NORTHERN SYDNEY
CENTRAL COAST
NSW HEALTH

HORNSBY KU-RING-GAI HOSPITAL

INTENSIVE CARE UNIT

Haemodynamic Monitoring Learning Package

Name:…………………………………………………………………………………

Package developed for use at Hornsby Ku-ring-gai Hospital by:
Wanda McDermott, Clinical Nurse Educator, Intensive Care Unit, Hornsby Ku-ring-gai Hospital
Jo Melloh, Clinical Nurse Specialist, Intensive Care Unit, Hornsby Ku-ring-gai Hospital

Endorsed by:

Halkhoree, R (Clinical Nurse Consultant, Intensive Care, Hornsby Ku-ring-gai Hospital)
Clarke, J (Staff Development Educator, Hornsby Ku-ring-gai Hospital)
Smith, K (Acting Nursing Unit Manager, Intensive Care, Hornsby Ku-ring-gai Hospital)
Castree-Croad, S (Divisional Manager, Medicine, Emergency & Intensive Care, Hornsby Ku-ring-gai Health Service)
Hawkins, L (Acting Director of Nursing and Midwifery Services, Hornsby Ku-ring-gai Hospital)

Completed: December 2008.
Review due: December 2011

INTRODUCTORY INFORMATION

Purpose of the Package

This learning package explains invasive haemodynamic monitoring, focusing on arterial and central lines. The purpose of the package is to provide, in an easily-accessible format, comprehensive information that assists with using invasive monitoring and an understanding of the principles behind it.

Expectation of Prior Learning

There is an expectation that the staff member completing this learning package has an existing understanding of the anatomy and physiology of the cardiovascular system, and is able to perform a basic cardiovascular assessment.

Target Audience

It is expected that all staff caring for a patient with an arterial or central line will complete this learning package.

This package will be useful for both the novice as well as those who would like to revise the subject.

Aims and Objectives

By completing this learning package, staff will be able to:

- have the knowledge and skills necessary to care for a patient with an arterial and/or central line.
- detect and prevent potential complications associated with an arterial and/or central line.
- explain the conditions under which an arterial and/or central line may be required.
- take an active role in their own professional development.
- safely care for a patient with an arterial and/or central line.

Mode of Delivery

This is a self-directed learning package, periodic cardiovascular workshops and regular in-services will be run in ICU to provide additional information.

Assessment Process

Successful completion of the Haemodynamic Monitoring Competency will provide sufficient evidence that the aims and objectives of this package have been achieved. The assessment must be conducted by an accredited assessor who has completed the competency.

Directions for Use

1. Study the learning package.
2. Complete the worksheet.
3. Clinical Educator/Facilitator on the Unit/Ward will mark completed worksheet.
4. Assessment of competence using the "Haemodynamic Monitoring Competency".
5. Completion of competency documented in staff member's Education folder. Certification for the staff member's professional portfolio will be provided on application.

HAEMODYNAMIC MONITORING

Haemodynamic monitoring provides information about the functioning of the cardiovascular system of the patient. It can be used for the diagnosis and treatment of the patient. This can be achieved by non-invasive or invasive methods, continuously or intermittently depending on the requirements of the patient.

Non-invasive monitoring does not require any device to be inserted into the body and therefore does not breach the skin. Non invasive haemodynamic monitoring is achieved by:

- blood pressure reading from a manual cuff pressure,
- heart rate from the electrocardiograph (ECG),
- temperature (surface)
- respiratory rate and end tidal CO2 monitoring
- pulse oximetry (saturation readings)
- urine output and
- measurement of jugular venous pressure (JVP)

Invasive monitoring is achieved by the insertion of an arterial, central or pulmonary artery catheter. Arterial and central lines are used most commonly in intensive care patients. A pulmonary artery catheter is used less frequently. *This learning package will concentrate on arterial and central lines only.*

The use of invasive pressure monitoring provides:

- a more in-depth understanding of the patient’s condition, ie; helps with making a correct diagnosis
- continuous and accurate blood pressure measurement,
- allows for the adjustment of treatments in a more appropriate manner and
- provides continuous access for regular blood samples

Comparison between a non invasive and invasive blood pressure measurement

The two readings are measuring different components of the circulating blood volume. Comparing the two allows the accuracy of the arterial line reading to be assessed.

An arterial line measures the amount of force exerted by circulating blood over a specific area.

Sphygmomanometer blood pressure readings measure flow (circulating blood volume) over a specific time.

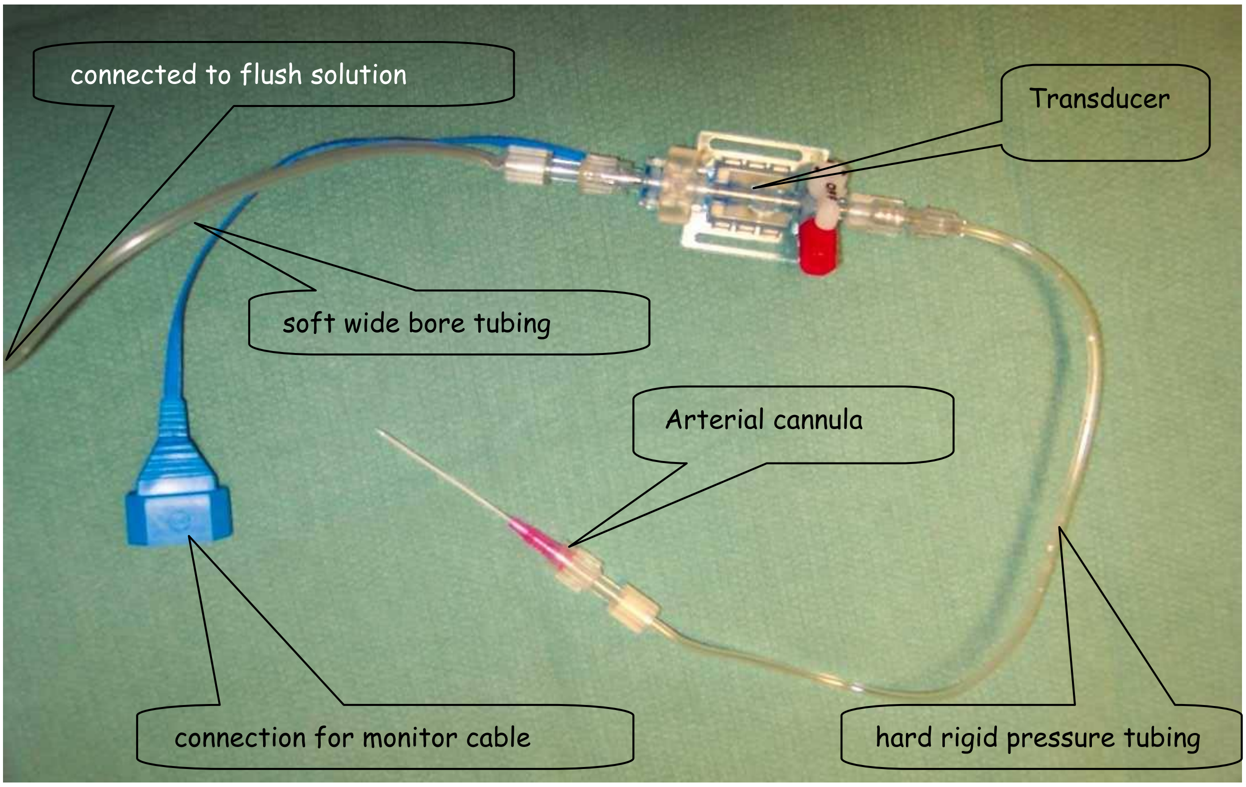
In a healthy patient there should be no greater than 10mmHg difference in the mean arterial pressure (MAP) recorded by either method.

ARTERIAL LINES

An arterial line is a cannula placed into an artery so that the actual pressure in the artery can be measured. This provides continuous measurement of systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP). The cannula is connected to an infusion set fitted with a transducer. This line consists of 3 sections:

- a hard, rigid, non-compressible section of tubing
- the transducer itself and
- soft, wide-bore tubing.

The cannula detects the flow of blood and the pressures exerted with each contraction of the heart. These mechanical pressures are transmitted through the cannula into the fluid filled rigid tubing and up to the transducer. The transducer converts this mechanical pressure into kinetic energy. The kinetic energy is then transmitted to the monitor and graphically displayed on the monitor as both numerical pressures and an arterial waveform.



