Hemodynamic Monitoring and Circulatory Assist Devices

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Learning Unit 2: Hemodynamic Monitoring and Circulatory Assist Devices

Hemodynamic monitoring refers to the measurement of pressure, flow, and oxygenation within the cardiovascular system. Both invasive and noninvasive hemodynamic measurements can be made. Values commonly measured include the systemic and pulmonary arterial pressures, the central venous pressure (CVP), the pulmonary artery wedge pressure (PAWP), the cardiac output (CO)/cardiac index (CI), the stroke volume (SV)/stroke volume index (SVI), the \( \text{O}_2 \) saturation of arterial blood (\( \text{SaO}_2 \)), and the \( \text{O}_2 \) saturation of mixed venous blood (\( \text{SvO}_2 \)). These parameters, along with clinical assessment data, can give the nurse a picture of the patient’s status and the effect of therapy.

Some general principles and terminology that we must understand when discussing hemodynamic monitoring include:

- **Cardiac output (CO):** the volume of blood pumped by the heart in 1 minute, normal range 4 to 8 liters per minute
- **Cardiac index (CI):** the cardiac output adjusted for body size
- **Stroke volume (SV):** volume ejected with each heartbeat
- **Stroke volume index (SVI):** SV adjusted for body size
- **Systemic vascular resistance (SVR):** opposition to blood flow by the systemic vasculature
- **Pulmonary vascular resistance (PVR):** opposition to blood flow by the pulmonary vasculature
- **Preload:** volume of blood within ventricle at end of diastole
- **Afterload:** forces opposing ventricular ejection (systemic arterial pressure, resistance from the aortic valve, mass and density of blood to be moved)
- **Contractility:** strength of ventricular contraction
- **Pulmonary artery wedge pressure (PAWP):** measurement of pulmonary capillary pressure, reflects left ventricular end diastolic pressure (preload)
- **Central venous pressure (CVP):** right ventricular preload or right ventricular end diastolic pressure, measured in the right atrium or in vena cava close to heart
- **Mean arterial pressure (MAP):** a measurement of perfusion pressure, must be at least 60 to perfuse organs, most physicians want it >70, calculated by adding the systolic blood pressure and 2 diastolic blood pressures and dividing by 3.

No matter what type of invasive pressure monitoring is being completed, there are some common principles to follow. The equipment must be referenced and zero balanced to the environment and dynamic response characteristics optimized. Referencing is positioning the transducer so the zero reference point is at the level of the atria of the heart. This is referred to as the phlebostatic axis. Zeroing confirms that when the pressure within the system is zero, the monitor reads zero. Zeroing is done during initial setup of the pressure line, immediately after insertion of the pressure line, when the transducer has been disconnected from the pressure cable or the pressure cable has been disconnected.
from the monitor, and when the accuracy of the values is questioned. Most facilities routinely zero the system every four hours. Optimizing dynamic response characteristics involves checking that equipment reproduces, without distortion, a signal that changes rapidly. This is completed with a dynamic response test (square wave test) performed every 4 to 8 hours, when the system is opened to air, or when the accuracy of values is questioned.

The two most common types of invasive pressure monitoring are continuous arterial pressure monitoring and pulmonary artery pressure monitoring. Continuous arterial pressure monitoring can be utilized with acute hypertension or hypotension, respiratory failure, shock, neurologic shock, coronary interventional procedures, the continuous infusion of vasoactive drugs, or for the patient requiring frequent ABG sampling.

Arterial pressure monitoring requires a catheter which the physician inserts into either the radial or femoral artery. The most commonly used site is the radial artery. Other components needed are the pressure tubing, a 500 ml bag of heparinized saline, a pressure bag, and the cable to connect the pressure tubing to the monitor. The monitor has both high- and low-pressure alarms that are set based on the patient’s status. Alarms should never be turned off. Readings should be obtained at the end of expiration.

Risks related to arterial pressure monitoring include hemorrhage, infection, thrombus formation, neurovascular impairment, and the loss of the limb. The Continuous flush system with the heparinized saline helps to prevent clot formation and maintain line patency. It delivers a low dose of heparin, 3 to 6 ml per hour. The neurovascular status distal to the arterial insertion site needs to be assessed hourly.

Pulmonary artery (PA) pressure monitoring can help guide the management of patients with complicated cardiac, pulmonary, and intravascular volume problems. With a pulmonary artery catheter the pulmonary artery diastolic (PAD) pressure and the pulmonary artery wedge pressure (PAWP) can be measured. These are indicators of cardiac function and fluid volume status. Monitoring the pulmonary artery pressures allows for therapeutic manipulation of the preload.

