Cardiogenic Shock in Acute MI: Role for Mechanical Circulatory Support

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No Disclosures
Coronary Syndromes: Improvement in Treatment

A. Age-Adjusted Death Rates (United States: 1940-95)

- Coronary Heart Disease
- Stroke
- High Blood Pressure

Death Rates Per 100,000 Population

Age-adjusted to 1940 U.S. population and to the 6th Revision ICDA.
National Center for Health Statistics and the AHA.

[BROWN: Lewis RP; JACC 2000]

B. Short-Term Mortality from Acute Myocardial Infarction

- Defibrillation, Hemodynamics
- Reperfusion, β-blockers, Aspirin

Pre-CCU Era [Before 1962]
CCU Era [1962-1984]
Reperfusion Era [1984-Present]

[BROWN: Braunwald E; NEJM 1997]
Cardiogenic Shock
Prognosis

Patients in NRMI registry presenting with cardiogenic shock who died (%)

P<0.001

< 75 years
≥75 years

Babaer et al: JAMA 1294:448, 2005
**Timing is Everything...**

- After acute MI with Primary PCI
  - Vfib: 94.7% before or during PCI
  - 6.3% AV Block (86% before/during PCI: 90+% resolve)
  - 4.5% “impeding shock” coming into PCI
  - 4.2% Shock- most prehospital
  - 1% develop post PCI


- Shock trial: median 6.2 hours after symptom onset (74% within 1 day)
  - LM: 1.7 hrs
  - RCA: 3.5 hrs
  - LCx: 3.9 hrs
  - LAD: 11hrs
  - Late shock (>24hours): recurrent ischemia, Q waves, LAD

  JACC 2000 Sep; 36 (3 Suppl A): 1084-90.
EVOLUTION OF THE CARDIAC CARE UNIT
“...times they are a changin’ ” B Dylan

1980s
Resuscitation
- Rapid Defibrillation
- Post MI Care
- STEMI
- Gen ICU RN

1990s
Intervention
- Rapid Defibrillation
- Antiarrhythmics
- All ACS
- CHF
- IABP
- Specialized RN

Today
Comprehensive Critical Care
- TTM
- MCS
- Advanced CHF
- Pul HTN
- Multidisciplinary
- Performance Tracked
Cardiogenic Shock

• Not “just” decreased CI (def ≤ 1.8, or 2.2 with pressors, SBP ≤ 90mmHg)

• Multiorgan dysfunction syndrome due to peripheral hypoperfusion with microcirculatory dysfunction

• Complicated by SIRS (~25%)

• Once multiple systems involved, difficult to improve prognosis by merely fixing CO.

• Most due to decompensated CHF
In 100 CICU Patients:

50 *without* acute kidney injury, acute respiratory failure, or sepsis

Only 1 will die

50 *with* acute kidney injury, acute respiratory failure, or sepsis

11 will die

Exam !?
The ST pattern in Cardiogenic shock:

70-85% $\rightarrow$ ST elevations MI/ New LBBB
  • Mortality: 53-63%

15-30 % $\rightarrow$ Non-ST elevation MI
  • Older
  • Mortality: 77%
Physical Exam

- **BP**
  - Pulse pressure: large (elderly/AI), narrow (pre-shock)
    - Proportional pulse pressure = SBP-DBP/ SBP
    - No BETA BLOCKERS
    - Does pulse disappear with respiration? (tamponade)
    - Pulse equal in both arms? (dissection)
    - Fistula in the arm? (Effusion)

- **Murmur**
  - New?
    - Upper right sternal border: AS (elderly) HOCM (young)
    - Listen for the MR murmur in the back if Q waves!

