THE GOOD, THE BAD, AND THE UGLY
CHANGING OUTCOMES IN CARDIOGENIC SHOCK

Scott Silvestry MD
Florida Hospital Transplant Institute
What do you do?

- 55 year old male presents with acute chest pain and SOB. He is tachycardic and hypotensive.
- His EKG suggests STEMI and his enzymes are positive.
- He undergoes PCI of the LAD and remains hypotensive in the cath lab.
- He has frequent runs of VT and is started on lidocaine.
Treatment options

- Intubate?
- IABP
- CABG?
- Impella
- ECMO
- LVAD

- What dose of vasopressor/inotrope indicates the need for escalation of care?
  - Dopamine 10 mcg/kg/min
  - Levophed 1 mcg/min
  - Epinephrine 0.1 mcg/kg/min
  - Dobutamine 10 mcg/kg/min
  - When we run out in the hospital?
Definition of Shock

• In 1852, shock was defined as “a rude unhinging of the machinery of life.” Probably no better definition exists to describe the devastating effects of this process on a patient, but a more recent definition calls shock “the collapse and progressive failure of the cardiovascular system.”

• Shock left untreated may be fatal. It must be recognized and treated immediately, or the patient will likely die.
Cardiogenic shock

Organ hypoperfusion caused by left ventricular, right ventricular or biventricular dysfunction

Clinical criteria

• Persistent hypotension

• Clinical signs of hypoperfusion
  – Cooled extremities
  – Decreased urine output
  – Altered mental status

Hemodynamic criteria

• Systolic blood pressure less than 80-90 mmHg or mean arterial pressure 30 mm lower than the baseline

• Cardiac index less than 1.8 L/m/m² or less than 2.0-2.2 L/m/m² with inotropic support

• Elevated filling pressures
  – LVEDP greater than 18 mmHg
  – RVEDP greater than 10-16 mmHg
Cardiogenic Shock, Clinical Challenge

~7% of AMI’s Suffer Cardiogenic Shock

<table>
<thead>
<tr>
<th>Year</th>
<th>Cardiogenic Shock (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>7.4</td>
</tr>
<tr>
<td>1986</td>
<td>7.5</td>
</tr>
<tr>
<td>1995</td>
<td>7.9</td>
</tr>
<tr>
<td>2004</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Mortality Remains ≥ 50% @ 6 months for Shock

- Emergency Revascularization
- Initial Medical Stabilization

2000 SHOCK Trial

Hochman, JAMA 285: 190, 2001
Hochman et al, NEJM 1999; 341:625-624

~1M US Heart Attacks (AMI) / year
~70,000 US AMI Shock Patients/ year
>30K AMI Shock Deaths / year
Mortality/Morbidity

- The historic mortality rates from cardiogenic shock are 80-90%; more recent studies have reported somewhat lower in-hospital mortality rates, in the range of 56-67%.
Prognosis of Patients with AHF admitted to the ICU

355 patients admitted to the CCU/ICU for acutely decompensate heart failure

Diagram showing survival rates for different cardiac output groups and left ventricular ejection fraction (LVEF) levels.
Cardiogenic Shock Kills

Time trends in hospital case fatality rates (CFR) in patients with acute myocardial infarction ± cardiogenic shock in the Worcester (MA, USA) metropolitan area.

Karl Werdan et al. Eur Heart J 2013;eurheartj.eht248
WHY CHANGE?

Because the tools we are using do not work.