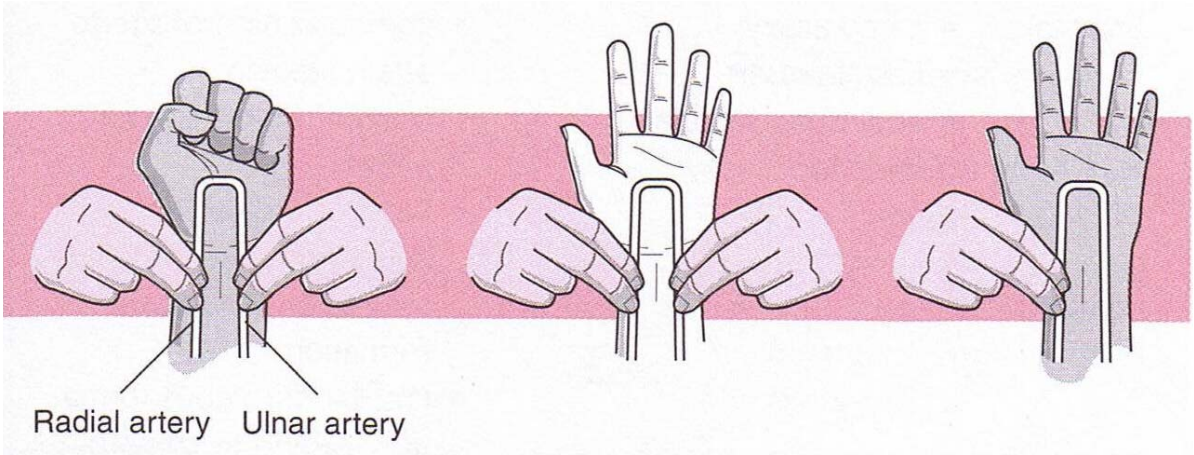
Hornsby Ku-Ring-Gai Hospital Intensive Care unit photograph taken by J Melloh (CNS), 2008

Arterial line site for insertion

The catheter may be inserted by a qualified medical officer into the radial, femoral, brachial or pedal artery however the site of choice is the radial artery. The radial artery site is readily accessible and there is usually good collateral flow to the hand via the ulnar artery. It is also easy to compress (to affect haemostasis) following removal of the arterial line. An Allen's test should be performed by the medical staff prior to the insertion of a radial arterial line.

Allen's Test

- Elevate the hand to be cannulated and apply pressure to occlude both the radial and ulnar arteries.
- Observe the hand blanching as circulation is restricted.
- Release the pressure on the ulnar artery only and observe the hand for return of circulation (hand should reperfuse within 10 seconds).
- Once collateral circulation is established then it is safe to use the radial artery for an arterial line without compromising circulation to the patient's hand.



Hodges, R; Garrett, K; Chernecky, C; Schumacher, L. (2005) Real World Nursing Survival Guide, hemodynamic monitoring, Elsevier Science, United States of America

Nursing responsibilities during the insertion procedure include:

- assist with patient positioning and explanation to the patient
- preparation of the flush bag and transducer system
- ensure infection control procedures and protocols are adhered to
- assist the medical officer as required
- closely monitor the patient during the procedure.

In order to competently manage a patient with an arterial line the nurse is required to:

- interpret the data on the monitor,
- respond appropriately (adjust treatments as necessary)
- understand the components of the waveform
- observe for complications and
- troubleshoot as needed

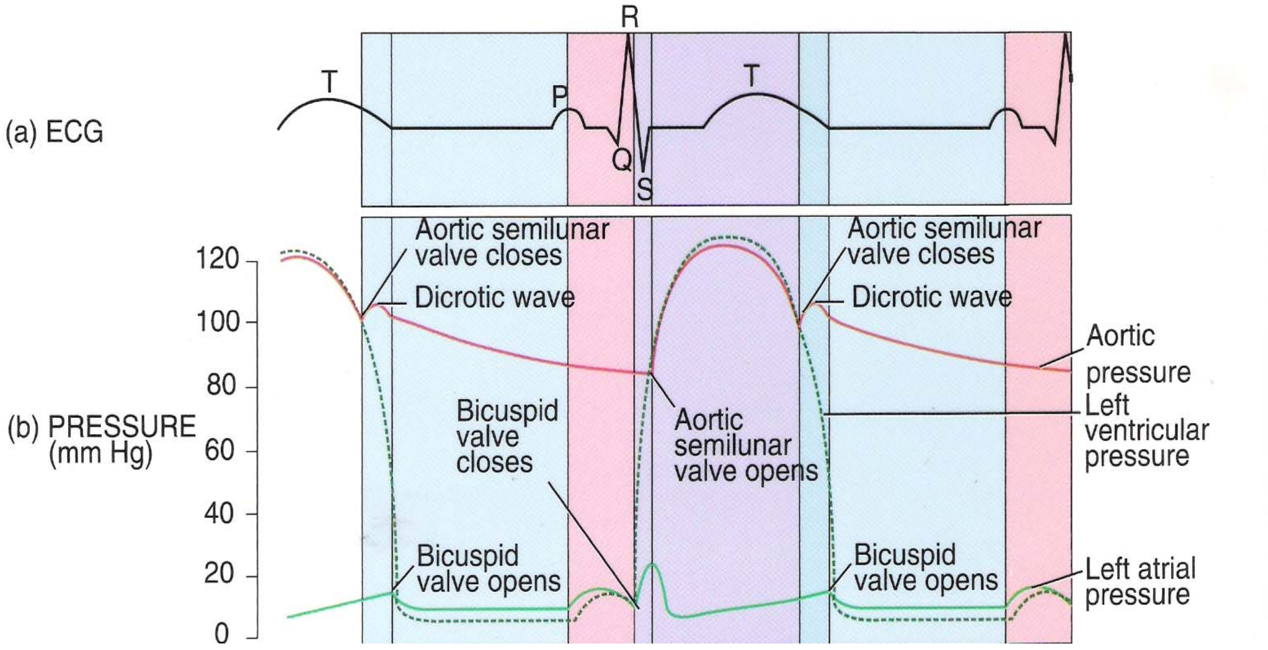
Interpreting the numbers

The SBP, DBP and MAP are all displayed but it is the MAP that tends to guide our practice. The MAP is the average arterial pressure during the cardiac cycle, and it provides an overall indication of peripheral tissue perfusion. For this reason, the MAP is used clinically to help guide management of the patient's haemodynamic status. In critically ill patients, the

MAP is normally maintained ≥ 70mmHg in order to maintain adequate renal and cerebral perfusion. MAP is automatically calculated by the bedside monitor, but can also be calculated by using the equation.

$$MAP = \frac{\text{Systolic BP} + (\text{Diastolic BP} \times 2)}{3} \quad \text{or} \quad \tfrac{1}{3}\text{ systolic} + \tfrac{2}{3}\text{ diastolic} = MAP$$

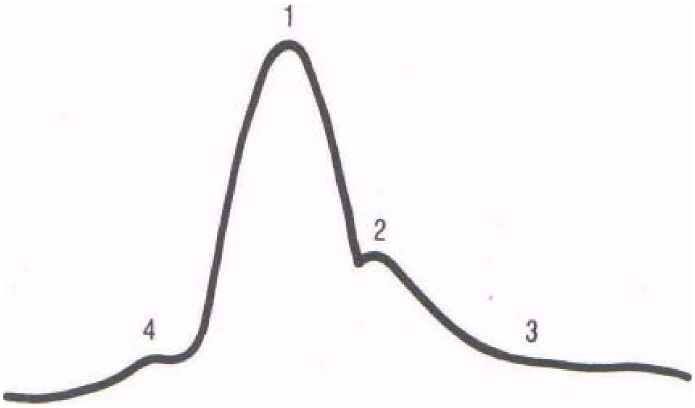
Understanding the arterial waveform



The waveform is a diagrammatic representation of the flow of blood in the artery. It correlates directly with the ECG trace. The ECG trace is the electrical activity of the heart and the arterial waveform is a diagrammatic trace of flow of blood or mechanical response to the electrical activity.

The wave form consists of 4 components:

1. Peak Systolic Pressure (PSP)
2. Dicrotic Notch
3. Diastolic Pressure
4. Anacrotic Notch



Headley, J. (2002) Invasive hemodynamic monitoring:

Peak Systolic Pressure (PSP)

This reflects maximum left ventricular systolic pressure. This phase begins with the opening of the Aortic Valve. A sharp uprise is seen in the waveform that reflects the outflow of blood from the left ventricle and into the arterial system. (QRS complex on ECG) The upward stroke is also referred to as the ascending limb.

Dicrotic Notch

With the greater pressure in the aorta than in the left ventricle, blood flow attempts to equalise by flowing backwards, this causes the aortic valve to close. On the waveform, aortic valve closure is seen as the dicrotic notch. This event marks the end of systole and the onset of diastole (end of T wave on ECG). This is not the case for a radial arterial line, however this will be explained later.

Diastolic Pressure

This value relates to the level of vessel recoil or amount of vasoconstriction in the arterial system. There is also a relation between the diastolic pressure and diastolic time during the cardiac cycle. During diastole, there must be ample time for the blood in the arterial system to drain down into the smaller arteriole branches. If the heart rate is faster and therefore has a shorter diastolic time, there is less time for run off into the more distal branches. The result is a higher diastolic pressure. This decline in pressure during diastole is called the descending limb.

