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Contemporary Management of Cardiogenic Shock

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Disclosures

- None

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How it started

How it's going

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Objectives

- Discuss cardiogenic shock etiologies, phenotypes and staging
- Review the pathophysiology of cardiogenic shock and its management options
- Highlight MHI's approach to cardiogenic shock

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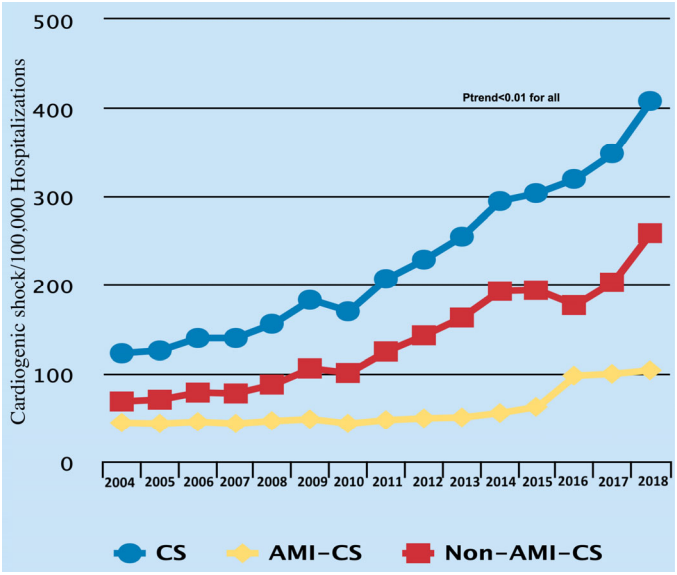

Osman et al. JAHA. Volume 10, Issue 15, 3 August 2021.

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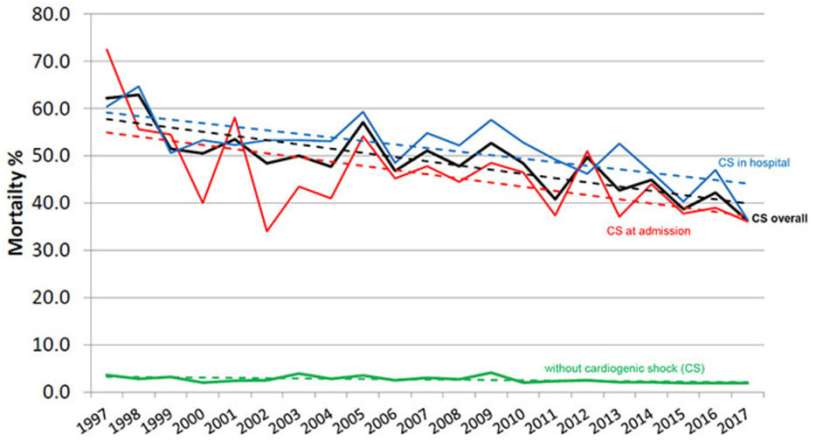
Phenotyping & staging



Hunziker et al. Circ. Volume 12, Issue 4, April 2019.

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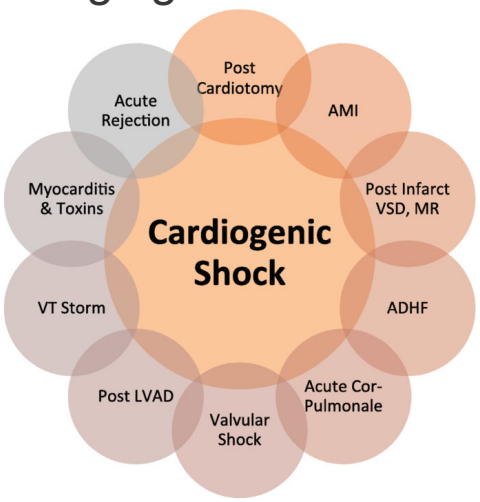
Phenotyping & staging



Jumean, M., Kar, B. (2024). Cardiogenic Shock. In: Gregoric I.D., Myers, T.J., Mihalj, M. (eds) Management of Acute and Chronic Severe Heart Failure. Springer, Cham.

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Phenotyping & staging

Clinical Trial/Guideline	CS Criteria
SHOCK Trial (1999)[3]	• SBP <90 mm Hg for >30 min or vasopressor support to maintain SBP >90 mm Hg • Evidence of end-organ damage (UO <30 mL/h or cool extremities) • Hemodynamic criteria: CI <2.2 and PCWP >15 mm Hg
IABP-SOAP II (2012)[4]	• MAP <70 mm Hg or SBP <100 mm Hg despite adequate fluid resuscitation (at least 1 L of crystalloids or 500 mL of colloids) • Evidence of end-organ damage (AMS, mottled skin, UO <0.5 mL/kg for 1 h, or serum lactate >2 mmol/L)
EHS-PCI (2012)[5]	• SBP <90 mm Hg for 30 min or inotropes use to maintain SBP >90 mm Hg • Evidence of end-organ damage and increased filling pressures
ESC-HF Guidelines (2016)[6]	• SBP <90 mm Hg with appropriate fluid resuscitation with clinical and laboratory evidence of end-organ damage • Clinical: cold extremities, oliguria, AMS, narrow pulse pressure. Laboratory: metabolic acidosis, elevated serum lactate, elevated serum creatinine
KAMIR-NIH (2018)[7]	• SBP <90 mm Hg for >30 min or supportive intervention to maintain SBP >90 mm Hg • Evidence of end-organ damage (AMS, UO <30 mL/h, or cool extremities)

Vahdatpour, et al. JAHA. DOI: 10.1161/JAHA.119.011991

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Cardiogenic Shock (CS)

- Persistent hypotension
- End-organ hypoperfusion
  - AMS
  - Oliguria <30cc/hr
  - Lactate >2.0 mmol/L
- Cardiac dysfunction
  - Imaging
  - Invasive hemodynamics

CONCISE CLINICAL GUIDANCE

2025 Concise Clinical Guidance: An ACC Expert Consensus Statement on the Evaluation and Management of Cardiogenic Shock

A Report of the American College of Cardiology Solution Set Oversight Committee

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Symptoms/Signs	Altered mental status, confusion, chest pain or pressure, cold and clammy extremities, rapid pulse, low pulse pressure (<25% of SBP), elevated jugular venous pressure, crackles, rales, orthopnea, paroxysmal nocturnal dyspnea, lower extremity edema
Urine output	Oliguria or anuria, <30 mL/h (<0.5 mL/[kg·h])
Sustained hypotension	SBP <90 mm Hg, MAP <65 mm Hg for >30 min or a >30-mm Hg decrease from baseline, or the need for pharmacological or mechanical support to maintain SBP >90 mm Hg
Perfusion	Evaluate markers of end-organ malperfusion, including lactic acid >2 mmol/L, ALT >200 U/L or >3× upper limit of normal, creatinine ≥2× upper limit of normal, pH <7.2, metabolic acidosis without another known cause
ECG/Echocardiogram	Evaluate acute ischemia, including ECG and sonographic evidence of STEMI (regional wall motion abnormalities); evidence of LV or RV dilation and systolic dysfunction; valvular pathology
Congestion	Presence or absence of congestion based on physical signs and hemodynamics; elucidation of ventricular involvement (LV vs RV vs BiV)
Triage	Appropriate triage/shock team activation or possible transfer to a higher level of care

ALT = alanine transaminase; BiV = biventricular; CS = cardiogenic shock; ECG = electrocardiogram; LV = left ventricular; MAP = mean arterial pressure; pH = potential of hydrogen; RV = right ventricular; SBP = systolic blood pressure; STEMI = ST-segment elevation myocardial infarction.

Sinha, S, et al. JACC. 2025 Apr, 85 (16) 1618–1641.

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	PCWP <18 mm Hg	PCWP ≥18 mm Hg
CI ≥2.2 L/min/m²	"Warm and Dry" Normal or Vasodilatory shock	"Warm and Wet" Congestion
CI <2.2 L/min/m²	"Cold and Dry" Euvolemic cardiogenic shock or hypovolemic shock	"Cold and Wet" Cardiogenic shock

Rajagopolan, N. et al. JACC. Volume 12, Issue 7. July 2024, Pages 1141-1156.

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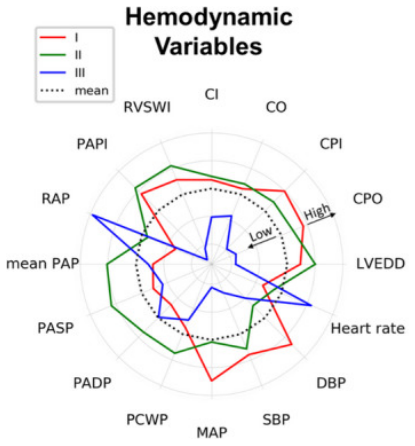
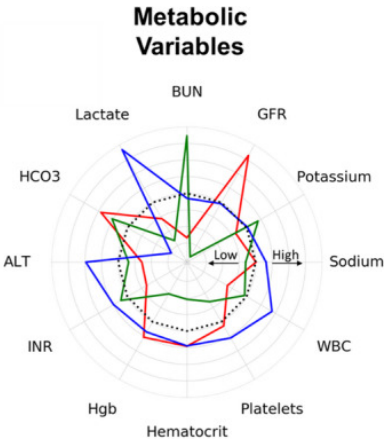
Non-congested (I)
- More stable HR, MAP
- - RAP , - PCWP

Cardio-renal (II)
- LV-dominant
  - PCWP >15mmHg
- AKI

Cardio-metabolic (III)
- RV-dominant
  - ↑ RA:PCWP
    - >0.63 (AMI-CS)
    - >0.86 (post-LVAD)
  - ↓ PAPi
    - ≤0.9 (AMI-CS)
    - <1.85 (post-LVAD)
- ↑↑ Lactate





Mehta et al. Front. Cardiovasc. Med. 11:1354158.

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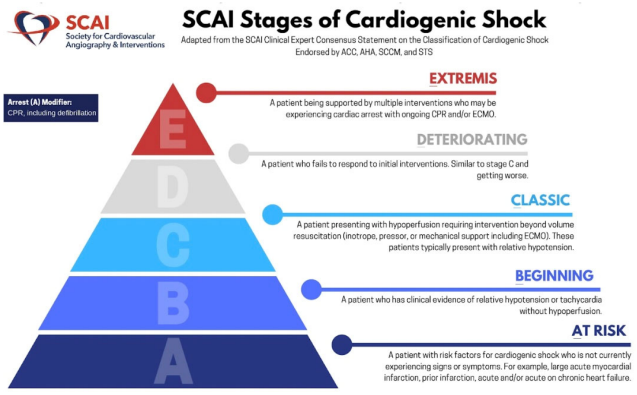
Phenotyping & staging



SCAI SHOCK STAGE	PHYSICAL EXAM	BIOCHEMICAL MARKERS	HEMODYNAMICS
A	Normal JVP Lung sounds clear Strong distal pulses Normal mentation	Normal renal function Normal lactic acid	Normotensive (SBP>100 or normal for pt.) If hemodynamics done: • Cardiac Index >2.5 • CVP <10 • PA Sat >65%
B	Elevated JVP Rales in lung fields Strong distal pulses Normal mentation	Normal lactate Minimal renal function impairment Elevated BNP	SBP <90 OR MAP <60 OR >30mmHg drop Pulse >100 If hemodynamics done: • Cardiac Index >2.2 • PA Sat >65%
C	Ashen, mottled, dusky Volume overload Extensive Rales Killip class 3 or 4 BiPap or mechanical ventilation Acute alteration in mental status	Lactate >2 Creatinine doubling OR >60% drop in GFR Increased LFTs Elevated BNP Urine Output <30mL/h	Drugs/device used to maintain BP above stage B values • Cardiac Index <2.2 • PCWP >15 • RAP/PCWP >0.8 • PAPI <1.85 • Cardiac Power Output <0.6
D	Any of stage C	Any of stage C AND deteriorating	Any of stage C AND Requiring multiple pressors OR addition of mechanical circulatory support devices to maintain perfusion
E	Near pulselessness Cardiac collapse Mechanical ventilation Defibrillator used	Lactate >5 pH < 7.2	No SBP without resuscitation PEA or Refractory VT/VF Hypotension despite maximal support

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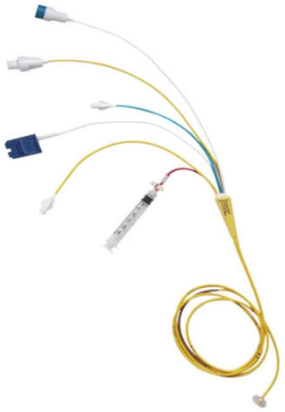
Phenotyping & staging

Swan Ganz catheter

- Indications
  - Differentiating shock
  - Phenotyping & Staging CS
  - Tailoring interventions
    - Vasopressors
    - Inotropes
    - MCS
- Guidelines
  - ACC/AHA Class 2b – No RCTs
  - Escape from ESCAPE – AMI & CS excluded



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Characteristics	Cluster/Phenotype I "Noncongested" CS	Cluster/Phenotype II "Cardiorenal" CS	Cluster/Phenotype III "Cardiometabolic" CS
Mean age, y	≈60	≈70	≈65
Comorbidities	Few	DM2, CKD, hypertension…	Few
Blood pressure	↓	↓	↓ ↓
Congestion	None	Left ventricular	Right ventricular
Heart rate	↔	↔	↑ ↑
Hemoglobin	↔	↓	↔
Transaminases	↔	↔	↑ ↑
Lactate	↔ or ↑	↓	↑ ↑
Kidney function	↔	↓ ↓	↓

Zweck, et al. 2021. JAHA.10:e020085.

