OUT-OF-HOSPITAL CARDIAC ARREST: NEW PERSPECTIVES

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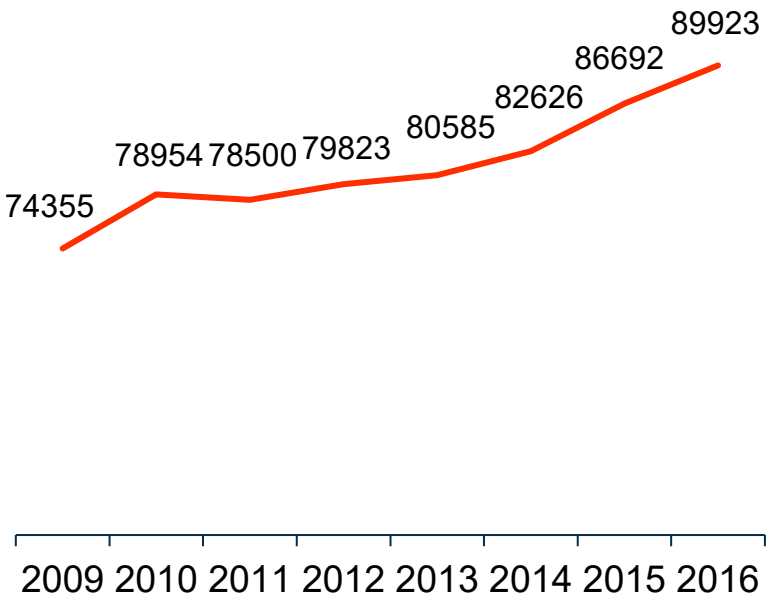
The Christ Hospital™ Health Network

Cardiogenic Shock: Selected Issues

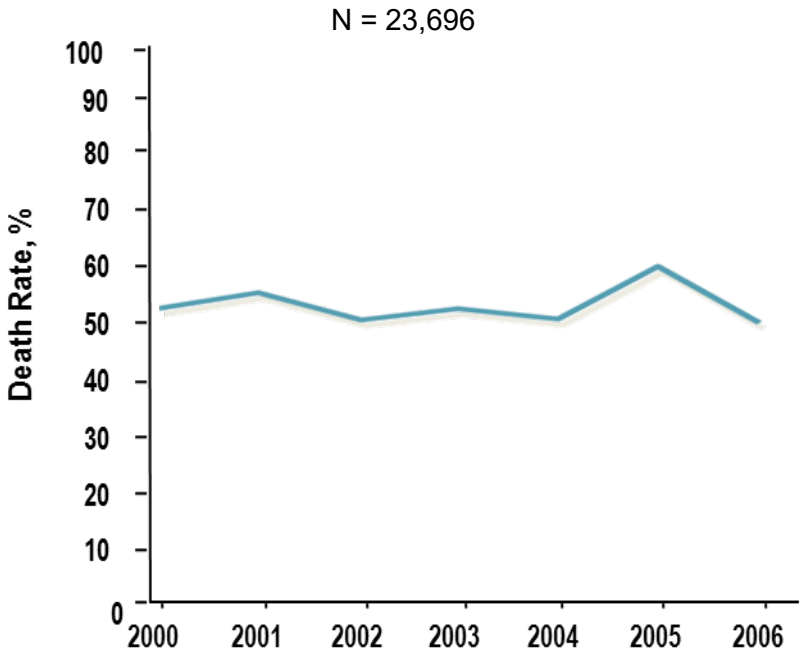
- SCAI Shock Classification
- Cardiac Arrest-CS interaction
- Shock centers and teams
- US National Shock Initiative
- Role of MSC: New data
- Refractory Shock

AMI Shock Mortality Unchanged in > 20 years

US AMI/CGS cases per year[1,2]



High In-Hospital Mortality
During AMI Cardiogenic Shock[3]



Worsening Mortality of AMI-CS??

JACC: CARDIOVASCULAR INTERVENTIONS
VOL. 9, NO. 4, 2016

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER
http://dx.doi.org/10.1016/j.jcin.2015.10.039

Temporal Trends and Outcomes of Patients Undergoing Percutaneous Coronary Interventions for Cardiogenic Shock in the Setting of Acute Myocardial Infarction

A Report From the CathPCI Registry

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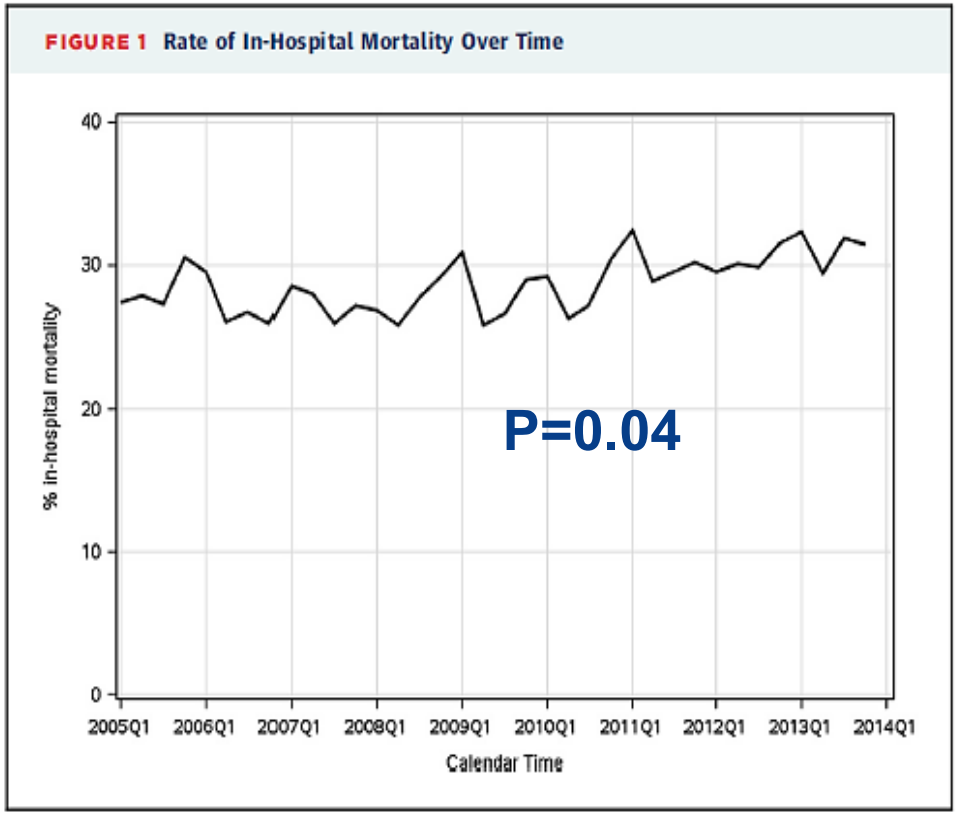
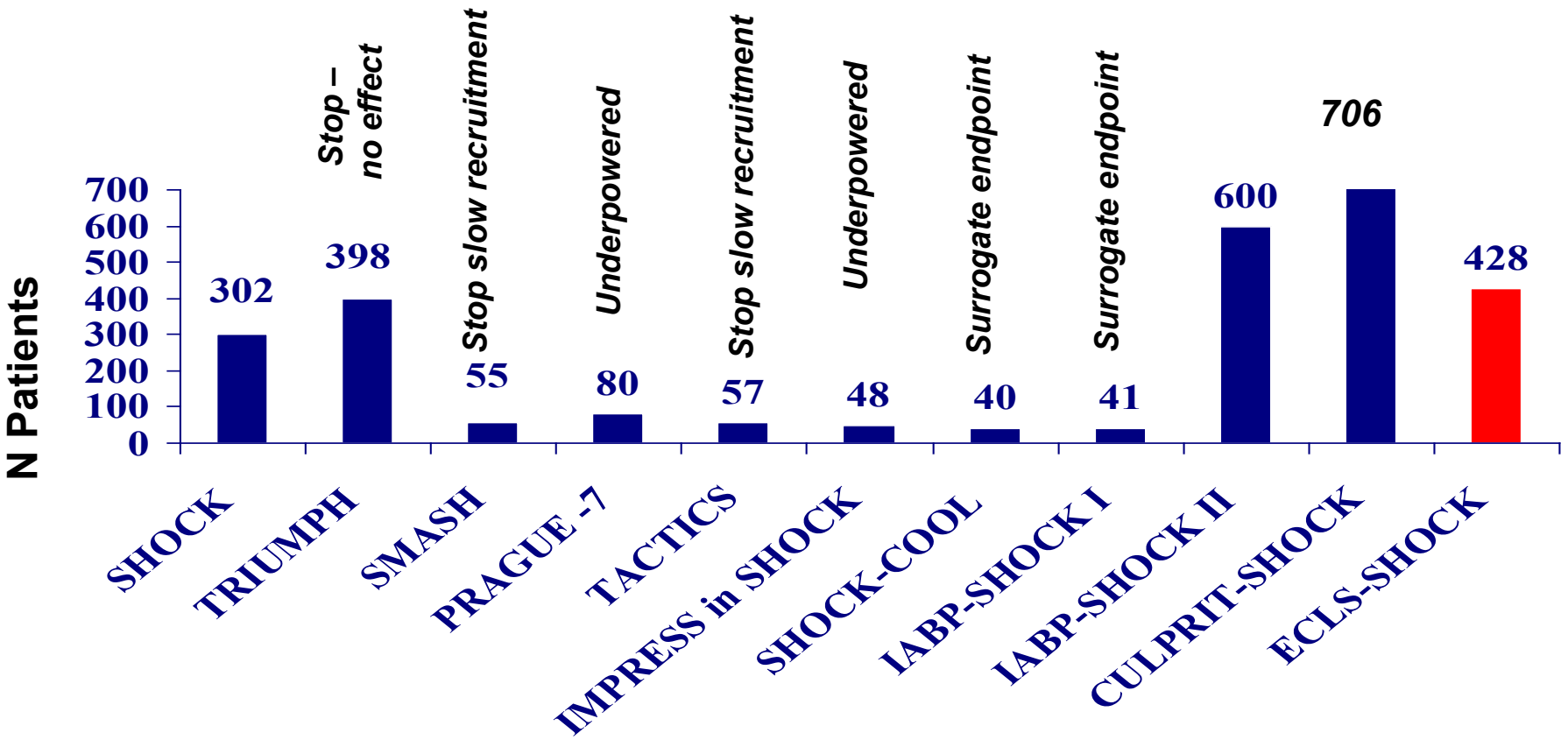


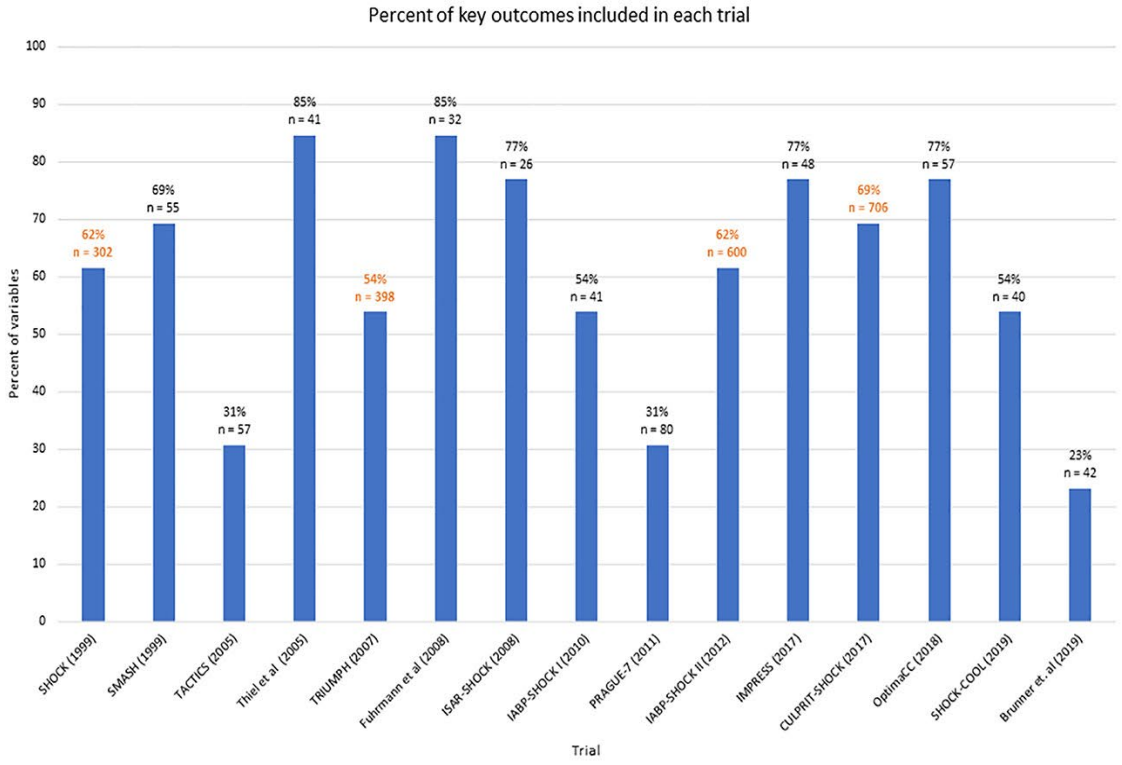
Inclusion in Cardiogenic Shock Trials

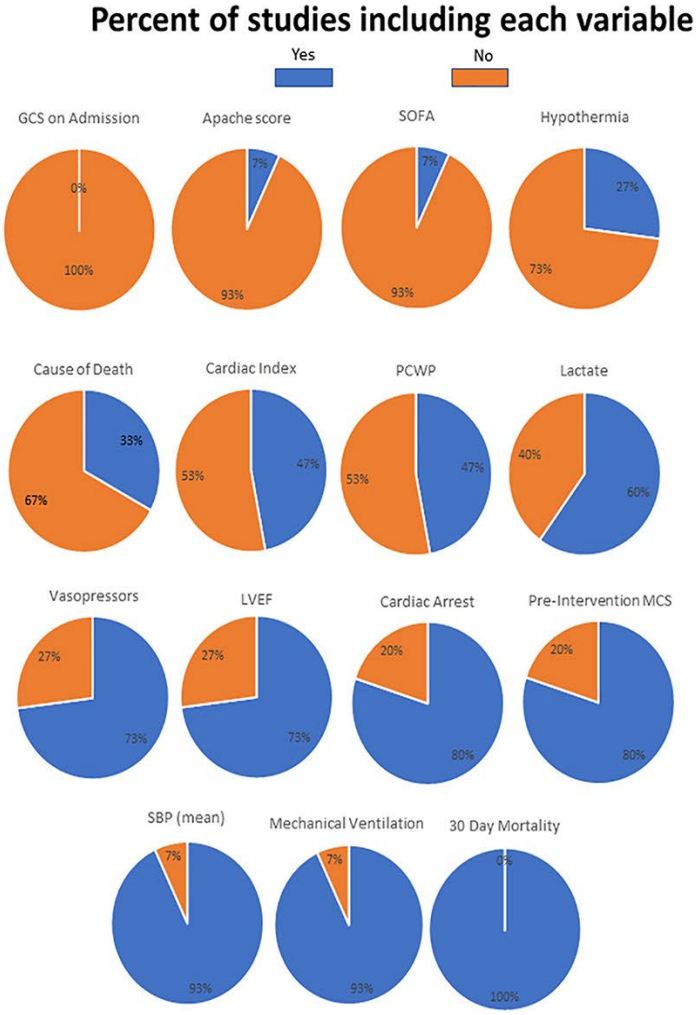


Variability in reporting of key outcome predictors in AMI cardiogenic shock trials

Key Outcome Predictors in Cardiogenic Shock

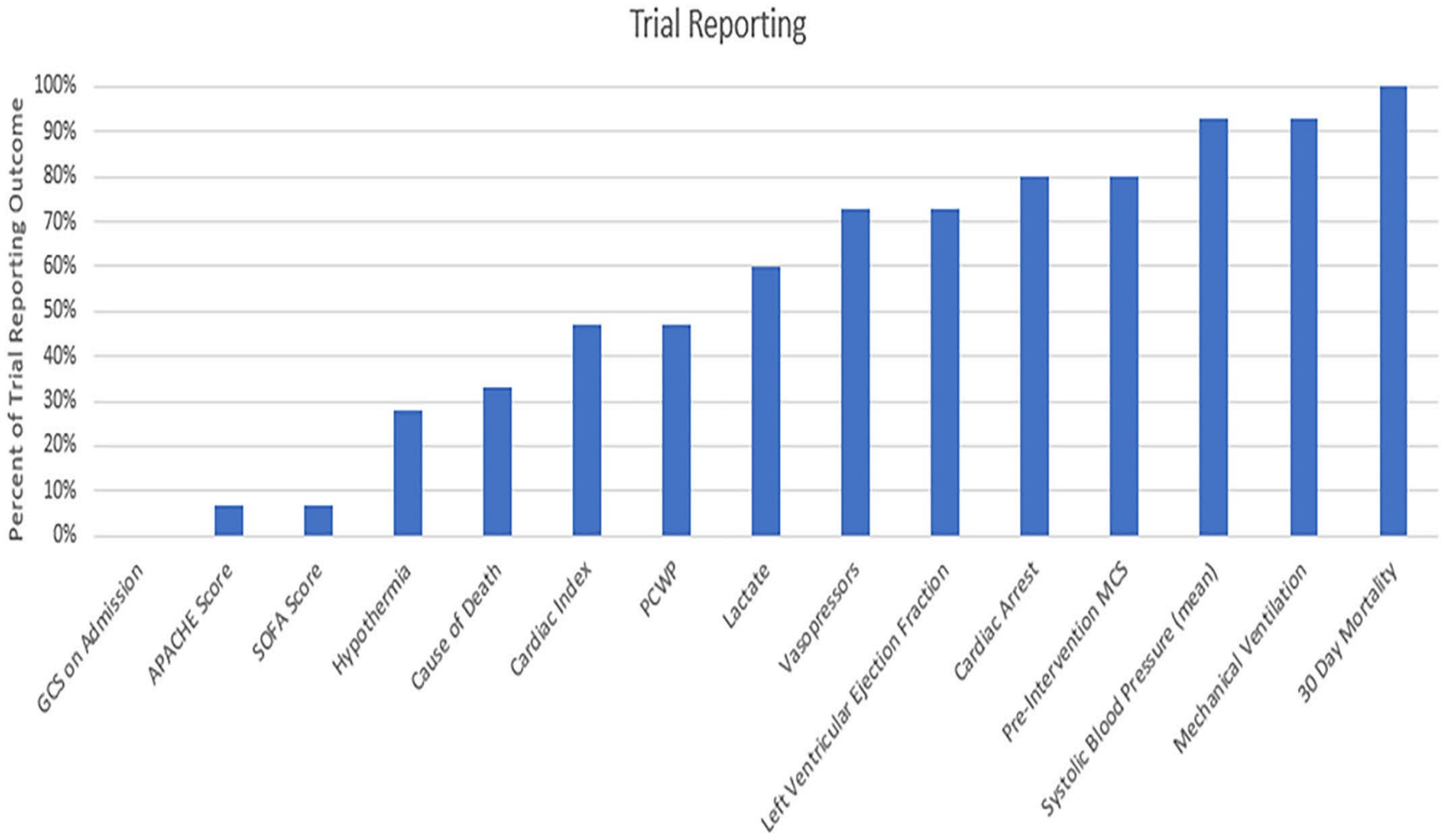
- Only15 randomized clinical trials in over 20 years including a total of 2525 patients
- Only 4 have enrolled over 80 patients
- Key outcome predictors in AMICS are frequently underreported
- Future CS trials and registries should include more consistent ascertainment of key prognostic variables and reporting of SCAI shock stage to improve our assessment of novel therapies





CCI: Tyler, Henry et al 19 April 2021, DOI: (10.1002/ccd.29710)

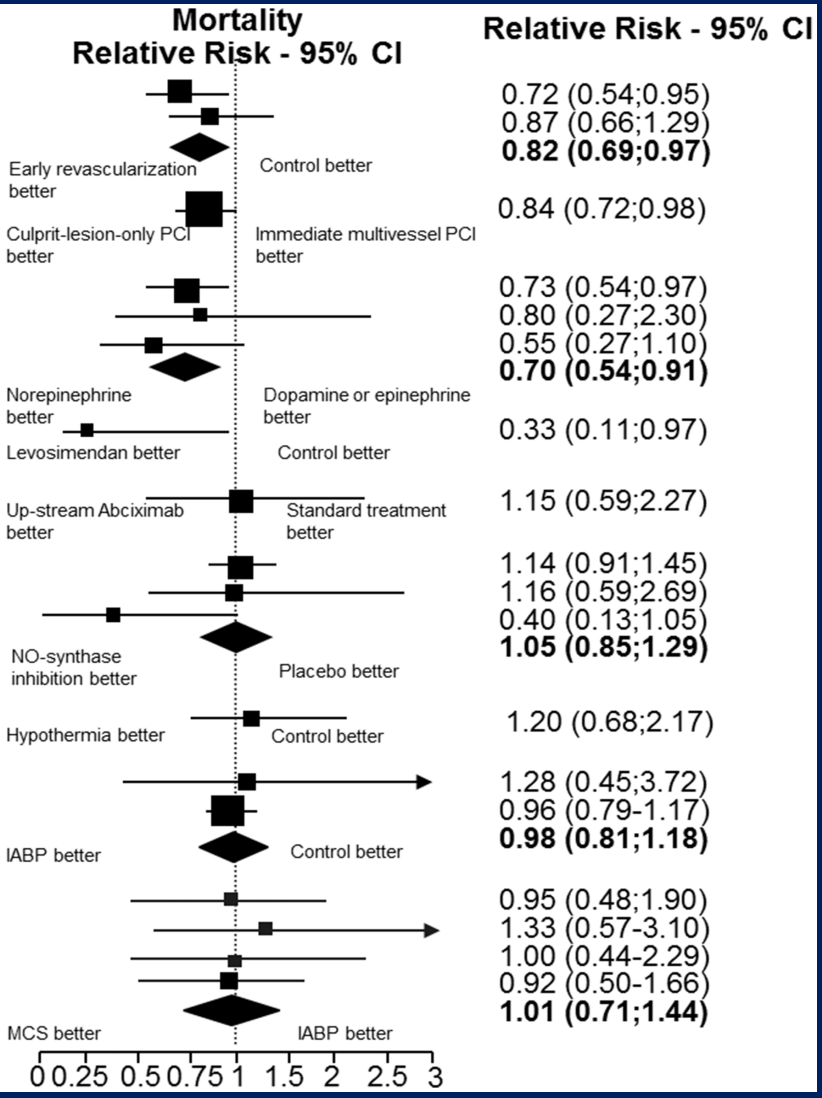
Variability in reporting of key outcome predictors in AMI cardiogenic shock trials



CCI: Tyler, Henry et al 19 April 2021, DOI: (10.1002/ccd.29710)

Current Evidence From Randomized Clinical Trials in Cardiogenic Shock in the Percutaneous Coronary Intervention Era

Trial	Follow-up	n/N	n/N	Relative Risk - 95% CI
Revascularization (PCI/CABG)				
SHOCK	1 year	81/152	100/150	0.72 (0.54;0.95)
SMASH	30 days	22/32	18/23	0.87 (0.66;1.29)
Total		**103/184**	**118/173**	**0.82 (0.69;0.97)**
Type of revascularization				
CULPRIT-SHOCK	30 days	149/344	176/341	0.84 (0.72;0.98)
Vasopressors				
SOAP-2 (CS subgroup)	28 days	50/145	64/135	0.73 (0.54;0.97)
Levy et al.	28 days	4/15	5/15	0.80 (0.27;2.30)
OptimaCC	28 days	8/30	13/27	0.55 (0.27;1.10)
Total		**62/190**	**82/177**	**0.70 (0.54;0.91)**
Inotropes				
Fuhrmann et al.	30 days	5/16	10/16	0.33 (0.11;0.97)
Glycoprotein IIb/IIIa-Inhibitors				
PRAGUE-7	In-hospital	15/40	13/40	1.15 (0.59;2.27)
NO-Synthase-Inhibition				
TRIUMPH	30 days	97/201	76/180	1.14 (0.91;1.45)
SHOCK II	30 days	24/59	7/20	1.16 (0.59;2.69)
Cotter et al.	30 days	4/15	10/15	0.40 (0.13;1.05)
Total		**125/275**	**93/215**	**1.05 (0.85;1.29)**
Hypothermia				
SHOCK-COOL	30 days	12/20	10/20	1.20 (0.68;2.17)
IABP				
IABP-SHOCK I	30 days	7/19	6/21	1.28 (0.45;3.72)
IABP-SHOCK II	30 days	19/301	123/298	0.96 (0.79-1.17)
Total		**126/319**	**129/319**	**0.98 (0.81;1.18)**
Mechanical circulatory support				
Thiele et al.	30 days	9/21	9/20	0.95 (0.48;1.90)
Burkhoff et al.	30 days	9/19	5/14	1.33 (0.57-3.10)
ISAR-SHOCK	30 days	6/13	6/13	1.00 (0.44-2.29)
IMPRESS-IN-SEVERE-SHOCK	30 days	11/24	12/24	0.92 (0.50-1.66)
Total		**35/77**	**32/71**	**1.01 (0.71;1.44)**



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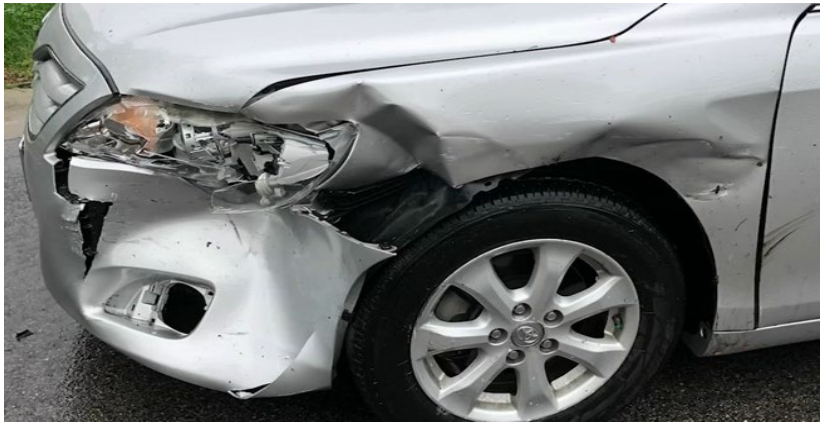
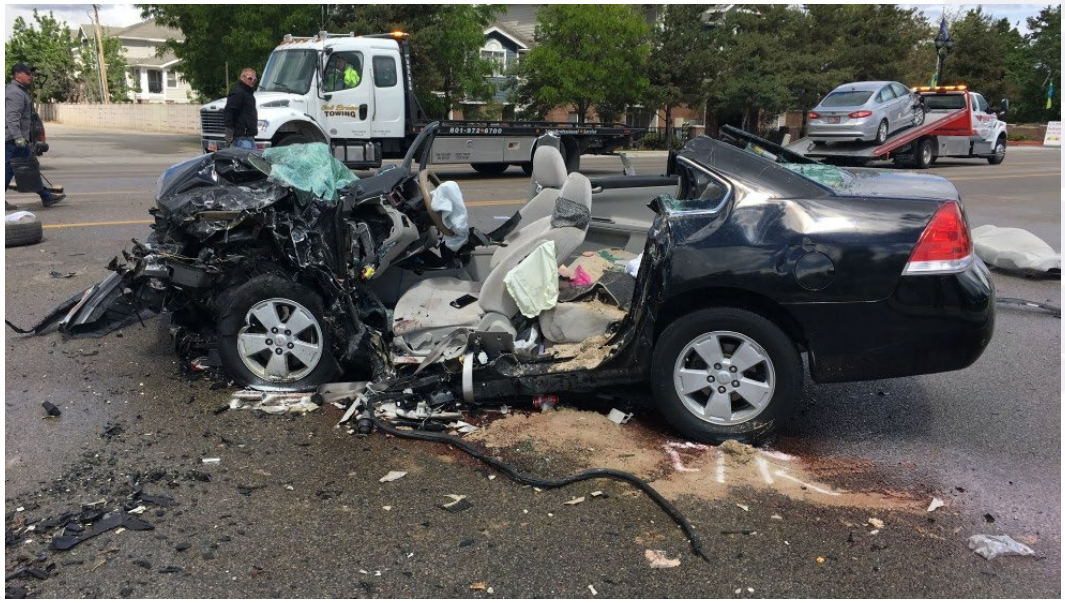
Thiele et al. *EHJ* 2019; 40:2671–2683

THOUGHTS ON SHOCK

- Not all shock is created equally
- What has held the field back is the lack of a common language!

Car Crashes are Variable





The SCAI SHOCK Classification System

SCAI 2019
Las Vegas, NV

Received: 23 April 2019 | Accepted: 24 April 2019
DOI: 10.1002/ccd.28329

CLINICAL DECISION MAKING

WILEY

SCAI clinical expert consensus statement on the classification of cardiogenic shock

This document was endorsed by the American College of Cardiology (ACC), the American Heart Association (AHA), the Society of Critical Care Medicine (SCCM), and the Society of Thoracic Surgeons (STS) in April 2019

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[11]Heart Center Leipzig at University of Leipzig, Department of Internal Medicine/Cardiology, Leipzig, Germany

Abstract

Background: The outcome of cardiogenic shock complicating myocardial infarction has not appreciably changed in the last 30 years despite the development of various percutaneous mechanical circulatory support options. It is clear that there are varying degrees of cardiogenic shock but there is no robust classification scheme to categorize this disease state.

Methods: A multidisciplinary group of experts convened by the Society for Cardiovascular Angiography and Interventions was assembled to derive a proposed classification schema for cardiogenic shock. Representatives from cardiology (interventional, advanced heart failure, noninvasive), emergency medicine, critical care, and cardiac nursing all collaborated to develop the proposed schema.

Results: A system describing stages of cardiogenic shock from A to E was developed. Stage A is "at risk" for cardiogenic shock, stage B is "beginning" shock, stage C is "classic" cardiogenic shock, stage D is "deteriorating", and E is "extremis". The difference between stages B and C is the presence of hypoperfusion which is present in stages C and higher. Stage D implies that the initial set of interventions chosen have not restored stability and adequate perfusion despite at least 30 minutes of

*ACC Representative.
†AHA Representative.
‡SCCM Representative.

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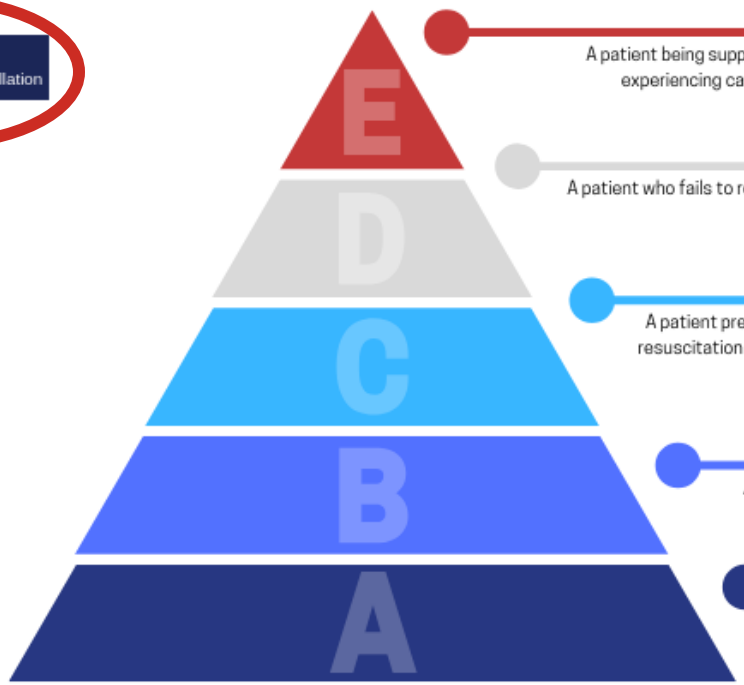
SCAI Stages of Cardiogenic Shock

Adapted from the SCAI Clinical Expert Consensus Statement on the Classification of Cardiogenic Shock
Endorsed by ACC, AHA, SCCM, and STS

Arrest (A) Modifier:
CPR, including defibrillation



EXTREMIS
A patient being supported by multiple interventions who may be experiencing cardiac arrest with ongoing CPR and/or ECMO.

DETERIORATING
A patient who fails to respond to initial interventions. Similar to stage C and getting worse.

CLASSIC
A patient presenting with hypoperfusion requiring intervention beyond volume resuscitation (inotrope, pressor, or mechanical support including ECMO). These patients typically present with relative hypotension.

BEGINNING
A patient who has clinical evidence of relative hypotension or tachycardia without hypoperfusion.

AT RISK
A patient with risk factors for cardiogenic shock who is not currently experiencing signs or symptoms. For example, large acute myocardial infarction, prior infarction, acute and/or acute on chronic heart failure.

Baran DA, Grines CL, Bailey S, et al. SCAI clinical expert consensus statement on the classification of cardiogenic shock. Catheter Cardiovasc Interv. 2019;1–9. https://doi.org/10.1002/ccd.28329
For more information, please visit: www.scai.org/shockdefinition

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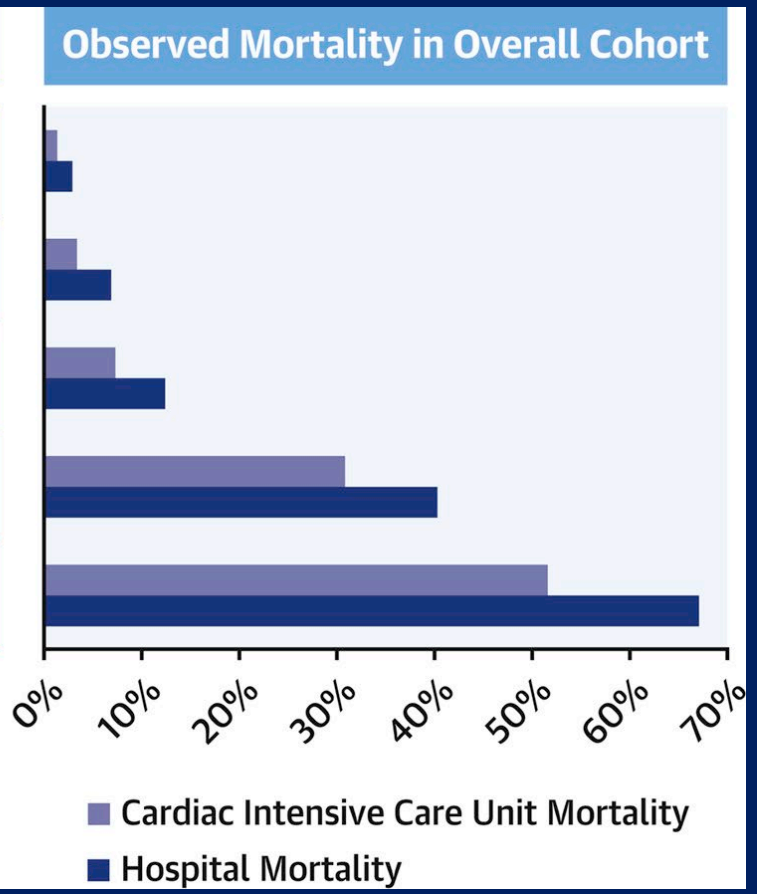
Validation of SCAI Shock Classification

Cardiogenic Shock Stage	Study Definition
Stage A ("At risk")	Neither hypotension/tachycardia nor hypoperfusion
Stage B ("Beginning")	Hypotension/tachycardia WITHOUT hypoperfusion
Stage C ("Classic")	Hypoperfusion WITHOUT deterioration
Stage D ("Deteriorating)"	Hypoperfusion WITH deterioration NOT refractory shock
Stage E ("Extremis")	Hypoperfusion WITH deterioration AND refractory shock



Jentzer et al., *JACC* 2019

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Contents lists available at ScienceDirect

Journal of the Society for Cardiovascular Angiography & Interventions

journal homepage: www.jscai.org

Standards and Guidelines

SCAI SHOCK Stage Classification Expert Consensus Update: A Review and Incorporation of Validation Studies

This statement was endorsed by the American College of Cardiology (ACC), American College of Emergency Physicians (ACEP), American Heart Association (AHA), European Society of Cardiology (ESC) Association for Acute Cardiovascular Care (ACVC), International Society for Heart and Lung Transplantation (ISHLT), Society of Critical Care Medicine (SCCM), and Society of Thoracic Surgeons (STS) in December 2021.

