About the Pulmonary Artery Catheter

Swan Ganz™ is the brand of pulmonary artery catheter used in CCTC. The VIP™ model is the standard Swan Ganz™ model in CCTC. It is a 7.5 French catheter with 5 lumens. It must be inserted through an introducer that is an 8.5 French. The catheter is inserted through a sterility sleeve to maintain aseptic technique if the catheter requires repositioning. The Swan Ganz™ contains latex (wedging ballon); the VIP™ model we use is heparin free. The Paceport™ model does contain heparin.

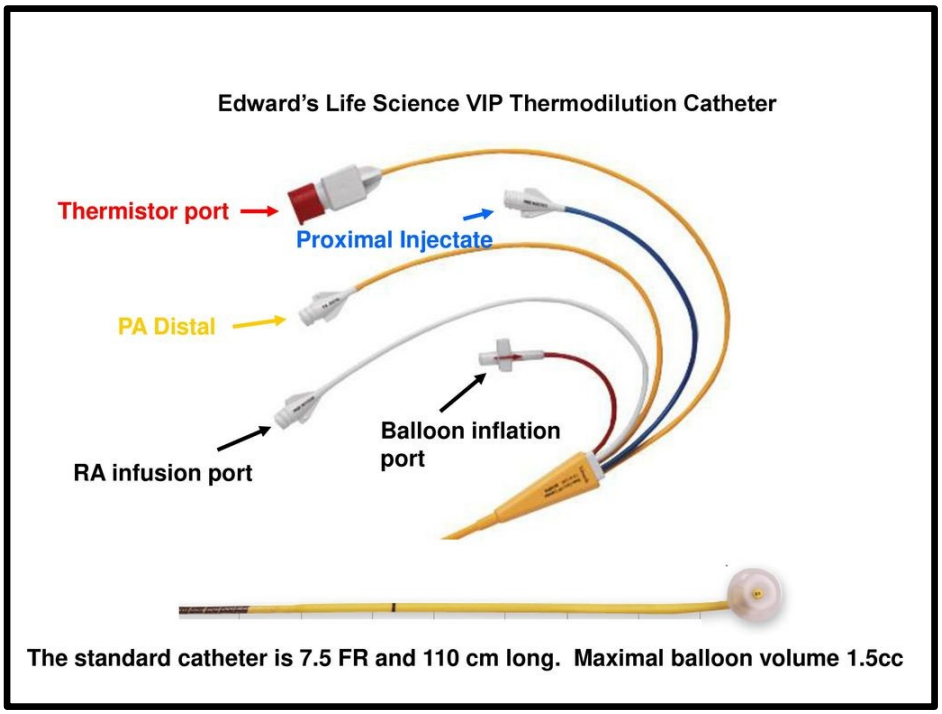

Figure 1: VIP™ Model Swan Ganz catheter

It has 5 lumens as follows:

1. **Thermistor (square white connector with red cap):** Connected to the cardiac output trunk cable. Measures core blood temperature in the pulmonary artery. Detects changes in blood temperature after an injection of room temperature or cold IV fluid; this is done to calculate cardiac output.

2. **Blue Port (proximal injectate):** A vascular lumen that terminates 30 cm from the catheter tip (in right atrium if in correct position). Location for injecting a fluid bolus into the catheter for determination of cardiac output. Connect to continuous right atrial pressure monitoring with waveform display. Can be used for intermittent IV therapy but not vasoactive drugs.

3. **Yellow Port (distal tip):** A vascular lumen that terminates at the tip of the 110 cm catheter. It is connected to a pressure transducer to display the location of the catheter tip. The tip should be located in the pulmonary artery except during insertion, repositioning or wedging.

4. **Balloon port (syringe attached)**: Used to inflate the balloon at the tip of the catheter. Maximum volume is 1.5 cc of ***air.***

5. **White Port (proximal infusion port):** A vascular lumen that terminates 31 cm from the catheter tip (terminates in the right atrium above and on the opposite side of the catheter from the blue port). Can be used to administer IV fluid/medications (vasopressors should be administered through introducer so that flow is unaffected by catheter repositioning).

ABOUT THE INTRODUCER AND SLEEVE

Pulmonary artery catheters must be inserted through an introducer that is at last 1 full French size larger than the catheter (a VIP™ model Swan Ganz requires an 8.5 French introducer).

