart Recovery Initiative



Tehrani, B.N. et al. J Am Coll Cardiol. 2019;73(13):1659–69.

Schematic representation of the care pathways in the upstream and critical care management of patients with acute myocardial infarction (AMI) and acute decompensated heart failure (ADHF) cardiogenic shock at the INOVA Heart and Vascular Institute. CPO = [mean arterial pressure x cardiac output]/451; PAPi = [systolic pulmonary arterial pressure - diastolic pulmonary arterial pressure]/right atrial pressure.

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INOVA Heart Recovery Initiative: CICU Management

INOVA HEART AND VASCULAR INSTITUTE

Cardiogenic Shock Team Management

Call 703-776-5905 to activate Heart Team

Serial Assessment q4hr x 24hrs

- Lactate
- Fick CO/CI
- CPO and PAPi
- Continuous hemodynamics

***and* if PMCS:**

- LDH & Haptoglobin
- Neurovascular checks
- Limited Echo daily
- IVF to keep RA >10, PCWP >12

*Criteria for Refractory Shock

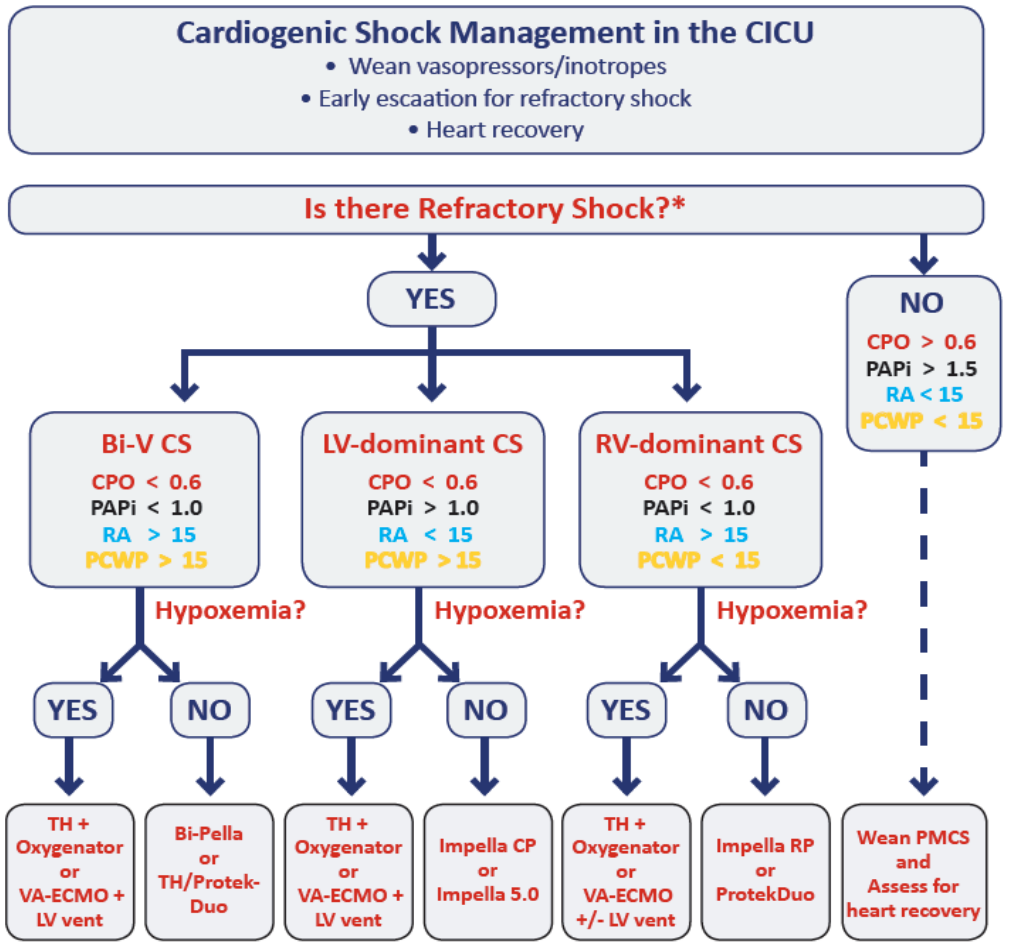
- Lactate > 3
- UOP < 30cc/hr
- CPO < 0.6
- Increasing pressor requirement
- Evidence of organ hypo-perfusion

