# Pulmonary Artery Catheter Insertion

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## 13.1 Introduction

Pulmonary artery catheters (PACs) were introduced in the 1970s as a means to monitor hemodynamics of critically ill patients [9]. This balloon-tipped catheter is advanced by blood flow through the right atrium and right ventricle and terminates in the pulmonary artery; this technology offers clinicians real-time pressure measurements from inside the right heart.

The use of PACs has been controversial since their inception and continues to be debated among intensivists today. Several randomized controlled trials have concluded that there is no outcome benefit in the use of PACs in high-risk surgical patients, congestive heart failure, acute lung injury, and sepsis [1, 2]. In the acute myocardial infarction cohort, evidence has shown an increased risk of mortality with the use of PACs [3].

However, in specific patient populations, the application of PACs may prove beneficial. The ATTEND trial suggested that patients with acute heart failure benefited from PAC use, especially if hypotensive or requiring inotropic support [4]. Furthermore, the use of PACs represents the standard of care in patients with severe pulmonary hypertension and those undergoing preoperative evaluation for liver transplantation [5, 6].

Regardless of the controversy, practitioners must be fully aware of the indications and the prudent application in selected patient populations. Indeed, practitioners should consider the utility of less invasive monitoring technologies as alternatives where applicable. Additionally, they should be experts in interpretation of the data provided by PACs and be comfortable translating it to guide therapy.

## 13.2 Indications

There is currently no evidence to suggest that the routine use of PACs results in improved patient outcomes [6]. Nevertheless, the effective use of PACs can provide a powerful tool to guide interventions in critically ill patients. In their recent review of the use of PACs, Gidwani et al. [6] recommended the following list of indications for PA catheterization in the critical care setting:

- Patients undergoing liver transplantation work-up
- Patients with cardiogenic shock receiving supportive therapy
- Patients with discordant right and left ventricular failure

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- Patients with severe chronic heart failure requiring inotropic, vasopressor, and vasodilator therapy
- Patients with potentially reversible systolic heart failure
- Patients being evaluated for pulmonary hypertension
- Patients who are being treated for precapillary and mixed types of pulmonary hypertension to assess their response to therapy

The PAC can be used for both diagnostic and therapeutic purposes. The clinician should evaluate the goal of placement and the inherent risks to assess whether insertion benefits that particular patient. With the advent of alternative technologies in hemodynamic monitoring and evidence disputing the efficacy of PACs, there has been decreased utilization across the United States [7].

## 13.3 Contraindications

The advanced clinical practitioner should weigh the risks and benefits prior to insertion of the PAC. There are no absolute contraindications for this procedure but there are several relative ones.

The first relative contraindication is preexisting left bundle branch block (LBBB). An electrocardiogram should be obtained prior to the insertion of the PAC to rule out the presence of LBBB. The risk of insertion for a patient with a LBBB is that injury or interruption to the right bundle could result in complete heart block and asystole. In the event a PAC is absolutely necessary in a patient with a LBBB, the practitioner should anticipate this complication and be prepared for direct cardiac pacing.

The following is a summary of other relative contraindications for insertion:

- Right-sided heart mass (thrombus or tumor)
- Presence of pacer or defibrillator electrodes
- Severe coagulopathy or current systemic anticoagulation therapy
- Tricuspid valve prosthetic or stenosis
- Severe hypothermia

## 13.4 Informed Consent

Prior to beginning the PAC insertion, the practitioner must obtain informed consent from the patient or their designated surrogate decision maker. In order to properly obtain consent, the risks and benefits of the procedure must be described to the person signing the consent release.

Benefits to be discussed include accurate hemodynamic data derived from PAC in order to guide therapy. The presentation should explain that insertion will allow real-time information to the healthcare team to help direct medication and fluid delivery to the patient.

Providers should discuss the indications as well as contraindications and recommendation to proceed with the use of PAC. Risks associated with the procedure itself as well as the use of the catheter after insertion should also be disclosed.

The most common complication during insertion is cardiac arrhythmias including ectopies and tachycardias. They are usually short lived, but occur in 12.5–70 % of insertions; however, only about 3 % require antiarrhythmic therapy [2]. In addition, there is approximately a 0.5–1 % risk of pneumothorax and hemothorax during insertion.

