Hemodynamics: Interpretation of Right Heart Cath Findings

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Objectives

- 1. Participants will be able to recognize different waveforms and what part of the heart they are coming from
- 2. Participants will gain knowledge of what the normal values of right heart measurements are and how to interpret abnormal values

Conflict of interest

- Nothing to disclose

Agenda

- History
- Indications and contraindications
- Technique
- Cardiac cycle
- Pressure wave interpretation
- Cardiac output
- Normal values
- Common RHC findings
- Summary

History

- Stephen Hales (1711): obtaining pressure from a horse jugular vein
- Claude Bernard (1844): obtaining pressures from cardiac chambers of a horse (heart catheterization)
- Adolph Fick (1870): calculation of blood flow
- Werner Forssmann (1929): first heart catheterization of a living human under fluoroscopic guidance (on himself)
- Sven Seldinger (1953): percutaneous method of entry into vein/artery (before that it was “cut-down” technique)
- Jeremy Swan and William Ganz (1970): balloon-tipped catheter

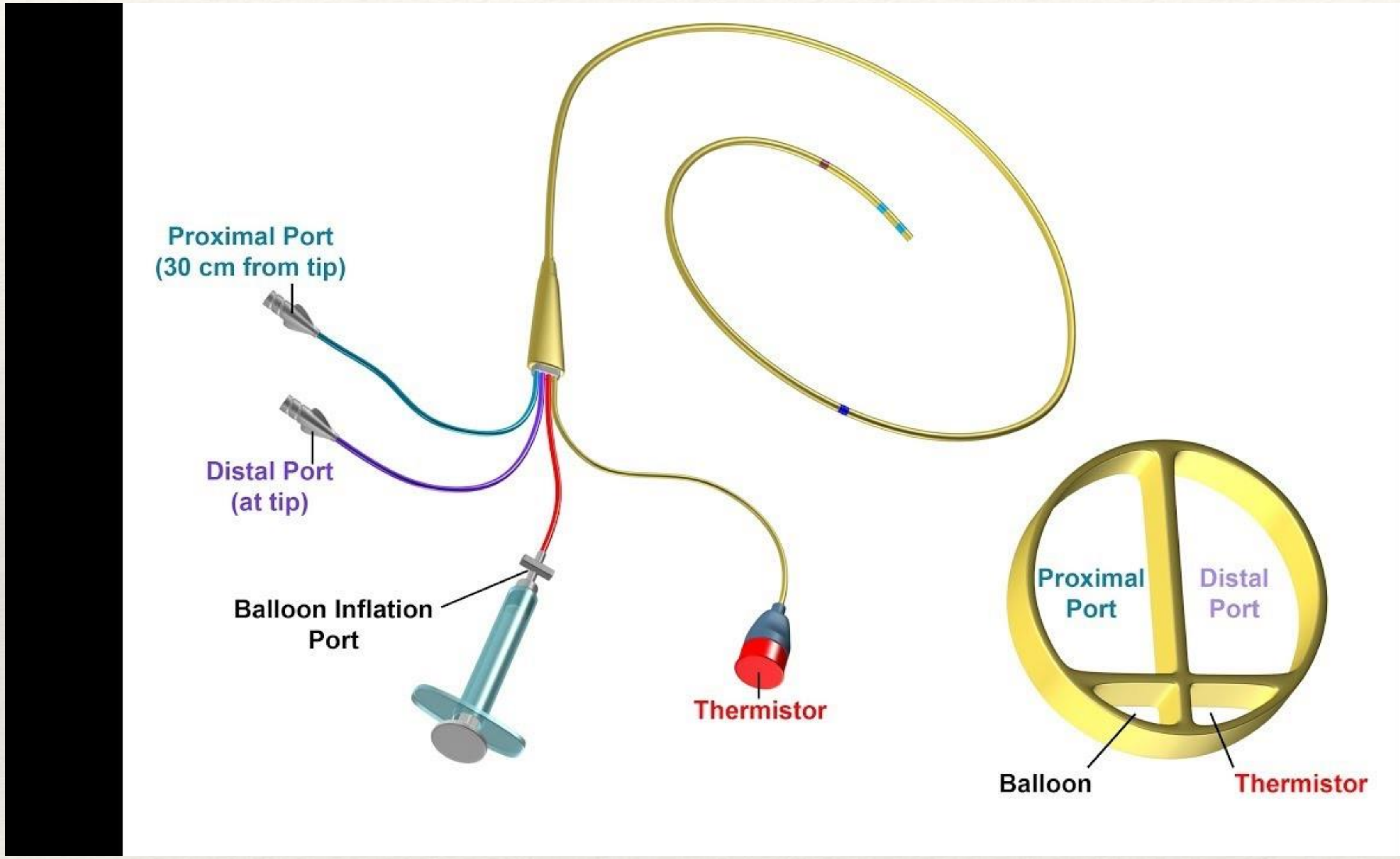
Indications

- Shock: causes, fluid management and hemodynamic monitoring
- Pulmonary hypertension: diagnosis (gold standard) and assessing response to therapy
- Valvular disease: when non-invasive assessment is equivocal
- Intracardiac shunts
- Constrictive vs restrictive physiology