Srihari S. Naidu, MD, FSCAI [a,*], David A. Baran, MD, FSCAI [b], Jacob C. Jentzer, MD [c], Steven M. Hollenberg, MD [d,1], Sean van Diepen, MD, MSc [e,2], Mir B. Basir, DO, FSCAI [f], Cindy L. Grines, MD, MSCAI [g], Deborah B. Diercks, MD, MSc, FACEP [h,3], Shelley Hall, MD [i], Navin K. Kapur, MD, FSCAI [j], William Kent, MD, MSc [k,4], Sunil V. Rao, MD, FSCAI [l,5], Marc D. Samsky, MD [l,5], Holger Thiele, MD, FESC [m,6], Alexander G. Truesdell, MD, FSCAI [n,7], Timothy D. Henry, MD, MSCAI [o]

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JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY VOL. ■, NO. ■, 2022

MULTISOCIETAL CLINICAL DOCUMENT

SCAI SHOCK Stage Classification Expert Consensus Update: A Review and Incorporation of Validation Studies

This statement was endorsed by the American College of Cardiology (ACC), American College of Emergency Physicians (ACEP), American Heart Association (AHA), European Society of Cardiology (ESC) Association for Acute Cardiovascular Care (ACVC), International Society for Heart and Lung Transplantation (ISHLT), Society of Critical Care Medicine (SCCM), and Society of Thoracic Surgeons (STS) in December 2021.

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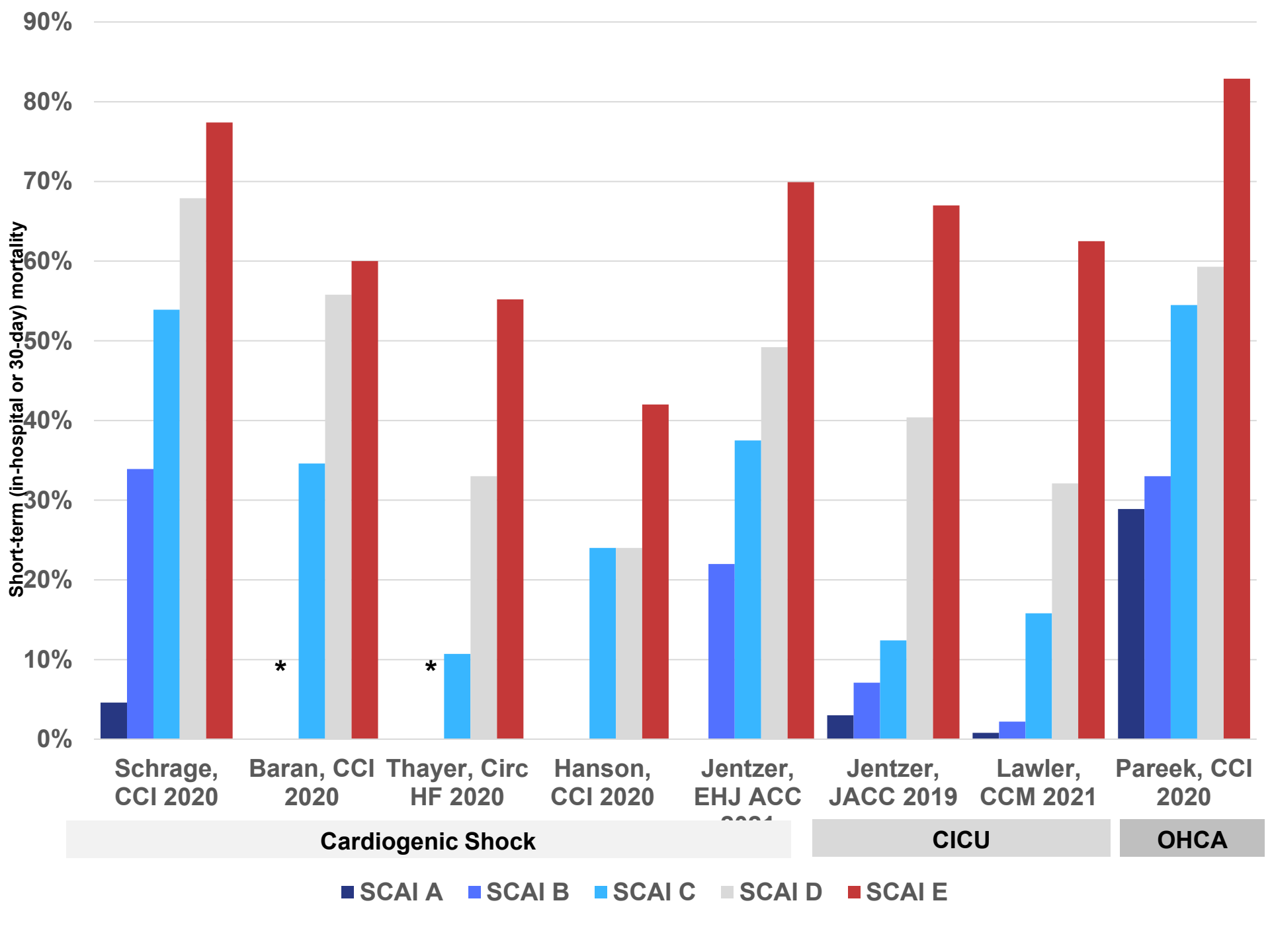
INTRODUCTION

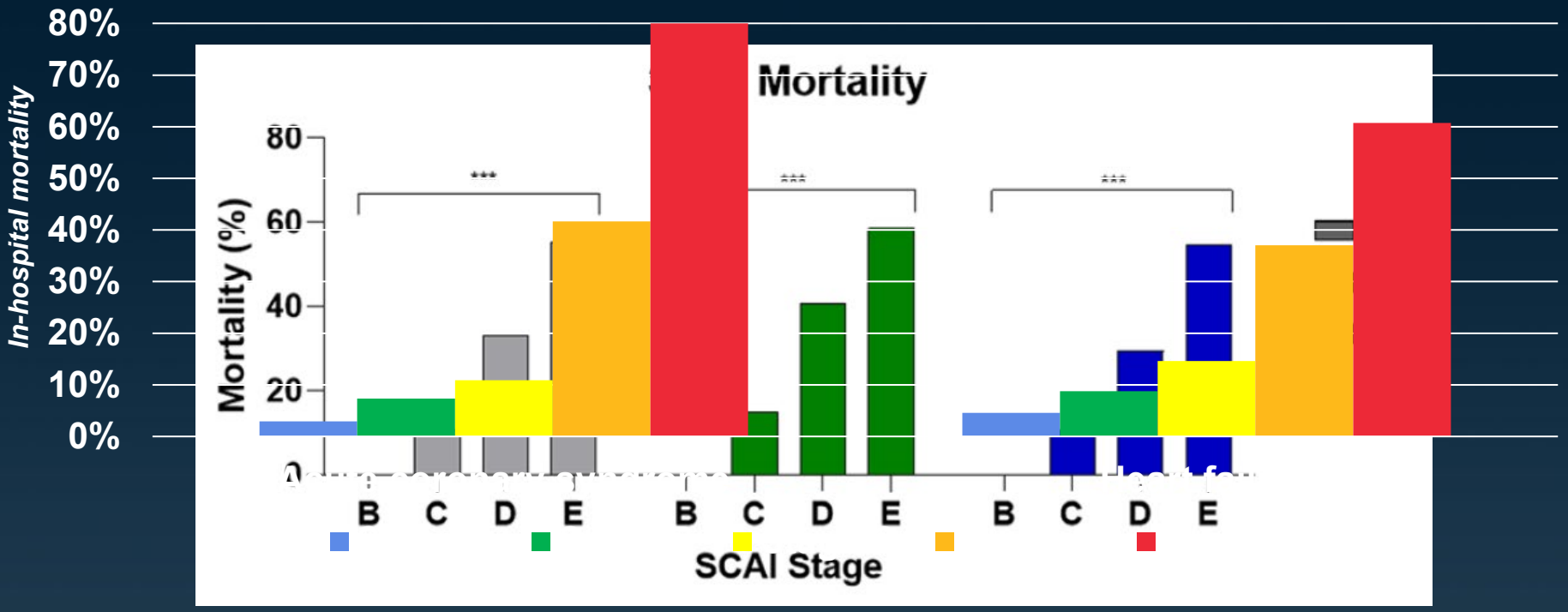
Since its development and release in 2019, the Society for Cardiovascular Angiography and Interventions (SCAI) shock stage classification for adult patients has been widely cited and increasingly incorporated, owing to its simplicity across all clinical settings, easily understood and visualized framework, and notable endorsement by relevant societies and organizations that manage cardiogenic shock (CS).[1] Ensuing validation studies over the course of the subsequent 2 years documented both its ease and rapidity of use as well as its ability to meaningfully discriminate patient risk across the spectrum of CS, including various phenotypes, presentations, and health care settings. Nonetheless, several areas of potential refinement have been identified to make the classification scheme more applicable across all settings and clinical time points, given that data from validation studies have provided useful information not previously available that could serve to significantly refine the classification. With this background, a clinical expert consensus writing group of all relevant stakeholders was reconvened to re-evaluate and refine the SCAI SHOCK stage classification based on the existing literature and clinician feedback from real-world experience.

Reprinted from the Journal of the Society for Cardiovascular Angiography & Interventions.
Accepted December 10, 2021.
ISSN 0735-1097/$36.00
https://doi.org/10.1016/j.jacc.2022.01.018

SCAI
Society for Cardiovascular Angiography & Interventions


90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Short-term (in-hospital or 30-day) mortality
*
*
Schrage, CCI 2020
Baran, CCI 2020
Thayer, Circ HF 2020
Hanson, CCI 2020
Jentzer, EHJ ACC
Jentzer, JACC 2019
Lawler, CCM 2021
Pareek, CCI 2020
Cardiogenic Shock
CICU
OHCA
SCAI A
SCAI B
SCAI C
SCAI D
SCAI E

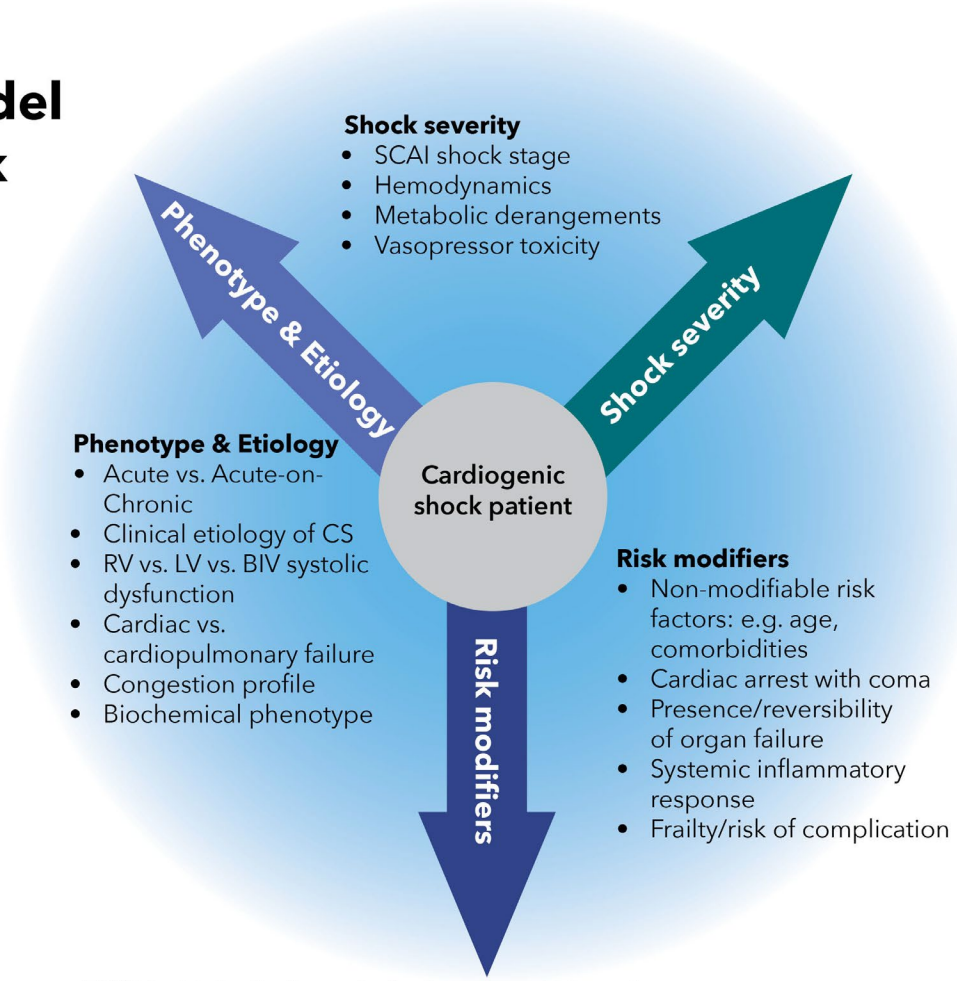
Association between SCAI stages and mortality was consistent across ACS & HF subgroups

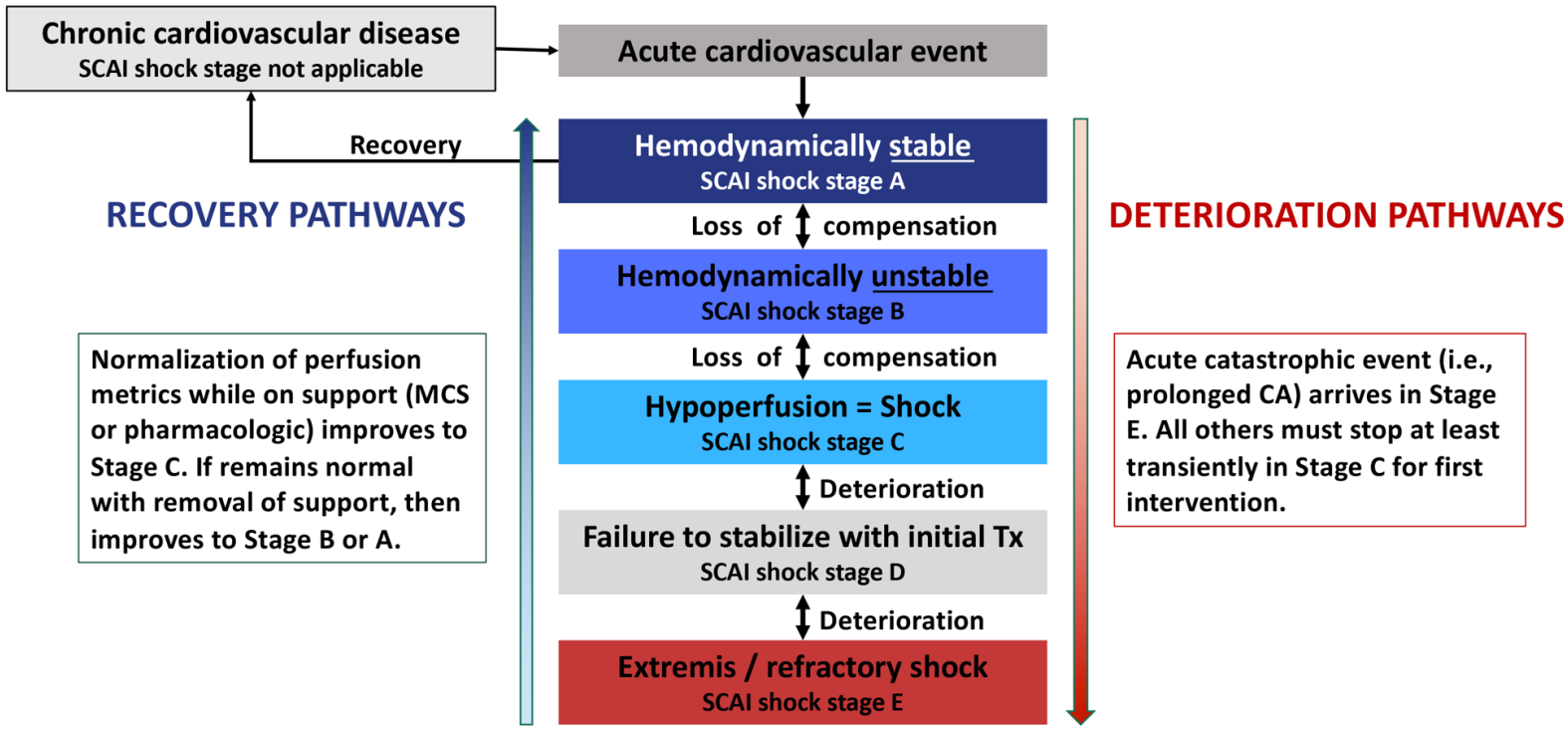


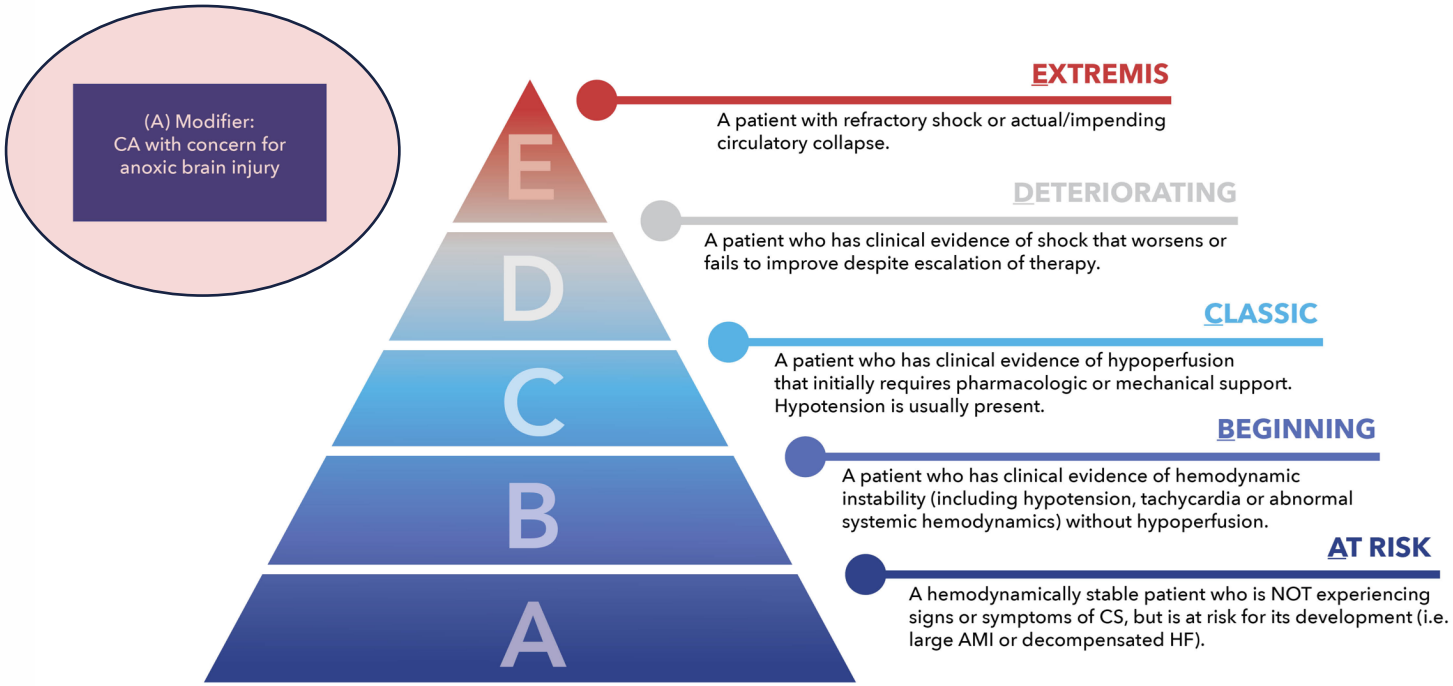
Jentzer, JACC 2019 – CICU patients

Thayer, Circ HF 2020 – CS patients

Proposed 3-axis model of cardiogenic shock evaluation and prognostication







Cardiogenic Shock: Selected Issues

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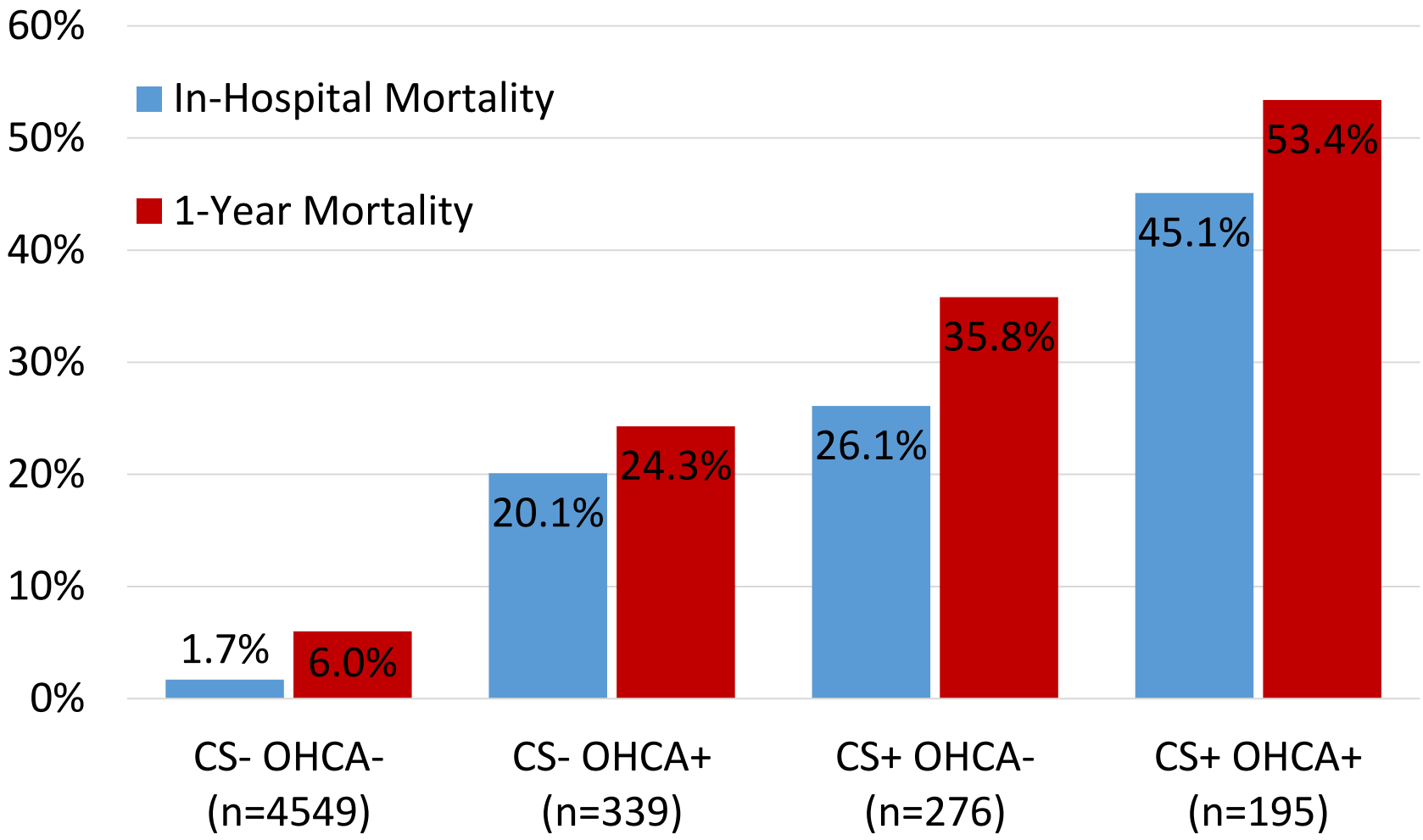
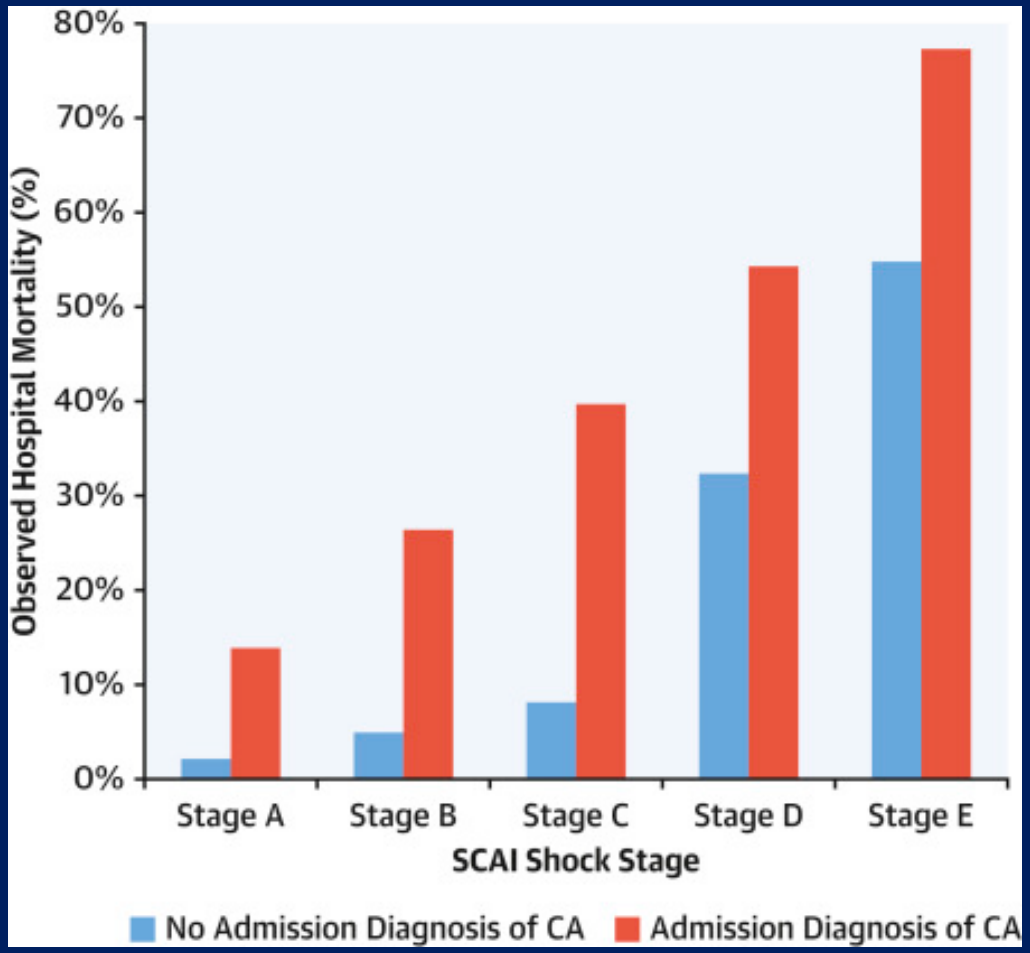
- Shock centers and teams
- US National Shock Initiative
- Role of MSC: New data
- Refractory Shock

Interaction of Cardiac Arrest and Cardiogenic Shock



Cardiac Arrest Impact on Cardiogenic Shock



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Jentzer et al., *JACC* 2019

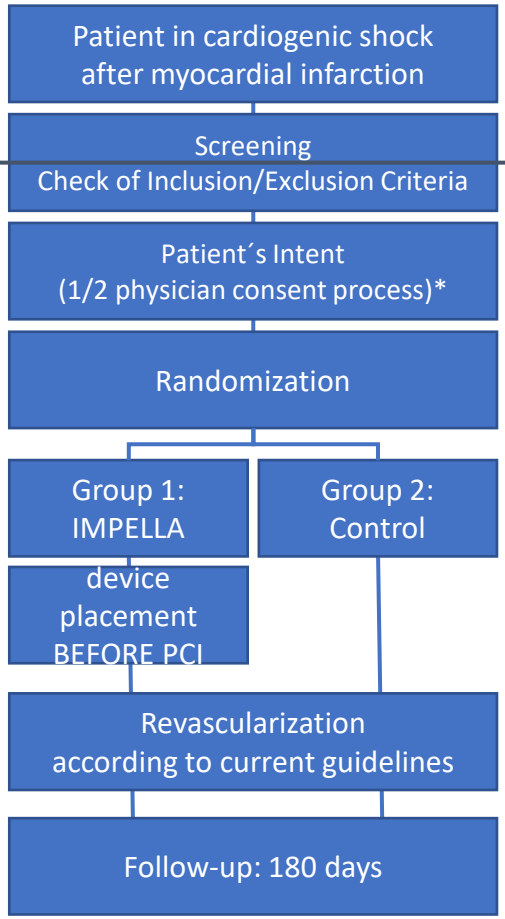
Trial Protocol

DanGer Shock
Danish German Cardiogenic Shock trial

Inclusion:

1. **STEMI** of <36 hrs (ECG, Angio)
2. **CGS** <24 hrs
   lactate >2.5 &/or SvO_2 <55% (at normal PaO_2) and
   SBP < 100 mmHg or
   vasopressors
3. **LVEF <45%**

additional inclusion (same criteria) if shock is developed within 12 hrs of procedure



Exclusion:

- other cause of shock (hypovolemia, sepsis, embolism, anaphylaxis)
- cardiac mechanical complications (papillary muscle rupture, VSD, rupture of free wall)
- severe aortic valve regurgitation / stenosis / mechanical valve
- severe RV failure (e.g. TAPSE <1cm)
- OOH cardiac arrest with GCS <8 after ROSC
- shock >24 hrs
- already established MCS
- DNR / severe comorbidity
- known intolerance to Heparine, Aspirin, ADPr/P2Y12 inhibitors, (e.g. clopidogrel) contrast media

Primary Endpoint: Death from all causes through 180 days

Secondary Endpoints:

- Composite cardiovascular events (survival with native heart: need for additional MCS, cardiac transplantation, death of all causes)
- hemodynamics (CPO, Lactate clearance, PAP)
- sequential organ failure assessment (SOFA) score @ 24, 48, 72 hrs after randomization
- use and dosage of vasopressor and inotropes @ 24, 48, 72 hrs after randomization
- renal function
- LV function @ 180 days

* patient / proxy consent as soon as safe and feasible

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- **Shock centers and teams**
- US National Shock Initiative
- Role of MSC: New data
- Refractory Shock

AHA SCIENTIFIC STATEMENT

Contemporary Management of Cardiogenic Shock

A Scientific Statement From the American Heart Association

ABSTRACT: Cardiogenic shock is a high-acuity, potentially complex, and hemodynamically diverse state of end-organ hypoperfusion that is frequently associated with multisystem organ failure. Despite improving survival in recent years, patient morbidity and mortality remain high, and there are few evidence-based therapeutic interventions known to clearly improve patient outcomes. This scientific statement on cardiogenic shock summarizes the epidemiology, pathophysiology, causes, and outcomes of cardiogenic shock; reviews contemporary best medical, surgical, mechanical circulatory support, and palliative care practices; advocates for the development of regionalized systems of care; and outlines future research priorities.

Cardiogenic shock (CS) is a low-cardiac-output state resulting in life-threatening end-organ hypoperfusion and hypoxia.[1,2] Acute myocardial infarction (MI) with left ventricular (LV) dysfunction remains the most frequent cause of CS.[3–5] Advances in reperfusion therapy have been associated with improvements in survival, but significant regional disparities in evidence-based care have been reported, and in-hospital mortality remains high (27%–51%).[1,6–9] Management recommendations are distributed between disease-specific statements and guidelines, and a dedicated and comprehensive clinical resource in this area is lacking. Thus, consolidating the evidence to define contemporary best medical and surgical CS practices for both MI-associated CS and other types of CS may be an important step in knowledge translation to help attenuate disparities in evidence-based care.

Regional systems of care coupled with treatment algorithms have improved survival in high-acuity time-sensitive conditions such as MI, out-of-hospital cardiac arrest (OHCA), and trauma.[10–12] Applying a similar framework to CS management may lead to similar improvements in survival, and CS systems of care are emerging within existing regional cardiovascular emergency care networks; however, guidance from a national expert group on structure and systems of care has not been available.[13,14] Accordingly, the purposes of this American Heart Association (AHA) scientific statement on CS are to summarize our contemporary understanding of the epidemiology, pathophysiology, and in-hospital best care practices into a single clinical resource document; to suggest a stepwise management algorithm that integrates medical, surgical, and mechanical circulatory support (MCS) therapies; and to propose a Mission: Lifeline–supported pathway for the development of integrated regionalized CS systems of care.

