Hemodynamics: Interpretation of Right Heart Cath Findings

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Objectives

1. Participants will be able to recognize different waveforms and what part of the heart they are coming from.

2. Participants will gain knowledge of what the normal values of right heart measurements are and how to interpret abnormal values.
Conflict of interest

- Nothing to disclose
Agenda

- History
- Indications and contraindications
- Technique
- Cardiac cycle
- Pressure wave interpretation
- Cardiac output
- Normal values
- Common RHC findings
- Summary
History

- Stephen Hales (1711): obtaining pressure from a horse jugular vein
- Claude Bernard (1844): obtaining pressures from cardiac chambers of a horse (heart catheterization)
- Adolph Fick (1870): calculation of blood flow
- Werner Forssmann (1929): first heart catheterization of a living human under fluoroscopic guidance (on himself)
- Sven Seldinger (1953): percutaneous method of entry into vein/artery (before that it was “cut-down” technique)
Indications

- Shock: causes, fluid management and hemodynamic monitoring
- Pulmonary hypertension: diagnosis (gold standard) and assessing response to therapy
- Valvular disease: when non-invasive assessment is equivocal
- Intracardiac shunts
- Constrictive vs restrictive physiology
Contraindications

❖ Absolute: right-sided endocarditis, intracardiac mass/thrombus (RA or RV), mechanical valve (tricuspid or pulmonary)
❖ Relative: LBBB, severe coagulopathy, recent pacemaker placement
Technique
Technique

- Place an introducer: IJ, SC or femoral
- Inspect, flush all ports and test the balloon; connect distal (yellow) port to pressure transducer; zero the transducer; turn other ports OFF
- Place *swandom* (repositioning sheath) on catheter if it is to stay for hemodynamic monitoring
- Insert about 15 cm and inflate the balloon
- Slowly and steadily advance catheter while watching waveforms or under fluoroscopy
- If difficulty getting into PA: Valsalva, HOB up, 0.025 wire
Technique - tips

- Establish the zero level and balance the transducer
- Confirm the scale of the recording (40 mmHg for RHC, 200 mm Hg for LHC)
- Collect hemodynamics in a systematic manner
- Always record pressures at end-expiration (during inspiration pressures will be lower due to decrease in intrathoracic pressure)
- Carefully assess pressure waveforms for proper fidelity and timing with ECG
## Technique

### Typical Catheter Insertion Landmarks

<table>
<thead>
<tr>
<th>Anatomic Structure</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right atrium</td>
<td>20 to 25 cm</td>
</tr>
<tr>
<td>Right ventricle</td>
<td>30 to 35 cm</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>40 to 45 cm</td>
</tr>
<tr>
<td>Pulmonary capillary wedge</td>
<td>45 to 55 cm</td>
</tr>
</tbody>
</table>
Simultaneous Right- and Left-Heart Catheterization

- 1. PA catheter to PA (pulmonary artery)
- 2. Measure thermodilution CO (x3) and measure O2 sat in PA and Ao blood samples (for Fick CO and screen for shunt)
- 3. Record Ao pressures w Ao catheter (pigtail); cross the AV into LV - wedge the PA catheter - measure simultaneous LV/PCWP (mitral valve assessment)
- 4. Pull back from PCWP to PA (traspulmonary gradient)
- 5. Pull back from PA to RV (screen for pulmonic stenosis) and record RV
- 6. Record simultaneous LV/RV (constriction vs restriction)
- 7. Pull back from RV to RA (screen for tricuspid stenosis) and record RA
- 8. Pull back from LV to Ao (screen for aortic stenosis)
Pressure wave interpretation - RA

- Atrial contraction
- Tricuspid valve elevation into the right atrium
- Downward movement of the contracting right ventricle
- Back-pressure wave from blood filling the right atrium
- Tricuspid valve opens in early ventricular diastole
- Contraction of the right ventricle

Graphs showing pressure and time with annotations for "x" and "y" points in inspiration.
Pressure wave interpretation - RV
Pressure wave interpretation - PA
Pressure wave interpretation - PCWP
Cardiac output - thermodilution

- Bolus injection of saline into proximal port
- Change in temperature is measured by thermistor in the distal portion of the catheter
Cardiac output - Fick

- Assumes rate of O2 consumption is a function of the rate of blood flow times the rate of O2 pickup by the RBC
- O2 consumption: direct or indirect measurement (3 ml O2/kg)

\[
\text{FICK C.O.} = \frac{O_2 \text{ consumption (VO}_2\text{) mL/min}}{\text{AVO}_2 \text{ difference} \times 10} \\
= \frac{3 \text{ mL O2} \times \text{ weight (Kg)}}{((Hgb \times 1.36 \times AO \text{ sat}) - (Hgb \times 1.36 \times PA \text{ sat})) \times 10}
\]
Cardiac output - limitations

- **Thermodilution**
  - Not accurate in tricuspid regurgitation
  - Overestimates CO at low output states

- **Fick**
  - O2 consumption is often estimated by body weight (rather than measured directly)
  - Large errors possible with small differences in saturations and hemoglobin
  - Measurements on room air
# Normal values