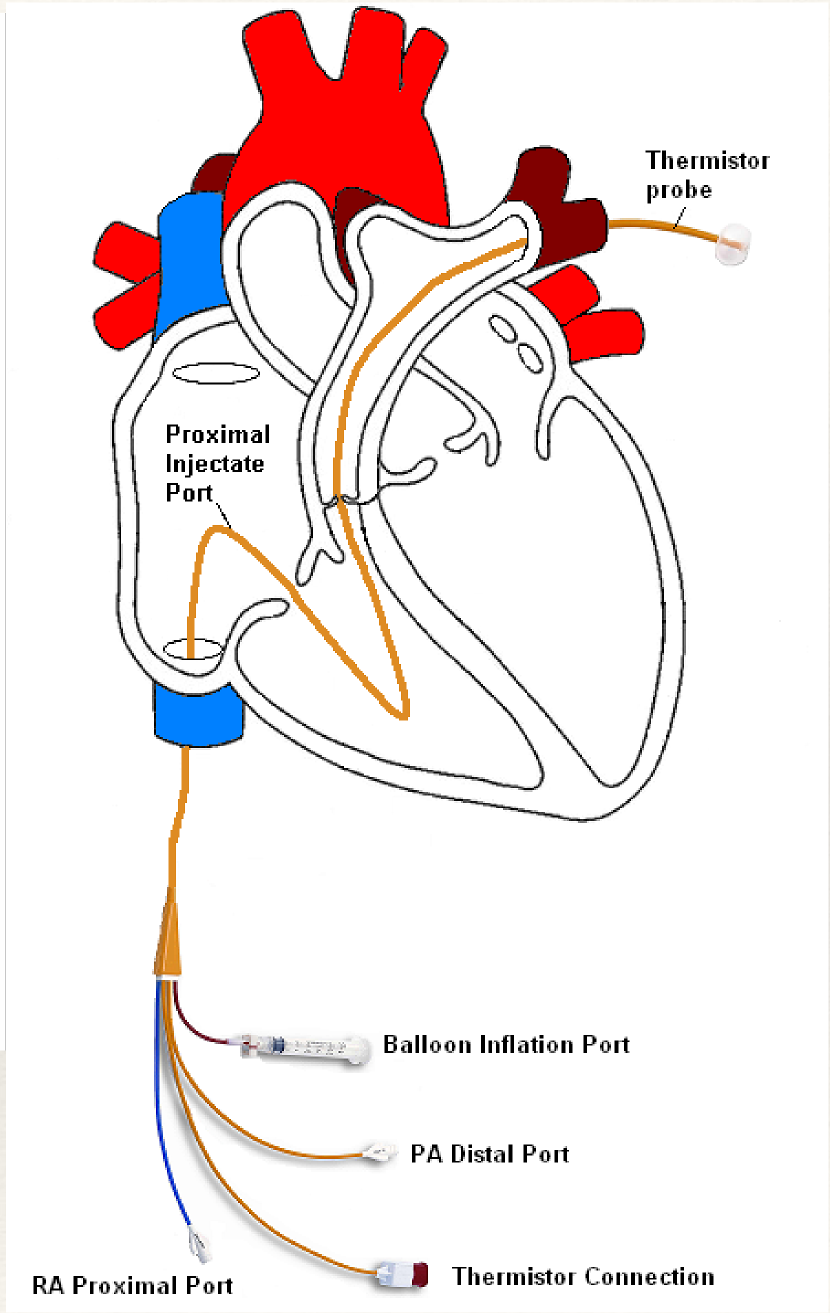
Contraindications

- Absolute: right-sided endocarditis, intracardiac mass/thrombus (RA or RV), mechanical valve (tricuspid or pulmonary)
- Relative: LBBB, severe coagulopathy, recent pacemaker placement

Technique



Proximal Port
(30 cm from tip)
Distal Port
(at tip)
Balloon Inflation
Port
Thermistor
Proximal
Port
Distal
Port
Balloon
Thermistor

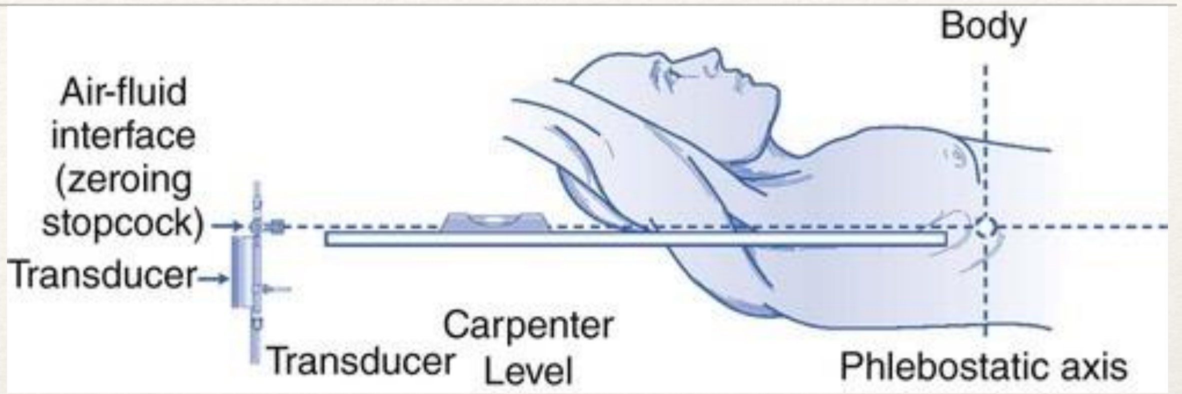


Thermistor
probe
Proximal
Injectate
Port
Balloon Inflation Port
PA Distal Port
RA Proximal Port
Thermistor Connection