Anacrotic Notch

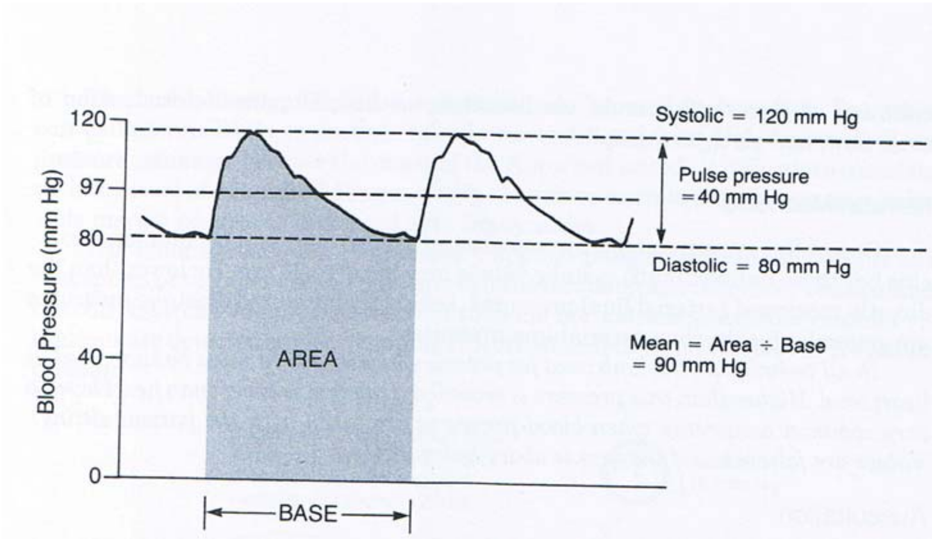
During the first phase of ventricular systole (isovolumetric contraction), a presystolic rise may be seen. This rise is called the anacrotic notch, which will occur before the opening of the aortic valve. This wave typically will be seen only in central aortic pressure monitoring, an aortic root tracing, or in some pathological conditions.

Pulse pressure

The difference between the systolic and diastolic pressure is called the pulse pressure. Factors that can affect the pulse pressure are changes in stroke volume, as noted in the systolic pressure, and also changes in vascular compliance, as seen in the diastolic pressure.

Incisure notch

In a radial arterial waveform the second notch is called the incisure and represents the pressure rise caused by the rebound of the wave from the periphery. If circulation is "shut down" the incisure occurs higher up the pressure downstroke. If peripherally dilated it occurs further down the pressure downstroke or may even appear as a second small pressure wave.



Darovic GO: Hemodynamic Monitoring:

Arterial line waveform alterations

Pulses alternans is an abnormality where during a regular sinus rhythm. it refers to a regular, alternating pattern of changes in pressure pulse, with every other pulse being slightly greater than the previous one. It results in an alteration of weak and strong beats without change in the pulse rate.

Figure 44
Pulses Alternans

Pulses paradoxus is when there is a large decrease in systolic blood pressure and pulse waveform during inspiration. The normal fall in pressure is less than 10mmHg. An excessive decline may be a sign of tamponade, adhesive pericarditis, severe lung disease, advanced heart failure.

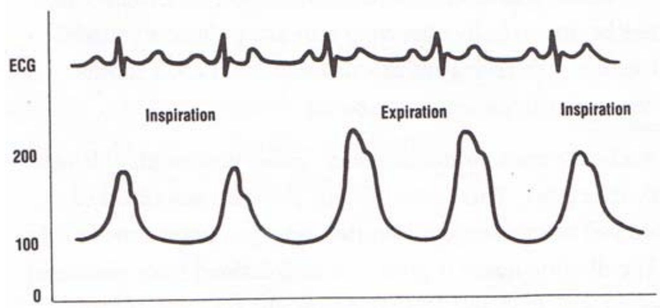


Figure 45
Pulses Paradoxus

Headley, J. (2002) Invasive hemodynamic monitoring:

Pulses Alternans is an abnormality where during a regular sinus rhythm, there is regular altering amplitudes of the peak systolic pressures. This condition may be a result of alterations in calcium or myocardial muscle fibres. Pulses alternans is a valuable visual assessment tool for patients with severe left ventricular failure. Clinically, the varying amplitudes may be difficult to palpate at a peripheral artery.

During inspiration, there is a lower intrathoracic pressure. This lower pressure results in an increased pooling of blood in the pulmonary vasculature. There is then less blood volume in the left side of the heart. As a result of this phenomenon, systolic pressure may be 3 to 10mm Hg lower on inspiration.

On expiration, the blood volume that was pooled in the pulmonary bed during inspiration is now shunted to the left heart. This increase in blood volume is responsible for a higher systolic pressure on expiration.

When there is a greater than 10mm Hg difference in systolic pressures from inspiration to expiration, the abnormality is referred to as *pulses paradoxus*. A variety of conditions can cause this phenomenon. More common conditions include inspiratory exaggerations, either from patient-related causes of pathophysiological -related causes and pericardial diseases. The mechanism is the alteration in venous return to the right heart and changes in intrathoracic or intrapericardial pressures.

Aortic stenosis produces a small pulse wave with a delayed systolic peak. This lower systolic pressure is a result of slowed ventricular ejection through the stenotic aortic valve. The dicrotic notch is often not well defined from abnormal closure of the valve leaflets during the onset of diastole. Since the systolic pressure is lower, these patients have a narrow pulse pressure.

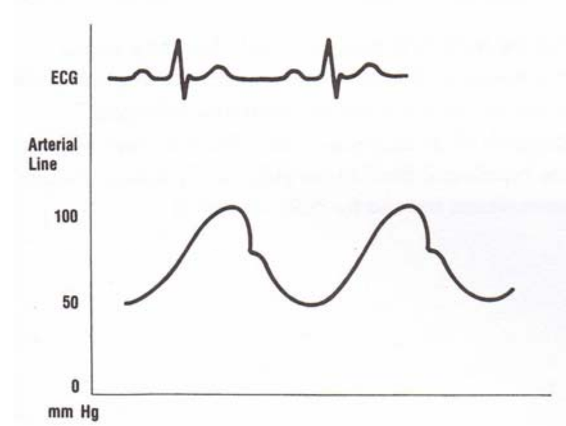
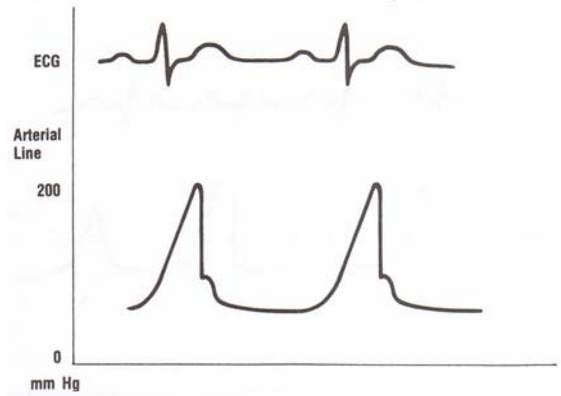


Figure 41

Aortic insufficiency is also known as aortic regurgitation. This condition is classically identified by a wide pulse pressure. During diastole, the left ventricle receives more backflow blood volume form the incompetent valve. This increase in blood volume is reflected as a higher peak systolic pressure during the next systole.



Atrial Fibrillation, with the classic irregularity, produces varying amplitudes in the arterial waveform. During episodes of premature ventricular complexes, the shortening of the diastolic filling time is also noted with a resultant decrease in systolic amplitude.

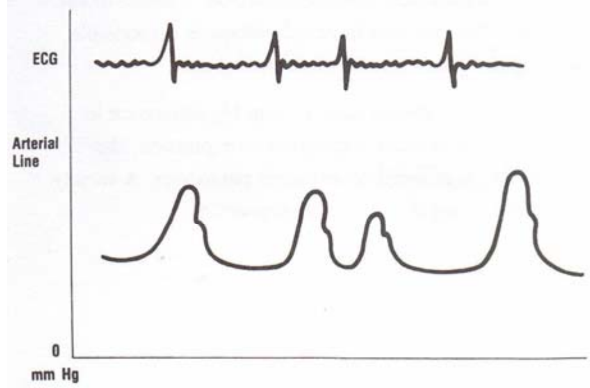


Figure 43
Atrial Fibrillation

Headley, J. (2002) Invasive hemodynamic monitoring

Arterial line accuracy

The clinical usefulness of the invasive haemodynamic monitoring system is dependent on the accuracy of the information it provides. When caring for a patient with invasive haemodynamic monitoring, there are several important nursing responsibilities that will help to maintain accuracy. These responsibilities include:

- patency of the line
- levelling the transducer
- zeroing the transducer and
- square wave testing

each of these 4 responsibilities need to be carried out at the commencement of each shift, following a change in the patient's position / bed height, and after access to the line.

Patency of the line

Patency of the monitoring system is maintained by connecting the soft tubing to a bag of 0.9% Sodium Chloride 500mL + 1000units Heparin, this is called the flush solution. This fluid bag is then placed into a pressure bag which is inflated to 300mmHg, pressurising the flush solution. At a pressure of 300mmHg approximately 3mL/hr of fluid is administered to the patient.

The flush solution serves a number of purposes.

- It provides a continual slow flow of fluid through the monitoring system to maintain line patency
- It allows the monitoring system to be flushed using the fast-flush device on the transducer
- It provides a medium for the transmission of physiological pressure waves from the patient to the transducer

Levelling the transducer

The purpose of levelling is to align the disposable transducer with the tip of the invasive catheter. It will ensure that there is a standard position used in relation to the atria in order to achieve consistent measurements. Levelling minimises the effect of hydrostatic pressure on the transducer, ensuring the accuracy of the measurement. If the transducer is positioned too low, the fluid within the tubing above the transducer exerts a greater pressure on the transducer and produces an abnormally high pressure value. If the transducer is positioned too high, the fluid within the tubing above the transducer exerts a lower pressure and produces an abnormally low pressure value. For every 2.5cm the transducer is below the tip of the catheter, the fluid pressure in the system increases by 1.87mm and visa versa if the transducer is above the tip of the catheter.

