LEARNING OBJECTIVES

At the completion of this learning package the Registered Nurse will be able to:

1. Recognize the nursing responsibilities in patient care during catheter insertion, maintenance and removal.
2. Understand the principles of Pulmonary Catheter use and define basic parameters. This will also include the basic principles involved in the care, maintenance and removal of the percutaneous introducer. See Policy Cordis, SLIC, PICL - Care, Maintenance and Removal of CC 80-030
3. Identify normal hemodynamic waveforms seen during insertion, maintenance, wedging and cardiac outputs.
4. Identify a continuous wedge tracing.
5. List complications that may occur with Pulmonary (PA) Catheters and nursing interventions to prevent or minimize complications.
6. Complete the proficiency standards checklist with 100% accuracy.

METHOD

To be deemed competent the RN will:

1. Review the learning module and policy and procedure associated with Hemodynamic Monitoring
2. Complete the self test
3. Successfully demonstrate skills (following the proficiency standards check list) to the clinical educator or preceptor.
4. Perform an annual self assessment of competency and meet ongoing needs.

PREREQUISITE NURSING KNOWLEDGE

1. An understanding of cardiac and pulmonary anatomy and physiology
2. Basic cardiac rhythm interpretation
3. An understanding of the basic principles of hemodynamic monitoring

THEORY—Diagram is from the product insert- Sorenson Critical Care products

(Back to LM TOC)
Figure 1. Sketch of a #7 Fr. length, 110-cm (44-inch), four-lumen Swan-Ganz thermobulbulation catheter. In the cross section, note the two insulated wires; these run the thermistor lumen's length from its port to its opening 3.7 cm (1.5 inches) from the catheter tip.

Figure 2. A four-lumen Swan-Ganz catheter in position. When the catheter balloon wedges in a pulmonary artery branch, monitors can record (among other things) pulmonary artery pressure, pulmonary capillary wedge pressure, central venous pressure, and cardiac output.
1. There are several types of PA catheters with different functions. The standard PA catheter in use at the Capital District Health Authority (CDHA) is a four lumen, size 7.0 French, 110 cm. long and is made of a radiopaque fiber, which is yellow in color with black markings (bands).

1.1. Narrow black bands represent 10cm. lengths and wider bands represent 50cm.lengths. The Pulmonary Artery Catheter is usually inserted through the internal jugular or subclavian vein.

2. Central Venous Access may be obtained in a variety of places. The tip of the PA catheter should reach the PA after being advanced 45 to 55 cm. from the internal jugular or subclavian vein or approximately 70 to 80 cm. from the antecubital or femoral vein. The PA catheter contains a:

- Proximal lumen port - used to monitor right atrial pressure, withdraw venous blood samples and to inject the solution to allow for cardiac output measurements.
- Distal lumen port - used to monitor systolic, diastolic, and mean pressures in the PA and withdraw blood for mixed venous blood gases. NEVER INJECT ANYTHING INTO THIS LUMEN.
- The balloon inflation lumen - used to obtain pulmonary artery wedge or pulmonary occlusive pressure. The latex rubber balloon has a capacity of 1.5ml, and when inflated extends slightly over the tip of the catheter. The balloon is left deflated except for insertion of the catheter or to obtain a wedge pressure. Always keep the syringe off the lumen and never lock the port. Keep the balloon deflated during withdrawal of the catheter and inflated for insertion. Improper usage can cause damage to the valves of the heart (AACN Procedure Manual for Critical Care, 2005)
- The thermistor - connected to the monitoring cable and reads core (blood) temperature and calculates cardiac output measurements.

There are black markings on the PA Catheter to determine the distance the catheter has been inserted. The thin black lines indicate 10cm and the large black lines indicate 50 cm. They begin at the distal end of the catheter. To measure how far the catheter has been inserted, count the lines from the sleeve attachment outward.

