**Interpretation**

**Critical Care Monitoring**

Hemodynamic Monitoring Interpretation

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**Hemodynamic Monitoring**

- Is easy!
- Don’t work to make it hard!!!
Interpretation

**Hemodynamic Monitoring**

- Circulation occurs because of blood pressure

\[ \text{. Hemodynamics} = \]

**Physiology of BP**

- Without enough BP, tissues will not receive needed oxygen & nutrients

- However, high BP strains the heart & will eventually cause heart failure

**Physiology of BP**

- If BP $\uparrow$ →
- If BP $\downarrow$ →

- Arterial BP can change w/o affecting venous BP so must measure all BP’s
Interpretation

Control of BP - 3 factors

• Heart
  • Pump that creates pressure gradient
  • Changes in the heart itself will directly affect BP:
    †HR or strength of contraction →
    ↓ HR or strength of contraction →

Control of BP - 3 factors

• Blood
  • Amount of fluid in circulatory system affects BP:
    †blood volume →
    ↓ blood volume →

Control of BP - 3 factors

• Vessels
  • Tone of the blood vessels affect BP:
    vasoconstriction →
    vasodilation →
Control of BP

- We can manipulate all 3 factors that control BP
  - HR, contractility (epinephrine, Dopamine)
  - Blood volume (diuretics)
  - Vessel tone (epinephrine, Nitroprusside, Dopamine)

- Changes in hemodynamic measurements will reveal which of the 3 has been altered

Normal Pressures

- “Rule of 4’s”
  - Heart has 4 chambers
  - Each chamber serves 1 of the 4 circulatory branches:
    - LV -
    - RA -
    - RV -
    - LA -

Normal Pressures

- Each chamber & connecting artery or venous system has its own BP - 4 pressures
  - LV - systemic arteries -
  - RA - systemic veins -
  - RV - pulmonary arteries -
  - LA - pulmonary veins -

- Hemodynamics measures each of these pressures
Interpretation

**Normal Pressures (mmHg)**

- Leave capillaries
- In capillaries
- Enter capillaries

Interpretation

**Cardiac Output**

1. Must be the same from both ventricles
2. Normally =
3. If not:

   - HR
   - RVSV
   - LVSV

   \[ \text{HR} \times \text{RVSV} \times \text{60 min} = 420 \text{ liters} \]
   \[ \text{HR} \times \text{LVSV} \times \text{60 min} = 419.4 \text{ liters} \]

   Where is that 600 ml?

Interpretation

**CVP**

- CVP = RAP = RVEDP = RV preload
- Measures pressure in the systemic venous system
- Much lower than mean ABP
- Since most of blood is in the venous system, changes in the CVP reflect changes in vascular volume . . . .
**CVP**

CVP used to monitor vascular fluid levels & right heart function

- Treat when -
- Transducer at level of RA

<table>
<thead>
<tr>
<th>Condition</th>
<th>CVP</th>
<th>PAP</th>
<th>PCWP</th>
<th>QT</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV Failure</td>
<td>↑</td>
<td>(N) ↓</td>
<td>(N) ↓</td>
<td>(N) ↓</td>
</tr>
<tr>
<td>Hypervolemia</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

**PAP**

- Measures blood moving through the pulmonary arteries into the lungs

  Increases in PAP occur in lung disease/↑ PVR
### Interpretation

#### PAP

<table>
<thead>
<tr>
<th>Condition</th>
<th>CVP</th>
<th>PAP</th>
<th>PCWP</th>
<th>QT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung Problems</td>
<td>↑</td>
<td>↑</td>
<td>(N)↓</td>
<td>(N)↓</td>
</tr>
<tr>
<td>COPD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary emboli</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARDS (Pulm. edema)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypervolemia</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

#### PCWP

- \( \text{PCWP} = \text{PWP} \neq \text{LAP} \neq \text{LVEDP} \neq \text{LV} \) preload
- When BTFDC “wedged” - no longer measures forward flow of blood
- Measures back pressure from pulm. veins which are in direct communication with left heart

#### PCWP

**PCWP monitors left heart**

- (LV & mitral valve)