Method

At HKH the arterial line transducer is levelled to the tip of the catheter as mentioned above. This means that for a radial arterial line the transducer will be secured to the wrist of the patient, requiring only a short length of hard rigid tubing between the cannula and the transducer. Therefore there is very little distortion of the waveform from the cannula to the transducer. As a result a constantly accurate SBP, DBP and MAP are achieved.

Some units use the phlebostatic axis to level their arterial lines to, this requires a longer length of hard rigid tubing and results in increased distortion of the waveform to the transducer. The SBP and DBP numerics may be inaccurate but the MAP will remain constant. Irrespective to where the transducer is levelled as long as everyone is using the same reference point then the treatment and management of the patient will remain unchanged.

Zeroing the transducer

Zeroing is designed to negate the influence of external pressures, such as atmospheric pressure, on the monitoring system. Zeroing the arterial line ensures that only the actual pressures from the patient will be measured by the transducer, thus providing accurate data on which to base treatment decisions.

Method

1. The monitor alarms are suspended
2. The three-way tap at the transducer is turned off to the patient. This blocks all pressure readings from the patient.
3. The cap/bung is removed. This opens the monitoring system to air and atmospheric pressure. At this point the pressure waveform and pressure readings on the monitor will be temporarily lost.
4. Select the 'art' box on the monitor
5. Scroll down to the 'zero' tab, select this and wait. Watching the monitor you will see both the flattened pressure waveform and the pressure value will be seen to return to '0'.
6. Turn the three-way tap at the transducer off to air and replace the red bung this will open the arterial line to the patient.
7. The pressure waveform, and values will reappear on the monitor.

Square wave testing

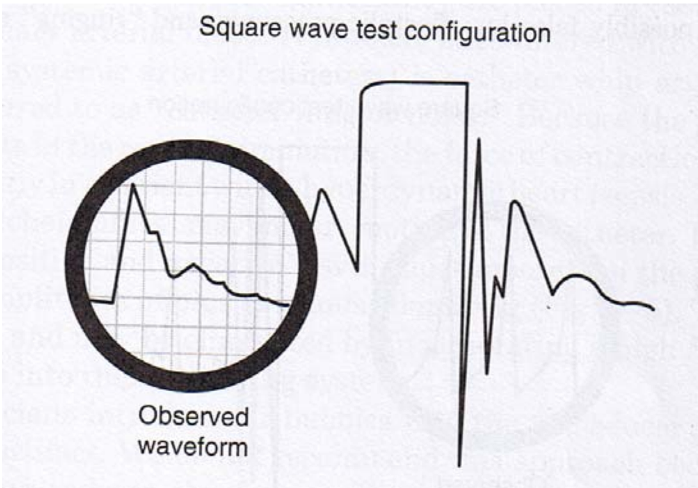
This test is designed to assist the bedside nurse in identifying if the arterial line is over or underdamped.

Method

1. Activating the fast flush device on the transducer.
2. Observe the arterial line waveform square off at the top of the scale and then drop to zero as the flush is released.

Optimally Damped System

When the fast flush of the continuous flush system is activated and the quickly released, a sharp upstroke terminates in the flat line at the maximum indicator on the monitor. this is then followed by an immediate rapid downstroke extending below baseline with just 1 or 2 oscillations within0.12 seconds (minimal ringing) and a quick return to baseline. The pressure waveform is also clearly defined with all components of the waveform visible, such as the dicrotic notch.



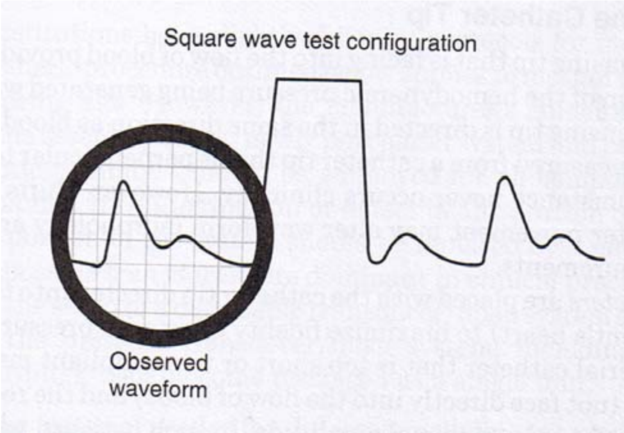
Darovic GO: Hemodynamic Monitoring:.

Nil intervention required

Overdamped System

Overdamping of the pressure waveform occurs when activation of the fast flush device generates a slurred upstroke and downstroke with no oscillations above or below the baseline.

It leads to underestimation of the systolic pressure and falsely high diastolic as well as poor defined components of the pressure trace (no dicrotic notch)



Darovic GO: Hemodynamic Monitoring:.

To correct this:

Check for the presence of clots/air bubbles in the catheter or tubing

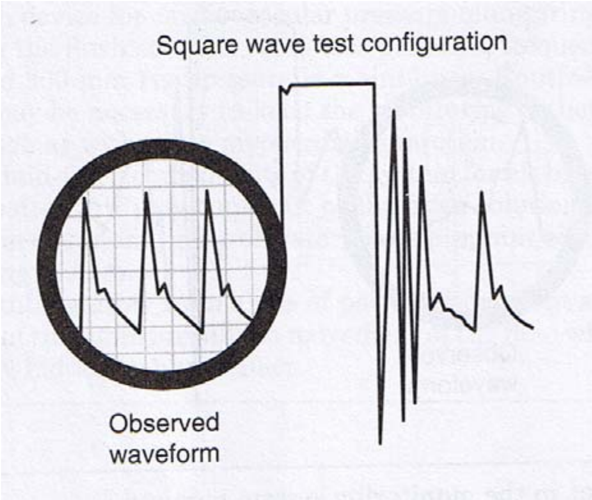
Ensure that the catheter is not resting against a vessel wall.

Check for any kinking in the catheter or tubing

Change the tubing to a short rigid monitoring tubing set.

Underdamped System

Underrdamping of the pressure waveform occurs when activation of the fast flush device generates a waveform that is characterised by numerous (more than three) amplified oscillations above and below the baseline. It leads to an overestimation of the systolic pressure and the diastolic may be under-estimated. It does however leave the mean arterial pressure unchanged.



Darovic GO: Hemodynamic Monitoring:

To correct this:

Remove excessive lengths of tubing and/or multiple stopcocks.

Patient factors such as tachycardia and high cardiac outputs states may lead to an underdamped state. It is more common to see an underdampened waveform in a young healthy patient as they produce strong contractions that may cause an overshoot or increased resonance in the fluid filled system.

In both of these cases, the accuracy of the haemodynamic data is reduced, which may have implications for patient management.

Trouble shooting

Problem	Solution
Difficulty with zeroing Does not reach "O" Waveform does not reach baseline	Check all equipment and connections, taps & lines Ensure line is correctly labelled on the monitor Ensure adequate fluid in pressure bag and pressure is at 300mmHg Ensure all roller clamps are open Check system for air bubbles and blood clots Consider replacing transducer cable to monitor
Unable to aspirate	Check patient side of line for any kinks Ensure 3 way tap is open in the correct direction Apply gentle traction on cannula while trying to aspirate Flush gently Consider replacing cannula
Falsely high readings	Check position of catheter and transducer Check waveform appears normal, not over/under dampened Re zero Remove any kinks/ air bubbles/ clots Perform manual blood pressure to confirm reading

Complications

- Haemorrhage – ensure line and all connections are secure, luer lock caps insitu, insertion site visible at all times, immobilise limb/joint.
- Infection – maintain dressing patency, monitor for signs of infection, attend line/dressing changes as per protocol.
- Disruption to distal circulation – monitor line for air bubbles, monitor limb distal to line for colour, temperature, movement and sensation, **NEVER** inject any fluids/medications through line other than the flushing solution insitu.
- Blockage and clotting – monitor line for obvious clots/kinks/clamps, monitor waveform for patency and correct pressure in flushing system.
- Accidental or patient removal – ensure line and dressing secure, maintain visibility, inform patient of risks and care of their arterial line (if possible), immobilise limb/joint as much as possible, some patients may require use of mechanical restraint (in accordance with HKH ICU Mechanical Restraint flowchart and the NSCCH restraint policy).

Dressings, Line Change and removal

- Ensure the arterial line dressing is intact. The dressing used for arterial lines in ICU at HKH is Tegaderm. See ICU Manual, for dressing and line change (A4), blood sampling (A5) and removal (A6) procedures.
- Check the patient care plan at the commencement of each shift to determine if the line and dressing change is due. Line/dressing changes are performed every 3 days. If attended remember to update the patient's care plan and progress notes accordingly
- An arterial line can remain insitu for an unlimited number of days. It is only removed on medical orders and usually because it is no longer required or when there is suspicion of arterial line site infection. Firm pressure needs to be placed on the site post removal for at least 5 minutes and a clear dressing placed over the site.

