

- 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 misrepresent 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

- 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

- 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)

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

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

**general** all measurements should be made at the end of expiration

**indications**

1. to characterise a haemodynamic perturbation
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)

**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:**

- characterised by dichrotic notch and elevated diastolic pressure

**pulmonary artery pressure:**

- characterised by respiratory variation
- peak of the a wave reflects the left ventricular end diastole

**pulmonary artery occlusion pressure:**

- 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 occurred and the catheter should be withdrawn until the waveform is re-established.

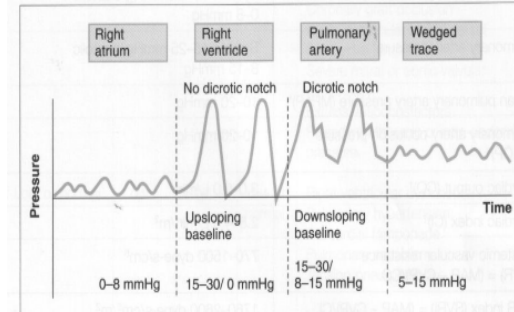
Site	mmHg
Right atrium mean	-1-7
Right ventricle: systolic	15-25
Right ventricle: diastolic	0-8
Pulmonary artery: systolic	15-25
Pulmonary artery: diastolic	8-15
Pulmonary artery: mean	10-20
Pulmonary artery occlusion pressure	6-15

**derived measures**

Parameter	Abbreviation	Formula	Normal range	Units
Mean arterial pressure	MAP	$DBP + 0.33 \times (SBP - DBP)$	70-105	mmHg
Mean pulmonary artery pressure	MPAP	$PADP + 0.33 \times (PASP - PADP)$	9-16	mmHg
Mean right ventricular pressure	MRVP	$CVP + 0.33 \times (PASP - CVP)$		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 m <sup>2</sup>
Stroke volume index	SVI	$CI/HR$	35-70	ml/beat per m <sup>2</sup>
Systemic vascular resistance index	SVRI	$(MAP - CVP)/CI \times 79.92$	1760-2600	dyn s/cm <sup>2</sup> per m <sup>2</sup>
Pulmonary vascular resistance index	PVRI	$(PAP - PAoP)/CI \times 79.92$	44-225	dyn s/cm <sup>2</sup> per m <sup>2</sup>
Left ventricular stroke work index	LVSWI	$SVI \times MAP \times 0.0144$	44-68	g m/m <sup>2</sup> per beat
Right ventricular stroke work index	RVSWI	$SVI \times PAP \times 0.0144$	4-8	g m/m <sup>2</sup> per beat
Body surface area	BSA	$Weight(kg) \times 0.425 \times Height(cm) \times 0.007184$		m <sup>2</sup>

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

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



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