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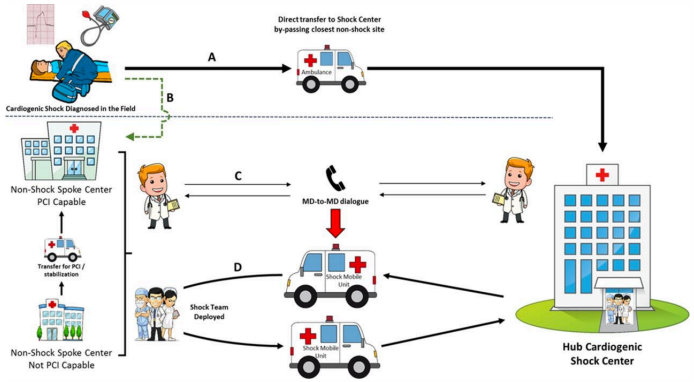
On behalf of the American Heart Association Council on Clinical Cardiology; Council on Cardiovascular and Stroke Nursing; Council on Quality of Care and Outcomes Research; and Mission: Lifeline

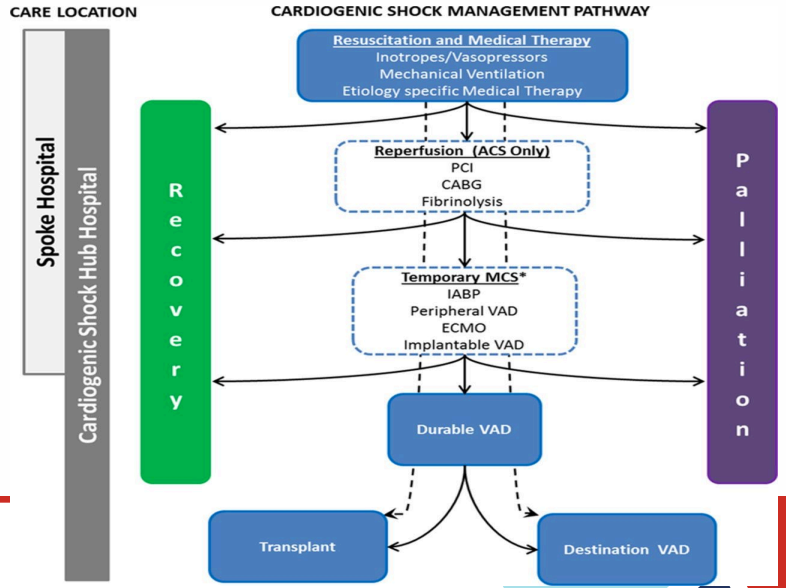
Key Words: AHA Scientific Statements ■ delivery of health care ■ disease management ■ shock, cardiogenic

DEFINITION OF CS

Acute cardiac hemodynamic instability may result from disorders that impair function of the myocardium, valves, conduction system, or pericardium, either in isolation

Circulation. 2017;136:e232–e268. DOI: 10.1161/CIR.0000000000000525





SCAI
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SHOCK Team Approach

Interventionl Cardiologist

Heart Failure Cardiologist

Severe Refractory Cardiogenic Shock Patient

Cardiac Surgeon

ICU Cardiologist

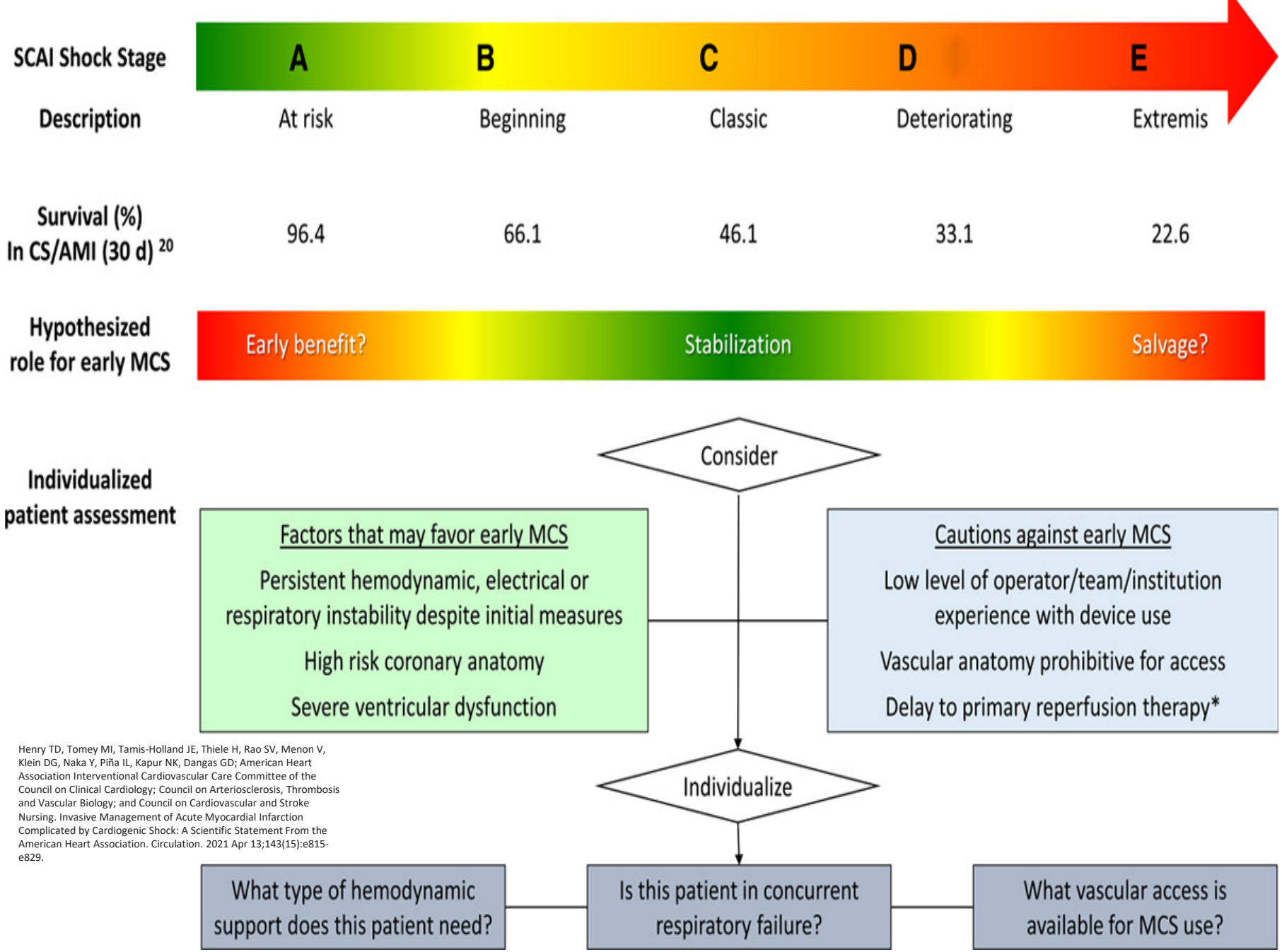
- 24 x 7 Availability
- Match Proper Device to Patient needs
- Facile with Invasive Hemodynamics and all devices

SLUCare Physician Group

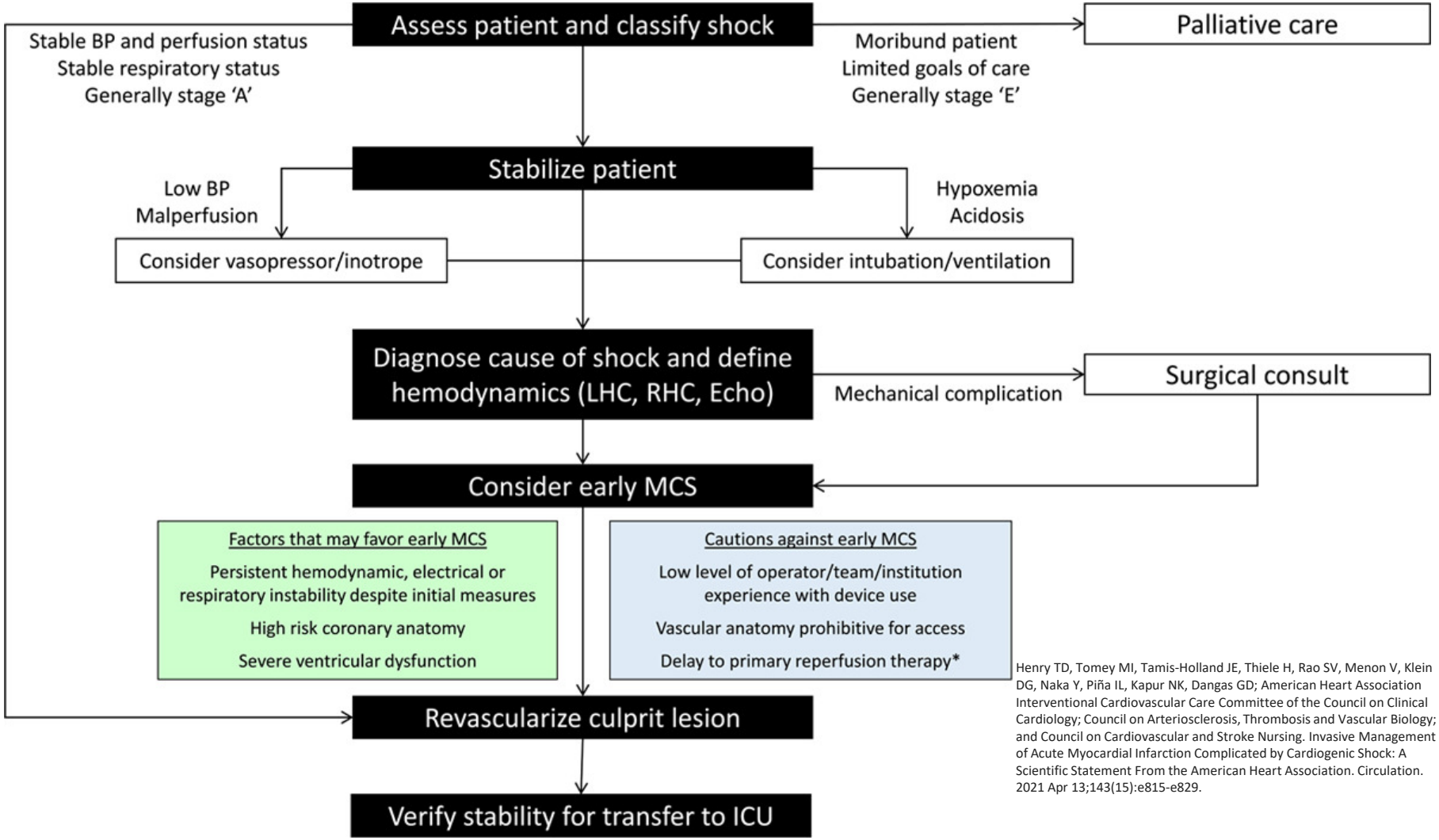
AHA SCIENTIFIC STATEMENT

Invasive Management of Acute Myocardial Infarction Complicated by Cardiogenic Shock: A Scientific Statement From the American Heart Association

Timothy D. Henry, MD, FAHA, Chair, Matthew I. Tomey, MD, Jacqueline E. Tamis-Holland, MD, FAHA, Holger Thiele, MD, Sunil V. Rao, MD, Venu Menon, MD, Deborah G. Klein, MSN, APRN, ACNS-B, CCRN, FAHA, Yoshifumi Naka, MD, PhD, Ileana L. Piña, MD, MPH, FAHA, Navin K. Kapur, MD, FAHA, George D. Dangas, MD, FAHA, Vice Chair, and On behalf of the American Heart Association Interventional Cardiovascular Care Committee of the Council on Clinical Cardiology; Council on Arteriosclerosis, Thrombosis and Vascular Biology; and Council on Cardiovascular and Stroke Nursing



Henry TD, Tomey MI, Tamis-Holland JE, Thiele H, Rao SV, Menon V, Klein DG, Naka Y, Piña IL, Kapur NK, Dangas GD; American Heart Association Interventional Cardiovascular Care Committee of the Council on Clinical Cardiology; Council on Arteriosclerosis, Thrombosis and Vascular Biology; and Council on Cardiovascular and Stroke Nursing. Invasive Management of Acute Myocardial Infarction Complicated by Cardiogenic Shock: A Scientific Statement From the American Heart Association. Circulation. 2021 Apr 13;143(15):e815-e829.



Henry TD, Tomey MI, Tamis-Holland JE, Thiele H, Rao SV, Menon V, Klein DG, Naka Y, Piña IL, Kapur NK, Dangas GD; American Heart Association Interventional Cardiovascular Care Committee of the Council on Clinical Cardiology; Council on Arteriosclerosis, Thrombosis and Vascular Biology; and Council on Cardiovascular and Stroke Nursing. Invasive Management of Acute Myocardial Infarction Complicated by Cardiogenic Shock: A Scientific Statement From the American Heart Association. Circulation. 2021 Apr 13;143(15):e815-e829.

CARDIAC SAFETY RESEARCH CONSORTIUM

Advancing Pragmatic Priorities and Pathways in Shock Research

February 22, 2020
CRT 2020

CSRC Shock II – Formation of Working Groups

I. **Shock networks for treatment and research**

II. **Defining cardiogenic shock for research and regulatory purposes – *Academic Research Consortium (SHARC)***

  – *Creation of a minimum requirement case report form*

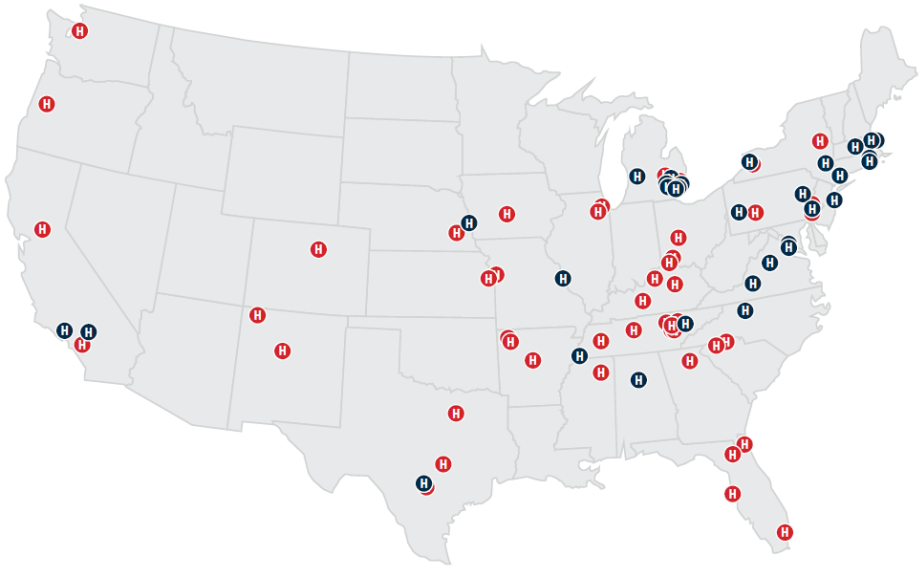
III. **Informed consent for Cardiogenic Shock Res**

IV. **Core questions to be answered: trial design**

Cardiogenic Shock: Selected Issues

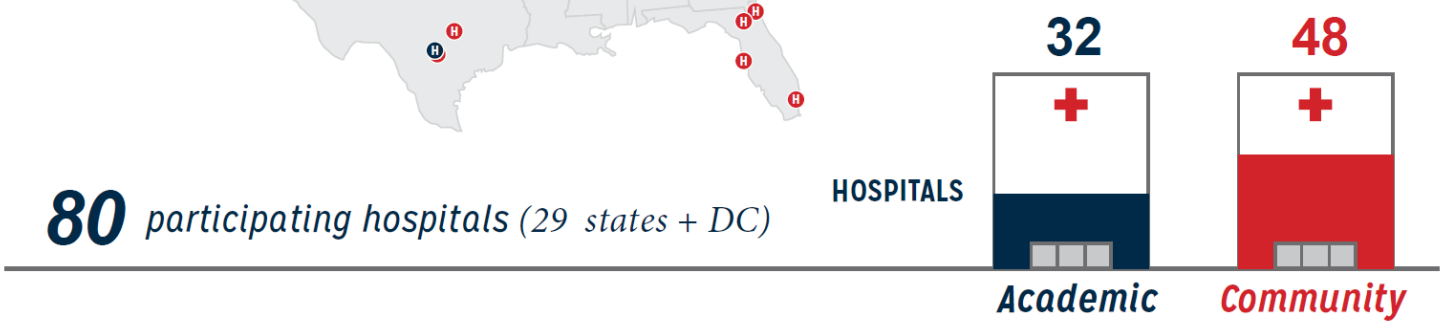
- New SCAI Shock Classification
- Cardiac Arrest-CS interaction
- Shock centers and teams
- **US National Shock Initiative**
- Role of MSC: New data
- Refractory Shock

NCSI: CLINICAL SITES



406 *patients enrolled nationally*

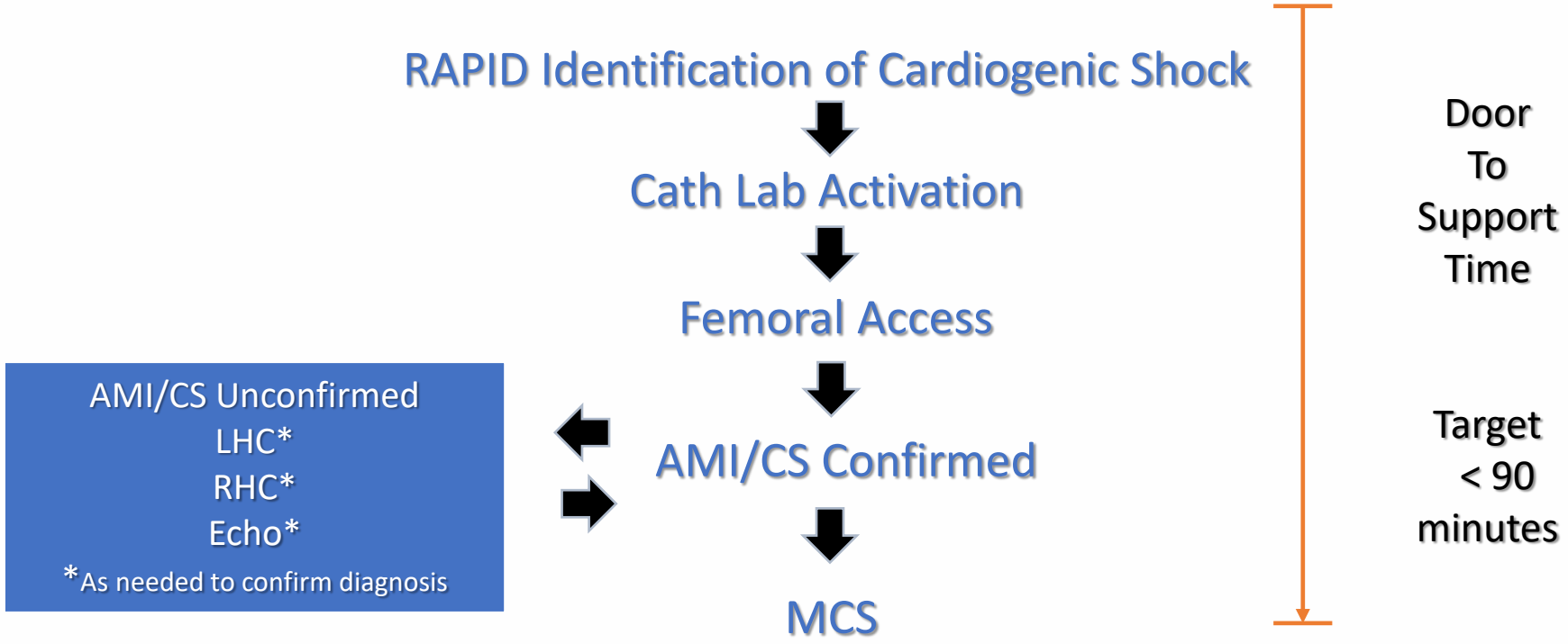
1,103 *total patients screened (with AMI + cardiogenic shock)*



80 *participating hospitals (29 states + DC)*

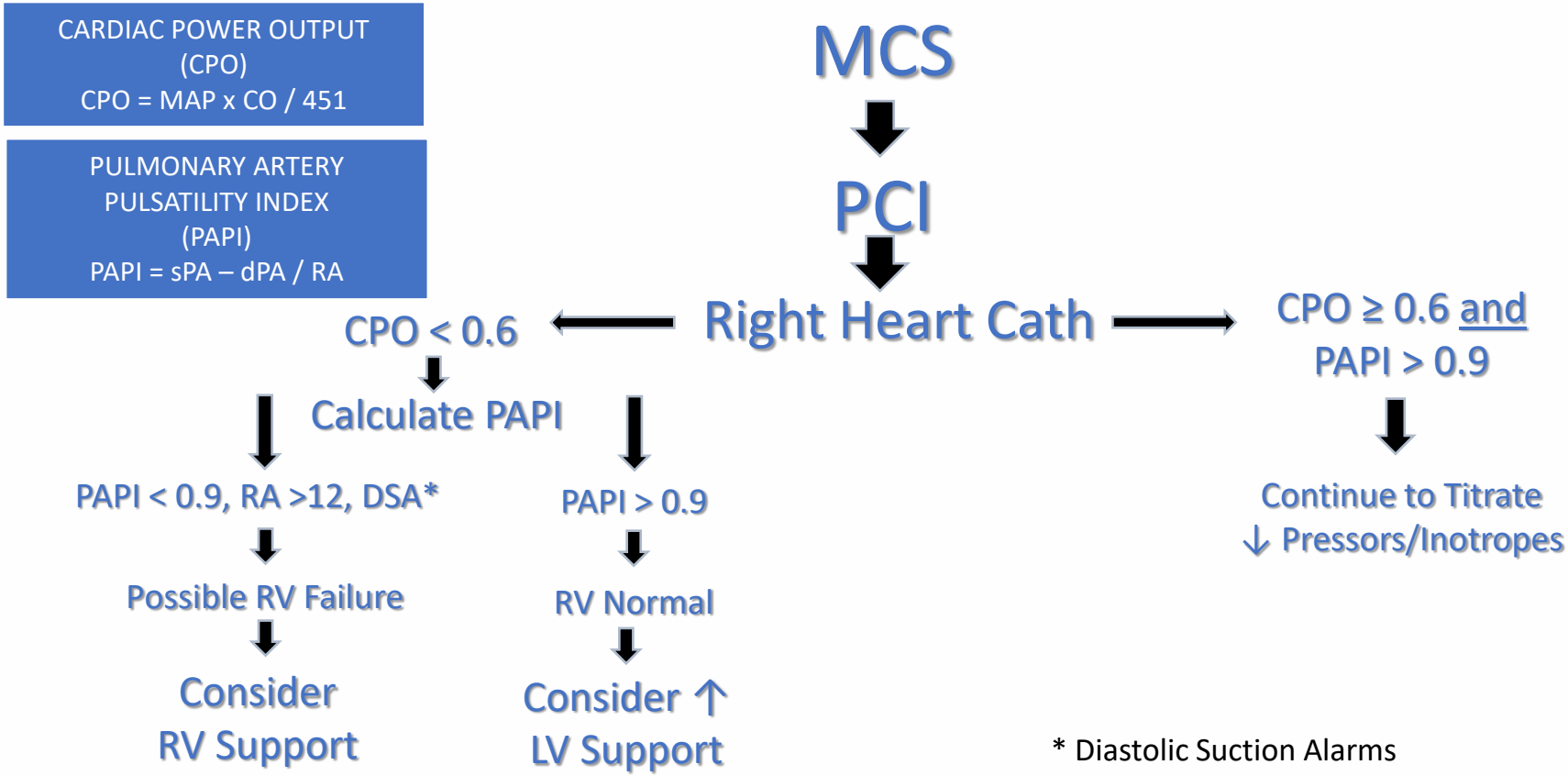
SCAI
Society for Cardiovascular Angiography & Interventions

NATIONAL CSI ALGORITHM



CARDIAC POWER OUTPUT
(CPO)
CPO = MAP x CO / 451

PULMONARY ARTERY
PULSATILITY INDEX
(PAPI)
PAPI = sPA – dPA / RA

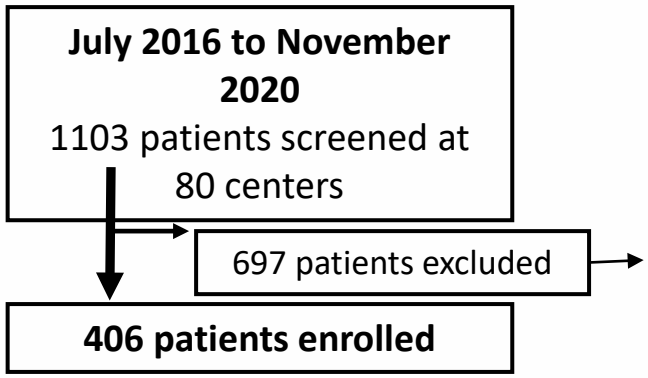


* Diastolic Suction Alarms

National Cardiogenic Shock Initiative

Study Design

- DESIGN: Prospective, non-randomized, single-arm, multi-center study
- OBJECTIVE: To assess the impact of early MCS, guided by invasive hemodynamics, on outcomes in AMICS, using the NCSI protocol.
- NCT03677180

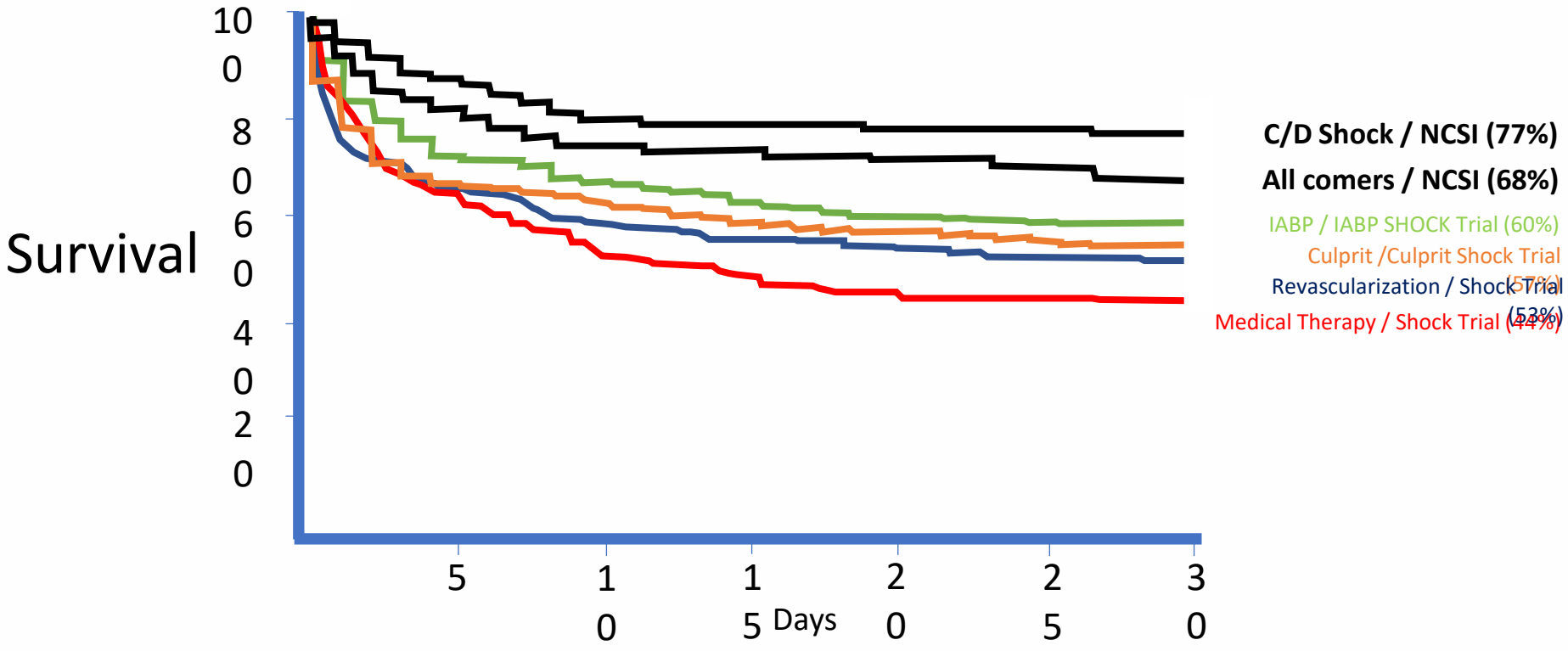


*more than one exclusion criteria can apply

Inclusion Criteria Not Met*	
No PCI performed	231
No evidence of hypotension	36
No evidence of hypoperfusion (clinically or by invasive hemodynamics)	36
No evidence of AMI	24
Exclusion Criteria Met*	
IABP prior to Impella	195
Unwitnessed Arrest or ROSC >30 min	108
Other Shock	57
Active Bleeding	43
Mechanical Complication of AMI	29
Recent Major Surgery	21
LV Thrombus	10
Mechanical Aortic Valve	4

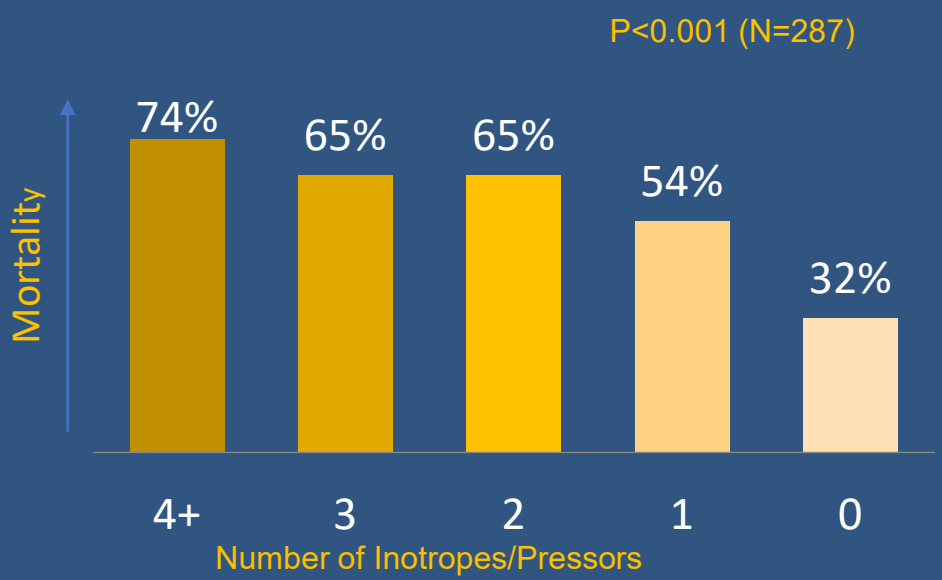
SCAI
Society for Cardiovascular Angiography & Interventions

30-Day Survival Rates from Two Decades of Cardiogenic Shock Trials

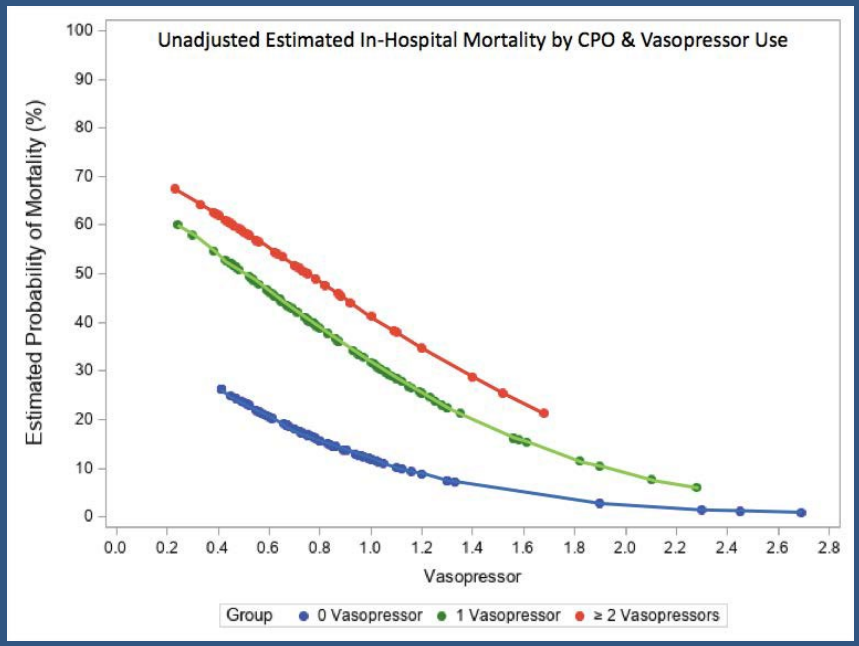


SCAI
Society for Cardiovascular Angiography & Interventions

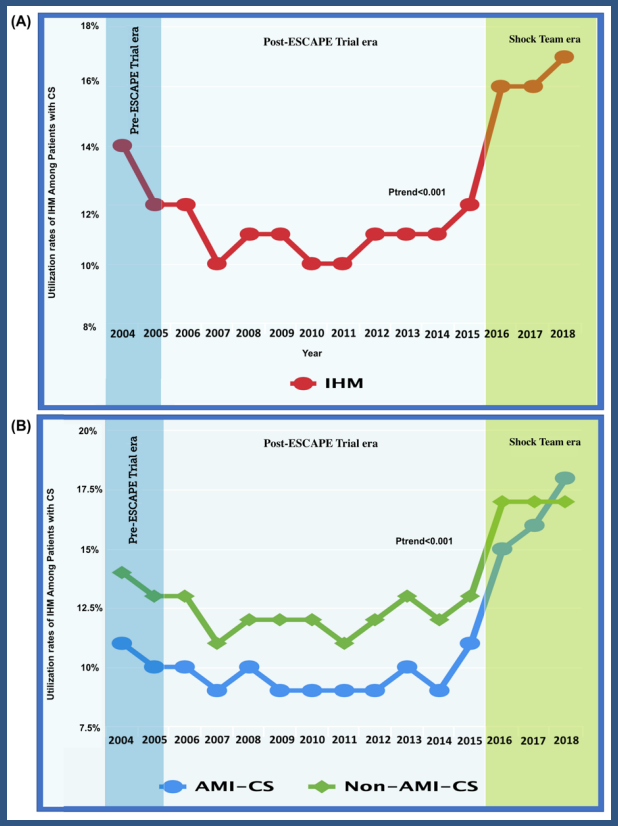
Vasopressors/Inotropes are Associated with Mortality in AMI-CS

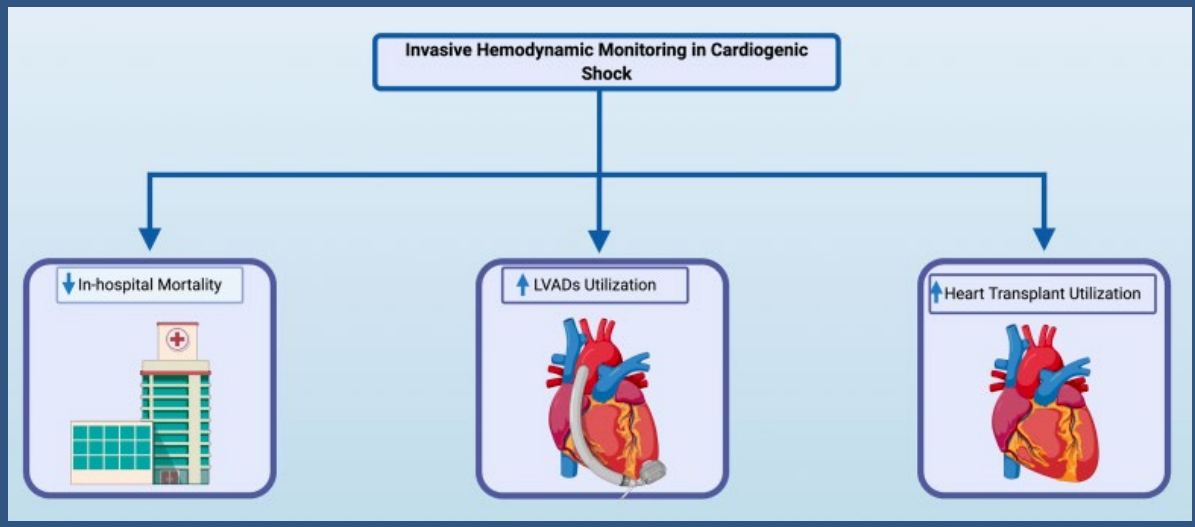


Basir M, Schreiber T, Grines C, et al. Effect of Early Initiation of Mechanical Circulatory Support on Survival in Cardiogenic Shock. Am. J. of Cardiology, 2016.



