**Pulmonary Artery Catheter**

- **CVP** measures right atrial pressure and is used as a clinical indicator of RV preload
  - Normal CVP = 2-6 mmHg
- **PWP** reflects left atrial pressure and is used as a clinical indicator of LV preload
  - Normal PWP = 8-12 mmHg

- **PVR** is a calculated value based on mean PA pressure and PWP and is used as a clinical indicator of RV afterload
  - Normal PVR = < 250 dynes
- **SVR** is a calculated value based on mean arterial pressure and CVP and is used as a clinical indicator of LV afterload
  - Normal SVR = 900-1200 dynes

In order for these calculated values to be accurate, the parameters they are based on need to be accurate: CVP & PWP
**Hemodynamic Monitoring:**
Getting Accurate Data From a Pulmonary Artery Catheter

**Pressure Monitoring System**

- **Fluid System**
  - **Fluid source:** IV bag of 500 cc of NS
    - Caution: if patient has history of or suspected heparin induced thrombocytopenia (HIT) DO NOT use heparin in flush solution!
  - A continuous fluid filled line from the IV bag to the transducer and from the transducer to the catheter tip is needed in order to monitor pressures.
  - **Pressure bag:** IV bag must be pressurized at 300 mmHg to overcome the resistance of the flush device in the transducer and to deliver 3ml per hour through the catheter to keep the line from clotting off.

- **Tubing:** high pressure rigid tubing is necessary to accurately transmit vascular pressures to the transducer.
- **Transducer with flush device:** contains a one-way valve that allows 3ml/hr of fluid to pass through unless the resistance is released by pulling the tail or pushing the lever on the device which allows the line to run wide open.
- **PA Catheter**

- **Electrical System**
  - **Transducer:** contains fine wires that move back and forth with pressure changes and convert the pressure to an electrical signal that is sent to the monitor. Must be filled with fluid and be bubble-free to accurately transmit pressure.
  - **Connecting cable:** connects the transducer to the bedside monitor and transmits the electrical signal to the monitor.
  - **Monitor:** converts electrical signal to a waveform and displays it on the screen.

**AACN Practice Alert for Pulmonary Artery Pressure Monitoring - 2009**

- Perform square waveform test each shift
- Position patient supine with HOB between 0° – 60°, lateral, or prone (allow 15 minutes to stabilize before reading pressures)
- Level stopcock air-fluid interface to phlebostatic axis
- Use graphic tracing that includes the ECG
- Take measurements at end expiration (or adjust if airway release ventilation or active expiration)
**Square Waveform Test**

**“Fast Flush”**

- Determines ability of transducer to correctly reflect pressures in PA
- Identifies system problems
  - Air bubbles
  - Tubing too long
  - Loose connections
  - Loss of pressure on bag
  - Catheter patency

**Method of Performing Test**

- Verify 300 mmHg pressure on bag
- Pull pigtail and release - watch response of system on monitor
- If abnormal
  - Tighten connections
  - Pump up bag
  - Flush system
- Change transducer and tubing to patient if unable to correct

**Normal Square Waveform Test**

**Abnormal Fast Flush Tests**

- Over damped
  - Results in erroneously low SBP and high DBP
  - Caused by:
    - Large air bubbles
    - Loose/open connections
    - Low fluid level in flush bag

**Abnormal Fast Flush Tests**

- Under damped
  - Results in erroneously high SBP and low DBP
  - Caused by:
    - Small air bubbles
    - Tubing too long
    - Defective transducer
Marking the Phlebostatic Axis

★ Phlebostatic axis is 4th intercostal space at mid anterior-posterior chest level (left atrial level)
★ System needs to be zeroed and leveled at the phlebostatic axis
★ Measure accurately and mark on chest

Zeroing and Leveling

★ Zeroing tells the monitoring system that atmospheric pressure is “zero”
  • It removes the effect of hydrostatic pressure in the tubing system and establishes a baseline of zero so all pressure recorded by the system is patient pressure
★ Leveling means that the stopcock that was used to zero must be at the phlebostatic axis for all pressure readings
  • Keep the transducer at the phlebostatic axis while monitoring pressure