Technique

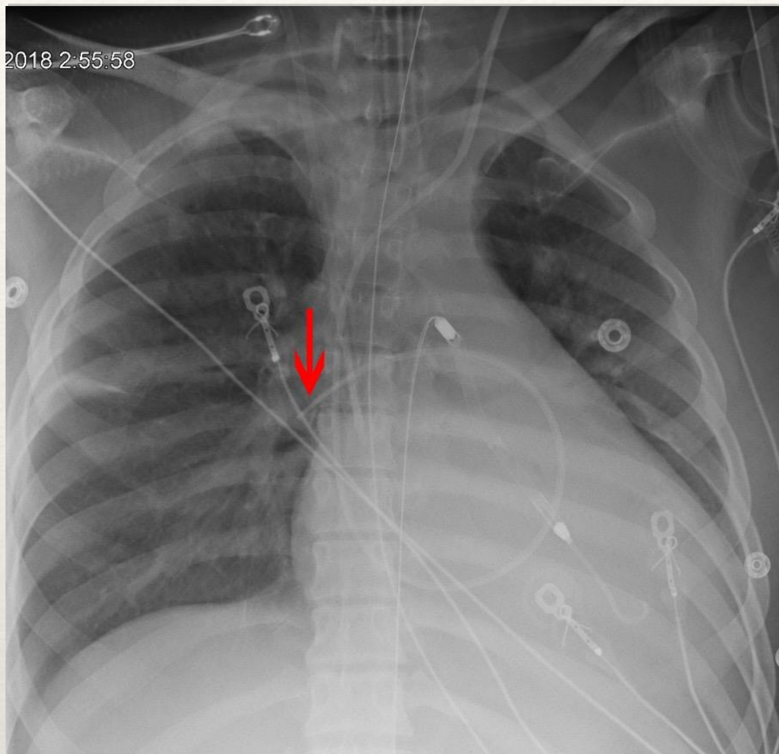
- Place an introducer: IJ, SC or femoral
- Inspect, flush all ports and test the balloon; connect distal (yellow) port to pressure transducer; zero the transducer; turn other ports OFF
- Place *swandom* (repositioning sheath) on catheter if it is to stay for hemodynamic monitoring
- Insert about 15 cm and inflate the balloon
- Slowly and steadily advance catheter while watching waveforms or under fluoroscopy
- If difficulty getting into PA: Valsalva, HOB up, 0.025 wire

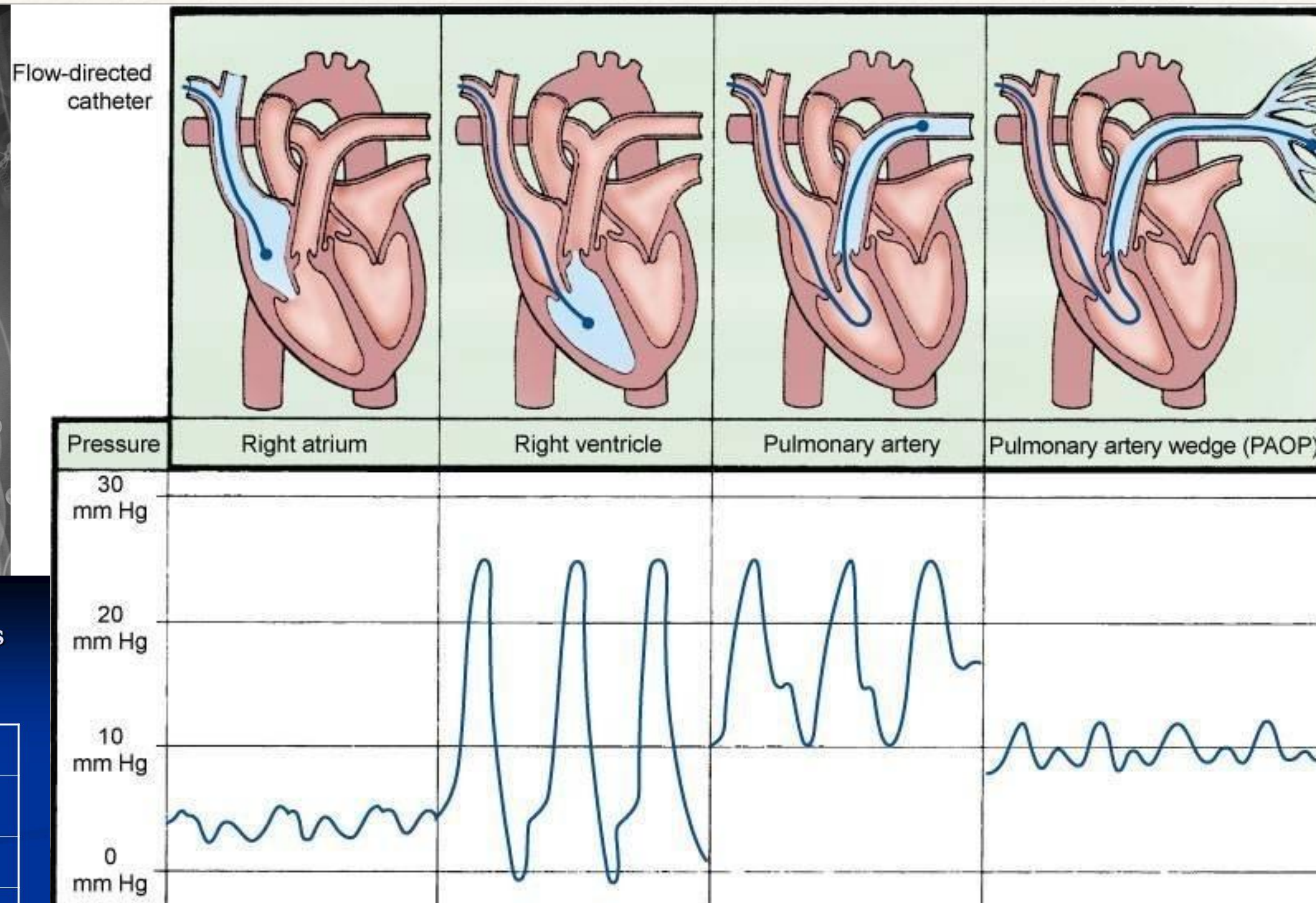
Technique - tips



- Establish the zero level and balance the transducer
- Confirm the scale of the recording (40 mmHg for RHC, 200 mm Hg for LHC)
- Collect hemodynamics in a systematic manner
- Always record pressures at end-expiration (during inspiration pressures will be lower due to decrease in intrathoracic pressure)
- Carefully assess pressure waveforms for proper fidelity and timing with ECG