Use of Invasive Hemodynamics is Associated with Survival in AMI-CS





Osman et al.. Invasive Hemodynamic Monitoring in Cardiogenic Shock is Associated with Lower In-Hospital Mortality. JAHA 2021

Osman M, Balla S, Dupont A, O'Neill WW, Basir MB. Reviving Invasive Hemodynamic Monitoring in Cardiogenic Shock. Invasive Hemodynamic Monitoring in Cardiogenic Shock. Am J Cardiol. 2021 Jul 1;150:128-129.

Delay in MCS associated w/ Mortality in AMI-CS

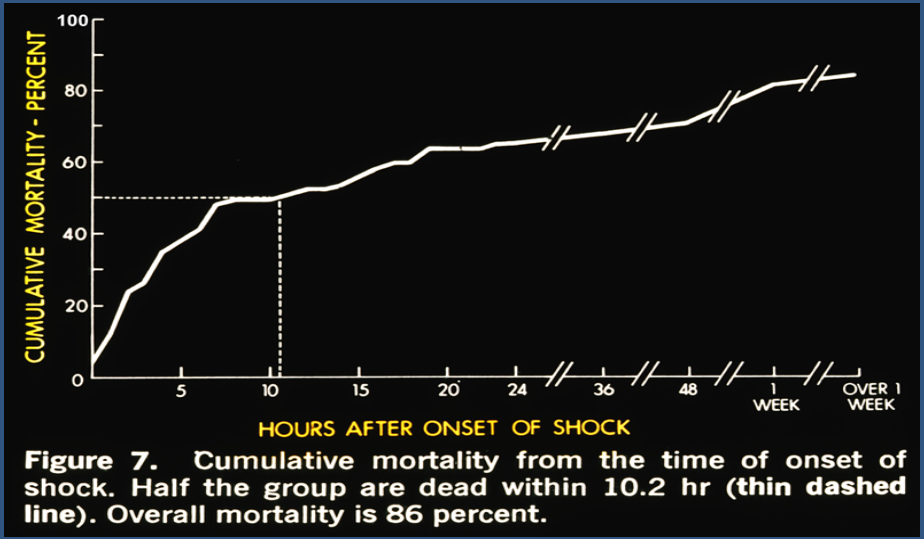
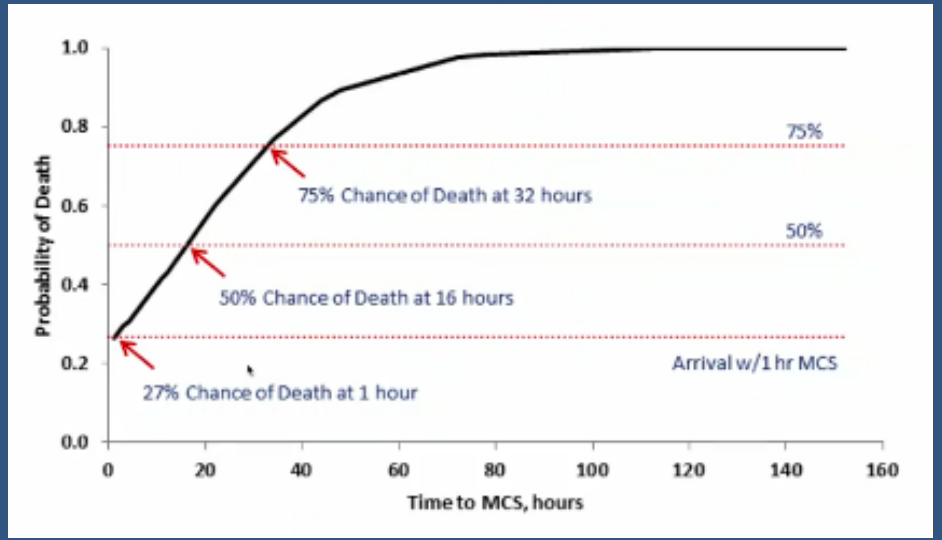


Figure 7. Cumulative mortality from the time of onset of shock. Half the group are dead within 10.2 hr (thin dashed line). Overall mortality is 86 percent.



Tehrani et al. Standardized Team-Based Care for Cardiogenic Shock. J Am Coll Cardiol. 2019 Apr 9;73(13):1659-1669. doi: 10.1016/j.jacc.2018.12.084.

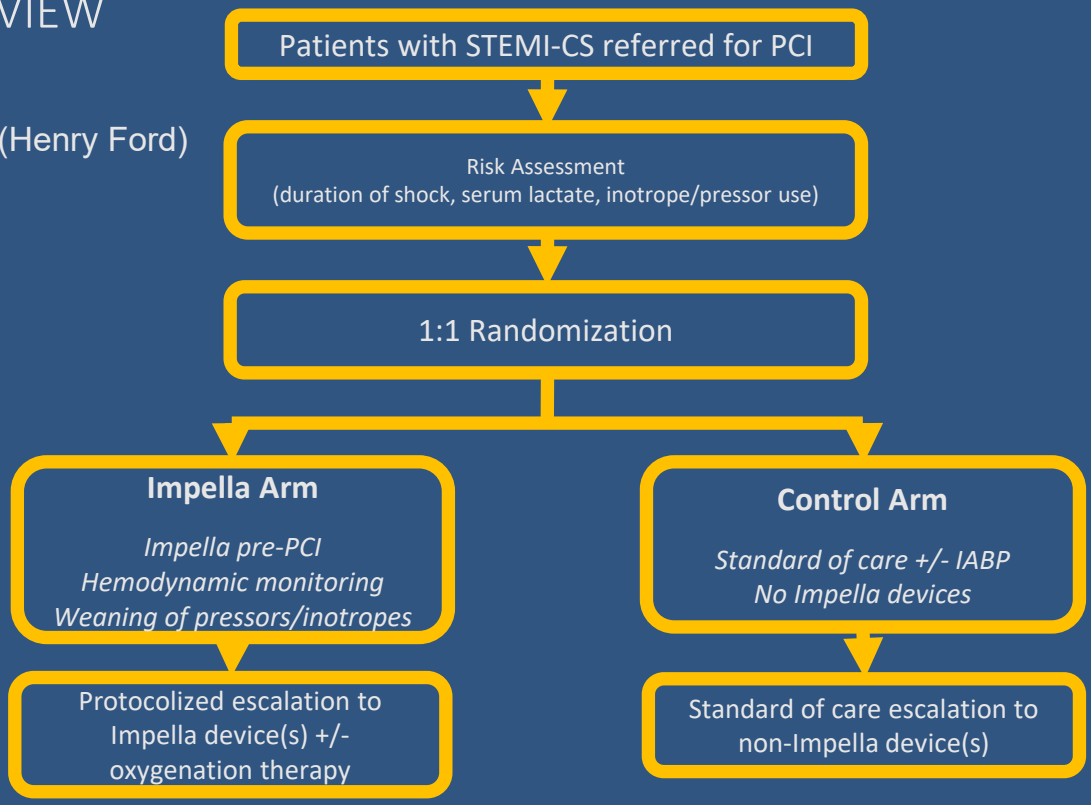
RECOVER IV Trial Design Overview

Co-PI's: Dr. Navin Kapur (Tufts) & Dr. Bill O'Neill (Henry Ford)

Program Chair: Dr. Gregg Stone (Mt. Sinai)

Design Committee

- Navin Kapur, MD
- William O'Neill, MD
- Gregg Stone, MD
- Dan Burkhoff, MD, PhD
- Jacob Moller, MD
- Mark Anderson, MD



Cardiogenic Shock: Selected Issues

- New SCAI Shock Classification
- Cardiac Arrest-CS interaction
- Shock centers and teams
- US National Shock Initiative
- **Role of MSC: New data**
- Refractory Shock

New From Last Year!!

- ECMO-CS trial
- ECLS SHOCK trial
- IPD meta-analysis
- NCSI 1 year analysis
- DANGER

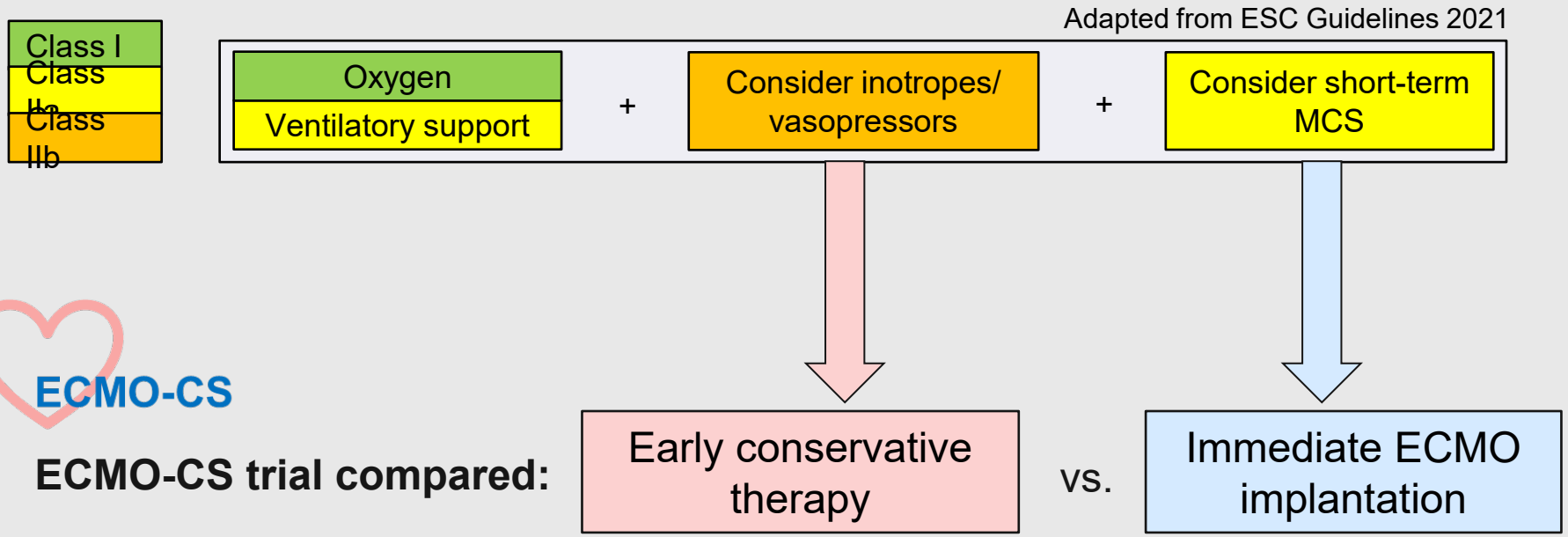
Circulation

ORIGINAL RESEARCH ARTICLE

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

Petr Ostadal, MD, PhD; Richard Rokyta, MD, PhD; Jiri Karasek, MD, PhD; Andreas Kruger, MD, PhD; Dagmar Vondrakova, MD, PhD; Marek Janotka, MD; Jan Naar, MD, PhD; Jana Smalcova, MD; Marketa Hubatova, MSc; Milan Hromadka, MD, PhD; Stefan Volovar, MD; Miroslava Seyfrydova, MD; Jiri Jarkovsky, PhD; Michal Svoboda, MSc; Ales Linhart, MD, PhD; Jan Belohlavek, MD, PhD; for the ECMO-CS Investigators

Current Management of Cardiogenic Shock



in **rapidly deteriorating** or **severe cardiogenic shock**

Trial Organization

- Multicenter, randomized, investigator-initiated, academic clinical trial without industry involvement
- **Four centers in the Czech Republic**
  - Na Homolce Hospital, Prague
  - General University Hospital, Prague
  - University Hospital Pilsen, Pilsen
  - Hospital Liberec, Liberec
- Supported by a grant from the Czech health research council No. 15-27994A
- ClinicalTrials.gov No. NCT02301819
- Enrollment between September 2014 and January 2022

ECMO-CS

Inclusion Criteria

A. Rapidly deteriorating cardiogenic shock (corresponding to SCAI stage D-E)

repeated bolus of vasopressors to maintain MAP > 50 mmHg

B. Severe cardiogenic shock (corresponding to SCAI stage D)

1. Hemodynamic conditions:

CI < 2.2 L/min/m^2 + NOR + DOBU

or

SBP < 100 mmHg + NOR + DOBU + (LVEF < 35% or LVEF 35–55% + severe MR or AoS)

2. Metabolic:

Lactate ≥ 3 mmol/L

or

SvO_2 < 50%

3. Hypovolemia exclusion:

CVP > 7 mmHg or PAWP > 12 mmHg

Trial Procedures and Endpoints

ECMO-CS

Randomization 1:1

Immediate ECMO implantation

or

Early conservative therapy

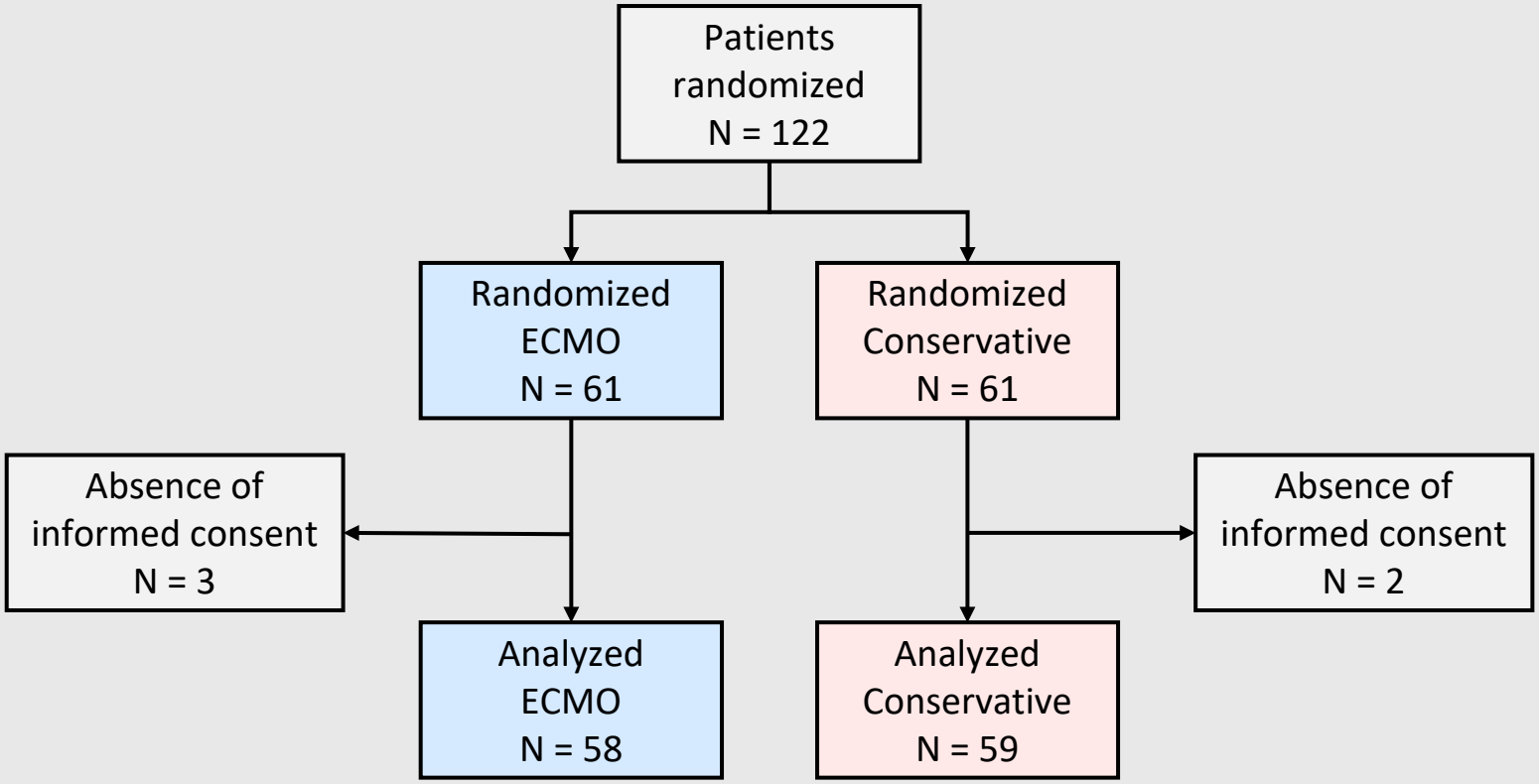
Downstream ECMO allowed in case of hemodynamic worsening (rise of lactate by 3 mmol/L)

Primary composite endpoint

Death from any cause, **resuscitated circulatory arrest**, and implementation of **another mechanical circulatory support** (including ECMO in the conservative arm) **at 30 days**

ECMO-CS

Patient flow



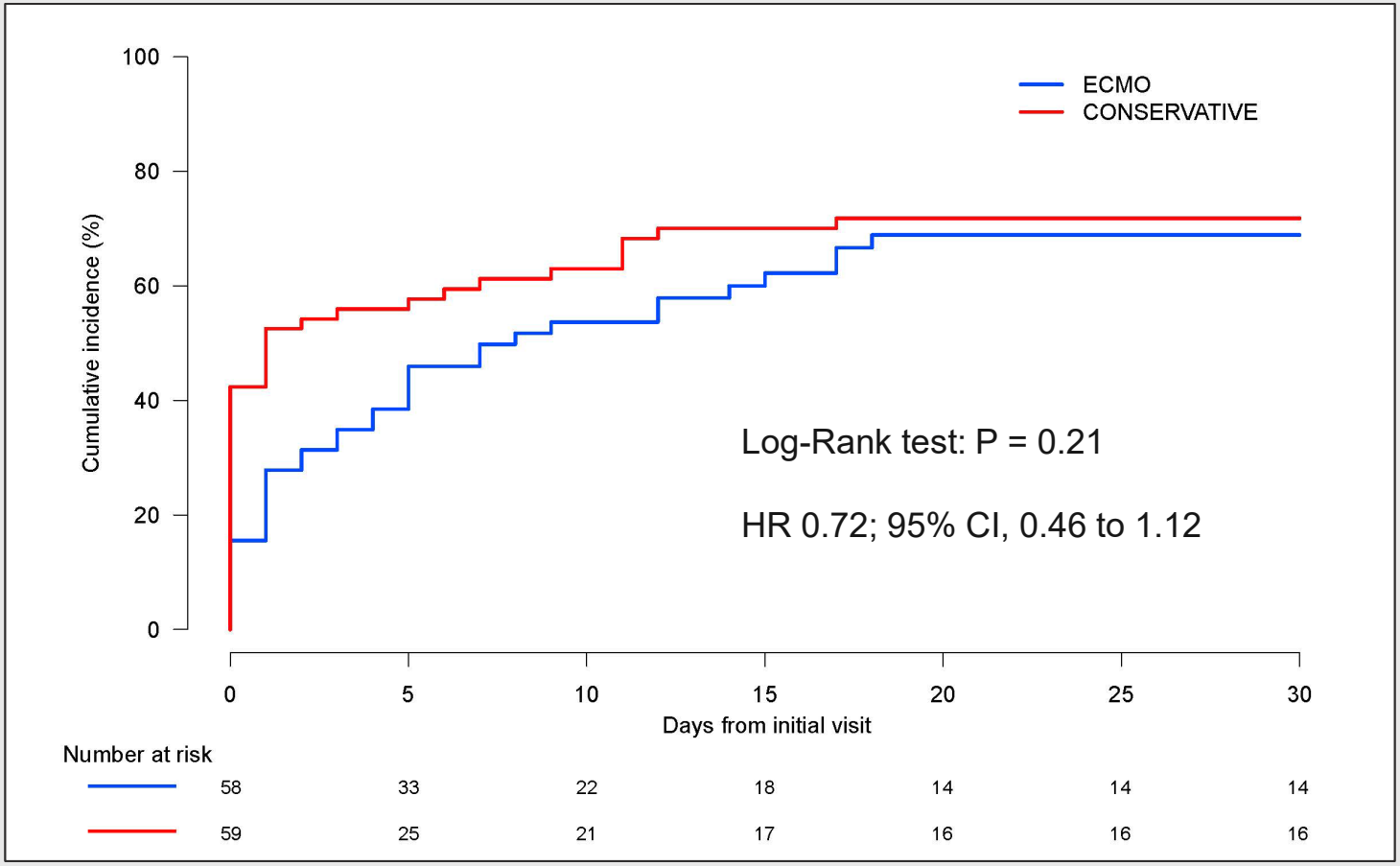
ECMO-CS

Baseline Characteristics

	ECMO N = 58	Conservative N = 59
Age – years (IQR)	**67 (60; 74)**	**65 (58; 71)**
Male (%)	**43 (74.1 %)**	**43 (72.9 %)**
Clinical parameters at randomization - median (IQR)		
Lactate (mmol/L)	**5.3 (3.1; 8.4)**	**4.7 (3.3; 7.4)**
MAP (mmHg)	**63.3 (56.7; 68.7)**	**64.5 (54.3; 75.3)**
Therapy at randomization - no. (%)		
Mechanical ventilation	41 (74.5 %)	40 (70.2 %)
Norepinephrine	50 (86.2 %)	50 (84.7 %)
Dobutamine	31 (53.4 %)	33 (55.9 %)
Milrinone	22 (37.9 %)	16 (27.1 %)
Vasopressin	19 (32.8 %)	22 (37.3 %)
Vasoactive-inotropic score - median (IQR)	59.9 (32.8; 121.5)	61.0 (28.0; 124.9)
Cause of cardiogenic shock – no. (%)		
STEMI	**30 (51.7 %)**	**29 (49.2 %)**
NSTEMI	**7 (12.1 %)**	**7 (11.9 %)**
Decompensation of CHF	14 (24.1 %)	13 (22.0 %)
Mechanical complications of MI	1 (1.7 %)	2 (3.4 %)
Other	6 (10.3 %)	8 (13.6 %)

Primary Composite Endpoint

Death from Any Cause, Resuscitated Arrest, Another MCS



Secondary Endpoints

	ECMO N = 58	Conservative N = 59	Hazard ratio (95% CI)
Primary composite endpoint	**37 (63.8 %)**	**42 (71.2 %)**	**0.72 (0.46; 1.12)**
Death from any cause	29 (50.0 %)	28 (47.5 %)	1.11 (0.66; 1.87)
Resuscitated cardiac arrest	6 (10.3 %)	8 (13.6 %)	0.79 (0.27; 2.28)
Another mechanical circulatory support	10 (17.2 %)	25 (42.4 %)	0.38 (0.18; 0.79)
Downstream ECMO in early conservative arm		**23 (39.0 %)**	
Safety endpoints	**ECMO**	**Conservative**	**P-value**
Serious adverse events	35 (60.3 %)	36 (61.0 %)	0.941
Bleeding	18 (31.0 %)	12 (20.3 %)	0.185
Leg ischemia	8 (13.8 %)	3 (5.1 %)	0.107
Stroke	3 (5.2 %)	0 (0.0 %)	0.119
Pneumonia	18 (31.0 %)	18 (30.5 %)	0.951
Sepsis	23 (39.7 %)	23 (39.0 %)	0.941

ECMO-CS

Conclusion

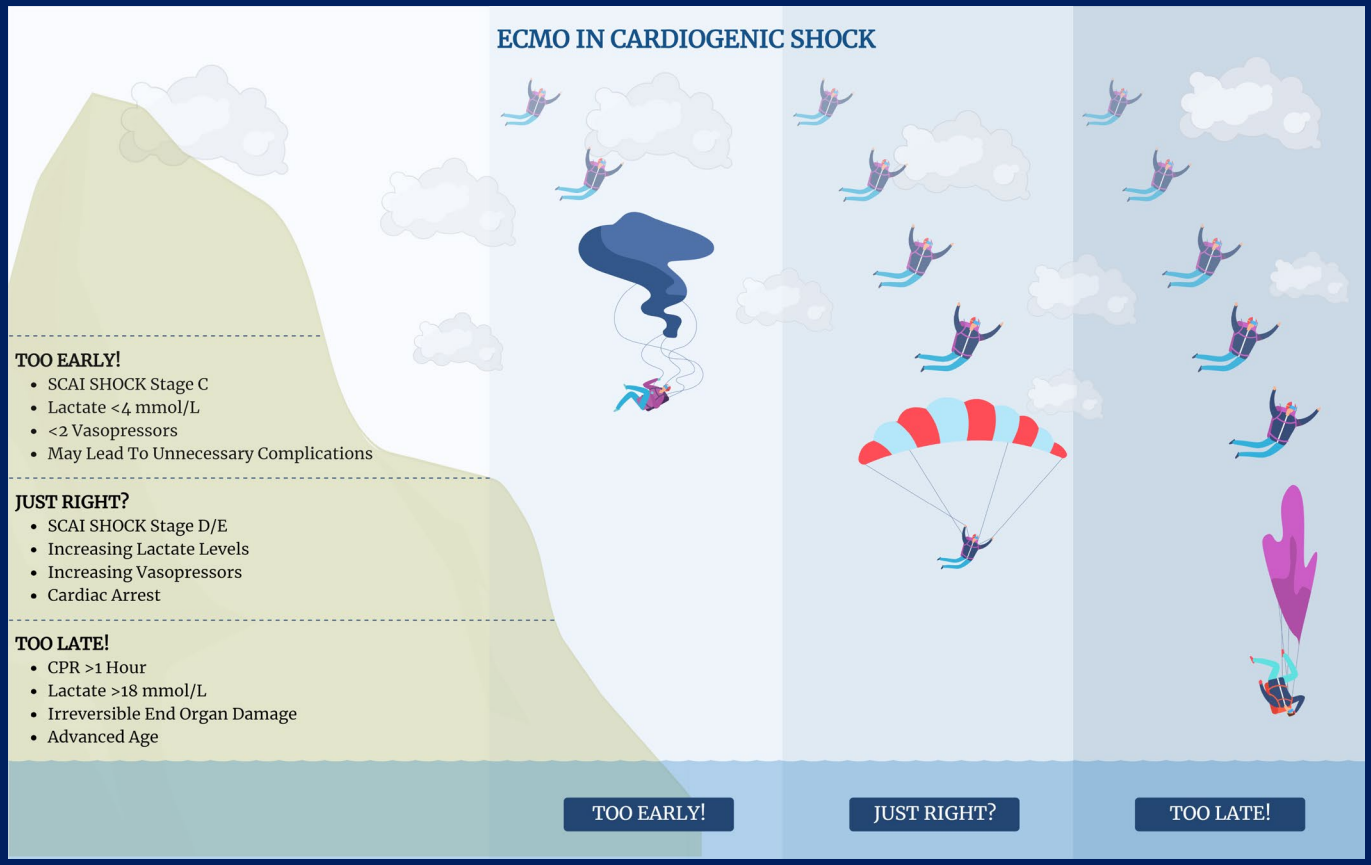
- **Immediate implementation of ECMO in patients with rapidly deteriorating or severe cardiogenic shock did not improve clinical outcomes** compared with an early conservative strategy that permitted downstream use of ECMO in case of hemodynamic worsening

- A **substantial proportion of patients with early conservative therapy required downstream use of ECMO or other MCS** due to further deterioration of hemodynamic status

Implication

- **Even in patients with severe or rapidly deteriorating cardiogenic shock (SCAI stage D-E)**, early hemodynamic stabilization using inotropes and vasopressors with **implementation of MCS only in case of further hemodynamic worsening** is a therapeutic strategy comparable to the immediate insertion of ECMO

ECMO-CS TRIAL



The NEW ENGLAND JOURNAL of MEDICINE

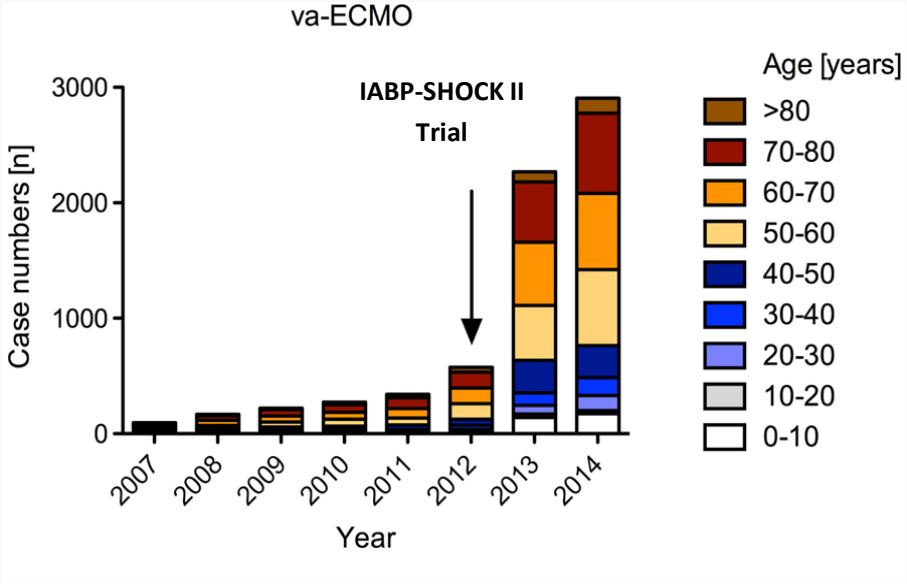
ORIGINAL ARTICLE

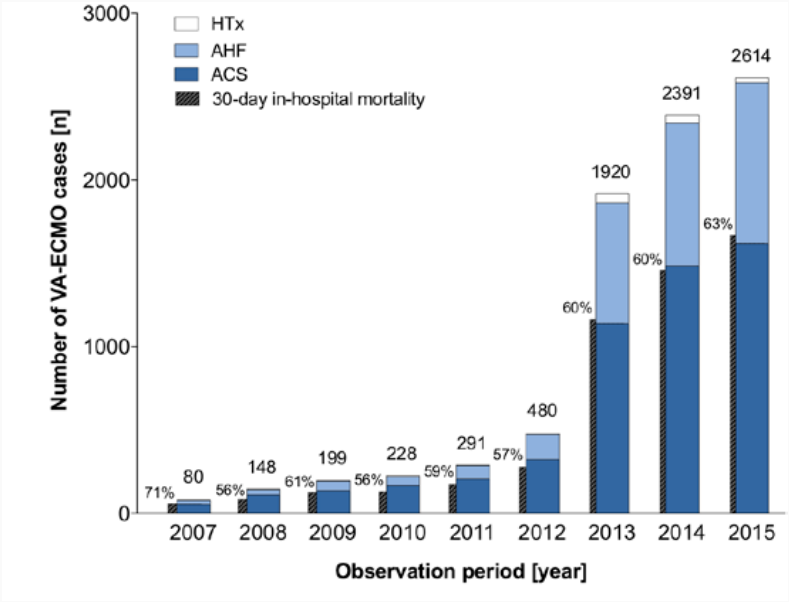
Extracorporeal Life Support in Infarct-Related Cardiogenic Shock

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*

Background

Increase in VA-ECMO (ECLS) Over Time





Karagiannidis et al. Intensive Care Med.2016;42:889–896
Becher et al. Circulation 2018;138:2298-2300

Slide courtesy of Prof. Holger Thiele

Methods

Inclusion and Exclusion Criteria

ECLS-SHOCK

Inclusion Criteria	Exclusion Criteria
• Cardiogenic shock complicating AMI (STEMI or NSTEMI) plus obligatory: 1. Planned revascularization 2. SBP <90 mmHg >30 min or catecholamines required to maintain SBP >90 mmHg 3. Signs of impaired organ perfusion with at least one of the following criteria: ➢ Altered mental status ➢ Cold, clammy skin and extremities ➢ Oliguria with urine output <30 ml/h 4. Arterial lactate >3 mmol/l • Informed consent	• Resuscitation >45 minutes • Mechanical cause of cardiogenic shock • Onset of shock >12 h • Severe peripheral artery disease with impossibility to insert ECLS cannulae • Age <18 years or >80 years • Shock of other cause (bradycardia, sepsis, hypovolemia, etc.) • Other severe concomitant disease with limited life expectancy <6 months • Pregnancy • Participation in another trial

Slide courtesy of Prof. Holger Thiele

Thiele et al. Am Heart J 2021;234: 1-1

Methods

Endpoints/Statistical Methodology

ECLS-SHOCK

Primary endpoint

30-day all-cause mortality

Secondary endpoints

- Time to hemodynamic stabilization
- Duration of catecholamine therapy
- Serial creatinine-level and creatinine-clearance until hemodynamic stabilization
- Mean and area under the curve of arterial lactate during 48 hours after PCI
- Peak release of myocardial enzymes
- Serial SAPS II
- Length of mechanical ventilation
- Length of ICU stay
- Length of hospital stay
- Acute renal failure requiring renal replacement therapy within 30 days
- Recurrent myocardial infarction within 30 days
- Need for repeat revascularization (PCI and/or CABG) within 30-days
- Rehospitalization for heart failure within 30 days
- Cerebral performance category (CPC) at 30 days

Sample size

- **Estimated event rate** for primary endpoint**:**
  - **49%** in **control group** versus
  - **35%** in **ECLS group**
- 1 interim analysis (50% of patients)
- 2-sided Chi^2-test; power: 80%, alpha=0.048 for final analysis → **390 patients**
- To compensate for losses in follow-up → **420 patients**