- Treat when -
Interpretation

**PCWP**

<table>
<thead>
<tr>
<th>Condition</th>
<th>CVP</th>
<th>PAP</th>
<th>PCWP</th>
<th>QT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Heart Problems</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>(N)↓</td>
</tr>
<tr>
<td>LV failure</td>
<td></td>
<td></td>
<td></td>
<td>&gt;12 mmHg</td>
</tr>
<tr>
<td>Mitral valve stenosis</td>
<td></td>
<td></td>
<td></td>
<td>&gt;18 mmHg</td>
</tr>
<tr>
<td>Cardiogenic pulm. edema</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High PEEP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypervolemia</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

**Hypervolemia**

- ↑  
- ↑  
- ↑  
- ↑

**Hypovolemia**

- ↓  
- ↓  
- ↓  
- ↓

**Right heart**

<table>
<thead>
<tr>
<th>Condition</th>
<th>CVP</th>
<th>PAP</th>
<th>PCWP</th>
<th>QT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right heart</td>
<td>↑</td>
<td>(N)↓</td>
<td>(N)↓</td>
<td>(N)↓</td>
</tr>
<tr>
<td>Lung Problems</td>
<td>↑</td>
<td>↑</td>
<td>(N)↓</td>
<td>(N)↓</td>
</tr>
<tr>
<td>Left heart</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Hypervolemia</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

**Hansen’s Helpful Hint #1**

- ↑ PAP + normal PCWP =

- ↑ PAP + ↑ PCWP =
Interpretation

Hansen’s Helpful Hint #2

PAd - PCWP:

Hansen’s Helpful Hint #3

PCWP cannot be >

Trivia To Remember

- Preload =
- Afterload =
- BTFDC tip should lie in a Zone III artery
- \( Q_T \downarrow \rightarrow O_2 \text{ extraction } \uparrow \rightarrow P_{vO_2}, S\text{vO}_2 \downarrow \rightarrow C(a-v)O_2 \uparrow \)
- \( S\text{vO}_2 \) is best indicator of tissue oxygenation
Interpretation

**Problem #1**
56 yof, post-op chole, MVS

<table>
<thead>
<tr>
<th>BP (mmHg)</th>
<th>1500 hrs</th>
<th>1700 hrs</th>
<th>1900 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>128/100</td>
<td>126/90</td>
<td>100/60</td>
<td></td>
</tr>
<tr>
<td>CVP (cmH₂O)</td>
<td>10</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>HR</td>
<td>88</td>
<td>96</td>
<td>126</td>
</tr>
</tbody>
</table>

**Problem #2**

- 64 yom

  - PAP: 40/26 mmHg
  - PCWP: 18 mmHg
  - CVP: 10 cmH₂O
  - Q₇: 3.4 lpm

**Problem #3**

- 70 kg. male

  - PAP: 53/34 mmHg
  - PCWP: 28 mmHg
  - CVP: 10.6 cmH₂O
  - C(a-β)O₂: 2.7 vol%
**Problem #4**

- ICU patient
  
  \[
  \begin{align*}
  \text{PAP} & \quad 26/8 \text{ mmHg} \\
  \text{PA mean} & \quad 15 \text{ mmHg} \\
  \text{PCWP} & \quad 28 \text{ mmHg} \\
  \dot{Q}_T & \quad 6.0 \text{ lpm}
  \end{align*}
  \]

**Problem #5**

- 68 yof
  
  \[
  \begin{align*}
  \text{PAP} & \quad 52/30 \text{ mmHg} \\
  \text{PCWP} & \quad 10 \text{ mmHg} \\
  \text{CVP} & \quad 12 \text{ mmHg} \\
  \dot{Q}_T & \quad 3.9 \text{ lpm}
  \end{align*}
  \]

**Problem #6**

- 50 kg. patient
  
  \[
  \begin{align*}
  \text{PAP} & \quad 43/21 \text{ mmHg} \\
  \text{PCWP} & \quad 3 \text{ mmHg} \\
  \text{CVP} & \quad 12 \text{ cmH}_2\text{O} \\
  \dot{Q}_T & \quad 3.9 \text{ lpm} \\
  \text{C(a-v)O}_2 & \quad 7.2 \text{ vol%}
  \end{align*}
  \]
Interpretation

**Practice Problem #1**

Which of the following disorders is known to cause the PCWP to become elevated?

a. ARDS
b. LVF
c. RVF
d. hypervolemia
e. increased PVR

**Practice Problem #2**

Data of 70 kg patient in ICU:

| PAP  | 53/39 mmHg |
| PCWP | 32 mmHg    |
| \(\dot{Q}_t\) | 3.4 lpm |
| C(a-v)O\(_2\) | 7.3 vol% |
| Temp. | 36.8\(^\circ\)C |

