PARTNERSHIP IN CRITICAL CARE DEPT. WAIKATO

CRITICAL CARE WAIKATO HOSPITAL

WORKBOOK

NAME: ______________________________

Section 5

Pulmonary Artery Catheter

Pulmonary Artery Catheter (Swan Ganz)

The Swan Ganz catheter is a balloon-tipped catheter inserted into the heart to measure haemodynamic pressures. The catheter permits continual monitoring of left sided heart function, pulmonary function, and circulating volume in the critically ill patient. The catheter is usually inserted via the internal jugular vein, but can be via the femoral, subclavian or brachial veins. There are markings along the shaft of the catheter at 10cm increments to identify the position of the catheter in the heart. The catheter lumen is divided into five sections, which are discussed below.

Distal Lumen
This is the largest lumen. It terminates in an opening at the tip of the catheter. When the catheter is in place, the opening lies in the pulmonary artery and is used to measure the following pressures:

Pulmonary Artery Systolic	(PAS)
Pulmonary Artery Diastolic	(PAD)
Pulmonary Artery Mean	(PAM)
Pulmonary Artery Wedge Pressures	(PAWP)

Proximal Lumen
This lumen opens into the right atrium and is 30 cm from the catheter tip. It is used to measure right atrial pressure (RA) indicating right sided heart function. RA pressures correlate to central venous pressures (CVP). This lumen also carries the injectate fluid necessary for cardiac output computation.

The Balloon Port
Is used to inflate and deflate the 1.5 ml capacity balloon. The balloon assists in floating the catheter through the chambers of the heart and when fully inflated the balloon covers the catheter, occluding the vessel, blocking off the pressure and fluid behind it, hence it will measure the forward pressures of the left side of the heart. This is called wedging.

The Thermister Port
This port consists of a three pin plug that is connected to the cardiac output machine. The opening of the thermister is located 4 cm from the tip of the catheter. It contains temperature sensitive wires, instrumental in determining cardiac outputs by measuring the temperature changes in the injectate fluid as it flows through the heart.

The Right Ventricular Port
This port sits at 19 cm from the catheter tip, in the RV. It can be used to insert a ventricular pacing wire into the ventricle or, if this is not required for the infusion of fluids.

Definitions associated with PA Catheters

Preload
Refers to the filling pressure; the load on the cardiac muscle fibers at the end of diastole or just before contraction primarily determined by venous return to the heart

Afterload

The pressure (or resistance) the ventricles must overcome to open the aortic and pulmonic valves and pump blood out of the heart

Contractility
Is the intensity at which the myofibrils contract

Systemic Vascular Resistance (SVR)
Refers to the resistance to blood flow offered by all of the systemic vasculature, excluding the pulmonary vasculature. This is sometimes referred as total peripheral resistance (TPR).
Normal range: 900 – 1400 dynes/sec/cm^{-5}
SVR = (MAP - CVP) ÷ CO

Cardiac Output
The volume of blood ejected by the heart in one minute. The amount of blood ejected by the left ventricle in a single contraction is called the stroke volume. The stroke volume and the heart rate determine the cardiac output.
Normal range: 4 – 8 L/min
CO = SV X HR

Cardiac Index
Cardiac index is the cardiac output indexed to a patient's body surface area. This value is given in litres per minute per square meter of body surface area (BSA). The BSA is calculated from the patient's height and weight.
Normal Range: 2.5 – 4 L/min/m^2
CI = CO/BSA