Intra-aortic balloon pump

IABP – Shock II trial

Mortality (%) vs Days after randomisation

Number at risk:
- IABP: 301
- Control: 299

40% vs 50% 12 month mortality

p=0.94; log-rank test

Relative risk 1.02, 95% CI 0.88-1.39
Current evidence from randomized clinical trials in cardiogenic shock in the era of percutaneous coronary intervention.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Follow-up</th>
<th>n/N</th>
<th>Mortality Relative risk</th>
<th>Relative risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revascularization (PCI/CABG)</td>
<td>1-year</td>
<td>76/152</td>
<td>0.60 (0.66;0.98)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 days</td>
<td>22/32</td>
<td>0.67 (0.66;1.29)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>103/184</td>
<td>0.82 (0.70;0.98)</td>
<td></td>
</tr>
<tr>
<td>Catecholamines</td>
<td>28 days</td>
<td>64/145</td>
<td>0.75 (0.55;0.93)</td>
<td></td>
</tr>
<tr>
<td>SOAP II (CS subgroup)</td>
<td></td>
<td>50/135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycoprotein IIb/IIIa inhibitors</td>
<td>In-hospital</td>
<td>15/40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRAGUE-7</td>
<td></td>
<td>13/40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO synthase inhibitors</td>
<td>30 days</td>
<td>97/201</td>
<td>1.14 (0.91;1.45)</td>
<td></td>
</tr>
<tr>
<td>TRIUMPH</td>
<td></td>
<td>76/180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHOCK-2</td>
<td>30 days</td>
<td>24/59</td>
<td>1.16 (0.59;2.69)</td>
<td></td>
</tr>
<tr>
<td>Cotter et al.</td>
<td>30 days</td>
<td>4/15</td>
<td>0.40 (0.13;1.05)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>125/275</td>
<td>1.05 (0.85;1.29)</td>
<td></td>
</tr>
<tr>
<td>IABP</td>
<td>30 days</td>
<td>7/19</td>
<td>1.28 (0.45;3.72)</td>
<td></td>
</tr>
<tr>
<td>IABP-SHOCK I</td>
<td></td>
<td>6/21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LVAD</td>
<td>30 days</td>
<td>9/21</td>
<td>0.95 (0.48;1.90)</td>
<td></td>
</tr>
<tr>
<td>Thiele et al.</td>
<td></td>
<td>9/20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burkhoff et al.</td>
<td>30 days</td>
<td>9/21</td>
<td>1.33 (0.57–3.10)</td>
<td></td>
</tr>
<tr>
<td>Seyfarth et al.</td>
<td>30 days</td>
<td>6/13</td>
<td>1.00 (0.44–2.29)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>24/53</td>
<td>1.06 (0.68–1.66)</td>
<td></td>
</tr>
</tbody>
</table>

Holger Thiele et al. Eur Heart J 2010;eurheartj.ehq220
Coronary revascularization
Vasopressor and inotropic therapy
Mechanical circulatory support

THERAPIES
Early Revascularization in Acute Myocardial Infarction Complicated by Cardiogenic Shock

Overall 30-Day Survival in the Study

Revascularization (n = 152)
Survival = 53%

Medical therapy (n = 150)
Survival = 44%

p = 0.11

SHOCK Trial Mortality

- **30 days**
  - Revasc: 46.7%
  - Med Rx: 56%
  - $P = 0.11$

- **6 months**
  - Revasc: 50.3%
  - Med Rx: 63.1%
  - $P = 0.027$

- **1 year**
  - Revasc: 54.3%
  - Med Rx: 66.4%
  - $P < 0.03$
Figure 5. Long-term follow-up of the SHOCK trial cohort. Early revascularization (ERV) is associated with sustained benefit.


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TIMELINESS
Sometimes late isn't better than never.
The body must be perfused
Evolution of Shock from AMI

Frequently, shock develops after presentation for myocardial infarction.

- **SHOCK Registry**
  - At presentation: 25% in shock
  - Within 24 hours: 75%
    (median delay = 7 hours)

- **GUSTO Trial**
  - At presentation: 11% in shock
  - After admission: 89%

*GUSTO J Amer Coll Cardiol. 1995;26:668-74.*
Figure 1. Current concept of CS pathophysiology.

