Cardiogenic Shock and Hemodynamic Support in the STEMI Patient: Approaches & Considerations for EMS, Air and Hospital Providers

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Disclosures:
I have no financial relationships or other conflict of interests to disclose, and I will not discuss off label use and/or investigational use in my presentation.
79 yo male with:

- CAD s/p recent 3V CABG
- Previous moderate to severe decrease LVEF
- Presented 1.5 months post-CABG via EMS to local ER with escalating chest pain and SOB
- Flash pulmonary edema, cardiogenic shock, and presumed AMI
- Intubated, Heparin, NTG, Lasix, and bicarbonate
- Transported from local ER to St. Luke’s Cath lab
- Hypotension requiring phenylephrine and norepinephrine in lab
Case Study
Left Coronary Angiogram
RCA
SVG to Right Coronary
LIMA to LAD
SVG to OM (occluded)
Case Study

- Complex distal Left Main CAD
- Occluded SVG to OM
- Patent LIMA to LAD (diseased)
- Patent SVG to RCA
- Severely elevated LVEDP 51 mmHg

Plan:
- Impella
- PCI and DES x 2 to distal LM bifurcation into LAD and LCX.
Impella and Wires...
Impella and Stents...
Impella and Results
**SHOCK= Inadequate Tissue Perfusion**

- **Mechanisms:**
  - Inadequate oxygen delivery
  - Release of inflammatory mediators
  - Further microvascular changes, compromised blood flow and further cellular hypoperfusion

- **Clinical Manifestations:**
  - Multiple organ failure
  - Hypotension
Hemodynamic Parameters

• Systemic Vascular Resistance (SVR)
• Cardiac Output (CO)
• Mixed Venous Oxygen Saturation (SvO2)
• Pulmonary Capillary Wedge Pressure (PCWP)
• Central Venous Pressure (CVP)
# Normal RHC Values

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right Atrial Pressure, CVP</strong></td>
<td>Mean</td>
<td>0-6mmHg</td>
</tr>
<tr>
<td><strong>Pulmonary Artery Pressure</strong></td>
<td>Systolic End-diastolic mean</td>
<td>15-30mmHg 4-12mmHg 9-19mmHg</td>
</tr>
<tr>
<td><strong>PCWP</strong></td>
<td>Mean</td>
<td>4-12mmHg</td>
</tr>
<tr>
<td><strong>Cardiac Output</strong></td>
<td></td>
<td>4-8 L/min</td>
</tr>
<tr>
<td><strong>Mixed Venous O2 Sat</strong></td>
<td></td>
<td>&gt;70%</td>
</tr>
<tr>
<td><strong>SVR</strong></td>
<td></td>
<td>800-1200</td>
</tr>
</tbody>
</table>
# Types of Shock

<table>
<thead>
<tr>
<th>Type of Shock</th>
<th>SVR</th>
<th>CO</th>
<th>CVP</th>
<th>PAOP</th>
<th>Svo₂ or Scvo₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septic</td>
<td>↓</td>
<td>↑ or N (rarely ↓)</td>
<td>↓ or N</td>
<td>↓ or N</td>
<td>↓ or N</td>
</tr>
<tr>
<td>Neurogenic</td>
<td>↓</td>
<td></td>
<td>↓</td>
<td></td>
<td>↑ or N</td>
</tr>
<tr>
<td>Hypovolemic</td>
<td>↑</td>
<td></td>
<td>↓</td>
<td></td>
<td>↓</td>
</tr>
<tr>
<td>Cardiogenic</td>
<td>↑</td>
<td></td>
<td>↑</td>
<td></td>
<td>↑</td>
</tr>
<tr>
<td>Obstructive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac tamponade</td>
<td>↑</td>
<td></td>
<td>↑</td>
<td></td>
<td>↑</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>↑</td>
<td></td>
<td>↑</td>
<td></td>
<td>↓ or N</td>
</tr>
</tbody>
</table>

CO = cardiac output; N = normal, ↑ = increase; ↓ = decrease. Reprinted with permission from ACCP Pulmonary Medicine Board Review. 25th ed. Northbrook, IL: American College of Chest Physicians; 2009.
CS Definition

- CS is a state of end-organ hypoperfusion due to cardiac failure with the following hemodynamic parameters –
  - Persistent hypotension – SBP < 80 to 90 mmHg or MAP 30 mmHg lower than baseline
  - Severe reduction in cardiac index (generally < 1.8 L/min [w/o support] or 2.0-2.2 L/min [w/support])
  - Adequate/elevated filling pressures (LVEDP/RA/RVEDP/PCWP etc.)
CS Pathophysiology

