Cardiogenic Shock
Heart Team Approach to Management

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Disclosures

- Consultant: Medtronic, Abiomed
Overview – Nearly Two Decades of Poor Outcomes

**Survival in AMI-Shock**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Year</th>
<th>Survival Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHOCK TRIAL</td>
<td>1999</td>
<td>53%</td>
</tr>
<tr>
<td>ISAR-SHOCK</td>
<td>2008</td>
<td>54%</td>
</tr>
<tr>
<td>IMPRESS</td>
<td>2016</td>
<td>48%</td>
</tr>
<tr>
<td>CULPRIT-SHOCK 1-YEAR</td>
<td>2018</td>
<td>49%</td>
</tr>
<tr>
<td>IABP-SHOCK II 6 YEARS</td>
<td>2018</td>
<td>34%</td>
</tr>
</tbody>
</table>
Proverbial “Death Spiral” of CS

Coronary Problem

Ventricular Failure

Vascular Response

Scope of Problem - High Morbidity and Mortality

Lifeline STEMI Systems Accelerator Project

**TABLE 2 In-Hospital Outcomes Stratified by CS**

<table>
<thead>
<tr>
<th></th>
<th>No-CS</th>
<th>CS</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-admission reinfarction</td>
<td>0.9 (184)</td>
<td>1.3 (25)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart failure at discharge</td>
<td>5.4 (1,184)</td>
<td>15.3 (303)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Bleeding event</td>
<td>3.7 (802)</td>
<td>11.0 (218)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Stroke</td>
<td>0.6 (137)</td>
<td>2.5 (49)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mortality</td>
<td>3.5 (754)</td>
<td>34.4 (686)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are % (n).
CS = cardiogenic shock.
Scope of Problem: End-Organ Failure

Central Illustration: Acute Noncardiac Organ Failure in Acute Myocardial Infarction With Cardiogenic Shock

Heart with Coronary Map
Coronary Artery with Thrombus
Heart with Dilated Left Venticle

Organ Failure/Dysfunction

Lungs
Kidney
Liver
Red Blood Cells
Brain

0
31% In-Hospital Mortality
1
38% In-Hospital Mortality
≥2
48% In-Hospital Mortality


Acute myocardial infarction with cardiogenic shock is often associated with respiratory, renal, hepatic, hematologic, and neurological failure that results in incrementally higher in-hospital mortality.
### Scope of Problem – Practice Variations

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

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<tr>
<td>ND-MCS (percutaneous)—n (%)</td>
<td>0.0 (0.0)</td>
<td>82 (2.5)</td>
<td>160 (4.9)</td>
<td>110 (6.7)</td>
<td>&lt; 0.001</td>
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<tr>
<td>ND-MCS (nonpercutaneous)—n (%)</td>
<td>0 (0.0)</td>
<td>†</td>
<td>†</td>
<td>†</td>
<td>0.51</td>
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<tr>
<td>IABP—n (%)</td>
<td>0 (0.0)</td>
<td>628 (18.9)</td>
<td>1234 (37.6)</td>
<td>946 (59.9)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>ECMO—n (%)</td>
<td>0 (0.0)</td>
<td>48 (1.4)</td>
<td>50 (1.5)</td>
<td>35 (2.2)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PCPS—n (%)</td>
<td>0 (0.0)</td>
<td>†</td>
<td>†</td>
<td>†</td>
<td>0.72</td>
</tr>
</tbody>
</table>

*Strom JB et al. Circulation Cardiovascular Interventions 2019*
Current State: Spectrum of Acute MCS
IABP—Minimal Hemodynamic & No Mortality Benefit

Table 1. Clinical Outcomes at 6 Years

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

Thiele H et al. Circulation 2018
(A) Flow-dependent changes of the pressure-volume loop with LV-to-aortic pumping. The loop becomes triangular and shifts progressively leftward (indicating increasing degrees of LV unloading). Corresponding LV and aortic pressure waveforms at baseline (B), 4.5 l/min (C), 6.0 l/min (D) and 7.5 l/min (E). With increased flow, there are greater degrees of LV unloading and uncoupling between aortic and peak LV pressure generation. LVAD = left ventricular assist device; other abbreviations as in Figures 1, 4, and 5.
VA-ECMO

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

**Figure 1** Growth of Adult Cardiac Extracorporeal Membrane Oxygenation Runs

Graph depicting the increase in the number of adult cardiac extracorporeal membrane oxygenation runs. There was an increase of 1,880% in the last decade. There were <200 runs/year between 1997 and 2007, increasing to >2,000 runs/year in 2014 to 2016. Data are from the Extracorporeal Life Support Organization (2).

**Figure 2** Venoarterial Extracorporeal Membrane Oxygenation Circuit

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

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

**CENTRAL ILLUSTRATION VA-ECMO Is a Bridge**

- **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

- **Cardiac Arrest**

- **Heart or Heart/Lung Transplantation**

- **VA-ECMO**

- **Refractory Ventricular Arrhythmia**

- **Durable Mechanical Circulatory Support**

- **Recovery**

- **Decision**


The fundamental premise underlying extracorporeal membrane oxygenation (ECMO) is that it is a bridge—to recovery, to a more durable bridge, to definitive treatment, or to decision. This figure shows indications for ECMO and the potential outcomes. RV = right ventricular; VA = venoarterial.