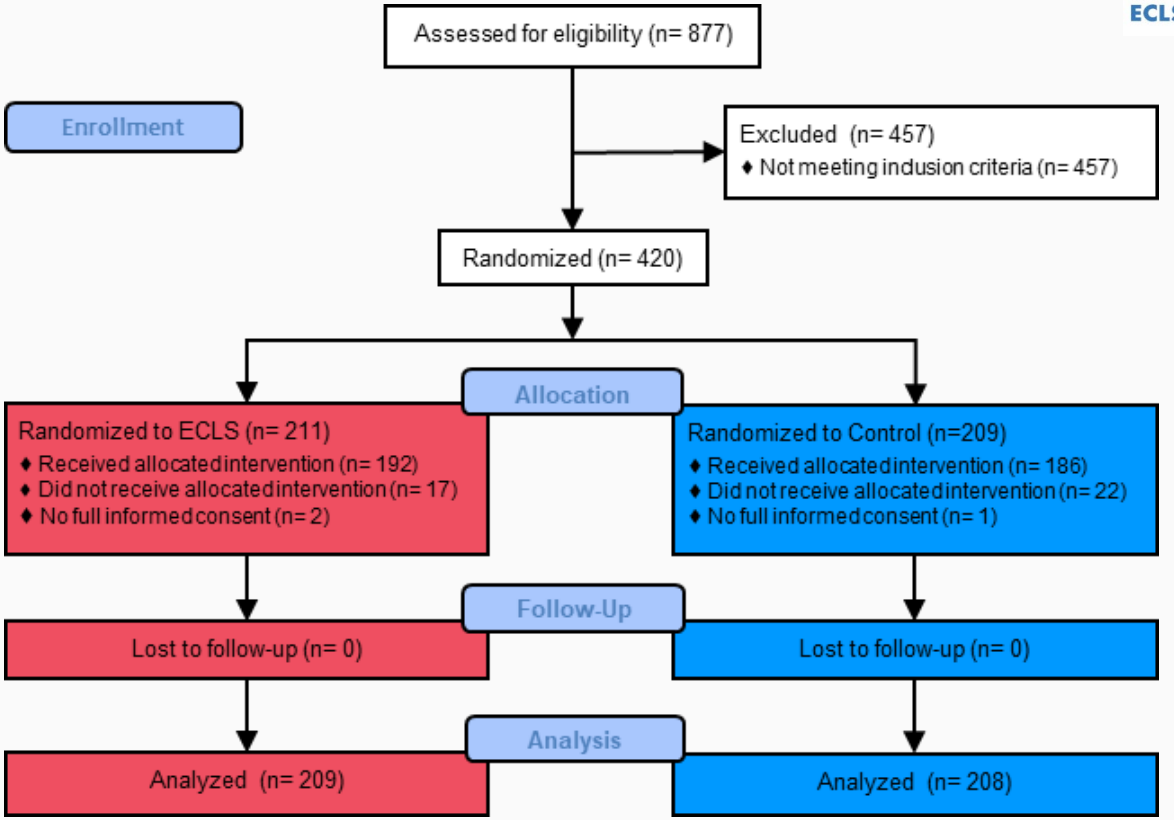
Slide courtesy of Prof. Holger Thiele

Thiele et al. Am Heart J 2021;234: 1-1

Results

44 study sites

Trial Flow



Slide courtesy of Prof. Holger Thiele

Thiele et al. *Am Heart J* 2021;234: 1-1

Results

Baseline Characteristics

	ECLS (n=209)	Control (n=208)
Age (years); median (IQR)	**62 (56 - 69)**	**63 (57 - 71)**
Male sex; n/total (%)	170/209 (81.3)	169/208 (81.3)
Mean blood pressure (mmHg); median (IQR)	71 (61 - 87)	72 (60 - 88)
STEMI; n/total (%)	135/204 (66.2)	141/207 (68.1)
Resuscitation before randomization; n/total (%)	**162/209 (77.5)**	**162/208 (77.9)**
No. of diseased vessels; n/total (%)		
1	71/203 (35.0)	63/200 (31.5)
2	71/203 (35.0)	53/200 (26.5)
3	61/203 (30.0)	84/200 (42.0)
LVEF (%); median (IQR)	30 (20 - 35)	30 (20 - 40)
Laboratory values on admission		
pH; median (IQR)	7.2 (7.1 - 7.3)	7.2 (7.1 - 7.3)
Lactate (mmol/L); median (IQR)	**6.8 (4.5 – 9.6)**	**6.9 (4.6 – 10.0)**
SCAI Shock classification; n/total (%)		
C	**104/209 (49.8)**	**111/208 (53.4)**
D	38/209 (18.2)	18/208 (8.7)
E	67/209 (32.1)	79/208 (38.0)

Slide courtesy of Prof. Holger Thiele

Results

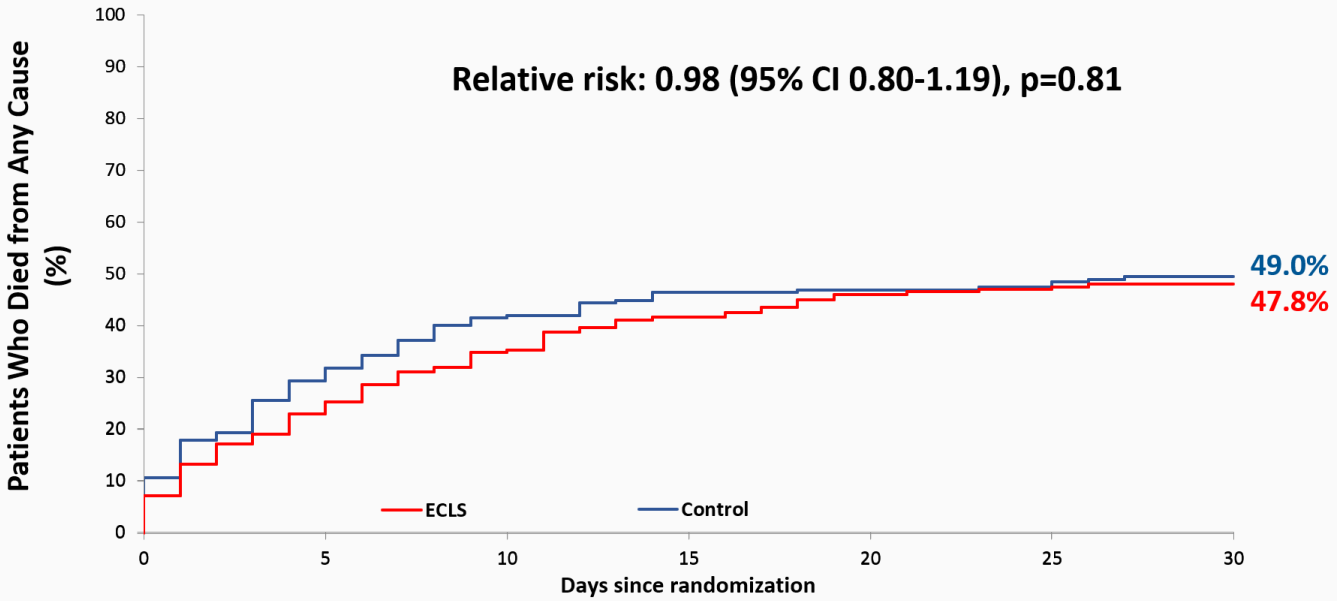
Treatment

	ECLS (n=209)	Control (n=208)
Type of inital revascularization; n/total (%)		
PCI	**199/208 (95.7)**	**199/204 (97.5)**
CABG	1/208 (0.5)	0/204
PCI with emergent transfer to CABG	2/208 (1.0)	0/204
ECLS therapy; n/total (%)	**192/209 (91.8)**	**26/208 (12.5)**
Initiation in catheterization laboratory		
Prior 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 hours	**0/192**	**3/26 (11.5)**
≥24 hours	**0/192**	**4/26 (15.4)**
Duration of ECLS therapy (days); median (IQR)	2.7 (1.5 - 4.8)	2.7 (2.2 – 3.8)
Peripheral antegrade perfusion sheath; n/total (%)	183/192 (95.3)	16/19 (84.2)
Active left ventricular unloading in ECLS; n/total (%)	**11/191 (5.8)**	**6/19 (31.6)**
Other MCS in patients without ECLS; n/total (%)	**0/17**	**28/182 (15.4)**
Invasive mechanical ventilation; n/total (%)	183/203 (90.1)	177/202 (87.6)

Slide courtesy of Prof. Holger Thiele

Results

Primary Endpoint – 30-Day All-Cause Mortality

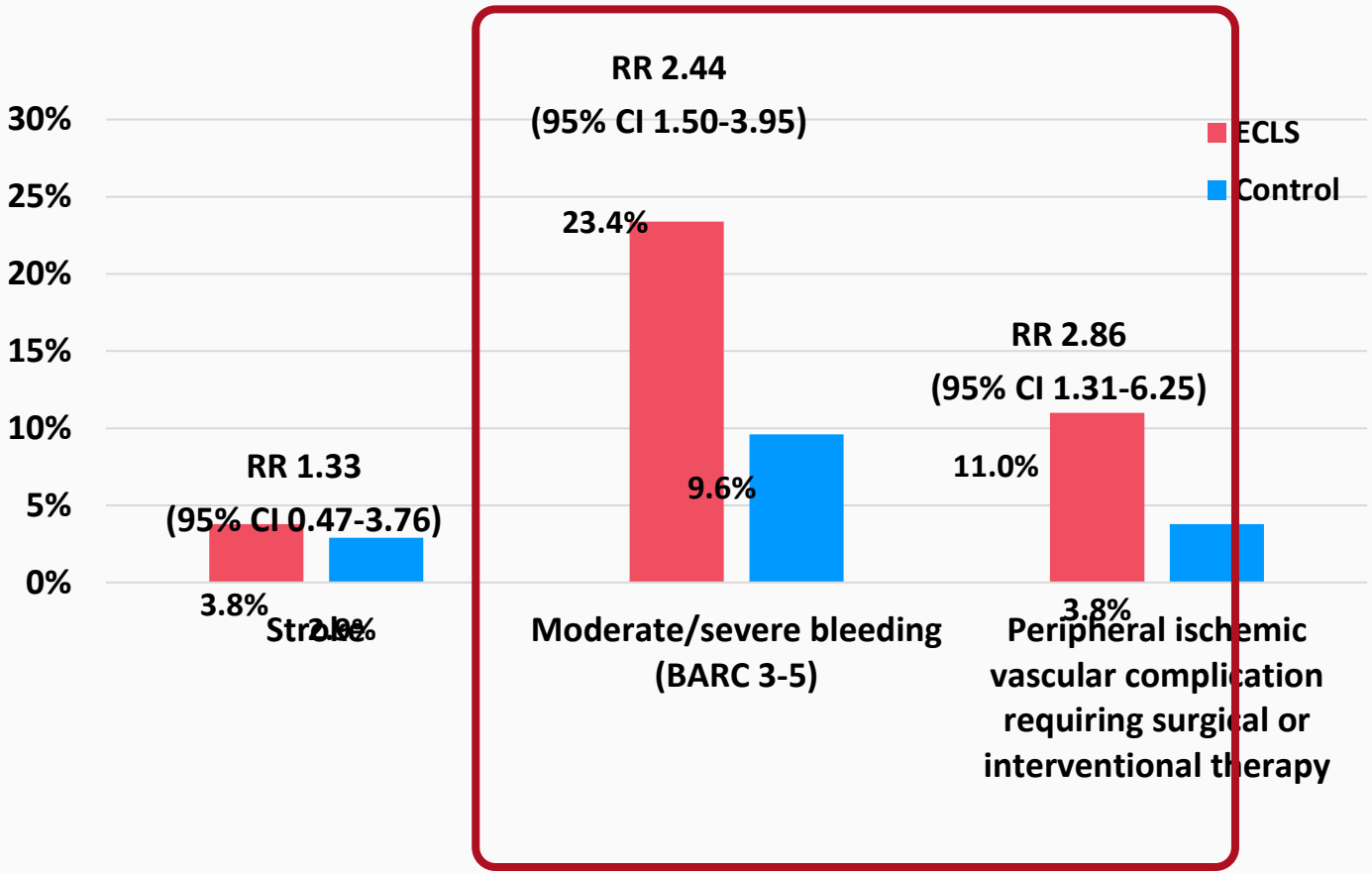


No. at Risk							
ECLS	209	161	136	119	109	107	105
Control	208	146	120	109	105	104	100

Slide courtesy of Prof. Holger Thiele

Results

Safety



Slide courtesy of Prof. Holger Thiele

Venoarterial extracorporeal membrane oxygenation in patients with infarct-related cardiogenic shock: an individual patient data meta-analysis of randomised trials

Uwe Zeymer, Anne Freund*, Matthias Hochadel, Petr Ostadal, Jan Belohlavek, Richard Rokyta, Steffen Massberg, Stefan Brunner, Enzo Lüsebrink, Marcus Flather, David Adlam, Kris Bogaerts, Amerjeet Banning, Manel Sabaté, Ibrahim Akin, Alexander Jobs, Steffen Schneider, Steffen Desch, Holger Thiele*

Individual patient data (IPD) meta-analysis

	ECLS-SHOCK I[11]	ECMO-CS[12]	EURO SHOCK[13]	ECLS-SHOCK[14]
Identifier	NCT02544594	NCT02301819	NCT03813134	NCT03637205
Participants	42 patients	117 patients (73 with acute myocardial infarction)	35 patients	420 patients
Enrolment period	November, 2015, to November, 2017	November, 2015, to January, 2022	January, 2020, to January, 2022	June, 2019, to November, 2022
Main inclusion criteria	Infarct-related cardiogenic shock (STEMI or NSTEMI) <12 h; planned revascularisation; age 18–75 years	Cardiogenic shock of various causes; rapidly deteriorating shock or severe shock; arterial lactate >3 mmol/L; age >18 years	Infarct-related cardiogenic shock (STEMI or NSTEMI) <24 h; persistence of cardiogenic shock minimum 30 min after revascularisation; arterial lactate >2 mmol/L; age 18–90 years	Infarct-related cardiogenic shock (STEMI or NSTEMI) <12 h; arterial lactate >3 mmol/L; planned revascularisation; age 18–80 years
Main exclusion criteria	In patients who underwent CPR, CPR duration >60 min; mechanical infarct complications	Comatose patients after out-of-hospital cardiac arrest	Mechanical infarct complications	In patients who underwent CPR, CPR duration >45 min; mechanical infarct complications
Intervention	VA-ECMO plus optimal medical therapy	VA-ECMO plus optimal medical therapy	VA-ECMO plus optimal medical therapy	VA-ECMO plus optimal medical therapy
Control	Optimal medical therapy	Optimal medical therapy	Optimal medical therapy	Optimal medical therapy
Primary outcome	LVEF after 30 days	All-cause 30-day death or resuscitated circulatory arrest or need for another MCS	All-cause 30-day death	All-cause 30-day death
Statistical assumptions	5% improvement in LVEF with VA-ECMO	Combined endpoint: 50% control *vs* 25% with VA-ECMO	Death: 50% control *vs* 36% with VA-ECMO	Death: 49% control *vs* 35% with VA-ECMO
Special characteristics	Control group: downstream VA-ECMO not allowed; use of MCS other than VA-ECMO possible in case of defined escalation criteria	Control group: downstream VA-ECMO or other MCS allowed	Control group: IABP allowed; no other MCS allowed	Intervention group: VA-ECMO insertion preferably before PCI; control group: use of MCS other than VA-ECMO possible in case of defined escalation criteria

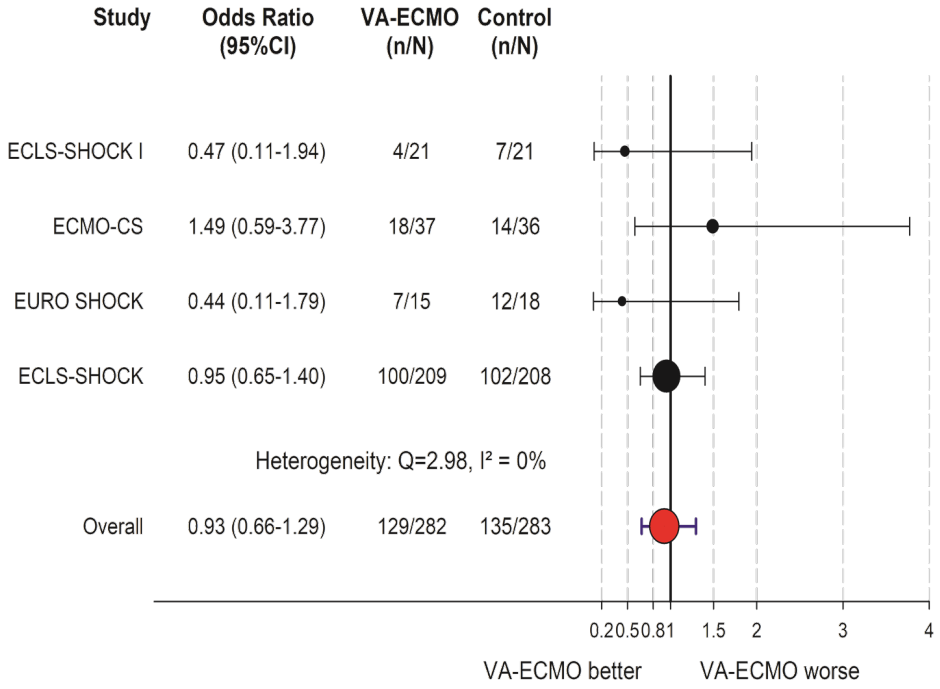
CPR=cardiopulmonary resuscitation. IABP=intra-aortic balloon pump. LVEF=left ventricular ejection fraction. MCS=mechanical circulatory support. NSTEMI=non-ST-elevation myocardial infarction. PCI=percutaneous coronary intervention. STEMI=ST-elevation myocardial infarction. VA-ECMO=venoarterial extracorporeal membrane oxygenation.

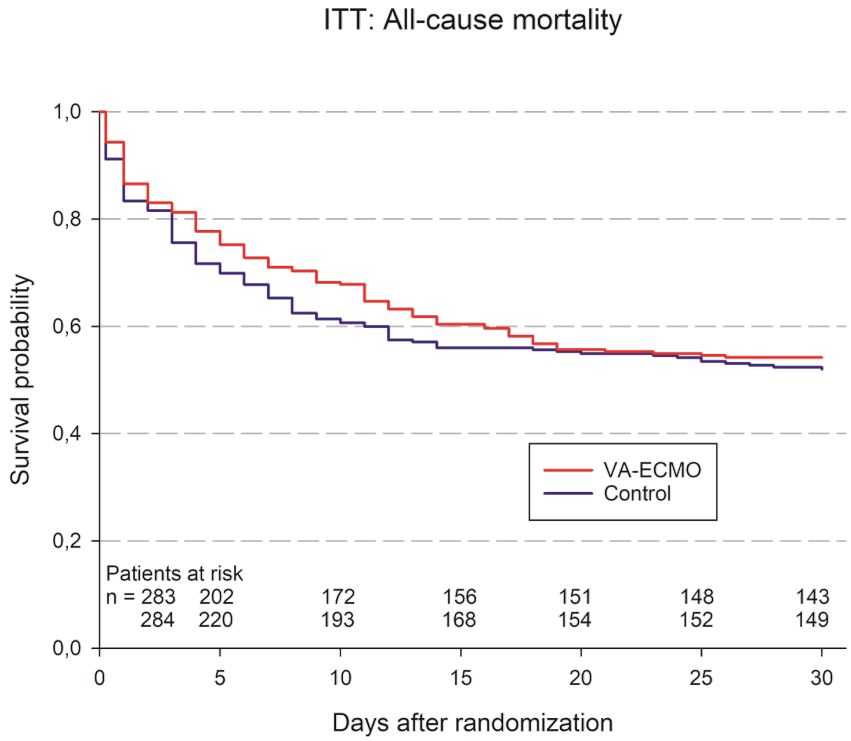
Table 1: **Key design features of included trials**

Zeymer U, Freund A, Hochadel M, *et. al.* *Lancet* 2023. https://doi.org/10.1016/S0140-6736(23)01607-0

Individual patient data (IPD) meta-analysis

Primary endpoint: 30-day all-cause mortality

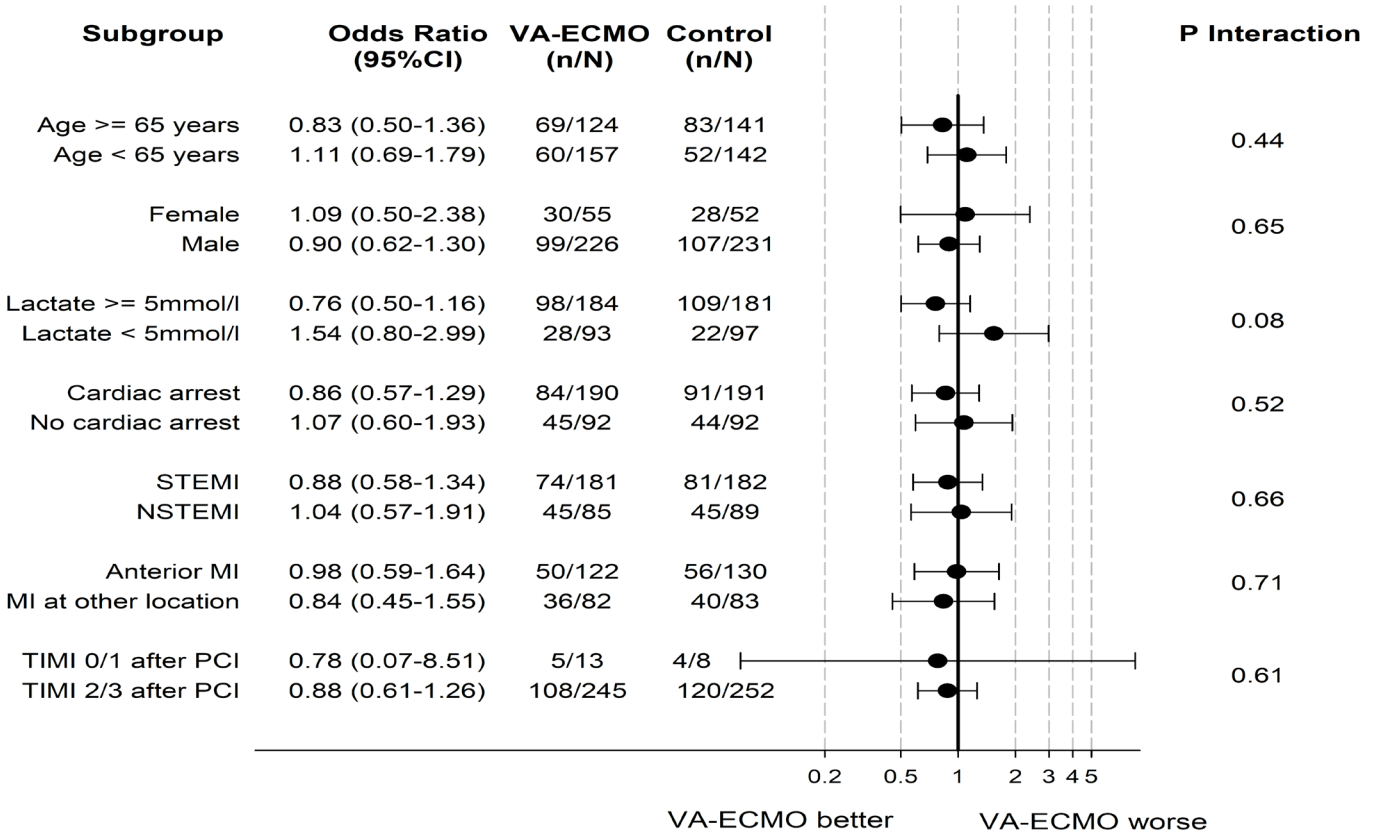




Zeymer U, Freund A, Hochadel M, *et. al.* *Lancet* 2023. https://doi.org/10.1016/S0140-6736(23)01607-0

Individual patient data (IPD) meta-analysis

Primary endpoint: 30-day all-cause mortality

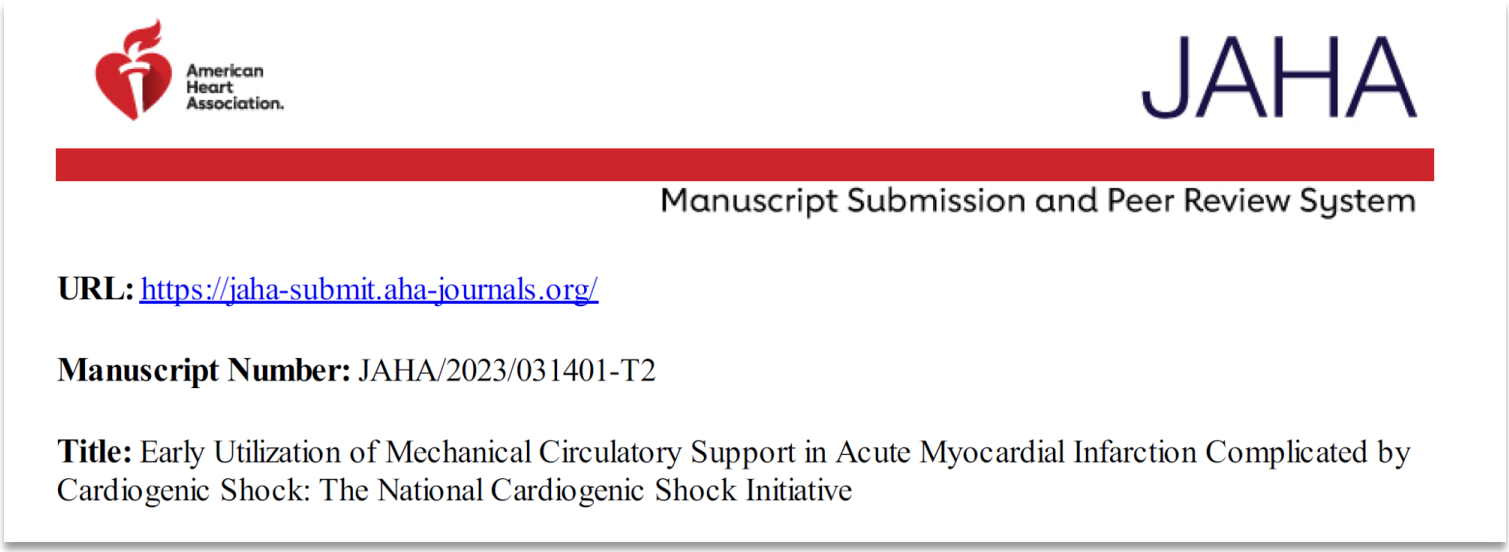


Zeymer U, Freund A, Hochadel M, *et. al.* *Lancet* 2023. https://doi.org/10.1016/S0140-6736(23)01607-0

Summary and conclusions

- In patients with **acute myocardial infarction and cardiogenic shock** with planned revascularization **ECLS (VA-ECMO) versus control does not reduce 30-day all-cause mortality**.
- This **lack of mortality benefit is supported by an IPD metaanalysis** of all 4 RCTs comparing ECLS vs control.
- This lack of mortality benefit is further supported by the fact that there were **no differences in the secondary endpoints (e.g. lactate, renal function, SAPS-2, etc.)**.
- **ECLS is associated with higher rates** of moderate or severe **BARC bleeding and peripheral ischemic complications** requiring intervention.
- The findings challenge current guideline recommendations and clinical practice with increasing rates of mechanical circulatory support in cardiogenic shock.

Zeymer U, Freund A, Hochadel M, *et. al.* *Lancet* 2023. https://doi.org/10.1016/S0140-6736(23)01607-0



American Heart Association.

JAHA

Manuscript Submission and Peer Review System

URL: https://jaha-submit.aha-journals.org/

Manuscript Number: JAHA/2023/031401-T2

Title: Early Utilization of Mechanical Circulatory Support in Acute Myocardial Infarction Complicated by Cardiogenic Shock: The National Cardiogenic Shock Initiative

- The **NCSI** (NCT03677180) is a **single-arm, multicenter study** to assess the feasibility and effectiveness of utilizing **early Impella support** in patients presenting with **AMI-CS**
- A **total of 406 patients were enrolled at 80 sites** between 2016-2020.
- **32 hospitals were academic** medical centers and **48 were community** medical centers

Manuscript courtesy of Dr. Babar Basir, being presented with permission

National Cardiogenic Shock Initiative

Short- and long-term survival

RESULTS

- **Average age was 64±12 years**, 24% were female, **17% had a witnessed OHCA, 27% had IHCA**, and **9% were under active CPR** during MCS implantation.
- Patients:
  - Presented with **mean SBP of 77.2±19.2 mmHg**,
  - **85% of patients were on vasopressors** or inotropes,
  - Mean **lactate was 4.8±3.9** mmol/L
  - **Cardiac power output (CPO) was 0.67±0.29 W**

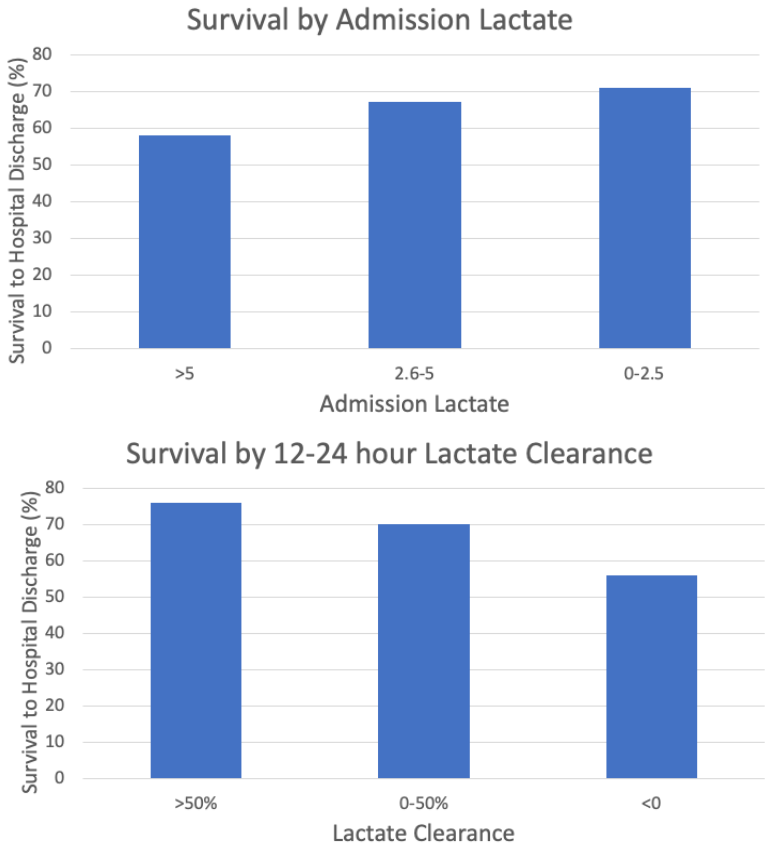
- **At 24-hours, mean SBP improved to 103.9 ± 17.8 mmHg, lactate to 2.7±2.8 mmol/L**, and **CPO to 1.0±1.3 W**.