Systemic Inflammatory response syndrome (IL-6, TNF-α, NO)

- Cardiac output ↓
- Stroke volume ↓
- Hypotension
- Coronary Perfusion pressure ↓
- Systemic perfusion
- Hypoxemia

Ischemia

Compensatory vasoconstriction

Myocardial infarction
Myocardial dysfunction
Systolic
Diastolic

LVEDP
Pulmonary congestion

Revascularization

Progressive myocardial dysfunction

Relief of ischemia

Survival with good quality of life

Death
LVEF and CS
Clinical Presentation

- Cool extremities
- Decreased urine output
- Altered mental status
Causes of Cardiogenic Shock

- MI (most common)
- Aortic dissection
- PE
- Cardiac tamponade
- Cardiomyopathy (restrictive or dilated), myocarditis
- Medication overdose (beta/calcium-channel blockers)
- Cardiotoxic drugs (doxorubicin)
- Electrolyte abnormalities (calcium, phosphate)
- Valvular abnormalities (all comers)
- Takotsubo (Stress) Cardiomyopathy
Mechanical Complications To Consider

- VSD
- Contained free wall rupture
- Papillary muscle rupture
Other Issues to Consider

• Hemorrhage
• Infection
• Bowel ischemia
Markers of Worse Mortality

- Advanced age
- Anoxic brain damage*
- Low LVEF
- Low LV Power Index
- Lower SBP
- Need for vasopressor support
- AKI
- Elevated serum lactate
Epidemiology

- Most common cause is STEMI, Occurs in 5-8% of STEMI cases
- NSTEMI with 2.5% of cases
- 22-30% in IABP-SHOCK II and TRIUMPH Trials presented with NSTEMI
- In-hospital mortality = 59%
- Mild shock associated with 40% 30-day mortality; Refractory shock - >45%
- Accounts for 40,000-50,000 cases in the US annually
- 70-80% present with multi-vessel disease and have a higher mortality as c/t CS patients with single-vessel disease
# Cardiogenic Shock: United States

<table>
<thead>
<tr>
<th></th>
<th>AMI</th>
<th>PCCS</th>
<th>ADHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admissions / Surgeries</td>
<td>785,000</td>
<td>528,000</td>
<td>1 million</td>
</tr>
<tr>
<td>Shock Incidence</td>
<td>6% (5-8%)</td>
<td>1.0% (0.5 - 1.5%)</td>
<td>2.0% (1-3%)</td>
</tr>
<tr>
<td>Refr IABP / Inotropes</td>
<td>40% (30 – 50%)</td>
<td>75% (70 - 80%)</td>
<td>80% (70-90%)</td>
</tr>
<tr>
<td>Relative Incidence</td>
<td>1:40</td>
<td>1:150</td>
<td>1:60</td>
</tr>
<tr>
<td>Device Candidates</td>
<td>18,000</td>
<td>4,000</td>
<td>16,000</td>
</tr>
</tbody>
</table>

< 10% of device candidates are receiving support

AHA Heart Disease and Stroke Statistics-2011 Update
Treatment

• Only preventive therapy is coronary reperfusion
• Only mortality modifying therapy is coronary reperfusion
  • SHOCK Trial – No difference at 30-days, but significant reduction noted at ½, 1 and 6 years
  • NNT to save 1 life with early revascularization versus initial medical stabilization is <8
• Multi-vessel revascularization is recommended but only performed in 33% of patients*
• CULPRIT-SHOCK Trial
Treatment

Anti-thrombotic therapy – Cath Lab

- Aspirin
- Heparin
- Ticagrelor/Clopidogrel/Prasugrel (enteral absorption)
- Bivalirudin
- Kengreal
- Eptifibatide etc.
Treatment

Initial stabilization measures
- Volume expansion
- Ventilatory support
- Vasopressors (target MAP of 65-70 mmHg)*
- Inotropes
- Treatment for MODS
Dopamine versus Norepinephrine

- 1679 shock patients; 280 with CS
- Dopamine associated with significantly more arrhythmic events with no improvement in mortality
- Higher mortality as c/t norepinephrine (RR 0.75 [0.55-0.93])
Downside of Vasopressors

• Increase myocardial oxygen demand/consumption
• Impaired microcirculation and tissue perfusion
Inotropes

• Dobutamine
• Levosimendan
• Milrinone (phosphodiesterase-inhibitors)

All increase myocardial contractility without increasing oxygen requirements (afterload reducers)
Bleeding

20-90% of all patients with CS develop clinically significant bleeding depending upon definition