Catheters must only be inserted into an introducer that has had sterility maintained. This is achieved by inserting the introducer and pulmonary artery catheter at the same time, or by maintaining insertion site sterility at the time of introducer insertion with a sterile obturator cap. When a CVC or pulmonary artery catheter is removed from an introducer, an obturator cap should be immediately inserted and locked; this is done to maintain aseptic technique and prevent air entry or leakage.

Full barrier precautions are required when inserting a CVC catheter into an established introducer.

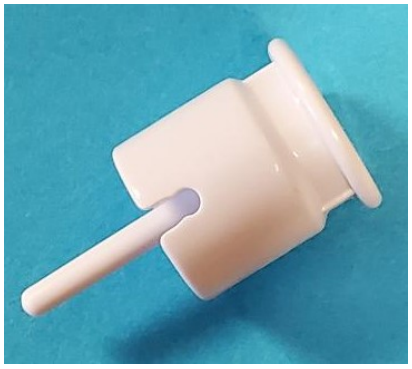

Figure 2: Obturator cap. Use to maintain introducer sterility before insertion or after removal of a CVC or pulmonary artery catheter.

Figure 3: Edwards™ Introducer with obturator cap in place.

The introducer kit contains a sleeve. The pulmonary artery catheter is inserted through the sleeve ***prior to*** insertion. The sleeve keeps the exposed portion of the catheter sterile. This allows the catheter to be advanced if required for repositioning.

Figure 6 shows an Arrow™ introducer and packaged sleeve. An 8.5F Arrow™percutaneous sheath introducer is used. Sleeves and obturators are introducer specific – Arrow™ sleeves and obturators do not fit Edwards™ products and vice versa. The Edwards Lifesciences introducers shown in Figure 2 and 3 is being phased out.

A pulmonary artery catheter must be inserted through a sleeve ***before it is inserted into the introducer.***

Figure 4: Pulmonary artery catheter (Swan Ganz) is inserted through a sleeve into a central venous introducer.

Figure 5: A sterile sleeve is contained within the introducer kit. An Arrow™ sleeve is shown in Figure 5. The Edwards™ sleeve has white caps as shown in Figure 4.

Figure 6: The pulmonary artery catheter must be inserted though the sleeve **BEFORE** insertion into the introducer.

The Edwards™ introducer has a Tuohy-Borst locking valve at the entrance to the introducer. A second valve is located at the distal end of the sleeve. **The valve must be opened (turned counterclockwise) during insertion, repositioning and removal.**

Following insertion, both the introducer and the sleeve Tuohy-Borst valve must be tightened to prevent catheter movement. Avoid overtightening which may compress the catheter.

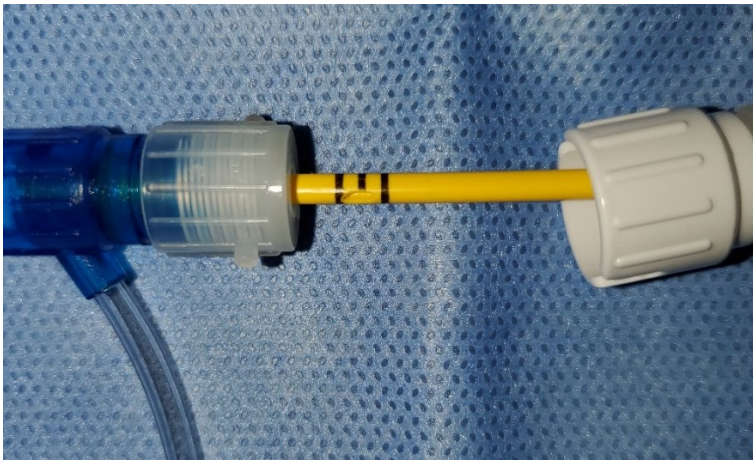

Figure 7: Introducer showing side infusion port and Tuohy-Borst valve. ***The valve must be open during insertion, repositioning and removal.***