## Normal Pressures

<table>
<thead>
<tr>
<th>Site</th>
<th>Normal Value (mmHg)</th>
<th>Mean Pressure (mmHg)</th>
<th>Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Atrium (or CVP)</td>
<td>0-5</td>
<td></td>
<td>75%</td>
</tr>
<tr>
<td>Right Ventricle</td>
<td>25/5</td>
<td></td>
<td>75%</td>
</tr>
<tr>
<td>Pulmonary Artery</td>
<td>25/10</td>
<td>10-20</td>
<td>75%</td>
</tr>
<tr>
<td>PCWP</td>
<td>7-12</td>
<td></td>
<td>95-100%</td>
</tr>
<tr>
<td>LV</td>
<td>120/10</td>
<td></td>
<td>95-100%</td>
</tr>
<tr>
<td>Aorta</td>
<td>120/80</td>
<td></td>
<td>95-100%</td>
</tr>
</tbody>
</table>
Normal Values

<table>
<thead>
<tr>
<th>Site</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sv02</td>
<td>0.60-0.75</td>
</tr>
<tr>
<td>Stroke Volume</td>
<td>60-100 ml/beat</td>
</tr>
<tr>
<td>Stroke Index</td>
<td>33-47 ml/beat/m2</td>
</tr>
<tr>
<td>Cardiac Output</td>
<td>4-8 L/min</td>
</tr>
<tr>
<td>Cardiac Index</td>
<td>2.5-4.0 L/min/m2</td>
</tr>
</tbody>
</table>

- SVR: 800-1200 dynes sec/-cm5
- PVR: <250 dynes sec/-cm5
- MAP: 70-110 mmHg

Derived parameters from cardiac output

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Calculation</th>
<th>Normal values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke Volume (Index)</td>
<td>Cardiac output × 1000 ÷ Heart rate (using cardiac index to give the stroke volume index)</td>
<td>60 – 100 ml/beat (35 – 47 ml/m²-beat)</td>
</tr>
<tr>
<td>Systemic Vascular Resistance (Index)</td>
<td>(MAP – RAP) ÷ 80 Cardiac Output (Index)</td>
<td>1000 – 1500 dyne s/cm² (1700 – 2300 dyne s/cm²/m²)</td>
</tr>
<tr>
<td>Pulmonary Vascular Resistance (Index)</td>
<td>(MPAP – PAWP) ÷ 80 Cardiac output (Index)</td>
<td>&lt;250 dyne s/cm² (255 – 295 dyne s/cm²/m²)</td>
</tr>
<tr>
<td>Left Ventricular Stroke Work (Index)</td>
<td>(MAP – PAWP) × SV (LV) × 0.0136</td>
<td>58 – 104 gm-m/beat (60 – 112 gm-m/m²/beat)</td>
</tr>
<tr>
<td>Right Ventricular Stroke Work (Index)</td>
<td>Cardiac output (Index)</td>
<td>8 – 16 gm-m/beat (8 – 16 gm-m/m²/beat)</td>
</tr>
</tbody>
</table>

MAP = mean arterial pressure; RAP = right atrial pressure (i.e., CVP); PAWP = pulmonary artery wedge pressure; MPAP = mean pulmonary artery pressure; PAWP = pulmonary artery wedge pressure; SV = stroke volume; SF = static filling; BP = blood pressure; 119 and 8.10220 are the numbers required for conversion to the units of measurement.
Common RHC findings: Shock

**Table 1: Hemodynamic Profile of Shock States**

<table>
<thead>
<tr>
<th>Physiologic Variable</th>
<th>Preload</th>
<th>Pump Function</th>
<th>Afterload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Measurement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Central Venous</td>
<td>Cardiac Output</td>
<td>Systemic Vascular Resistance</td>
</tr>
<tr>
<td></td>
<td>Pressure*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypovolemic</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Cardiogenic</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Distributive**</td>
<td>↓ or ↔</td>
<td>↑</td>
<td>↓</td>
</tr>
</tbody>
</table>

**Figure 1: Hemodynamic profile of shock states.**
Common RHC findings: Mitral Stenosis

**Mean Mitral Gradient**
- 15 mm Hg
- 6 mm Hg

*LV* (Left Ventricle) and *PAWP* (Pulmonary Artery Occlusion Pressure) are shown in the diagram.
Common RHC findings: AS vs HOCM

- Aortic stenosis: fixed obstruction
- HOCM: dynamic obstruction (Brockenbrough phenomenon)
Common RHC findings: restriction

Hemodynamics of Restrictive Physiology

- Elevated left- and right-sided filling pressures
- “Square root” sign in ventricular pressure recordings
- LV-RV EDP diff>5mmHg
- Respiratory LV-RV systolic “concordance“
Common RHC findings: restriction vs contraction

- Restriction: concordant
- Constriction: discordant
Common RHC findings: Tamponade
Summary

- **Left heart failure**: Low CI, high PCWP, high SVR
- **Right heart failure**: Low CI, high CVP, high PVR
- **Tamponade**: low CI, high PCWP = high CVP

- **Hypotension**
- Hypovolemia: low CI, low PCWP, low CVP, high SVR
- Cardiogenic: low CI, high PCWP, high CVP, high SVR
- Sepsis: high CI, low PCWP, low CVP, low SVR
Thank you!
Stay safe!