Criteria for RV Dysfunction

- PAPi < 1.0
- RA > 15mmHg
- RA/PCWP ratio > 0.63

CPO = MAP x CO/451
PAPi = (sPAP-dPAP)/RA

Revised March 6, 2019



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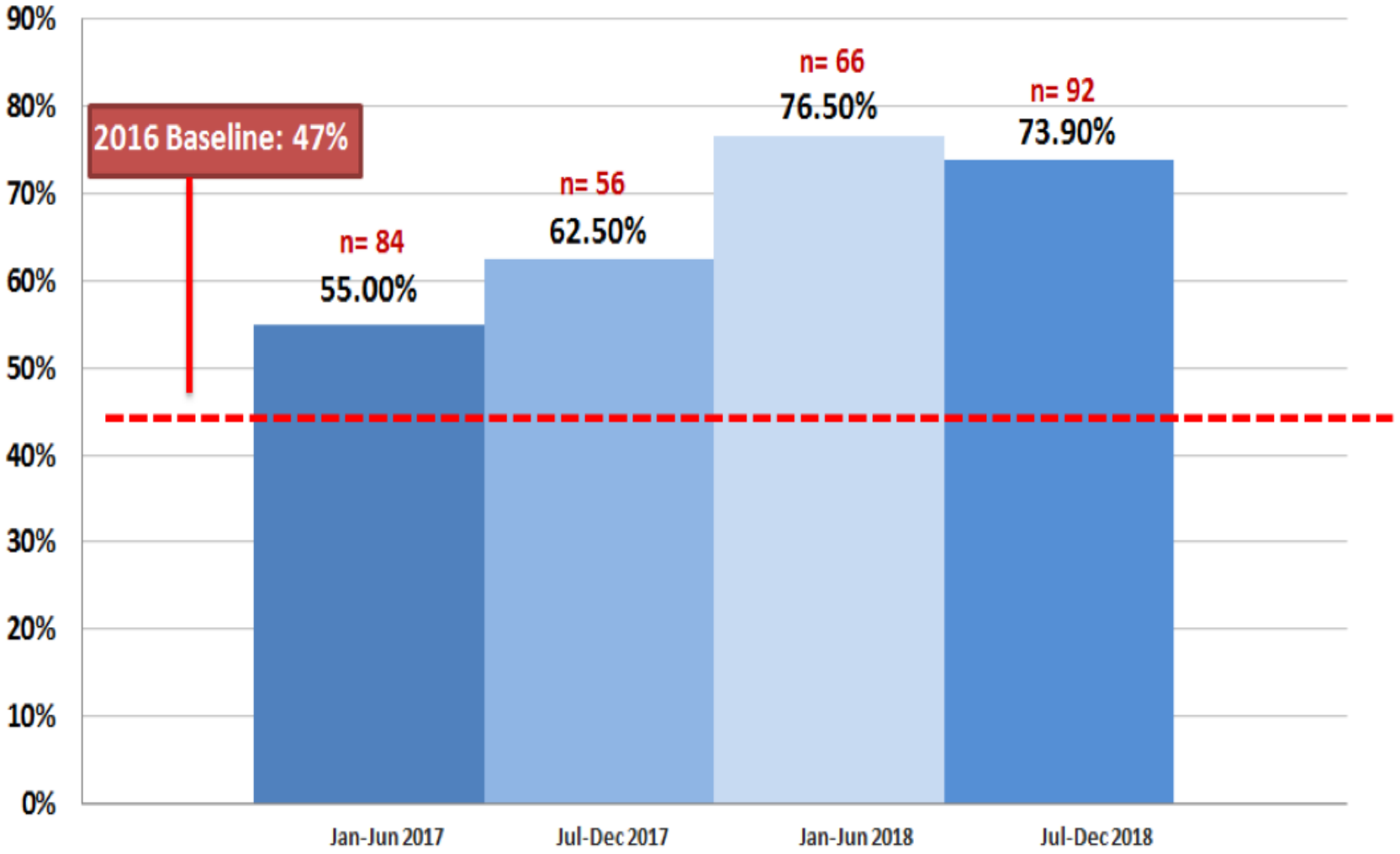
Improvement in CS survival: IHVI 2 year outcomes



Total patients treated for CS 2017-2018	285
# of survived patients 2017-2018	194
# of patients would have survived before CS team	134
Additional Lives Saved	**60***

