Hemodynamic Monitoring: 
Waveform Analysis and 
Nursing Responsibilities

Critical Care Competency
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Compiled by Professional Nursing Development
What does hemodynamic monitoring mean to us?

Hemodynamic monitoring is a foundation of care when monitoring critical or unstable patients. One of the primary goals is to alert the healthcare team of impending cardiovascular injury before organ dysfunction occurs. Many times the information provided to us through hemodynamic monitoring can guide us to alter our therapies, potentially increasing survival and quality of life following acute illness.

What are the indications for invasive hemodynamic monitoring?

Indications for hemodynamic monitoring include any conditions where accurate measurements of fluid volume status, cardiovascular function, oxygen delivery and consumption must be determined (i.e. heart failure, acute myocardial infarction, shock). Note that the Swan Ganz catheter used for hemodynamic monitoring does not ‘treat’ the patient; it is used for diagnostic purposes only.

How do we monitor hemodynamic stability of our patients?

A Swan Ganz catheter is inserted into the patient through a central vein, usually the internal jugular or subclavian through a large bore IV, such as a percutaneous sheath introducer (i.e. cordis). When access is extremely limited, a femoral site can be used, but is not preferred due to risk of infection. The Swan Ganz catheter is then attached to a pressurized set of bifurcated tubing which connects to bedside monitoring. The pressures detected by the distal tip of the catheter are then measured against the pressure of the fluid in the bifurcated tubing. The bedside monitoring will then display the calculated figure, giving a general perspective of the patient’s cardiopulmonary status.

Fundamental components of cardiac performance also include:

- **Heart rate**
  Most non-diseased hearts can tolerate heart rate changes from 40-170 beats per minute. Elevated heart rates compromise cardiac output by increasing the amount of oxygen consumed by the myocardium. A reduction in diastolic time can result in less perfusion time for the coronary arteries and a shorter ventricular filling time, thus, decreasing the blood volume to pump with contraction.

- **Preload**
  Preload refers to the amount of myocardial stretch at the end of diastole. It also refers to the volume of blood in the ventricle at the end of diastole.

- **Afterload**
  Afterload refers to the resistance, impedance, or pressure that the ventricle must overcome to eject its blood volume. Afterload is determined by a number of factors, including: volume and mass of blood ejected, the size and wall thickness of the ventricle, and the impedance of the vasculature. The most sensitive measurement of afterload for the left ventricle is systemic vascular resistance (SVR).

$$SVR= (MAP – RAP) \times 80$$

$$\frac{CO}{Normal \ Value: \ 800-1200 \ dynes/sec/cm^2}$$
The most sensitive measure of afterload for the right ventricle is pulmonary vascular resistance (PVR).

\[
PVR = \frac{(MPA - PAW) \times 80}{CO}
\]

Normal Value: <250 dynes/sec/cm\(^5\)

- **Contractility**

There are multiple factors that influence the contractile state of the myocardium. The sympathetic nervous system can cause an increase in contractility. Metabolic changes such as acidic states will decrease contractility. Drug therapy can be provided to elicit either a positive or negative inotropic state, depending on patient conditions or hemodynamic requirements.

**Insertion of a Swan Ganz catheter**

Before insertion of a Swan Ganz catheter, prepare the pressure monitoring system by flushing the bifurcated tubing, ensuring that all air is out of the line and new (blue) caps are applied steriley to all ports, replacing the white caps. The patient must be positioned supine or in a slight trendelenberg position. The bifurcated tubing should be connected to the bedside monitor and zeroed prior to insertion. Working with the physician the RN will assist in the priming and flushing of the swan catheter itself, all while maintaining sterility of the field. The defibrillator/monitor must be in the patient’s room prior to the procedure beginning as the risk for arrhythmia is high. The RN is responsible for recording the monitor tracings upon insertion of the catheter into the right atrium. Typically this is when the catheter reached the 20 cm marking on the catheter, but can vary based on insertion site. See below:

**Catheter Insertion Sites**

<table>
<thead>
<tr>
<th>Distance Until location Vena Cava/RA junction (cm)</th>
<th>Internal jugular</th>
<th>15 to 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior Vena Cava</td>
<td>10 to 15</td>
<td></td>
</tr>
<tr>
<td>Femoral Vein</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Right Antecubital Fossa</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Left Antecubital Fossa</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