Some PA Catheters have the capability of pacing of measuring mixed venous oxygen. Some catheters may be a different size. The PA Catheter is used to measure parameters such as cardiac output and mixed venous oxygenation as well as other parameters. It is also used to evaluate treatments and the response to various drugs. The following values can be obtained from the use of a PA Catheter:

1. **Pulmonary Artery Systolic (PAS)** – represents pressure generated by right ventricular systolic pressure into the pulmonary vasculature. (CCN). Normal 20 – 30 mm hg
2. **Pulmonary Artery Diastolic (PAD)** – indication of left ventricular pressure in the absence of increased pulmonary vascular resistance. Normal 6 - 10 mm hg
3. **Pulmonary Artery Mean (PAM)** – the average pressure over an entire cardiac cycle.
4. **Cardiac Output** – amount of blood pumped out by the left ventricle in one minute. Normal is 4 – 8 L/min

5. **Cardiac Index** – cardiac output adjusted for patient’s body surface area. Normal is 2.5 to 4.5

6. **Stroke Volume** – the volume of blood ejected during systole.

7. **Systemic Vascular Resistance (SVR)** – resistance to ejection of blood during left ventricular contraction.

8. **SVR Index (SVRI)** – SVR adjusted for the patient’s body surface area (BSA).


10. **PVR Index (PVRI)** – PVR adjusted for patient’s body surface area.

11. **LVSWI** – Left ventricular stroke work index

12. **RVSWI** – right ventricular stroke work index.

**DEFINITIONS**

1. **Central Venous Pressure/ Right Atrial Pressure (CVP/RAP)**—Right atrial pressure reflects right ventricular preload. If the volume of blood returning to the right atrium is low, the amount of blood entering the right ventricle is low. **This pressure is usually between 0-8 mmHg.**

2. **Right Ventricular Pressure (RVP)** – the pressure in the right ventricle is much higher then the right atrium. The normal range for:

   2.1. Right ventricular systolic is 20-30 mmHg.
   2.2. Right ventricular diastolic is 2-8 mmHg.
   2.3. Right ventricular end-diastolic is 2-6 mmHg. (RVEDP) The right ventricular pressure is what is recorded as the ventricle is filling. END DIASTOLIC occurs when the ventricle is completely filled and stretched

3. **Pulmonary Artery Pressure (PAP)**- The catheter is carried along from the right atrium through the pulmonic valve and into the pulmonary artery. The significant differences between the RV and the PA waveforms are a sudden increase in diastolic pressure and the presence of a dichrotic notch signaling the closure of the pulmonic valve and the beginning of diastole. The normal range for:

   3.1. Pulmonary Artery Systolic (PAS) =15-30 mmHg.
   3.2. Pulmonary Artery End Diastolic (PAD) = 6-12mmHg.
   3.3. Pulmonary artery Mean Pressure (PAM) = 9-18 mmHg.

4. **Pulmonary Artery Wedge/Occlusive Pressure- (PAWP/PAOP)**-The catheter, which is now in the pulmonary artery, is advanced into a branch of the pulmonary artery. The balloon occludes this branch and will measure the pressure distal to it. Blood continues to flow through other
branches of the pulmonary circulation into the pulmonary veins and the left side of the heart. The wedge pressure is reflective of the pressure within the left atrium since the blood flowing through the pulmonary veins is equal to that in the left atrium. The normal for this measurement is 4-12 mm Hg.

The PA Catheter has the capability to display 4 wave forms in total. They are:

1. RIGHT ATRIAL WAVEFORM – as the PA catheter is advanced a RA waveform is visible on the monitor. The normal mean pressure in this chamber is 2-5 mm Hg. The balloon must now be inflated to allow for ease of insertion and protection of the heart. RA pressure is used to determine volume status and right ventricular function.
2. RIGHT VENTRICULAR WAVEFORM – this waveform has distinct systolic and diastolic pressures. Normal RV pressures are 20 – 30 mm Hg systolic and 0 – 5 mm Hg diastolic. It is common for some premature ventricular contractions (PVC’s) to occur during insertion. RV pressure is used to determine RV function and volume.
3. **PULMONARY ARTERY WAVEFORM** – this has a dichrotic notch visible on the downward slope representing closure of the pulmonic valve. PA pressure is used to determine the amount of resistance in the pulmonary vasculature and RV function.
4. **PULMONARY ARTERY WEDGE WAVEFORM** – the waveform decreases in size. It is described as a wedge tracing because the balloon becomes wedged into a small pulmonary vessel. The normal range is 5 – 12 mm Hg. Usually the PAWP is 1 – 4 mm Hg less than the PADP and, therefore the PADP can be used if the catheter is not to be wedged. The PAWP is used to determine left ventricular function.