Infection is always a risk of insertion of a foreign object into the human body. Infections can occur in the subcutaneous tissue at the insertion site, in the bloodstream, or in the heart tissue itself. Risks of bacteremia associated with PACs range from 1.3 to 2.3 % and endocarditis 2.2–7.1 % [2]. Patients with prosthetic valves are at higher risk for endocarditis [2].

Pulmonary artery rupture is perhaps the most severe complication associated with PA catheterization, although it is extremely rare with an incidence of 0.03–0.20 % [2]. Risk factors for perforation include pulmonary hypertension, hypercoagulopathy, age of greater than 60, improper catheter positioning, and improper balloon inflation [2].

As you prepare to complete the consenting process, it is important to acknowledge that there is always overall risk of death when undergoing invasive procedures to the person providing

consent. In one study of critically ill patients, 4 % died from complications related to the PAC with an estimated 20–30 % with other major complications related to the catheter [8]. Clinicians should remind themselves that there is never a benign procedure.

## 13.5 Preparation

Prior to beginning the procedure, it is important to gather all the necessary equipment as well as to inform the bedside registered nurse who can assist during the procedure with the equipment setup (Fig. 13.1). Most intensive care units are equipped with PAC kits that contain all the necessary supplies needed for insertion; however, the provider may choose to obtain extra pressure tubing, saline flushes, sterile skin prep, and gauze sponges. The nurse will zero the monitor and add the patient-specific demographics prior to insertion so that the information is calculated correctly for the patient.

## 13.6 Procedure

In order to reduce the risk of bacteremia, this procedure is performed using sterile technique. All persons in the room should be required to wear masks and a surgical cap during the insertion. The provider should wear sterile gloves, gown, mask, and a surgical cap. The patient's insertion site should be prepped with chlorhexidine and draped with full-length drapes.