**Supplies needed**

- Swan ganz kit
- Transducer holder
- Sterile Towels
- IV pole
- Bifurcated Tubing
- Sterile Gloves
- Co-set
- Sterile procedure pack
- Pressure bag
- 18g needle
- Gauze 4x4’s
- 10cc syringes
- Chloraprep
- D5W 500cc IV bag
- 1-IV valve clearlink cap
- 10cc NS flushes

The first tracings seen will be from the right atrium. Pressures are usually low and will produce two small upright waves. *(Normal Value 2-6 mmHg)*

![Right Atrial Waveform](image)

The next chamber seen is the right ventricle. Waveforms show taller, sharp uprises as a result of ventricular systole. Special attention should be paid to the patient’s ECG to identify any ventricular ectopy that may occur. (*Normal Value 15-25 mmHg systolic, 0-8 mm Hg diastolic*)

![Figure 17](image17.png)

*Figure 17*
Right Ventricular Waveform


Following the right ventricle, the catheter is advanced into the pulmonary artery. Typical pulmonary artery tracings resemble the right ventricular tracing slightly with a large slope upward, being more rounded at the top. The onset of diastole begins with the closure of the pulmonic valve, which produces a dicrotic notch on the pulmonary artery tracing. (*Normal Value 15-25 mmHg systolic, 8-15 mmHg diastolic*)

![Figure 18](image18.png)

*Figure 18*
Pulmonary Artery Waveform


With the balloon still inflated, the catheter is advanced further until it finally wedges in a central branch of the pulmonary artery. At this point, right heart pressures and pulmonary influences are occluded. The catheter tip is “looking” at left heart pressures. The pressure will be slightly higher than the right atrium, and the waveform will have two small rounded excursions from left atrial systole and diastole. The value recorded will also be slightly less than the pulmonary artery diastolic pressure, usually 1-4 mmHg lower. (*Normal Value 6-12 mmHg*)

![Figure 19](image19.png)

*Figure 19*
Pulmonary Artery Wedge Waveform

Once the catheter has been pulled back 1-2 cm by the physician and a wedge has been re-confirmed, the catheter is in place and continuous pulmonary artery tracings can be monitored. **Note catheter measurement at the entrance or ‘hub’ of percutaneous sheath introducer and document.**

*If a patient has an existing medical condition where wedging the catheter would be contraindicated, the pulmonary artery diastolic (PAD) pressure can be measured to reflect the PAW pressure.*

**Continuous Pressure Monitoring**

Continuous monitoring of pulmonary artery pressures is useful for several reasons. Foremost, medical management and therapies often depend upon the values obtained from the pulmonary artery pressures and intermittent wedge recordings. Secondly, catheter tip position changes that may present potential risks to the patient can be detected.

The catheter may spontaneously migrate into a more distal pulmonary artery branch when the balloon is deflated. The migration is due primarily to the softening of the catheter once it has been warmed to body temperature.

![Diagram of proper PA position and catheter migration](image)

*Figure 21: Proper PA Position*  
*Figure 22: Catheter Migration*  
*Headley, J. M. (2002).*

Occasionally the catheter tip may slip back into the right ventricle. This can be recognized by observing the right ventricular tracings on the monitor screen. If this occurs, the balloon should be inflated to protect the right ventricle from irritability. Because this a flow directed catheter, inflating the balloon may again float the catheter into the pulmonary artery, and should be completed by a physician.

![Diagram of catheter tip in right ventricle](image)

*Figure 23: Catheter Tip in Right Ventricle*  
*Headley, J. M. (2002).*
**Zeroing**

Zeroing is performed to eliminate the effects of atmospheric pressure on the transducer. Zeroing should be performed before and after connecting the pressure system to the patient, with any leveling changes, whenever there is significant change in the hemodynamic variables, after blood draws and at the beginning of each shift. To level the patient, place the patient in a supine position with the head of bed from zero to 45 degrees. Level the transducer to the phlebostatic axis (mid axillary line between 4th and 5th intercostal spaces) with a level.