Basir MB, Lemor A, Gorgis S, et. al. *JAHA* 2023. *In press.*

National Cardiogenic Shock Initiative

Short- and long-term survival

Table 4. Survival Rates According to SCAI Shock Stage at the Time of the Index Procedure				
	All	Stage C/D	Stage E	p value
Procedural Survival	99%	99%	98%	0.74
Survival to Discharge	71%	79%	54%	<0.01
Survival at 30-days	68%	77%	49%	<0.01
Survival at 1-Year	53%	62%	31%	<0.01



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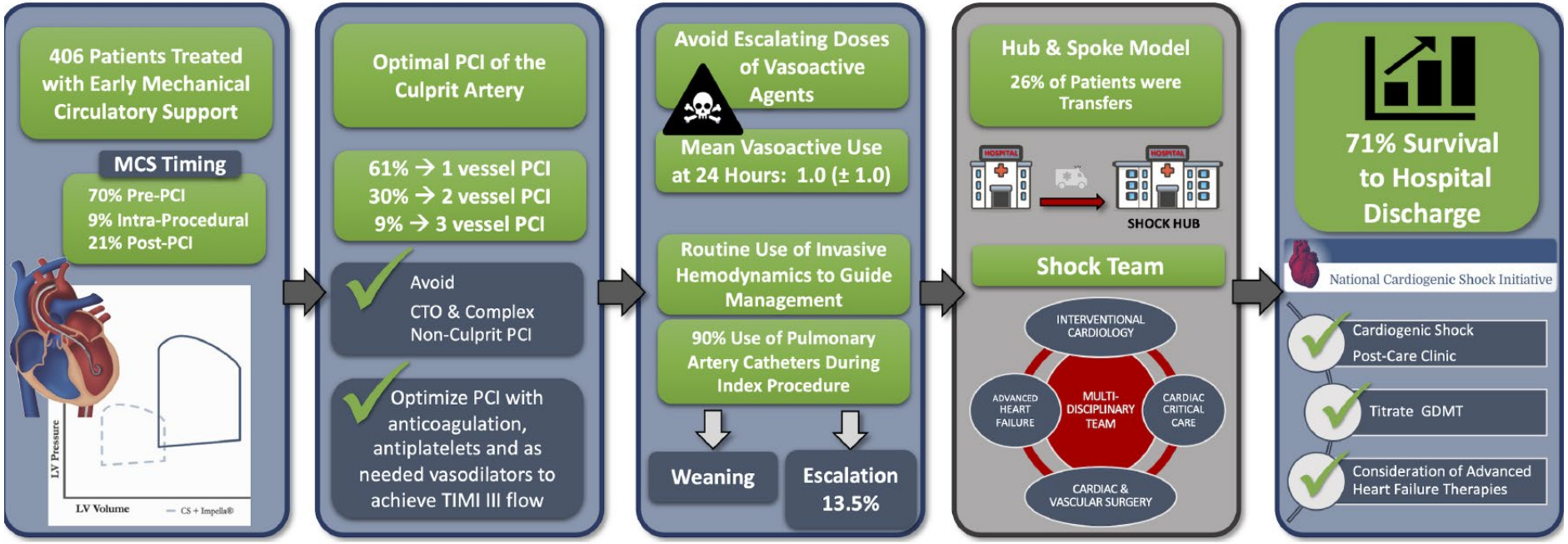
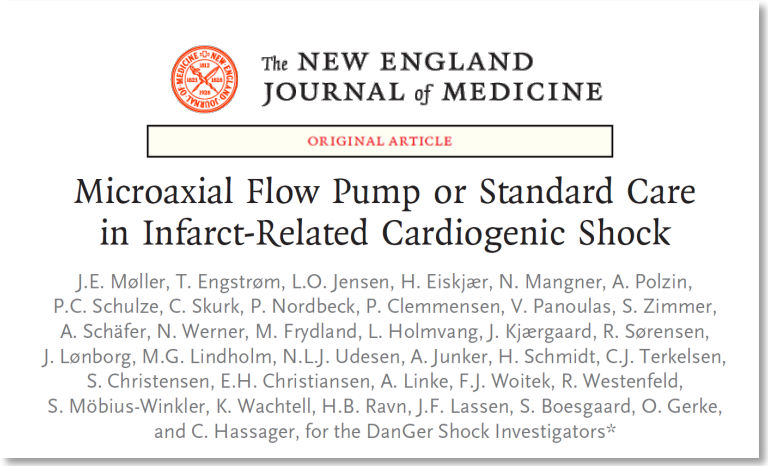


Basir MB, Lemor A, Gorgis S, et. al. *JAHA* 2023. *In press.*

DanGer Shock RCT



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*

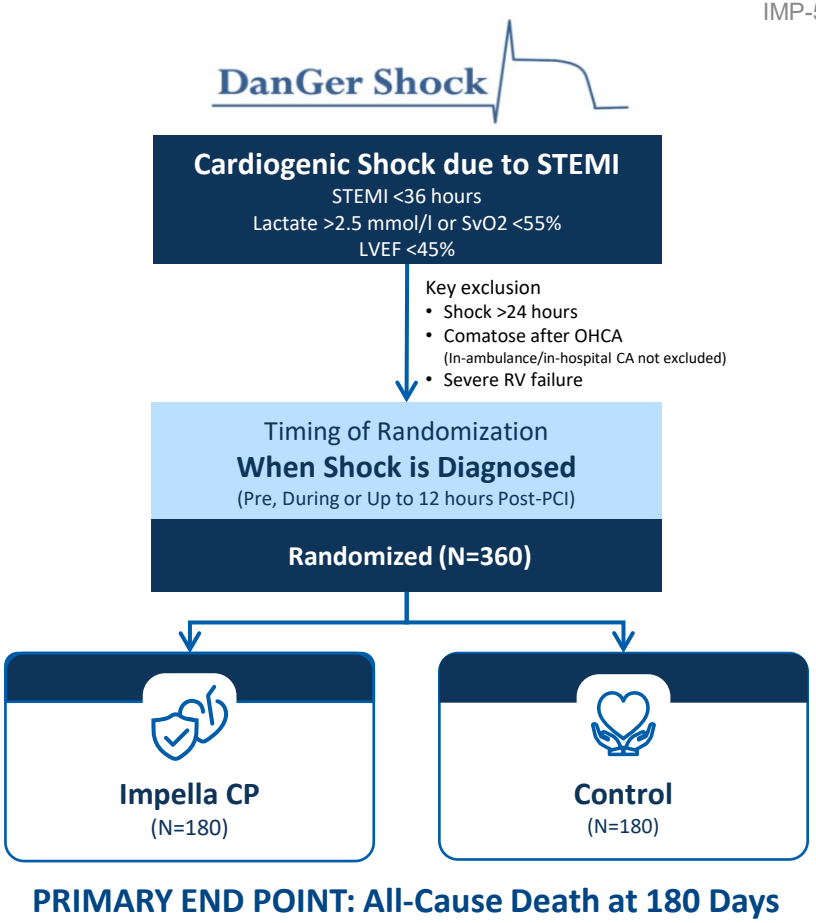
Independent Investigator-Initiated Study

First Completed Impella RCT in AMI-CS

- 360 patients randomized from 2013 to 2023
- 14 centers across Denmark, Germany and UK

MCS Device Trial Hypothesis

Routine Impella CP use reduces mortality in AMI-CS due to STEMI



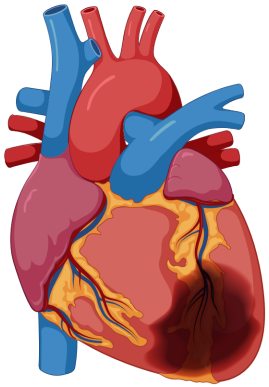
PRIMARY END POINT: All-Cause Death at 180 Days

ACC.24 Late-Breaking Clinical Trials

Møller J, et al. Microaxial Flow Pump or Standard Care in Infarct-Related CS. N Engl J Med 2024. DOI: 10.1056/NEJMoa2312572.

DanGer Shock
Danish German Cardiogenic Shock Trial

Background

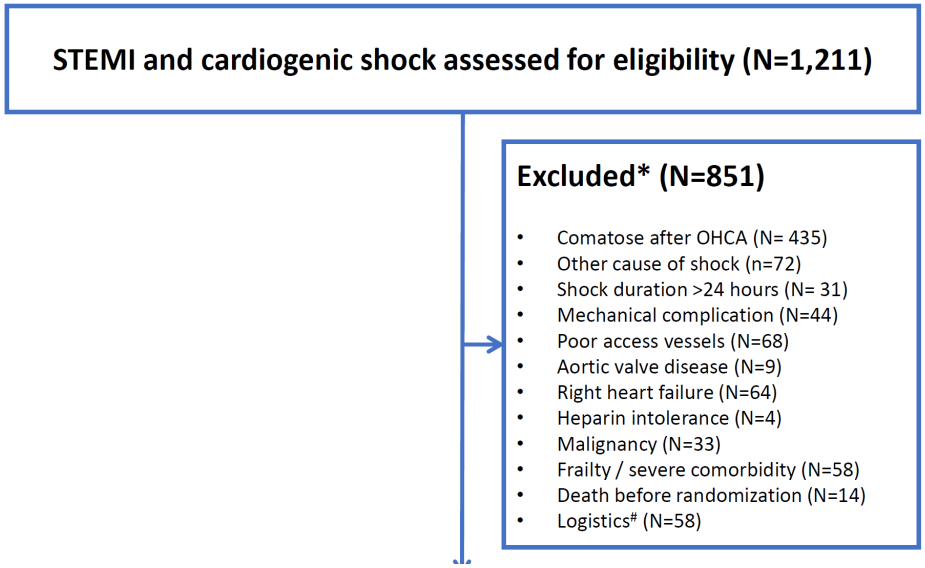


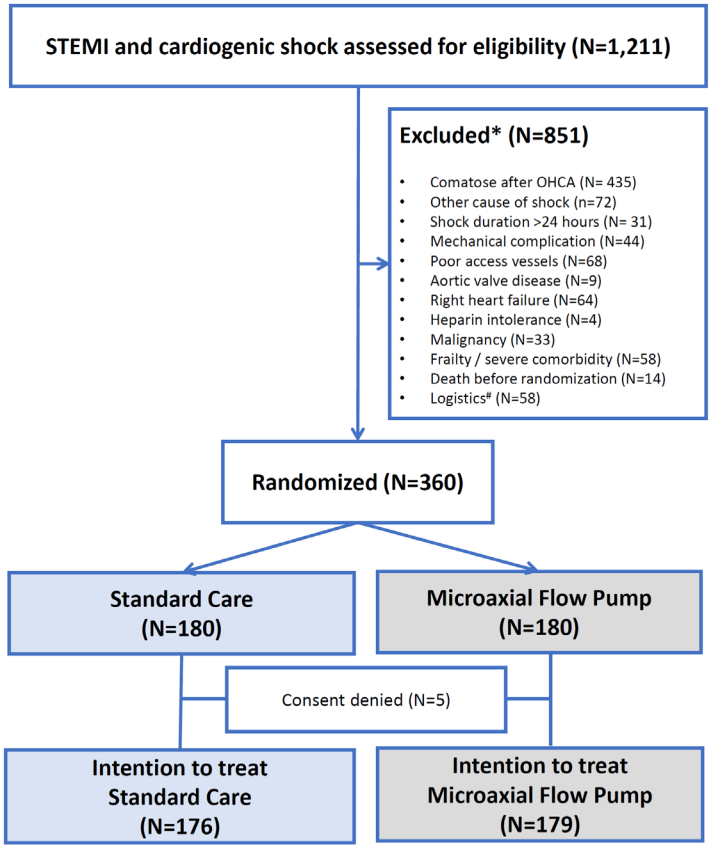
STEMI

One in ten will develop CS

½ will survive

Trial Flow


STEMI and cardiogenic shock assessed for eligibility (N=1,211)
Excluded* (N=851)
Comatose after OHCA (N= 435)
Other cause of shock (n=72)
Shock duration >24 hours (N= 31)
Mechanical complication (N=44)
Poor access vessels (N=68)
Aortic valve disease (N=9)
Right heart failure (N=64)
Heparin intolerance (N=4)
Malignancy (N=33)
Frailty / severe comorbidity (N=58)
Death before randomization (N=14)
Logistics# (N=58)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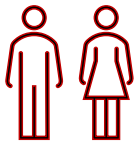
Heparin intolerance (N=4)
Malignancy (N=33)
Frailty / severe comorbidity (N=58)
Death before randomization (N=14)
Logistics# (N=58)
Randomized (N=360)
Standard Care (N=180)
Microaxial Flow Pump (N=180)
Consent denied (N=5)
Intention to treat Standard Care (N=176)
Intention to treat Microaxial Flow Pump (N=179)

Patients characteristics – N=355



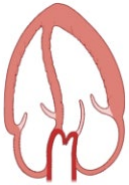
Median 67 years
79% male

Median lactate 4.5 mmol/L

72% LAD or LM culprit
72% Multi vessel disease

Median 4 hrs from onset of STEMI symptoms to randomization

84% randomized in cath lab

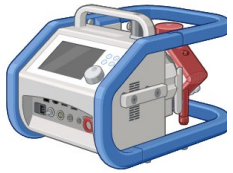


Median LVEF 25%

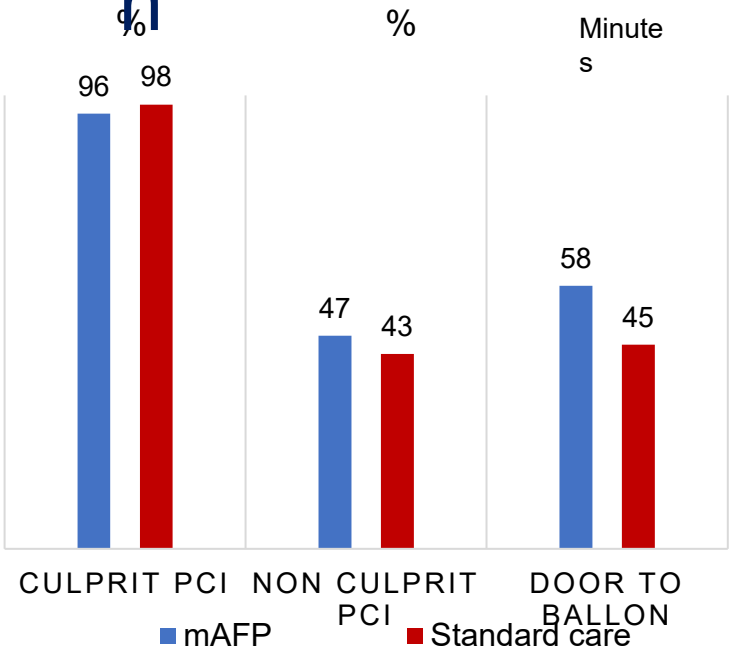
55% SCAI class C
45% SCAI class D or E

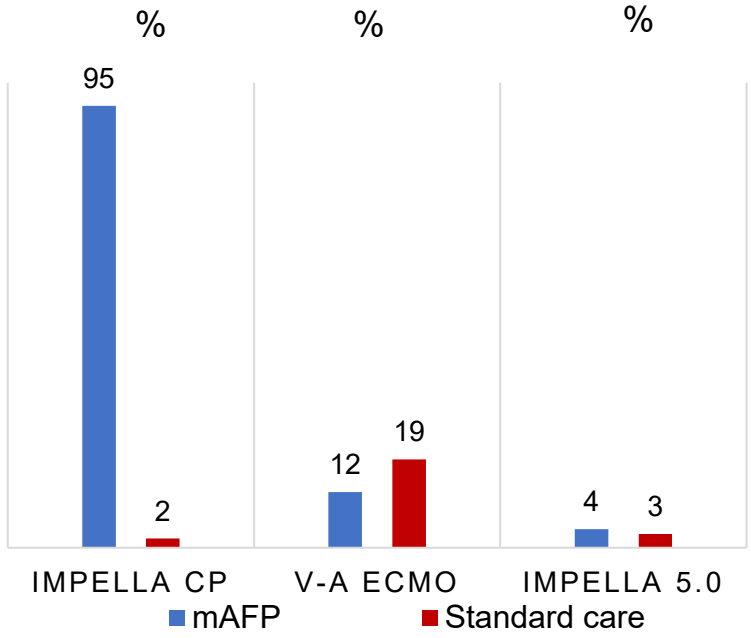
Median systolic BP 82 mmHg

Revascularization

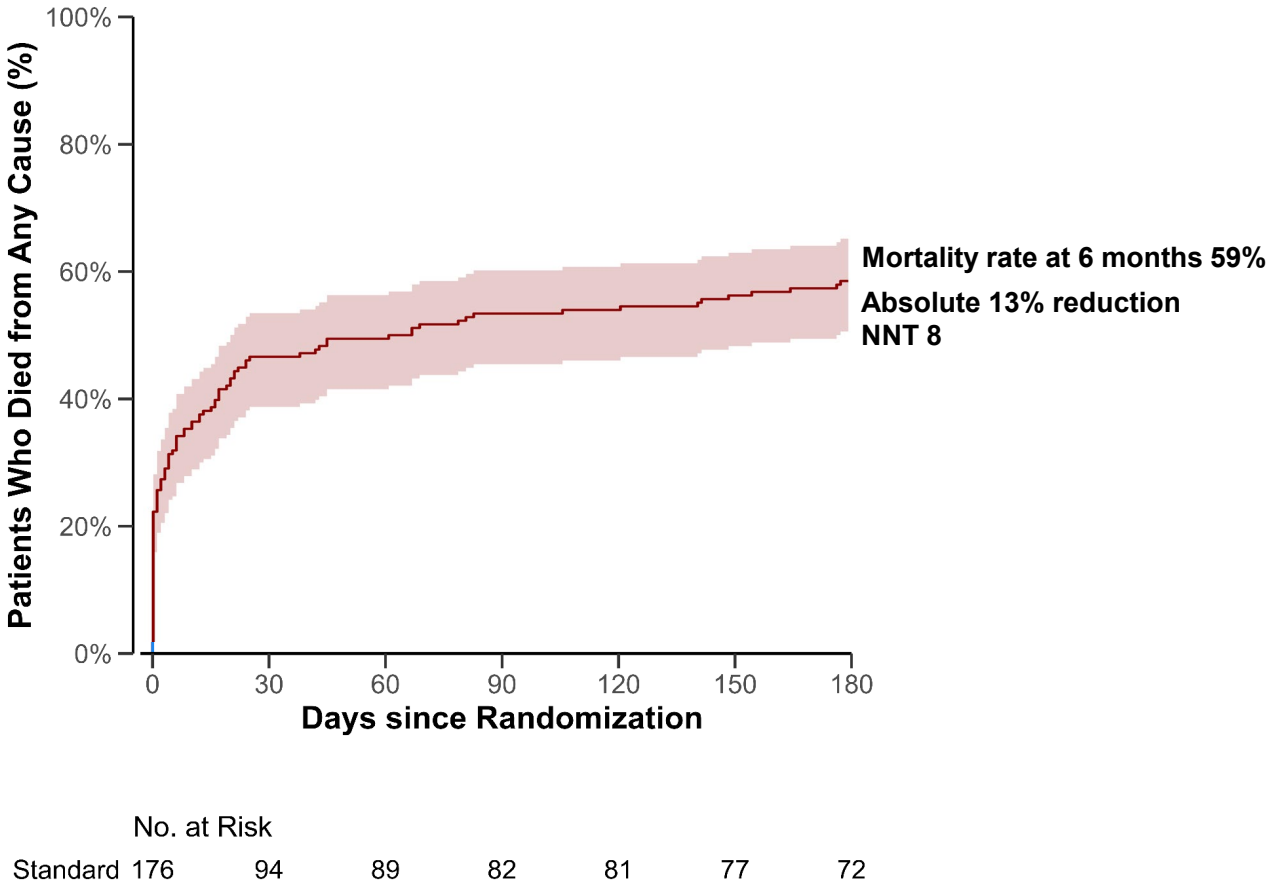


Temporary MCS



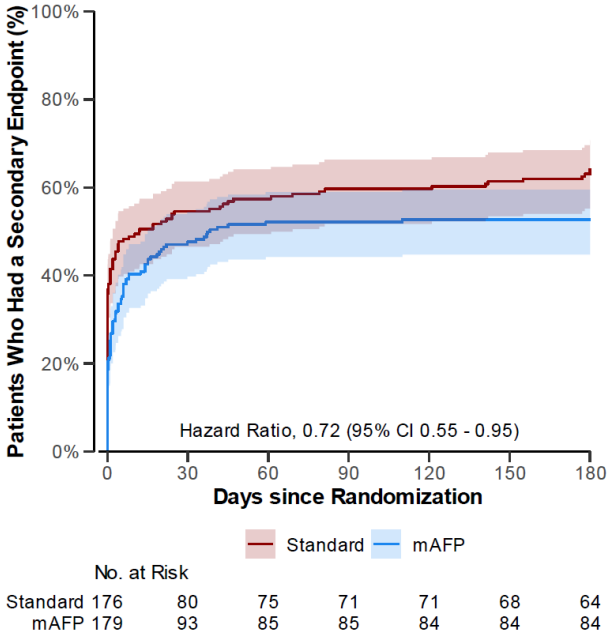


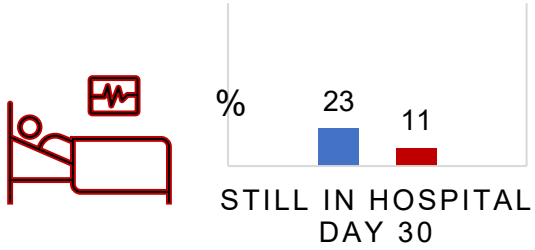
Primary end point



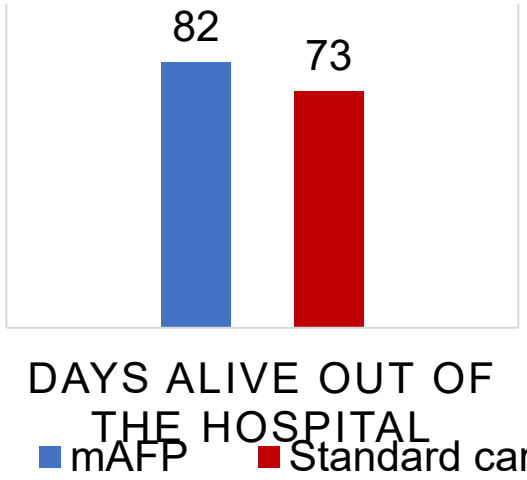
Secondary end points

Escalation to short or longterm MCS, HTX or Death from any cause at 180 days

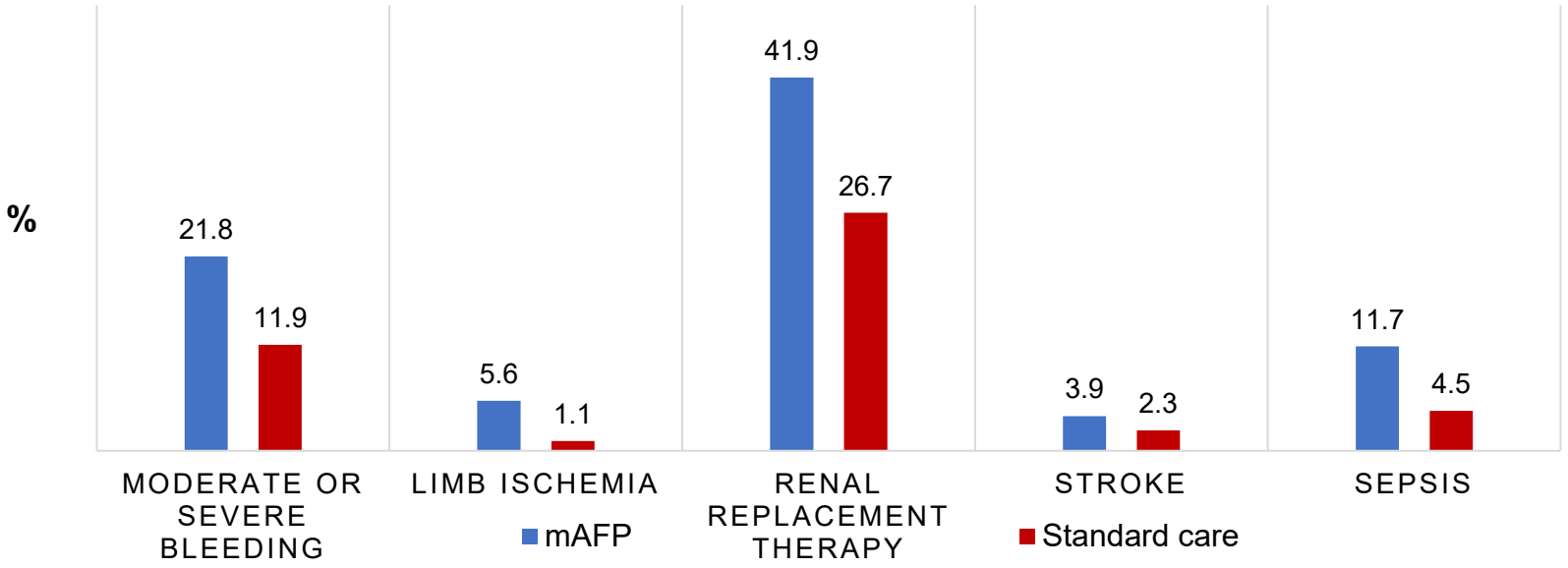




Mean difference 8 days (95%CI -8 to 25)



Adverse events



Conclusion

- The routine use of a mAFP on top of standard care reduced death from any cause in patients with STEMI and cardiogenic shock.
- This was associated with an increased risk of adverse events.
- The study results cannot be extrapolated to other causes of cardiogenic shock including comatose OHCA, NonSTEMI and nonischemic cardiogenic shock

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ORIGINAL ARTICLE

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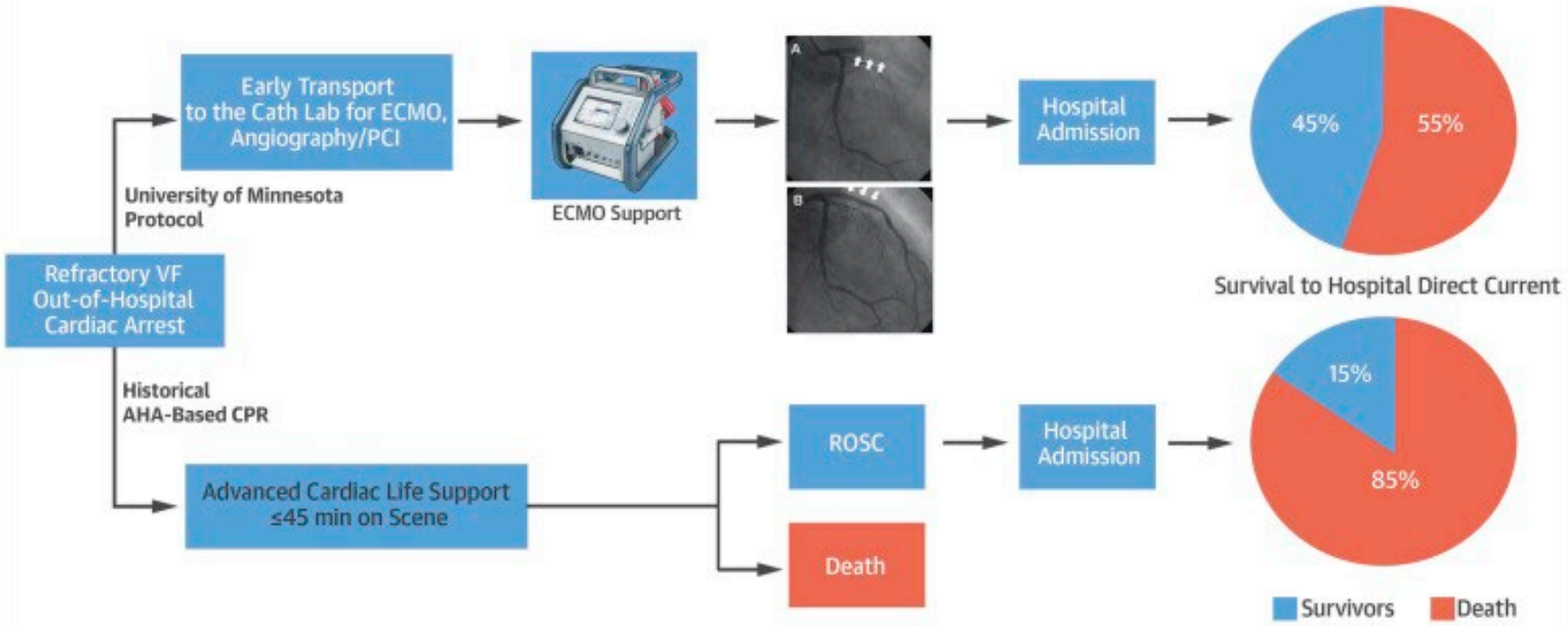
Cardiogenic Shock: Selected Issues

- New SCAI Shock Classification
- Cardiac Arrest-CS interaction
- Shock centers and teams
- US National Shock Initiative
- Role of MSC: New data
- **Refractory Shock**

Early Transport to Cath Lab for ECMO and Revasc in Refractory VF (?OHCA)

CENTRAL ILLUSTRATION: Refractory Cardiac Arrest Due to VF/VT and the University of Minnesota ECLS/PCI Protocol



Yannopoulos, D. et al. J Am Coll Cardiol. 2017;70(9):1109-17.

Early Transport to Cath Lab for ECMO and Revascularization in Refractory Ventricular Fibrillation

Out of Hospital

- VF/VT Initial rhythm
- DCCV x3 and 300mg Amiodarone without ROSC
- Time to CCL <30 min

Initial CCL

- ABG and lactate
- Stop if: ETCO2<10mmHg, PaO2<50mmHg or Lactate >18 mmol/L
- If ROSC, immediate Cor Angio +/- IABP.
- If no ROSC, ECLS , then Cor Angio +/- IABP.
  - Continue ACLS/ECLS for 90 minutes/PCI; if no ROSC by 90 minutes, declared dead

Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial

Demetris Yannopoulos, Jason Bartos, Ganesh Raveendran, Emily Walser, John Connett, Thomas A Murray, Gary Collins, Lin Zhang, Rajat Kalra, Marinos Kosmopoulos, Ranjit John, Andrew Shaffer, R J Frascone, Keith Wesley, Marc Conterato, Michelle Biros, Jakub Tolar, Tom P Aufderheide

Lancet. 2020;396:1807-1816

THE ARREST TRIAL - STUDY ALGORITHM FLOW CHART

Out-of-Hospital

Determine early EMS transport criteria:

- OHCA of presumed cardiac etiology, VT/VF as first presenting rhythm, 18-75 years of age (estimated if not known)
- Receive three DC shocks without achieving ROSC
- Body morphology able to accommodate LUCAS – automated CPR device
- Estimated transfer time to ED <30 minutes
- **Activate the University of Minnesota ECMO resuscitation line per standard EMS practice.**

Mobilize patient per standard EMS protocol with ongoing mechanical CPR to the University of Minnesota Medical Center.

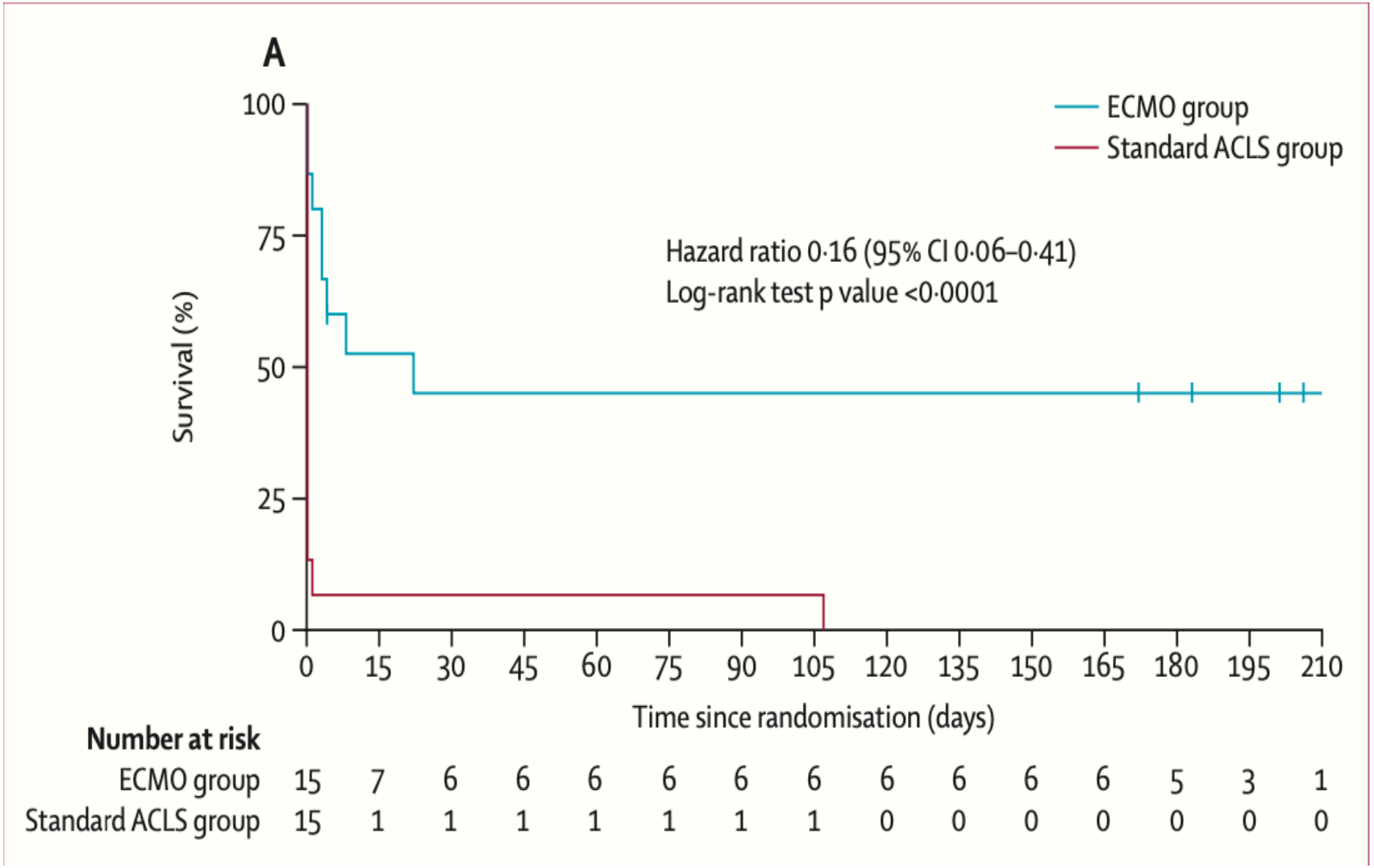
↓

Upon arrival to the ED:

verify eligibility criteria and RANDOMIZE.

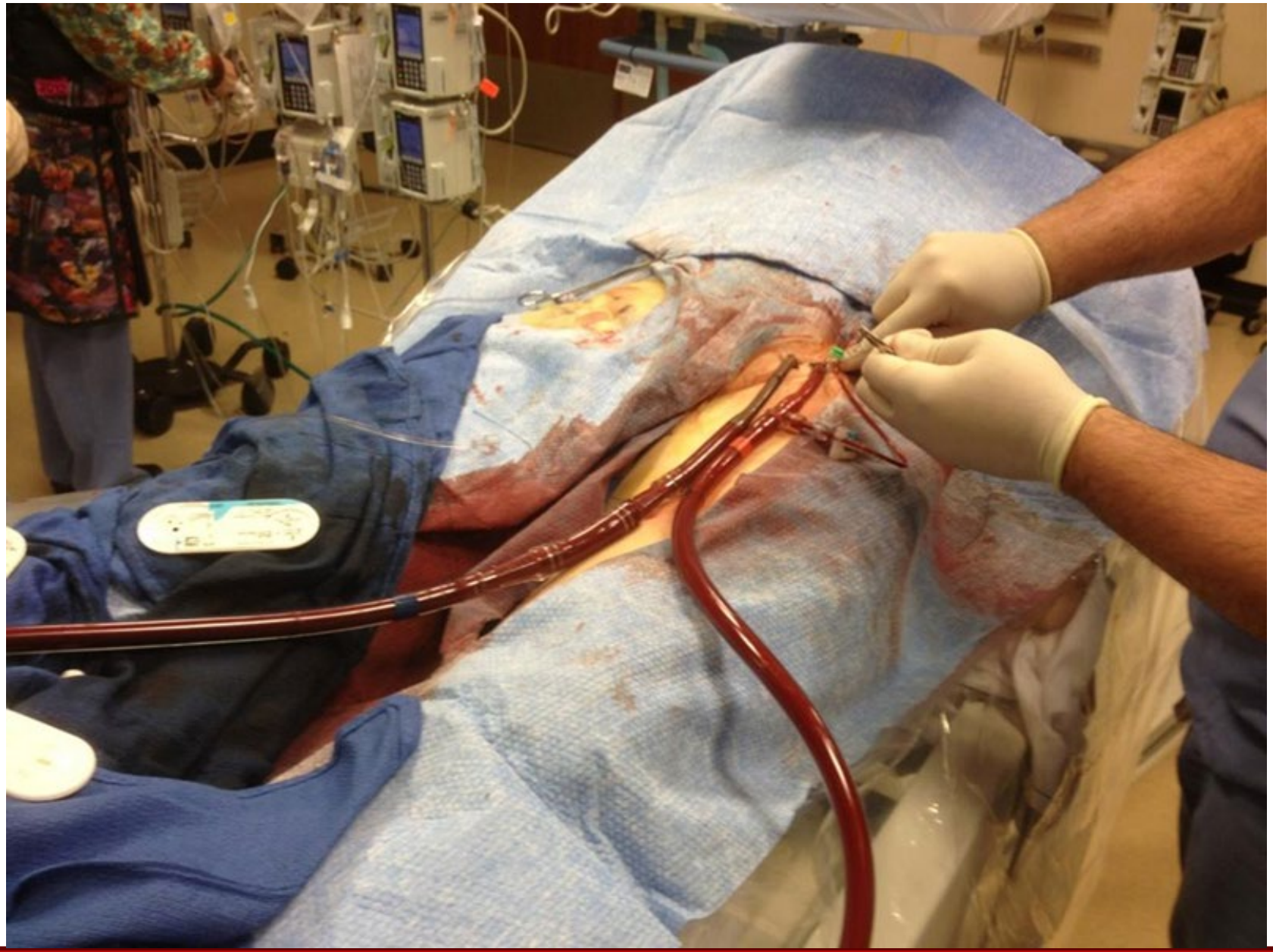
Treatment 1	**Treatment 2**
Early ECMO facilitated resuscitation	**Standard ACLS resuscitation**

N = 30



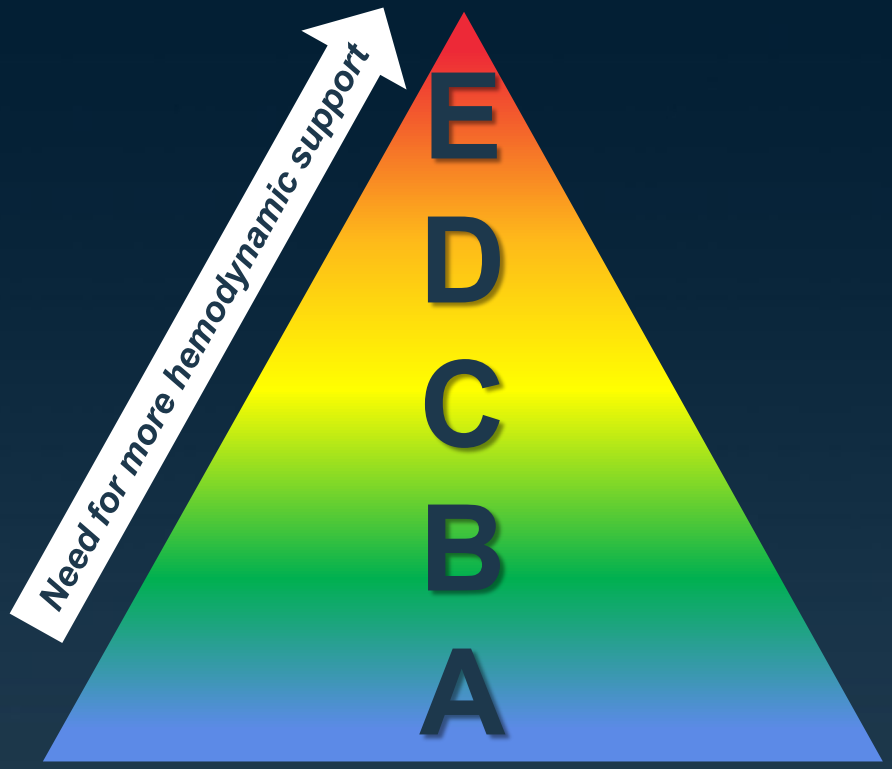
The Christ Hospital Health Network

Not so Simple!