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

An Issue of Timing: Diagnosis, Stratification, Therapy

Circulatory Support
- Systemic Perfusion
  - Mean Arterial Pressure
  - Lactate
  - Creatinine

Ventricular Support
- LV/RV Unloading
  - LV-ESP & EDP
  - Aortic Pulse Pressure
  - Vent Tachycardia
  - BNP

Coronary Perfusion
- MAP - LVEDP
  - ST-Changes
  - Troponin/CK-Mb

Renal & Hepatic Unloading
- RA-PA Hemodynamics
  - Creatinine, LFTs, Coagulopathy

Hemodynamic Problem
- Recovery
- Hemo-Metabolic Problem
- Time in Cardiogenic Shock
- Death

Rx: Hemodynamic Support
  Circulatory and Ventricular

Rx: Multi-organ Support
  Unloading, Ventilator, CVVHD

Kapur and Esposito Curr Cardio Risk 2016

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

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

Rao P et al. Circ Heart Fail 2018;11:e004905
VA-ECMO - LV Venting

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

HR 0.79, 95% CI (0.72-0.87)

p < 0.00001
Shock Algorithms

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

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

C) Improve Outcomes
- Enhanced Disease Recognition
- Appropriate revascularization and utilization of MCS
Cardiac Shock Care Centers

**Figure 2** Levels of Cardiac Shock Care

- **Level I**: Dedicated Cardiac Shock Care Centers
- **Level II**: STEMI receiving and PCI capable hospital without advanced MCS
- **Level III**: Non-PCI capable hospital (generally rural hospital)
- **Advanced MCS**: Culprit PCI
- **Triage and transfer**

Rab T et al. JACC 2018; 72(16):1972-80
Timeline of IHVI Heart Recovery Initiative

**Shock Team Assembly**
- Interventional Cardiology
- Advanced HF
- Cardiac Critical Care
- CV Surgery

**Service Line Outreach/Education**
- Cardiology Section
- Critical Care
- Cath Lab Staff
- ER
- House staff
- CICU/CVICU Nursing

**After-action Review**
- Every CS team activation
- Identify lessons learned

- **July 25, 2016**
  - Multidisciplinary taskforce review current state of CS in IHVI
- **December 6, 2016**
  - Approval of CS Algorithms
- **January 3, 2017**
  - Shock Team Go Live
- **January 2019**
  - Health System CS Sprint
  - 350 CS Cases
INOVA Heart Recovery Initiative

**CENTRAL ILLUSTRATION** Cardiogenic Shock Algorithm

**Clinical criteria to rapidly identify shock state:**
- Systolic blood pressure (SBP) < 90 mm Hg for > 30 minutes (or use of inotropes/vasoressors to maintain SBP)
- Evidence of end-organ hypoperfusion
- Lactate level > 2 mmol/L

**Activate Shock Team through a one-call line for multidisciplinary discussion:**
- Interventional Cardiology
- Cardiac Surgery
- Advanced Heart Failure
- Critical Care

**Transfer patient to cardiac catheterization lab or cardiac intensive care unit (CICU) for evaluation:**
- If acute decompensated heart failure cardiogenic shock (ADHF-CS) suspected:
  - Right heart catheterization
  - Echo
- If acute myocardial infarction cardiogenic shock (AMI-CS) suspected:
  - Right heart catheterization
  - Coronary angiography + revascularization
  - Assessment of peripheral vascular anatomy

**Hemodynamic Criteria for Cardiogenic Shock:**
- Fick cardiac index < 1.8 l/min/m² without inotropes/vasoressors
- Pulmonary capillary wedge pressure > 15 mm Hg
- Cardiac power output (CPO) < 0.6 W
- PAPi < 1.0

**If Hemodynamic Criteria are met, consider Percutaneous Mechanical Circulatory Support (PMCS):**

**Admit Patient to CICU:**
- Daily bedside echocardiograms for patients with PMCS
- Frequent neurovascular assessments for patients with PMCS
- Serial assessment of end-organ perfusion and hemodynamics: CPO, PAPi and Lactate
- Evaluation for weaning vs. escalation of support


Schematic representation of the care pathways in the upstream and critical care management of patients with acute myocardial infarction (AMI) and acute decompensated heart failure (ADHF) cardiogenic shock at the INOVA Heart and Vascular Institute. CPO = (Mean arterial pressure x cardiac output)/40; PAPi = (systolic pulmonary arterial pressure - diastolic pulmonary arterial pressure)/right atrial pressure.
INova Heart Recovery Initiative: CICU Management

Cardiogenic Shock Team Management

Call 703-776-5905 to activate Heart Team

Serial Assessment q4hr x 24hrs

- Lactate
- Fick CO/Ci
- CPO and PAPI
- Continuous hemodynamics

and if PMCS:

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

*Criteria for Refractory Shock

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

Criteria for RV Dysfunction

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

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

Cardiogenic Shock Management in the CICU

- Wean vasopressors/inotropes
- Early escalation for refractory shock
- Heart recovery

Is there Refractory Shock?*

> YES

Bi-V CS

- CPO < 0.6
- PAPI < 1.0
- RA > 15
- PCWP > 15

LV-dominant CS

- CPO < 0.6
- PAPI > 1.0
- RA < 15
- PCWP > 15

RV-dominant CS

- CPO < 0.6
- PAPI > 1.0
- RA > 15
- PCWP < 15

Hypoxemia?