- **Neck Veins**
  - TR with elevated INR → think Pul HTN and RV failure
  - PRELOAD ASSESSMENT IS KEY!
Mortality by Clinical Presentation

<table>
<thead>
<tr>
<th>Mortality</th>
<th>Respiratory Distress</th>
<th>Hypotension</th>
<th>Hypoperfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>21%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>60%</td>
<td></td>
<td>1.4%</td>
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<tr>
<td></td>
<td></td>
<td>5.6%</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>65%</td>
</tr>
</tbody>
</table>

SHOCK Registry JACC Sept. 2000, Supp. A
Critical cardiogenic shock describes a patient who is “crashing and burning”, in which a patient has life threatening hypotension and rapidly escalating inotropic pressor support, with critical organ hypoperfusion often confirmed by worsening acidosis and lactate levels.
**CS Level 1**

SBP <90 30 min pre-ionotropes

Pulmonary congestion

or

Impaired end-organ perfusion:

AMS

Cold/Clammy

Oliguria

Lactate >2

**CS Level 2 (Profound)**

CS Level 1

CI <2.2 L/min/m or

Lactate > 3

**Despite**

2 Ionotropes/Pressors

**CS Level 3 (Deep)**

CS Level 2

Two of the following:

Lactate > 8mmol/l

Anuria

RHF

Escalating Pressors

Respiratory Failure

Courtesy of Eddie Rame MD

UPENN
Three High Dose: 2%, 3%, 7.5%, 21%, 42%, 80%

- No Hemodynamic Support
- Needs Partial Hemodynamic Support
- Needs Full Hemodynamic Support

Pre-Shock
- Low Dose
- Moderate Dose
- One High Dose

Shock
- Two High Dose

Profound Shock
- Three High Dose

Mortality Risk with Inotrope Dosing

The two strongest predictors (age and prior stroke) cannot be modified by any acute intervention.

The next three predictors (lactate, oliguria, and pH) suggest that the amount of LV support is important.

Thiele et al, Lancet 2013
Objective Data

(Was) Controversial

Gusto 1/Shock benefit
SHOCK Trial
Primary Endpoint

30-Day Mortality

Revascularization (n=152)
Medical therapy (n=150)

P=0.11

Proportion alive

Days after randomization

Hochman et al: NEJM 341:625, 1999

P=NS, .02@ 6mo.
The Challenge of Age…
Clinical Intuition in the Information Age:
Shock in the Elderly

30-day Mortality (%)

<75 years (n=246)
- ERV: 41%
- IMS: 57%

>75 years (n=56)
- ERV: 75%
- IMS: 53%

p=0.01
Elderly - SHOCK & other registry data
Clinicians Needed!

<table>
<thead>
<tr>
<th>Registry</th>
<th>Mortality (%)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHOCK Registry</td>
<td>48%</td>
<td>44</td>
</tr>
<tr>
<td>Mayo Clinic</td>
<td>47%</td>
<td>61</td>
</tr>
<tr>
<td>Northern New England</td>
<td>46%</td>
<td>74</td>
</tr>
</tbody>
</table>

30-day Mortality (%)

ERV vs IMS
PA Cath: Resistance is not futile! Importance of SVR
55 yo diabetic/ trop 70
  No fever
  SVR high
  IABP
  Monomorphic VT

64 yo/ trop 70
  No fever
  SVR mildly up
  Just meds
  Walked out in 3 days

42 yo/ trop 70
  38.5 at hour 36 then
  SVR 400
  Mechanical Support
  LOS 12 days
With RBCs and O2, Comes WBCs....
Inflammation / NOS : Local & Systemic Effects

Fever, leukocytosis, Big temp (38.5+) typically hour 24-30
Nitric Oxide (neuronal, endothelial, *inducible*)

• Low levels (eNOS) is cardioprotective, increases contractility

• High levels (iNOS) in inflammatory conditions particularly MI and reperfusion
  – ↓ Contractility
  – Suppression of mitochondrial respiration in nonischemic myocardium
  – Alters substrate metabolism (glucose)
  – Reduced efficacy of catechols
  – Vasodilation
  – Interaction at high levels with free radicals causes cell death/toxicity
CS Survivors...

Average EF only ~ 30%

Huge variability in SVR, may not be elevated despite vasopressors

SIRS (~20% of CS, 2 days post)

Most survivors of CS have NYHA Class I
   Inconsistent with >40% myonecrosis
# Hemodynamic Phenotype

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>Classic Cardiogenic Shock</td>
<td>Euvoletic Shock</td>
</tr>
<tr>
<td></td>
<td>↓CI; ↑SVRI</td>
<td>↓CI; ↑SVRI</td>
</tr>
<tr>
<td>Warm</td>
<td>Vasodilatory Cardiogenic Shock or Mixed Shock</td>
<td>Vasodilatory Shock</td>
</tr>
<tr>
<td></td>
<td>↓CI; ↓↔SVRI</td>
<td>↑CI; ↓SVRI</td>
</tr>
</tbody>
</table>

