Cardiogenic Shock: less stress for the pump

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Clinical Course of Chronic Heart Failure characterized by acute decompensation

<table>
<thead>
<tr>
<th>Time (Years)</th>
<th>NYHA I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compensated</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Acutely Decompensated</td>
<td></td>
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<tr>
<td>Chronically Decompensated</td>
<td></td>
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Episode of Acute Decompensation

Admission to ICU for Inotropic Treatment

Death
Prognosis of Patients with AHF admitted to the ICU

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

Adamopoulos et al., Eur. J. Heart Fail., 2007, 9:935
Assessment of left ventricular function in acute heart failure

Assessment of Ventricular Function
Left Ventricular Ejection Fraction

Reduced LVEF
- Systolic LV dysfunction
  - Transient Systolic Dysfunction

<40%

"Preserved" LVEF
- Diastolic Dysfunction
- Error in evaluation, Other causes of heart failure, Diagnostic error (no heart failure)
Clinical assessment of the acute heart failure patient

Adapted from Nohria, JAMA, 287, 2002

Adequate Peripheral Perfusion

Warm / Dry

Warm and Wet

Cold / Dry

Cold and Wet

Pulmonary congestion

Adapted from Nohria, JAMA, 287, 2002
Clinics and Hemodynamics of cardiogenic shock: Forrester classification

- Hypovolemic shock
  - Cardiac index: < 2.2 l.min⁻¹.m²
  - Tissue perfusion: Warm / Dry
  - Cardiac filling pressure: Normal
  - PAOP: > 18 mmHg

- Pulmonary edema
  - Cardiac index: > 2.2 l.min⁻¹.m²
  - Tissue perfusion: Warm / Wet
  - Cardiac filling pressure: PAOP: > 18 mmHg

- Cardiogenic Shock
  - Cardiac index: > 2.2 l.min⁻¹.m²
  - Tissue perfusion: Cold / Wet
  - Cardiac filling pressure: PAOP: > 18 mmHg

Forrester Am J Cardiol 1977 39:137
To restore cardiac function in order to meet body oxygen requirements, hence improve oxygen supply and organs perfusion.

Clinical goals

- Reduction of the clinical symptoms and signs of heart failure, restore oxygenation and diuresis

Hemodynamic goals (ESC Guidelines)

- Cardiac Index > 2.2 l.m⁻¹.m²
- Mean blood pressure > 70 mmHg
- Pulmonary artery occlusion pressure < 18 mmHg
Relationship between LVEF and hemodynamics on ICU admission

344 patients admitted to ICU with acute decompensated congestive heart failure

<table>
<thead>
<tr>
<th>Cardiac Index (l/min/m²)</th>
<th>&lt; 20%</th>
<th>20-30%</th>
<th>30-40%</th>
<th>&gt;40%</th>
<th>P &lt; 0.0003</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>81 ± 14</td>
<td>86 ± 16</td>
<td>92 ± 13</td>
<td>95 ± 14</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>RAP (mmHg)</td>
<td>13 ± 7</td>
<td>13 ± 6</td>
<td>14 ± 6</td>
<td>16 ± 7</td>
<td>ns</td>
</tr>
<tr>
<td>PAOP (mmHg)</td>
<td>26 ± 6</td>
<td>25 ± 6</td>
<td>26 ± 6</td>
<td>26 ± 6</td>
<td>ns</td>
</tr>
</tbody>
</table>

Uriel et al. et al., Eur. J. Heart Fail., 2005, 7:815
Targeting PAOP < 15 mmHg doesn't affect time to clinical resolution of congestion

Days alive and out of hospital

Impact of intervention across subgroups

ESCAPE Trial, JAMA 2005, 294:1695
Acute Heart Failure

Systolic dysfunction

Diastolic dysfunction
Acute Heart Failure

Immediate resuscitation? Patient distressed or in pain?
- yes
- no

Art. oxygen saturation > 95%?
- yes
- no

Normal heart rate and rhythm?
- yes
- no

Mean BP > 70mmHg?
- yes
- no

Adequate Preload?
- yes
- no

Adequate cardiac output?
- yes
- no

Adequate cardiac power?
- yes
- no

Reversal of metabolic acidosis, ScvO2 > 65%, clinical signs of adequate organ perfusion

monitoring

Clinic, Chest-x-ray, EVLW

Arterial line

Global end-diastolic volume

CO (Themodilution) ScvO2

Cardiac power output, Cardiac function index

FiO2, ev. CPAP, NIPPV

Pacing, atiarrhythmics etc.

