

# HOW TO INSERT A PULMONARY ARTERY FLOATATION CATHETER

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## INTRODUCTION

A pulmonary artery catheter can provide vital information regarding cardiac output and pulmonary vascular pressures in critically ill patients. The non-balloon pulmonary catheter was first described by Bradley in 1964<sup>1</sup>. The introduction of a flow- guided catheter by Swan and Ganz<sup>2</sup> in 1970 and subsequently named after them, revolutionised this procedure by allowing an invasive study of the right heart and pulmonary vasculature without x-ray control. The addition of a thermistor to the catheter enabled the physicians to accurately and repeatedly measure cardiac output at the bedside by the thermodilution technique<sup>3</sup>. Recent developments include continuous monitoring of cardiac output, oxygen uptake and oxygen delivery. The addition of a fibre-optic channel allows continuous monitoring of mixed venous oxygen saturation and the addition of a pacerport can be used for temporary ventricular pacing. Although these sophisticated catheters can provide more data, their narrow bore limits the infusion rate and dampens the tracing. They are also more expensive, fragile and erratic.

### Description

In this article the quadruple-lumen Swan-Ganz thermodilution catheter will be described. The standard Swan-Ganz catheter is 110 cm long, marked at 10 cm intervals along the exterior. The commonly used external diameter is either 5F or 7F (1F=0.0335 mm). The lumens are for (1) the distal port, (2) the balloon, (3) the proximal port and (4) the thermistor. The distal or the pulmonary artery port is situated at the tip of the catheter. It is used for monitoring the pulmonary capillary wedge pressure when the balloon is inflated, the pulmonary artery pressures when the balloon is deflated and for sampling blood. The balloon port inflates and deflates the balloon with the help of a syringe. It ends 1 cm from the tip of the catheter and is used for measuring the wedge pressure. The proximal port lies in the right atrium and is 30 cm from the tip of the catheter. This channel is used to record the central venous pressure or for sampling right atrial blood. The proximal and distal lumens are attached to transducers for monitoring pressures. The proximal end of the balloon lumen is connected to a syringe. The thermistor lumen contains electrical wires. The thermistor is 4 cm from the tip of the catheter and measures pulmonary artery blood temperature. The thermistor lumen is connected to the bed side computer via a thermistor connector.

### Indications and contraindications

The central venous pressure is used as a measure of right ventricular end diastolic pressure and reflect left heart functions. However it is not always an accurate representation of left heart functions as increased venous volume may reflect other pathologies like volume overload and right ventricular failure. In these circumstances left atrial pressure can provide useful information regarding left ventricular functions and intravascular volume. The pulmonary artery flow guided catheter is most useful in all critically ill patients as summarised in Table I.

**TABLE I. Indications for Swan-Ganz catheterisation.**

1. Cardiogenic shock
2. Septic shock
3. Traumatic shock
4. Profound hypoxia
5. Major surgery in the presence of myocardial dysfunction
6. Clinical setting involving large scale fluid replacement in the critically ill patient
7. Cardio-vascular surgery
8. Adult respiratory distress syndrome
9. Assessment of cardiac tamponade

There are no absolute contraindications. However the potential benefits should be weighed against the risks of an invasive procedure, which though small can be fatal. Anticoagulation and coagulopathies can be a relative contraindication. In these circumstances the catheter should be inserted from a peripheral site. The catheter carries a risk in patients with a pre-implanted cardiac pacemaker, as the catheter can form a knot with the pacing wire or dislodge it. In patients with pre-existing left bundle branch block the insertion of the catheter can result in damage to the right bundle branch and lead to complete heart block. The Swan-Ganz catheter may be damaged by magnetic resonance imaging and should not be used with MRI scans. Some of the relative contraindications are shown in Table II.