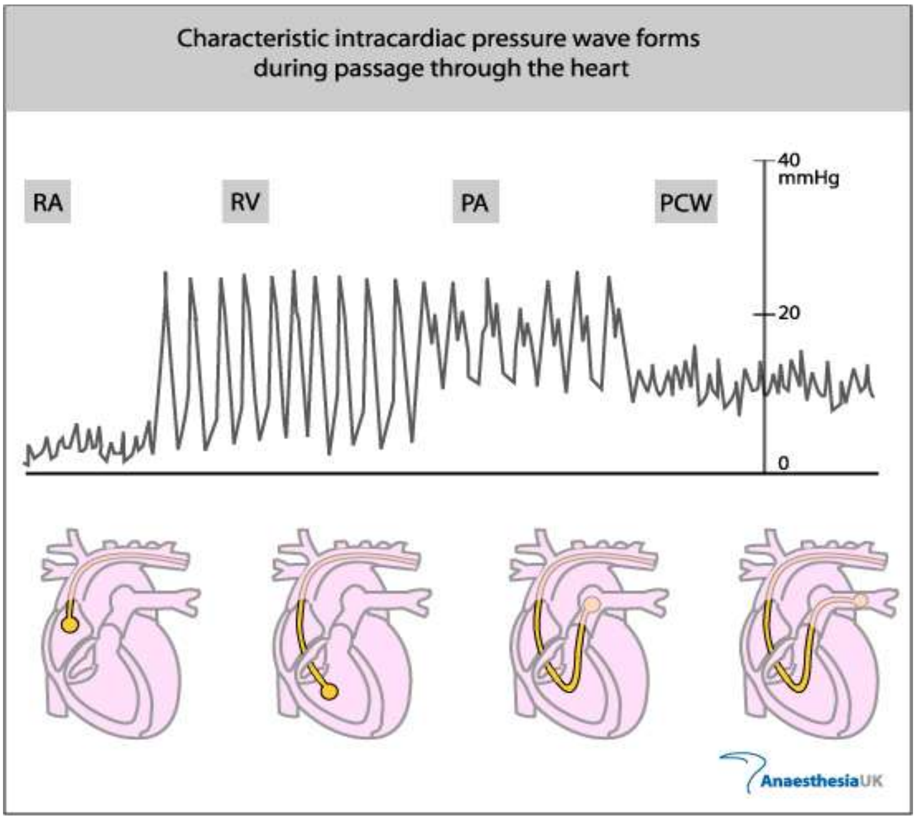
Purpose of PA Catheter
The PA catheter can provide information about the following:

1. Right ventricular function
2. Pulmonary vascular status
3. Left ventricular function
4. Measures RA, RV, PA pressures and pulmonary artery wedge pressure (PAWP)
5. Measures CI/CO
6. Facilitates diagnosis of cardiovascular and cardiopulmonary dysfunction

(Morton 2009)

<u>Haemodynamic Pressures/Pressure Waveforms</u>

The picture below depicts the appearance of the pressure waveform as the catheter is advanced through the heart.



<u>Right Sided pressures</u>

The central venous pressure (CVP) and right atrial pressure (RAP)

- has been shown to accurately correlate with the diastolic RV pressure in the absence of heart or lung disease
- indirect indicator of right ventricular preload
- mean CVP and RAP normally range from 0-5 mm Hg

<u>PA pressures</u>

<u>PA Systolic Pressure (PAS)</u>

- begins with the opening of the pulmonic valve, resulting in rapid ejection of blood into the pulmonary artery
- shown as sharp rise in pressure followed by a decline in pressure as the volume being injected decreases
- corresponds to the RV systolic pressure
- normal range: 20 – 30 mmHg

<u>PA Diastolic Pressure (PAD)</u>

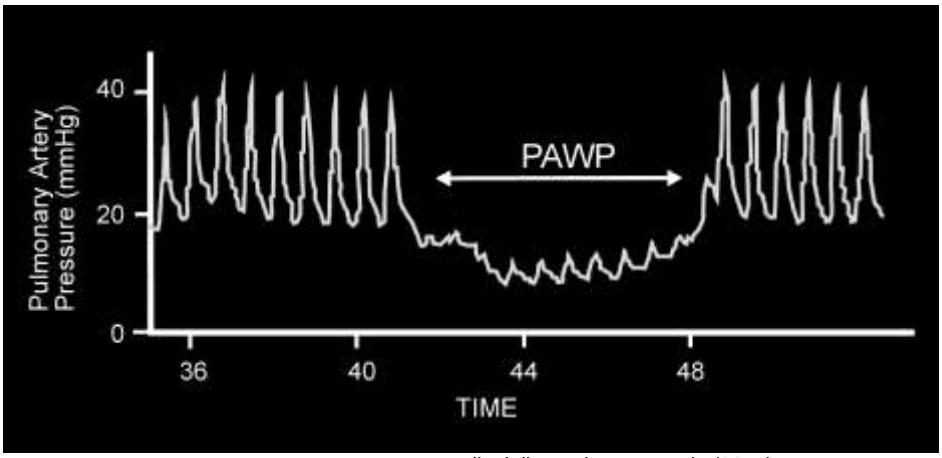
- follows the closure of the pulmonic valve
- corresponds to the LV end-diastolic pressure (LVEDP) in the absence of pulmonary vascular resistance or downstream obstruction (e.g., mitral stenosis)
- normal range: 8-15 mmHg (WDHB protocol, based on Lippincott, 2015)