Technique





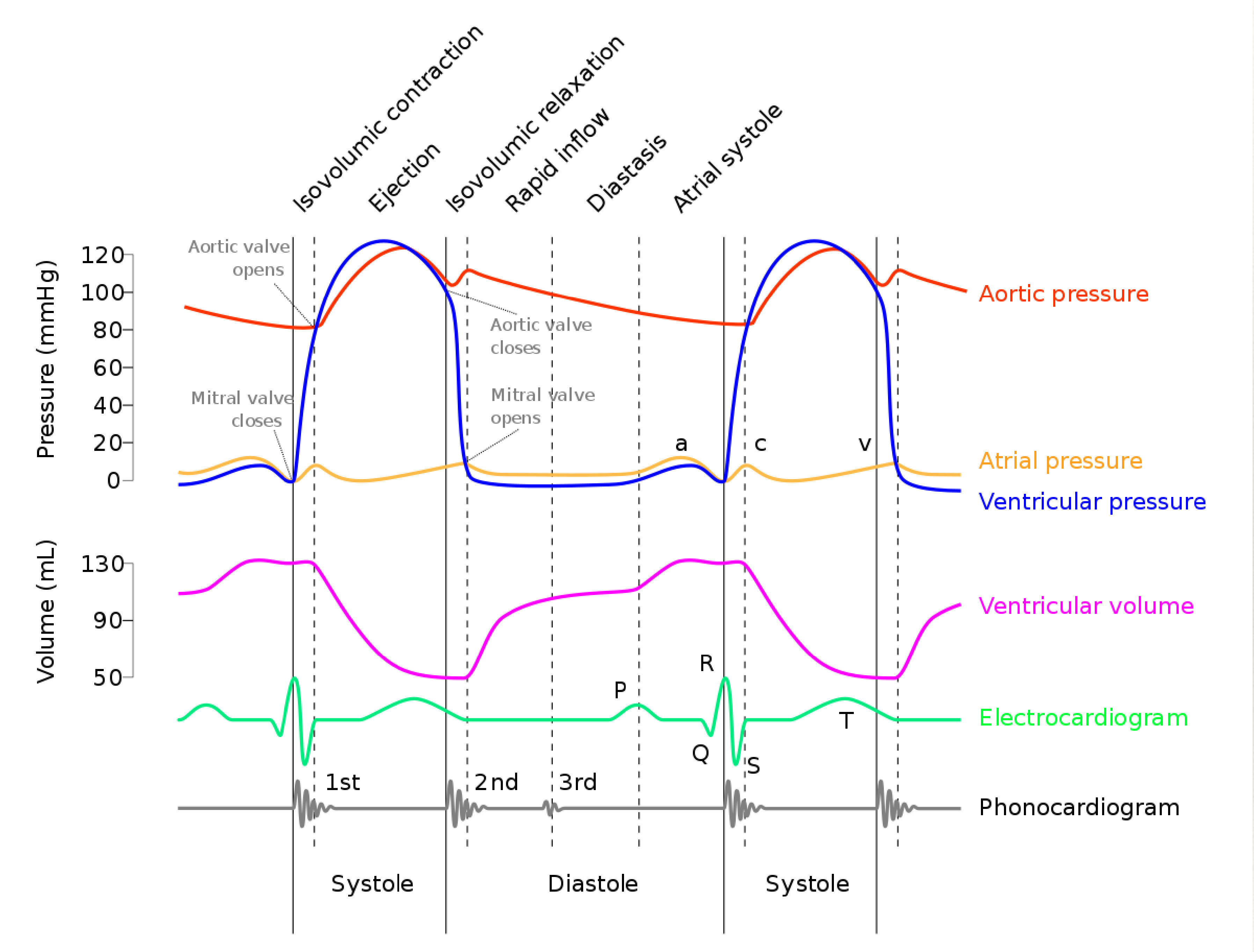
Typical Cather Insertion Landmarks

Anatomic Structure	Distance
Right atrium	20 to 25 cm
Right ventricle	30 to 35 cm
Pulmonary artery	40 to 45 cm
Pulmonary capillary wedge	45 to 55 cm

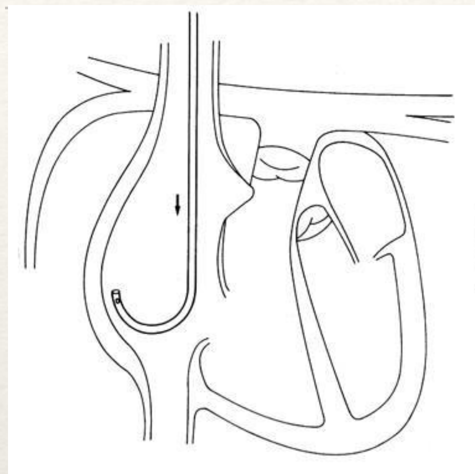
Simultaneous Right- and Left-Heart Catheterization