**TABLE II. Relative contraindications for pulmonary artery flotation catheters.**

1. Cardiac pacemaker
2. Prosthetic tricuspid or pulmonary valve
3. Pulmonary or tricuspid valve disease
4. Left bundle branch block
5. Bleeding diathesis
6. Anticoagulation
7. Sensitivity to heparin (for heparin-coated catheters)
8. Magnetic resonance imaging
9. Inexperience

### **Concept**

The pulmonary artery catheter can continuously demonstrate pulmonary artery systolic pressure (PAPs), pulmonary artery diastolic pressure (PAPd) and mean pulmonary artery pressure (PAPm). The PAPs closely relates to the right ventricular systolic function. The PAPd approximates to the left atrial pressure and the left ventricular end diastolic pressure provided the mitral valve is unobstructed, the diastolic filling period is of sufficient duration and the pulmonary vascular resistance is normal<sup>4</sup>. The pulmonary capillary wedge pressure (PCWP), also known as the pulmonary capillary venous pressure (PCVP) is measured when the inflated balloon at the tip of the catheter occludes one of the peripheral branches of the pulmonary artery. The PAWP relates to the left atrial pressure which, during diastole, approximates the left ventricular end diastolic pressure (LVEDP). Hence in practice PCWP is nearly identical to LVEDP. Occasionally PCWP is not an accurate reflection of LVEDP. The conditions which can lead to this clinical setting include mitral stenosis and regurgitation, atrial myxoma, chronic

obstructive lung disease, pulmonary embolic disorders and pulmonary venous obstruction. PCWP decreases in spontaneous inspiration, whereas intermittent positive pressure ventilation increases PCWP; it still reflects left atrial and LVEDP. These pressures should be measured at the end of expiration whether artificial or spontaneous. The rise in the value of PCWP of more than 18 mmHg is associated with pulmonary venous congestion. On the other hand, low cardiac output state associated with low PCWP reflects hypovolemia. This low output state requires volume expansion leading to an increase in the left ventricular filling and hence an increase in stroke volume. In situations where the optimum PCWP of 18 mmHg is exceeded, the stroke volume can be enhanced by decreasing the after-load with diuretics, vasodilators or by using inotropic drugs. The normal pressures for various chambers are shown in Table III.

**TABLE III. Normal pressures of right heart and pulmonary artery.**

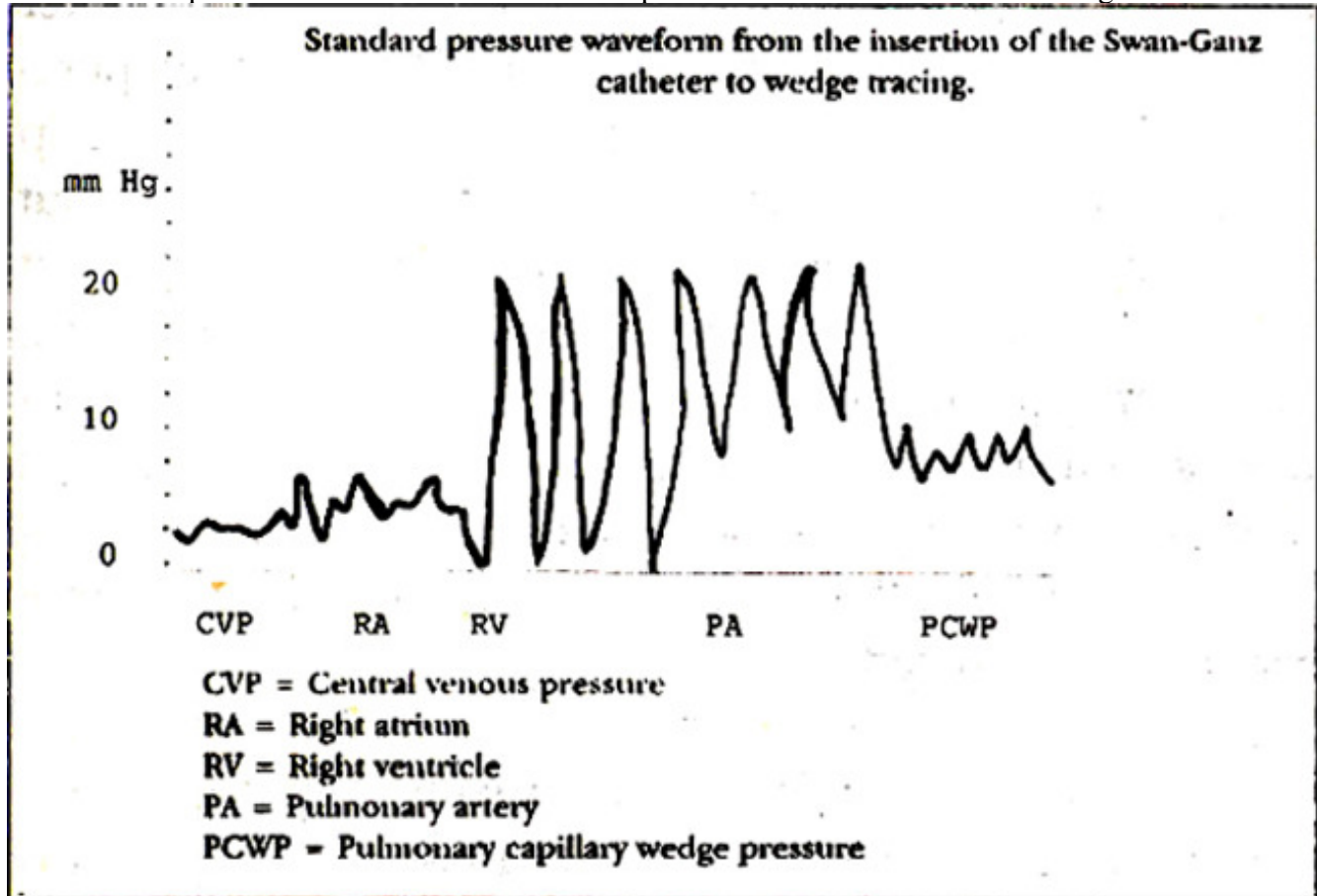
<b>Right atrium</b>	<b>-1 - +7 mmHg</b>
<b>Right ventricle systolic</b>	<b>15 - 30 mmHg</b>
<b>Right ventricle diastolic</b>	<b>0 - 8 mmHg</b>
<b>Pulmonary artery systolic</b>	<b>15 - 30 mmHg</b>
<b>Pulmonary artery diastolic</b>	<b>8 - 15 mmHg</b>
<b>Pulmonary artery mean</b>	<b>10 - 20 mmHg</b>
<b>Pulmonary capillary wedge mean</b>	<b>6 - 15 mmHg</b>