The pulmonary artery catheter is a multi-lumen, flow directed catheter. The distal lumen opens to the pulmonary artery. It is the port used for monitoring the PA pressure and can be used to draw mixed venous blood samples. The thermistor lumen port opens near the distal tip of the catheter. It monitors the core temperature and is used with the thermodilution method of measuring cardiac output. The right atrium port allows for measurement of the CVP, is the injection port for cardiac output measurement, and can also be used for blood draws. The second proximal port is most commonly used for the infusion of fluids and drugs and can also be used for blood sampling. The balloon port is used to obtain pulmonary artery wedge pressures and in insertion of the catheter.

The pulmonary artery catheter is inserted by the physician either through the subclavian or jugular vein or through the femoral vein. The catheter is connected to the pressure system prior to insertion so the waveform can be seen during insertion. The physician inserts the catheter into the right atrium and the balloon is inflated and the catheter advances through the heart to the pulmonary artery. The waveform
changes as the catheter moves through the chambers of the heart and into the pulmonary artery. Placement is verified with a chest x-ray.

When measurements are obtained from the pulmonary artery catheter they should be obtained at end expiration. The pulmonary artery wedge pressure is obtained by inflating the balloon with air until the PA waveform changes to a PAWP waveform. The balloon should be inflated slowly and for no more than four respiratory cycles or 8 to 15 seconds.

Central venous pressure monitoring is a measurement of right ventricular preload. It may be obtained from the PA catheter using one of the proximal lumens or from a central venous catheter that is placed in the internal jugular or subclavian vein.

Cardiac output is measured with the pulmonary artery catheter by either the intermittent bolus thermodilution method or by the continuous cardiac output method. Normal cardiac output is 4 to 8 liters per minute. Once the cardiac output is obtained, the SVR, SVRI, SV, and SVI can be calculated.

An elevated SVR can be caused from vasoconstriction from shock, hypertension, increased release or administration of epinephrine or other vasoactive inotropes, or left ventricular failure. A decreased SVR is seen with vasodilation from shock states and drugs that decrease afterload. Changes in SV are becoming more important indicators of the pumping status of the heart than other parameters are.

One type of noninvasive hemodynamic monitoring is impedance cardiography (ICG). It is a continuous or intermittent, noninvasive method of obtaining CO and assessing thoracic fluid status. Impedance-based hemodynamic parameters (e.g., CO, SV, SVR) are calculated from Z₀, dZ/dt, MAP, CVP, and ECG. It involves attaching 4 specialized electrodes to the chest. The major indications for impedance cardiography are early signs and symptoms of pulmonary or cardiac dysfunction, differentiation of cardiac or pulmonary cause of shortness of breath, evaluation of etiology and management of hypotension, monitoring after discontinuing a PA catheter or justification for insertion of a PA catheter, evaluation of pharmacotherapy, and diagnosis of rejection following a cardiac transplantation.

Venous oxygen saturation can be monitored with PA and CVP catheters. Venous oxygen saturation levels can help to determine tissue oxygenation. The values that are assessed are the SvO₂ and the ScvO₂. The SvO₂ and ScvO₂ reflect the balance between oxygenation of arterial blood, tissue perfusion, and tissue oxygen consumption (VO₂). The normal SvO₂/ScvO₂ at rest is 60% to 80%. A decrease in the SvO₂/ScvO₂ indicates a decrease in arterial oxygenation, a low cardiac output, a low hemoglobin level, or an increase in oxygen consumption or extraction. An increase in the SvO₂/ScvO₂ may indicate clinical improvement (e.g., improved arterial oxygen saturation) or a worsening the clinical condition, like sepsis.

Complications with PA catheters can occur. The risk of infection and sepsis can be reduced by using asepsis for insertion and maintenance of catheter and tubing. The flush bag, pressure tubing, transducer, and stopcock need to be changed every 96 hours. Air embolus can occur. The risk for air embolism can be reduced by making sure connections are secure. Ventricular dysrhythmias can occur during PA catheter insertion or removal and if the tip migrates back from the PA to the right ventricle.
If the PA catheter cannot be wedged, the catheter most likely is out of position. The physician should be notified. Pulmonary infarction or PA rupture can also occur. This can happen in relation to balloon rupture (e.g., overinflation), prolonged inflation, spontaneous wedging, or thrombus or embolus formation. To help prevent PA rupture and pulmonary infarction, never inflate the balloon beyond the balloon’s capacity which is usually 1 to 1.5 ml of air. The PA pressure waveforms need to be checked often for signs of catheter occlusion, dislocation, or spontaneous wedging. If spontaneous wedging occurs, the physician needs to be notified immediately. The system needs to be maintained with a slow infusion of heparinized saline solution to prevent clot formation as the arterial line is.