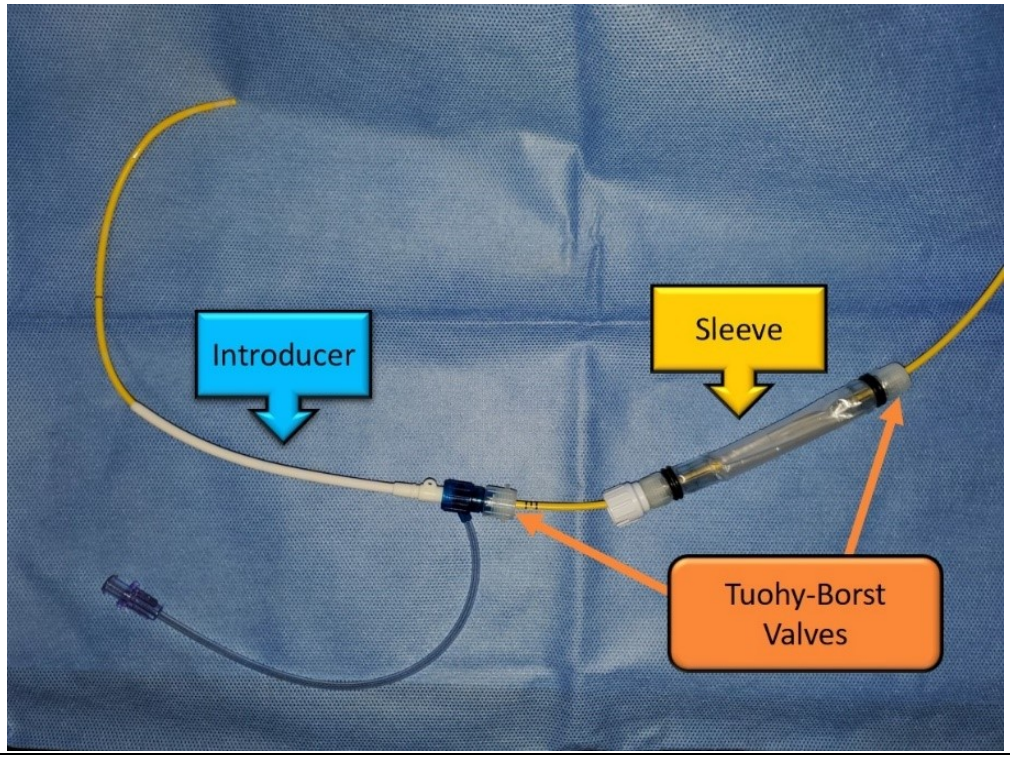

Figure 8: Edwards™ introducer showing side infusion port and Tuohy-Borst valve. Our current product has white ends to the sleeve and Tuohy – Borst valve. Intermittently, we may see yellow or blue ended sleeves.

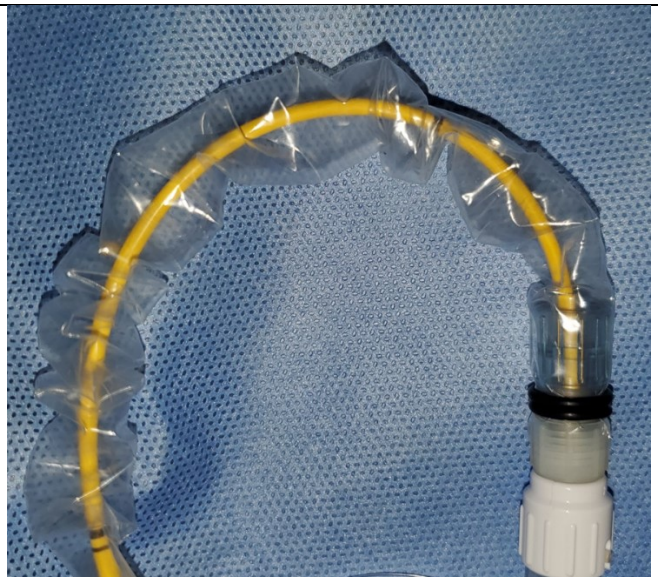

Figure 9: Edwards™ Swan Ganz catheter inserted through Edwards™ sleeve and introducer

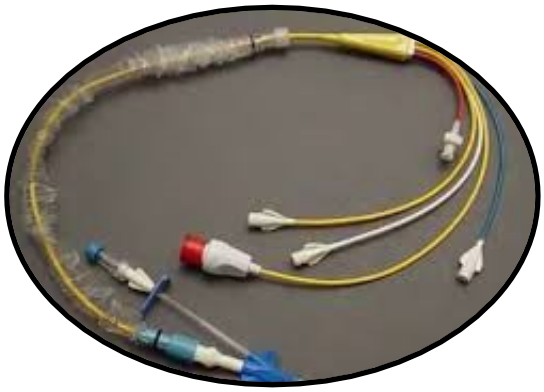

Figure 10: Following insertion, the sleeve is stretch out to cover the exposed catheter up to the hub.