![Pulmonary Artery Wedge Waveform](image)

**Nursing Responsibilities during PA Catheter Insertion:**

1. Explain the procedure to the patient and/or family. Provide patient pamphlet on Pulmonary Artery Catheter (IC85-0072).
2. Maintain sterile technique at all times during insertion
3. Place patient in Trendelenberg
4. Flush lines (the solution used at the CDHA for flushing is normal saline unless otherwise ordered) and test balloon inflation with physician
5. Ensure all connections are tight
6. Ensure that the sterile plastic sheath is placed over the catheter prior to insertion to enable the physician to manipulate the catheter if needed once it has been inserted.
7. Observe wave forms as the catheter is inserted and monitor for any arrhythmias
8. Measure the distance the catheter had been inserted into the patient and document.
9. Confirm with physician on CXR if the catheter lies in the right or left pulmonary artery and document.

(Back to LM TOC)
Maintenance of the Catheter Once Inserted

1. Continuously monitor the PA Pressure to quickly visualize any change in wave form (i.e. See if the PA Catheter had migrated to a Wedge position)
2. Continuously monitor for any arrhythmias
3. Maintain aseptic technique at all times
4. Allow the syringe on the balloon inflation port to passively deflate. Remove syringe once the balloon is deflated and do not lock the balloon inflation port.
5. If drawing blood from the PA port withdraw the syringe slowly because it is possible to cause pulmonary collapse and/or trauma to the wall of the artery.
6. During any manipulation of the catheter by the physician make sure the balloon is deflated before the catheter is withdrawn to prevent any damage to the heart valves.
7. Take all readings at the end of expiration when the intrathoracic pressure is equal to the atmospheric pressure. When spontaneously breathing intrathoracic pressure decreases during inspiration, increases during expiration and equal to atmospheric pressure at end expiration. During positive pressure ventilation, intrathoracic pressure increases during inspiration or ventilation, decreases during expiration and is equal to atmospheric pressure at end expiration. (Critical Care Nurse)
8. Use the 4th intercostals space mid – axillary line as a reference point to the right atrium. The stopcock on the transducer is used for reference to atmosphere when leveling to the right atrium.
9. PA Pressures can be affected for PEEP greater than 10 mm hg.
10. If you need to draw a mixed venous blood gas from the pulmonary artery port, aspirate slowly. It is possible to cause pulmonary artery collapse and/or trauma to the wall of the artery.

Cardiac Output
Cardiac output is defined as the amount of blood ejected by the heart in one minute.

Cardiac Output (CO) = Heart Rate (HR) x Stroke Volume (SV)

Cardiac output (CO) is usually measured by an intermittent thermodilution method. The thermodilution method uses temperature change as an indicator. A known amount of solution with a known temperature is injected rapidly unto the proximal port of the PA catheter. The cooler than blood temperature solution mixes with the surrounding blood, and the temperature is measured downstream in the pulmonary artery by a thermistor imbedded in the catheter. The change in temperature is plotted on a time temperature curve and the computer calculates a numerical value denoting cardiac output (Thelan et al, 1998). The set up and preparation for performing a cardiac output may vary from one ICU to another based on the monitor being used. It is recommended to use D5W when obtaining a thermodilution cardiac output (TDCO) measurement because the specific gravity of D5W is a component in the formula used to obtain CO by this method and the use of saline can cause a 2% decrease in TDCO measurement (AACN Procedure Manual for Critical Care, 2005).
The normal thermodilution curve for CO shows a sharp upstroke from rapid injection of injectate. This is followed by a smooth curve and slightly prolonged down slope back to the baseline.

When the cardiac output is low, more time is required for the temperature to return to baseline, producing a larger area under the curve.