To Zero the System

• Place the stopcock located on top of the transducer at the level of the phlebostatic axis
• Open the stopcock to air (turn it off to the patient)
• Push the Zero button on the monitor.
  – This tells the transducer that atmospheric pressure is “Zero” and sets a baseline for pressure measurements.
• Close the stopcock to air (turn back to neutral position)
  – This opens the line between the patient and the transducer and allows the transducer to “see” the patient’s pressure

Leveling

★ Stopcock used to zero must remain at phlebostatic level regardless of patient position.
★ Leveling must occur with every reading
★ For every cm deviation from true phlebostatic axis, pressures can change 1.86 mmHg

Reading Waveforms Accurately

★ Obtain measurements from graphic tracing that includes the ECG
★ Read at end expiration
Right Atrial Waveforms

- a wave = atrial contraction and follows P wave
- c wave = closure of tricuspid valve
- v wave = atrial filling and follows QRS

Record the mean of the “a” wave for the CVP.

Normal CVP

CVP

Identify “a” and “v” waves
What is the CVP measurement?

Swan Insertion RA to RV

Right Ventricular Waveforms

The monitor is never right on the RV diastolic pressure!
- It reads the lowest point
- We want to record the plateau (true RVEDP)

Normal RV Waveform

Identify RV systolic and diastolic pressure.

RV Pressure = 38/10
RV Pressure

Identify RV Systolic and Diastolic Pressure

RV Pressure = 22/7

Swan Insertion RV to PA

Pulmonary Artery Waveforms

* The monitor is usually right about PA pressures
  * No false lows
  * Ignore the “pre-systolic” bump

Pulmonary Artery Waveforms

PA Waveform

Identify PA Systolic and Diastolic pressure

What is the pressure?  PAP = 54/20

Swan Insertion PA to PWP

Wedge Pressure Waveform

* Same “a”, “c”, and “v” waves as CVP
* Further removed from the ECG waves
  * “a” wave near end of QRS
  * “V” wave after T wave

Record the mean of the “a” wave for the PWP
PWP Waveform

Identify a and v waves and state the value of the PWP

PWP = 6 mmHg

Normal PAW

Identify “a” and “v” waves and state the PWP measurement

PAW = 10 – 11 mmHg

Large “v” Waves in PAW Waveform

Identify two problems this patient has.

LV failure: elevated PAWP (mean of “a” wave)
Mitral regurgitation: large “v” wave

Respiratory Variations

End Expiration in Spontaneous Breathing

Inspiration is a negative dip in waveform.

Spontaneous Breathing

Find end-expiration.
Where would you read the PA and the PAW pressure?
PA to PAW
Spontaneous Breathing

PA pressure = 58/32
PAW pressure = 25

End Expiration in Ventilator Breath

Inspiration is a rise in waveform

Ventilator Breaths

Find the ventilator breath.
Where would you read this PAW pressure?
PWP = 16

Goals of Hemodynamic Monitoring

★ Determine magnitude of pulmonary congestion (LV preload)
★ Assess peripheral perfusion (forwards flow)
★ Determine LV function based on preload and forwards flow

Analyzing Data:
What To Do With The Numbers

Left Ventricular Function Curves

Preload: PWP, lung sounds (dry or wet)
Changing Preload: moves patient along the curve they are on.

Forwards flow: CI/SV, skin temp (warm or cold)
Preload: PWP, lung sounds (dry or wet)

Changing Contractility: moves patient to a higher curve

Forwards flow: CI/SV, skin temp (warm or cold)
Preload: PWP, lung sounds (dry or wet)

Changing Afterload: moves patient up and to the left (improves forwards flow and reduces preload)

Forwards flow: CI/SV, skin temp (warm or cold)
Preload: PWP, lung sounds (dry or wet)

Relationship of PWP to Clinical Signs of Pulmonary Congestion

PWP
18 – 20 mmHg Pulmonary State
Pulmonary Congestion
20 – 25 mmHg Moderate Congestion
25 – 30 mmHg Severe Congestion
> 30 mmHg Pulmonary Edema

The value for PWP that best separates patients with and without pulmonary congestion is 18 mmHg.
Physical assessment: lung sounds dry or wet.