PRIOR TO INSERTION:

The pulmonary artery catheter has **3 vascular lumens that must be thoroughly flushed** by the provider prior to insertion of the catheter into the sheath (blue proximal (CVP), white proximal (VIP) and yellow distal (PA) (Figures 9, 10). Sterility of the entire catheter and its ports must be maintained.

Figure 11: Flush all 3 vascular lumens before starting insertion.

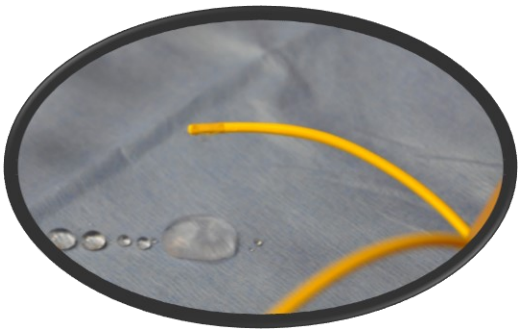

Figure 12: Confirm that saline exits in a steady stream from each lumen. The yellow exists at the tip, the blue at 30 cm and the white at 31 cm.

Check balloon integrity before insertion by inflating the balloon under a small amount of sterile saline. Check for leaks and confirm that the balloon inflates symmetrically. Note that the inflated balloon leaves a dimple at the tip to maintain patency while the balloon is inflated. This allows pressure to be measured during balloon inflation.

When the balloon is inflated, it wraps forward around the tip of the catheter to reduce the risk of trauma or ventricular irritation during advancement. The inflated balloon helps to float the catheter in the direction of blood flow (hence the term “flow directed catheter”). **The balloon must always be inflated during advancement of the catheter and deflated during catheter withdrawal or removal.**

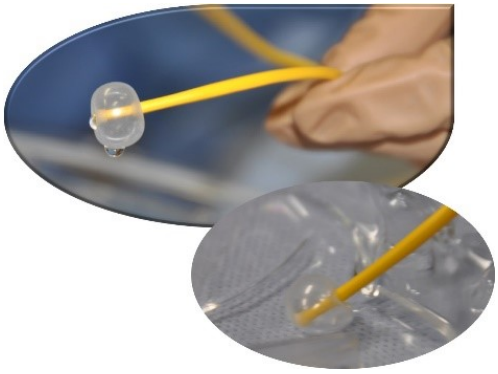

Figure 13: Flush all 3 vascular lumens before starting insertion.

Figure 14: Open path displays patent and rounded tip when balloon is inflated. This provides flow direction and protects against myocardial injury or irritation.

Once these vascular lumens are flushed, the pulmonary artery port (yellow distal port) is connected to pressure monitoring. Relevel and rezero the transducer once it is connected the catheter, before proceeding with insertion.

The location of the tip of the catheter determines the waveform that is displayed. During insertion, the waveform will change as the tip passes from right atrium to right ventricle to pulmonary artery to pulmonary wedge placement. Once inserted, the tip should display a continuous pulmonary artery tracing. The distal lumen must always be connected to pressure monitoring display to identify if the catheter migrates out of position.

VASCULAR ACCESS THROUGH INTRODUCER AND PA CATHETER

Preventing Disruption of Vasopressor Therapy or Back-up of Fluid into the Sleeve

The blue and white ports of the pulmonary artery catheter should terminate in the right atrium in most patients, but this only occurs if the catheter is in good position. At the start of insertion, the blue and white ports will terminate inside the sleeve. Infusions into the white or blue port during insertion or removal of the catheter will end up flowing into the sleeve. Blue and white port infusions will not become intravascular until ~35 cm of catheter has been advanced into the introducer. Consequently, all white and blue port infusions ***must be turned off during insertion, withdrawal or removal*** of the catheter. Leave the sterile syringe used to preflush the lumens attached. If fluid backs up into the sleeve, the entire pulmonary artery and sleeve needs to be changed.

Vasoactive agents should be administered through the introducer.