PA Mean (PAM)

- average pressure of the entire cardiac cycle
- normal range: 10-20 mmHg (WDHB protocol)

PA Wedge Pressure (PAWP)

- backward reflection of the LA pressure (LV preload)
- resting PAW mean pressure: 4 – 12 mmHg
- *NB – on this Unit PAW procedures are not routinely performed*



Medical Illustration Paunovic (2011)

Complications of PA Catheter Insertion

Complications of PA catheter insertion include arterial puncture, pneumothorax, air embolism and infection, which are general complications of central venous catheter insertion (Scales, 1999). Additional complications include:

1. Dysrhythmias - Commonly associated with PA catheter insertion because the catheter passes through the heart. Most dysrhythmias resolve spontaneously while 1 – 3% require treatment (Boyd et.al., 1983).

2. PA rupture - is an important and fatal complication associated with over-inflation of the PA balloon but can also be caused by erosion of the wall of the PA. It is more common in patients with pulmonary hypertension, patients on anticoagulants and patients over 60 years.
   - Symptoms:
     - Haemoptysis
     - Severe respiratory distress
     - Shock, hypotension
   - Causes:
     - Erosion by impacted (wedged) catheter tip
     - Balloon inflation in small branch vessel
     - Excess amount of air used
   - Treatment:
     - Notify medical staff **immediately – emergency situation**
     - Commence CPR if indicated

Note: Symptoms of PA perforation must be differentiated from those of severe pulmonary oedema and treated accordingly.

3. Distal migration - The forward movement of the PA catheter into a narrower section of the artery so that it becomes accidentally wedged, without balloon inflation. This may also occur as patients are repositioned. If catheter becomes displaced forward, it may spontaneously wedge. If this occurs, severe damage can occur within 15 minutes. Inform ICU medical staff who will re-position the catheter

(usually pulled back until the catheter is no longer wedged.) DO NOT INFLATE THE BALLOON OR FLUSH THE LUMEN as pulmonary artery rupture is possible.

4. Proximal migration - If catheter is displaced backwards, it may recoil into the right ventricle. This can precipitate arrhythmias. Inform ICU medical staff who will consider repositioning the catheter (insert further until positioned correctly in the pulmonary artery). If these corrective actions are unsuccessful, the catheter should be removed.

5. Haemorrhage - insertion site with visible bleeding, swelling, tenderness at site.
   - Treatment:
     - apply pressure to site
     - redress
     - if continuing, inform medical staff

6. Right Ventricle Perforation – is caused by the catheter at a weak area in the RV wall
   - Symptoms:
     - cardiac tamponade, shock, hypotension and cardiac arrest
   - Treatment:
     - notify medical staff **immediately** – this is an **emergency situation**
     - commence CPR if indicated
     - assemble equipment for pericardiocentesis

Nursing Care for a Cardiac Surgery Patient with PA Catheter

- To ensure accuracy of the recordings the haemodynamic monitoring system should be zeroed to atmospheric pressure and levelled with the patient's right atrium (phelobostatic axis) (McGhee & Bridges, 2002). The phlebostatic axis can be located at the intersection of two reference lines: an imaginary line from the fourth intercostal space (ICS) at the point where the ICS joins the sternum, drawn to the side of the body, and a line drawn midway between the anterior and posterior surfaces of the chest (Bridges, 2000)

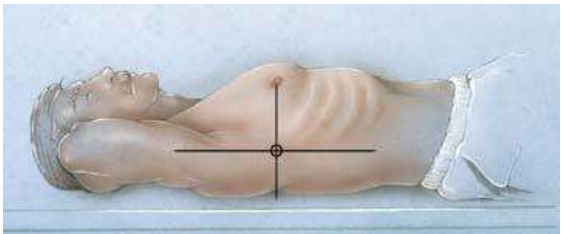


Figure 3: The phlebostatic axis, marked on the patient's chest, is the precise anatomical point of origin of the hemodynamic pressures being measured.

