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# Hemodynamic Monitoring of Critically Ill Patients

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## 1. Introduction

**Hemodynamic monitoring: Introduction**

Hemodynamic monitoring measures the blood pressure inside the veins, heart, and arteries. It also measures blood flow and oxygen proportion in the blood. Monitoring hemodynamic events provides information about the adequacy of a patient's circulation , perfusion, and oxygenation of the tissues and organ systems. The effectiveness of hemodynamic monitoring depends both on available technology and on physician ability to diagnose and effectively treat the disease.

**General Principles of Hemodynamic Monitoring**

a) Hemodynamic monitoring involves assessment of several physiological parameters pertaining to the circulatory system, which includes measuring blood pressure in artery, vein & heart; oxygenation of the tissue and organs.
b) Hemodynamic monitoring involves physical assessments of the patient and interventions while interpreting monitor data.
c) Knowing the medical equipment used for hemodynamic monitoring, helps to rule out malfunctioning of gadgets and wrong reading recording (data bais).
d) Single readings of data are not considered as significant data.
e) The knowledge of the previous readings and interventions taken are very important.

**Purpose of hemodynamic monitoring**

a) Early detection and treatment of life threatening conditions such as heart failure and cardiac tamponade.
b) Evaluate the patient's immediate response to treatment such as drugs and mechanical support.
c) Evaluate the effectiveness of cardiovascular function such as cardiac output and other parameters, after cardiac surgery.
d) To differentiate among various organ system dysfunction's.

**Hemodynamic parameters which are commonly monitored in the critically ill**

| Sr No: | Variable | Normal values |
|---|---|---|
| 1 | Heart rate (HR) | 72–88 bpm |
| 2 | Mean arterial pressure (MAP) | 81–102 mmHg |
| 3 | Central venous pressure (CVP | 1–9 mmHg |
| 4 | Mean pulmonary artery pressure (MPAP) | 11–15 mmHg |
| 5 | Pulmonary artery occlusion pressure (PAOP, PAWP) | 0–12 mmHg |
| 6 | Cardiac index (CI) | 2.8–3.6 L/min/m2 |
| 7 | Stroke index (SI) | 30–50 ml/m2 |
| 8 | Left ventricular stroke work index (LVSWI) | 44–68 g*m/m2 |
| 9 | Right ventricular stroke work index (RVSWI) | 4–8 g*m/m2 |
| 10 | Systemic vascular resistance index (SVRI) | 1760–2600 dyne*s/cm5*m2 |
| 11 | Pulmonary vascular resistance index (PVRI) | 45–225 dyne*s/cm5*m2 |
| 12 | Hemoglobin (Hgb) | 12–16 g/dl |
| 13 | Arterial pH (pH) | 7.36–7.44 |
| 14 | Arterial oxygen tension (Pao2) | 10.7–13.3 kPa |
| 15 | Mixed venous oxygen tension (Pvo2) | 4.4–7.1 kPa |
| 16 | Arterial hemoglobin saturation (Sao2) | 95–99% |
| 17 | Mixed venous hemoglobin saturation (Svo2) | 75–79% |
| 18 | Arterial oxygen content (Cao2) | 15–20 ml/dl |
| 19 | Mixed venous oxygen content (Cvo2) | 10–15 ml/dl |
| 20 | Arterial-mixed venous oxygen content difference (C(a-v)o2) | 4–5.5 ml/dl |
| 21 | Oxygen delivery index (Do2I) | 520–720 ml/min/m2 |
| 22 | Oxygen consumption index (Vo2I) | 100–180 ml/min/m2 |

**Types of hemodynamic monitoring**

Two basic categories of monitoring are available, **Invasive and Noninvasive**

Invasive types of hemodynamic monitoring involve measurement of intravascular (blood pressure) and intracardiac (right atrial [RA] and PA) pressures by gaining access into an artery or vein. The catheter is connected to fluid-filled tubing and a pressure transducer that communicates with the bedside monitor.