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Phenotyping & staging

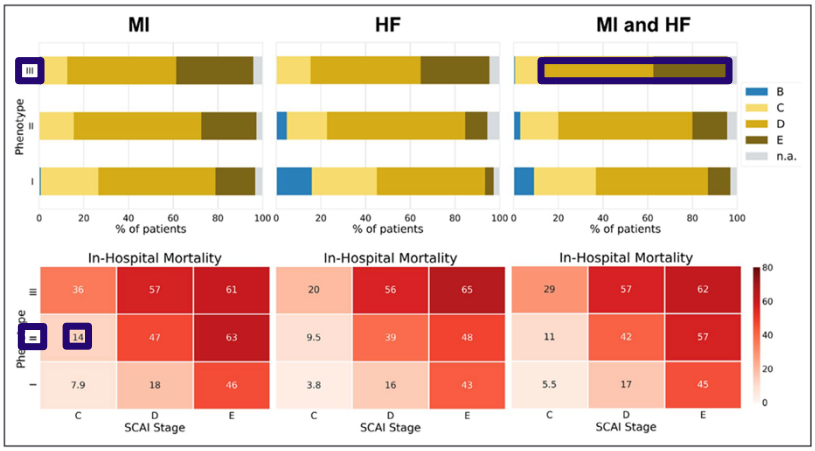

Figure 4. Society for Cardiovascular Angiography and Interventions (SCAI) stages reached during hospital stay by phenotype.

Zweck, et al. 2021. JAHA.10:e020085.

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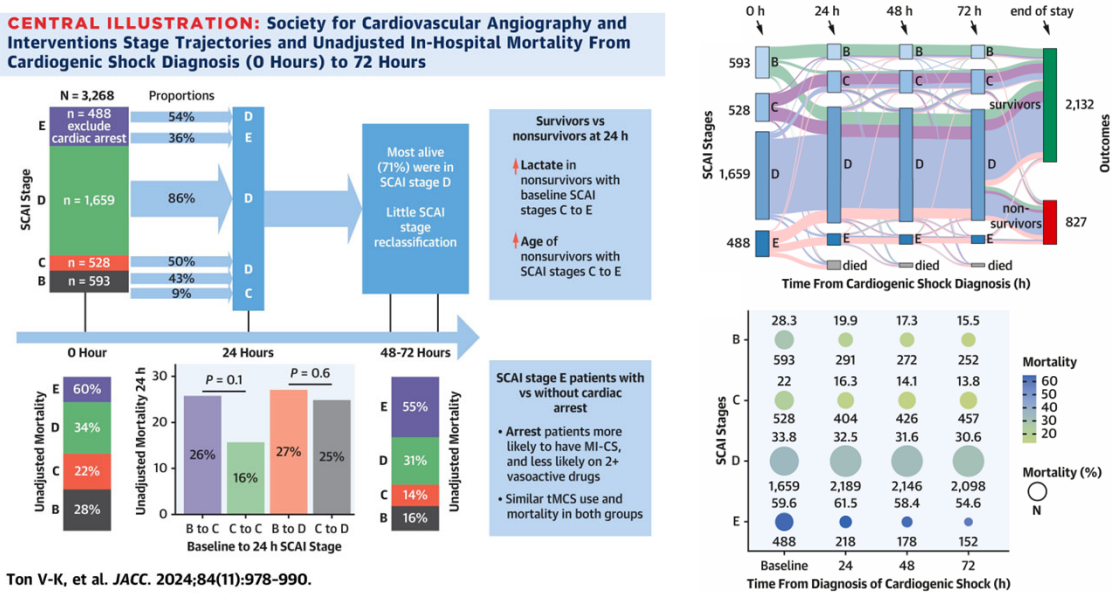
CENTRAL ILLUSTRATION: Society for Cardiovascular Angiography and Interventions Stage Trajectories and Unadjusted In-Hospital Mortality From Cardiogenic Shock Diagnosis (0 Hours) to 72 Hours



Ton V-K, et al. *JACC*. 2024;84(11):978-990.

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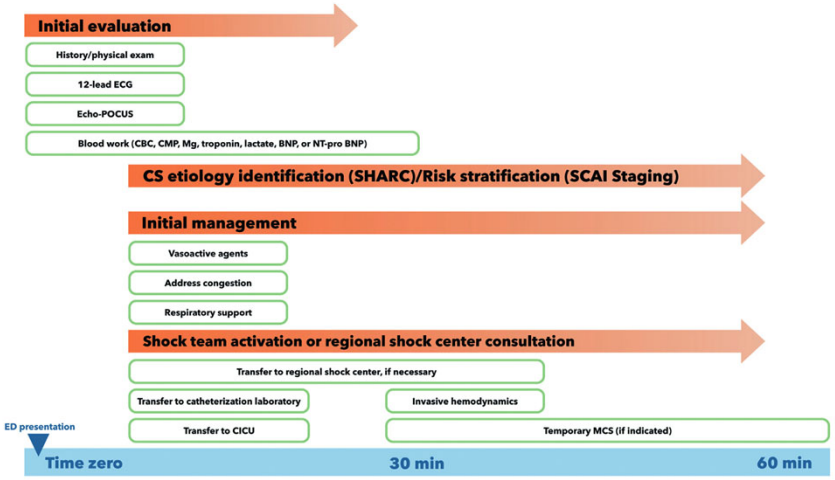

Sinha, S, et al. JACC. 2025 Apr, 85 (16) 1618–1641.

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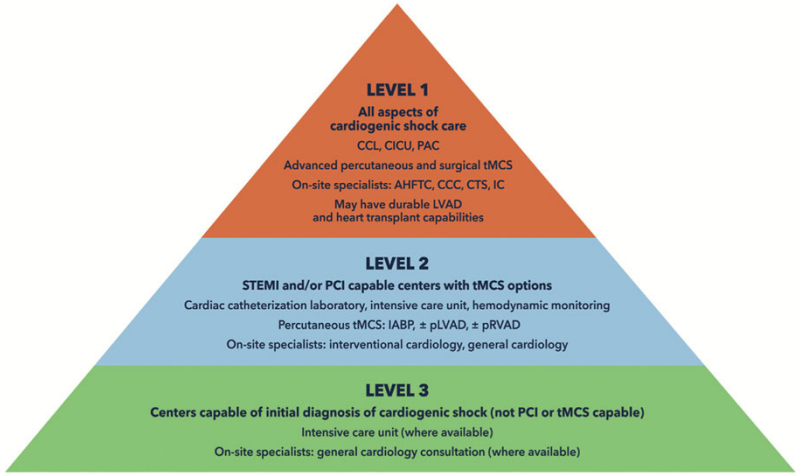

et al. JACC. 2025 Apr, 85 (16) 1618–1641.

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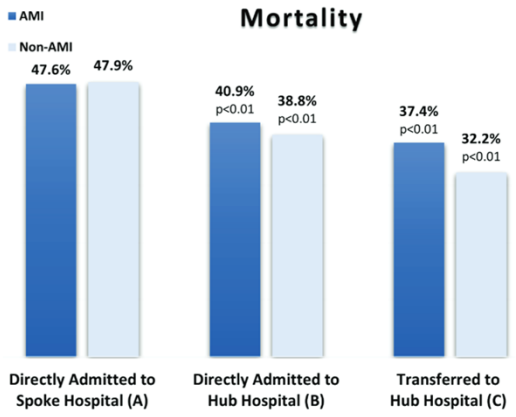
Phenotyping & staging

Cardiogenic Shock Hospitalizations, 2010-2014

	Directly Admitted to Spoke Hospital n = 130,656	Directly Admitted to Hub Hospital n = 253,234	Transferred to Hub Hospital n = 28,777
Mortality	**47.8%**	**39.3%**	**33.4%**
Unadjusted OR*	1 (reference)	0.71 (0.67-0.74)	0.55 (0.52-0.58)
Multivariable-adjusted OR	1 (reference)	0.86 (0.84-0.89)	0.72 (0.69-0.76)
Propensity-score-matched OR	1 (reference)	0.93 (0.90-0.95)	0.78 (0.74-0.83)
Average Length of Stay	**8.9 days**	**12.6 days**	**18.6 days**
Estimated Cost	**$33,123**	**$53,296**	**$81,875**
Procedures Performed			
RHC	5.7%	12.6%	26.5%
PCI	20.9%	20.8%	20.6%
CABG	6.2%	13.1%	19.6%
Temporary MCS	16.7%	24.1%	34.4%
LVAD	<0.1%	2.0%	4.4%
Heart Transplant	<0.1%	1.0%	0.7%

*Odds ratios presented as OR (95% confidence interval)



D.Y. Lu et al. European Journal of Heart Failure (2021) 23, 1927–1937.

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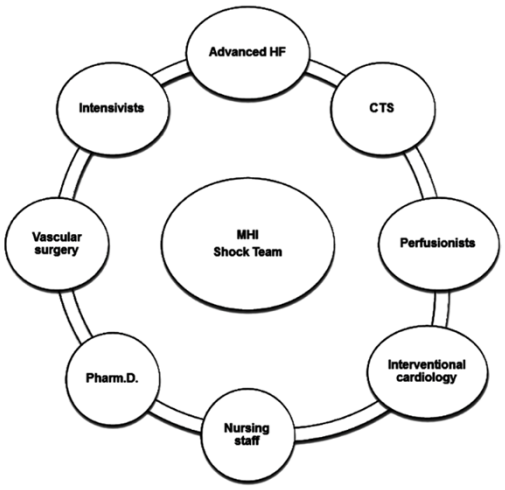

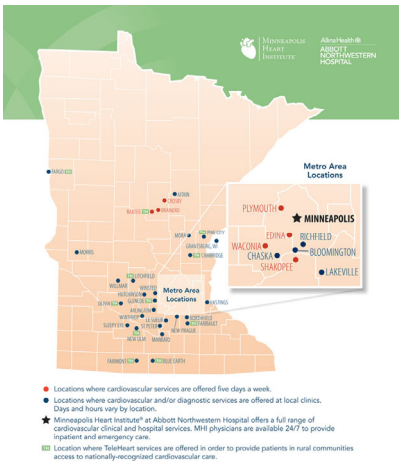

Hryniewicz, K. et al. JASAIO. 2016;62(4):397-402.

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Objectives

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- Review the pathophysiology of cardiogenic shock and its management options
- Highlight MHI's approach to cardiogenic shock

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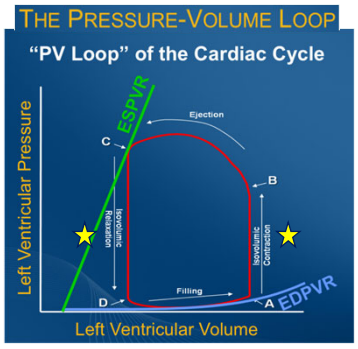
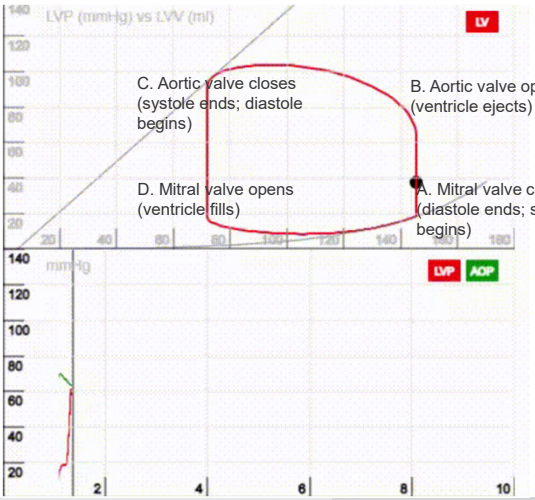
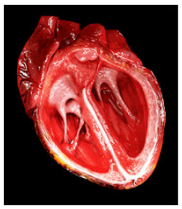
CS Management



★ Isovolumic contraction and relaxation = most energy intensive phases of the cardiac cycle.





Courtesy of Abiomed

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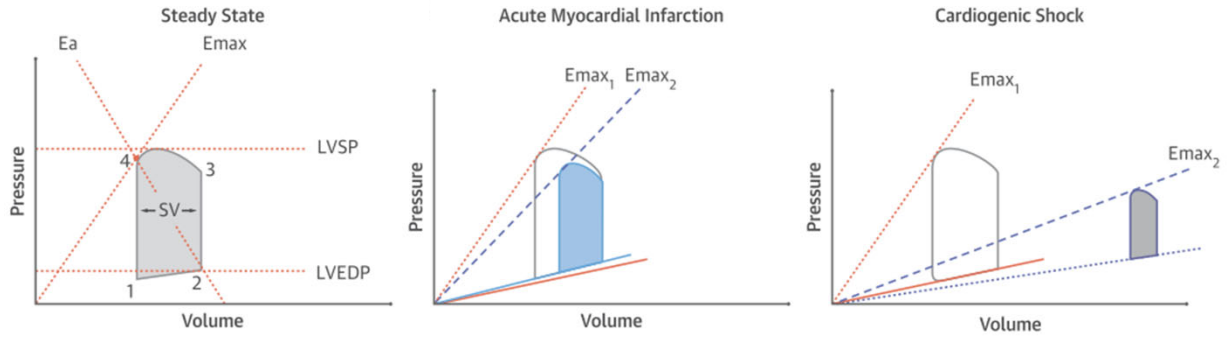
CS Management



Adapted from: Szeto et al. SCAI 2015. 85(7) E175-196.

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CS Management

Early Revascularization in Acute Myocardial Infarction Complicated by Cardiogenic Shock

Authors: Judith S. Hochman, M.D., Lynn A. Sleeper, Sc.D., John G. Webb, M.D., Timothy A. Sanborn, M.D., Harvey D. White, D.Sc., J. David Talley, M.D., Christopher E. Buller, M.D., +16, for the SHOCK Investigators* Author Info & Affiliations

Published August 26, 1999
N Engl J Med 1999;341:625-634

Recommendations for Revascularization in ACS With Cardiogenic Shock
Referenced studies that support recommendations are summarized in the Evidence Table.