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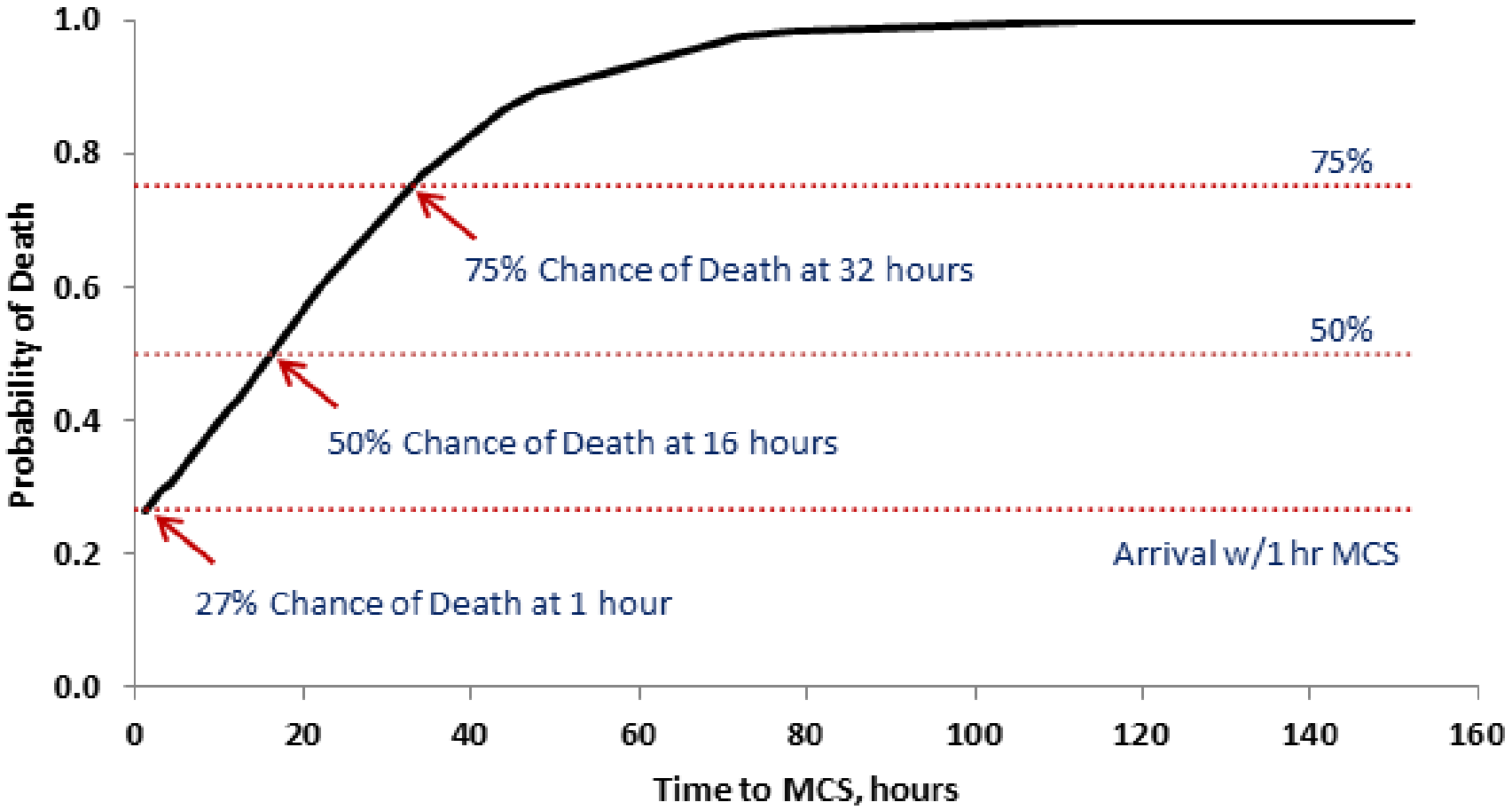
IHVI Heart Recovery Initiative: Impact of time to MCS