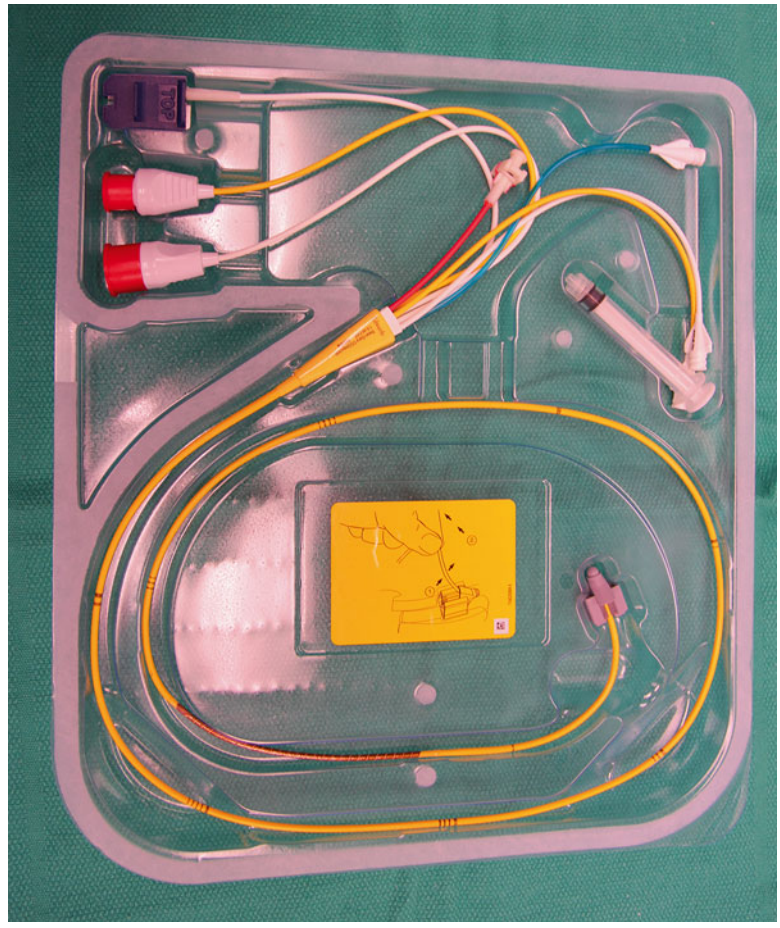


**Fig. 13.1** Example of pulmonary artery insertion kit

If a transducer is not in place for the patient, then one must be placed using the Seldinger technique. The most direct insertion site for placement of the PA catheter is either the left subclavian or the right internal jugular vein; however, any insertion site including a femoral approach is appropriate. This transducer is larger in diameter than a central venous line, but is inserted similarly. During insertion, it is imperative that the provider insure that the transducer is placed in the venous vasculature. Dilation of the arterial system can be catastrophic. Using a jugular or femoral approach will allow for ultrasound confirmation prior to PAC insertion.

Once the patient is prepped and draped and the introducer is in place, the PAC itself must be tested prior to insertion. All the ports should be flushed with sterile saline and the balloon should be tested for inflation. The provider should insure that the tip is enclosed into the balloon upon inflation, and it should not extend past the balloon to prevent damage to the tissue upon insertion. The catheter should also have the protector sterile sheath covering it so that manipulations can occur via a sterile field.

As the catheter is connected to the pressure transducer and the monitor, the provider should wave the tip of the catheter to make sure it is properly connected by confirming a wave formation on the monitor. Finally, the ACP should orient the catheter so that its natural curvature is in alignment with the vasculature system depending on the insertion site.

Once the tip has been inspected and monitor connection confirmed, the catheter is inserted into the introducer until the catheter tip is about 15–20 cm from the right internal jugular or left subclavian. The catheter has measurement markings along its side to help the provider determine the length inserted into the patient. One should confirm placement in the right atrium via the waveform on the monitor (Fig. 13.2). During insertion, the provider should always reference the monitor to verify the location within the heart chambers.

Upon confirmation that the tip is in the right atrium, the balloon should be inflated. The registered nurse assisting with the procedure should state when they inflate or deflate the balloon. Once inflated, the syringe should be locked to the catheter. The provider then advances the catheter into the right ventricle which should occur around 30 cm. This position is then confirmed by the right ventricle waveform on the monitor (Fig. 13.2).

The provider continues to advance the catheter through the pulmonary valve which will be identified by a pulmonary artery waveform (Fig. 13.2), a dicrotic notch, and an increase in diastolic pressure. This typically will occur at 40 cm. As the balloon continues to float further into the pulmonary artery, it will become wedged and the tracing will flatten usually at approximately 50 cm.

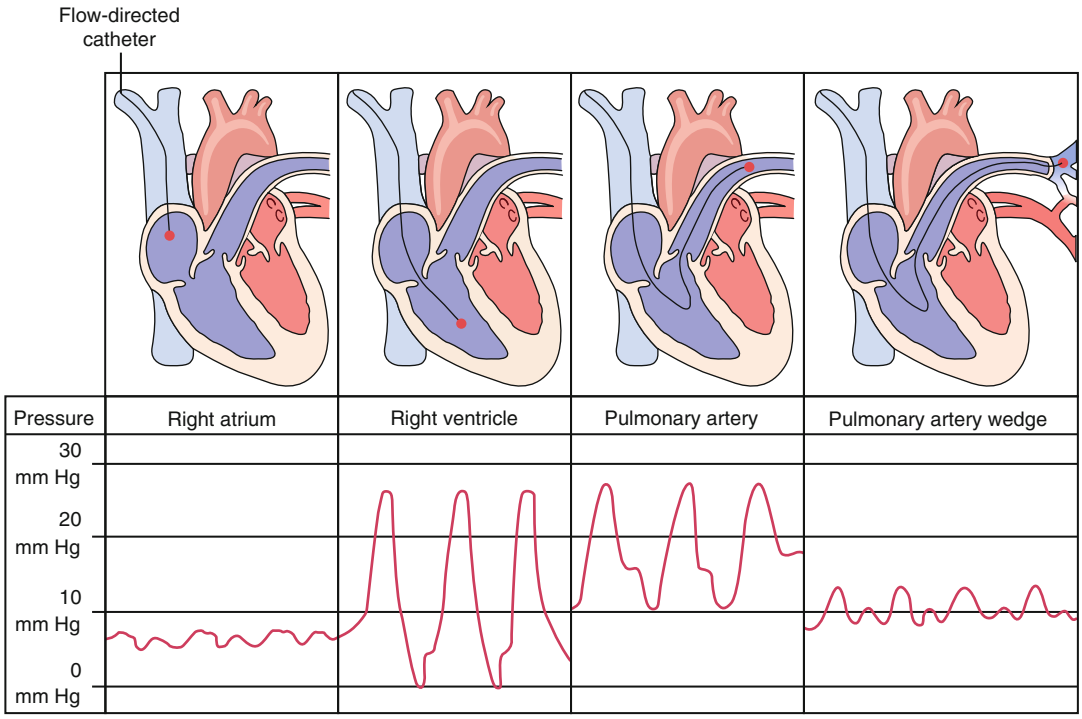
The balloon should then be deflated and reinflated gently. If there is resistance felt as it is reinflated or the waveform shows signs of overwedging, balloon insertion should be stopped immediately. If the balloon is unable to be fully inflated, this could be a sign that the catheter has passed too far distally and should be deflated and pulled back about a centimeter.