With a high cardiac output, the cooler injectate is carried more quickly through the heart, and the temperature returns to baseline faster. This produces a smaller area under the curve (AACN Procedure Manual for Critical Care, 2005).

See graphs below (Courtesy of Abbott Sorenson Critical Care).

If any hemodynamic calculations are required after the cardiac output is obtained, the height and weight of the patient must be inserted into the computer.
CARDIAC OUTPUT

THERMODILUTION CURVES

Smooth upstroke to peak, then gradual downslope to Computer looks for a smooth curve.

Computer extrapolates downslope to calculate area and Respiratory variation. Increase baseline from recirculation of injectate.

Small area under the curve is typical of a high cardiac output change in injectate temperature over time).

Large area under the curve seen in patients with low cardiac (greater change in temperature over time).

Uneven upstroke on curve.

Severe artifact on both upstroke and downstroke of curve

Injectate delivered in over four seconds.

A, Variations in the normal cardiac output curve. B, Abnormal cardiac output curves that produce an erroneous cardiac output valve.
Complications of Pulmonary Artery Catheters

Because the PA Catheter is a central line, it is prone to the complications of central line catheters as outlined in Policy Non-tunnelled Central Venous Access Catheter (multilumen) CC 80-015.

There are complications specific to the PA Catheter which includes the following:

1. **Ruptured Pulmonary Artery Catheter / Pulmonary Infarct** – this is a medical emergency that requires immediate intervention. This can be fatal and surgical repair is necessary. If this occurs, place the patient with the bad lung down. If it is not known which pulmonary artery the catheter has migrated to, assume it is the right side and lie the patient on their right side.
   1.1. To try and prevent this complication from happening, do not inflate the balloon with more than 1.5 cc’s of air and continuously monitor the waveform for over wedging.

2. **Balloon Rupture** – this can occur as a result of over inflation, frequent inflation or repeated aspirations of air from the balloon port. Always allow the air to passively deflate from the balloon port. A balloon rupture should be suspected if blood occurs in the balloon lumen or no resistance is felt when the balloon is inflated. If it occurs, do not try and inflate the balloon; tape the port closed and call a physician.

3. **Ventricular Arrhythmias** – these usually occur during insertion of the catheter. If noted while the catheter is in place, the catheter may need to be repositioned.

4. **Spontaneous Wedging of the Catheter** – continuously monitor the waveforms to try and detect this quickly before further complications arise.

5. **Knotting of the catheter** – if it is noted on x-ray that this has occurred, notify the physician and do not try to remove the catheter.

6. **Valve damage** – to try and prevent this, always deflate the balloon of the catheter before it is pulled back.

REFERENCES


SELF TEST

The following questions will help you evaluate your understanding of basic Hemodynamic Monitoring principles.

1. Guidelines for removal of PA catheter include all of the following except:
   a) Physicians order for removal
   b) Instructing patient to hold his breath after a deep inspiration then withdrawing
   c) Removing catheter when resistance is met
   d) Removing catheter if temporary transvenous pacemaker is present
   e) Supine positioning
   f) Weaning patient from all inotropes before removal

2. Complications associated with inflation of the balloon to measure pulmonary artery wedge pressure are:
   a) Thrombophlebitis
   b) Pulmonary infarction
   c) Pulmonary artery perforation
   d) Arrhythmias
   e) B and C

3. How do you measure how far the catheter is inserted into the patient? The heavy (thick) black lines indicate 50 cm in length and the thin lines indicate 10 cm markings.
   a) Count the lines from the entry point outward
   b) Check for the catheter line at the position where the catheter meets the entry point into the chest. Record this length in your notes
   c) Count the lines from the sleeve attachment outward.
   d) The distance the catheter is in has no significance.