Administration can begin as soon as venous placement of the introducer has been confirmed by pressure measurement. Using the introducer for vasoactive drugs permits immediate administration, prevents backup of IV fluids into the sleeve during advancement a+nd ensures that vasoactive drugs remain uninterrupted during repositioning or removal of the catheter.

Vascular Lumens:

All vascular lumens MUST be flushed prior to insertion. Sterile saline syringes (for sterile field) are used to maintain patency until insertion is complete. The pulmonary artery port (yellow) must be connected to pressure monitoring prior to insertion to determine tip location. Relevel and rezero the transducer immediately before insertion begins.

All vascular ports including the introducer, blue proximal injectate (CVP), white proximal infusion (venous infusion port) and yellow distal (pulmonary artery) ports must have ***continuous positive pressure*** flow using either an IV infusion pump or pressure monitoring circuit. These are long and narrow lumens with higher venous pressure than peripheral IVs. The catheter within the lumen of the introducer makes it more susceptible to clotting. Saline lock should not be used for the introducer or pulmonary artery catheter lumens; use an infusion pump with minimal flow rates (5-10 ml per hour) or pressurized flush device.

Catheter Length

The pulmonary artery catheter is 110 cm long. Thin black distance markers appear at 10 cm intervals from the tip to hub. Two thick black distance markings indicate 50 cm. Record the distance marking at the start of each shift. Unless the catheter was repositioned, this distance at the insertion site should remain the same as during the previous shift assessment. If the distance marking located at the entrance to the introducer is 45 cm, it means 45 cm of catheter is inside the patient.

It is important to note that the tip of the catheter can spontaneously advance until the diameter of the catheter is equal to the pulmonary vessel diameter. This will produce a “spontaneous wedge pattern”. Conversely, the catheter tip can coil backward until the tip is in the right ventricle. ***The tip of the catheter can migrate forward or curl backward without any change to the markings at the insertion site.***

Continuous pressure monitoring is required to determine the tip location and to promptly identify spontaneous catheter migration.

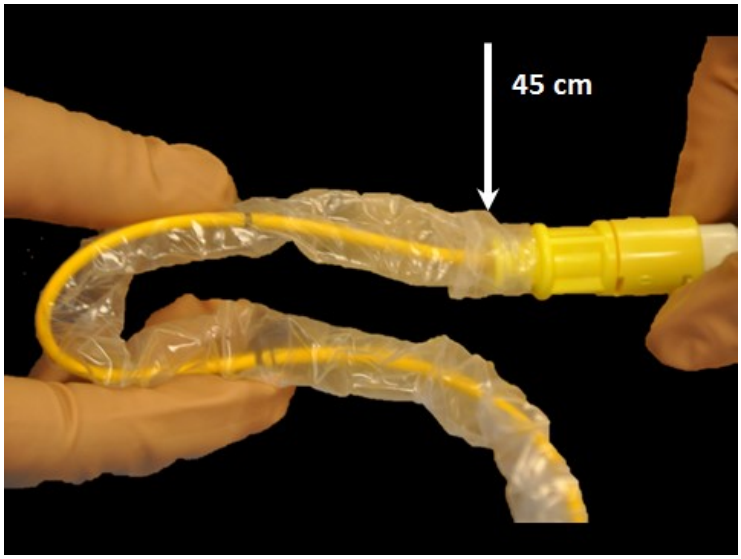

Figure 15: Distance marking showing 45 cm of catheter "in" the patient. Notice the thick line representing 50 cm and the thick plus single thin line representing 60 cm. The catheter marking is less than 50 cm. It is approximately half the distance between 50-60 cm from the 50 cm mark (or approximately 45 cm).

Figure 16: Record the distance marking in the Electronic Health Record in the Grouper for Pulmonary Artery Catheter. Ensure that waveforms of CVP, RV, PAP and PWP are printed at insertion and posted to the chart. Be aware that the tip of the catheter can migrate distally into a spontaneous wedge position or slip back into the right ventricle even if the distance marker remains unchanged.

INSERTION OF THE PULMONARY ARTERY CATHETER:

Insertion begins after ensuring:

- All 3 catheter lumens have been flushed and syringe is attached to yellow and blue port
- Balloon has been checked
- Pulmonary artery catheter has been inserted into the sleeve
- Tuohy-Borst valve on the introducer has been opened
- PA is connected to pressure monitoring and transducer has been leveled and zeroed

Insertion:

1. **Right Atrium (RA)**

   Monitor the pressure waveform during insertion. Once the catheter has been advanced ~15 cm, the tip of the PA catheter will be beyond the end of the introducer. The balloon can now be **inflated**. A right atrial waveform should be displayed. The normal RA pressure will have 2 distinct waves for every cardiac cycle (if sinus rhythm), with a pressure that is usually 10-15/0-5.

