# pulmonary artery catheter [created by Paul Young 02/10/07]

## pulmonary artery occlusion pressure

- pulmonary artery occlusion pressure closely approximates left atrial pressure which approximates left ventricular end diastolic pressure (wedge creates a static column of blood)
  - conditions where PAoP may mispresent LVEDP:
  1. alveolar pressure > pulmonary venous pressure (i.e.catheter outside West's zone 3)
  2. pulmonary venous obstruction (atrial myxoma, pulmonary fibrosis, vasculitis)
  3. valvular heart disease:
  MS (PAoP >LVEDP)
  MR (PAoP >LVEDP)
  AR (PAoP <LVEDP)
  4. markedly reduced pulmonary vascular bed
  - pneumonectomy
  - massive PE
  5. LV dysfunction (PAoP < LVEDP)
    - waveform analysis:
    - MR may cause a large v wave which may be confused with PA wave form
    - MS, CHF and VSD may also cause large v waves
    - Factors confounding a direct relationship between LVEDP and LVEDV:

The normal curvilinear LVEDV/LVEDP compliance curve
Increased juxta-cardiac pressures (reducing ventricular transmural pressure)
- Extrinsic PEEP
- Intrinsic PEEP
- Active expiration
- Cardiac tamponade
- Pneumothorax

Reduced diastolic ventricular compliance
Myocardial ischaemia
Sympathetic stimulation – tachycardia
LV preload and afterload
Diastolic ventricular interaction (pericardial constraint, interventricular septal deviation)
Sepsis
Ageing
- Left ventricular hypertrophy
- Cardioplegia, e.g. post coronary artery bypass
- Inotropic drugs
- Cardiomyopathy – hypertrophic cardiomyopathy, cardiac infiltrations

Increased ventricular compliance
- Dilated cardiomyopathy

## pulmonary artery diastolic pressure

- the normal PADP-PAoP gradient is <5mmHg so that PADP may be used as a close approximation for PAoP
- this gradient is variably increased by:
1. tachycardia
2. increased pulmonary vascular resistance (eg ARDs, COPD, and PE)
- an increased gradient, if present, tends to be stable for a number of hours so that once ascertained it can be assumed to be constant for a number of hours without repeating wedge

## cold thermodilution

- a bolus injected into the right atrium of cold injectate transiently decreases blood temperature in the pulmonary artery (monitored by a thermistor proximal to the balloon)
- the mean decrease in temperature is inversely proportional to the cardiac output
- margin of error with the technique is +/- 15%

Causes of inaccurate cold thermodilution cardiac output measures:
1. catheter malposition (wedge or vessel wall)
2. abnormal respiratory pattern (respiration causes fluctuations)
3. intracardiac shunt
4. tricuspid regurg
5. cardiac arrhythmias
6. injectate port close to or within introducer sheath
7. abnormal haematocrit affecting blood density
8. extremes of cardiac output
9. poor technique (slow injection, incorrect injectate volume)

## complications

1. complications of catheter insertion:
- dysrhythmia
- knotting / kinking
- valve damage
- perforation of pulmonary artery
- RBBB
- complete heart block

2. complications post-insertion:
- thrombosis
- PA rupture (0.2%)
- sepsis
- endocarditis
- pulmonary infarction
- arrhythmia (37%)
- air embolus (due to multiple attempts to fill ruptured balloon)

3. risk factors for major morbidity (esp PA rupture)
- pulmonary hypertension
- anticoagulants
- in situ >3 days

## general

all measurements should be made at the end of expiration

## indications

1. to characterised a haemodynamic pertubation
2. to differentiate cardiogenic from non-cardiogenic pulmonary oedema
3. to guide the use of vasoactive drugs, fluids & diuretics (especially when haemodynamic disturbances are coupled with increased lung water, RV or LV dysfunction, pulmonary hypertension and organ dysfunction)

| MAP | CI | CVP | PAOP | Potential causes |
|---|---|---|---|---|
| Low or normal | Low | Low | Low | Hypovolaemia<br>Bleeding |
| Low or normal | Low | High | High | Biventricular failure<br>Tachydysrhythmia or bradydysrhythmia<br>Acute myocardial infarction<br>Coronary graft occlusion<br>Acute ventricular septal defect<br>Pericardial tamponade<br>Severe mitral or aortic valvular dysfunction<br>Excess vasoconstrictors<br>Raised intrathoracic or intra-abdominal pressure |
| Low or normal | Low | High | Low or normal | Right ventricular dysfunction<br>Pulmonary hypertension<br>Pericardial tamponade<br>Pulmonary embolism<br>Tension pneumothorax |
| Low | High | Low or normal | Low or normal | Vasodilating drugs<br>Vasoplegia after cardiopulmonary bypass<br>Sepsis<br>Anaphylaxis<br>Hypoadrenalism<br>Spinal cord injury<br>Hyperthyroidism<br>Liver failure<br>Left to right shunt (left-sided cardiac output may be low) |
| High | Low | Variable | Variable | Pain<br>Awareness<br>Hypoxia<br>Early pericardial tamponade<br>Early biventricular failure<br>Excess vasoconstrictors |
| High | High | High | High | Volume overload<br>Excess inotropes |