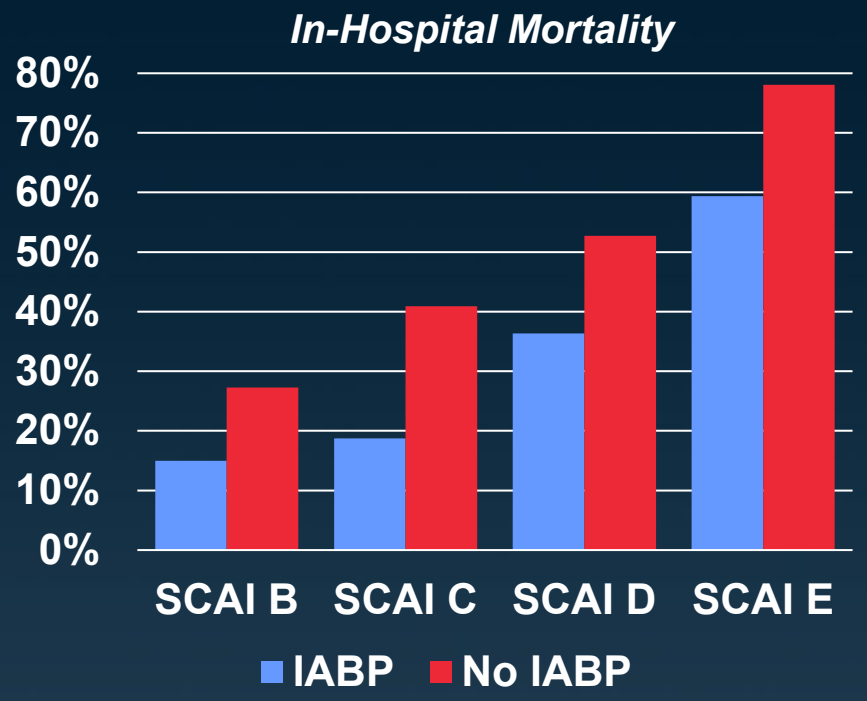


Selecting temporary MCS by SCAI stage

Greater hemodynamic compromise = more support

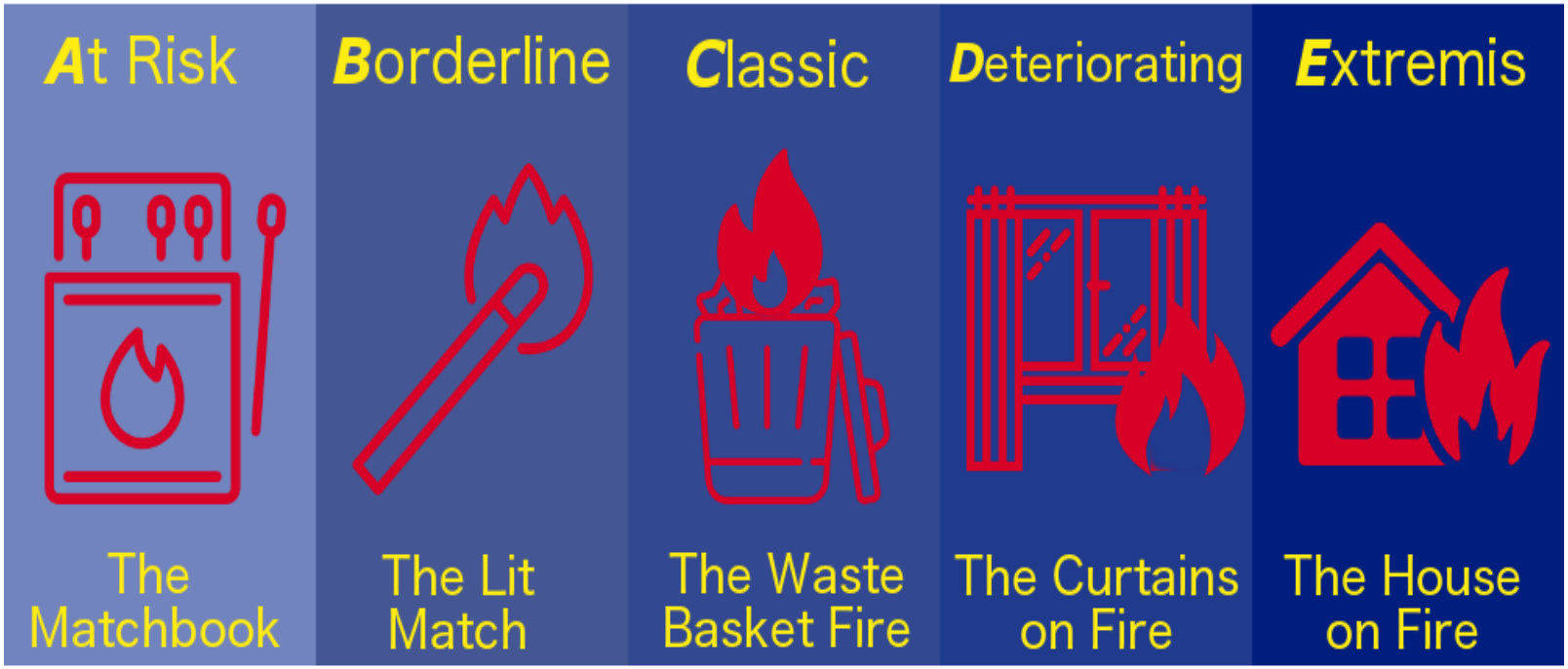


Adapted from Wiley, CCM 2021



Mayo Clinic CS patients
Jentzer, CCI 2021

Cardiogenic Shock Classification A through E



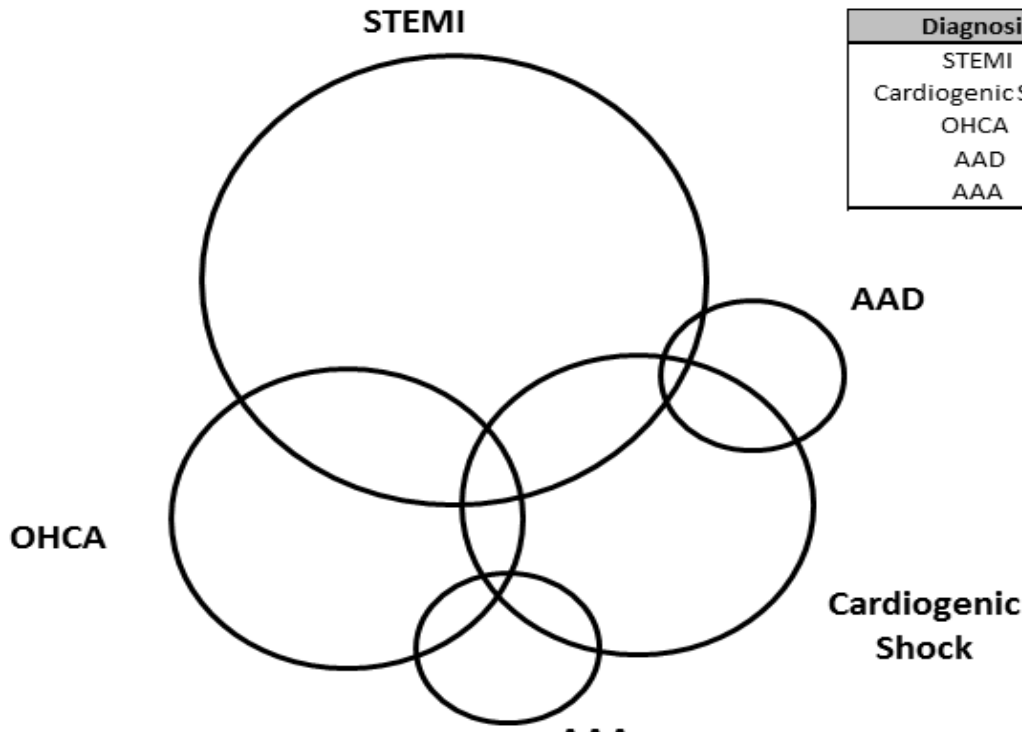
Designed by Freepik from www.flaticon.com

SCAI
Society for Cardiovascular Angiography & Interventions

Special Report

Has the Time Come for a National Cardiovascular Emergency Care System?

Kevin J. Graham, MD; Craig E. Strauss, MD, MPH; Lori L. Boland, MPH; Michael R. Mooney, MD; Kevin M. Harris, MD; Barbara T. Unger, RN; Alexander S. Tretinyak, MD; Paul A. Satterlee, MD; David M. Larson, MD; M. Nicholas Burke, MD; Timothy D. Henry, MD



Diagnosis	Annual Volume
STEMI	400-500
Cardiogenic Shock	40-50
OHCA	30-40
AAD	15-20
AAA	10-15

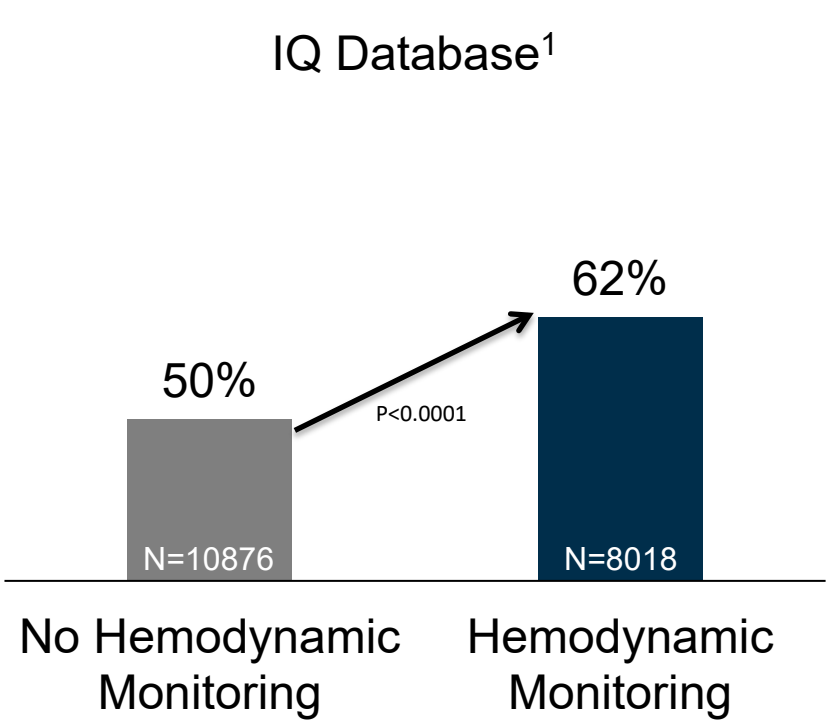
You've got to be very careful if you don't know where you are going, because you might not get there.
-Yogi Berra

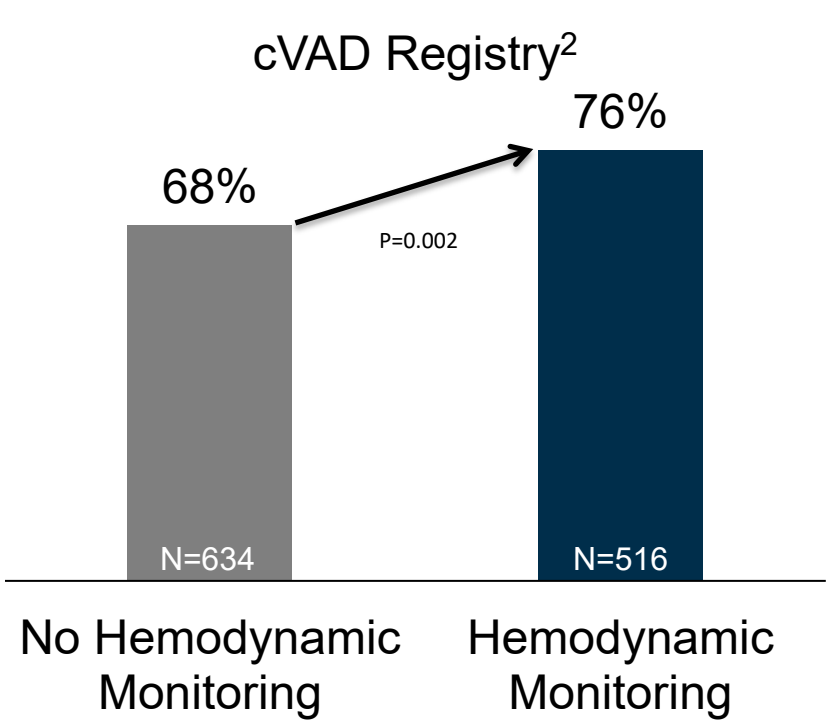
SELECTED ISSUES IN CARDIOGENIC SHOCK 2024

Timothy D. Henry, MD

Medical Director, The Carl and Edyth Lindner Center for Research and Education
The Carl and Edyth Lindner Center Distinguished Chair in Clinical Research
Director of Programmatic and Network Development

Hemodynamic Monitoring associated with Improved Survival in AMI/CGS

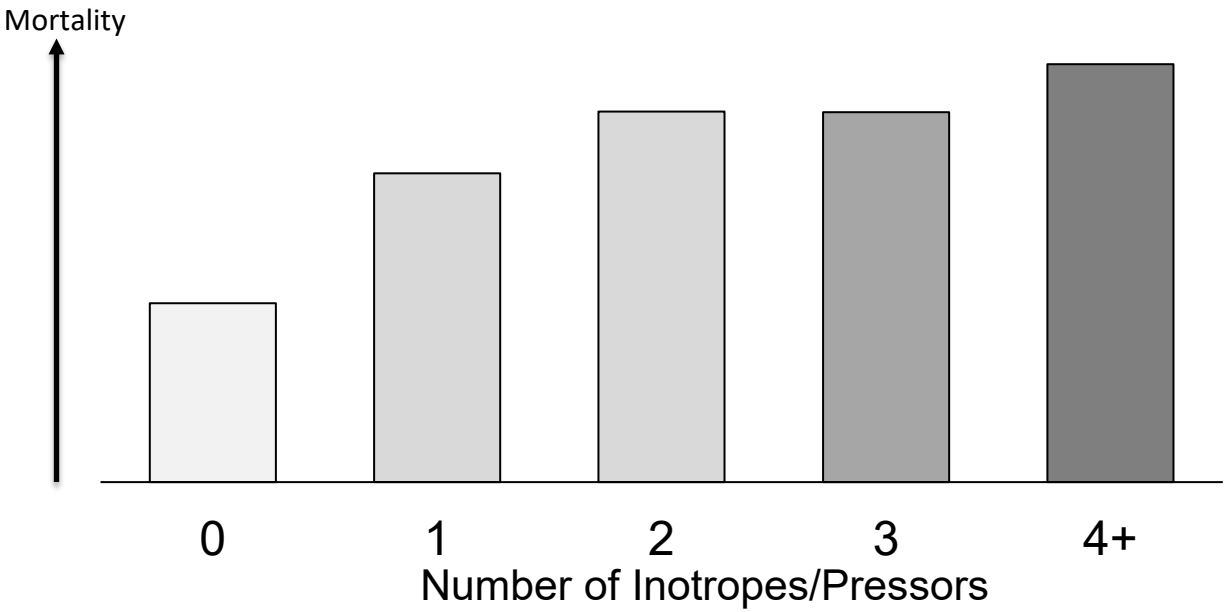




Increased Inotrope Exposure is associated with Mortality in AMI/CGS

Mortality and Number of Inotropes from cVAD Registry[1]

P<0.001 (N=287)



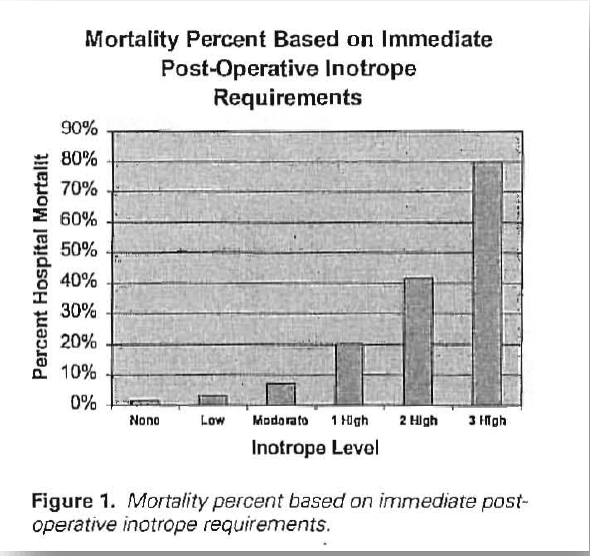


Figure 1. *Mortality percent based on immediate post-operative inotrope requirements.*

Samuels LE et al , J Card Surg. 1999

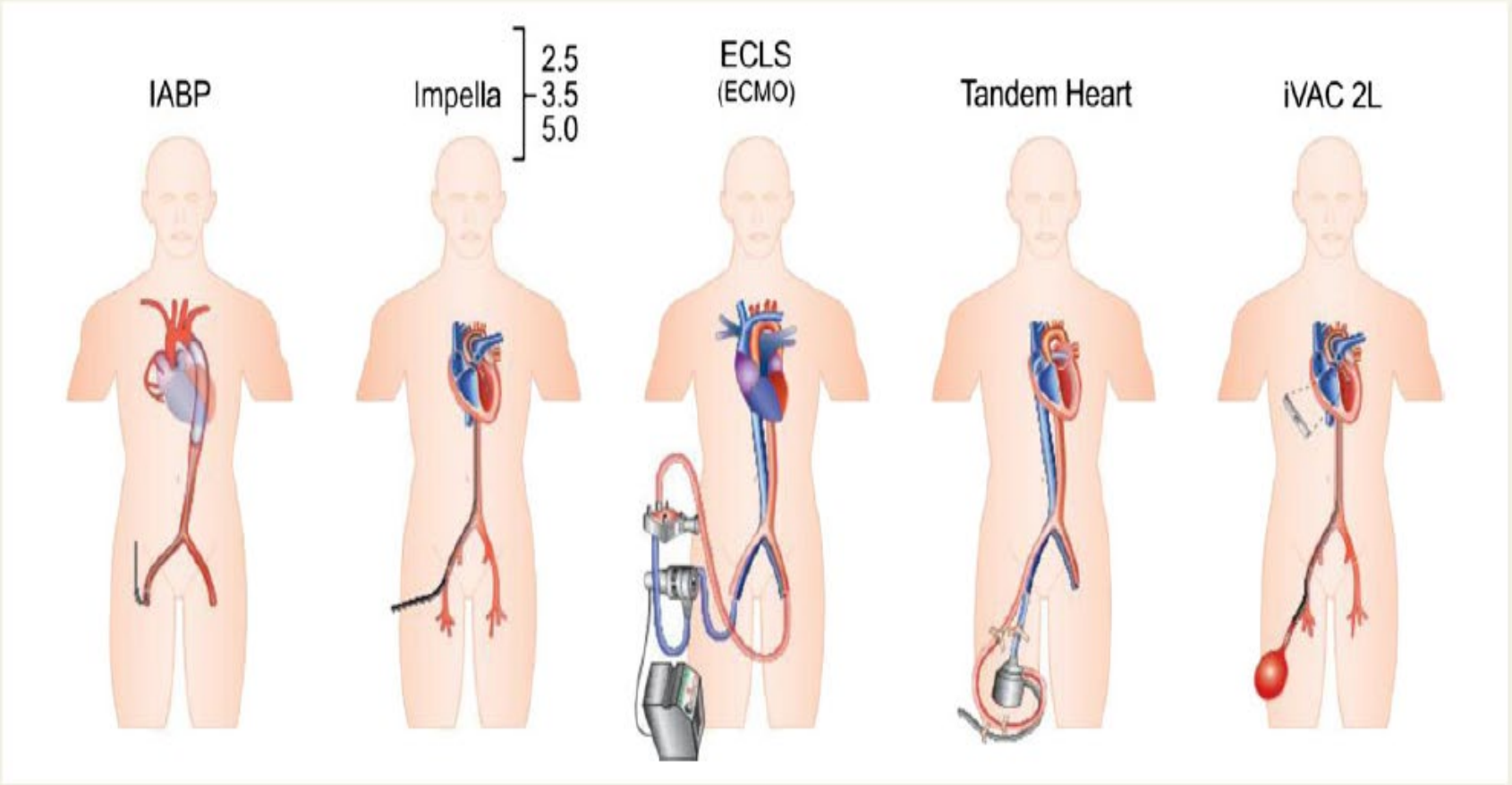


Figure 2 Schematic drawings of current percutaneous mechanical support devices for CS: intraaortic balloon pump (*A*), Impella® (*B*), TandemHeart™, (*C*) extracorporeal life support, (*D*) iVAC 2L®.

Thiele EHJ 2015

Interaction of Cardiac Arrest and Cardiogenic Shock

Trial	Cardiac arrest Culprit only PCI N (%)	Cardiac arrest Multivessel PCI N (%)	P value	Type of ACS	Brain death Culprit	Brain death multivessel	1 year mortality Culprit only PCI N (%)	1 year mortality Multivessel PCI N (%)	Culprit or MV better
Culprit Shock	177 (51.9)	189 (55.3)	NA	STE MI	14 (8.1)	25 (12.9)	172 (50.0)	194 (56.9)	Culprit
British Columbia Cardiac Registry	NON patient level 29.4%	NON patient level 29.4%	NA	Both	Not listed	Not listed	135 (32.6)	104 (44.3)	Culprit
KAMIR -NIH	151 (37.8)	85 (32.7)	0.18	STE MI	Not listed	Not listed	126 (31.7)	55 (21.3)	MV

NB

Culprit shock and BCCR MVI was defined as non-culprit PCI at the time of index intervention, and CVI was defined as PCI of culprit vessel only at the time of index intervention. Thus staged non-culprit PCI were still included in the CVI group

Korean registry, MVI included non-culprit PCI, even if it were performed as an in-hospital staged procedure.

Cardiogenic Shock: Selected Issues

- New SCAI Classification
- Cardiac Arrest-Cardiogenic shock interaction
- Shock with Multivessel disease
- Refractory Shock
- Shock centers and teams

Cardiogenic Shock: Selected Issues

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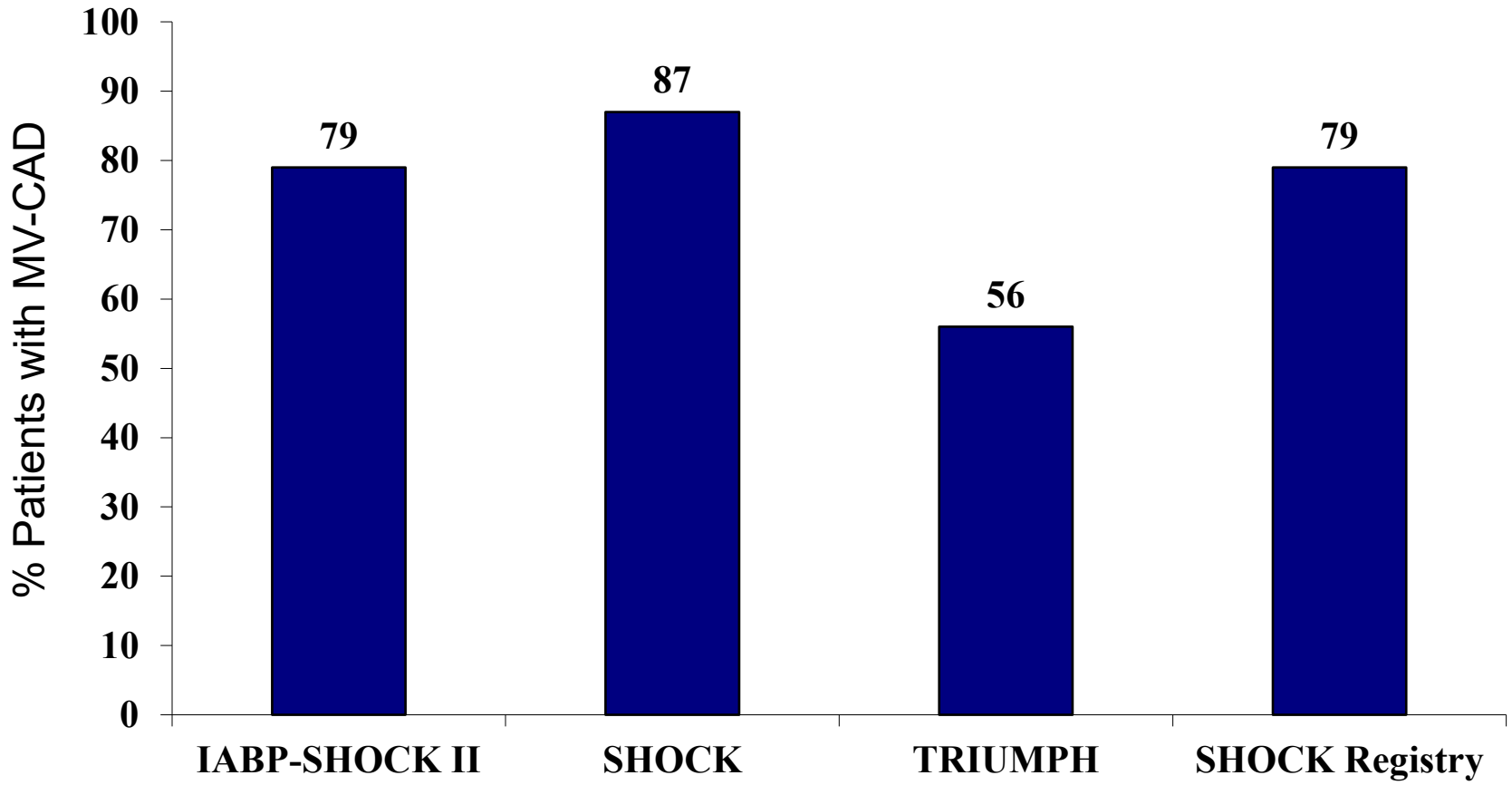
Incidence Multivessel CAD – Cardiogenic Shock



Multivessel PCI in Cardiogenic Shock

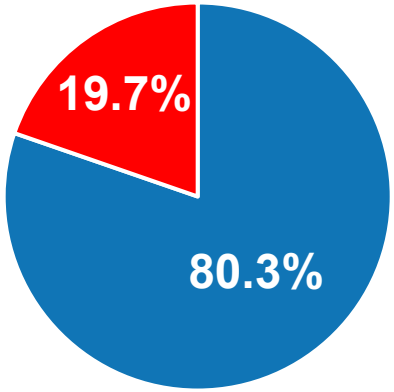
Metaanalysis Mortality – Registry-Data:

10 observational studies published between 2003 and 2016

↓

6,051 patients:

IABP-SHOCK II, ALKK, KAMIR, Yang et al., Cavender et al.; Mylotte et al., van der Schaaf et al., EHS-PCI, NCDR, SHOCK



- Culprit only-PCI (n=4,857)
- Multivessel-PCI (n=1,194)

STEMI with Multivessel Disease Without Cardiogenic Shock

The COMPLETE TRIAL

The Christ Hospital™ Health Network

COMPLETE Trial Design

STEMI WITH MULTIVESSEL CAD AND SUCCESSFUL PCI TO THE CULPRIT LESION
MVD defined as at least one additional non-culprit lesion ≥ 2.5 mm diameter and ≥70% stenosis or 50-69% with FFR ≤0.80

Exclusion Criteria: Intent to revascularize NCL, planned surgical revascularization, prior CABG

RANDOMIZATION
Stratified for intended timing of NCL PCI:
During initial hospitalization or after discharge (max 45 d)

Actual Time to study NCL PCI in Complete Group (median)
During initial hospitalization: 1 day (IQR 1-3)
After hospital discharge: 23 days (IQR 12.5-33.5)

COMPLETE REVASCULARIZATION
Routine staged PCI* of all suitable non-culprit lesions with the goal of complete revascularization
N=2016

CULPRIT-LESION-ONLY REVASCULARIZATION
No further revascularization of non-culprit lesions, guideline-directed medical therapy alone
N=2025

*Everolimus-eluting stents strongly recommended

Guideline-Directed Medical Therapy
ASA, P2Y12 inhibitor (Ticagrelor strongly recommended), Statin, BB, ACE/ARB + Risk Factor Modification

MEDIAN FOLLOW-UP: 3 YEARS

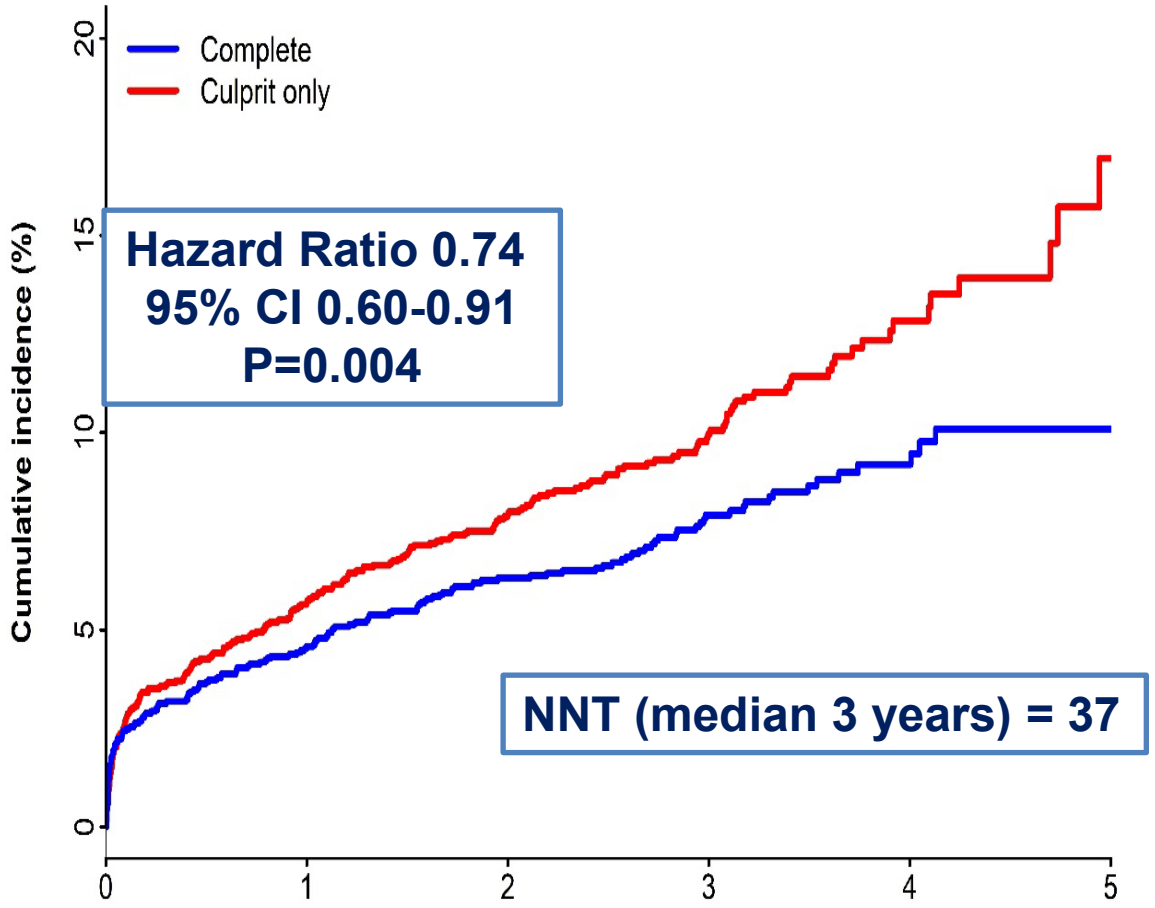
CO-PRIMARY OUTCOMES:
1. Composite of CV death or new MI
2. Composite of CV death, new MI or IDR

KEY SECONDARY OUTCOME: CV death, new MI, IDR, unstable angina, NYHA class IV heart failure

Mehta SR et al. *Am Heart J* 2019; 215:157-166.