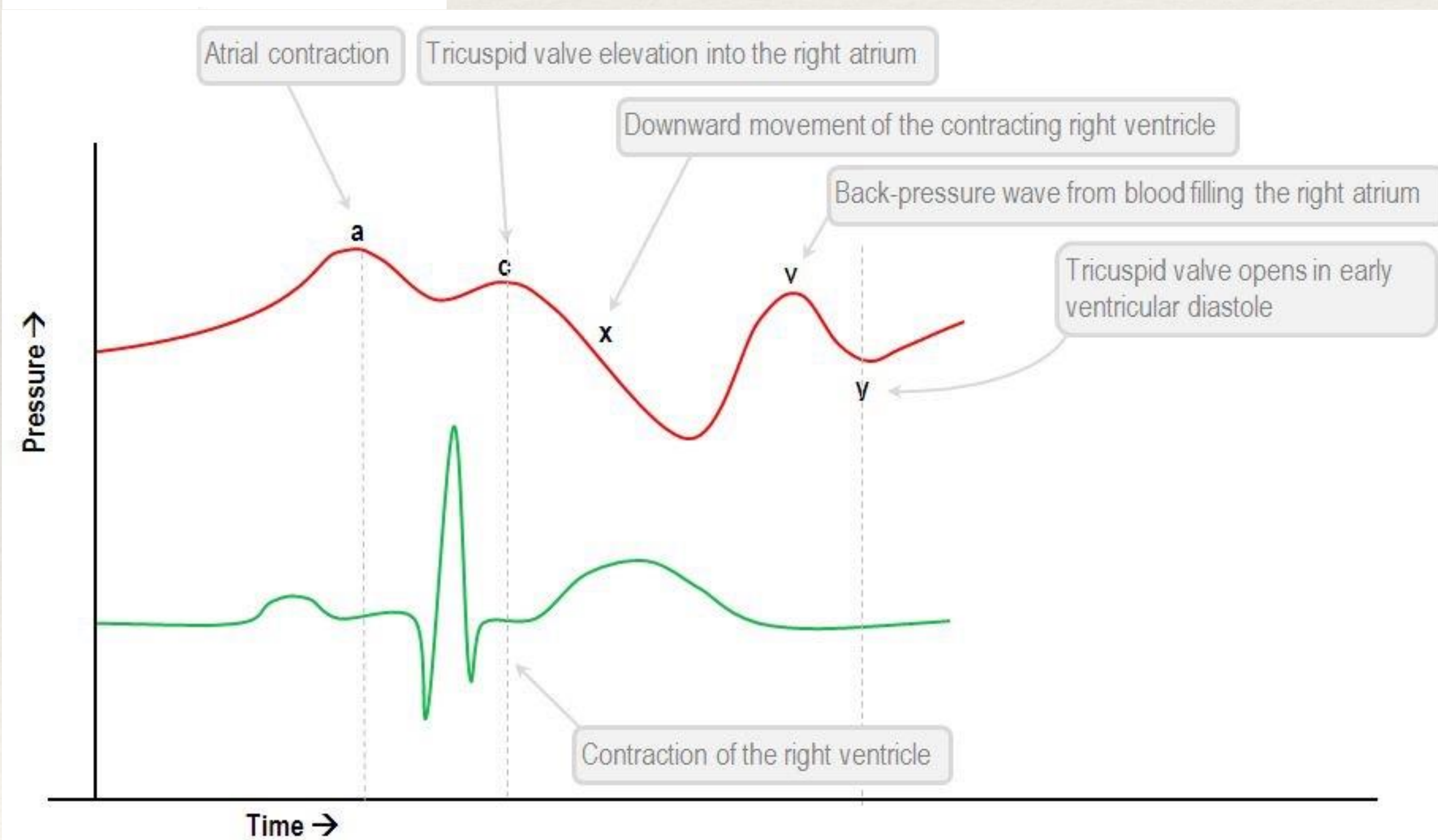
- 1. PA catheter to PA (pulmonary artery)
- 2. Measure thermodilution CO (x3) and measure O2 sat in PA and Ao blood samples (*for Fick CO and screen for shunt*)
- 3. Record Ao pressures w Ao catheter (pigtail); cross the AV into LV - wedge the PA catheter - measure simultaneous LV/PCWP (*mitral valve assessment*)
- 4. Pull back from PCWP to PA (*trasnpulmonary gradient*)
- 5. Pull back from PA to RV (*screen for pulmonic stenosis*) and record RV
- 6. Record simultaneous LV/RV (*constriction vs restriction*)
- 7. Pull back from RV to RA (*screen for tricuspid stenosis*) and record RA
- 8.Pull back from LV to Ao (*screen for aortic stenosis*)