![Hemodynamic Profiles in Shock](chart)

- **LV Congestion**
- **BiV Congestion**
- **Hypovolemic**
- **RV Congestion**

**Left Heart Filling Pressures (PCWP)**

**Right Heart Filling Pressures (CVP or RA)**
48 yo male with 2 hours CP:
Stormy Course

• **Day 1**: CVP 16, **SVR 1800**, CI 2.2 (MCS), MAPs OK

• **Day 2**: Fever to 39 C, CVP 12, **SVR 600**, CI 2.4 (MCS), Levophed

• **Day 4**: CVP 20, suction alarms on MCS, **SVR 1600**, CI 1.9 (MCS), Milrinone

• **Day 9**: antibiotics → CVP 6, **SVR 600**, CI 3, Neo and fluids
Shock mortality predictor ≠ CI, CO, SVR, PCWP but rather reserve pumping capacity.

Heart pump dependent on preload and resistance circuit, function can be variable (i.e. what do you want the EF to be?)

**Cardiac Power** (or reserve) = pressure x flow
MAP x CO/451 (Left Ventricle)
CS Level 1

SBP <90 30 min pre-ionotropes

Pulmonary congestion  
or

Impaired end-organ perfusion:
  AMS
  Cold/Clammy
  Oliguria
  Lactate >2

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CS Level 3 (Deep)

CS Level 2

Two of the following:
  Lactate > 8mmol/l
  Anuria
  RHF
  Escalating Pressors
  Respiratory Failure
CS: Hemo-Metabolic Problem (aka “Post-ICEBERG SYNDROME”)
“More Horsepower”
Cardiogenic Shock Line: Triggers

**CS Level 1**

SBP <90 30 min pre-ionotropes

- tachy
- PP = 20
- PPP (PP/SBP) = 0.2

Pulmonary congestion or Impaired end-organ perfusion:

- AMS
- Cold/Clammy
- Oliguria (<30cc/hr)
- Lactate >2

Make the Call

**2x4 Rule**

- Lactate 2 = ICU
- Lactate 4 = Meds No More
Lactate within the first 24 hours, the Greatest Predictor

- **Non-Survivors**
  - Pre: 4.72
  - 12 hours: 2.53
  - 24 hours: 1.82

- **Survivors**
  - Pre: 6.15
  - 12 hours: 7.04
  - 24 hours: 7.34
IMPROVED END ORGAN PERFUSION WITH pVAD

Changes in Sublingual Microcirculation

Baseline prior to Impella support

After 48hrs of Impella support

Lam, et. al., Clin Res Cardiol, 2009,
Percutaneous Left Ventricular Support Devices- Which one?

A  IABP  B  Impella  C  TandemHeart  D  ECMO
“Unloading” … Reducing Work

**Inotropic Drugs**
- Increase peak systolic pressure
- Stroke volume increase

**Balloon Pump**
- Reducing systolic aortic pressure
- Stroke volume increase

**Impella**
- Unloads from ventricle
- Reduces diastolic volume

---

**Work Reduction**
*Reduced Area of PV Loop?*

- No: Increases PV loop area
- No: Stroke Volume increase offsets pressure reduction
- Yes: Volume reduction reduces PV loop area
Hemodynamic Effects of VA-ECMO

Increased afterload reduces native CO and causes increase in LVEDP and LVEDV

ECMO: No LV decompression

Stagnant areas of blood in LV and Ao Root → thrombus

LV distension and pulmonary hemorrhage

*No recovery of LV*
Important of maintaining residual LV flow

Timing is Everything

Primary Study Endpoint (30-Day Mortality)

Only 15% with IABP pre PCI
Timing is Everything

Single center registry Primary PCI for shock
Brodie AJC 1999;84:18
Impella 2.5 initiated prior to unprotected left main PCI in acute myocardial infarction complicated by cardiogenic shock improves early survival
Timing of Support Impacts Outcomes

30 Day Survival

![Graph showing survival rates for different types of support methods over time.](image)

- **Impella Pre - PCI**
- **IABP/Inotropes Pre-PCI**

Log-Rank, p=0.004

Days from initiation of Impella


**Door to Balloon Metric** - Cardiogenic Shock & hemodynamic support are excluded from Door to Balloon (DTB) metrics. Source: CMS, SCAI & ACC.