Medical Illustration Beattie (2003)

- The proximal end of the plastic sheath should be locked onto the PA catheter to ensure that the catheter does not become dislodged (Scales & Collie, 2007)

- Upon initial assessment, the nurse should note the position of the PA catheter by measuring the catheter depth markings at the entrance to the percutaneous sheath, and confirming that this position produces an unwedged PA waveform (Scales & Collie, 2007). See photo below:

- Careful monitoring of the PA waveform should be done, particularly when repositioning the patient, to recognise a wedged trace (Scales, 1999). If catheter becomes displaced forward, it may spontaneously wedge. If this occurs, severe damage can occur within 15 minutes. This can precipitate arrhythmias
- Secure the entire length of the PA Catheter on the patient's shoulder and make sure that it doesn't bear weight at the insertion point. See photo below:

- Distal lumen (yellow) is always connected to a pressure transducer for continuous monitoring of pulmonary artery pressure. This is to ensure the catheter does not inadvertently "wedge". If this complication occurs, inform medical staff immediately. A continuous flush of 0.9% saline is administered to keep the lumen patent
- Right atrial lumen (blue) is usually connected to a pressure transducer to measure CVP. CVP is measured at 2 hourly intervals with the patient in supine position. Cardiac output syringe/fluid is also connected to the RA lumen when cardiac output measurements are required
- Monitor Pulmonary artery pressure continuously and document hourly:
    a. Pulmonary artery systolic (PAS)
    b. Pulmonary artery means (PAM)

   c. Pulmonary artery diastolic (PAD)

1. Ensure that the patient's height and weight has been entered into the patient's data screen
2. Upon taking cardiac output measurements, the injectate should be injected smoothly within four seconds, beginning at end expiration to decrease variations in measurements caused by the respiratory cycle. At end expiration, intrathoracic pressures come closest to the atmospheric pressure (Daily & Schroeder, 1994). Proper timing of the injection to the same phase of respiration provides more consistent measurements. Averaging the values of 3 injections is recommended to minimize sampling errors (Paunovic, 2011)
3. The fluid volume injected for cardiac output determinations should be included on the patient's fluid balance chart
4. Before catheter removal, the nurse must ensure that the balloon is completely deflated to prevent damage to the pulmonary and tricuspid valves. If resistance is felt during the removal of the PA catheter the procedure should be stopped and medical advice sought (Scales & Collie, 2007). Refer to the pulmonary artery catheter management ICU service-specific controlled document
5. If dysrhythmias occur during catheter removal, continue removing the catheter rather than stopping, to avoid leaving the catheter tip positioned in a valve, thus causing further damage and more severe dysrhythmias (Scales & Collie, 2007)

Clinical Significance of Cardiac Output Measurement Results

Abnormal PA Pressures

Elevated PA systolic and diastolic pressures can occur in the following conditions:

- Increased PVR e.g. pulmonary diseases, pulmonary hypertension or pulmonary embolus
- Increased pulmonary venous pressure e.g. mitral stenosis or LV failure
- Increased pulmonary blood flow e.g. L-to-R shunt caused by an atrial or ventricular septal defect

Reduced PA systolic and diastolic pressures can occur in the following conditions:

- Hypovolaemia
- Excessive vasodilation

Abnormal PAW Pressures

Elevated PAW pressures can occur in the following conditions:

- LV failure
- Mitral stenosis or regurgitation
- Cardiac tamponade
- Constrictive pericarditis
- Volume overload

Reduced PAW pressures can occur in the following conditions:

- Hypovolaemia
- Vasodilation

Low Preload

Efforts are directed towards increasing preload levels, achieved by administration of fluid in an attempt to increase circulating volume

Signs of hypoperfusion:

- RA pressure or CVP <6 mmHg
- PAW or LA pressure < 8mmHg in patients without cardiac dysfunction
- PAW or LA pressure < 18 mmHg in patients with cardiac dysfunction

High Preload

Acute increase of PAW pressure to > 20 – 22 mmHg can indicate congestion/oedema.

