

Fig. 1 Placement of the PAC guided by the characteristics of normal vascular pressures and waveforms . *For placement in the left internal jugular vein or left subclavian vein one should add 5 cm to each of

the landmarks . CVP central venous pressure, PAC pulmonary artery catheter, PAP pulmonary artery pressure, RVP right ventricular pressure

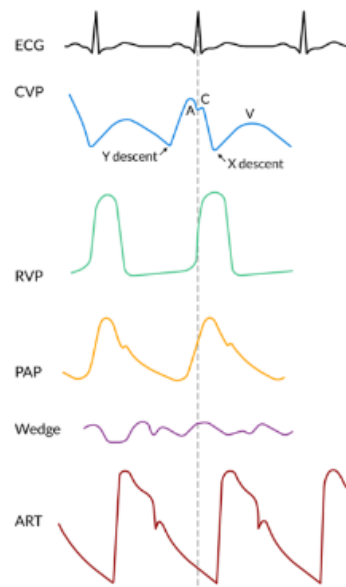
Table 1 Hemodynamic variables obtained from the pulmonary artery catheter

Variable	Abbreviation	Equation	Normal range
Mixed venous oxygen saturation	SvO ₂	n.a	60–80%
Cardiac output	CO	$HR \times SV / 1000$	4.0–8.0 L min ⁻¹
Cardiac index	CI	CO / BSA	2.5–4.0 L min ⁻¹ m ⁻²
Cardiac power index	CPI	$(MAP - CVP) \times CI / 451$	0.5–0.7 W m ⁻² , population specific
Central venous Pressure	CVP	n.a	2–6 mmHg
Stroke volume	SV	$CO / HR \times 1000$	60–100 mL
Stroke volume Index	SVi	$CI / HR \times 1000$	33–47 mL m ⁻²
Stroke volume variation	SVV	$(SV_{max} - SV_{min}) / SV_{mean} \times 100$	10–15%
Systemic vascular resistance	SVR	$80 \times (MAP - CVP) / CO$	800–1200 dynes sec cm ⁻⁵
Systemic to pulmonary pressure ratio	MAP/MPAP	$MAP / MPAP$	4.0 ± 1.4 in uncomplicated cardiac surgery
Pulmonary artery systolic pressure	PASP	n.a	15–30 mmHg
Pulmonary artery diastolic pressure	PADP	n.a	8–15 mmHg
Pulmonary artery wedge pressure	PAWP	n.a	6–12 mmHg
Pulmonary vascular resistance	PVR	$80 \times (MPAP - PAWP) / CO$	< 250 dynes sec cm ⁻⁵
Pulmonary artery pulsatility index	PAPI	$(PASP - PADP) / CVP$	population specific
LV stroke work index	LVSWi	$SVi \times (MAP - PAWP) \times 0.0136$	50–62 mmHg ml m ⁻²
RV stroke work index	RVSWi	$SVi \times (MPAP - CVP) \times 0.0136$	5–10 mmHg ml m ⁻²
RV function index	RFI	$PASP / CI$	31.7 ± 16.7 in ICU survivors with PH
RV end-diastolic volume	RVEDV	SV / EF	100–160 mL
RV end-diastolic volume index	RVEDVi	$RVEDV / BSA$	60–100 mL m ⁻²
RV end-systolic volume	RVESV	$EDV - SV$	50–100 mL
RV ejection fraction	RVEF	$(SV / EDV) \times 100$	40–60%
RV systolic pressure	RVSP	n.a	15–30 mmHg
RV diastolic pressure	RVDP	n.a	2–8 mmHg

BSA body surface area; CI cardiac index; EDV end diastolic volume; EF ejection fraction; HR heart rate; LV left ventricle; MAP mean arterial pressure; MPAP mean pulmonary arterial pressure; n.a. not applicable; PAWP pulmonary artery wedge pressure; PH pulmonary hypertension; RV right ventricle

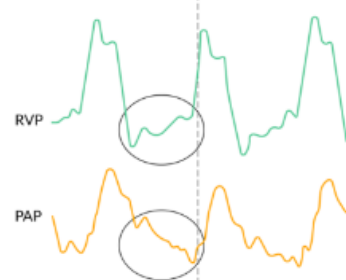
Adapted from: Edwards Clinical Education Quick Guide to Cardiopulmonary Care [4]

Normal waveforms



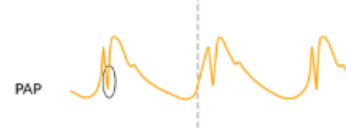
A. Distinction between RV and PAP waveform

Characteristics:
Upslope of the diastolic portion of the waveform. The PAP has a downslope part of the curve.