Influenced by whether a mechanical circulatory device is utilized

Blood transfusions increase mortality in CS
Cardiac Arrest

Therapeutic Hypothermia*
Evolution of Percutaneous Cardiac Support

- ECMO
- IABP
- PCPS
- Hemopump
- TandemHeart
- Impella

Decades:
- 70’s
- 80’s
- 90’s
- 00’s
Mechanical Support
Mechanical Support

- IABP - ~50,000 per year from 2007 to 2011 in US
  - Improved diastolic pressure with improved afterload
  - Improved coronary perfusion
  - AHA/ACC and ESC downgrades to IIb and IIIa based upon IABP-SHOCK II Trial
    (30-day mortality*, serum lactate, renal function, catecholamine doses, ICU stay)
- Impella (2.5/CP/5/RP)
- ECMO
- TandemHeart
PV Loop Changes vs. Treatment

**Inotropic Drugs**
- ESPVR shifts up
- Increases pressure, stroke volume, work

**IABP**
- Reduces aortic pressure “afterload”
- Stroke volume increases
- No change in work

**ECMO/CPS**
- Reduces ventricular volume (indirectly)
- Increases peak pressure (afterload)
- Increases work

**VAD/Impella**
- Reduces ventricular volume
- Reduces peak pressure
- Reduces work
Impella Catheters
Impella 2.5, CP, 5

- 2.5 - 5.0 L/min Active Forward Flow
- Single vascular access
- 9 Fr catheter; 12 (2.5), 21 Fr motor
- ~5 min set-up
- Perc or Surgical cut-down for femoral insertion
- Multiple insertion sites possible
- Operation independent of cardiac waveforms
Physiology of Impella

Myocardial Protection of Hemodynamic Support

Inflow (ventricle)

Outflow (aortic root)

EDV, EDP

AOP

Flow

O₂ Demand

O₂ Supply

Cardiac Power Output

Myocardial Protection

Systemic Hemodynamic Support
Myocardial Protection

Improvement in Myocardial Perfusion with Impella Support (Tc-99 MIBI Imaging)

Infarct Size as Proportion of Area at Risk (%)

<table>
<thead>
<tr>
<th>Group</th>
<th>Infarct Size (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>67.2 ± 4.6</td>
</tr>
<tr>
<td>IABP</td>
<td>65.0 ± 6.3</td>
</tr>
<tr>
<td>Impella 2.5</td>
<td>54.0 ± 8.0</td>
</tr>
<tr>
<td>Impella 5.0</td>
<td>41.6 ± 5.8</td>
</tr>
<tr>
<td>Impella 5.0</td>
<td>18.1 ± 10 (73%)</td>
</tr>
</tbody>
</table>

Decrease (3%) (20%) (38%) (73%)
ECMO

Defer to the subsequent talk
Therapy / Device Summary

Hemodynamic Support (CPO)

- Inotropes
- IAB + Inotropes
- Impella 2.5: forward flow
- TandemHeart: retrograde flow
- ECMO: retrograde flow
- Impella 5.0: forward flow

Myocardial Protection (PVA)

- Low
- Med
- High

Ease of Use

- Negative
- Positive

- Implantation
- Patient management
Impella 2.5 used for AMI Cardiogenic Shock (physician’s decision)

**Exclusion Criteria:**
- AMI patients with stable hemodynamics
- Other forms of Shock with no AMI
- Prophylactic support for high risk PCI
- Contra-indication to use Impella 2.5

**Inclusion Criteria:**
- STEMI or NSTEMI patients with Cardiogenic shock
- Shock defined clinically as:
  - SBP < 90mmHg for > 30min or need of inotropes to maintain SBP
  - or Cardiac index <2.2 l/min/m2
- Pump placed emergently to restore hemodynamics

**Survival to Discharge or 30-days**
Patient Characteristics
Prior to Impella Support Initiation

- Inotropes: 84%
- Acidemia pH<7.35: 77%
- Mechanical Ventilation: 58%
- Cardiogenic Shock > 6 hours: 54%
- On IABP support: 53%
- Cardiac Resuscitation: 46%
- Anoxic Brain Injury: 17%
Improvement of Hemodynamic and Metabolic Parameters with Impella

**Cardiac Index**
- Pre Impella: $1.9 \pm 0.7$
- On Impella: $2.8 \pm 0.7$

$p = 0.0001$

**Mean Arterial Pressure**
- Pre Impella: $61 \pm 18$
- On Impella: $94 \pm 23$

$p < 0.0001$

**pH**
- Pre Impella: $7.2 \pm 0.2$
- On Impella: $7.4 \pm 0.1$

$p < 0.0001$

**Wedge Pressure**
- Pre Impella: $32 \pm 12$
- On Impella: $20 \pm 11$

$P < 0.0001$
Outcome: Survival to Discharge Post PCI

**Survival to Discharge**
For ALL Patients
\[ p = 0.007 \]

**Pre-PCI**
- **STEMI**: 60.0%
  - N = 2
  - N = 6
  - Pre-PCI: 50.0%
  - Post-PCI: 69.6%
- **NSTEMI**: 60.0%
  - N = 2
  - N = 1
  - Pre-PCI: 50.0%
  - Post-PCI: 50.0%