![Image of patient lying supine]

Turn the stopcock upwards (off to the patient), remove the cap and press the zero button on the pressure module (sterility of the cap must be maintained, caps are to be changed as needed if considered unsterile). Once the 'zero completed' message appears on the screen, re-apply the cap in sterile fashion and neutralize the stopcock position. The PA waveform should appear on the monitor.

**Wedging**

After observation of properly formed pulmonary artery waveforms, the RN can obtain the pulmonary artery wedge pressure. Proper inflation techniques are important because overinflation of the balloon may cause overdistention of the pulmonary artery, which can cause rupture of the vessel.

The balloon should always be inflated slowly while the waveform tracing is noted on the monitor. Once the characteristic wedge tracing is noted, inflation of the balloon should stop immediately. **Maximum balloon inflation volume should never be exceeded.** If the wedge tracing is achieved with an inflation volume less than 1.5 cc’s, then the catheter may have slightly migrated and may need to be pulled back (by the physician). Also, if the pulmonary artery wedge tracing is observed at a low inflation volume, and inflation is continued, the resulting pressure may become progressively higher with a loss of clarity to the waveform. This occurrence is termed, “overwedged.”

![Images of proper wedge and overinflation](Figure 24, Figure 25)

Catheter Ports

- **Yellow (PA distal):** The ‘brain’ of the catheter. Measures PA and PAWP pressures. Mixed venous blood can be drawn SLOWLY from this port as to not collapse the lumen of the catheter.

- **White (Proximal infusion):** The infusion port can be used for any IV infusion. Venous blood can be drawn from this port. This is the back-up port for performing cardiac outputs.

- **Blue (Proximal injectate):** Measures CVP pressure. Used for injection when performing cardiac outputs. Can be used for infusion or injection of IV medications/liquids.

- **Red (Wedge):** Comes with attached syringe with a stop notch at the 1.5cc mark. If the syringe that comes with the catheter is lost or broken, a whole new catheter must be removed to obtain a new safety syringe. When not in use the port must be locked by sliding the white clamp until the red line no longer lines up.

- **Yellow/red cap (Thermistor):** Connects to the bedside monitor and transmits the temperature from the tip of the Swan Ganz catheter. The gold colored tines inside the thermistor must not be bent or broken; this could render the catheter non-functional.

### Computation Constants

The bedside monitoring equipment must be calibrated with the Swan Ganz catheter to ensure the accuracy of its readings. Below are the tables that provide the computation constants for the various catheters. Before beginning cardiac output measurements the computation constant should be verified and confirmed.

#### Computation Constants for Thermodilution Cardiac Outputs

<table>
<thead>
<tr>
<th>Swan Ganz Model</th>
<th>Computation Constant</th>
<th>Computation Constant (28°C)</th>
<th>Computation Constant (30°C)</th>
<th>Computation Constant (32°C)</th>
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<tr>
<td>1006D</td>
<td>-</td>
<td>0.029</td>
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<td>0.012</td>
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#### Computation Constants Infrared CO-2000 Closed Intake Delivery System

<table>
<thead>
<tr>
<th>Swan Ganz Model</th>
<th>Computation Constant</th>
<th>Computation Constant (28°C)</th>
<th>Computation Constant (30°C)</th>
<th>Computation Constant (32°C)</th>
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<td>0.394</td>
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Performing Cardiac Outputs using the Thermodilution Method

The thermodilution method applies using temperature change as the primary cardiac output indicator. A known amount of solution with a known temperature is injected rapidly into the right atrial lumen of the catheter (the proximal injectate/blue port). This cooler solution mixes with and cools the surrounding blood, and the temperature is measured downstream in the pulmonary artery by a thermistor bead embedded in the catheter. The resultant change in temperature is then plotted on a time temperature-curve.

A normal curve shows a sharp upstroke from rapid injection of the injectate, followed by a smooth curve and slightly prolonged downslope back to the baseline.

![Figure 29 Normal Cardiac Output](image)


A low cardiac output state shows the sharp upstroke from rapid injection of the injectate; however more time is required to return to baseline producing a larger area under the curve.

![Figure 30 Low Cardiac Output](image)


A high cardiac output state shows the sharp upstroke from rapid injection of the injectate, however less time is required to return to baseline because the cool fluid is being moved through the heart faster, producing a smaller area beneath the curve.