COR	LOE	Recommendations
1	B-R	1. In patients with ACS and cardiogenic shock or hemodynamic instability, emergency revascularization of the culprit vessel by PCI or with CABG is indicated to improve survival, irrespective of time from symptom onset.[1–4]
3: Harm	B-R	2. In patients with ACS complicated by cardiogenic shock, routine PCI of a noninfarct-related artery at the time of PPCI should not be performed because of the higher risk of death or renal failure.*[5–7]

*Modified from the "2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization."[8]

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CS Management - Vasoactives

TABLE 2 Vasoactive Agents Used in CS

Category	Agent(s)	Mechanism of Action/Receptor Binding	Dosing	Hemodynamic Effects			
				SVR	BP	CO	HR
Inopressor	Norepinephrine	α1 (+++), β1 (++), β2 (+)	0.05-1 μg/kg/min	↑↑	↑↑	↑	↑
	Epinephrine	β1 (+++), α1 (++), β2 (++)	0.01-0.5 μg/kg/min	↑↑	↑↑	↑↑	↑↑
	Dopamine	D1 (+++), β1 (++), α1 (+)	Low: 2-5 μg/kg/min Intermediate: 5-10 μg/kg/min High: 10-20 μg/kg/min	↑↑	↑↑	↑	↑↑
Inodilator	Dobutamine	β1 (+++), β2 (++)	2-10 μg/kg/min	↓↔	↓↔	↑↑	↑
	Milrinone	PDE-3 inhibitor	0.125-0.5 μg/kg/min	↓↓	↓↓	↑↑	↔↑
Vasopressor	Phenylephrine	α1 (+++)	0.1-10 μg/kg/min	↑	↑↑	↔↓	↔↓
	Vasopressin	Vasopressin receptor	0.01-0.04 U/min	↑↑	↑↑	↔↓	↔↓
Vasodilator	Nitroprusside	NO production	0.3-10 μg/kg/min	↓	↓	↑↔	↑↔
	Nitroglycerin	Converts to NO	25-200 μg/min	↓	↓	↑↔	↑↔
Chronotrope	Isoproterenol	β1 (+++), β2 (+++)	2-20 μg/min	↓	↔	↑	↑↑
	Dopamine	See above					
Inotrope	Levosimendan*	Binds to troponin C, making it more sensitive to calcium thereby improving interaction between troponin C and I	0.05-0.2 μg/kg/min	↓	↓	↑	↔

*Not FDA approved for clinical use in the United States.

↑ = increased effects; ↓ = decreased effects; ↔ = neutral effects; (+++) = strong binding; (++) = moderate binding; (+) = weak binding; α1 = α-1 receptor; β1 = β-1 receptor; β2 = β-2 receptor; BP = blood pressure; CO = cardiac output; CS = cardiogenic shock; D1 = D1 receptor; FDA = U.S. Food and Drug Administration; HR = heart rate; NO = nitric oxide; PDE-3 = phosphodiesterase 3; SVR = systemic vascular resistance.

Sinha, S, et al. JACC. 2025 Apr, 85 (16) 1618–1641.

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CS Management - Vasoactives

Study	Setting	Population	Sample size	Agents assessed	Mortality	Adverse events
Milrinone as Compared With Dobutamine in the Treatment of Cardiogenic Shock (CAPITAL-DOREMI), 2021[196]	ICU, single center	Cardiogenic shock	192	Dobutamine vs milrinone	No difference	Nil
Epinephrine Versus Norepinephrine for Cardiogenic Shock After Acute Myocardial Infarction (Optima CC), 2018[31]	ICU, multicenter	Post PCI AMI-CS	57	Epinephrine vs norepinephrine	No difference	Increased refractory shock in epinephrine Increased cardiac double product with epinephrine Increased serum lactate
Sepsis Occurrence in Acutely Ill Patients-II (SOAP-II), 2010[41]	ICU, multicenter	Undifferentiated shock	1679	Dopamine vs norepinephrine	No difference	Increased arrhythmic events with dopamine Increased mortality in cardiogenic shock treated with dopamine.
A Comparison of Epinephrine and Norepinephrine in Critically Ill Patients (CAT), 2008[42]	ICU, multicenter	Undifferentiated shock	280	Epinephrine vs norepinephrine	No difference	Epinephrine associated with metabolic acidosis requiring agent cessation No difference in mortality for cardiogenic shock subgroup
Effect of Tilarginine Acetate in Patients With Acute Myocardial Infarction and Cardiogenic Shock (TRIUMPH), 2007[53]	ICU, multicenter	Post PCI AMI-CS	398	Tilarginine acetate vs placebo	No difference	Nil
Levosimendan vs Dobutamine for Patients With Acute Decompensated Heart Failure (SURVIVE), 2007[54]	In-hospital, multicenter	Decompensated heart failure +/– low cardiac output	1327	Levosimendan vs dobutamine	No difference	Increased atrial fibrillation, hypokalemia, and headache with levosimendan
Efficacy and Safety of Intravenous Levosimendan Compared With Dobutamine in Severe Low-Output Heart Failure (LIDO), 2002[55]	In-hospital, multicenter	Low output heart failure (including decompensated heart failure and post cardiotomy)	203	Levosimendan vs dobutamine	No difference	Increased arrhythmia events and angina with dobutamine treatment

AMI-CS indicates acute myocardial infarction cardiogenic shock; ICU, intensive care unit; and PCI, percutaneous coronary intervention. Studies included were randomized controlled trials performed after the year 2000 that included patients with cardiogenic shock and included over 50 enrolled patients.

Bloom, J. et al. J Am Heart Assoc. 2023;12:e029787.

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CS Management - Vasoactives

Milrinone as Compared with Dobutamine in the Treatment of Cardiogenic Shock

Authors: Rebecca Mathew, M.D., Pietro Di Santo, M.D., Richard G. Jung, Ph.D., Jeffrey A. Marbach, M.B., B.S., Jordan Hutson, M.D., Trevor Simard, M.D. , F. Daniel Ramirez, M.D., +14 , and Benjamin Hibbert, M.D., Ph.D. Author Info & Affiliations

Published August 4, 2021 | N Engl J Med 2021;385:516-525 | DOI: 10.1056/NEJMoa2026845 | VOL. 385 NO. 6

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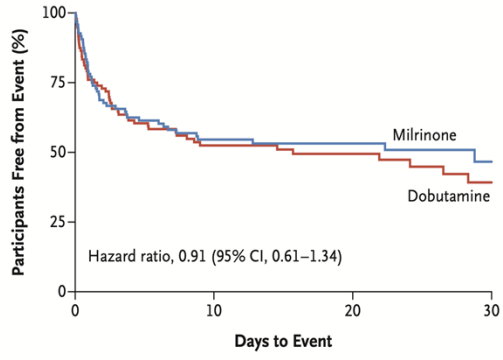
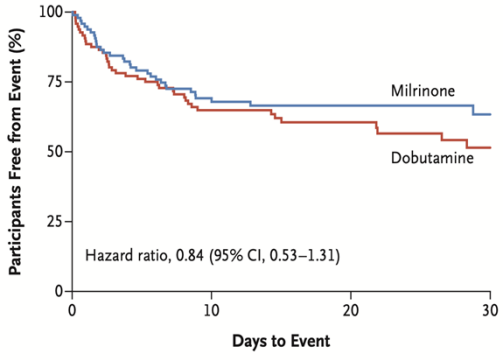
CS Management - Vasoactives

Primary Composite Outcome



No. at Risk				
Milrinone	96	42	26	7
Dobutamine	96	43	25	13

In-Hospital Death from Any Cause



No. at Risk				
Milrinone	96	55	34	15
Dobutamine	96	55	33	19

Mathew, R. N Engl J Med 2021;385:516-25.

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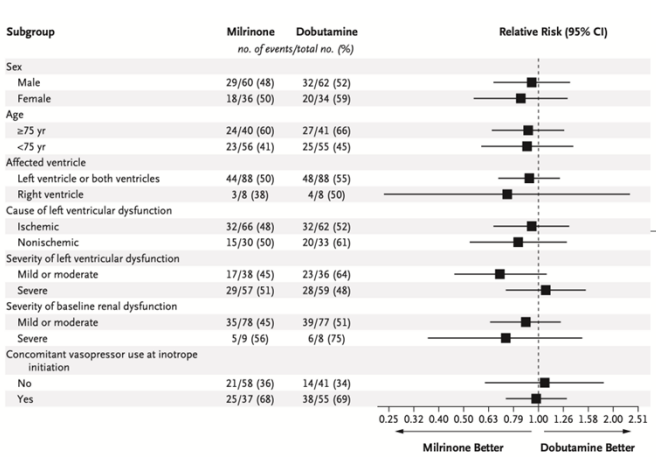
CS Management - Vasoactives



Subgroup	Milrinone	Dobutamine
	no. of events/total no. (%)	
Sex		
Male	29/60 (48)	32/62 (52)
Female	18/36 (50)	20/34 (59)
Age		
≥75 yr	24/40 (60)	27/41 (66)
<75 yr	23/56 (41)	25/55 (45)
Affected ventricle		
Left ventricle or both ventricles	44/88 (50)	48/88 (55)
Right ventricle	3/8 (38)	4/8 (50)
Cause of left ventricular dysfunction		
Ischemic	32/66 (48)	32/62 (52)
Nonischemic	15/30 (50)	20/33 (61)
Severity of left ventricular dysfunction		
Mild or moderate	17/38 (45)	23/36 (64)
Severe	29/57 (51)	28/59 (48)
Severity of baseline renal dysfunction		
Mild or moderate	35/78 (45)	39/77 (51)
Severe	5/9 (56)	6/8 (75)
Concomitant vasopressor use at inotrope initiation		
No	21/58 (36)	14/41 (34)
Yes	25/37 (68)	38/55 (69)

Mathew, R. N Engl J Med 2021;385:516-25.

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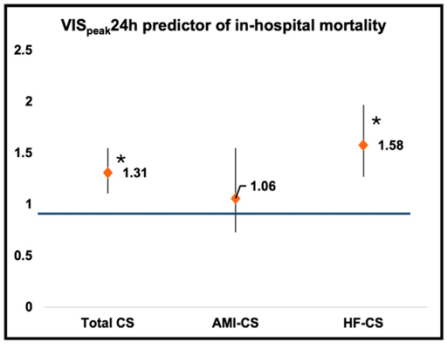
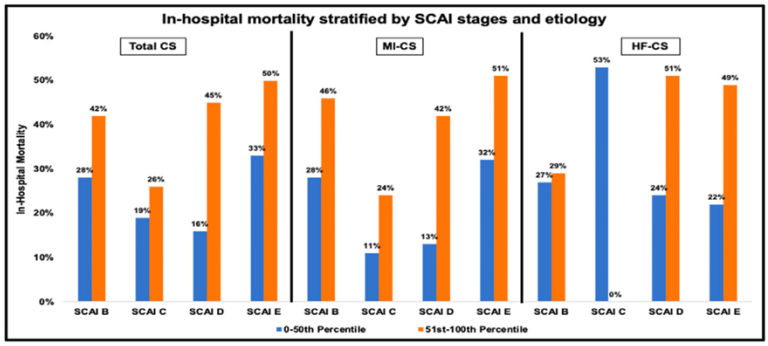
CS Management - Vasoactives

VIS (Vasoactive Inotrope Score)



Odds ratio for VISpeak24h as a predictor of in-hospital mortality in Total, MI-CS, HF-CS



In-hospital mortality in those below and above the median VISpeak24h stratified by SCAI stage

Vallabhajosyula, S. et al. Journal of Cardiac Failure 30 (2024) 1516-1521.

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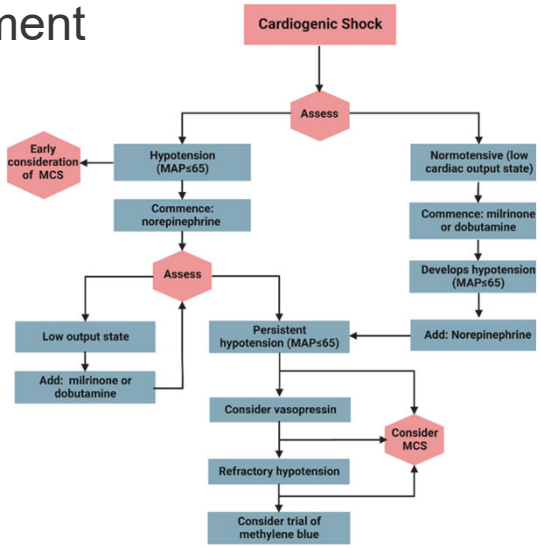
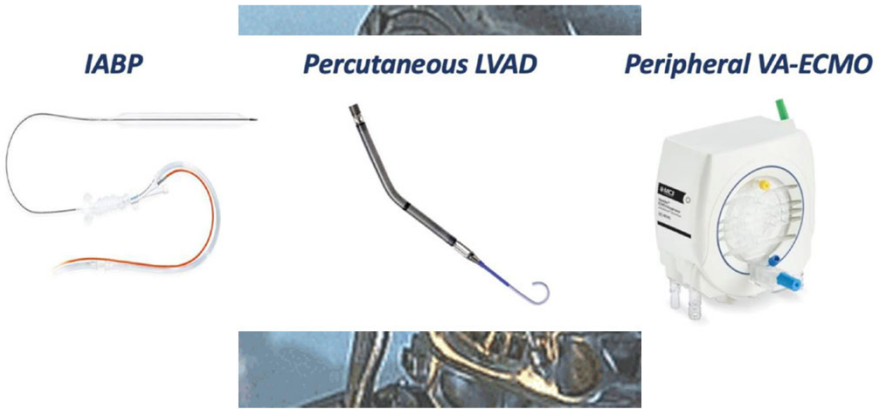
CS Management



Bloom, J. et al. J Am Heart Assoc. 2023;12:e029787.

33

CS Management - tMCS



Adapted from: Hungerford, S. et al. Circ Heart Fail. 2025;18:e012016.