COMPLETE TRIAL

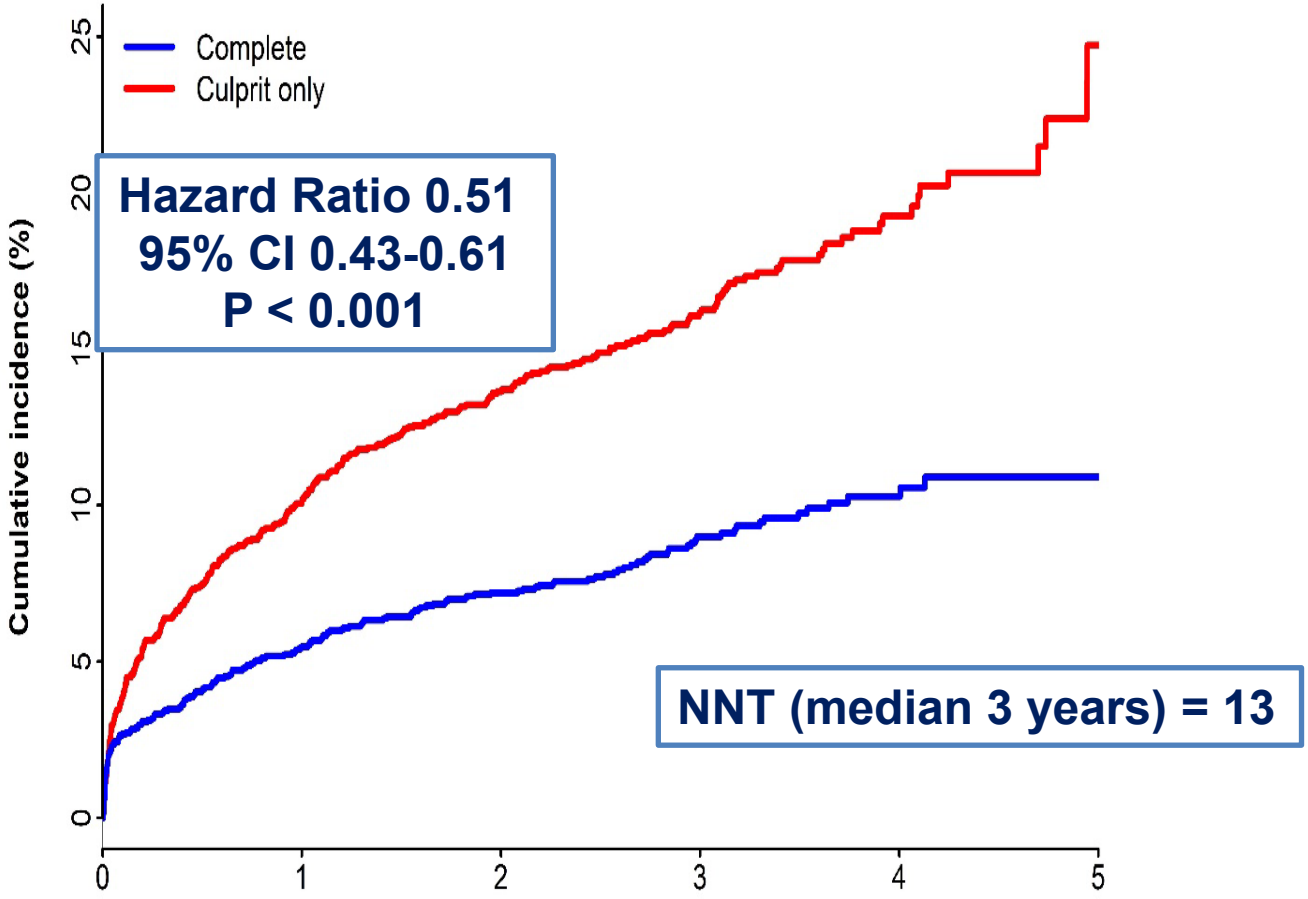
First Co-Primary Outcome: CV Death or New MI



No. at Risk						
Complete	2016	1904	1677	938	337	70
Culprit only	2025	1897	1666	933	310	59

COMPLETE TRIAL

2nd Co-Primary Outcome: CV Death, New MI, or IDR



No. at Risk						
Complete	2016	1886	1659	925	329	66
Culprit only	2025	1808	1559	865	294	57

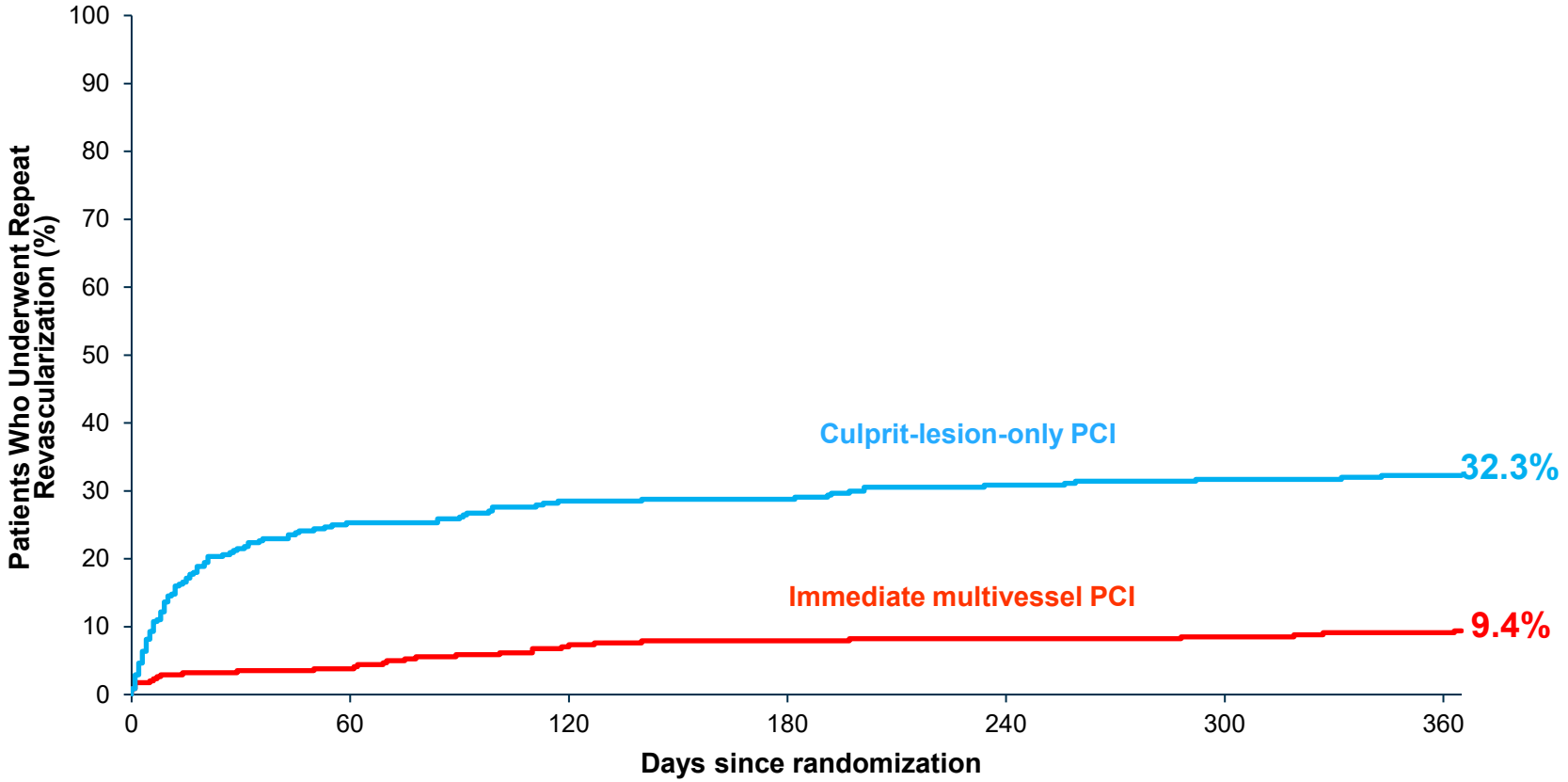
STEMI with Multivessel Disease With Cardiogenic Shock

CULPRIT SHOCK TRIAL

The Christ Hospital Health Network

1-Year Repeat Revascularization

CULPRIT-SHOCK



Number at risk:

Culprit-lesion only PCI	344	256	245	244	237	234	223
Multivessel PCI	341	327	316	313	312	311	293

Culprit Shock: No Difference in Cardiac Causes of Death

Cause	Culprit only	Multivessel
Sudden death	11 (7.4%)	12 (6.8%)
Recurrent MI	2 (1.3%)	2 (1.1%)
Refractory Shock	104 (69.8%)	108 (61.4%)

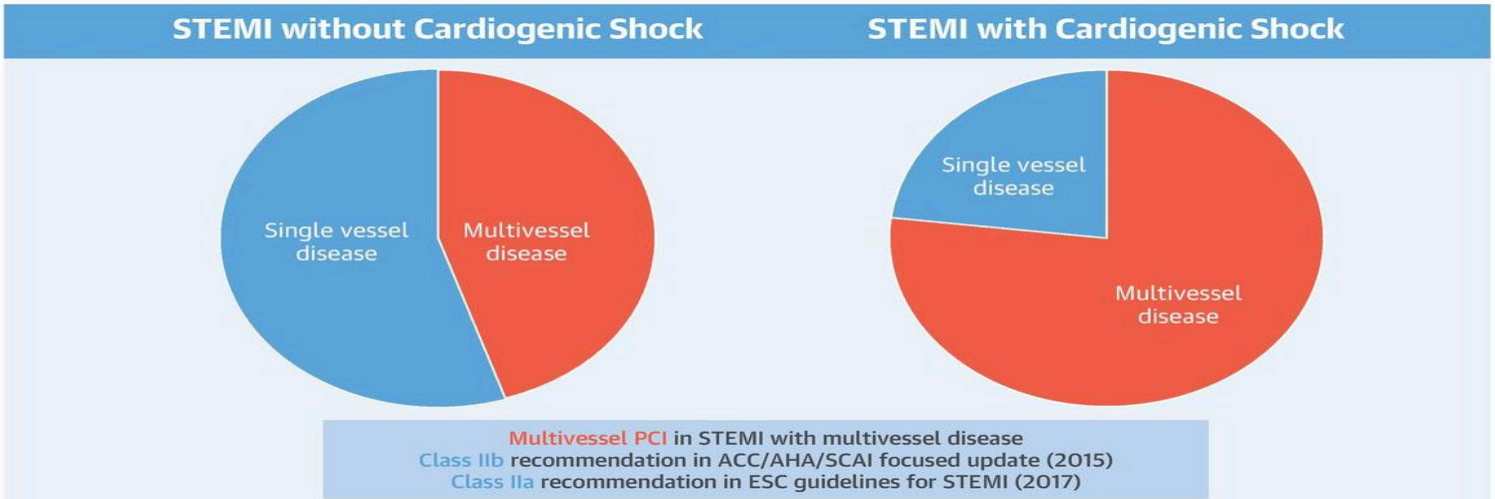
Multivessel PCI did not worsen cardiac outcomes

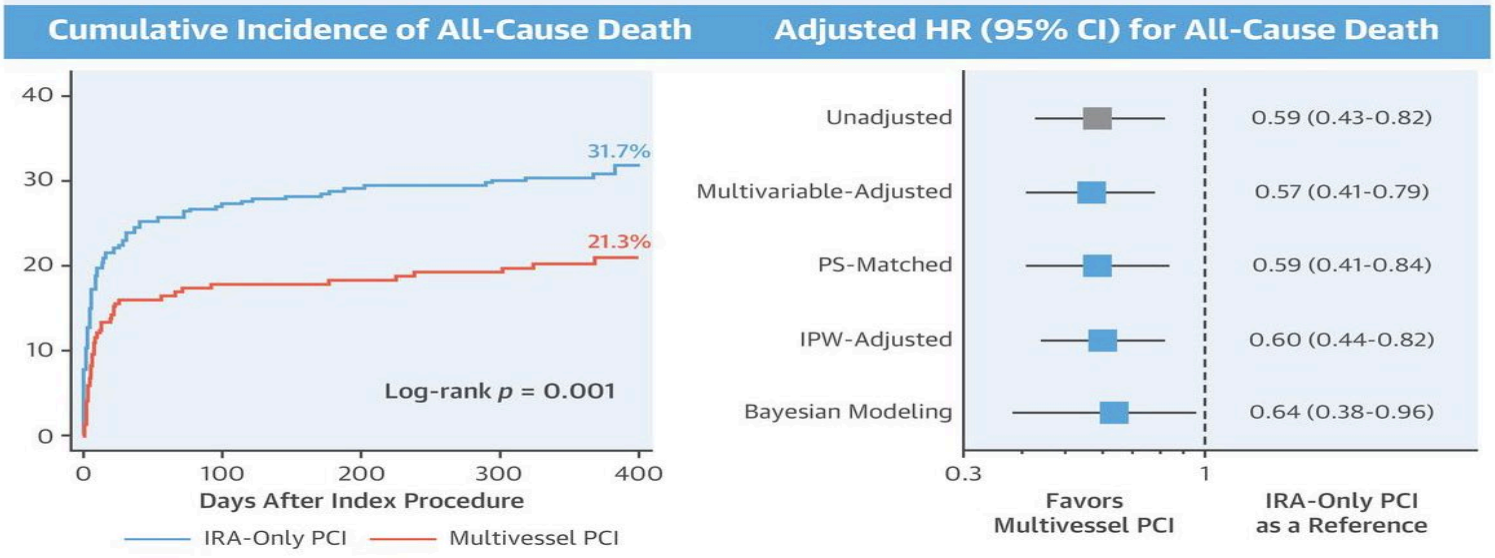
Culprit Shock
Non-Cardiac Causes of Death

Cause	Culprit only	Multivessel
Brain Injury	11 (7.4%)	25 (14.2%)
Unknown	2 (1.3%)	4 (5.1%)
Other	9 (6%)	12 (6.8%)

Should Cardiac Arrest Patients been Excluded?

Prognostic Impact of Multivessel PCI With STEMI Multivessel Disease Accompanied With Cardiogenic Shock





The Christ Hospital Health Network

Lee et al. JACC 2018;71:844-856

UNIVERSITÄT LEIPZIG
HERZZENTRUM

CULPRIT-SHOCK

www.nejm.org

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

PCI Strategies in Patients with Acute Myocardial Infarction and Cardiogenic Shock

H. Thiele, I. Akin, M. Sandri, G. Fuernau, S. de Waha, R. Meyer-Saraei, P. Nordbeck, T. Geisler, U. Landmesser, C. Skurk, A. Fach, H. Lapp, J.J. Piek, M. Noc, T. Goslar, S.B. Felix, L.S. Maier, J. Stepinska, K. Oldroyd, P. Serpytis, G. Montalescot, O. Barthelemy, K. Huber, S. Windecker, S. Savonitto, P. Torremante, C. Vrints, S. Schneider, S. Desch, and U. Zeymer, for the CULPRIT-SHOCK Investigators*

Baseline Characteristics

Characteristic	Culprit only PCI (n=344)	Multivessel PCI (n=342)
Age (years); median (IQR)	70 (60-78)	70 (60-77)
Male sex; n/total (%)	257/343 (74.9)	267/342 (78.1)
Prior myocardial infarction; n/total (%)	60/339 (17.7)	53/335 (15.8)
Prior PCI; n/total (%)	64/339 (18.9)	63/335 (18.8)
Prior coronary arterial bypass surgery; n/total (%)	20/341 (5.9)	13/337 (3.9)
Signs of impaired organ perfusion; n/total (%)		
Altered mental status	237/341 (69.5)	224/341 (65.7)
Cold, clammy skin and extremities	233/338 (68.9)	236/335 (70.4)
Oliguria	80/334 (24.0)	93/326 (28.5)
Arterial lactate >2.0 mmol/l	216/334 (64.7)	224/330 (67.9)
Fibrinolysis <24 h before randomization; n/total (%)	19/341 (5.6)	15/341 (4.4)
Resuscitation before randomization; n/total (%)	177/341 (51.9)	189/342 (55.3)
ST-elevation myocardial infarction; n/total (%)	206/335 (61.5)	209/330 (63.3)
No. of diseased vessels; n/total (%)		
1	3/343 (0.9)	2/342 (0.6)
2	122/343 (35.6)	124/342 (36.3)
3	218/343 (63.6)	216/342 (63.2)
Patients with at least one CTO; n/total (%)	77/344 (22.4)	82/342 (24.0)
Left ventricular ejection fraction (%); median (IQR)	33 (25-40)	30 (21-40)

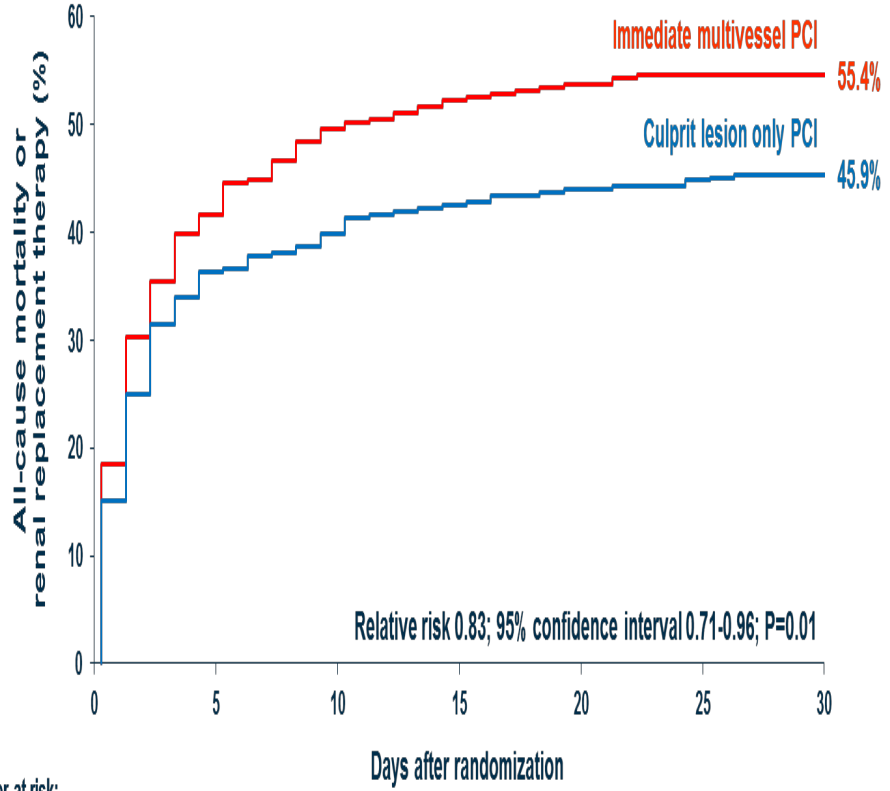
Treatment

Characteristic	Culprit only PCI (n=344)	Multivessel PCI (n=342)	
Femoral access; n/total (%)	287/343 (83.7)	277/342 (81.0)	0.36
Radial access; n/total (%)	61/343 (17.8)	66/342 (19.3)	0.61
Stent implanted in culprit lesion; n/total (%)	326/343 (95.0)	324/342 (94.7)	0.86
Drug-eluting stent in culprit lesion; n/total (%)	305/326 (93.6)	308/324 (95.1)	0.41
TIMI-flow III post PCI of culprit lesion; n/total (%)	289/342 (84.5)	293/338 (86.7)	0.46
Immediate PCI of non-culprit lesions; n/total (%)	43/344 (12.5)	310/342 (90.6)	<0.001
Immediate complete revascularization; n/total (%)	26/344 (7.6)	277/342 (81.2)	<0.001
Total amount of contrast agent (ml); median (IQR)	190 (140-250)	250 (200-350)	<0.001
Staged PCI of non-culprit lesions; n/total (%)	60/344 (17.4)	8/341 (2.3)	<0.001
Staged coronary artery bypass surgery; n/total (%)	1/344 (0.3)	0/341	>0.99
Mechanical circulatory support; n/total (%)	99/344 (28.8)	95/342 (27.8)	0.77
Intraaortic balloon pump; n/total (%)	25/99 (25.3)	26/95 (27.4)	0.74
Impella 2.5; n/total (%)	16/99 (16.2)	18/95 (18.9)	0.61
Impella CP; n/total (%)	30/99 (30.3)	18/95 (18.9)	0.07
TandemHeart; n/total (%)	2/99 (2.0)	0/95	0.50
ECMO; n/total (%)	18/99 (18.2)	27/95 (28.4)	0.09
Mild hypothermia; n/total (%)	111/344 (32.3)	118/340 (34.7)	0.50
Mechanical ventilation; n/total (%)	273/344 (79.4)	282/339 (83.2)	0.20
Duration of mechanical ventilation (days); median (IQR)	3 (1-7)	3 (1-7)	0.97
Duration of intensive care treatment (days); median (IQR)	5 (2-12)	5 (2-11)	0.61

CULPRIT-SHOCK Trial – 30-Day Results

CULPRIT-SHOCK

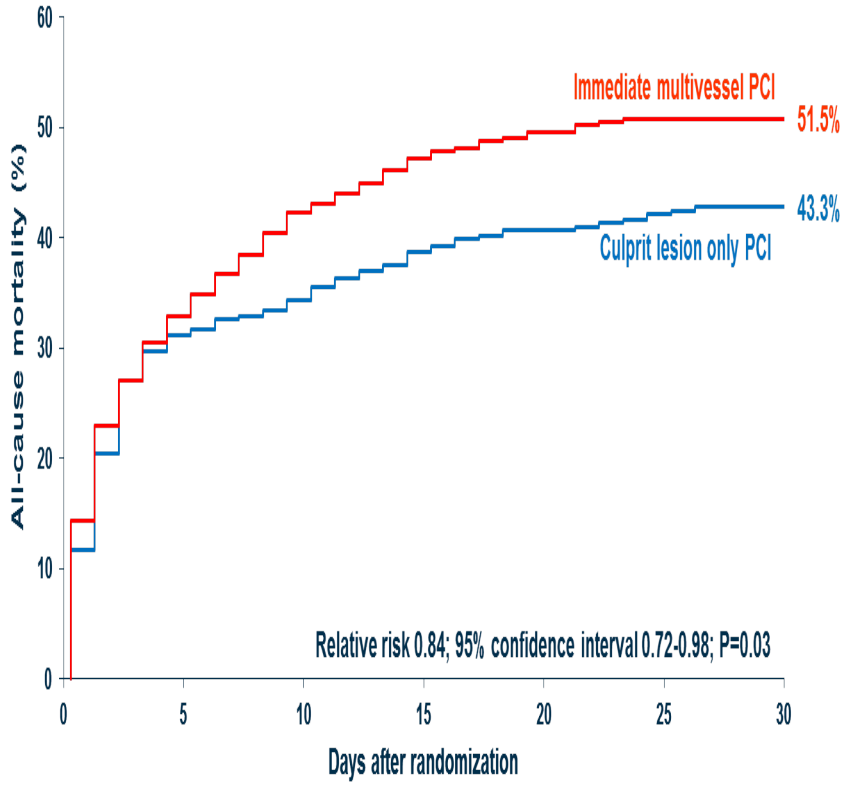
Primary study endpoint – 30 *d*ays
All-cause mortality or renal replacement therapy



Number at risk:

Culprit lesion only PCI	344	219	207	198	192	189	184
Immediate multivessel PCI	341	199	172	162	156	153	152

All-cause mortality – 30 days



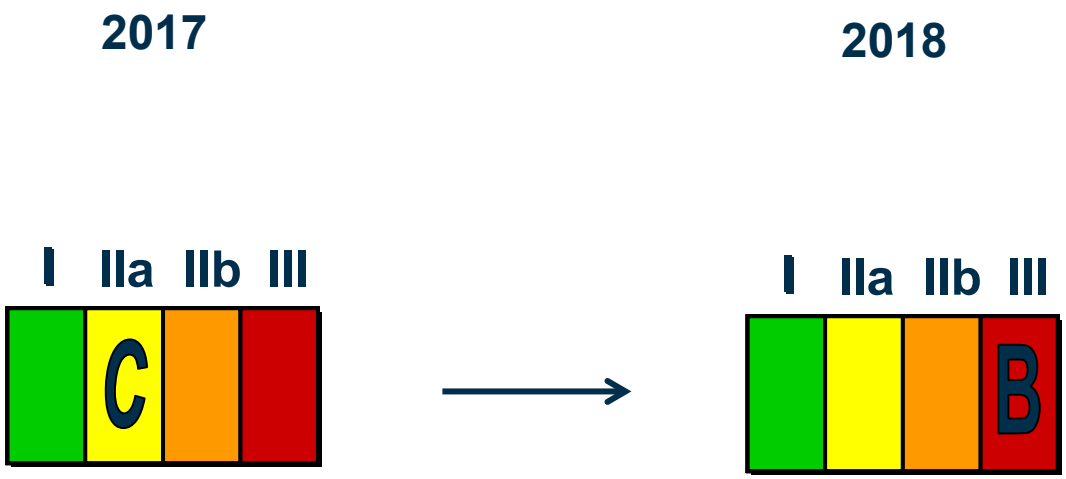
Number at risk:

Culprit lesion only PCI	344	237	226	211	203	198	193
Immediate multivessel PCI	341	229	197	179	170	166	165

Thiele et al. NEJM 2017; 377:2419-2432

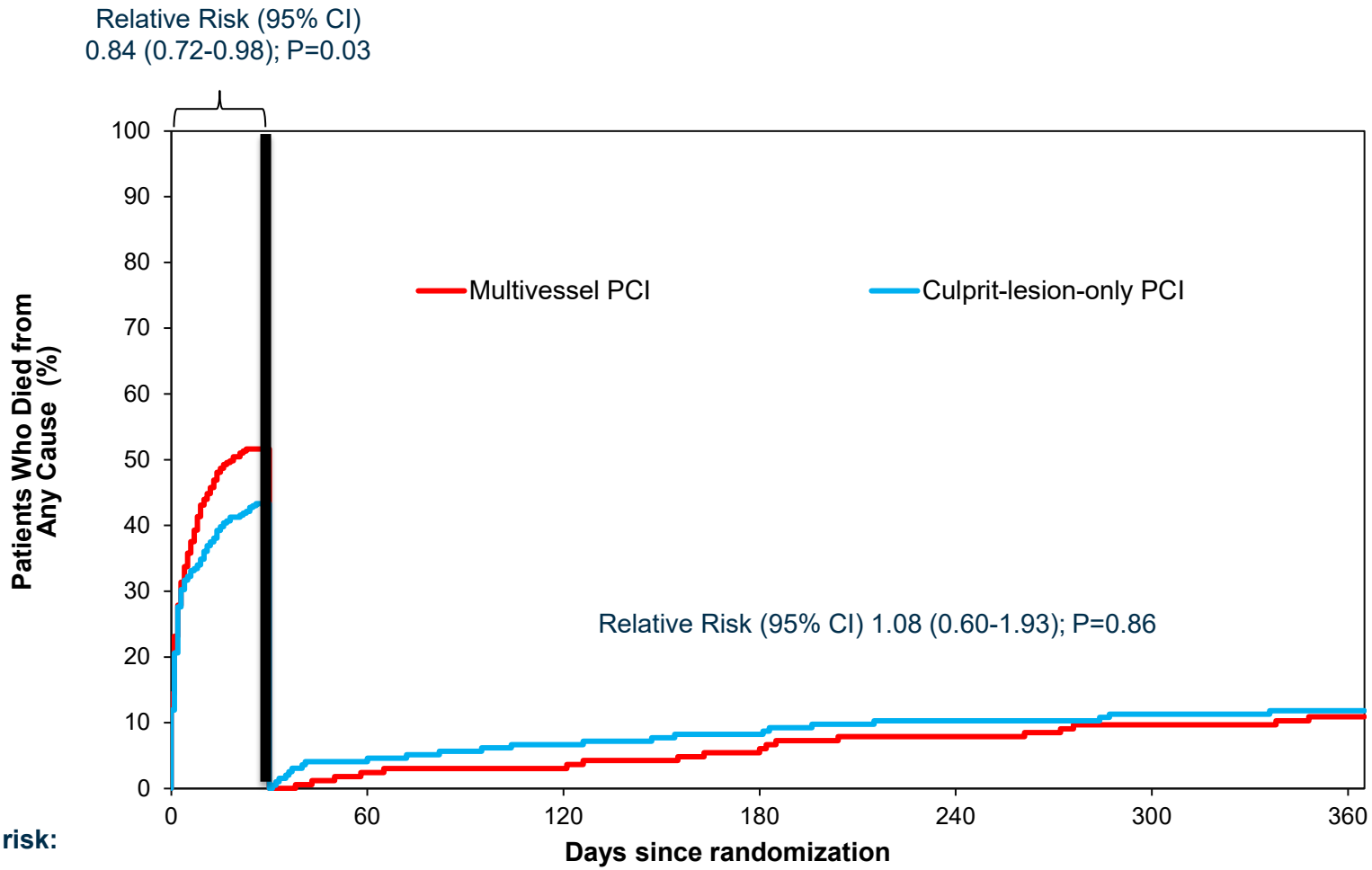
Multivessel PCI in Shock - Guideline Evolution

ESC STEMI Guidelines 2017 → Revascularization Guidelines 2018



Ibanez et al. Eur Heart J 2018;39:119-177
Neumann et al. Eur Heart J 2018;epub 25.08.2018

1-Year All-Cause Mortality – Landmark Analysis



Number at risk:

Multivessel PCI	165	161	160	156	152	149	131
Culprit-lesion-only PCI	195	186	181	178	174	172	147

Cardiogenic Shock: Selected Issues

- New SCAI Classification
- Cardiac Arrest-Cardiogenic shock interaction
- Shock with Multivessel disease
- Refractory Shock
- Shock centers and teams

Cardiogenic Shock: Selected Issues

- New SCAI Classification
- Cardiac Arrest-Cardiogenic shock interaction
- Shock with Multivessel disease
- Refractory Shock
- Shock centers, teams and standarized Protocols!

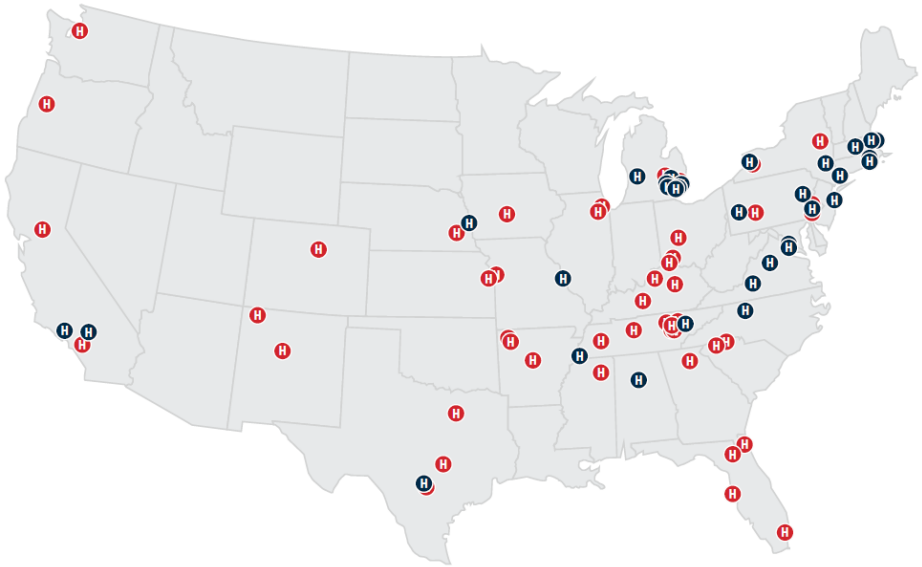
Cardiogenic Shock: Selected Issues

- New SCAI Shock Classification
- Cardiac Arrest-C Shock interaction
- Shock centers and teams
- US National Shock Initiative
- Refractory Shock

Methodology

- SCAI-sponsored consensus update to the 2019 SCAI SHOCK classification
- PubMed review to collect studies examining clinical outcomes as a function of SCAI SHOCK stage in any population
- Recommendations were iteratively discussed by the full writing group in a series of virtual consensus meetings with ≥80% majority agreement on the text and qualifying remarks
- Peer reviewed in September 2021
- Formal endorsements in progress for publication in December 2021

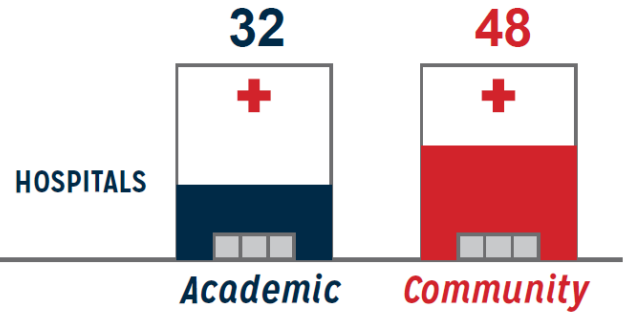
NCSI: CLINICAL SITES



406 *patients enrolled nationally*

1,103 *total patients screened (with AMI + cardiogenic shock)*

80 *participating hospitals (29 states + DC)*



NATIONAL CSI ALGORITHM

RAPID Identification of Cardiogenic Shock

↓

Cath Lab Activation

↓

Femoral Access

↓

AMI/CS Confirmed

↓

MCS

AMI/CS Unconfirmed
LHC*
RHC*
Echo*
*As needed to confirm diagnosis

Door To Support Time

Target < 90 minutes

National Cardiogenic Shock Initiative

CARDIAC POWER OUTPUT
(CPO)
CPO = MAP x CO / 451

PULMONARY ARTERY
PULSATILITY INDEX
(PAPI)
PAPI = sPA – dPA / RA

MCS

PCI

Right Heart Cath

CPO < 0.6

Calculate PAPI

PAPI < 0.9, RA >12, DSA*

Possible RV Failure

Consider
RV Support

PAPI > 0.9

RV Normal

Consider ↑
LV Support

CPO ≥ 0.6 and
PAPI > 0.9

Continue to Titrate
↓ Pressors/Inotropes

* Diastolic Suction Alarms

National Cardiogenic Shock Initiative

Comparison of Cardiogenic Shock Studies

	Sample Size	Age	Inotropes	Cardiac Arrest	HR	BP	Lactate	Lactate ≥ 2 mmol/l	30-Day Survival %
SHOCK	302	66	99	28	102	89/54	N/A	N/A	53
IABP SHOCK	600	70	90	45	92	90/55	4.1	74	60
Culprit SHOCK	686	70	90	54	91	100/60	5.1	66	49
DanGer	100	68	94	0	N/A	76/50	5.5	100	N/A
NCSI	**406**	**64**	**85**	**46**	**95**	**77/50**	**4.8**	**77**	**68**

National Cardiogenic Shock Initiative

Cardiogenic Shock 2022: Selected Issues From a US Perspective

Timothy D. Henry, MD

Medical Director, The Carl and Edyth Lindner Center for Research and Education
The Carl and Edyth Lindner Center Distinguished Chair in Clinical Research
Director of Programmatic and Network Development