Which of the following drugs would the RCP be least likely to recommend?

a. Dopamine
b. morphine sulfate
c. oxygen
d. propanolol (Inderol)
e. furosemide (Lasix)

**Practice Problem #3**

Data of 70 kg patient in ICU:

| PAP  | 60/38 mmHg |
| PCWP | 26 mmHg    |
| \(\dot{Q}_t\) | 11.7 lpm |
| C(a-v)O\(_2\) | 1.9 vol% |
| \(\dot{V}O_2\) | 285 ml/min |

Which of the following is most likely to be responsible for this patient’s elevated PCWP?

a. hypervolemia
b. hypovolemia
c. LVF
d. ARDS
e. RVF
Interpretation

**Practice Problem #4**

Data of 70 kg. patient in ICU:

- PAP: 22/6 mmHg
- PCWP: 2 mmHg
- C(a-v)O$_2$: 7.9 vol%
- Temp.: 37°

Which of the following assessments regarding this patient is true?

- Patient is hypovolemic.
- LVF exists.
- The Q$_{T}$ is decreased.
- Pulm. edema is inevitable.

**Practice Problem #5**

RCP is monitoring a patient in ICU:

- PAP: 23/7 mmHg
- PCWP: 26 mmHg
- PA mean: 16 mmHg
- Q$_{T}$: 10.6 lpm

Which of the following is the most appropriate assessment?

- Data is in error
- LV dysfunction exists
- PVR is increased
- Patient is hypovolemic
- Normal study

**Practice Problem #6**

Data of 50 kg. patient in ICU:

- CVP: 10 mmHg
- PAP: 43/21 mmHg
- PCWP: 2 mmHg
- Q$_{T}$: 2.9 lpm
- C(a-v)O$_2$: 8.2 vol%
- VO$_2$: 280 ml/min

Which of the following is(are) true statements?

- LVF exists.
- Patient is hypovolemic.
- CV reserves are excellent.
- PVR is increased.
Practice Problem #7

28 yo, 4 days post- Fx femur: Which of the following is most likely responsible?

RR 40/min
PAP 44/27 mmHg
PCWP 6 mmHg
Q_1 5 lpm
BP 85/50 mmHg

a. LVF exists.
b. Patient is hypervolemic.
c. Pulm. emboli are present.
d. PVR is increased.

Practice Problem #8

Data of 70 kg. patient in ICU: Which of the following mechanisms is(are) responsible for the low Q_1?

PCWP 36 mmHg
Q_1 3.1 lpm
C(a-v)O₂ 7.9 vol%
VO₂ 245 ml/min

a. RVF
b. LVF
c. hypovolemia
d. increased PVR
e. ARDS

Practice Problem #9

Data of 70 kg. patient in ICU: Which of the following mechanisms is(are) responsible for the low Q_1?

PCWP 3 mmHg
Q_1 3.1 lpm
C(a-v)O₂ 7.9 vol%
VO₂ 245 ml/min

a. RVF
b. LVF
c. hypovolemia
d. ARDS
1. Which of the following hemodynamic values can be measured with a 4 lumen balloon tipped flow directed catheter in place.
   I. MAP
   II. CVP
   III. PAP
   IV. PAD
   V. Cardiac Output
   A. I,II and V only
   B. I,III,IV and IV only
   C. II,III and IV only
   D. II,III,IV and V only
   E. I,II,III,IV and V

2. The CVP is used to monitor:
   I. fluid volume
   II. urine output
   III. cardiac output
   IV. circulatory dynamics
   V. pulmonary artery pressure
   A. I and IV only
   B. II and III only
   C. I,III and IV only
   D. II,IV and V only
   E. I,II,III,IV and V

3. A patient's blood pressure has been recorded, using a cuff and sphygmomanometer as 120/80. What is the mean arterial pressure?
   A. 80 mmHg
   B. 90 mmHg
   C. 90 mmHg
   D. 108 mmHg
   E. 117 mmHg
4. Mean pulmonary artery pressure is normally:
   A. 8 mmHg
   B. 15 mmHg
   C. 25 mmHg
   D. 30 mmHg
   E. 35 mmHg