Relationship of CI to Clinical Signs of Hypoperfusion

Cl
Clinical State
2.7 – 4.7 Normal
2.2 – 2.7 Subclinical depression
1.8 – 2.2 Clinical hypoperfusion
< 1.8 Cardiogenic shock

The value for CI that best separates patients with and without hypoperfusion is 2.2 L/min/M².
Physical assessment: skin temperature warm or cold.

Hemodynamic and Clinical Subsets
Mini Case #1
A patient returns to the ICU after a AAA repair with a PA catheter in place. This is the first set of data: HR = 96, BP = 114/72, CO = 4.2, CI = 2.2, CVP = 3, PWP = 8, SVR = 1580.

Mini Case #2
A patient with acute anterior M returns from the cath lab with a PA catheter in place following two stents to the LAD coronary artery. The first set of numbers looks like this: BP 100/60, HR = 106, CO = 3.0, CI = 1.8, CVP = 10, PWP = 30, SVR = 1680.

Mini Case #3
A 20 year old motor cycle accident victim with multiple trauma is on the ventilator in the ICU and becomes hypotensive and febrile. His BP is 80/45, HR 120 in sinus tachycardia, skin is hot and dry. A PA catheter is inserted and these are the numbers: CO = 10.4, CI = 5, CVP = 4, PWP = 10, SVR = 404.

Mini Case #4
A 65 year old woman with a history of HF returns from CABG with the following data: BP 136/76, HR = 84, CO = 5.5, CI = 3.1, CVP = 8, PWP = 26, SVR = 1280.

Using Subsets As a Basis For Therapy

Preload changes: move patient along the current curve
**Afterload changes**: move patient up and to the left; improves forwards flow and reduces preload

- Must have adequate BP (SVR must be elevated)

**Contractility changes**: move patient to a higher curve

**Summary of the Effects of Therapies**

- D = Diuresis (preload reduction)
- F = Fluids (increase preload)
- I = Inotropes (increase contractility)
- V = Vasodilators (reduce afterload)
- V + I = Vasodilator + Inotrope

**Potential Therapies by Subset**

- **Normal Hemodynamics**
  - In sepsis or trauma:
  - Volume (if PWP low)
  - Inotropes (if PWP adequate)
  - Pacing (if HR low)
  - IABP

- **Backwards Failure**
  - Diuretics
  - Venous Dilators
  - Shock Box
  - Afterload reduction (if BP adequate and SVR high)
  - Preload reduction (inotropes, venous dilators, IABP)

**Mini Case #2**

A patient with acute anterior MI returns from the cath lab with a PA catheter in place following two stents to the LAD coronary artery. The first set of numbers looks like this: BP 100/60, HR = 106, CO = 3.0, CI = 1.8, CVP = 10, PWP = 30, SVR = 1680.

**Mini Case #2**

- Where do you want him to go?
- Is he a candidate for afterload reduction?
- Yes: BP is reasonable and SVR is high
**Hemodynamic Profiles in Shock**

<table>
<thead>
<tr>
<th>Subset</th>
<th>Preload (PWP)</th>
<th>Afterload (SVR)</th>
<th>Pump Function (CI/SV)</th>
<th>Tissue Perfusion (SVO2)</th>
<th>Therapy</th>
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<tbody>
<tr>
<td>Hypovolemic (Subset III)</td>
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</tr>
<tr>
<td>Cardiogenic (Subset IV)</td>
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<tr>
<td>Vasodilated (Subset I early) (Subset IV late)</td>
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More than one way to accomplish a goal

Forwards flow:

- CI/SV
- Skin temp (warm or cold)

Preload:

- PWP
- Lung sounds (dry or wet)

Hemodynamic Profiles in Shock

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Therapy:

- Volume
- Inotropes
- Preload reduction
- Afterload reduction
- Vasopressors