Safe management of an arterial line

- Check the arterial line insertion site and monitor for bleeding, kinking, dislodgement, signs of infection, dressing is occlusive and the line is sutured in place.
- Observe limb perfusion **distal** to the insertion site especially when withdrawing blood or flushing the cannula.
- Ensure that the arterial line is secured at a secondary anchorage point to reduce the risk of accidental removal.
- Ensure accuracy of the arterial pressure data by levelling the transducer system at the beginning of each shift and following each patient position change, and by zeroing the transducer at the commencement of the shift and following any system disconnection.
- Check the flush solution is pressurised to 300mmHg, and is changed every 24hrs.
- Monitor the arterial pressure waveform and troubleshoot as needed.
- Educate the patient as required.
- Set patient specific BP limits based on the medical orders and the patient's acuity.

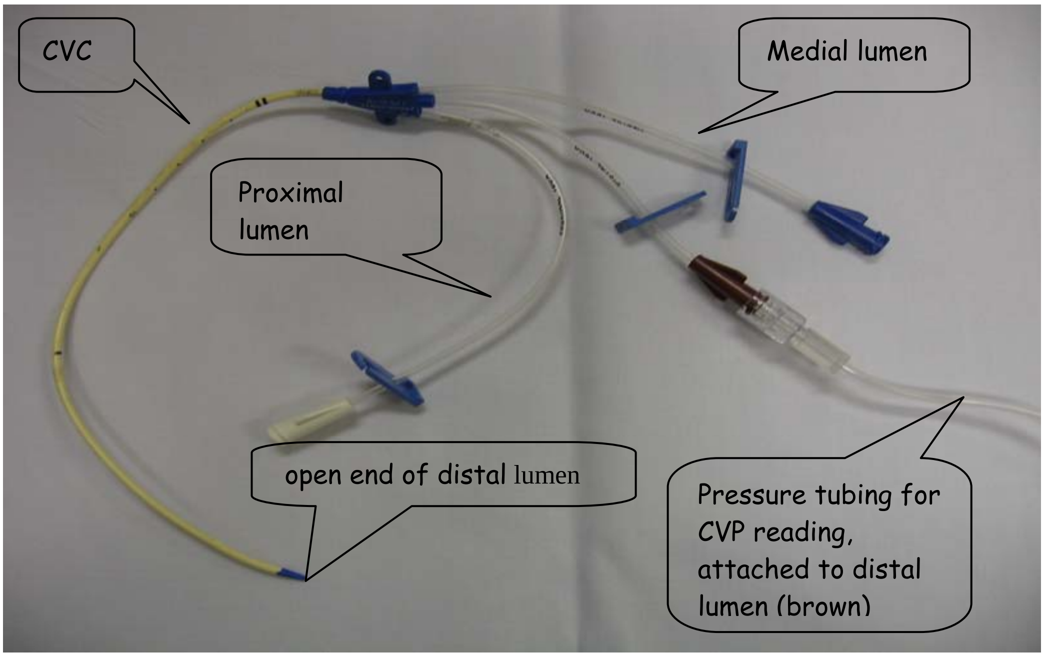
Central Venous Catheter (CVC)

A central venous catheter (CVC) is an invasive line that is inserted into a large vein where it measures the pressure generated by venous blood returning to the right side of the heart (the right atrium). A CVC can be made up of a single lumen or multiple lumens, multiple lumens are independent of each other and their exit into the blood steam is at different points along the catheter. The distal or brown lumen is the one that opens up at the very end of the catheter and is the one that is used to achieve central venous pressure (CVP) measurements. The catheter may have an antimicrobial coating.

If a CVP measurement is required then the distal lumen needs to be connected to a transducer line consisting of 3 sections:

- a hard rigid non compliant section of tubing
- the transducer itself and
- soft wide bore tubing.

The open end of the CVC detects the flow of blood in the vein and the pressures that are exerted with each contraction of the heart. These mechanical pressures are transmitted through the catheter into the fluid filled rigid tubing and up to the transducer. The transducer converts this mechanical pressure into kinetic energy. This kinetic energy is then transmitted to the monitor and graphically displayed on the monitor as both numerical pressures and a central venous waveform.



Hornsby Ku-Ring-Gai Hospital Intensive Care unit photograph taken by J Melloh (CNS) 2008

Central line sites for insertion

Several sites may be used but the subclavian is the optimal site of choice because of the longer subcutaneous tract, ease of fixation, ease of dressing and ease of keeping site clean. It also has the advantage of the lowest infection rate and increased patient comfort.

The internal jugular site has the lowest risk of pneumothorax on insertion and bleeding complication rates, but has a potentially higher infection rate.

The femoral vein site is easiest reached in an emergency but has a higher infection rate and decreased accuracy in CVP measurements.

The choice of site for central venous cannulation is determined by many factors including the balance between various risks associated with the technique (eg: patients' anatomical features like obesity), the duration required and the experience of the operator.

CVC's are inserted by a qualified medical officer.

Nursing responsibilities during the insertion procedure include:

- assist with patient positioning and explanation to the patient
- preparation of the flush bag and transducer system
- ensure infection control procedures and protocols are adhered to
- assist the medical officer as required
- closely monitor the patient during the procedure
- ensure the procedure outlined on Intranet: T Drive/Policies HKHS/CLI 37 or OWP CLI Manual is followed.

In order to competently manage a patient with a central line the nurse is required to:

- interpret the data on the monitor,
- respond appropriately (adjust treatments as necessary)
- understand the components of the waveform
- observe for complications and
- troubleshoot as needed

Understanding a CVP measurement

The primary use of the CVP measurement is to provide an indication of Right Ventricular Filling. In clinical situations of inadequate tissue perfusion - (eg indicated by reduced urine output, decreased blood pressure, poor peripheral perfusion) the CVP can be used as a guide for the administration of fluid volume. The aim of the fluid volume is to increase ventricular preload and thus increase stroke volume and cardiac output. An increase in cardiac output will increase the despatch of oxygen from the heart - the ultimate aim being to increase blood flow and oxygen delivery to tissues. Improved perfusion would be indicated by improved urine output, improved peripheral perfusion, etc.

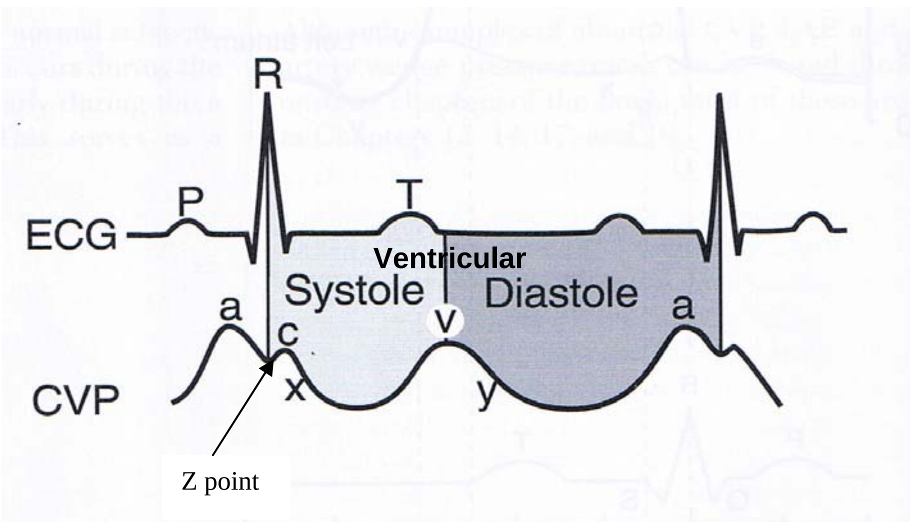
Clinically, fluid is given and CVP used as a guide to determine the degree of ventricular loading. The consequence of overfilling will be ventricular engorgement and decreased cardiac output. The aim is to find a point where the ventricle is “optimally preloaded” and to avoid overload. If the ventricle has been judged to be optimally preloaded and the signs of poor perfusion remain, indicating inadequate cardiac output, then medications to increase contractility may be used (eg adrenaline, dopamine, dobutamine etc).

The CVP is never treated as an isolated number. For instance if the patient is well perfused, has good end organ function, and is haemodynamically stable then the measurement of a low CVP has no significance and would not be “treated”.

Positive End Expiratory Pressure (PEEP) and Continuous Positive Airway Pressure (CPAP) raise intra-thoracic pressure during expiration (CPAP maintains a positive pressure during both inspiration and expiration). A proportion of this positive pressure can be transmitted to the vessels within the thorax and the pericardium. From the previous discussion on preload you will remember that preload is a distending or “stretching” pressure on the heart muscle fibers. Any pressure pushing from the outside is in effect pushing against the pressure inside the ventricle (cavity pressure). The effective pressure is actually the cavity pressure (CVP) less any transmitted intrathoracic pressure. This is important clinically because in the setting of high levels of PEEP / CPAP the CVP taken alone will overestimate the effective preload (ie: read higher than it actually is).

