Hemodynamic Support/
Shock Resuscitation

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slides courtesy of Eric L. Sarin, MD
Hemodynamic Support

Overview

• Differential Diagnosis of Shock

• Interpretation of Invasive Monitoring

• Use of Inotropes & Pressors

• Mechanical Support

• Evidence Based Guidelines for Resuscitation
Defining Shock

• **Physiologic state characterized by significant, systemic reduction in tissue perfusion causing end-organ dysfunction**

• **Hypotension with**
  – altered mental status
  – oliguria/anuria
  – dry mucous membranes, cool/clammy skin
  – delayed capillary refill
Differential Diagnosis of Shock

- Hypovolemic
- Cardiogenic
- Distributive
Hypovolemic Shock

• Decreased preload
  – Hemorrhage
    • Trauma
    • GI source
    • Ruptured aneurysm
  – Fluid Loss
    • Burn injury
    • Enteral (diarrhea/vomiting)
    • 3rd spacing
Cardiogenic Shock

- Pump failure
  - Cardiomyopathy
    - Infarction
    - Dilated cardiomyopathies
    - Stunned/depressed myocardium
  - Arrhythmias
    - Atrial or ventricular
    - Bradycardia
  - Mechanical
    - Valvular
    - Septal defects
    - Tumor/myxoma
  - Obstructive/Extracardiac
    - Tension pneumothorax
    - Tamponade
    - Severe pulmonary hypertension
Distributive/ Vasodilatory Shock

- Septic
- Neurogenic
- Drug/Toxin
- Systemic Inflammatory Response
- Adrenal Insufficiency
Shock Hemodynamics

TYPES OF FIRE EXTINGUISHERS
their uses and their colour coding according to BS EN 3: 1996

- WATER: For wood, paper, textile and solid material fires. DO NOT USE on liquid, electrical or metal fires.
- POWDER: For liquid and electrical fires. DO NOT USE on metal fires.
- FOAM: For use on liquid fires. DO NOT USE on electrical or metal fires.
- CARBON DIOXIDE (CO₂): For liquid and electrical fires. DO NOT USE on metal fires.
this *can* be your friend
# Pulmonary Artery Catheter Measurements

**TABLE 9.1 Cardiovascular Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abbreviation</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central venous pressure</td>
<td>CVP</td>
<td>1–6 mm Hg</td>
</tr>
<tr>
<td>Pulmonary capillary wedge pressure</td>
<td>PCWP</td>
<td>6–12 mm Hg</td>
</tr>
<tr>
<td>Cardiac index</td>
<td>CI</td>
<td>2.4–4 L/min/m²</td>
</tr>
<tr>
<td>Stroke volume index</td>
<td>SVI</td>
<td>40–70 mL/beat/m²</td>
</tr>
<tr>
<td>Left-ventricular stroke work index</td>
<td>LVSWI</td>
<td>40–60 g · m/m²</td>
</tr>
<tr>
<td>Right-ventricular:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke work index</td>
<td>RVSWI</td>
<td>4–8 g · m/m²</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>RVEF</td>
<td>46–50%</td>
</tr>
<tr>
<td>End-diastolic volume</td>
<td>RVEDV</td>
<td>80–150 mL/m²</td>
</tr>
<tr>
<td>Systemic vascular resistance index</td>
<td>SVRI</td>
<td>1,600–2,400 dynes · sec¹ · cm²/m²</td>
</tr>
<tr>
<td>Pulmonary vascular resistance index</td>
<td>PVRI</td>
<td>200–400 dynes · sec¹ · cm²/m²</td>
</tr>
</tbody>
</table>

**TABLE 9.2 Oxygen-Transport Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed venous oxygen saturation</td>
<td>SvO₂</td>
<td>70–75%</td>
</tr>
<tr>
<td>Oxygen delivery</td>
<td>DO₂</td>
<td>520–570 mL/min/m²</td>
</tr>
<tr>
<td>Oxygen uptake</td>
<td>VO₂</td>
<td>110–160 mL/min/m²</td>
</tr>
<tr>
<td>Oxygen-extraction ratio</td>
<td>O₂ER</td>
<td>20%–30%</td>
</tr>
</tbody>
</table>

1. Rate/Rhythm
2. Preload
3. Afterload
4. Contractility

<table>
<thead>
<tr>
<th></th>
<th>Hypovolemic</th>
<th>Cardiogenic</th>
<th>Vasogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVP/PCWP</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>CO/CI</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>SVR/SVRI</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
</tr>
</tbody>
</table>
Pulmonary Artery Catheter (PAC) Controversy

- **JAMA, 1996**
  - 5 yr prospective, non-randomized, cohort study of 5735 pts at 5 hospitals
  - PACs in initial 24hrs assoc with increased mortality (OR = 1.24) in case-matched patients

- **Cochrane Rev, 2006** - 12 RCTs of PACs
  - 12 studies, most small (single hospital, N < 200)
  - Not dangerous, not helpful either
  - Similar meta-analysis in *JAMA*, 2005 with combined N=5051, 13 studies
PAC Controversy: muddied waters