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CS Management - tMCS

Derived Variables

The goal is to provide enough oxygen delivery to satisfy tissues' demands

1. Oxygen is transported in the blood mainly by Hb

$$CaO_2 = (Hb \times 1.39 \times SaO_2) + 0.003_{(mmHg)} \times PaO_2$$

(Hb: Oxygen bound to Hb; $0.003_{(mmHg)} \times PaO_2$: Oxygen Dissolved)

2. Oxygen is in the blood is transported to the tissues by CO

$$DO_2 = CaO_2 \times CO$$

3. Oxygen Consumption

$$VO_2 = (CaO_2 - CvO_2) \times CO$$

Adapted from ELSO Learning Academy Online, elso.org

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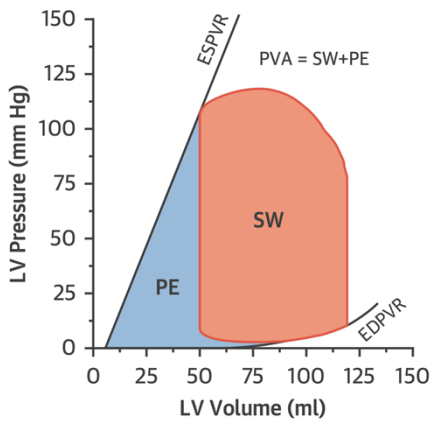
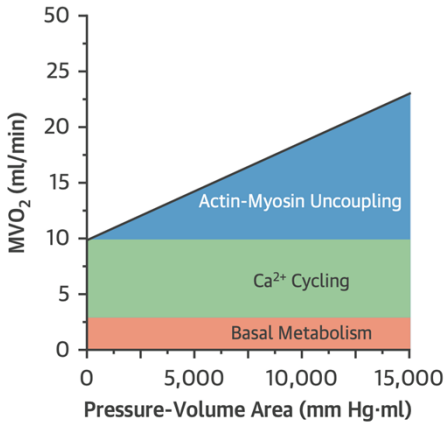
CS Management - tMCS

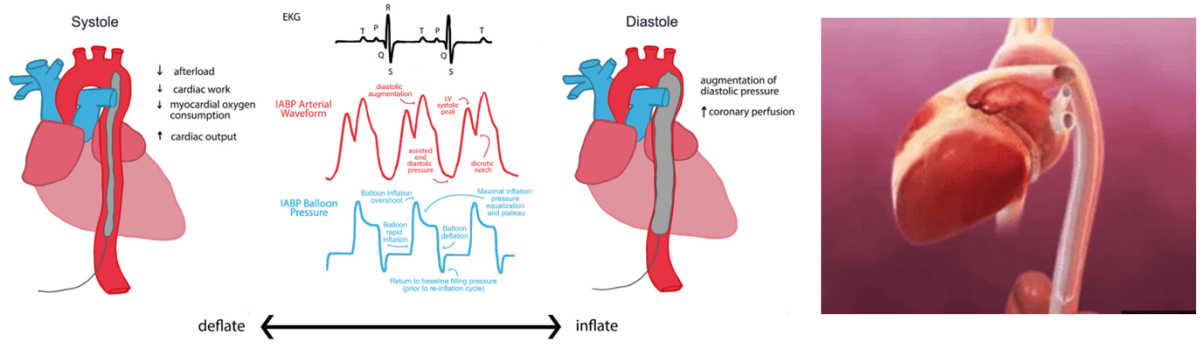




Uriel, N. et al. JACC VOL. 72, NO. 5, 2018 JULY 31, 2018:569–80

36

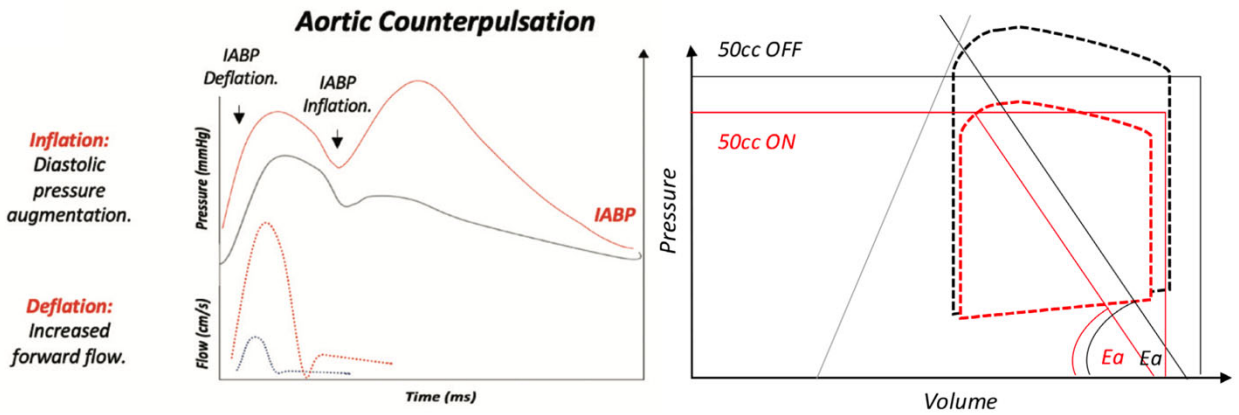
CS Management - IABP



Gillespie, L.E. et al. JSCAI. 3(2024) 101337.
Adapted from: https://share.google/images/UFzaqxTmV0Yaldj1T.

37

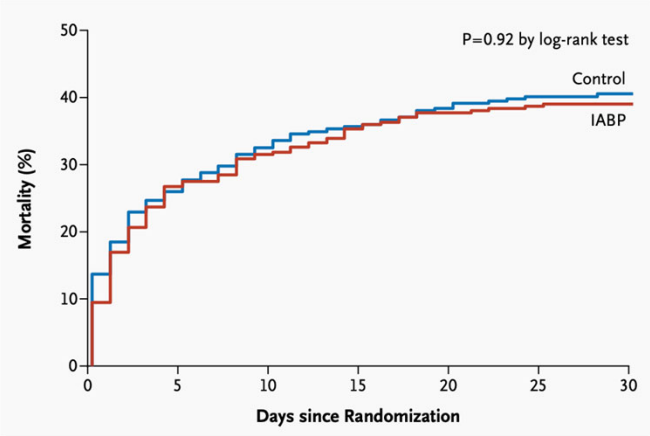
CS Management - IABP



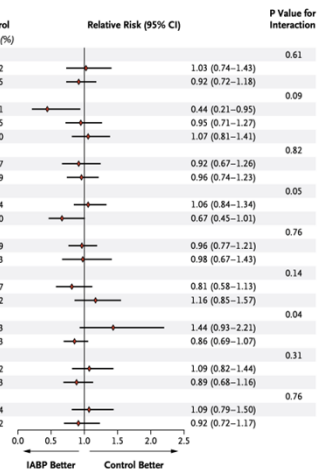
Hungerford, S. et al. Circ Heart Fail. 2025;18:e012016.

38

CS Management - IABP



Baseline Variable	No. of Patients	IABP	Control	Relative Risk (95% CI)	P Value for Interaction
		30-day mortality (%)			
Sex					0.61
Female	187	44.4	43.2	1.03 (0.74–1.43)	
Male	411	37.3	40.5	0.92 (0.72–1.18)	
Age					0.09
<50 yr	70	19.4	44.1	0.44 (0.21–0.95)	
50–75 yr	334	34.6	36.5	0.95 (0.71–1.27)	
>75 yr	194	53.7	50.0	1.07 (0.81–1.41)	
Diabetes					0.82
Yes	195	42.9	46.7	0.92 (0.67–1.26)	
No	399	37.2	38.9	0.96 (0.74–1.23)	
Hypertension					0.05
Yes	410	42.9	40.4	1.06 (0.84–1.34)	
No	183	28.9	43.0	0.67 (0.45–1.01)	
Type of MI					0.76
STEMI/LBBB	412	41.0	42.9	0.96 (0.77–1.21)	
Non-STEMI	177	37.5	38.3	0.98 (0.67–1.43)	
STEMI type					0.14
Anterior	216	35.4	43.7	0.81 (0.58–1.13)	
Nonanterior	196	48.3	42.2	1.16 (0.85–1.57)	
Previous infarction					0.04
Yes	131	47.9	33.3	1.44 (0.93–2.21)	
No	466	37.3	43.3	0.86 (0.69–1.07)	
Hypothermia					0.31
Yes	226	48.1	44.2	1.09 (0.82–1.44)	
No	372	35.1	39.3	0.89 (0.68–1.16)	
Blood pressure					0.76
<80 mm Hg	161	50.7	46.4	1.09 (0.79–1.50)	
≥80 mm Hg	432	35.9	39.2	0.92 (0.72–1.17)	



Thiele, H. et al. NEJM 2012. 367;14.

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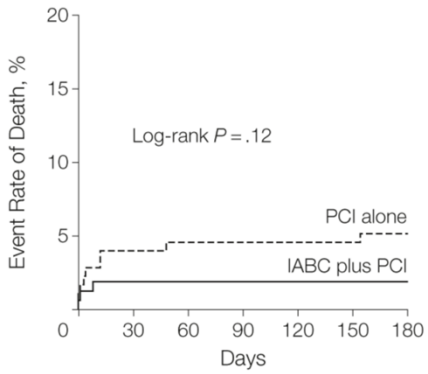
CS Management - IABP

Table 3. Cardiac Magnetic Resonance Imaging (MRI) Findings

	Total (N = 337)	IABC Plus PCI (n = 161)	PCI Alone (n = 176)	*P* Value
Time from symptom onset to MRI, median (IQR), d	4.0 (3.0-5.0)	4.0 (3.0-5.0)	4.0 (3.0-4.0)	.20
Primary End Point				
Infarct size, % of left ventricular mass				
Per-protocol analysis, No. (%)	275 (81.6)	133 (82.6)	142 (80.7)	
Mean (95% CI)	39.8 (37.4-42.1)	42.1 (38.7-45.6)	37.5 (34.3-40.8)	.06
Median (IQR)	38.8 (26.0-52.2)	42.8 (27.2-54.7)	36.2 (25.9-49.4)	
Multiple imputation analysis				
Mean (95% CI)	39.7 (37.3-42.1)	42.1 (38.6-45.6)	37.6 (34.3-40.9)	.07
Median (IQR)	39.0 (26.0-52.3)	42.5 (27.1-55.9)	36.4 (24.9-49.9)	
Proximal left anterior descending and TIMI flow score of 0 or 1				
Per-protocol analysis, No. (%)	192 (57.0)	93 (57.8)	99 (56.3)	
Mean (95% CI)	44.4 (41.7-47.1)	46.7 (42.8-50.6)	42.3 (38.6-45.9)	.11
Median (IQR)	42.1 (30.3-54.7)	45.1 (32.7-60.8)	38.6 (29.6-51.6)	
Multiple imputation analysis				
Mean (95% CI)	44.4 (41.7-47.1)	46.8 (42.9-50.8)	42.1 (38.4-45.7)	.08
Median (IQR)	42.5 (30.3-55.9)	45.3 (32.3-61.6)	39.2 (29.5-51.9)	
Secondary End Point				
MRI findings for ITT population				
Microvascular obstruction, No. (%)	274 (81.3)	131 (81.4)	143 (81.3)	.34
Mean (95% CI), %	6.2 (5.2-7.3)	6.8 (5.2-8.3)	5.7 (4.3-7.2)	
Median (IQR), %	2.6 (0.0-9.1)	2.8 (0.0-9.7)	2.0 (0.0-7.8)	
Left ventricular ejection fraction, No. (%)	284 (84.3)	136 (84.5)	148 (84.1)	.17
Mean (95% CI), %	47.2 (45.7-48.7)	46.1 (43.9-48.3)	48.2 (46.2-50.3)	
Median (IQR), %	46.9 (38.6-56.5)	46.2 (37.4-56.1)	47.6 (39.6-56.8)	
Left ventricular end-systolic volume, No. (%)	284 (84.3)	136 (84.5)	148 (84.1)	.10
Mean (95% CI), mL	73.5 (69.6-77.3)	76.9 (70.6-83.2)	70.3 (65.8-74.9)	
Median (IQR), mL	68.8 (51.0-86.0)	69.5 (51.7-86.5)	67.9 (49.2-86.0)	
Left ventricular end-diastolic volume, No. (%)	284 (84.3)	136 (84.5)	148 (84.1)	.32
Mean (95% CI), mL	137.5 (132.2-142.8)	140.3 (132.5-148.1)	134.9 (127.8-142.1)	
Median (IQR), mL	131.6 (107.4-166.6)	135.4 (112.0-166.8)	130.5 (103.9-166.5)	
Salvage index, No. (%)	263 (78.0)	126 (78.3)	137 (77.8)	.13
Mean (95% CI)	0.35 (0.32-0.38)	0.32 (0.27-0.37)	0.37 (0.33-0.41)	
Median (IQR)	0.30 (0.10-0.50)	0.30 (0.10-0.50)	0.30 (0.20-0.50)	

Abbreviations: IABC, intra-aortic balloon counterpulsation; IQR, interquartile range; ITT, intention-to-treat; PCI, percutaneous coronary intervention; TIMI, Thrombolysis in Myocardial Infarction.



No. at risk

PCI alone	174	167	165	165	165	165	164
IABC plus PCI	157	154	153	153	153	153	153

Patel, M. et al. JAMA. 2011;306;(12):1329-1337.

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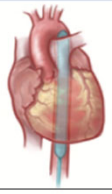
CS Management - IABP

ACC/AHA AMI GUIDELINES	2013 STEMI	2014 NSTEMI	2025 ACS
IABP 	2a (Is reasonable)	- →	3 (Not recommended)

Murugiah, K. et al. JACC. 2025 Jun, 85 (22) 2103–2106.

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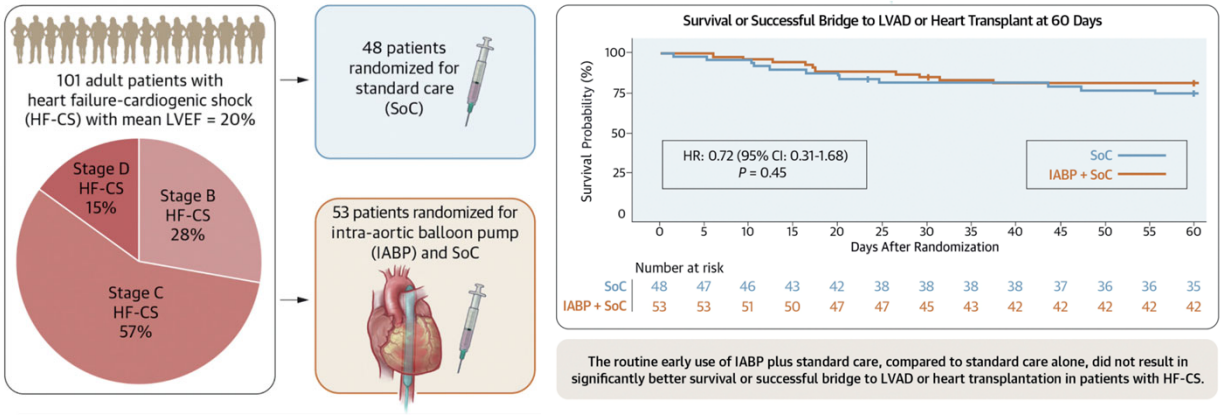
CS Management - IABP



The routine early use of IABP plus standard care, compared to standard care alone, did not result in significantly better survival or successful bridge to LVAD or heart transplantation in patients with HF-CS.