2. **Right Ventricle (RV)**

   As the catheter is advanced through the tricuspid valve, an RV waveform will appear (usually by 20 - 25 cm). The RV waveform can be recognized by its taller appearance. The height of the waveform is due to a dramatic rise in the systolic RV pressure when compared to the systolic RA pressure. The diastolic RV pressure remains the same as the diastolic RA (the right atrial and right ventricular pressure equilibrate in diastole).

The RV waveform consists of one large pressure wave that has a symmetrical upward and downward slope. A small wave before the upstroke may be visible (representing a small rise in ventricular pressure during atrial kick). Normal RV pressure is 20-25/0-5. Most patients requiring a pulmonary artery catheter have much higher pressures.

Watch closely for ventricular ectope. It is common to see PVCs and even brief runs of VT, but these should quickly resolve as the catheter is advanced from the RV.

3. **Pulmonary Artery (PA)**

As the catheter is advanced through the pulmonary valve, a PA waveform appears (usually ~15 cm after the RV first appeared). The systolic PA pressure is about the same as the systolic RV pressure (the right ventricle and pulmonary artery pressures equilibrate when the pulmonary valve is open). The diastolic PA pressure is higher than the diastolic RV pressure, making and individual's PA waveform shorter than their RV waveform.

The shape of the PA waveform is similar to an arterial waveform (asymmetrical when compared to the RV; quick upstroke with a more gradual downslope that contains a dicrotic notch). Respiratory fluctuation is common.

4. **Pulmonary Wedge Pressure (PWP)**

As the catheter is advanced further, the balloon will become "wedged" in a branch of the pulmonary circulation that is the same diameter as the balloon. This will block out any systolic flow toward the catheter, measuring only the pressure that can be seen from the tip of the catheter. Essentially, the wedge pressure is a measurement of the left atrial pressure. The left atrial waveform looks like a right atrial pressure, with a slightly higher pressure. A wedge waveform often has significant respiratory fluctuation and movement artifact.

Once the wedge pressure measurement has been identified, the balloon must be deflated. Observe the waveform to confirm the return of a PA waveform. This confirms that flow is once again able to pass around the catheter.

5. **Catheter Manipulation**

If the catheter does not advance quickly into position, the catheter will need to be withdrawn until the tip is back in the right atrium. Prolonged manipulation should be avoided; if it doesn't advance into position, the catheter is likely curling. Advancement is more difficult if the patient has atrial fibrillation, a dilated right ventricle and/or pulmonary hypertension. Several attempts may need to be made.

The balloon must be deflated before the catheter is withdrawn. The balloon must be reinflated prior to readvancement.

6. Balloon Operation

Balloon port should be left in the UNLOCKED position except during intentional balloon inflation. When the red line between the port and syringe is straight (no jog), the port is unlocked.

The unlocked position shown below ensures that the balloon will always default into the deflated position. The syringe is specially designed to prevent overfilling (it has a notch that prevents indrawing more than 1.5 ml of air). Leave the syringe deflated and attached to the port as shown.

Figure 17: Syringe is in open position with syringe deflated. This is how syringe port should be maintained when balloon is not being actively inflated.

Figure 18: Syringe has a notch that prevents overfilling.

Figure 19: Syringe is closed. This would prevent automatic deflation of the balloon. It is not possible to know if the balloon is locked with or without air.