4. Which of the following arrhythmias are associated with catheter insertion?
   a) PVCs
   b) PJC(junctional)
   c) Atrial fibrillation
   d) PVCs and ventricular fibrillation

5. Complications involving PA catheter removal may include all of the following except:
   a) Complete heart block
   b) Venous air emboli
   c) Dysrhythmias
   d) Thrombosis
   e) Valvular damage

6. Care of the PA balloon should include:
   a) Inflating slowly to prevent over inflation carefully observing waveform and stopping when PAWP trace is present
b) Recording the amount of air required to inflate the balloon in the nurse’s notes
c) Inflating the balloon as required to obtain a straight line wave form
d) A and B

7. Cardiac output is the volume of blood ejected by the heart each minute. Cardiac Index takes into account:
   a) Sex
   b) Body weight and size
   c) Previous cardiac output readings
   d) Age

8. A high SVR reading could be associated with:
   a) Pulmonary hypertension
   b) Hypovolemia and shock
   c) Heart Failure
   d) Hyperthermia
ANSWERS

1. C, D, F
2. E
3. B
4. A
5. D
6. B
7. B
8. B.
#1. **Skill: Assisting with Insertion**

<table>
<thead>
<tr>
<th>SKILL</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Explain the procedure to the patient and family. Obtain informed consent</td>
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<tr>
<td>2. Assembles appropriate equipment.</td>
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<tr>
<td>3. Primes PA and introducer tubing according to manufacturers instructions.</td>
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<tr>
<td>4. Inflates pressure bag to 300 mmHg.</td>
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<tr>
<td>5. Levels and zeros transducer.</td>
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<tr>
<td>6. Sets gain on monitor.</td>
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<tr>
<td>7. Opens equipment and assists physician to prepare for procedure.</td>
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<tr>
<td>8. Assist with patient positioning.</td>
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<tr>
<td>10. Assist as requested placing sterile equipment on insertion tray</td>
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<tr>
<td>11. Assists physician to prepare for the rest of the procedure (draping patient, connecting PA tubing, flushing ports, testing balloon, ensuring sleeve has been placed, ensuring artefact appears on monitor when PA tip is wiggled).</td>
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<tr>
<td>12. Inflates and passively deflates balloon as directed by physician during insertion.</td>
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<tr>
<td>13. Monitors the patient’s cardiac rhythm during the insertion procedure and alerts physician to any abnormalities.</td>
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<tr>
<td>14. Monitors and identifies waveforms as the PA catheter advances</td>
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<tr>
<td>15. Monitors the patient for any distress and signs of complications during the procedure.</td>
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<tr>
<td>16. Assist physicians with application of clear dressing, secures catheter and obtains order for CXR.</td>
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<tr>
<td>17. Ensures the principles of aseptic and sterile technique are followed Labels line with set-up date, time and initials</td>
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</table>
### TITLE:
Care of the Patient with a Pulmonary Artery Catheter

### #2. Skill: Maintenance of Pulmonary Artery Catheter

<table>
<thead>
<tr>
<th>SKILL</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1. Ensures PA tracing is continuously monitored.</td>
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<tr>
<td>2. Correctly identifies frequency of IV solution, tubing, and site change policies.</td>
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<tr>
<td>3. Levels and zeros transducer correctly.</td>
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<tr>
<td>4. Ensures pressure bag is inflated to 300 mmHg.</td>
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<tr>
<td>5. Identifies waveforms correctly.</td>
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<tr>
<td>6. Identify waveform abnormalities.</td>
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<tr>
<td>7. Monitors and intervenes within scope of practice potential complications.</td>
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<tr>
<td>8. Identifies situations which would require immediate notification of the physician.</td>
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<tr>
<td>9. Ensures aseptic technique is utilised in all aspects of the maintenance of the PA catheter.</td>
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</tbody>
</table>
**CAPITAL DISTRICT HEALTH AUTHORITY**  
**NURSING DIVISION**  
Proficiency Standards Skills Checklist

**TITLE:** Care of the Patient with a Pulmonary Artery Catheter

**Name/ Nursing Unit:**

#3. **Skill:** Obtaining Pressure Readings

<table>
<thead>
<tr>
<th>SKILL</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1. Correctly positions patient.</td>
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<tr>
<td>2. Ensures transducer is properly levelled.</td>
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<tr>
<td>3. Identifies waveforms correctly.</td>
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<tr>
<td>4. Correctly obtains PAS and PAD pressures. Documents q1h.</td>
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<tr>
<td>5. Correctly obtains RA pressure. Documents q 1h.</td>
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<tr>
<td>6. Correctly obtains PAWP. Documents as per unit standards.</td>
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<tr>
<td>7. Remove syringe from inflation port.</td>
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<tr>
<td>8. Verifies PA waveform once pressure readings obtained.</td>
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<tr>
<td>9. Identifies situations that would require notification of the Physician.</td>
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<tr>
<td>10. Identifies the procedure followed if balloon rupture is suspected.</td>
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### Title: Care of the Patient with a Pulmonary Artery Catheter