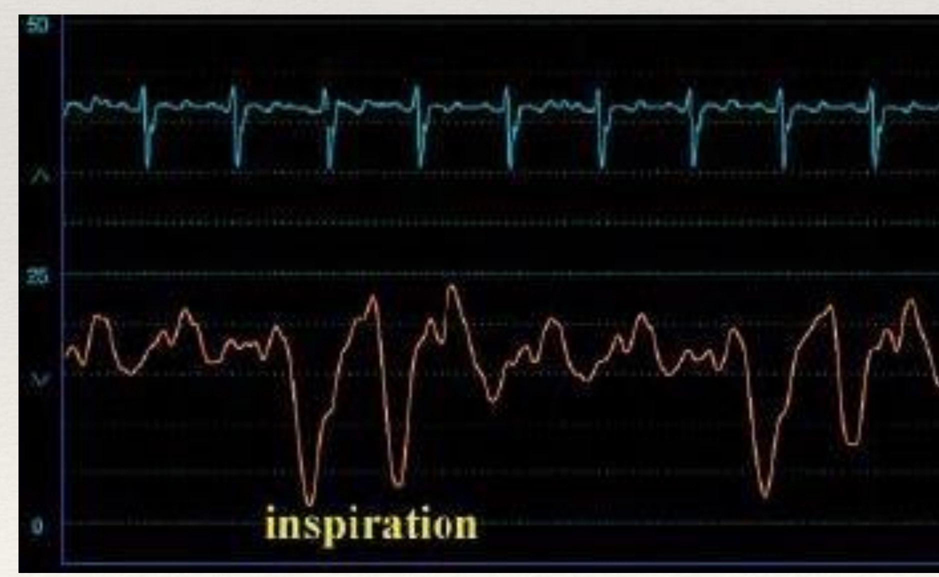
Cardiac cycle



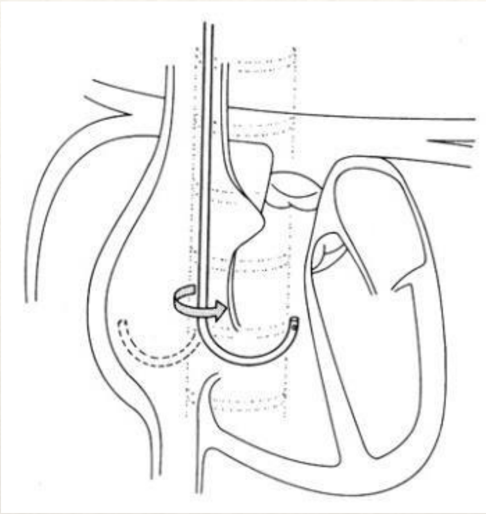
Pressure wave interpretation - RA

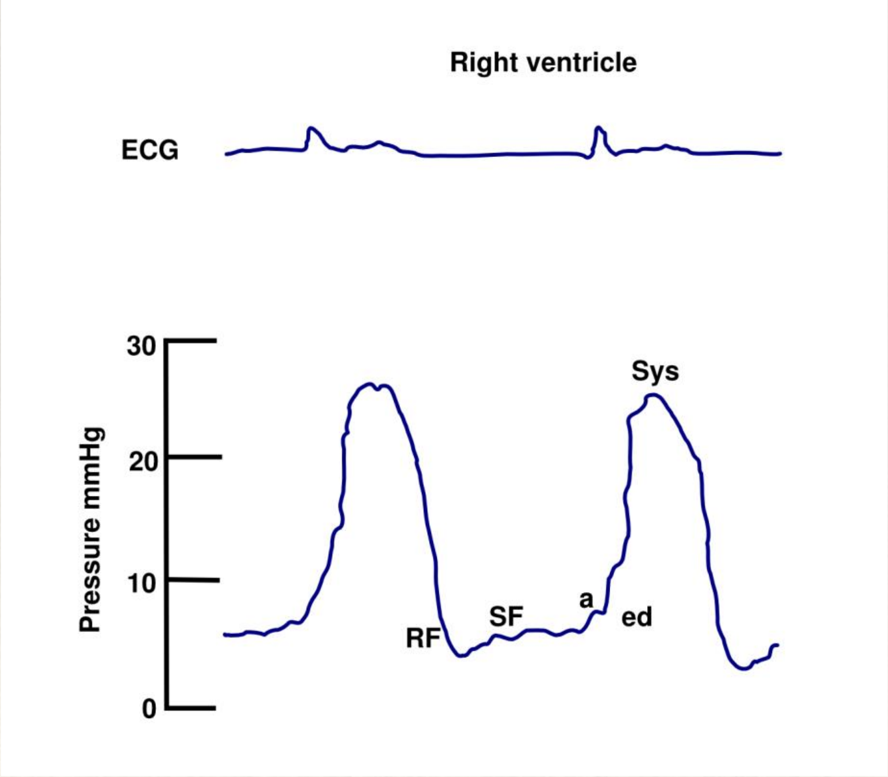




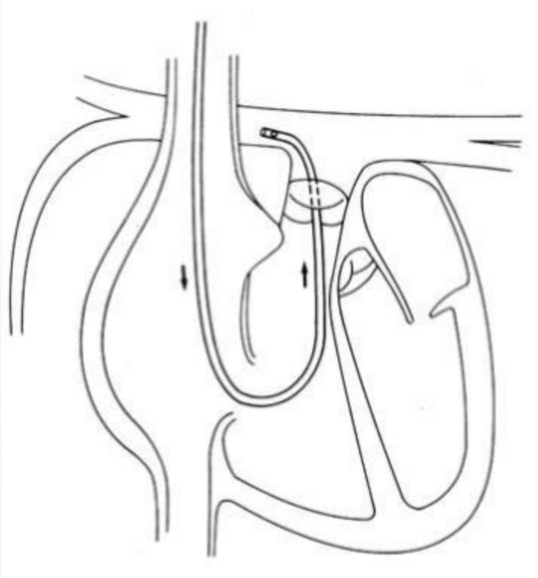


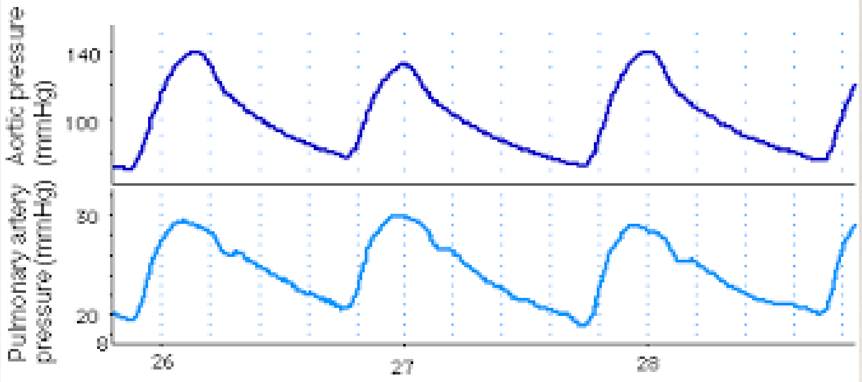
Pressure wave interpretation - RV



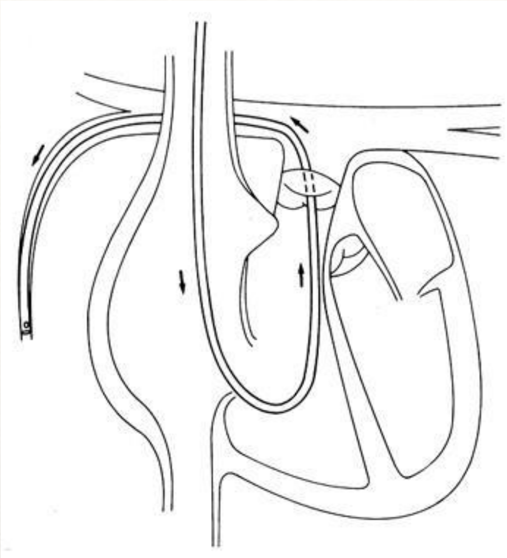


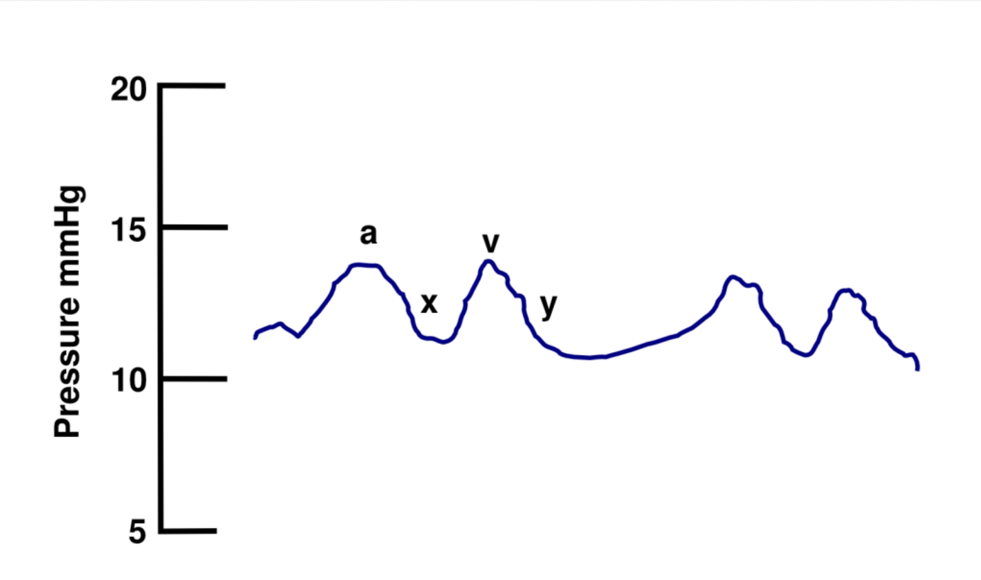
Pressure wave interpretation - PA

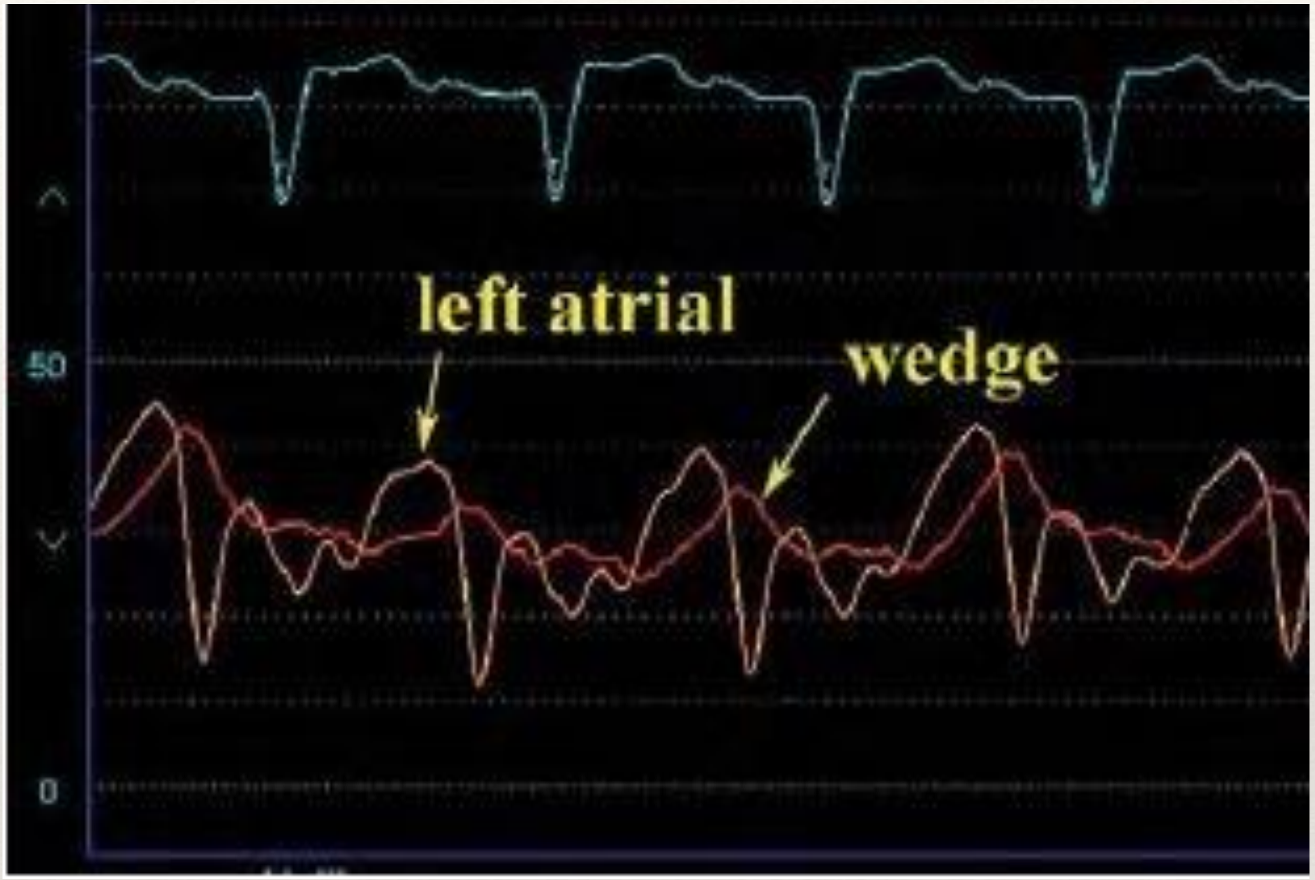




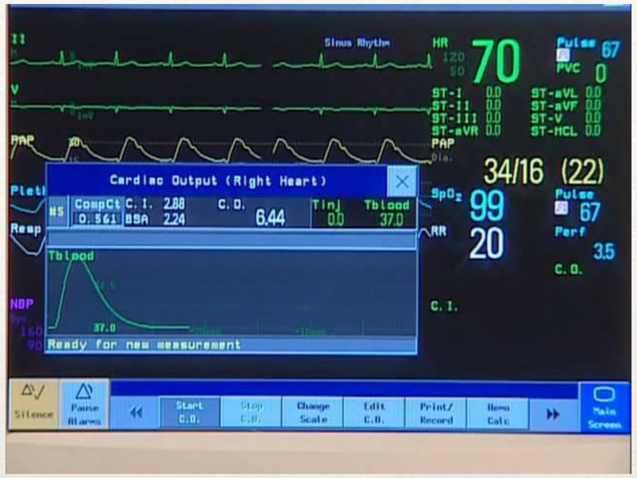
Pressure wave interpretation - PCWP

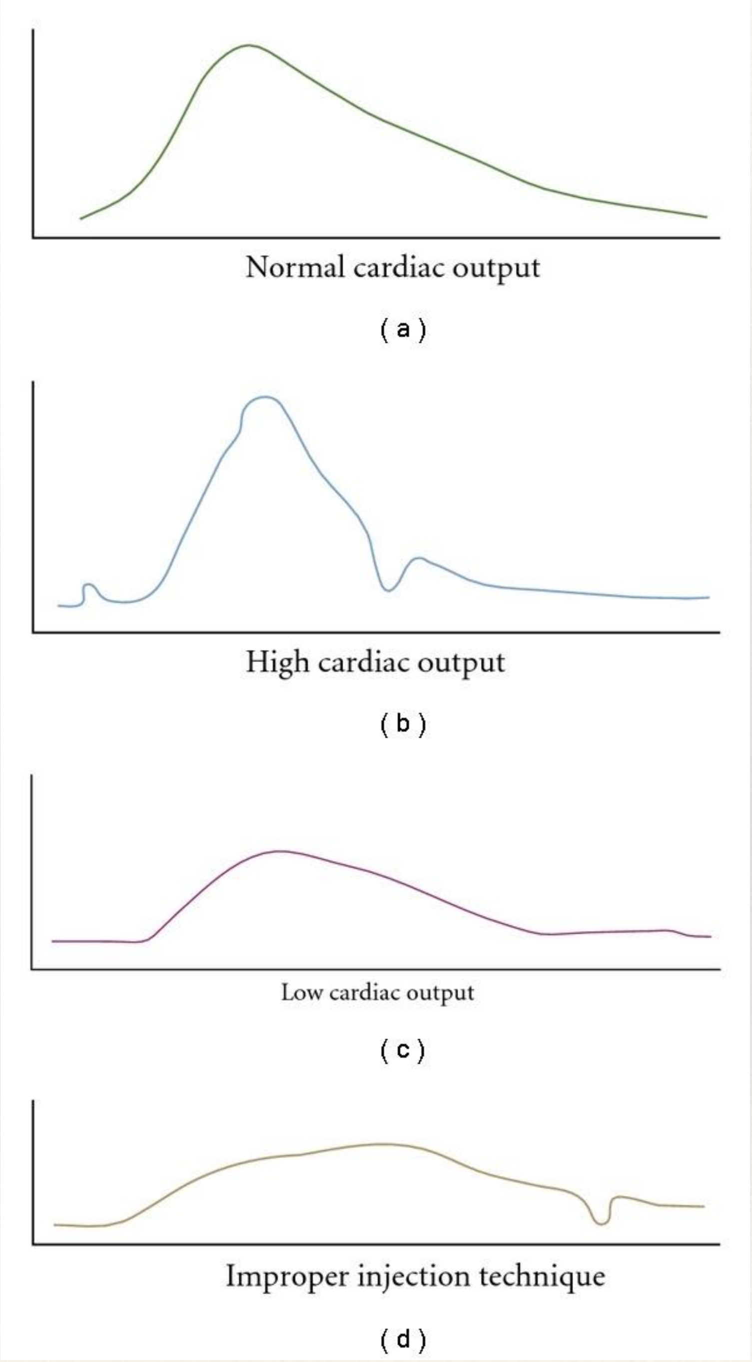






Cardiac output - thermodilution