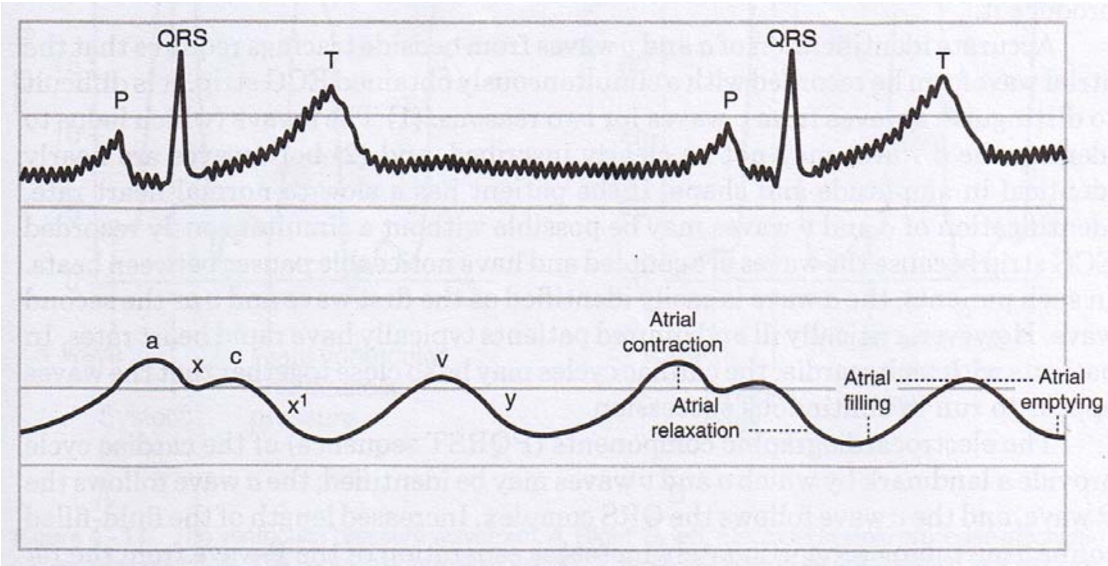
Interpreting the numbers

During diastole, the tricuspid valve opens to allow right ventricular filling prior to systole. When the tricuspid valve is open, there is an unobstructed passage between the tip of the catheter and the right ventricle, the pressure measured at this stage provides a reflection of right ventricular filling pressure, or, right ventricular end-diastolic volume (RVEDV). The CVP is calculated by the monitor as a mean pressure because right ventricular systolic and diastolic pressures are relatively low. Normal CVP can range from 0-8mmHg.



Mark, Jonathan B. (1998) Atlas of cardiovascular monitoring

Understanding components of the CVP waveform



Darovic GO: Darovic GO: Hemodynamic Monitoring:.

The CVP waveform reflects the pressure changes within the atria during the cardiac cycle. it consists of 2-3 positive waves and 2 downstrokes descents.

'a' wave: atrial contraction, starts just after P wave ends. Closely parallels the increase in right ventricular end diastolic pressure.

'x' descent: represents the fall in intra-atrial pressure that occurs during atrial relaxation. this descent may be distorted by a small crest, termed the 'c' wave.

'c' wave: occurs with closure of the tricuspid valve. The crest is the atrial pressure increase caused by the tricuspid valve bulging back into atrium. When this wave is present then the decline in the pressure following it is termed the x^1

'v' wave: represents passive atrial filling and follows the QRS complex. The crest of the 'v' wave coincides with the opening of the tricuspid valve. The downstroke is called the 'y' descent

'y' descent: represents a decrease in atrial pressure as the atrium empties into the ventricle.

'Z' point: coincides with the middle of the QRS wave, occurs just before closure of tricuspid valve. Good indicator of RVEDP is useful when 'a' waves are not visible such as in atrial fibrillation

Variations on the normal CVP waveform may occur with certain cardiac pathologies.

Atrial fibrillation: 'a' waves will be absent, and in atrioventricular disassociation (Complete Heart Block), 'a' waves may be dramatically increased ("cannon waves") if the atrium contracts against a closed tricuspid valve.

Tricuspid regurgitation: the 'c' wave will be replaced by a large positive wave of regurgitation as the blood flows back into the right atrium during ventricular contraction. This can elevate the mean CVP and give an inaccurate measurement.

CVC accuracy

The clinical usefulness of the invasive haemodynamic monitoring system is dependent on the accuracy of the information it provides. When caring for a patient with a CVP measurement, there are several important nursing responsibilities that will help to maintain accuracy. These responsibilities include:

- patency of the line
- levelling the transducer
- zeroing the transducer

Each of these 3 responsibilities need to be carried out at the commencement of each shift, following a change in the patient's position / bed height, and after access to the line.

Patency of the CVP lumen

A CVP reading is not required continuously and so infusions can be run on the same lumen you are using to measure the CVP. When a CVP measurement is required then the infusions must all be paused and the system levelled and zeroed.

Patency of the CVC is maintained by running continuous infusions on all lumens. As for the transducer set up on an arterial line, the soft tubing is connected to a bag of 0.9% Sodium Chloride 500mL + 1000units Heparin, this is called the flush solution. This fluid bag is then placed into a pressure bag which is inflated to 300mmHg pressurising the solution. At a pressure of 300mmHg approximately 3mL/hr of fluid is administered to the patient. The end of the rigid tubing (once primed) is then connected directly to the distal lumen.

The flush solution serves a number of purposes.

- It provides a continual slow flow of fluid through the monitoring system to maintain line patency
- It allows the monitoring system to be flushed using the fast-flush device on the transducer, this is especially important for the administration of emergency medications which can be flushed quickly. For this reason at least 1 spare 3 way tap should exist on this lumen.
- It provides a medium for the transmission of physiological pressure waves from the patient to the transducer

Levelling of the transducer

Transducers are levelled to the junction of the fourth intercostal space and midaxillary line, this point is referred to as the phlebostatic axis. This point on the chest is considered equivalent to the right atrium, and it is the right atrium from which most haemodynamic pressures, are measured.

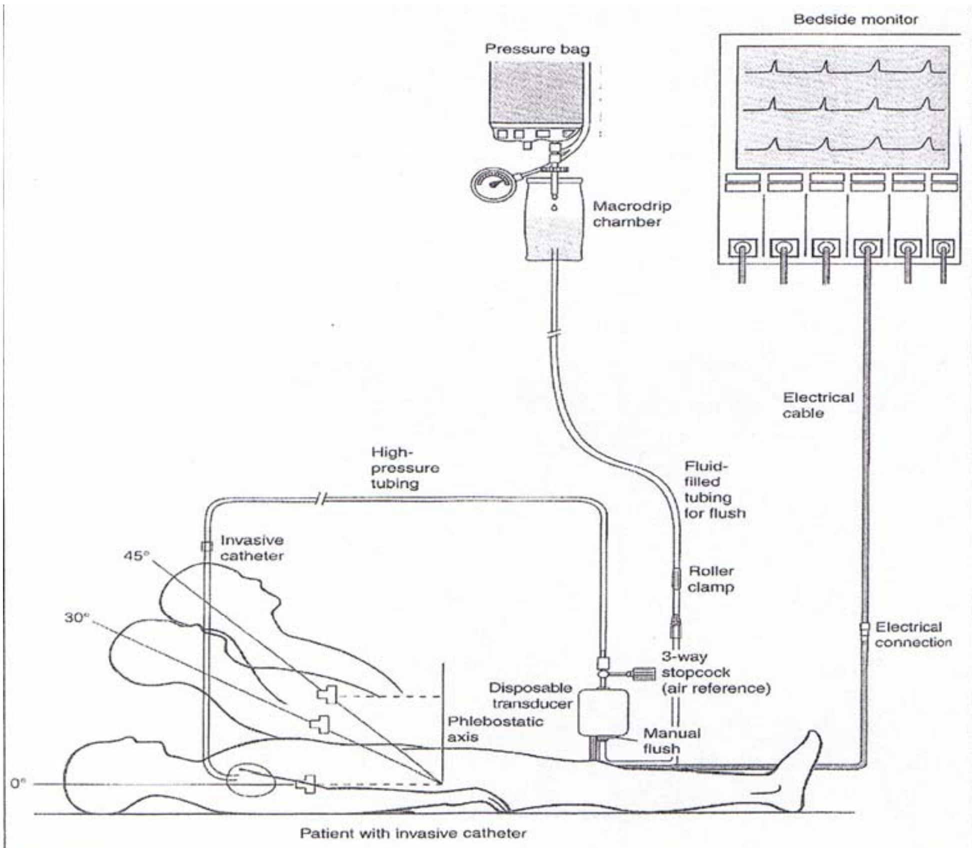


Fig. 15-57 The four parts of a hemodynamic monitoring include invasive catheter attached to high-pressure tubing to connect to the transducer; transducer; flush system, including a manual flush; and bedside monitor

Urden LD, Stacey Km, lough ME (2002) Thelan's Critical Care Nursing

Zeroing the transducer

Zeroing is designed to negate the influence of external pressures on the monitoring system, such as atmospheric pressure and other infusions running on the same lumen. Zeroing the CVP line ensures that only the actual pressures from the patient will be measured by the transducer, thus providing accurate data on which to base treatment decisions.

Method

1. Place the patient in a supine position (0-45^{o} is acceptable but it needs to be consistent)
2. The transducer is levelled to the phlebostatic axis
3. The monitor alarms are suspended
4. All infusions on the line are placed on pause.
5. The three-way tap at the transducer is turned off to the patient. This blocks all pressure readings from the patient.
6. The cap/bung is removed. This opens the monitoring system to air and atmospheric pressure. At this point the pressure waveform and pressure readings on the monitor will be temporarily lost.
7. Select the 'CVP' box on the monitor
8. Scroll down to the 'zero' tab, select this and wait. Watching the monitor you will see both the flattened pressure waveform and the pressure value will be seen to return to zero.