## contraindications

1. tricuspid or pulmonary valve mechanical prosthesis
2. right heart mass (thrombus / tumour)
3. tricuspid or pulmonary valve endocarditis

## insertion

- a 7.5F 15cm introduced sheath is first inserted by Seldinger technique
- balloon volume is 1.5ml & balloon should be inflated with air before passage through the heart to assist flow guidance & to protect myocardium against injury & dysrhythmias

references during insertion are as follows
- right atrium (15-20cm from internal jugular; 10-15cm from the subclavian vein, 30-40cm from the femoral vein, 40 & 50 cm from the right and left basilic veins respectively)
- the right ventricle and pulmonary artery are then entered at 10cm intervals with a further 10 cm to pulmonary artery occlusion (looping is likely and knotting can occur if continued insertion is attempted without passing these landmarks)

## pressure wave forms

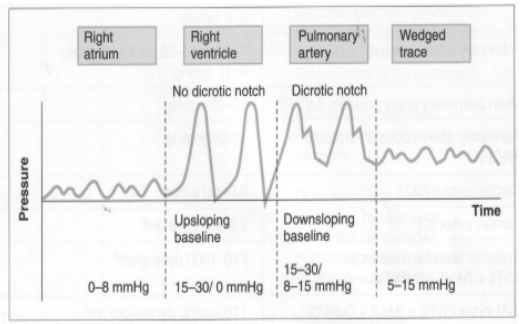
CVP:
- A wave is ventricular diastole
- C wave is tricuspid closure
- V wave is ventricular filling
- peak of the a wave coincides with the point of maximal ventricular filling of the right ventricle and is used for RVEDP measurement

right ventricular pressure:

pulmonary artery pressure:
- characterised by dichrotic notch and elevated diastolic pressure

pulmonary artery occlusion pressure:
- characterised by respiratory variation
- peak of the a wave reflects the left ventricular end diastole

- measurements of the PaOP should be performed by slow injection of air into the balloon while watching the pulmonary artery wave form. Overwedging can lead to falsely high occlusion pressures or pulmonary artery rupture
- deflation after PAoP measurement should re-establish the normal pulmonary artery waveform. If not, distal migration has occured and the catheter should be withdrawn until the waveform is re-established.




Conventionally the 'wedge' value or occlusion pressure is measured at the end of expiration.

## direct PAC measurements

| Site | mmHg |
|---|---|
| Right atrium mean | –1–7 |
| Right ventricle: systolic | 15–25 |
| Right ventricle: diastolic | 0–8 |
| Pulmonary artery: systolic | 15–25 |
| Pulmonary artery: diastolic | 8–15 |
| Pulmonary artery: mean | 10–20 |
| Pulmonary artery occlusion pressure | 6–15 |

## derived measures

| Parameter | Abbreviation | Formula | Normal range | Units |
|---|---|---|---|---|
| Mean arterial pressure | MAP | DBP + 0.33 × (SBP – DBP) | 70–105 | mmHg |
| Mean pulmonary artery pressure | MPAP | PADP + 0.33 × (PASP – PADP) | 9–16 | mmHg |
| Mean right ventricular pressure | MRVP | CVP + 0.33 × (PASP – CVP) | | mmHg |
| LV coronary perfusion pressure | LVCCP | DBP – PAoP | | mmHg |
| RV coronary perfusion pressure | RVCCP | MAP – MRVP | | mmHg |
| Cardiac index | CI | CO/BSA | 2.8–4.2 | l/min per m² |
| Stroke volume index | SVI | CI/HR | 35–70 | ml/beat per m² |
| Systemic vascular resistance index | SVRI | (MAP – CVP)/CI × 79.92 | 1760–2600 | dyn s/cm⁵ per m² |
| Pulmonary vascular resistance index | PVRI | (PAP – PAoP)/CI × 79.92 | 44–225 | dyn s/cm⁵ per m² |
| Left ventricular stroke work index | LVSWI | SVI × MAP × 0.0144 | 44–68 | g m/m² per beat |
| Right ventricular stroke work index | RVSWI | SVI × PAP × 0.0144 | 4–8 | g m/m² per beat |
| Body surface area | BSA | Weight(kg) 0.425 × Height(cm) 0.725 × 0.007184 | | m² |

HR, heart rate; CVP, central venous pressure; PAoP, pulmonary artery occlusion pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; PADP, pulmonary artery diastolic pressure; PASP, pulmonary artery systolic pressure; MRVP, mean right ventricular pressure