In patients with normal lungs, PAW pressure > 18 mmHg indicates pulmonary congestion and PAW pressure of approximately 24 mmHg indicates pulmonary oedema. In patients with chronic heart failure, pulmonary oedema may not occur until PAW pressure > 30 mmHg (Bridges, 2000). Preload is reduced to the lowest level compatible with adequate stroke volume through diuretics and venodilators:

- *Diuretics* - Loop diuretics (furosemide) inhibit the reabsorption of sodium in Henle's loop resulting in diuresis with resultant decreases in circulating blood volume and decreased preload (RA or CVP and PAWP). These agents also have pronounced venodilatory effect resulting in venous pooling, decreased venous return, and therefore decreased preload (CVP or PAW) pressures. The cumulative effect decrease in PAWP reduces pulmonary congestion and pulmonary oedema
- *Venodilators* - Venodilators (nitroglycerin) redistributes blood volume in the capacitance vessels and thus reduce ventricular filling. These agents reduce venous return and preload (RA/CVP and PAWP) and therefore relieve pulmonary congestion. They also dilate epicardial coronary arteries and improve collateral coronary blood flow.

Low Afterload

Arterial vasodilation results in decreased resistance (decreased afterload) and decreased pressure resulting in severe hypotension and consequently inadequate coronary artery perfusion. Vasopressors are used to increase resistance to establish an adequate perfusion pressure. Low afterload is indicated by an SVR of < 900 dynes/sec/cm^{-5}.

High Afterload

Increased afterload increases the work of the heart and therefore myocardial oxygen consumption. Vasodilators are used to increase stroke volume and to reduce myocardial oxygen demand. Vasodilation causes decreases in SVR that usually result in increases in CO with little or no reduction in blood pressure. High afterload is indicated by an SVR > 1400 dynes/sec/cm-5 (Daily & Spencer-Schroeder, 1994).

PA Catheter Removal

For information regarding PA catheter removal refer to the pulmonary artery catheter management procedure (ICU service-specific controlled document).

Required Reading:

Pulmonary artery catheter management. WDHB (2012). (ICU service-specific controlled document).

Additional Reading:

Beattie, S. 2003. A PA catheter refresher course. Retrieved August, 2012 from http://www.modernmedicine.com/modernmedicine/data/articlestandard/rnweb/312004/107057/r4a028f3.jpg

Boyd, K., Thomas, S., Gold, J. Boyd, A. (1983). A prospective study of complications of pulmonary artery catheterizations in 500 consecutive patients. *Chest*. 84(3), 245 – 249.

Bridges, E. (2000). Monitoring pulmonary artery pressures: Just the facts. *Cardiovascular Medicine*, *20*(6), 59-78.

Cardiac index. (2012) In Medterms medical dictionary. Retrieved August, 2012 from http://www.medterms.com/script/main/art.asp?articlekey=39852

Cardiac output. (2012) In Medterms medical dictionary. Retrieved August, 2012 from http://www.medterms.com/script/main/art.asp?articlekey=7525

Daily, E., & Spencer - Schroeder, J. (1994). Pulmonary artery and pulmonary artery wedge pressure monitoring (5th ed.). *Techniques in Bedside Hemodynamic Monitoring* (pp. 99-139). St. Louis: Mosby-Year Book Inc.

Kalbunde, R. 2007. Cardiovascular physiology concepts. Retrieved August, 2012 from http://www.cvphysiology.com/Blood%20Pressure/BP021.htm

Paunovic, B. (2011). Pulmonary Artery Catheterization. Retrieved August, 2012 from http://emedicine.medscape.com/article/1824547-overview#a30

Preload filling pressure. (2009). In *Mosby's Dictionary of Medicine, Nursing, & Health Professions*. Retrieved from http://ezproxy.auckland.ac.nz/login?qurl=http%3A%2F%2Fwww.credoreference.com/entry/ehsmosbymed/preload_filling_pressure

Scales, K., & Collie, E. (2007). A practical guide to using pulmonary artery catheters. *Nursing Standard*, *21*(43), 42-48.

Scales, K. (1999). Vascular access in the acute care setting. In Dougherty L,

Lamb J (Eds) Intravenous Therapy in Nursing Practice. Churchill Livingstone, London, 261 – 299.

Acknowledgements

Thanks to Charisse Verano, Staff Nurse, Waikato Hospital ICU, for creating the original version of the Pulmonary Artery Catheter (Swan Ganz) resource (2012).