Cardiac output can be estimated by using the thermodilution technique. This method is based on the Hamilton equation<sup>5</sup>. To measure cardiac output by this method, 10 ml of sterile solution at a known temperature is introduced into the right atrium. The temperature of blood is recorded by the bedside cardiac computer before the injection. Subsequent change in the temperature of the blood is measured by the thermistor at the tip of the catheter. The accuracy of the cardiac output measurement is enhanced if the injectate is at 0°C, but using solution at room temperature is more convenient. The drop in blood temperature secondary to the injectate is determined by the blood volume. The cardiac output and cardiac index is then calculated from the cooling curve by the computer. A mean of at least three readings is required.

#### **Method<sup>6</sup>**

A strict aseptic technique is used. Equipment for cardiopulmonary resuscitation is essential. Electrocardiogram and pressure monitors should be set up. Pressure transducers are zeroed to the left atrial level and all catheter lumen are flushed with heparinised solution. The balloon is checked for leaks and unequal inflation by inflating the balloon with air and submerging it in sterile saline. Various venous approaches can be used but the internal jugular approach is the preferred method. A prepacked catheter introducer kit is recommended. a) Lay the patient supine with 15° head-down tilt and with the head turned to the opposite side. Measure the approximate length of catheter required by placing it on the patient's chest. Connect the pressure transducer to the distal and the proximal lumen. b) The internal jugular vein lies posterior to the medial edge of the clavicular head of the sternocleidomastoid muscle. Lignocaine 1% is infiltrated at the bifurcation of the sternal and clavicular head of sternocleidomastoid muscle. The venepuncture needle is introduced 30° to the skin surface, advancing towards a point midway between the ipsilateral nipple and midline. Venepuncture occurs at 2 to 3 cm depth. c) Using the Seldinger technique, pass the Seldinger wire through the needle to 10 cm and remove the needle, leaving the guide wire in place. Enlarge the puncture site by making a small incision with a scalpel. Pass the vein dilator and the sheath over the wire into the vein. Remove the wire followed by the dilator. Check by aspirating the venous blood and flush the cannula. d) Pass the protective sleeve

over the catheter to decrease the risk of infection. Advance the catheter via the introducer sheath up to 15 cm and lay the patient flat. Inflate the balloon with the volume-limited syringe with CO<sub>2</sub> or air. Close the sliding gate valve. The balloon is only inflated to the recommended volume printed on the shaft of the catheter and should not be filled with liquids as they might block the lumen. The catheter follows the blood flow from the superior vena cava to the right atrium, right ventricle and ultimately to a branch of the pulmonary artery. Continuous pressure waveform monitoring enables the operator to determine the position of the catheter. The various pressure waveforms are shown in Figure.