Morici N, et al. JACC. 2025;85(16):1587-1597.

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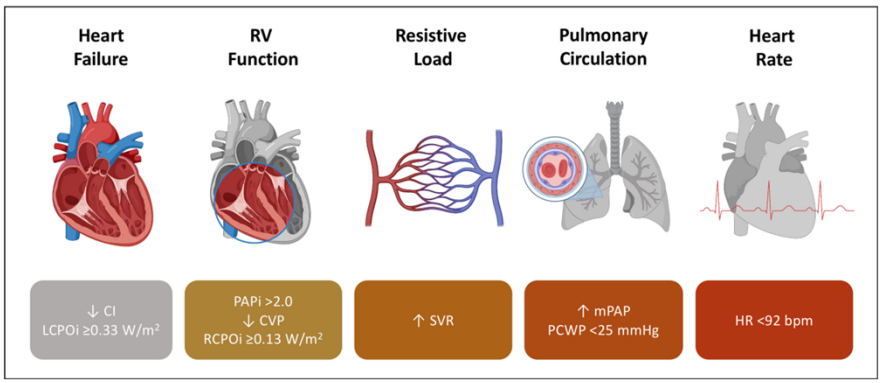
CS Management - IABP

The IABP "best responder" phenotype in hypoperfused ADHF



Baldetti, L. et al. Circ Heart Fail. 2021;14:e008527

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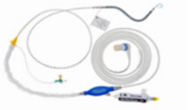
CS Management - Impella

Impella CP with SmartAssist	Impella 5.5 with SmartAssist	Impella RP with SmartAssist
		
• Inserted via femoral or axillary artery • Max flows 4.3 L/min • 14Fr cannula • Pigtail on end of cannula • 14Fr motor housing with stainless steel motor bearings • SmartAssist fiber optic pressure sensor • 135 cm catheter • 13Fr repositioning sheath • Red Impella plug • Pre-attached white Impella cable	• Inserted via axillary artery or direct into aorta • Max flows 6.0 L/min • 21Fr cannula • No pigtail on end of cannula • 19Fr motor housing with ceramic ball bearings • SmartAssist fiber optic pressure sensor • 70 cm catheter length • Sheath-less repositioning unit • Red Impella plug • Pre-attached white Impella cable	• Inserted via femoral vein • Max flow >4 L/min • 21Fr cannula • Pigtail on end of cannula • 21Fr motor housing with stainless steel motor bearings • SmartAssist fiber optic pressure sensor and differential pressure sensor • 15Fr repositioning sheath • Blue Impella plug • Pre-attached white Impella cable

Courtesy of Abiomed

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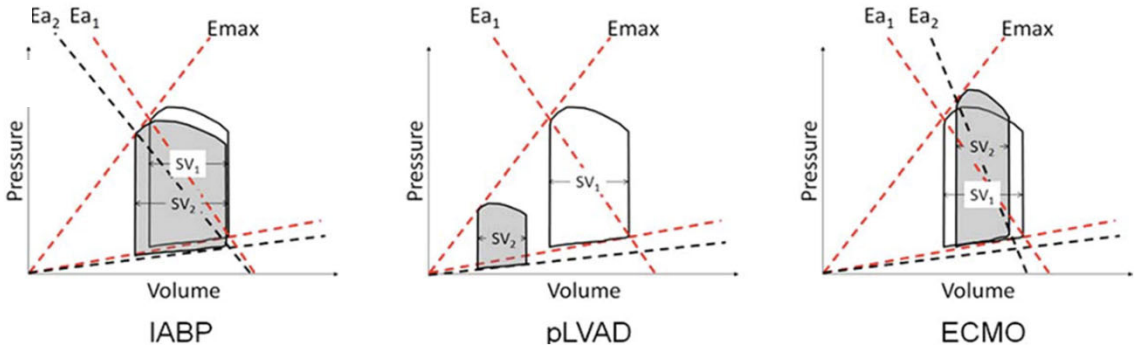
CS Management - Impella



Adapted from: Szeto et al. SCAI 2015. 85(7) E175-196.

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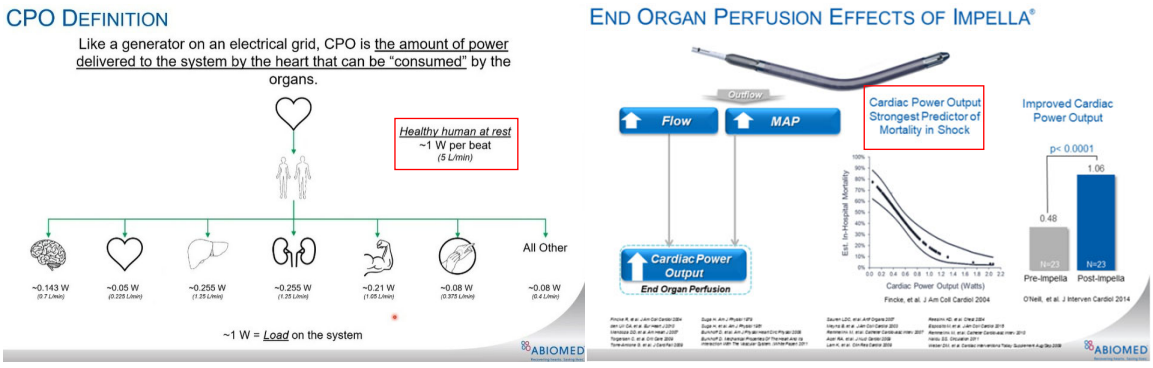
CS Management - Impella



Cardiac Power Output (CPO) = **MAP** x **CO** × 0.0022
- Measure of end-organ perfusion (**normal: 1-1.5 Watts**)

Courtesy of Abiomed

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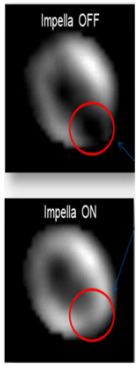
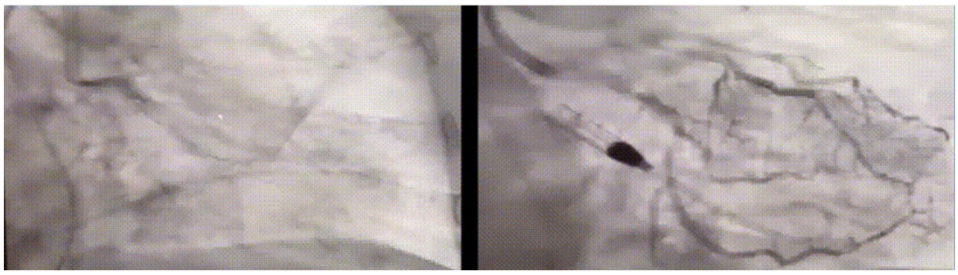
CS Management - Impella





Pre-PCI (no unloading) Pre-PCI (Unloaded with Impella)

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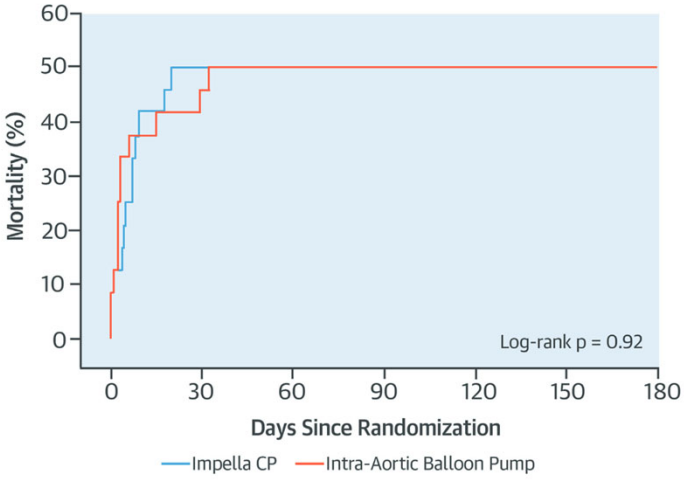
CS Management - Impella



Hemodynamic variables before randomization		
Heart rate, beats/min	81 ± 21	83 ± 28
Mean arterial pressure, mm Hg	66 ± 15	66 ± 15
Systolic blood pressure, mm Hg	81 ± 17	84 ± 19
Diastolic blood pressure, mm Hg	58 ± 22	57 ± 13
Medical therapy before randomization		
Catecholamines or inotropes	24/24 (100)	22/24 (92)
Mechanical ventilation	24/24 (100)	24/24 (100)
Cardiac arrest before randomization	24/24 (100)	20/24 (83)
Witnessed arrest	22/24 (92)	17/20 (85)
First rhythm VT/VF	22/24 (92)	17/20 (85)
Time till return of spontaneous circulation, min	21 (15-46)	27 (15-52)
Traumatic injuries at admission	5/24 (21)	2/24 (8)
Blood values on admission*		
Lactate, mmol/l	7.5 ± 3.2	8.9 ± 6.6
Hemoglobin, mmol/l	8.6 ± 1.2	8.6 ± 1.2
Creatinine, mg/dl	96 ± 29	102 ± 22
Glucose, mmol/l	16.2 ± 4.7	14.1 ± 5.3
Arterial pH	7.14 ± 0.14	7.17 ± 0.17
Baseline echocardiography†		
Estimated left ventricular ejection fraction		
<20%	5/22 (23)	8/18 (44)
20%-40%	10/22 (46)	6/18 (33)
>40%	7/22 (32)	4/18 (22)

Ouweneel, D. et al. JACC. 2017 Jan, 69 (3) 278–287.

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CS Management - Impella

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock

J.E. Møller, T. Engstrøm, L.O. Jensen, H. Eiskjær, N. Mangner, A. Polzin, P.C. Schulze, C. Skurk, P. Nordbeck, P. Clemmensen, V. Panoulas, S. Zimmer, A. Schäfer, N. Werner, M. Frydland, L. Holmvang, J. Kjærgaard, R. Sørensen, J. Lønborg, M.G. Lindholm, N.L.J. Udesen, A. Junker, H. Schmidt, C.J. Terkelsen, S. Christensen, E.H. Christiansen, A. Linke, F.J. Woitek, R. Westenfeld, S. Möbius-Winkler, K. Wachtell, H.B. Ravn, J.F. Lassen, S. Boesgaard, O. Gerke, and C. Hassager, for the DanGer Shock Investigators*

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CS Management - Impella

Inclusion Criteria

STEMI or STEMI equivalent with occluded coronary (<36 hours to 12 hours after revascularization)

CS <24 hours - SBP <100 mm Hg or vasopressor need

Arterial lactate ≥2.5 mmol/L

SvO_2 <55% with a normal PaO_2

LVEF <45%

Exclusion Criteria

RV failure

OHCA with GCS <8 after ROSC

Severe PAD precluding mAFP

Life expectancy <1 year

Mechanical complications of AMI

Severe AS/AR
Mechanical AVR
Severe aortic abnormalities
LV thrombus

Murugiah, K. et al. JACC. 2025 Jun, 85 (22) 2103–2106

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CS Management - Impella

Characteristic	Microaxial Flow Pump plus Standard Care (N=179)	Standard Care Alone (N=176)
Median age (IQR) — yr	67 (58–76)	69 (61–76)
Male sex — no. (%)	142 (79.3)	139 (79.0)
Medical history — no. (%)		
Hypertension	89 (49.7)	94 (53.4)
Diabetes	33 (18.4)	47 (26.7)
Myocardial infarction	29 (16.2)	28 (15.9)
Heart failure	16 (8.9)	17 (9.7)
Chronic kidney disease	17 (9.5)	18 (10.2)
SCAI–CSWG stage at admission — no. (%)†		
C	100 (55.9)	97 (55.1)
D	51 (28.5)	50 (28.4)
E	28 (15.6)	29 (16.5)

Møller, J.E. NEJM 2024;390:1382-93.

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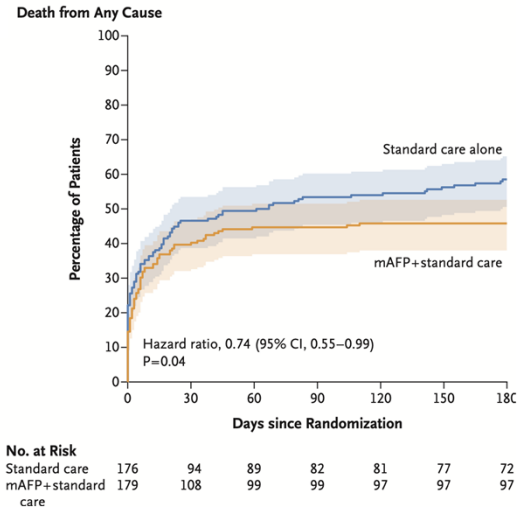
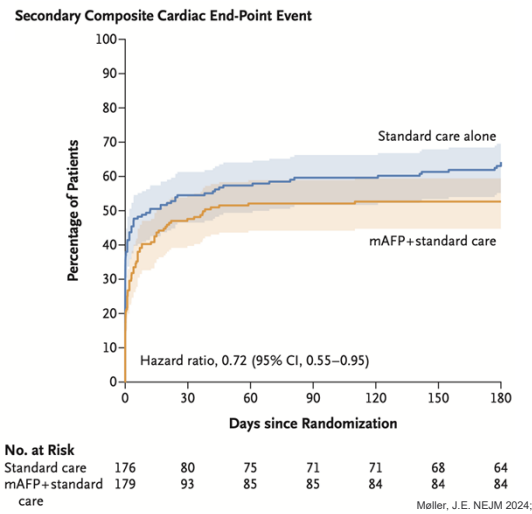
CS Management - Impella





Møller, J.E. NEJM 2024;390:1382-93.