Patients with ST segment elevation MI who have cardiogenic shock and are less than 75 years of age should be brought immediately or secondarily transferred to facilities capable of cardiac catheterization and rapid revascularization (PCI or CABG) if it can be performed within 18 hours of onset of shock. (Level of Evidence: A)
National Registry of MI Early Revascularization is Underutilized in Cardiogenic Shock

Despite ACC/AHA recommendation to treat patients < 75 years of age aggressively with early mechanical revascularization, in 2001, two years after the guidelines were published, only 41% of patients with cardiogenic shock complicating AMI were treated with primary PTCA and only 3.1% underwent early CABG.

These data demonstrate significant underutilization of guideline recommended therapy.

Differentiating Shock vs HF

- Cardiogenic Shock
  - High CVP
  - Low CI
  - High SVRI
  - Low VO2

- Heart Failure
  - High CVP
  - Low CI
  - High SVRI
  - Normal VO2
SHOCK Trial:
12-Month Mortality

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Initial Medical Stabilization</th>
<th>Emergency Revascularization</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-Day (302)</td>
<td>47.0%</td>
<td>54.0%</td>
</tr>
<tr>
<td>6-Month (301)</td>
<td>50.0%</td>
<td>63.0%</td>
</tr>
<tr>
<td>12-Month (299)</td>
<td>54.0%</td>
<td>67.0%</td>
</tr>
</tbody>
</table>

p = 0.109
p = 0.027
p = 0.025

Hochman, JAMA 285: 190, 2001
Ideal Goals of Cardiac Support

Common Themes

Ideal Cardiac Support

Safe, Simple Use

Systemic Hemodynamic Support

Myocardial Protection

Prophylactic

Emergent

Reperfuse the body quickly (EASE)
Save the heart (decompress)
Decompressing the LV is the cornerstone of recovery
Acute Heart Failure

Systolic dysfunction

Diastolic dysfunction

Left ventricular pressure

Left ventricular volume

\( \Delta P \)

\( \Delta V \)
Ventricular Unloading

- Direct Ventricular Unloading
- Reduces wall tension and myocardial O$_2$ demand$^{1-6}$
- Increases O$_2$ supply$^{6,10}$
- Reduces inotrope dependence$^7$

2. Dixon et al, JACC, 2009
4. Valgimigli et al, Cath Cardio Interventions, 2005
5. Reesink et al., CHEST, 2004
7. Recover I Trial Summary, 2008 TCT; N=17
8. Kawashima, D, et.al., ASAIO, 2010
10. Remmelink, Cath Cardio Interventions, 2007
<table>
<thead>
<tr>
<th></th>
<th>IABP</th>
<th>ECMO</th>
<th>TandemHeart</th>
<th>Impella 2.5</th>
<th>Impella 5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pump mechanism</strong></td>
<td>Pneumatic</td>
<td>Centrifugal</td>
<td>Centrifugal</td>
<td>Axial flow</td>
<td>Axial flow</td>
</tr>
<tr>
<td><strong>Cannula size</strong></td>
<td>7.9 Fr</td>
<td>18–21 Fr inflow; 15–22 Fr outflow</td>
<td>21 Fr inflow; 15–17 Fr outflow</td>
<td>13 Fr</td>
<td>22 Fr</td>
</tr>
<tr>
<td><strong>Insertion technique</strong></td>
<td>Descending aorta via the femoral artery</td>
<td>Inflow cannula into the right atrium via the femoral vein, outflow cannula into the descending aorta via the femoral artery</td>
<td>21 Fr inflow cannula into left atrium via femoral vein and transseptal puncture and 15–17 Fr outflow cannula into the femoral artery</td>
<td>12 Fr catheter placed retrogradely across the aortic valve via the femoral artery</td>
<td>21 Fr catheter placed retrogradely across the aortic valve, surgical cutdown of artery</td>
</tr>
<tr>
<td><strong>Haemodynamic support</strong></td>
<td>0.5 – 1.0 L min⁻¹</td>
<td>&gt;4.5 L min⁻¹</td>
<td>4 L min⁻¹</td>
<td>2.5 L min⁻¹</td>
<td>5.0 L min⁻¹</td>
</tr>
<tr>
<td><strong>Implantation time</strong></td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Risk of limb ischaemia</strong></td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Anticoagulation</strong></td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>++</td>
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<tr>
<td><strong>Haemolysis</strong></td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td>++</td>
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<tr>
<td><strong>Post-implantation</strong></td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
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<tr>
<td><strong>management complexity</strong></td>
<td>No</td>
<td>Yes</td>
<td>(Yes)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Optional active cooling in post-cardiopulmonary resuscitation patients</strong></td>
<td>No</td>
<td>Yes</td>
<td>(Yes)</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; +, ++, ++++, ++++, relative qualitative grading concerning time (‘Implantation time’), risk (‘Risk of limb ischaemia’), intensity (‘Anticoagulation’), post-implantation management complexity), and severity (haemolysis’). Modified from Ouweelen and Henriques.\textsuperscript{42}
### Table 5  Meta-analysis of RCTs: effects of left ventricular assist devices—TandemHeart 55,56 and Impella PL2.5 pump 63—in comparison with the effects of IABP on haemodynamics; 30-day mortality and adverse events in patients with cardiogenic shock, mainly due to myocardial infarction