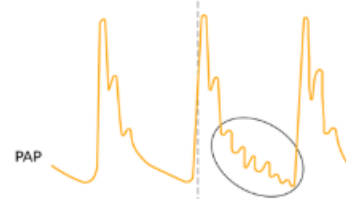
B. Catheter motion artefacts

Characteristics:
Very sharp pressure wave at the beginning of systole.



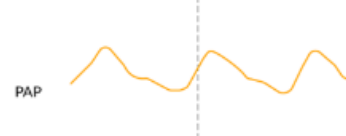
C. Underdamping

Characteristics:
Overestimation of the systolic blood pressure, underestimation of diastolic blood pressure and amplification of waveform artifacts.



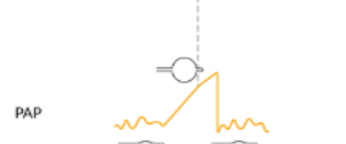
D. Overdamping

Characteristics:
Underestimation of systolic pressure, overestimation of diastolic pressure and attenuation of the waveform.



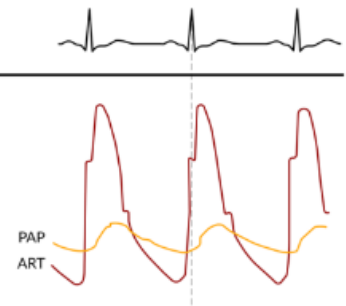
E. Overwedging

Characteristics:
Overwedging can be suspected if the pressure exceeds diastolic pulmonary pressure, continuous rising until the balloon is deflated, non-pulsatile pressure or wedge tracing recorded at a low balloon volume.



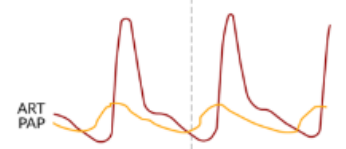
F. Right bundle branch block

Characteristics:
Arterial upstroke precedes the pulmonary artery upstroke.



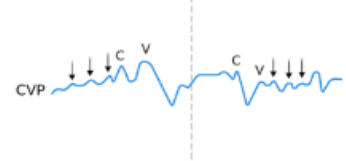
G. Left bundle branch block

Characteristics:
Pulmonary upstroke precedes the arterial upstroke



H. Atrial fibrillation/flutter

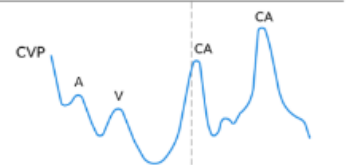
Characteristics:
- Absence of A-wave;
- C and V-waves most prominent peaks;
- Beat to beat changing morphologies;
- Small amplitude pressure waves (fibrillation/flutter waves)



I. AV dissociation

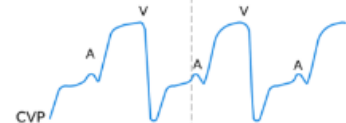
Ventricular tachycardia, AVNRT, Complete heart block

Characteristics:
- Cannon A-wave during ventricular systole



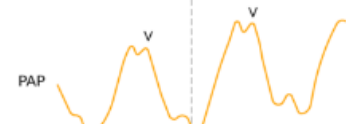
J. Tricuspid insufficiency

Characteristics:
- Early holosystolic large V-wave;
- Merge with the C-wave;
- Disappearance of X-descent



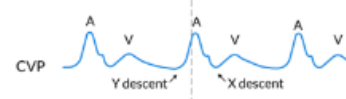
K. Mitral valve insufficiency

Characteristics:
- Early holosystolic large V-wave;
- V-wave merge with the C-wave;
- Disappearance of X-descent