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CS Management - Impella

Table 3. End Points and Adverse Events in the Intention-to-Treat Population.*

Event	Microaxial Flow Pump plus Standard Care (N=179)	Standard Care Alone (N=176)	Effect Size (95% CI)†
Primary end point: death from any cause at 180 days — no. (%)	82 (45.8)	103 (58.5)	0.74 (0.55 to 0.99)‡
Secondary end point			
Composite cardiac end point — no. (%)§	94 (52.5)	112 (63.6)	0.72 (0.55 to 0.95)
No. of days alive and out of the hospital (range)¶	82 (0 to 177)	73 (0 to 179)	8 (−8 to 25)
Adverse events			
Composite safety end point — no. (%)‖	43 (24.0)	11 (6.2)	4.74 (2.36 to 9.55)
Moderate or severe bleeding — no. (%)**	39 (21.8)	21 (11.9)	2.06 (1.15 to 3.66)
Limb ischemia — no. (%)	10 (5.6)	2 (1.1)	5.15 (1.11 to 23.84)
Renal-replacement therapy — no. (%)	75 (41.9)	47 (26.7)	1.98 (1.27 to 3.09)
Stroke — no. (%)	7 (3.9)	4 (2.3)	1.75 (0.50 to 6.01)
Cardioversion after ventricular tachycardia or fibrillation — no. (%)	59 (33.0)	52 (29.5)	1.17 (0.75 to 1.83)
Sepsis with positive blood culture†† — no. (%)	21 (11.7)	8 (4.5)	2.79 (1.20 to 6.48)

Møller, J.E. NEJM 2024;390:1382-93.

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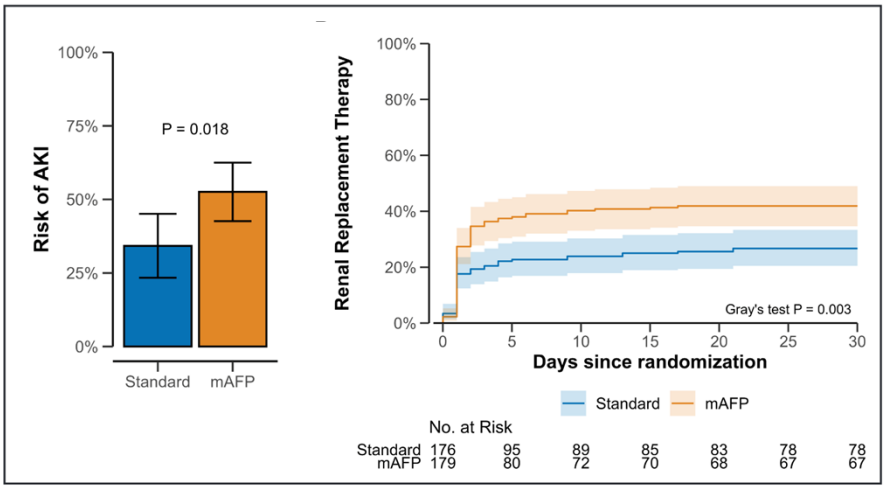
CS Management - Impella



Zweck et al. Circulation. 2024;150:1990–2003.

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CS Management - Impella

Characteristics	Standard						mAFP					
	Without AKI (n=97)	With AKI (n=79)	*P* value	Without RRT (n=129)	With RRT (n=47)	*P* value	Without AKI (n=69)	With AKI (n=110)	*P* value	Without RRT (n=104)	With RRT (n=75)	*P* value
Death from all causes at 180 d	49 (51)	54 (68)	0.017	68 (53)	35 (74)	0.010	23 (33)	59 (54)	0.008	40 (38)	42 (56)	0.020
Secondary end point: escalation, LVAD, or death	51 (53)	62 (78)	<0.001	72 (56)	41 (87)	<0.001	27 (39)	67 (61)	0.005	44 (42)	50 (67)	0.001

Zweck et al. Circulation. 2024;150:1990–2003.

55

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CS Management - Impella

2025 ACC/AHA ACS Guidelines

Recommendations for MCS in Patients With ACS and Cardiogenic Shock

COR	LOE	Recommendations
2a	B-R	1. In selected* patients with STEMI and severe or refractory cardiogenic shock, insertion of a microaxial intravascular flow pump is reasonable to reduce death.[1]
2a	B-NR	2. In patients with mechanical complication of ACS, short-term MCS devices are reasonable for hemodynamic stabilization as a bridge to surgery.[2–4]

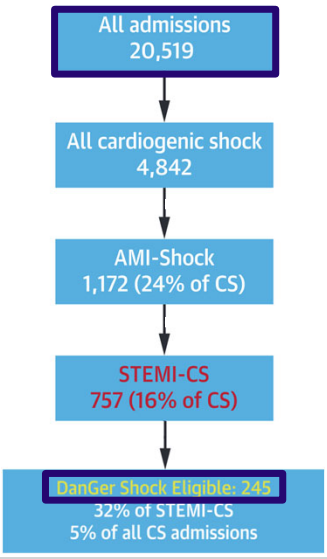
Rao, S. et al. Circulation. 2025;151:e771–e862

57

CS Management - Impella

Using Selection Criteria From the DanGer Shock Trial in a Contemporary Cohort With Cardiogenic Shock

Connor G. O'Brien, MD,[a] Samuel B. Brusca, MD,[a] Christopher F. Barnett, MD, MPH,[a] David D. Berg, MD, MPH,[b] Vivian M. Baird-Zars, MPH,[b] Jeong-Gun Park, PhD,[b] Erin A. Bohula, MD, DPhil,[b] David A. Morrow, MD, MPH,[b] the CCCTN Investigators



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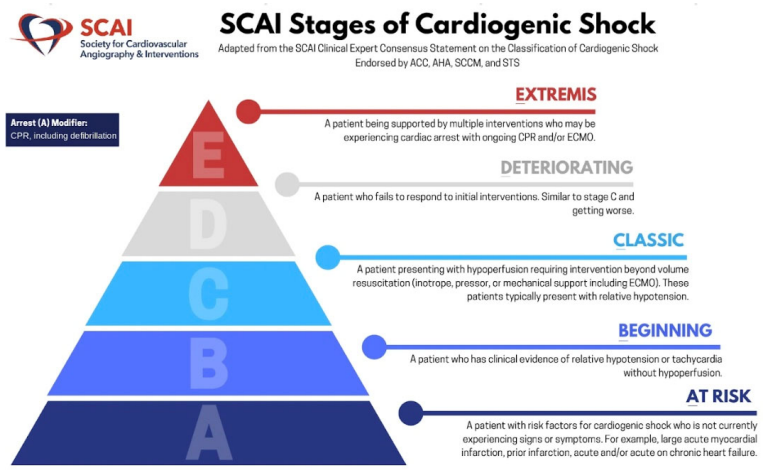
CS Management - tMCS



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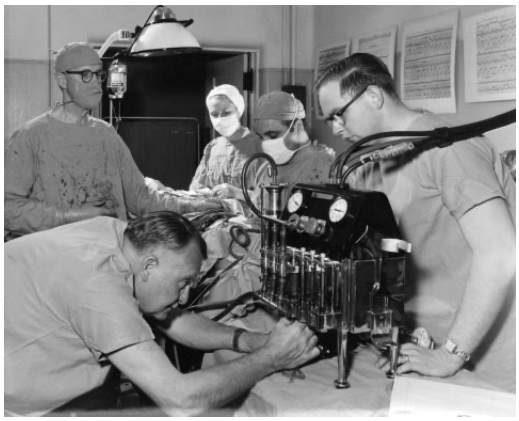
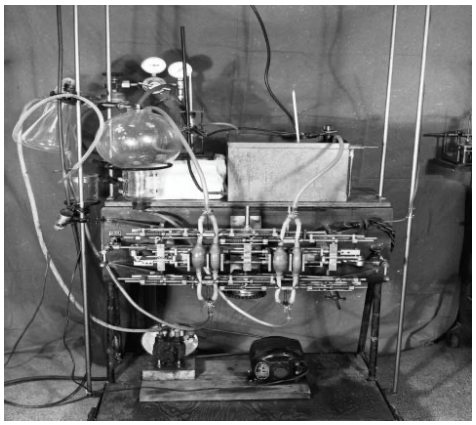
CS Management - tMCS

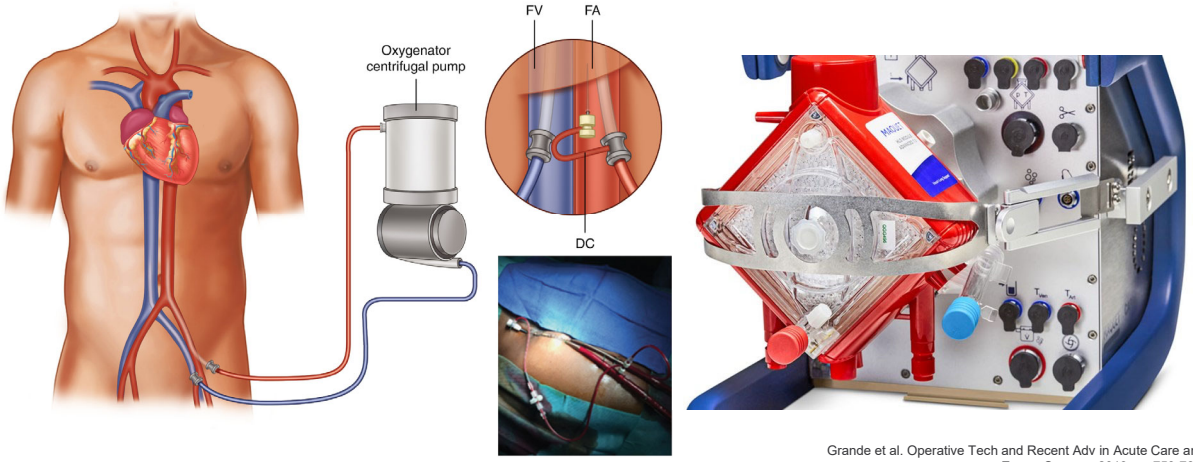




Stoney, W. Circulation. 2009;119:2844–2853

60

CS Management - ECMO

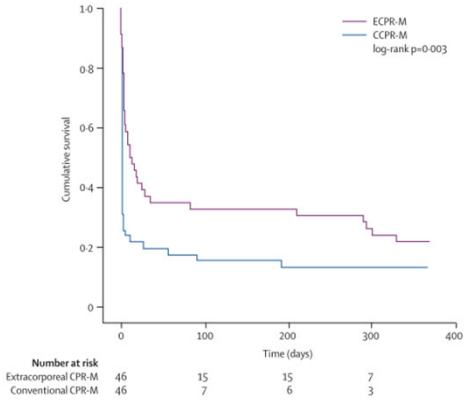


Grande et al. Operative Tech and Recent Adv in Acute Care and Emerg Surgery. 2019, pp 759-766.

61

Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis

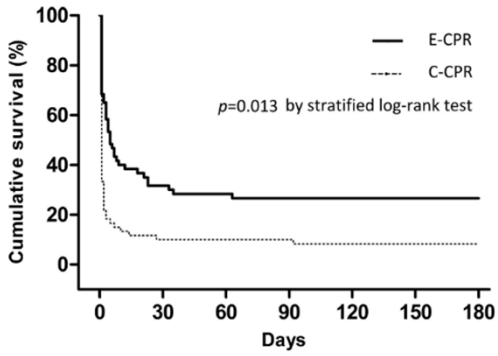
Yih-Sharng Chen*, Jou-Wei Lin*, Hsi-Yu Yu, Wen-Je Ko, Jih-Shuin Jerng, Wei-Tien Chang, Wen-Jone Chen, Shu-Chien Huang, Nai-Hsin Chi, Chih-Hsien Wang, Li-Chin Chen, Pi-Ru Tsai, Sheoi-Shen Wang, Juey-Jen Hwang, Fang-Yue Lin



Chen, Y. et al. Lancet 2008; 372: 554-61.

Extracorporeal cardiopulmonary resuscitation in patients with inhospital cardiac arrest: A comparison with conventional cardiopulmonary resuscitation*

Tae Gun Shin, MD; Jin-Ho Choi, MD, PhD; Ik Joon Jo, MD, PhD; Min Seob Sim, MD; Hyoung Gon Song, MD, PhD; Yeon Kwon Jeong, MD, PhD; Yong-Bien Song, MD, PhD; Joo-Yong Hahn, MD, PhD; Seung Hyuk Choi, MD, PhD; Hyeon-Cheol Gwon, MD, PhD; Eun-Seok Jeon, MD, PhD; Kiick Sung, MD, PhD; Wook Sung Kim, MD, PhD; Young Tak Lee, MD, PhD



Shin, T. et al. Crit Care Med. 2011; 39(1), 1-7.

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CS Management - ECMO

Indications

- Cardiac arrest (ECPR)
- AMI or HF-CS
- Myocarditis
- Refractory ventricular dysrhythmia
- Pulmonary embolus
- Hypothermia
- Cardiotoxin exposure
- Peri-procedural support
- Failure to wean from CPB
- Graft failure or rejection s/p OHT

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https://www.jems.com/2017/12/01/how-physicians-perform-prehospital-ecmo-on-the-streets-of-paris/

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CS Management - ECMO

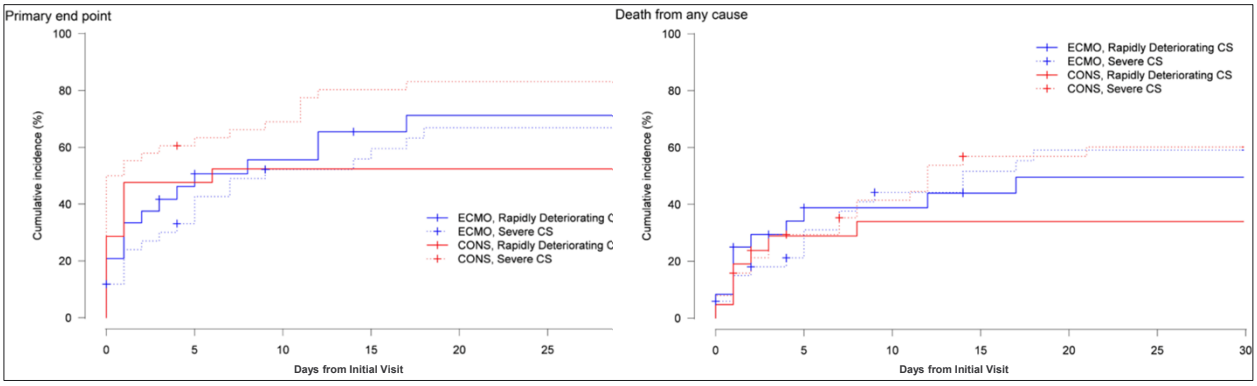
Circulation
Volume 147, Issue 6, 7 February 2023; Pages 454-464
https://doi.org/10.1161/CIRCULATIONAHA.122.062949

ORIGINAL RESEARCH ARTICLE

Extracorporeal Membrane Oxygenation in the Therapy of Cardiogenic Shock: Results of the ECMO-CS Randomized Clinical Trial

65

CS Management - ECMO



Ostadal, P. et al. Circulation. 2023;147:454–464.