Once the catheter balloon occludes a branch of the pulmonary artery, a sudden change in pressure denotes 'wedging'. The balloon is deflated and the pressure changes to pulmonary artery waveform. Slowly reinflate the balloon. Occasionally the wedge trace will appear at near full volume, this denotes that the catheter tip is too far peripherally. The balloon is deflated and withdrawn 2 cm to 3 cm, reinflated and advanced till it wedges. The distance in an adult from the right internal jugular vein to the pulmonary artery and then to the wedge position is between 45 to 55 cm. The catheter is then fixed to the collar of the introducer sheath which in turn is stitched to the skin. A chest x-ray confirms the correct position of the catheter and excludes a pneumothorax. Ideally the tip of the catheter is located near the hilum of the lungs within 2cm of the cardiac silhouette or 3 to 5 cm from the midline. A radiograph is repeated daily and the catheter can be used for up to 72 hours.

### **Precautions**

- a) The catheter should never be withdrawn with the balloon inflated, as this can damage the heart valves.
- b) Do not over-inflate the balloon.
- c) Inflation of the balloon for wedging should be gradual while monitoring pressure waveform.
- d) Wedge pressure measurement time must not exceed 10 to 15 seconds, as prolonged balloon inflation in wedge position can result in pulmonary infarction.

e) Do not flush the catheter when the balloon is in the wedge position.

f) Looping in the right ventricle is a common hazard.

Once the right ventricular trace is seen, the length of the catheter is noted. If the ventricular trace persists after additional 15 cm, then the catheter may be coiling in the right ventricle and there is risk of knotting. In this case, deflate the balloon and withdraw the catheter up to the right atrium and then proceed again.

### **Complications<sup>7</sup>**

The procedure carries all the risks and complications associated with indwelling catheters. The most common complication is cardiac arrhythmias, which occurs in up to 70% of patients. Although the majority of arrhythmias are transient, they can be life threatening<sup>8,9</sup>. Right bundle branch block and complete heart block has been reported. Pulmonary artery perforation, although rare, occurs in 0.2% cases. The factors predisposing to this complication are old age and pulmonary hypertension. Flexible catheters can form knots<sup>10</sup>. This complication is more common with small-bore floatation catheters. In this situation the catheter can still be withdrawn transvenously provided the balloon is not inflated. Arterial puncture and pneumothorax can occur in up to 2% of catheterisations. Balloon rupture may be suspected if there is no resistance to inflation. In most circumstances this is harmless and pulmonary artery pressure can still be monitored. In paediatric patients and with suspected right to left ventricular or intrapulmonary shunts, balloon rupture can be dangerous and in these cases only, carbon dioxide should be used. Injury to the heart valves during pulmonary artery catheterisation have been reported<sup>11</sup>. The catheter related sepsis rate is 0 to 2%. The pulmonary artery rupture have been reported around 0.1 to 0.2% and pulmonary infarction as 0 to 1%. Other complications associated with the Swan-Ganz catheter are illustrated in Table IV.

**TABLE IV. Complications associated with Swan-Ganz catheter.**

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- 1. Arrhythmias**
  - 2. Sepsis**
  - 3. Pneumothorax**
  - 4. Atrial puncture**
  - 5. Knotting of the catheter**
  - 6. Pulmonary arterial perforation**
  - 7. Pulmonary embolism**
  - 8. Pulmonary infarction**
  - 9. Heart block**
  - 10. Endocarditis**
  - 11. Valvular injury**
  - 12. Heparin-induced thrombocytopenia**
  - 13. Thrombosis and embolism**
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### **CONCLUSION**

The pulmonary artery floatation catheter can be invaluable in monitoring hemodynamic parameters and oxygen transport repeatedly and quickly at the bedside in critically-ill patients. However, considerable controversy exists over its routine use in clinical practice<sup>12</sup>. The potential benefits of new more

sophisticated catheters in the management of seriously ill patients still awaits clinical trials. The true value of pulmonary artery flotation catheters in decreasing mortality and morbidity in acutely ill subjects is still being evaluated.

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