Vasodilators, consider diuresis if volume overload

Volume bolus

Inotropics

CPR, Analgesia and sedation

Adapted from ESC Guidelines 2005
Cardiac power output

Definition: Is the power of the pump required to move blood through the circulation.

Cardiac power output (CPO) = cardiovascular flow * mean forward pressure

CPO (Watt) = (CO * MAP) / 451

Cotter et al. Curr Opin Cardiol 2003, 18:215
Cardiac Index and PAOP in different conditions of acute heart failure

Cardiac Index

Pulmonary artery occlusion pressure

Cotter et al. Eur J Heart Failure 2003, 5:443
Cardiac power output in different conditions of acute heart failure

Cotter et al. Eur J Heart Failure 2003, 5:443
Assessment of Cardiac Power Output using the PiCCO monitor

Blood Flow / Enddiastolic Volume relationship

- CFI = CI/GEDVI
- GEF = (CI/HR)/GEDVI

Cardiac Function Index

P<0.001

Ritter et al. (submitted)
Cardiac function index as a marker of cardiac performance

4 consecutive measurements within 19 hours in 12 acute heart failure patients

Relationship between cardiac function index and left ventricular stroke work index or cardiac power output

Ritter et al. Submitted 2008
Pulmonary artery occlusion pressure and mixed venous oxygen saturation as markers of cardiac performance

4 consecutive measurements within 19 hours in 12 acute heart failure patients

Relationship between cardiac function index and PAOP or SmapO2
Hemodynamic management using the PiCCO monitoring system

- Myocardial contractility
- Cardiac output
- Preload (GEDVI, 600-1000 ml/m²)
- Heart rate

Cardiac output:
- Flow = pressure / resistance
- CPO = Flow * pressure
- Pressure = Flow * resistance

Mean arterial pressure:

Cardiac power output:
- Cardiac Function Index
- Global ejection Fraction

Total systemic vascular resistance
Pulmonary vascular permeability index (PVPI) for the assessment of hydrostatic pulmonary edema

- 3 elements
- Pulmonary venous hypertension
- Pulmonary Blood Volume (PBV)
- Pulmonary vascular permeability

PVPI = EVLW / PBV

Monitoring changes in EVLW after ICU admission: a prognostic marker

- **3 elements**
  - Pulmonary venous hypertension
  - Pulmonary Blood Volume (PBV)
  - Pulmonary vascular permeability

### EVLW Evolution Cardiogenic pulmonary edema
Changes During first 3 ICU Days
Mean (SD) in Percent

<table>
<thead>
<tr>
<th></th>
<th>Survivors (17 Pts)</th>
<th>Non Survivors (9 Pts)</th>
</tr>
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<tbody>
<tr>
<td>Percent (%)</td>
<td>6.2% (20)</td>
<td>22.4% (10)</td>
</tr>
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</table>

\[ P = 0.03 \]

Ritter et al ESICM Berlin 2007
Hochman JS Circ 2003, 107:2998

Systemic inflammation

Inflammatory cytokines

↑ iNOS

NO

↑ ONOO

↓ Systemic perfusion

↓ Coronary perfusion pressure

Vasodilation

↑ Vessel permeability

Permeability type of Pulmonary edema

Myocardial Infarction

Myocardial Dysfunction

Systolic  Diastolic

Cardiac output

↓ Stroke volume

Hypotension

Compensatory vasoconstriction

Ischemia

Progressive
Myocardial dysfuncion

↑ LVEDP
Pulmonary congestion

Death