<table>
<thead>
<tr>
<th></th>
<th>Thiele et al. 55</th>
<th>Burkhoff et al. 56</th>
<th>Seyfarth et al. 63</th>
<th>Pooled (fixed effect model)</th>
<th>Pooled (random effects model)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LVAD (n = 21)</td>
<td>IABP (n = 20)</td>
<td>LVAD (n = 19)</td>
<td>IABP (n = 14)</td>
<td></td>
</tr>
<tr>
<td><strong>Haemodynamics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI ± SD (L min⁻¹ m⁻²)</td>
<td>2.3 ± 0.6</td>
<td>1.8 ± 0.4</td>
<td>2.2 ± 0.6</td>
<td>2.1 ± 0.2</td>
<td>2.2 ± 0.6</td>
</tr>
<tr>
<td>MAP ± SD (mmHg)</td>
<td>76 ± 10</td>
<td>70 ± 16</td>
<td>91 ± 16</td>
<td>72 ± 12</td>
<td>87 ± 18</td>
</tr>
<tr>
<td>PCWP ± SD (mmHg)</td>
<td>16 ± 5</td>
<td>22 ± 7</td>
<td>16 ± 4</td>
<td>25 ± 3</td>
<td>19 ± 5</td>
</tr>
<tr>
<td><strong>Clinical outcome</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-day mortality, n (%)</td>
<td>9 (43)</td>
<td>9 (45)</td>
<td>9 (47)</td>
<td>5 (36)</td>
<td>6 (46)</td>
</tr>
<tr>
<td><strong>Reported adverse events</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg ischaemia, n (%)</td>
<td>7 (33)</td>
<td>0 (0)</td>
<td>4 (21)</td>
<td>2 (14)</td>
<td>1 (8)</td>
</tr>
<tr>
<td>Bleeding, n (%)</td>
<td>19 (90)</td>
<td>8 (40)</td>
<td>8 (42)</td>
<td>2 (14)</td>
<td>2.59 (0.75; 8.97)</td>
</tr>
<tr>
<td>Fever of sepsis, n (%)</td>
<td>17 (81)</td>
<td>10 (50)</td>
<td>4 (21)</td>
<td>5 (36)</td>
<td>1.38 (0.88; 2.15)</td>
</tr>
</tbody>
</table>

CI, cardiac index; IABP, intra-aortic balloon pump; LVAD, left ventricular assist device; MAP, mean arterial pressure; PCWP, pulmonary capillary wedge pressure. From Cheng et al. 60 For details on the statistical analysis please refer to the original publication.
ECMO

Rapidly deployed
Minimal expertise/equipment needed
Relatively Inexpensive Triage tool
Provides full body support
Beware LV distension
ECMO support can rescue 40% of otherwise fatal cardiogenic shock patients.

What defines the threshold to initiate mechanical circulatory support (MCS)?

Adequacy of hemodynamic support?