Waveform Change During Catheter Advancement

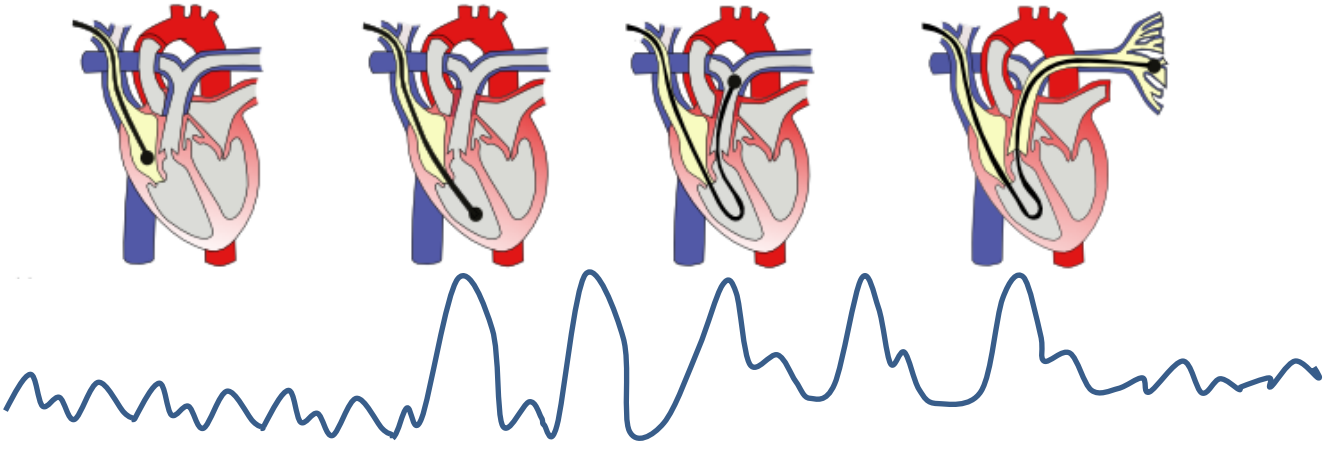

Figure 20: Waveform changes as catheter is advanced from RA to RV to PA to PWP.

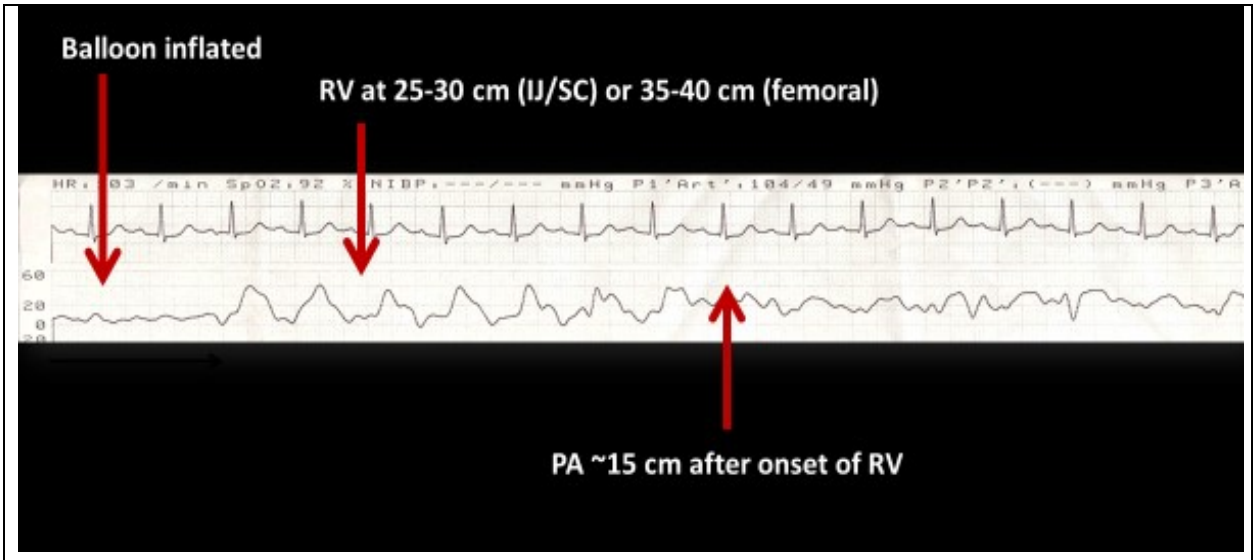

Figure 21: Advancement from RA to RV to PA showing changes in waveform shape.