9. Turn the three-way tap at the transducer off to air and replace the blue bung, thus opening the CVP line to the patient.
10. The pressure waveform and values will reappear on the monitor.

Read the CVP at the end of expiration to reduce the influence of elevated intrathoracic pressure. It is also important to remember ventilation may effect CVP measurements by increasing intrathoracic pressure, producing an elevated CVP reading.

Troubleshooting

Problem	**Solution**
Difficulty with zeroing Does not reach "O" Waveform does not reach baseline	Check all equipment and connections, taps & lines Ensure all infusions running on the lumen are paused and 3 way taps are off to the infusions. Ensure line is correctly labelled on the monitor Ensure adequate fluid in pressure bag and pressure is at 300mmHg Ensure all roller clamps are open Check system for air bubbles and blood clots Consider replacing transducer cable to monitor
Unable to aspirate	Check patient side of line for any kinks Apply gentle traction on cannula while trying to aspirate Reposition patient (lie flat if tolerated with the CVC side down) DO NOT flush if you are unable to aspirate from the lumen Label lumen as blocked and inform MO Consider replacing CVC if all lumens are blocked
Falsely high readings	Check position of catheter by markings on catheter and review position on previous chest x-ray and transducer Check waveform appears normal, re zero Remove any kinks/ air bubbles/ clots Take into account the amount of PEEP the patient is receiving if on invasive ventilation

Complications

- Suspected Central Line Sepsis
- Blocked CVC lumen(s)
- Air embolus
- Pneumothorax
- Bleeding around site or from a loose connection

Follow procedure outlined on Intranet: T Drive/Policies HKHS/CLI 37 or OWP CLI Manual.

Dressing change

- CVC dressings are attended every 6 days or earlier if required.
- Care should be taken to ensure the CVC remains inserted at the correct length throughout the procedure.
- Any exudate from the insertion site should be swabbed and sent for culture prior to cleaning of the site. The MO must be notified and a general septic workup commenced.
- Ensure the care plan is updated with the dressing change and documented in the patient's progress notes.

Follow procedure outlined on Intranet: T Drive/Policies HKHS/CLI 37 or OWP CLI Manual.

Line change

- Line changes are attended every 3 days. Exceptions to this are for TPN lines which are changed every 24hours with each new bag hung, and propofol lines which are changed every 12 hours along with the infusion.
- It is advisable to wait until after the patient has been reviewed by the Intensivist to avoid unnecessary manipulation of the CVC lumens.
- Ensure the patient's care plan is updated with the line change procedure.

Follow procedure outlined on Intranet: T Drive/Policies HKHS/CLI 37 or OWP CLI Manual.

Removal

- A CVC is removed when it is no longer required, or when a CVC site infection is suspected.
- In ICU at HKH, CVC's can be removed by Registered Nurses who have completed the Critical Care Competency – Haemodynamic Monitoring, or under supervision by an accredited assessor.
- **All** CVC line tips are sent off for culture.

Follow procedure outlined on Intranet: T Drive/Policies HKHS/CLI 37 or OWP CLI Manual.

Heparin Locking

- If a lumen is no longer required it must be heparin locked to maintain patency.
- Heparin locked lines must be re-locked every 3 days.
- Ensure the lumen(s) are labelled as “heparin locked” and documented in the patient’s progress notes and care plan.

Follow procedure outlined on Intranet: T Drive/Policies HKHS/CLI 37 or OWP CLI Manual.

General CVC nursing management

Each shift nursing responsibilities to safely manage a patient with a CVC includes:

- ensuring that an x-ray of the CVC line is performed post insertion and prior to use.
- checking the CVC insertion site each shift and monitoring for bleeding, kinking, dislodgement, dressing security and signs of infection.
- ensuring that the CVC is sutured in place and is secured at a secondary anchorage point to reduce the risk of accidental removal or migration.
- ensuring accuracy of the CVP data by levelling the transducer system at the beginning of each shift and following each patient position change, and by zeroing the transducer at the commencement of the shift and following any system disconnection.
- checking the flush bag is the correct fluid, that it is changed every 24 hours and is pressurised to 300mmHg.
- ensuring that there is an emergency point of access (a 3 way tap) on the CVP (distal) lumen.
- checking all infusion lines, ensuring that each line is clearly labelled, and that drugs & fluids being infused are correct. If infused together via 3 way taps check compatibility as per ICU Drug Manual available on the Intranet or the HKH ICU Drug Compatibility Chart.
- ensuring patient is commenced on a Fluid Balance Chart and a minimum of 4 hourly observations (temp, pulse, respirations, Sp02, BP) are attended.
- ensuring that the CVC dressing is intact. At Hornsby we use a flap dressing technique by using two pieces of Tegaderm to make a flap (10cmX12cm).
- checking the patient care plan at the commencement of each shift to determine if a line change (3^{rd} daily) and/or dressing change (6^{th} daily) is due.
- ensuring that a medical review of jugular catheter after 7 days and subclavian catheter after 14 days is attended.
- monitoring the CVP waveform and troubleshoot as needed.
- educating the patient and relatives as required.

References

Adji, K., O'rouke, M. (2006). Clinincal use of indices determined non invasively from the radial and carotid pressure waveforms. *Blood Pressure monitoring*, 11 (4).

Bailey, R., Bauer, J. & Yanos, J. (1995). Accuracy of disposable blood pressure transducers used in the critical care setting. *Critical Care Medicine*; *23*(1), 187-192.

Campbell, B. (1997). Arterial waveforms: monitoring changes in configuration. *Heart & Lung; 26*, 204-214.

Darovic GO: Hemodynamic Monitoring: Invasive and Noninvasive Clinical Application, p 161 Philadelphia, W B Saunders, 1995

Elliott, D., Aitken, L. & Chaboyer, W. (2007). ACCCN'S Critical Care Nursing. Elsevier Australia: New South Wales.

Flerida Imperial- P, & McRae M. (2002), Protocols for practice. Applying research at the bedside. *Critical care nurse;vol22(1), Feb 2002*

Headley, J. (2002) Invasive hemodynamic monitoring: physiological principles and clinical applications, Edwards Lifesciences, California, United States of America.

Hodges, R; Garrett, K; Chernecky, C; Schumacher, L. (2005) Real World Nursing Survival Guide, hemodynamic monitoring, Elsevier Science, United States of America.

Hornsby Ku-ring-gai Hospital (2006) Organisation Wide Policy Manual (Clinical), Policy CLI 37, Version1, Issue 1.

Hudak, C; Gallo, B; Morton, P. (1998), Critical Care Nursing: A Holistic Approach. Seventh Edition, Lippincott, Philadelphia.

Kauer, A. (2006). Caring for a patient with an arterial line. April, *Nursing 2006*

Magder, S. (2006). Central venous pressure monitoring. *Current Opinion in Critical Care; 12*, 219-227.

Mark, Jonathan B. (1998) Atlas of cardiovascular monitoring. Churchill Livingstone: USA

McGhee BH, Bridges MEJ (2002) Monitoring arterial blood pressure: What you may not know. Critical Care Nurse; 22(2):50-79

Morton, P; Fontaine, D; Hudak, C; Gallo, B. (2001) Critical Care Nursing: A Holistic Approach. Eighth Edition, Lippincott, Philadelphia.

Rice, W., Fernandez, E., Jarog, D. & Jensen, A. (2000). A comparison of hydrostatic levelling methods in invasive pressure monitoring. *Critical Care Nurse; 20*(6), 20-30.

Sole, M., Lamborn, M. & Hartshorn, J. (2001). Introduction to Critical Care Nursing (3rd Ed.) W.B Saunders Company: Philadelphia.

Urden LD, Stacey Km, lough ME (2002) Thelan's Critical Care Nursing: diagnosis and management. Fourth Edition. Mosby. Missouri

The Nursing Guideline and Procedures for Invasive Blood Pressure Monitoring. Royal North Shore Hospital – Intensive Care Unit Intranet.

Royal North Shore Hospital Central Venous Access Device Learning Package – NSCCAHS Intranet.

Acknowledgements

This learning package was based on the guidelines developed by Kylie Garnsworthy(CNS), Roz Elliot (CNC), Ros Balkin (CNS), Angela Everett (CNE) and Anna Latimore (CNS) Northern Beaches Intensive Care Unit and Royal North Shore Intensive Care Unit.

Haemodynamic Worksheet

ARTERIAL LINES

1. Why at HKH ICU is the policy not to place the arterial line transducer at the phlebostatic axis?

2. How do we ensure that the data we see on the monitor is correct?

3. When does the arterial line need to be zeroed?

4. Why is it important to check perfusion when withdrawing blood or flushing the cannula?

5. What is the first thing that you should do if you see a “flat” arterial line on the monitor?

6. How long can an arterial line remain insitu?

7. When would you get a falsely high or low SBP reading?

8. What is the importance of an accurate MAP recording?

9. List 5 complications associated with arterial lines and outline their prevention and/or management.

10. Why is it important NOT to allow anything other than the fluid in the flushing system to be infused through the arterial line.