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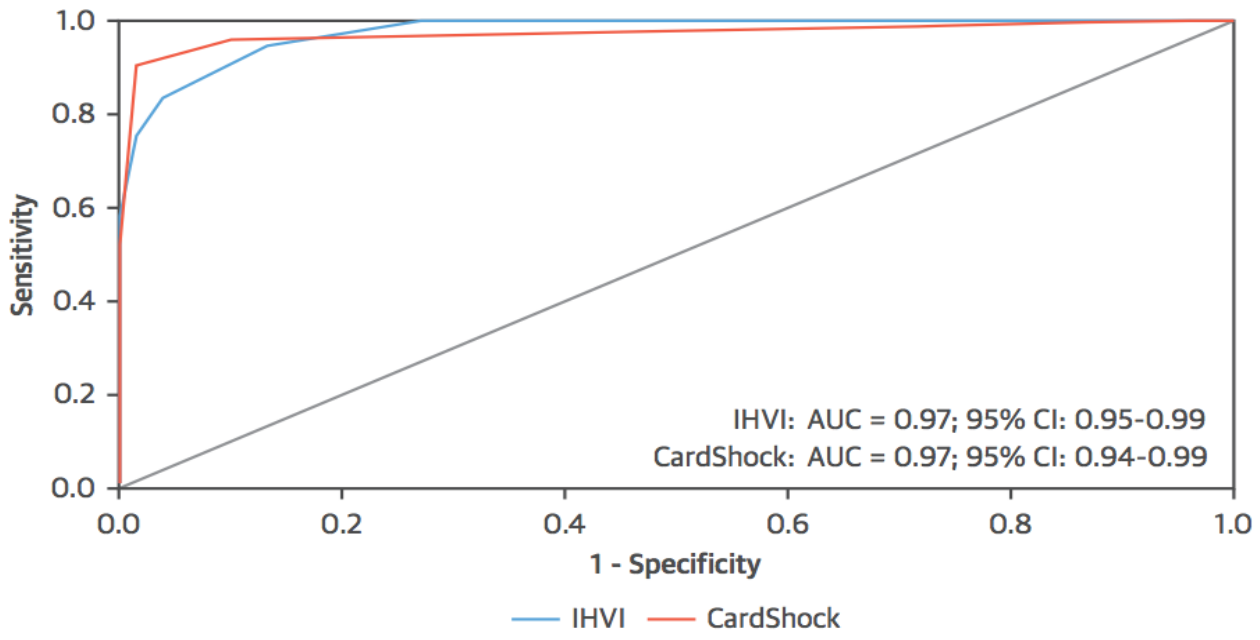
IHVI Cardiogenic Shock Risk Stratification Score

FIGURE 3 IHVI Cardiogenic S

Ris	
Lactate, mmol/L @24	
Pressors duration fro	
CPO @24 hrs <0.6 W	
Diabetes Mellitus	
Dialysis	
PAPi @24 hrs <1.0	
Age ≥71 years	

A multivariate model was run t
again following exclusion of pa
resulting in a final risk score mo
ratio (OR) and clinical relevance
score calculated by summing po
CPO = cardiac power output; I

FIGURE 4 Receiver Operating Characteristic Curve Comparing IHVI Cardiogenic Shock Versus CardShock Risk Prediction Models for 30-Day Mortality



Both risk scores showed excellent discriminant ability with area under the curve (AUC) statistics >90.0%. CI = confidence interval; IHVI = Inova Heart and Vascular Institute.

regression model

Tehrani B et al. JACC 2019;73:1659-1169

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IHVI Cardiogenic Shock "Hub-and-Spoke" Network