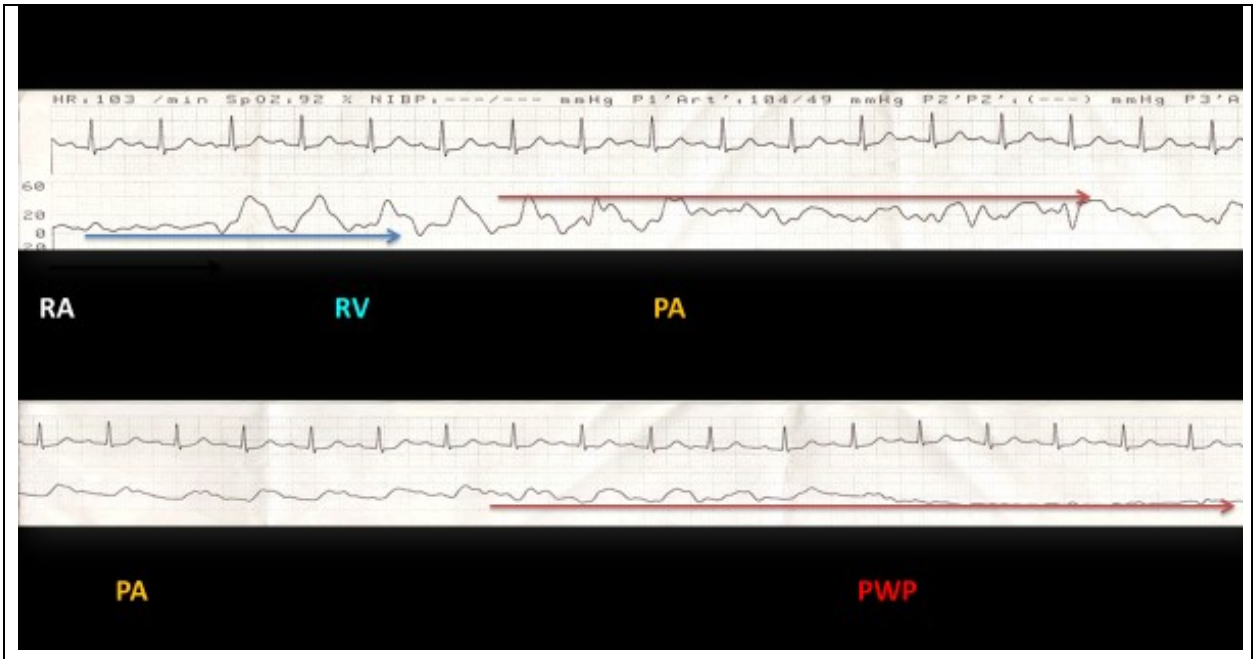

Figure 22: Waveform shapes and changes in systolic and diastolic pressures during advancement of a pulmonary artery catheter from RA to RV to PA to PWP.

Completion of Insertion:

Following insertion, the following steps are required:

1. Ensure Tuohy-Borst valves at entrance to introducer and insertion end of sleeve are tightened to prevent catheter movement for Edwards Lifesciences™ introducer, or the lock is enabled for an Arrow™ introducer.

2. Ensure transducer is level to obtain accurate pressures. The pressure at the tip of the PA catheter must be continually displayed on the monitor, even during transport. This ensure prompt identification of a spontaneous right ventricle or wedge tracing.
3. Connect the second pressure transducer to the blue proximal injectate port for continuous RA monitoring. Display this waveform continuously. If the PA diastolic pressure suddenly becomes equal to the RA diastolic pressure with no change in the PA systolic pressure, suspect that the catheter tip has migrated to the RV.
4. Ensure that CVP displays systolic, diastolic and mean pressure valued.
5. Display both CVP and PA waveforms continuously, and select a defined scale with zero baseline (do not select “optimize scale”). Maintain a defined scale with zero baseline provides visual identification if a waveform dampens or becomes taller – this visual change will be lost if you select optimize scale. Optimize scales adjusts the scale automatically to make the waveform fill the waveform channel.
6. Connect infusion to the white proximal infusion port (VIP). Do not saline lock ports of the PA catheter.
7. Vasoactive drugs should be administered via the introducer. This will prevent disruption or administration into the sleeve if the PA catheter requires repositioning or withdrawal.
8. Keep balloon deflated, balloon port unlocked and syringe attached and empty.
9. Print the insertion waveform in the chart for future comparison. These can be very helpful when troubleshooting waveform changes.
10. Record PA pressures in graphic record.
11. Enable PA systolic and diastolic alarms to .aid in prompt detection of spontaneous catheter migration.
12. Enable ventricular arrhythmia detection alarms.
13. Refer to cardiac output procedure