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

**1) Arterial Lines**

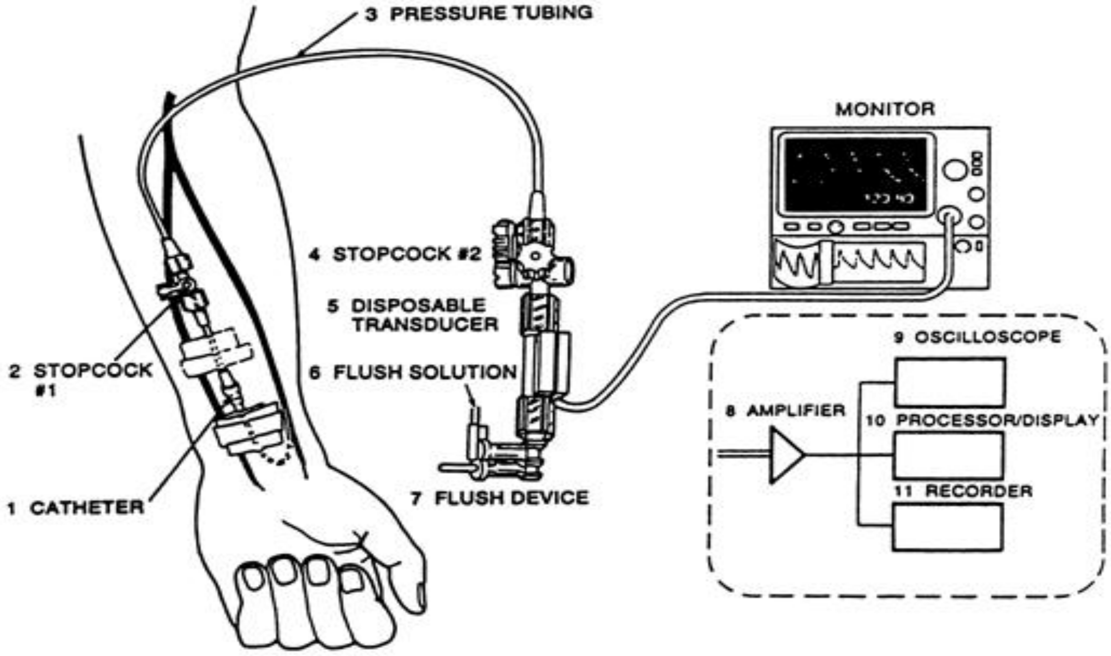
An arterial line is a cannula placed into an artery so that the actual pressure in the artery can be measured. This provides continuous measurement of systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP). The cannula is connected to an infusion set fitted with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

a) A hard, rigid, non-compressible section tubing.
b) The transducer with cardiac monitor.
c) 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. 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. An Allen's test should be performed by the medical staff prior to the insertion of a radial arterial line.

**Complications Related to Arterial Catheterization**
a) Infection
b) Arterial thrombosis
c) Distal ischemia, due to thrombosis (distal embolization) or local occlusion.
d) Air embolization

**Nursing responsibilities during the insertion of arterial line include:**
a) Explaining the procedure to the patient and consent from concern person.
b) Assist with patient positioning.
c) preparation of the articles required for procedure mainly flush bag and transducer system
d) Ensure infection control procedures and protocols are strictly followed.
e) Assist the medical officer as required
f) Closely monitor the patient during the procedure.




**Role and Responsibility of Nurse in Monitoring Arterial Blood Pressure**
a) Maintaining patency: The nurse sets up the line, zeroes the line, and levels it to patient's mid-axillary line.
b) Monitoring arterial BP and compare with manual BP.
c) Ensure waveform is appropriate and displayed on the monitor.
d) Maintains alarm limits and ensures that they are audible.
e) Monitors arterial site and maintains dressing.
f) Documents reading appropriately.