**Post-PCI**
- **STEMI**: 37.7%
  - N = 2
  - N = 6
- **NSTEMI**: 37.7%
  - N = 2
  - N = 1

*Early implant pts had better survival rates in univariate and multivariate analyses*
Impella Pre-PCI associated with Improved Survival in AMI/CGS

IQ Database¹

- IABP/Inotropes Pre-PCI: 52% (N=3121)
- Impella Pre-PCI: 59% (N=2450)

P<0.001

CVAD Registry²

- IABP/Inotropes Pre-PCI: 41% (N=91)
- Impella Pre-PCI: 65% (N=63)

P<0.003

Increased Inotrope Exposure is associated with Mortality in AMI/CGS

Mortality and Number of Inotropes from cVAD Registry

- 0 inotropes: 32%
- 1 inotrope: 54%
- 2 inotropes: 65%
- 3 inotropes: 65%
- 4+ inotropes: 74%

P < 0.001 (N=287)

Mortality Percent Based on Immediate Post-Operative Inotrope Requirements

Samuels LE et al., J Card Surg. 1999

Detroit CSI AMI/CGS Pilot Study

- July 2016 to February 2017
  - all sites performed >10 AMICS cases w/ Impella within last calendar year
- Enrolled 37 patients
  - Age 63 +/- 13 years (36-87)
- Rapid Door to Unloading times (average 82 minutes)
- 62% supported w/ Impella Pre-PCI
- RHC use 84%
- 86% of patients established TIMI III flow
- Decrease Inotropic/Vasopressor use in 80% of cases

Hemodynamic Improvement
On Support

Cardiac Power Output¹
(CPO = MAP x CO)

0.56 Watts
0.96 Watts

58% increase
P < 0.001

N=21
N=27

CPO Pre-Impella
CPO On Impella

¹ Fincke, et al., Cardiac Power Is the Strongest Hemodynamic Correlate of Mortality in Cardiogenic Shock: A Report From the SHOCK Trial Registry. JACC, Vol. 44, No. 2, 2004
100% Native Heart Recovery in Survivors

Outcomes

- Survival to Explant
  - Metro Detroit Before Study: 51%
  - Detroit CSI: 89%

- Survival to Discharge
  - Detroit CSI: 84%

1. Abiomed Impella Quality (IQ) Database, Jan 2015 to July 2016 for Aggregate DTW Metro Hospitals AMI/CGS Survival to Explant
BI-PELLA
CARDIOGENIC SHOCK ALGORITHM

Cardiogenic Shock (AMI/Myocarditis/Takotsubo etc.)
Refractory to 1 Inotrope/Vasopressor

Echocardiogram

Coronary angiogram

PA Catheter

Pericardial Disease Tamponade

Cardiac Index > 2.2
Consider noncardiac origin or intra-cardiac shunt

+ Severe Aortic Insufficiency

Treat

Cardiac Index < 2.2

+ Hypoxemia or Persistent VT/VF

Impella 2.5/CP (ECMO TX)

RA < 15
PCWP < 18

Hypovolemia

Volume Resuscitation

RA < 15
PCWP ≥ 18

LV-Dominant

Acute LV AMCS (Impella 2.5/CP)

*IABP at MD Discretion

RA ≥ 15
PCWP < 18

RV-Dominant

PAPI > 1.0

Inotropes Vasodilators Diuresis

Acute RV AMCS (Impella RP)* ECMO TX

RA ≥ 15
PCWP ≥ 18

BiV-Dominant

PAPI > 1.0

Acute LV AMCS (Impella 2.5/CP)

PAPI < 1.0

Acute BiV AMCS (‘BiPella’)* ECMO TX

RA ≥ 15
PCWP ≥ 18

BiV-Dominant

PAPI < 1.0

Acute LV AMCS (Impella 2.5/CP)

Acute RV AMCS (Impella RP)* ECMO TX

Acute LV AMCS (Impella 2.5/CP)

Acute BiV AMCS (‘BiPella’)* ECMO TX

Lucas PD, ET, CRF, K, LA, V, RA, PCWP
Transfer Considerations

• Drips
• Catheter movement
• System Alarms
Thank You