CENTRAL VENOUS CATHETERS

1. What does the central venous pressure (CVP) reflect?

2. How often should a CVP measurement be taken?

3. What may cause an increase in a CVP measurement?

4. What may cause a decrease in a CVP measurement?

5. What factors affect the accuracy of the CVP measurement and why?

6. Name 3 common sites for insertion of a central line?

7. Name 3 indications for the insertion of a central line?

8. What are the disadvantages of using the femoral site?

9. Name 5 complications associated with central lines and discuss their prevention and/or management.

10. Describe the strategy you would employ to minimise an air embolism occurring during the removal of a central line.

Unit of Competency
Haemodynamic Monitoring (Arterial Lines)

Elements A & B need to be completed at the beginning of each assessment if the assessment is not done all at once.

ELEMENTS (Expected Performance)	**PERFORMANCE CRITERIA** (Critical Aspects)
A *Demonstrate awareness of infection control guidelines.*	*1.1 Attend to hand hygiene* *1.2 Utilise relevant personal protective attire (standard precautions)* *1.3 Dispose of and /or return equipment*
B *Adhere to occupational health and safety standards.*	*2.1 Create a safe work environment* *2.2 Adjust bed height appropriately* *2.3 Recognise and clear trip hazards* *2.4 Dispose of equipment appropriately*

DESCRIPTOR: This competency is an entry level competency focussed on assessing the need for invasive monitoring, setting up for insertion of an arterial line, managing an arterial line, taking blood from an arterial line and removing an arterial line.

Element of Competency	**Performance Criteria**
1. Identify actual and potential patient problems with regard to patient's history and current condition.	• Identify need for monitoring of patient BP. • Identify and explain the factors that determine cardiovascular function. • Identify major reasons for haemodynamic instability. • Demonstrate knowledge required for non invasive haemodynamic monitoring. • Outline major indicators of a change in patient condition.
2. Assess need for arterial line insertion.	• State the relationship and differences between non-invasive blood pressure and invasive blood pressure measurement. • Identify rationale for arterial line insertion in relation to disease process, drug treatments and fluid status. • Identify potential sites for arterial line insertion. • Assess for collateral circulation at each site as required (Allen's test). • State the formula for calculating MAP.
3. Set up equipment required for arterial line insertion.	• Set up insertion equipment using sterile technique and in accordance with unit policy. • Identify OH&S issues. • Prime line and set up monitor and alarms appropriately. • Identify unit protocol for minimising line infection risk. • Check correct infusion fluid for flush bag is used and that it is pressurised to 300mmHg, explain the importance of this. • Ensure transducer is levelled and zeroed correctly as per unit policy. • Can explain why **no** IV injections may be given via the arterial line port.

Element of Competency	Performance Criteria
4. Ensure safe management of an arterial line.	• Identify and interpret physiology of normal arterial waveform. • Ensure line safety and limb perfusion. • Ensure checks of pressure bag, level and zero are attended each shift and after any patient position change or interruption to the line. • Describe the problems of overdamping and underdamping of waveforms and identify common causes. • Perform square waveform test to check for accuracy of measurements. • Identify any potential complications of maintaining an arterial line. • Demonstrate ability to troubleshoot at least 2 problems.
5. Demonstrate knowledge of specific unit observations.	• Update patient care plan. • Note line insertion and condition in progress notes. • Ensure hourly circulation observations are attended and documented. • Document SBP, DBP and MAP hourly.
6. Assess need to take blood from an arterial line.	• Check pathology order for blood tests required. • Correctly identifies tubes/syringes for common blood tests as ordered. • Correctly identifies any specific transport requirements for delivering blood tests to the pathology department. • Assemble equipment as required. • Correctly remove blood from arterial line.
7. Assess need for a dressing/line change.	• State unit protocol for routine dressing/line change. • Identify other conditions that require arterial line or dressing to be changed. • Perform dressing/line change as per unit policy. Maintain sterile technique in setting up and performing dressing change, demonstrate 'pinch' to dressing at line base to prevent line 'track' developing. • Document dressing/line change on patient care plan, progress notes and flow chart.
8. Assess need for arterial line removal.	• Identify factors which may indicate need for arterial line removal. • Recognise potential complications of removing an arterial line. • Position patient to minimise risks. • Remove arterial line safely. • Dress site appropriately and monitor.
9. Documentation.	• Document line/dressing change or removal in the patient care plan, on the flow chart and in the progress notes. • Document and inform MO if any sign of infection is identified. • Document blood results on the patient flow chart (ABG) and on the pathology/ABG flow charts. • Obtain review of results from MO and perform interventions as ordered.

Assessment decision: ☐ Competent ☐ Not yet competent (moving towards competency)

Action / further training required:

____

__

Details of feedback to candidate:

____

____

Details of feedback from candidate:

____

_

____

Assessor's signature: ___________________________ Date: _______________

Candidate's signature: __________________________ Date: _______________

Assessment Matrix									
Methods used to gather evidence	Elements of Competency								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Observation		✓	✓	✓	✓	✓	✓	✓	✓
Oral Questioning	✓	✓	✓	✓			✓	✓	✓
Confirmation of Result	✓	✓		✓	✓	✓	✓	✓	✓

Unit of Competency
Haemodynamic Monitoring (Central Venous Lines)

Elements A & B need to be completed at the beginning of each assessment if the assessment is not done all at once.

ELEMENTS (Expected Performance)	**PERFORMANCE CRITERIA** (Critical Aspects)
A *Demonstrates awareness of infection control guidelines.*	*1.1 Attend to hand hygiene* *1.2 Utilise relevant personal protective attire (standard precautions)* *1.3 Dispose of and /or return equipment*
B *Adhere to occupational health and safety standards.*	*2.1 Create safe work environment* *2.2 Adjust bed height appropriately* *2.3 Recognise and clear trip hazards* *2.4 Dispose of equipment appropriately*

DESCRIPTOR: This competency is an entry level competency looking at assessing the need for invasive monitoring, setting up for a central venous catheter (CVC), managing a CVC line, taking blood from a CVC line and removing a CVC line. This competency can be used in conjunction with information contained in the Organisational Wide Policy Manual OWP CLI 37.

Element of Competency	**Performance Criteria**
1. Assess the need to insert a central venous catheter (CVC).	• Discuss the importance of fluid, medication and fluid balance rationale necessitating central venous access. • Identify potential sites for CVC insertion. • Identify potential complications for each site.
2. Set up equipment for CVC insertion.	• Set up insertion equipment using sterile technique and in accordance with CLAB guidelines and unit policy. • Observe/assist insertion procedure in accordance with CLAB guidelines. • Ensure post-insertion CXR completed and reviewed by MO prior to infusing fluids. • In a timely fashion, prime infusion lines and set up monitor and alarms appropriately. • Ensure transducer is levelled and zeroed correctly as per unit policy. • Ensure correct infusion fluid for flush bag is used and that it is pressurised to 300mmHg. • Ensure CVP monitoring is on the distal lumen of the CVC without a non-reflux bung insitu. • Adhere to policy for minimising line infection risk.

Element of Competency	Performance Criteria
3. Ensure safe management of CVC.	• List 4 potential complications of a CVC. • State proactive nursing actions where appropriate to minimise these risks. • Identify the phlebostatic axis. • Discuss the importance of maintaining correct position of transducer and patient. • Ensure accuracy of CVC monitoring, perform a CVP measurement accurately and correctly. • Assess line for correct insertion length and fastening. • Identify normal parameters for CVP. • Identify and interpret physiology of normal CVP waveform. • Explain common causes for altered CVP waveform. • Assess site for signs of potential infection. • Ensure line security.
4. Awareness of unit observation requirements.	• Update patient care plan as per unit protocol. • Note line longevity and condition in progress notes. • Ensure daily observations of site are attended. • Document CVP when measured and inform MO.
5. Assess need for dressing change.	• Outline policy for routine dressing change. • Identify other conditions that require CVC dressing to be changed. • Perform dressing change, maintaining sterile technique for set up and procedure. Demonstrate 'flap' dressing as per OWP CLI 37.
6. Assess need for line change.	• Identify policy for routine line change. • Set up new infusions in accordance with medical orders and unit protocol. • Maintain sterile technique in setting up and performing line change. • Perform line change in accordance with OWP CLI 37.
7. Assess need for CVC removal.	• Identify length of time line in situ. • Identify reasons that may indicate need for line removal, both planned and unplanned. Discuss those requiring re-insertion and those which do not. • Identify 2 potential complications arising from removal of a central line. • Position patient appropriately and remove line safely as per OWP CLI 37. • Send tip for culture as required.
8. Documentation.	• Document line insertion, line and/or dressing change and line removal in the patient care plan, on the flow chart and in the progress notes. • Document and inform MO if any sign of infection is seen.

Assessment decision: Competent Not yet competent (moving towards competency)

Action / further training required:

____

Details of feedback to candidate:

____

____

Details of feedback from candidate:

____

____

Assessor's signature: ___________________________ Date: _______________

Candidate's signature: __________________________ Date: _______________

Assessment Matrix									
Methods used to gather evidence	Elements of Competency								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Observation		✓	✓	✓	✓	✓	✓	✓	✓
Oral Questioning	✓	✓	✓		✓	✓	✓	✓	✓
Confirmation of Result	✓	✓	✓	✓	✓	✓	✓	✓	✓