> YES

TH + Oxygenerator or VA-ECMO + LV vent

Bi-Pella or ThromboCath Duo

Impella CP or Impella 3.0

Impella RP or ProtekDuo

Wien PMCS and Access for heart recovery

NO

CPO > 0.6
PAPI > 1.5
RA < 15
PCWP < 15

Hypoxemia?

> YES

TH + Oxygenerator or VA-ECMO + LV vent

Bi-Pella or ThromboCath Duo

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Wien PMCS and Access for heart recovery

NO

CPO > 0.6
PAPI > 1.5
RA < 15
PCWP < 15

Revised March 5, 2019
Improvement in CS survival: IHVI 2 year outcomes

- **2016 Baseline:** 47%
- **Jan-Jun 2017:** 55.00% (n=84)
- **Jul-Dec 2017:** 62.50% (n=56)
- **Jan-Jun 2018:** 76.50% (n=66)
- **Jul-Dec 2018:** 73.90% (n=92)

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

*INOV A Heart and Vascular Institute*
IHVI Heart Recovery Initiative: Impact of time to MCS

- 75% Chance of Death at 32 hours
- 50% Chance of Death at 16 hours
- 27% Chance of Death at 1 hour
- Arrival w/1 hr MCS
A multivariate model was run again following exclusion of patients resulting in a final risk score model ratio (OR) and clinical relevance score calculated by summing points. CPO = cardiac power output.

Both risk scores showed excellent discriminant ability with area under the curve (AUC) statistics >90.0%. CI = confidence interval; IHVI = Inova Heart and Vascular Institute.
IHVI Cardiogenic Shock “Hub-and-Spoke” Network

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

Conclusions

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

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

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

- **IHVI Pathway in the management of CS:**
  - One-call access
  - Multidisciplinary Heart Team
  - Treatment protocols and validated risk scores
  - Regional destination center utilizing a hub-and-spoke model
<table>
<thead>
<tr>
<th>Name</th>
<th>Department</th>
<th>Job Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christopher M. O’Connor, MD</td>
<td>IHVI</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>Christopher deFilippi, MD</td>
<td>IHVI</td>
<td>Vice Chair, Academic Affairs</td>
</tr>
<tr>
<td>Wayne Batchelor, MD</td>
<td>Interventional Cardiology</td>
<td>System Director, Interventional Heart Program</td>
</tr>
<tr>
<td>Charles Murphy, MD</td>
<td>IHVI Critical Care</td>
<td>Chief Safety Officer, Director CVICU</td>
</tr>
<tr>
<td>Shashank Desai, MD, MBA</td>
<td>Advanced Heart Failure/Transplant</td>
<td>Director of AHF/Transplant</td>
</tr>
<tr>
<td>Behnam Tehrani, MD</td>
<td>Interventional Cardiology</td>
<td>Co-Director, Cardiac catheterization lab</td>
</tr>
<tr>
<td>Alexander Truesdell, MD</td>
<td>Interventional Cardiology</td>
<td>Co-director, Cardiogenic Shock Team</td>
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<tr>
<td>Shashank Sinha, MD, MSc</td>
<td>Advanced Heart Failure/Transplant</td>
<td>Medical Director, Cardiac Intensive Care Unit</td>
</tr>
<tr>
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<td></td>
<td>Director, CV Critical Care Research Program</td>
</tr>
<tr>
<td>Ramesh Singh MD</td>
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</tr>
<tr>
<td>Carolyn Rosner, NP</td>
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<td>Nurse Practitioner, IHVI programs</td>
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<tr>
<td>Matthew Sherwood, MD</td>
<td>Interventional Cardiology</td>
<td>Co-Director, Cardiac catheterization lab</td>
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<td>Co-Director, Structural Heart Program</td>
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<tr>
<td>Kelly Epps, MD</td>
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<td>Director, IHVI Women’s Cardiovascular Program</td>
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<tr>
<td>Henry Tran, MD</td>
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<td>Associate Director, Cardiology Fellowship</td>
</tr>
<tr>
<td>Mehul Desai, MD</td>
<td>Medical Critical Care Services</td>
<td>Critical Care Attending MD</td>
</tr>
<tr>
<td>Glenn Druckenbrod, MD</td>
<td>Emergency Room</td>
<td>Medical Director, Emergency Room</td>
</tr>
<tr>
<td>Aaron Bagnola, PharmD, BCPS</td>
<td>Pharmacy</td>
<td>Cardiology Specialty Pharmacist</td>
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