**2) Central Venous Pressure Monitoring**

The central venous pressure (CVP) provides information of right atrium pressure (RAP) and indirectly reflects the preload of the right ventricle (RV) or RV end-diastolic pressure. The CVP is measured in the superior vena cava or the RA by a water manometer which is measured in terms of centimeters of water (cm $H_2O$) or by a pressure transducer (the recommended method) in millimeters or mercury (mm Hg).Insertion of a CVP catheter is achieved percutaneously or by venous cut down through a central or peripheral vein. Most commonly acceptable insertion sites include the medial basilica, lateral cephalic, internal or external jugular, and subclavian veins.

**Measuring central venous pressure**

Central venous pressure (CVP) measurement can be recorded either manually, using a water manometer set, or electronically, using a transducer. Electronic measurement is most commonly used in all the critical care units.

**Manual measurement of CVP using water manometer**
- Explain the procedure to the patient and ensure that the patient is comfortable.
- The water manometer should be attached to intravenous fluid, for example normal saline 0.9 per cent.
- The three-way tap should be turned to fill the manometer with the fluid. Once full, the tap to the fluid should be turned off and the tap to the patient (that is CVP Cathter) should be opened.

- As the fluid drops in the manometer, the fluid level will rise and fall with the patient's respiration, and as it settles the mean pressure is recorded (that is the central point between the two is Centre venous pressure).
- After obtaining the CVP value, turn the stopcock to resume the IV infusion. Adjust the IV drip rate, as required.
- Place the patient in a comfortable position.
- Document the procedure.

**Electronic measurement of CVP using the transducer**

a) The transducer is fixed at the level of the right atrium and connected to the patient's CVP catheter via fluid filled extension tubing.

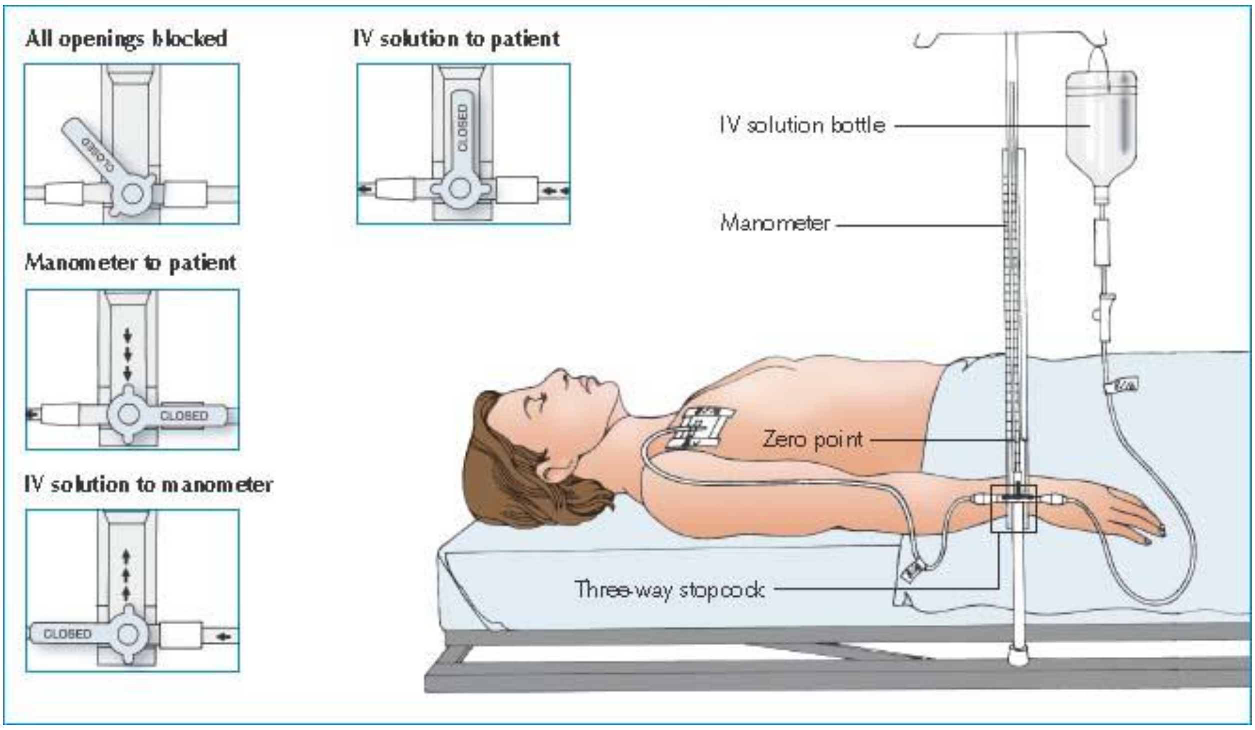
b) The transducer has to be calibrated (zeroed), this is carried out electronically via a monitor before each recording.