Once the provider feels that the catheter is in proper position and has obtained an appropriate wedge pressure and tracing, the balloon should be deflated and the catheter secured at the length it was obtained via the locking mechanism on the device. This measurement should be recorded in the medical record for reference. A chest x-ray should be ordered to confirm proper placement and rule out complications.

## 13.7 Complications

During insertion, it is possible that the balloon will not float easily between the chambers of the heart. When advancing the catheter and a length of 45 to 50 cm is reached without identifying the wedge tracing, it is likely that the catheter has become curled into the right ventricle. At this point, the provider would need to deflate the balloon and pull back until the right atrial waveform can be visualized.

The provider should never withdraw the catheter without confirming that the balloon is deflated. The catheter should also never be advanced without the balloon being inflated. Doing either of these maneuvers can lead to




From Urden LD, Stacy KM, Lough ME: *Thelan's critical care nursing: diagnosis and management,* ed 4, St Louis, 2002, Mosby.



**Fig. 13.2** Illustration of ECG tracings in relation to pulmonary artery catheter location during insertion [permission acknowledgment needed]

perforation or damage to the heart valves which is many times a fatal complication.

Finally, the clinician should be cautious when obtaining the wedge pressure to insure that the catheter has not migrated distally. As the catheter warms with the patient's body temperature, it can expand and move. Monitoring of placement by the measurement on the catheter is crucial as well as monitoring of placement via chest x-rays.

## 13.8 Pearls

There are several hemodynamic data directly measured by the PAC: central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP), mean pulmonary artery pressure (PAP), and mixed venous oxygenation ($SVO_2$). Other measurements are derived from this data including cardiac output (CO), cardiac index (CI), stroke volume index (SVI), systemic vascular resistance (SVR), and pulmonary vascular resistance (PVR).

The clinician is able to utilize this information to help direct therapy for the patient. Trends of these calculations can be helpful in goal-directed therapy and in diagnostic evaluation (Table 13.1).

## 13.9 Conclusion

While the utilization of the pulmonary artery catheter in the intensive care unit is on the decline, there are specific populations of patients in which it is beneficial in guiding care. The advanced clinical practitioner working as an intensivist must maintain the skills of insertion and interpretation of the PAC when the need arises.

**Table 13.1** Hemodynamic profiles

| Hemodynamic State | CVP | PAOP | CO | CI | SVR |
|---|---|---|---|---|---|
| Normal | 2–6 mmHg | 8–12 mmHg | 4–8 L/min | 2.5–4.0 L/min/$m^2$ | 900–1300 dynes/s/$cm^{-5}$ |
| Cardiogenic Shock | ↑ | ↑ | ↓ | ↓ | ↑ |
| Hypovolemic Shock | ↓ | ↓ | ↓ | ↓ | ↑ |
| Sepsis | ↕ | ↔ | ↑ | ↑ | ↓ |
| Pulmonary arterial hypertension | ↑ | ↔ | ↔ | ↔ | ↑ |

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