- *Chest*, 2002- 417 physicians presented a vignette
  - PAC data improved Rx plans (initially, 35% proposed harmful Rx)
  - 10% persisted with harmful plans despite compelling PAC data

- *Int Care Med*, 2003- survey of 126 board-certified intensivists using 3 vignettes and 6 choices of Rx
  - #1 50%, i.e. only half could agree on Rx
  - #2 44%
  - #3 37%
• J Trauma, 1998-
  – 39 pts with EF <40% w/ 
    ↑ splanchnic perfusion, 
    improved pH with ↑ 
    preload compared to 
    inotropes 
  – No adverse affect on 
    pulmonary 
    function/ARDS
• NEJM, 2001- early goal 
  directed therapy (CVP 8-12) 
  improves mortality in septic 
  shock
• Circulation, 2004 (ACC/AHA) -
  – 250ml bolus for cardiogenic 
    shock, no evidence of pulm 
    edema 
  – Optimal PCWP ≈ 18-25
• Increased preload needed for 
  right sided infarction
• Maximize Starling curve
Crystalloid vs Colloid

• *Cochrane Rev*, 2004
  – meta analysis of 46 RCTs comparing crystalloids to colloids
  – No survival benefit using colloid
  – Expense not justified outside of a randomized trial

• *SAFE* Trial: *NEJM*, 2004
  – Multicenter RCT, N=6997
  – 4% albumin vs. saline for fluid resuscitation
  – No difference in: ICU days, vent days, 28-day mortality

*Saline vs. Albumin Fluid Evaluation*
Pressors and Inotropes

• Pharmacologic manipulation of alpha adrenergic, beta adrenergic, and/or dopamine receptors

• Rational use relies on understanding the following
  – One agent can affect multiple receptors
  – Dose-dependent nature of effects
  – Direct versus reflex actions

• Optimizing physiology
  – Stop bleeding, treat infection
  – Adequate volume
  – Physiologic milieu

• Frequent reevaluation
<table>
<thead>
<tr>
<th>Drug</th>
<th>Receptor</th>
<th>HR</th>
<th>Inotropy</th>
<th>SVR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dopamine</td>
<td>DA → β₁ → α₁</td>
<td>↑</td>
<td>↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>(1-20 mcg/kg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dobutamine</td>
<td>β₁β₂ &gt; α₁</td>
<td>↑</td>
<td>↑↑</td>
<td>↓↓</td>
</tr>
<tr>
<td>(2.5-20 mcg/kg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>α₁α₂β₁</td>
<td>↑</td>
<td>↑↑</td>
<td>↑↑↑↑</td>
</tr>
<tr>
<td>(0.5-20 mcg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epinephrine</td>
<td>α₁α₂β₁β₂</td>
<td>↑↑</td>
<td>↑↑↑</td>
<td>↑↑↑</td>
</tr>
<tr>
<td>(2-10 mcg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenylephrine</td>
<td>α₁</td>
<td>0</td>
<td>0</td>
<td>↑↑↑</td>
</tr>
<tr>
<td>(20-200 mcg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoproterenol</td>
<td>β₁β₂</td>
<td>↑↑↑</td>
<td>↑↑</td>
<td>←→↓</td>
</tr>
<tr>
<td>(1-10 mcg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Pressors**

- **Vasopressin** - direct effect on vascular smooth muscle causing vasoconstriction
  - *Circulation*, 2003; *Anesth*, 2002:
    - Addition of vasopressin to norepinephrine improves outcomes in distributive shock
    - Norepinephrine alone → higher dose, more arrhythmias (7X), lower urine output

- **Milrinone** - phosphodiesterase inhibitor
  - ↑ cAMP levels = ↑ Ca\(^{++}\) = ↑ contractility
  - Peripheral actions limit use in hypotension, 1° use in heart failure
Mechanical Support
Intra-aortic balloon pump

• Inserted via femoral artery into descending aorta
• Inflation/deflation synchronized with cardiac cycle
• Augments coronary diastolic flow, decreases afterload
• Contraindications: Aortic insufficiency, ileofemoral disease
• Other modes:
  – Ventricular Assist Device (VAD)
  – Cardiopulmonary Bypass (CPB)
  – Extracorporeal Membrane Oxygenation (ECMO)
Goal-Directed Therapy (GDT)

- *NEJM*, 2001- application of GDT for septic shock in ED (N=263)
  - N = 263; single hospital
  - 2+ SIRS criteria & SBP < 90 or lactate > 4
- Randomized to 6hrs of GDT vs control** prior to ICU admission
- Overall mortality reduced from 46.5% to 30.5%

* T<36 or >38C; HR>89; RR>19; WBC <4k or >12k
**typically, CVP > 8-12 & MAP > 65 & UO > 0.5cc/kg/h
Conclusions

• Shock can be multifactorial & PACs can be helpful adjuncts to therapy

• Early recognition and prompt initiation of treatment are key

• Goal-directed resuscitation improves outcomes