c) care should be taken to avoid bubbles in tubing .

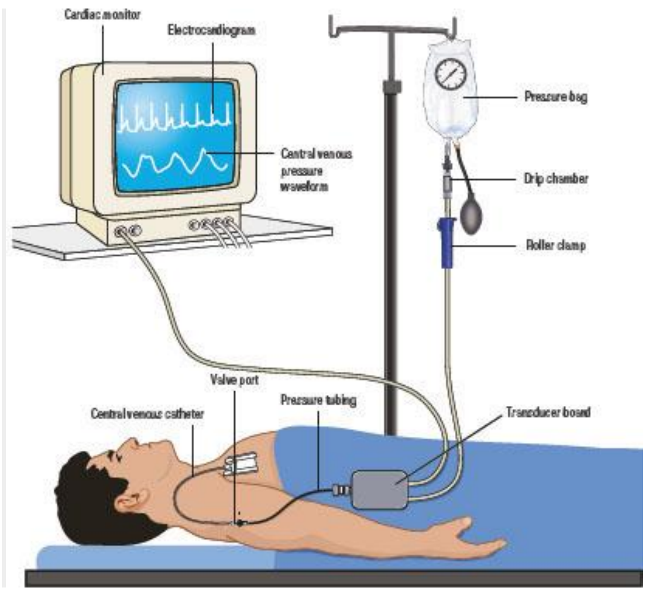
d) The transducer is then 'zeroed' to atmospheric pressure by turning its 3-way tap so that it is open to the transducer and to room air, but closed to the patient.

e) The 3-way tap is then turned so that it is now closed to room air and open between the patient and the transducer.

f) The monitor will display a CVP waveform, a continuous CVP reading, measured in mmHg rather than cmH2O, can be obtained




**Manual measurement of CVP using water manometer**




**Electronic measurement of CVP using the transducer**

**Complications of Central venous pressure measurement**

- Arterial puncture due to accidental puncture of the carotid, vertebral, subclavian, basilic, axillary or femoral arteries can occur during insertion.
- Pneumothorax may occur if the catheter punctures the chest wall, allowing air to enter the pleural cavity;
- Cardiac dysrhythmias can occur if the tip of the catheter touches the cardiac wall.
- A thrombosis in the vein or within the lumen of the catheter.
- Air embolism, where air enters the venous system.,
- septicaemia, if it is not cared for appropriately.

**Nursing care for CVP line and monitoring.**

- The patient should be informed and reassured and the procedure explained.
- The patient and the catheter site should be closely monitored.
- Any handling of the line should be done using aseptic precaution to reduce the risk of contamination.

- The dressing on the central venous site should be changed using aseptic techniques and a transparent dressing.
- The patient's vital signs should be monitored and recorded.
- Before removing the catheter, ask the medical practitioner if the tip of the catheter should be kept and sent for microbiological examination.
- The removal procedure is carried out using an aseptic technique. After removal of the sutures from around the catheter, a wad of sterile gauze should be held under pressure over the site.
- The catheter is pulled gently until it is removed, while the nurse continues to apply pressure to the site for up to five minutes until bleeding has stopped.
- The site is sealed with an airtight dressing, which should be left in place for 48 hours, and the patient can be returned to a comfortable position.
- If the tip is to be sent to the laboratory to be cultured it should be cut with sterile scissors and placed in a sterile specimen pot to prevent further contamination.