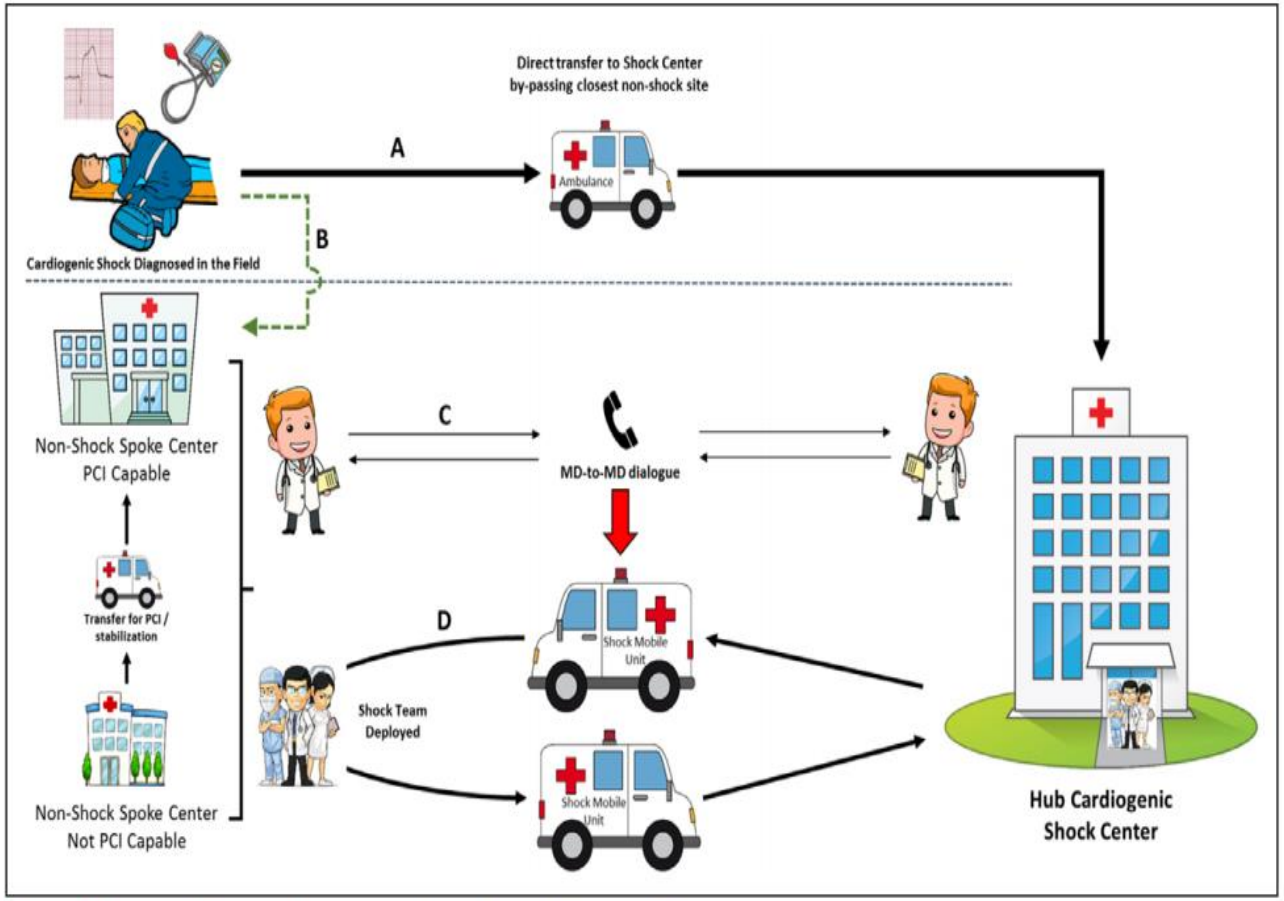

Figure 3. Proposed regional system of care for cardiogenic shock.

Van Diepen et al. *Circulation* 2017;136:e232-e268

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Conclusions

- **Cardiogenic shock** is a **multifactorial** and **hemodynamically complex** syndrome with **high morbidity/mortality.**

- **Few** evidence based **interventions** known to clearly **impact** patient **survival**

- A **standardized**, **team-based** approach significantly **improves survival** in CS

- **IHVI Pathway in the management of CS**:
  - One-call access
  - Multidisciplinary Heart Team
  - Treatment protocols and validated risk scores
  - Regional destination center utilizing a hub-and-spoke model

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Thank You

Name	Department	Job Title
Christopher M. O'Connor, MD	IHVI	Chief Executive Officer
Christopher deFilippi, MD	IHVI	Vice Chair, Academic Affairs
Wayne Batchelor, MD	Interventional Cardiology	System Director, Interventional Heart Program
Charles Murphy, MD	IHVI Critical Care	Chief Safety Officer, Director CVICU
Shashank Desai, MD, MBA	Advanced Heart Failure/Transplant	Director of AHF/Transplant
Behnam Tehrani, MD	Interventional Cardiology	Co-Director, Cardiac catheterization lab Co-Director, Cardiogenic Shock Team
Alexander Truesdell, MD	Interventional Cardiology	Co-director, Cardiogenic Shock Team
Shashank Sinha, MD, MSc	Advanced Heart Failure/Transplant	Medical Director, Cardiac Intensive Care Unit Director, CV Critical Care Research Program
Ramesh Singh MD	Cardiac Surgery	Surgical Director, Mechanical Circulatory Support
Carolyn Rosner, NP	Cardiac Research	Nurse Practitioner, IHVI programs
Matthew Sherwood, MD	Interventional Cardiology	Co-Director, Cardiac catheterization lab Co-Director, Structural Heart Program
Kelly Epps, MD	Interventional Cardiology	Director, IHVI Women's Cardiovascular Program
Henry Tran, MD	Cardiology	Associate Director, Cardiology Fellowship
Mehul Desai, MD	Medical Critical Care Services	Critical Care Attending MD
Glenn Druckenbrod, MD	Emergency Room	Medical Director, Emergency Room
Aaron Bagnola, PharmD, BCPS	Pharmacy	Cardiology Specialty Pharmacist

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