### Nursing Unit:

#4. Skill: Measurement of Cardiac Output

<table>
<thead>
<tr>
<th>SKILL</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1. Correctly prepares the bag and syringe of injectate.</td>
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<tr>
<td>2. Prepares cardiac output (CO) measurement equipment Correctly ensuring appropriate variables are entered. Height and weight entry is required.</td>
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<tr>
<td>3. Correctly positions patient.</td>
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<tr>
<td>4. Attaches injectate syringe to RA port maintaining a closed system.</td>
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<tr>
<td>5. Verifies PA waveform.</td>
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<tr>
<td>6. Activates CO mode, as per specific monitor requirements</td>
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<tr>
<td>7. Refills syringe with injectate and repeats procedure 3-5 times assessing thermodilution curves and values obtained.</td>
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<tr>
<td>8. Averages results appropriately.</td>
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<tr>
<td>9. Calculates hemodynamic data as per unit practice.</td>
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<tr>
<td>10. Verifies PA waveform when procedure complete.</td>
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<tr>
<td>11. Identifies situations when notification of the physician is necessary.</td>
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<tr>
<td>12. Ensures the principles of aseptic technique are practised throughout the procedure.</td>
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</tbody>
</table>
TITLE: Care of the Patient with a Pulmonary Artery Catheter

Name/ Nursing Unit:

#5. Skill: Mixed Venous Blood Sampling

<table>
<thead>
<tr>
<th>SKILL</th>
<th>YES</th>
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<tbody>
<tr>
<td>1. Assembles appropriate equipment.</td>
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<tr>
<td>2. Correctly obtains specimen.</td>
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<tr>
<td>3. Removes any air bubbles from sample.</td>
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<tr>
<td>4. Flushes blood from sidearm port and from the PA lumen of the PA catheter.</td>
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<tr>
<td>5. Does not exceed two-second flush.</td>
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<tr>
<td>6. Verifies PA waveform.</td>
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<tr>
<td>7. Ensures the principles of aseptic technique are practised throughout the procedure.</td>
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#6 Skill: Removal of Pulmonary Artery Catheter

<table>
<thead>
<tr>
<th>SKILL</th>
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</thead>
<tbody>
<tr>
<td>1. Verifies physicians order. (Chest x-ray should have been checked prior to removal)</td>
</tr>
<tr>
<td>2. Explains procedure to patient.</td>
</tr>
<tr>
<td>3. Assembles and prepares equipment.</td>
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<tr>
<td>4. Obtains baseline vital signs.</td>
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<tr>
<td>5. Correctly positions patient with HOB flat and instructs patient on the use of Valsalva manoeuvre; if introducer is being removed.</td>
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<tr>
<td>6. Ensures balloon is deflated and locks port.</td>
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<tr>
<td>7. Prepares catheter for removal (removes dressing, loosens introducer sleeve).</td>
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<tr>
<td>8. Correctly removes PA catheter.</td>
</tr>
<tr>
<td>9. Monitors waveform and cardiac rhythm during removal</td>
</tr>
<tr>
<td>10. Inspects catheter after removal, obtains tip for C &amp; S if ordered.</td>
</tr>
<tr>
<td>11. Inspects PA introducer and applies obturator cap.</td>
</tr>
<tr>
<td>12. Correctly removes introducer (if introducer is ordered to be removed) and applies pressure to the site until bleeding has stopped.</td>
</tr>
<tr>
<td>13. Applies Vaseline gauze dressing to the site</td>
</tr>
<tr>
<td>14. Monitors patient for and identifies possible complications related to the removal of the PA catheter.</td>
</tr>
</tbody>
</table>

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