**3) Pulmonary Artery Pressure**

Pulmonary artery pressures provide direct, simultaneous measurement of pressures in the right atrium, right ventricle, pulmonary artery, and the filling pressure ("wedge" pressure) of the left atrium. The pulmonary artery catheter is frequently referred to as a Swan-Ganz catheter

**Pulmonary artery pressure monitoring**

- The catheter is inserted percutaneously through a large vein ( internal jugular, subclavian, or femoral veins) with or without the use of fluoroscopy.
- Once the catheter reaches right atria, the balloon which is located on the distal end of the catheter, is inflated ,then catheter is "floated" through the right atria(RA) and right ventricles(RV) and out into the pulmonary artery (PA), where it wedges in a branch of the PA
- Once the characteristic PA wedge pressure (PAWP) tracing has been obtained, the balloon is deflated, allowing the catheter to recoil slightly into the PA. The catheter is left in the balloon-down position to prevent pulmonary infarction.
- As the catheter passes through the heart, three pressure waveforms can be visualized using a PA catheter: RA, PA, and PAWP.

**Role of nurse in monitoring PA pressure**

- A sterile dressing is placed over the insertion site and the catheter is taped in place
- The dressing changed with strict aseptic precaution every 48 hours or as per hospital protocol.
- Proper positioning of patient during hemodynamic readings will ensure accuracy.
- Continuous ECG monitoring is essential while the PA catheter is in place.

**Complication of Pulmonary artery pressure monitoring**

- Balloon rupture caused by overinflating the balloon or frequent use of the balloon.
- Pneumothorax - may occur during initial placement.
- Dysrhythmias - caused by catheter migration
- Air embolism - caused by balloon rupture or air in the infusion line.
- Pulmonary thromboembolism - improper flushing technique, non-heparinized flush solution.
- Pulmonary artery rupture - perforation during placement, overinflation of the balloon, overuse of the balloon.
- Pulmonary infarction - caused by the catheter migrating into the wedge position, the balloon left inflated, or thrombus formation around the catheter which causes an occlusion.

**Non Invasive Hemodynamic Monitoring**

Non-invasive monitoring does not require any device to be inserted into the body. Non invasive hemodynamic monitoring is achieved by monitoring following:

- Blood pressure reading using sphygmomanometer or digital BP apparatus.
- Heart rate and cardiac activity using the electrocardiograph (ECG),
- Body Temperature monitoring using digital or mercury thermometer.
- Respiratory rate and end tidal CO2 monitoring pulse oximetry (saturation readings)
- Urine output.
- Capillary refill, to monitor dehydration and the amount of blood flow to tissue.

**Role of nurse in non-invasive hemodynamic monitoring**

- Check for the availability of instruments and equipments, evaluate their reliability.
- Explain the procedure to the patient; make them comfortable before taking readings.
- Follow the standard protocol to collect precise reading.
- Compare the reading with data which is given by patient and relatives.
- Any abnormal reading of patients, must be notified to physician immediately.
- Proper documentation of readings and data is essential.

## 2. Conclusion

Hemodynamic monitoring plays an important role to rule out perioperative and post operative complication; and also essential for management of patients admitted to critical care unit. However, appropriate measurement and interpretation of cardiovascular variables may help guide therapeutic treatment, which in turn can improve patient outcomes. The nurse should use most appropriate system for hemodynamic monitoring of the individual patient. Appropriate interpretation of the information offered by hemodynamic monitoring requires the integration of several variables. To improve patient management and outcome, the clinician must understand the advantages and the limitations of the various tools and parameters used during patients monitoring.