—Hemodynamic criteria alone are not specific

  Degree of medical intervention

  Degree of vasopressor support

End-organ response to revascularization and/or medical therapy
CARDIOGENIC SHOCK TEAM APPROACH

The Massachusetts General Hospital Cardiogenic Shock Team provides urgent evaluation and care to patients experiencing cardiogenic shock, a condition in which the heart is unable to pump enough blood to support the needs of the body's organs.

Physicians should call 617-726-2056 for an urgent evaluation request and ask for the Cardiogenic Shock Team.

Learn more about the Mechanical Circulatory Support Program.

Learn more about the Mass General Heart Transplant Program.

Leading Expertise in Treating Cardiogenic Shock

Reach the Cardiogenic Shock Team

Physicians should call 617.726.2056 to speak with a Cardiogenic Shock team member on call.

The Mass General Cardiogenic Shock Team is available 24 hours a day, seven days a week, to assist with the immediate evaluation and management of cardiogenic shock patients.

Cardiogenic shock is a condition in which the heart is unable to pump enough blood to meet the needs of the body. It commonly occurs soon after a massive heart attack, but it can also occur after heart surgery or with an acute illness such as cardiomyopathy, which is a weakening of the heart muscle. Occasionally, patients with chronic heart failure will develop cardiogenic shock.

Patients with cardiogenic shock must be treated promptly in order to restore perfusion, the process of delivering blood to the body's organs, and prevent further deterioration so that the heart can recover. At Mass General Hospital, mechanical circulatory support devices are used when necessary to either temporarily support the heart as it recovers, or as a bridge to other interventions.

ECMO for Adult Heart Disease: The Importance of a Team Approach

Aug 13, 2015 | Michael S. Firstenberg, MD, F.A.C.C.; Timothy Byrnes, DO; Rana Hejal, MD

Introduction
Team Approach

- Cardiac Shock Team
- Interventionalist
- Advance Heart Failure
- Cardiac Surgeon
- Cardiologist
- Intensive Care Team
- Catheterization Staff
- Operating Room Staff
Jan 2015, Received FDA HDE Approval
Potential treatment algorithm for patients with CS complicating AMI (asterisks denote supported by randomized controlled trials).

Acute myocardial infarction and cardiogenic shock

- Fluids for optimal preload
- Vasopressors/Inotropes: Preferred norepinephrine/dobutamine*
- Early revascularization*

1–2 vessel disease
- PCI infarct-related artery*

Moderate 3-vessel disease
- IABP
- Weaning
  - Yes Adequate support?
    - No Percutaneous short-or mid-term left ventricular assist device
  - Yes Recovery?
    - No Implantable left ventricular assist device? Heart transplantation?

Severe 3-vessel disease
- CABG*

Acute multi-vessel PCI
- Staged multi-vessel PCI
- Staged CABG*
Device selection flow chart.

Advanced Heart Failure

- Listed for OHTx
- Acute Cardiogenic Shock
  - Unknown OHTx Status
    - IABP, ECMO
      - Abiomed AB5000, BV55000
      - Thoratec pVAD, CentriMag
      - TandemHeart, Impella
  - Short Term Mechanical Circulatory Support
    - Recovery
      - Abiomed AB5000, BV55000
        - Thoratec pVAD, IVAD
        - HeartMate XVE, II
  - BTD
    - Heartmate XVE, II

Ineligible for OHTx

- DT

Long Term Mechanical Circulatory Support

- OHTx—Possible Destination
- Recovery
- Destination—Possible OHTx

Conclusions

• Cardiac shock is a severe manifestation of acute heart failure and is associated with high mortality.

• Early revascularization was associated with improved long-term survival.

• Patients with refractory cardiac shock, mechanical circular support should be considered.

• The team approach with high relational coordination is necessary to achieve improved survival goals.

• Appropriate use of evolving technology to treat the right patient at the right time with the right tools will be a growing part of shock treatment.
Optimal Timing for mechanical circulatory support.