5. As the BTPC is wedged into the pulmonary artery the wedge pressure approximates:
   A. pulmonary artery pressure
   B. left ventricular pressure
   C. right heart pressure
   D. left ventricular and diastolic pressure
   E. right ventricular pressure

6. Which of the following formulas represent cardiac output?
   I. stroke volume x heart rate
   II. heart rate x diastolic pressure
      systolic pressure
   III. Stroke volume
      x diastolic volume
   IV. \( \frac{\text{CO}}{\text{Qc}} = (\text{CaO}_2 - \text{CvO}_2) \times 10 \)
   A. I only
   B. I and III only
   C. I and IV only
   D. II and IV only
   E. I, II, III, and IV
7. The pulmonary artery pressure has increased from a mean of 17 mm Hg to 28 mm Hg and the pulmonary capillary wedge pressure is 9 mm Hg. Which of the following is the most probable cause of this change?
   A. high PEEP effects
   B. hemorrhage
   C. overhydration
   D. pulmonary hypertension.
   E. mitral valve stenosis

8. The Respiratory Therapy Practitioner is unable to get a pulmonary capillary wedge pressure. Which of the following could be substituted for the wedge pressure?
   A. left ventricular systolic pressure
   B. right ventricular systolic pressure
   C. pulmonary artery systolic pressure
   D. pulmonary artery diastolic pressure
   E. mean right atrial pressure

9. What does preload refer to?
   A. filling of the heart during systole
   B. filling of the heart during diastole
   C. cardiac output
   D. pressure needed to force the blood from the ventricles
   E. systemic vascular resistance
10. What does afterload refer to?
A. Filling of the heart during systole
B. Filling of the heart during diastole
C. Cardiac output
D. Pressure needed to force the blood from the ventricles
E. Systemic vascular resistance

11. A respiratory therapy practitioner has inserted a balloon-tipped, flow-directed catheter and has taken the following measurements.
CVP 4 mm Hg
PAP 8 mm Hg
PWP 2 mm Hg
OC 2.5 L/min
Which of the following is the most probable cause of these values?
A. High PEEP effects
B. Hemorrhage
C. Overhydration
D. Pulmonary hypertension
E. Mitral valve stenosis

12. A patient is receiving mechanical ventilation with an N21 ventilator in the control mode with the following parameters.
VT 600 ml
FIO2 .60
Rate 16
PEEP 40 l/min
PEEP 20 cm H2O
Hemodynamic measurements are as follows.
CVP 6 mm Hg
PAP 28 mm Hg
PWP 15 mm Hg
OC 4.5 L/min
Which of the following is the most probable cause of these values?
A. High PEEP effects
B. Hemorrhage
C. Overhydration
D. Pulmonary hypertension
E. Mitral valve stenosis
13. A 70 kg (154 lb) patient with a history of congestive heart failure is admitted to the hospital and placed on a mechanical ventilator. A n-size CVP catheter is inserted and the following measurements are taken: CVP 12 cm H2O, pulmonary artery mean pressure 25 torr, pulmonary wedge pressure 16 torr and cardiac output is 4.8 L/min. Which of the following is the most probable cause of these values?
A. High PEEP effect
B. Hemorrhage
C. Overhydration
D. Pulmonary hypertension
E. Mitral valve stenosis

14. An 80 kg (176 lb) patient with a BTEDC in place has the following hemodynamic parameters:
PAP 70 mm Hg
PWP 19 mm Hg
C.O. 2.5 L/min
Which of the following is true for these results?
I. The results could be caused by left ventricular failure.
II. The results show increased left ventricular preload.
III. The results show increased right ventricular afterload.
IV. The results show increased pulmonary vascular resistance.
V. The results could be caused by mitral valve stenosis.
A. I and II only
B. II, III, and V only
C. III and IV only
D. I, II, III, IV and V only
E. I, II, III, IV and V

15. A 60 kg (132 lb) patient receiving CPAP via mask has a balloon-tipped, flow-directed pulmonary artery catheter in place. Results of hemodynamic monitoring are as follows: PAP 37 torr, PAP 25 torr, Cardiac Output 3.0 L/min. Possible explanations for these results include:
I. Left ventricular failure
II. Decrease pulmonary vascular resistance
III. Hypovolemia
IV. Hypertension
V. Mitral valve stenosis
A. I and II only
B. II, III and V only
C. III and IV only
D. I and V only
E. I, II, III, and V only