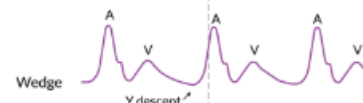
L. Tricuspid valve stenosis

Characteristics:
- Large A-wave;
- Slow Y-descent



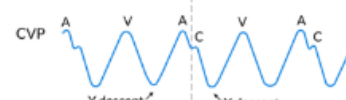
M. Mitral valve stenosis

Characteristics:
- Large A-wave;
- Slow Y-descent



N. Pericardial constriction, RV infarction or restrictive cardiomyopathy

Characteristics:
- Tall A-wave - Steep X-descent
- Tall V-wave - Steep Y-descent



O. Tamponade

Characteristics:
- Tall A-wave
- Tall V-wave
- Absent or diminished Y-descent

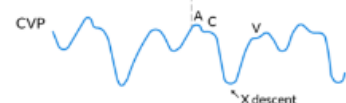


Fig. 2 Pressure waveform pitfalls and abnormalities . CA cannon a-wave, CVP central venous pressure, ECG electrocardiogram, RV right ventricle, RVP right ventricular pressure, PAP pulmonary artery pressure, ART arterial

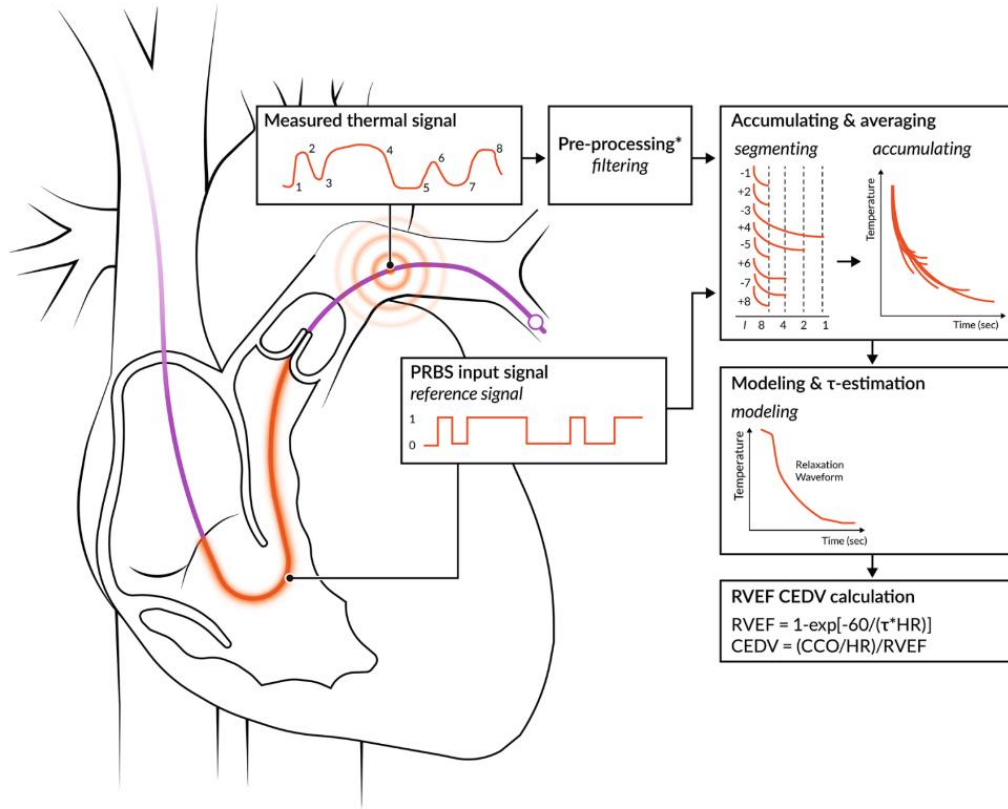


Fig. 1 Relaxation waveform for continuous cardiac output and concomitant calculations of right ventricular ejection fraction and right ventricular end-diastolic volume calculations. Shown are the thermal signal sent out by the proximal part of the PAC, how this is received in the more distal part of the PAC, and how this is transformed to derive the specific variables. PRBS Pseudo-Random Binary

Sequence; RVEF right ventricular ejection fraction. CEDV continuous right ventricular end-diastolic volume. CCO continuous cardiac output. τ =exponential decay time constant. * This step is skipped when using STAT-CCO over trend CCO monitoring. Adapted from: Wiesenack C et al. [46]