![Figure 31 High Cardiac Output](image)


Our ‘co-set’ is considered a closed system; it uses a closed-loop to reduce multiple entries into the sterile environment. The injectate solution used is D5W from a 500 mL bag (this bag is to be changed every 24 hours). The solution can be room temperature or iced. The co-set is assembled and attached to the proximal injectate port on the Swan Ganz catheter. A series of five injections are completed in succession and registered in the bedside monitor. The RN is then
required to compute the average cardiac output and cardiac index by eliminating the two outlying values. Once the values have been determined, the RN must complete a hemodynamic calculation (hemo calc) on the bedside monitor. The values required will be automatically input by the monitor (i.e. blood pressure, heart rate, MAP, etc.). The RN will be required to input and verify the patient’s current weight, height, PAWP, and CVP. Once the values have all been input, the RN must select the ‘show ranges’ option and then the ‘perform calc’ option. The calculation will be computed and displayed on the monitor. The RN must print a copy and place it in the nurses notes portion of the Clinical Management Record (CMR) and notify the ICU resident and/or the patient’s assigned cardiologist. Cardiac outputs are to be completed upon insertion of the Swan Ganz catheter, on a daily basis between 5 and 6 a.m., one hour after any changes in intravenous cardiovascular medications and as needed.

**Oxygen Summary Procedure**

Obtaining an oxygen summary is NOT considered a standard part of caring for a patient with a Swan Ganz catheter; therefore, a written physician order must be obtained prior to computing these values. Once an order has been written, the RN must notify the Respiratory Therapist (RT) to draw an arterial blood gas (ABG) and mixed venous blood gas (MVBG) from the patient. An RN or a trained Respiratory Therapist can draw these labs; however, much caution must be taken because pulling blood too quickly off of the PA distal port on the Swan can collapse the catheter walls. When the specimens have been obtained the RT should be sent to compute the values and bring back the day’s barometric pressure while the RN stays behind to complete the cardiac output procedure.

Once the ABG and MVBG have been resulted and the barometric pressure provided, the RN can begin performing the calculation. On the bedside monitor, select the TRENDS and CALCS button. Scroll up and over to the Oxygen Calc and select. A screen similar to the Hemo Calc will appear requiring the following values to be input/confirmed:

- Cardiac Output (CO)
- FiO2
- PaO2 (ABG value)
- PaCO2 (ABG value)
- SaO2 (ABG value)
- PvO2 (MVBG value)
- SvO2 (MVBG value)
- Hemoglobin (most recent)
- Barometric pressure
- Height (most recent)
- Weight (most recent)

The RN must next select the ‘show ranges’ option and then the ‘perform calc’ option. The calculation will be computed and displayed on the monitor. The RN must print a copy and place it in the nurses’ notes portion of the Clinical
Management Record (CMR) and notify the ICU resident and/or the patient’s assigned cardiologist.

**Removal of a Swan Ganz Catheter**

To remove a PA catheter turn the patient’s head away from insertion site. Attach the 1.5 cc syringe to the balloon port and pull back on the plunger to ascertain that the balloon is deflated and then lock the lumen. Position the patient flat and ask them to inspire deeply and hold their breath during removal. Hold the introducer (cordis) securely and pull the Swan catheter out with one smooth movement. If any resistance is felt, stop and notify the physician immediately. Have the defibrillator/monitor in the patient’s room because of the risk of ectopy/arrhythmia during removal. The RN will verify with the physician if the introducer (cordis) is to remain in place or be removed. The pressure bag is to be cleaned and stored after each patient use.

Care of a patient with a Swan Ganz catheter can be a labor intensive and time consuming process, but can provide the healthcare team with valuable information. The treatment of various illnesses can be tailored to a patient’s specific hemodynamic needs when accurate monitoring and reporting is completed. It is important as the bedside RN that we ensure our competency when caring for patient’s with specific monitoring needs.

**References**


Garden City Hospital Critical Care Services Procedure: Pulmonary Artery Pressure Monitoring

Garden City Hospital Critical Care Services Procedure: Performing Cardiac Outputs

Garden City Hospital Critical Care Services Procedure: Removal Swan-Ganz Catheter