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CS Management - ECMO

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Extracorporeal Life Support in Infarct-Related Cardiogenic Shock

H. Thiele, U. Zeymer, I. Akin, M. Behnes, T. Rassaf, A.A. Mahabadi, R. Lehmann, I. Eitel, T. Graf, T. Seidler, A. Schuster, C. Skurk, D. Duerschmied, P. Clemmensen, M. Hennersdorf, S. Fichtlscherer, I. Voigt, M. Seyfarth, S. John, S. Ewen, A. Linke, E. Tigges, P. Nordbeck, L. Bruch, C. Jung, J. Franz, P. Lauten, T. Goslar, H.-J. Feistritzer, J. Pöss, E. Kirchhof, T. Ouarrak, S. Schneider, S. Desch, and A. Freund, for the ECLS-SHOCK Investigators*

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CS Management - ECMO

Characteristic	ECLS (N=209)	Control (N=208)
Median blood pressure (IQR) — mm Hg		
Systolic	95 (80–120)	97 (80–120)
Diastolic	61 (50–73)	60 (50–71)
Median heart rate (IQR) — beats/min	90 (75–110)	95 (71–110)
Laboratory values on admission		
Median pH (IQR)	7.2 (7.1–7.3)	7.2 (7.1–7.3)
Median lactate (IQR) — mmol/liter	6.8 (4.5–9.6)	6.9 (4.6–10.0)
Median creatinine (IQR) — mg/dl	1.2 (1.0–1.5)	1.3 (1.1–1.6)
Median high-sensitivity cardiac troponin T (IQR) — ng/liter	1540 (232–6630)	987 (173–5700)
SCAI shock stage — no. (%)‡		
C	104 (49.8)	111 (53.4)
D	38 (18.2)	18 (8.7)
E	67 (32.1)	79 (38.0)

Thiele, H. et al. N Engl J Med 2023;389:1286-97

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CS Management - ECMO

Characteristic	ECLS (N=209)	Control (N=208)
ECLS therapy — no. (%)	192 (91.9)	26 (12.5)
Initiation in catheterization laboratory		
Before revascularization	42/192 (21.9)	4/26 (15.4)
During revascularization	50/192 (26.0)	8/26 (30.8)
After revascularization	100/192 (52.1)	7/26 (26.9)
Initiation after catheterization laboratory		
<24 hr	0/192	3/26 (11.5)
≥24 hr	0/192	4/26 (15.4)

Thiele, H. et al. N Engl J Med 2023;389:1286-97

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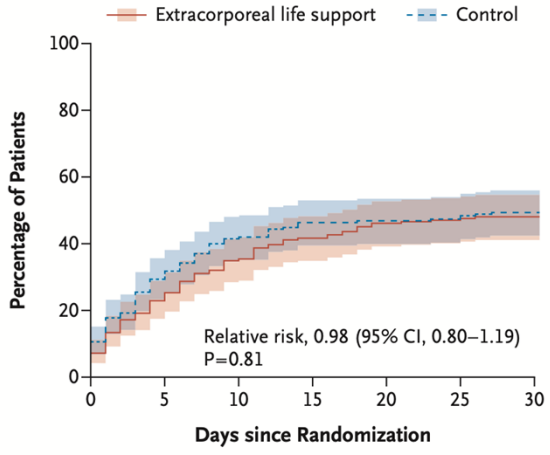
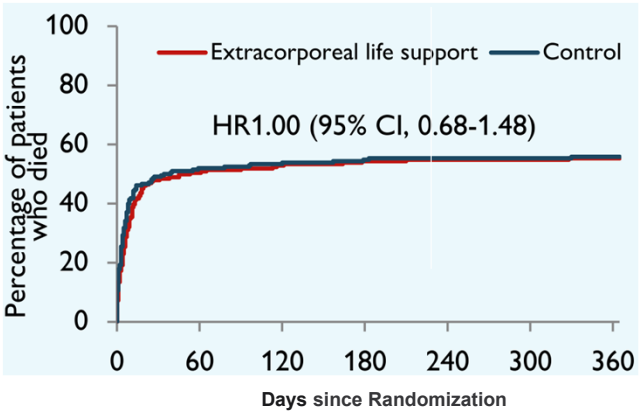
CS Management - ECMO



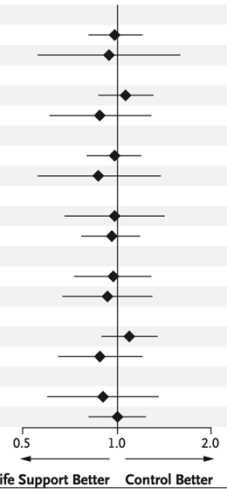


Thiele, H. et al. N Engl J Med 2023;389:1286-97.

Desch, S. et al. EHJ 2024; 45, 4200–4203.

70

Subgroup	Death from Any Cause at 30 Days: Control (no. of patients with events/total no. of patients (%))	Death from Any Cause at 30 Days: Extracorporeal Life Support (no. of patients with events/total no. of patients (%))	Relative Risk (95%)
Sex			
Male	79/169 (46.7)	78/170 (45.9)	0.98 (0.81–1.20)
Female	23/39 (59.0)	22/39 (56.4)	0.94 (0.56–1.58)
Age			
<65 yr	41/112 (36.6)	50/124 (40.3)	1.06 (0.87–1.30)
≥65 yr	61/96 (63.5)	50/85 (58.8)	0.88 (0.61–1.28)
Diabetes			
No	62/146 (42.5)	57/138 (41.3)	0.98 (0.80–1.19)
Yes	39/60 (65.0)	42/70 (60.0)	0.87 (0.56–1.37)
Type of infarction			
Non–ST-segment elevation myocardial infarction	36/66 (54.5)	37/69 (53.6)	0.98 (0.68–1.41)
ST-segment elevation myocardial infarction	65/141 (46.1)	59/135 (43.7)	0.96 (0.77–1.18)
ST-segment elevation myocardial infarction type			
Anterior infarction	39/85 (45.9)	33/75 (44.0)	0.97 (0.73–1.28)
Nonanterior infarction	26/56 (46.4)	25/59 (42.4)	0.93 (0.67–1.29)
Arterial lactate			
≤6 mmol/liter	24/85 (28.2)	30/87 (34.5)	1.09 (0.89–1.34)
>6 mmol/liter	75/120 (62.5)	69/120 (57.5)	0.88 (0.65–1.20)
CPR			
No	24/46 (52.2)	22/47 (46.8)	0.90 (0.60–1.35)
Yes	78/162 (48.1)	78/162 (48.1)	1.00 (0.81–1.23)



Thiele, H. et al. N Engl J Med 2023;389:1286-97

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CS Management - ECMO

ECLS-SHOCK Limitations

- Retrospective SCAI Stage adjudication
- High # SCAI Stage C – ~50%
- Short support-time – Median 2.7days
- Risk of anoxic brain injury – >75% cardiac arrest
- Low rate of LV unloading – 5.8%
- Transplant vs durable VAD?

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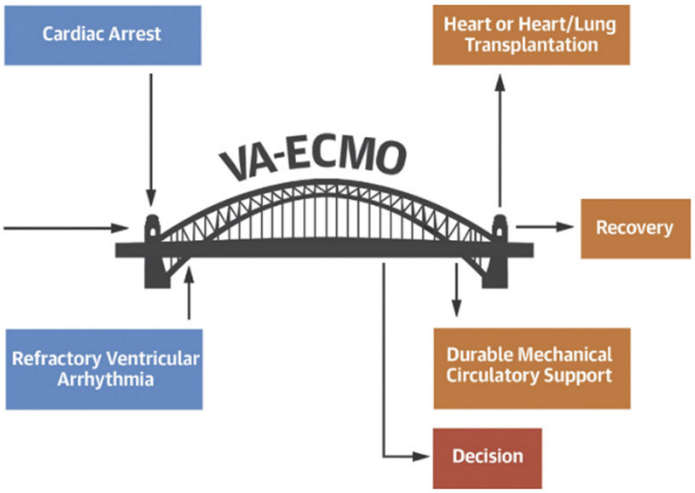
CS Management - ECMO

Cardiogenic Shock

- Acute myocardial infarction
- Acute or chronic heart failure due to left ventricle or biventricular
  - Myocarditis
  - Chronic cardiomyopathy
  - Septic cardiomyopathy
  - Graft failure after heart transplantation
- Chronic right ventricle (RV) failure
- Pulmonary embolism with RV failure
- Postcardiotomy syndrome



Guglin, M. et al. J Am Coll Cardiol. 2019;73(6):698–716.

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CS Management - tMCS

	2013 STEMI	2014 NSTEMI	2025 ACS
IABP	2a (Is reasonable)	- →	3 (Not recommended)
VA-ECMO	-	- →	3 (Not recommended)
mAFP	2b (May be reasonable)	- →	2a (STEMI) (Is reasonable)

ACC/AHA guidelines

Murugiah, K. et al. JACC. 2025 Jun, 85 (22) 2103–2106

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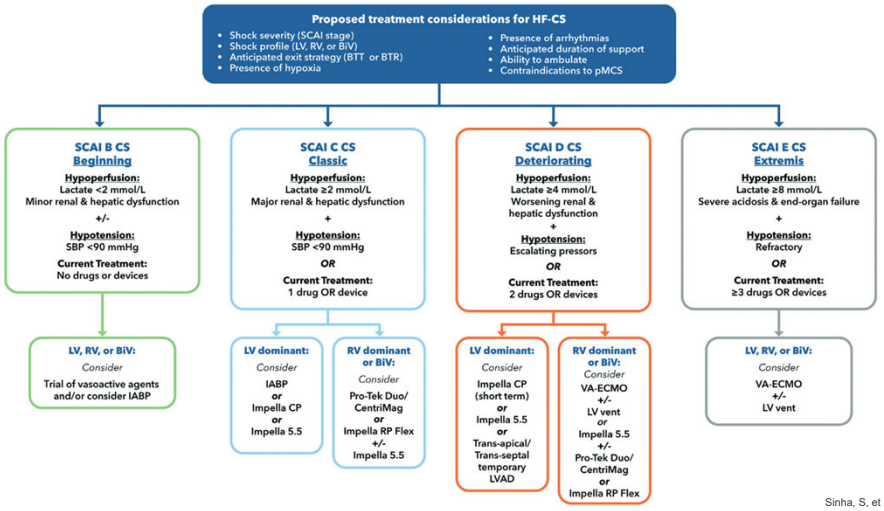
CS Management - tMCS



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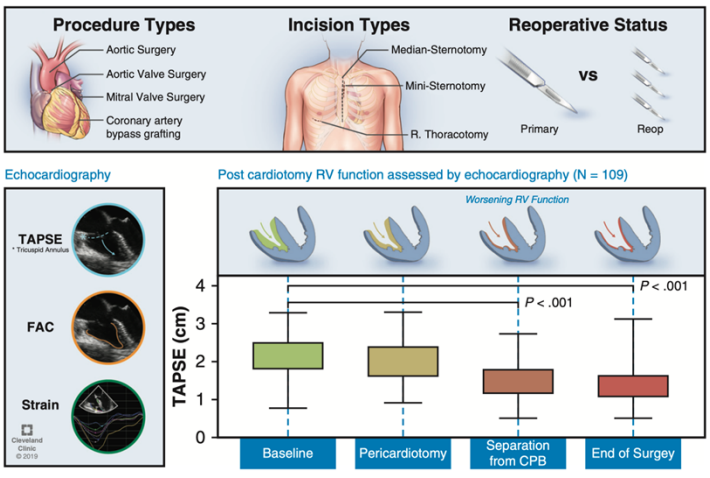
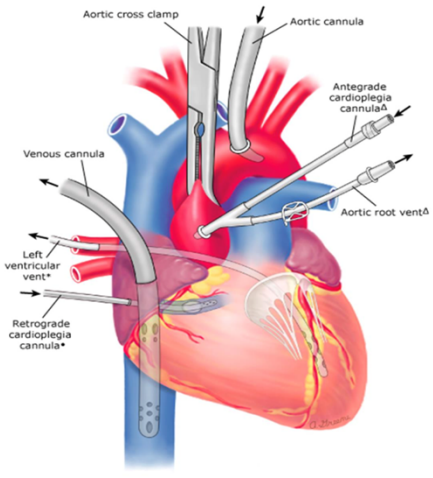
75

CS Management - RV support





Singh, A. et al. J Thorac Cardiovasc Surg 2020;159:1430-8.

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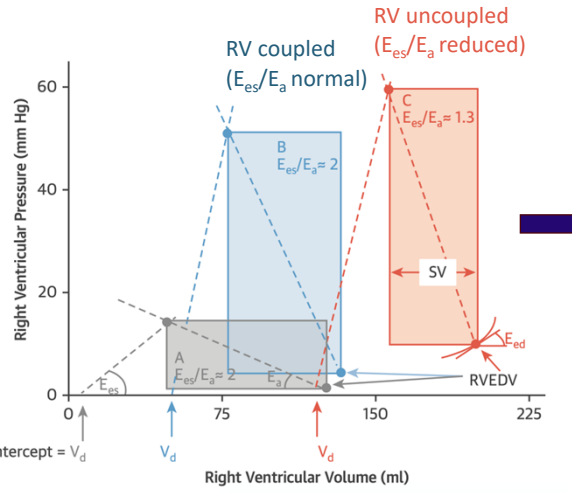
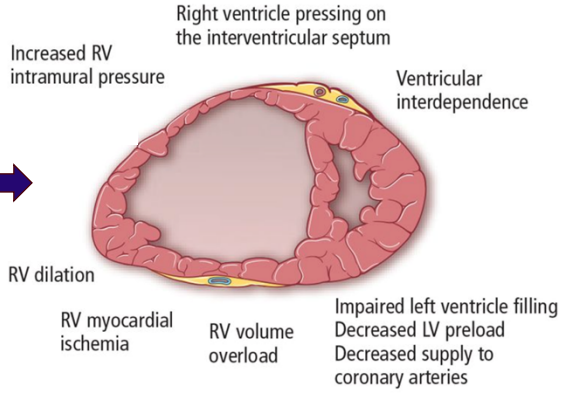
CS Management - RV support





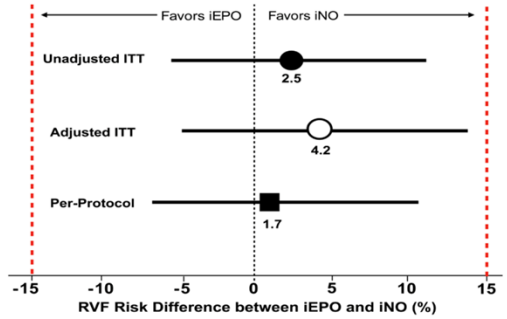
Noordegraf, A et al. J Am Coll Cardiol 2017;69:236–43).