*The catheter based VAD Registry is a worldwide, multicenter, IRB approved, monitored clinical registry of all patients at participating sites. Registry data is used for FDA PMA submissions.*
LV
Physically Larger
One job
Gets most of the attention
Replaceable with machine
Simple algorithm
Easy to understand
LV
Physically Larger
One job
Gets most of the attention
Replaceable with machine
Simple algorithm
Easy to understand

RV
Physically Smaller
Multiple jobs
Underappreciated
When fails, all hell breaks loose
Can’t put a number on it
Understanding is nuanced
RV Physiology

- RV empties when relaxing
- Very sensitive to afterload
- Prolongs isovolumetric time increases O2 cost

1 Ejection (opened PV)
2 Relaxation
3 Close of pulmonic/aortic valve
   end of ejection
RV: Lots of Ways to Fail!
When to pull the trigger?

Impella: Left

“Bipella”: Left & Right
(a few) Predictors of RV failure

CVP / PCWP

MAP/CVP

PAPi (Pulmonary artery pulsatility index) = \( \frac{\text{PASP-PADP}}{\text{RA}} \)

RVSWI = (mPAP-CVP) x Stroke Volume Index
National Shock Initiative: CS with Acute MI

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

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

IMPELLA

PCI

CPO < 0.6 Right Heart Cath PAPI < 0.9 Possible RV Failure Consider RV Support

CPO ≥ 0.6 and PAPI > 0.9

Continue to Titrate
↓ Pressors/Inotropes

Calculate PAPI

PAPI > 0.9

RV Normal

Consider ↑

LV Support

www.henryford.com/cardigenicshock

On behalf of the National CSI Investigators - September, 2018
Predictors of Survival at 12-24 hours (N=75)

CARDIAC POWER OUTPUT

<table>
<thead>
<tr>
<th>LACTATE</th>
<th>&gt; 0.6</th>
<th>≤ 0.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 4</td>
<td>63% Survival (n=5/8)</td>
<td>30% Survival (n=3/10)</td>
</tr>
<tr>
<td>&lt; 4</td>
<td>96% Survival (n=45/47)</td>
<td>80% Survival (n=8/10)</td>
</tr>
</tbody>
</table>
National Shock Initiative

Admission to ICU/CCU

Monitor CPO, PAPI, Lactate at 12-24 Hours

CPO < 0.6
Lactate > 4

Early Escalation
Goals of Care

CPO < 0.6
Lactate < 4

Close Observation
Consider Escalation

CPO > 0.6
Lactate < 4

Wean Pressors
Wean MCS
Importance of Escalation and Recovery strategies

**No Recovery Escalate (＆ Ambulate) or Transfer**

*Guidance by RHC Is Critical*

**Worsening / not improving clinical, echocardiographic & hemodynamic parameters (concordant):**
- ↓ Cardiac output
- ↓ CPO
- ↓ Urine output
- ↑ Lactate, ↓ MVO2
- Inotrope dependent
- Absent pulsatility

---

**RV Failure as defined by Recover Right**:  
- CI < 2.2 L/min/m² (despite continuous infusion of ≥ 1 high dose inotrope, ie, da/dobutamine ≥ 10 µg/kg/min or equivalent) and any of the following:
  1. CVP > 15 mmHg, or
  2. CVP/PCWP or LAP ratio >0.63, or
  3. RV dysfunction on TTE (TAPSE score ≤14 mm)

**PAPi ≤ 0.9 (RV Failure)**  
- **Biventricular support with Impella RP® on the right side** (transfer if not available)

**0.9 < PAPi ≤ 1.5 (RV dysfunction)**  
- **Consider supporting the right side with Impella RP** (transfer if not available)

**PAPi > 1.5 (acceptable RV function)**  
- **Consider left-side escalation with Impella 5.0™** (transfer if not available)

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\[ CPO = \frac{(MAP \times CO)}{451} \]

\[ PAPi = \frac{sPAP - dPAP}{RA} \]


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64
Should you pull the trigger?
What ICEBERG?