Noninvasive arterial oxygenation monitoring is completed using pulse oximetry. It is a noninvasive intermittent or continuous method of determining arterial oxygenation. It is recorded as the SpO₂. Monitoring SpO₂ may decrease the frequency of ABG sampling. Normally it ranges from 95% to 100%. Measurements may be difficult to obtain if patients are hypothermic, receiving IV vasopressors, or experiencing hypoperfusion. The finger is the most common measurement site. Alternate locations for the placement of the probe are the forehead and the earlobe.

Nursing management of the patient with hemodynamic monitoring includes doing a baseline assessment. We need to evaluate the patient’s general appearance, level of consciousness, skin color and temperature, vital signs, peripheral pulses, and urine output. The baseline assessment data is correlated with data obtained from biotechnology, which includes the ECG, arterial, CVP, PA and PAWP pressures, and the SvO₂/ScVO₂. The trends of hemodynamic monitoring are monitored and evaluated with the whole clinical picture. A single hemodynamic value is rarely significant. The goals of management are to recognize early clues to intervene before problems develop or escalate. For example, if the cardiac output is decreased, but the SVR and PAWP are in the normal range, the patient needs an increase in the heart rate. If the SVR is increased, the patient may be on too high of a dose of a vasopressor agent. If the PAWP is increased and the preload is increased, the patient is fluid overloaded and needs a diuretic.

**Circulatory Assist Devices (CADs)**

Circulatory assist devices are used to decrease cardiac work and improve organ perfusion when drug therapy fails. They provide interim support when the left, right, or both ventricles require support while recovering from injury (e.g., myocardial infarction), the heart requires surgical repair and patient must be stabilized (e.g., ruptured septum), or the heart has failed and patient needs cardiac transplantation.

One circulatory assist device is the intraaortic Balloon Pump (IABP). It provides temporary circulatory assistance by decreasing afterload and augmenting the aortic diastolic pressure. The outcomes of use include improved coronary blood flow and improved perfusion of vital organs.

The intraaortic Balloon Pump (IABP) consists of a sausage-shaped balloon, a pump that inflates and deflates the balloon, a control panel for synchronizing the balloon inflation to the cardiac cycle, and fail-safe features. The balloon is inserted through the femoral artery and placed in the descending thoracic aorta above the renal arteries. The balloon is then inflated and deflated to assist in blood flow.
The inflation is referred to as counterpulsation. The timing of the balloon inflation is opposite to the ventricular contraction. The assist ratio is 1:1 in the acute phase of treatment which means that there is one IABP cycle of inflation and deflation for every heartbeat. The assist ratio is decreased as the patient improves and therapy is weaned (e.g., 1:2, 1:3, 1:4). If the IABP therapy is successful there will be increased coronary artery perfusion, increased perfusion to the vital organs, an increase in cardiac output, and an increase in urine output.

Complications can occur with the use of the intraaortic Balloon Pump (IABP). Complications of IABP therapy include vascular injuries related to the dislodging of plaque, aortic dissection, or compromised distal circulation. There may also be thrombus and embolus formation. Mechanical complications may also occur. These can include improper timing of the balloon inflation which will result in an increased afterload, a decreased cardiac output, myocardial ischemia, and an increased myocardial oxygen demand.

To decrease risks of IABP therapy nursing must obtain cardiovascular, neurovascular, and hemodynamic assessments every 15 to 60 minutes, based on the patient’s status. The patient should be kept immobile and limited to side-lying or supine positions with HOB <45 degrees. The leg with the IABP catheter must not be flexed at the hip to avoid kinking or dislodgement of catheter.

Ventricular assist devices (VADs) are another type of circulatory assist device. They temporarily support the circulation until the heart recovers or a donor heart is found. It provides longer-term support for the failing heart as it may remain in place for several months. It allows more mobility than IABP. It is inserted into the path of flowing blood to augment or replace the action of the ventricles. They typically are placed between the left side of the heart and the aorta. The blood leaves the left side of the heart through the VAD which pumps it into the aorta. VADs can be implanted (e.g., peritoneum) or positioned externally. They also can provide biventricular support.

Indications for VAD therapy include those that need an extension of cardiopulmonary bypass from failure to wean or postcardiotomy cardiogenic shock and as a bridge to recovery or cardiac transplantation. They are also indicated for patients with New York Heart Association Classification IV who have failed medical therapy. Nursing management and care is similar to care for a patient with an IABP. Nursing needs to observe the patient for bleeding, cardiac tamponade, ventricular failure, infection, dysrhythmias, renal failure, hemolysis, and thromboembolism. The patient may be mobile and will require an activity plan. It is not a transplant so immunosuppressants will not be necessary.

The goals of therapy with circulatory assist devices are recovery through ventricular improvement, heart transplantation, or artificial heart implantation. Nursing needs to be aware that many patients will die or choose to terminate the device, causing death. Psychologic support for the patient and family is essential.