Sorathia, S. Cleveland Clinic Journal of Medicine May 2025, 92 (5) 301-309.

77

Inhaled Epoprostenol Compared With Nitric Oxide for Right Ventricular Support After Major Cardiac Surgery

Circulation
Volume 148, Issue 17, 24 October 2023; Pages 1316-1329
https://doi.org/10.1161/CIRCULATIONAHA.122.062464



Analysis	Number/Total Number (%) iEPO	iNO	*Risk Difference, % (90% CI)	†Relative Risk (95% CI)
ITT	30/120 (25.0%)	25/111 (22.5%)		
Unadjusted			2.5 (-6.6, 11.6)	1.11 (0.70, 1.75)
‡Adjusted			4.2 (-5.2, 13.6)	1.11 (0.75, 1.66)
§Per-Protocol	28/116 (24.1%)	24/107 (22.4%)	1.7 (-7.5, 10.9)	1.08 (0.67, 1.72)

Outcome	iEPO (n=120)*	iNO (n=111)*	Relative risk (95% CI)†, (mean ratio [95% CI] for length of stay outcomes)	*P* value
Death, n (%)				
In-hospital	11 (9.2)	6 (5.4)	1.70 (0.65–4.45)	0.28
30 days	7 (5.8)	4 (3.%)	1.62 (0.49–5.38)	0.43
90 days	12 (10.0)	5 (4.5)	2.22 (0.81–6.10)	0.12
1 y‡	21/117 (17.9)	10/106 (9.4)	1.90 (0.94–3.85)	0.07
Acute kidney injury stages 2 or 3§	34 (28.3)	39 (35.1)	0.81 (0.55–1.17)	0.26
Renal replacement therapy	19 (15.8)	22 (19.8)	0.80 (0.46–1.40)	0.43
Discharge on new dialysis	9 (7.5)	7 (6.3)	1.19 (0.45–3.11)	0.72
Tracheostomy placement	15 (12.5)	8 (7.2)	1.72 (0.76–3.90)	0.20
Duration of mechanical ventilation, Kaplan-Meier estimate, median (95% CI), hl	26.1 [18.0–37.1]	26.3 [19.5–34.4]	NA	0.64#
Intensive care unit length of stay, days	6 [4, 11]	6 [4, 11]	0.94 (0.57–1.56)	0.82
Hospital length of stay, days	17 [11, 28]	16 [12, 30]	0.97 (0.73–1.28)	0.83

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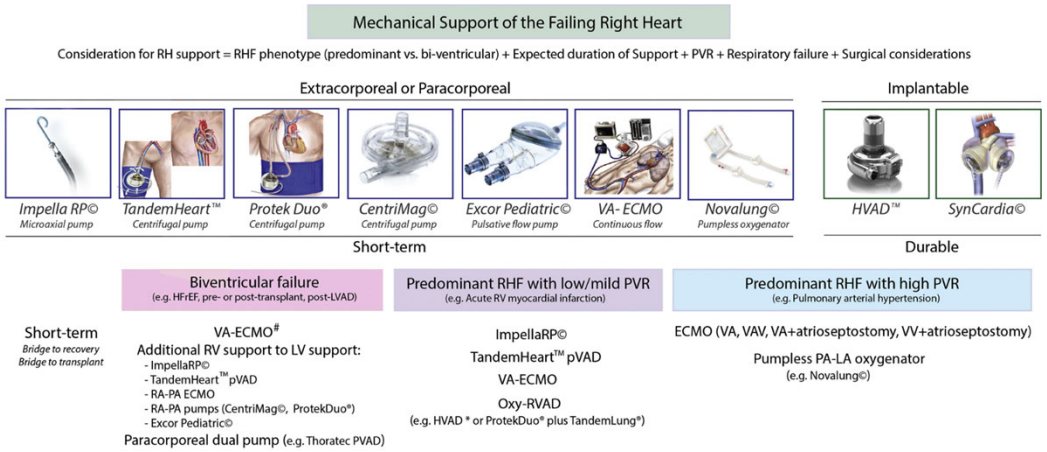
CS Management - RV support



Amsallem, M. et al. JACC HF. 2018; 6,11: 891-903

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Objectives

- Discuss cardiogenic shock etiologies, phenotypes and staging
- Review the pathophysiology of cardiogenic shock and its management options
- Highlight MHI's approach to cardiogenic shock

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MHI Case

73 y.o. F w/ HTN, HL, no previous cardiac hx

- CC: 3-days chest burning, ?GERD
- Exam: VSS, NAD, RRR, no m/r/g, warm well-perfused
- Diagnostics:
  - Tpn-I 4.3
  - Lactate 2.0
  - ECG ischemic STD
  - POCUS - "reduced EF"
- Rec.d
  - ASA 325mg
  - Heparin bolus + gtt
  - Nitroglycerin gtt
- Transfer to ANW

SCAI SHOCK STAGE

A

B

C

D

E

HOPE DISCOVERED HERE | Minneapolis Heart Institute Foundation

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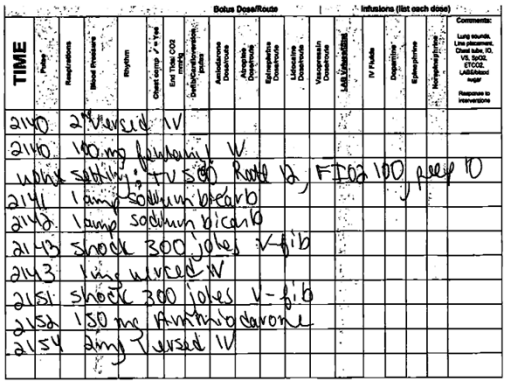
MHI Case

73 y.o. F w/ NSTEMI, SCAI Stage A CS



SCAI SHOCK STAGE

A

B

C

D

E

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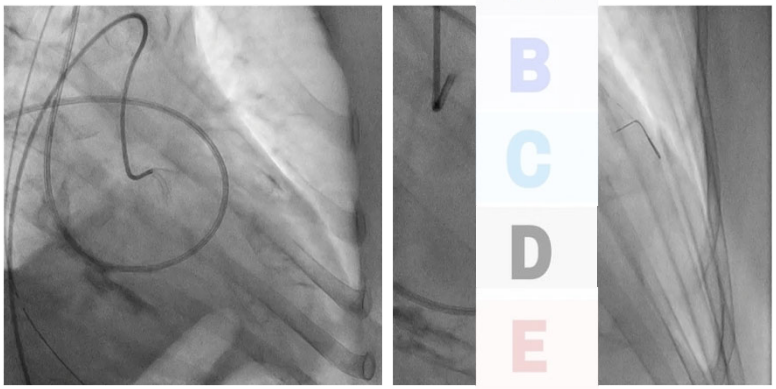
MHI Case

73 y.o. F w/ AMI-CS, SCAI Stage D, cardiorenal phenotype

- RHC
  - RA 8 mmHg
  - PA 32/18 (23) mmHg
    - PAPi 1.7
  - PCWP 18 mmHg
  - CI 1.8 mL/m2
  - SVR 830 DSC
- LHC
  - LAD occluded
  - RCA & LCx mild dx



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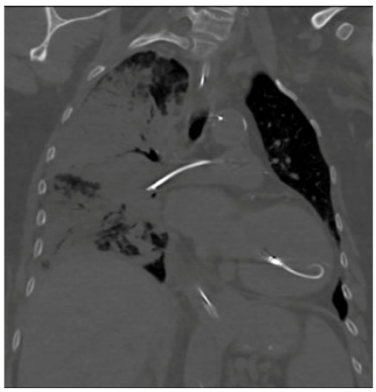
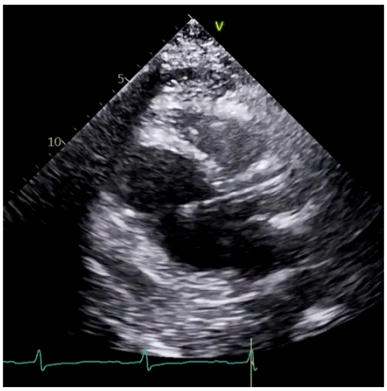
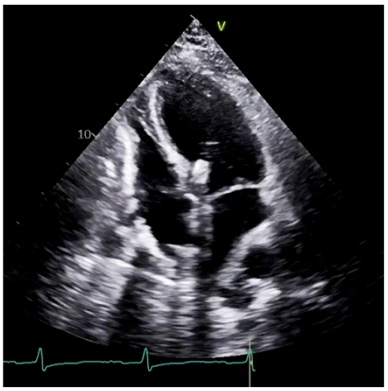
MHI Case

73 y.o. F w/ AMI-CS, SCAI Stage E, cardiometabolic phenotype







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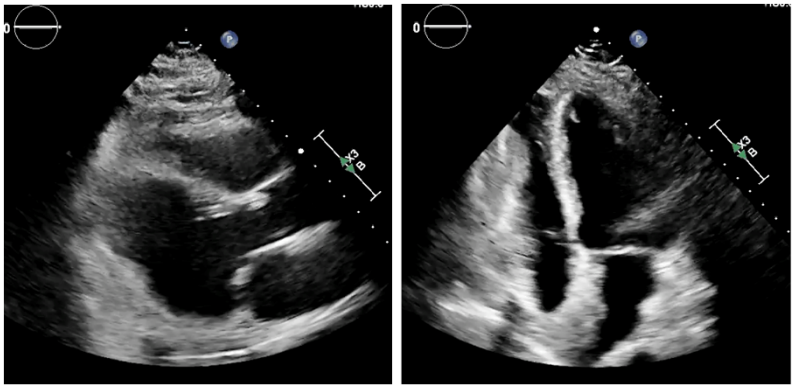
MHI Case

73 y.o. F w/ AMI-CS, SCAI Stage E, cardiometabolic phenotype

- HD #0 ECPELLA
- HD #2 Decannulated
- HD #3 Extubated
- HD #9 Discharged to SNF



HOPE DISCOVERED HERE

Minneapolis Heart Institute Foundation

Creating a world without heart and vascular disease

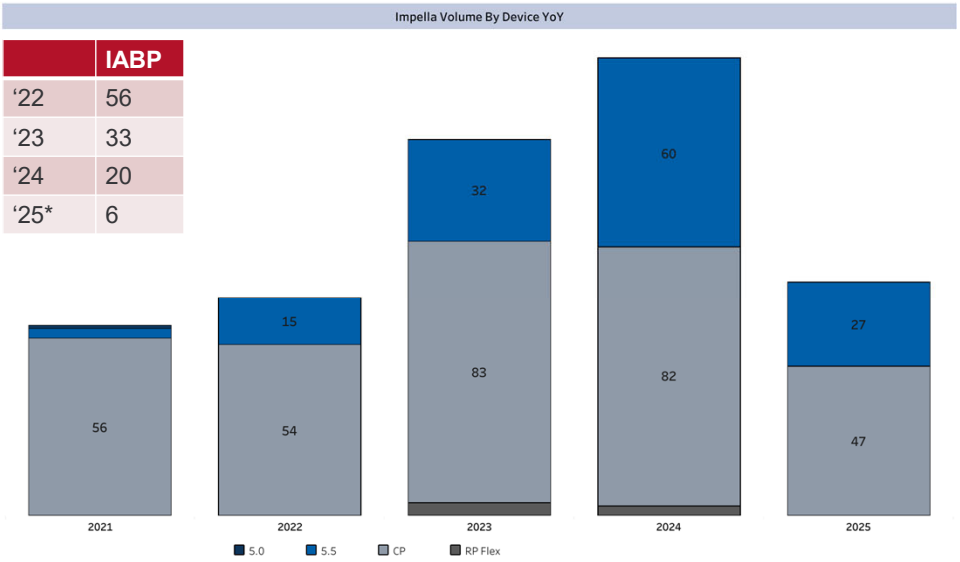
85

Impella Volume By Device YoY

Data from 1/2021 - 6/2025

Impella Volume By Device YoY

	IABP
'22	56
'23	33
'24	20
'25*	6



Johnson & Johnson MedTech

1. Abiomed Impella Quality (IQ) Database, Danvers MA

ABIOMED

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MHI Volumes

Year	Level 1	Level 2	AoD	VV	VA	ECPR	Impella	Impella 5.5
2020	249	126	10	35	42	21	29	0
2021	316	132	16	37	71	18	60	3
2022	426	142	28	8	42	23	69	15
2023	473	122	28	16	43	42	84	31
2024	439	213	19	19	60	38	81	59
2025 (Annualized)	492	340	30	22	81	61	138	100

2023-2024

Row Labels	Count of Outcome
AMI/CGS	**74**
Expired	20
Survived	54
Cardiomyopathy	**69**
Expired	15
Survived	54
Elective Placement	**18**
Expired	2
Survived	16
HRPCI	**77**
Expired	1
Survived	76
HTx Rejection	**1**
Survived	1
Other	**1**
Expired	1
PCCS	**13**
Expired	6
Survived	7
Post-op CT Surgery	**2**
Expired	1
Survived	1
Grand Total	**255**

Impella Survival to Explant

AMI: 73%

CMO: 78%

HRPCI: 99%

PCCS: 54%

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Objectives

- Discuss cardiogenic shock etiologies, phenotyping and staging
- Review the pathophysiology of cardiogenic shock and its management options
- Highlight MHI's approach to cardiogenic shock

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