- Bolus injection of saline into proximal port
- Change in temperature is measured by thermistor in the distal portion of the catheter

Cardiac output - Fick

- Assumes rate of O2 consumption is a function of the rate of blood flow times the rate of O2 pickup by the RBC
- O2 consumption: direct or indirect measurement (3 ml O2/kg)

$$\text{FICK C.O.} = \frac{\text{O2 consumption (VO2) mL/min}}{\text{AVO2 difference x 10}}$$

$$= \frac{\text{3 mL O2 * weight (Kg)}}{\{(\text{Hgb * 1.36 * AO sat}) - (\text{Hgb * 1.36 * PA sat})\} * 10}$$

Cardiac output - limitations

- **Thermodilution**
- Not accurate in tricuspid regurgitation
- Overestimates CO at low output states

- **Fick**
- O2 consumption is often estimated by body weight (rather than measured directly)
- Large errors possible with small differences in saturations and hemoglobin
- Measurements on room air

Normal values

Normal Pressures

Site	Normal Value (mmHg)	Mean Pressure (mmHg)	Saturation
Right Atrium (or CVP)	0-5		75%
Right Ventricle	25/5		75%
Pulmonary Artery	25/10	10-20	75%
PCWP	7-12		95-100%
LV	120/10		95-100%
Aorta	120/80		95-100%

Normal values

Normal Values

Site	Value
Sv02	0.60-0.75
Stroke Volume	60-100 ml/beat
Stroke Index	33-47 ml/beat/m2
Cardiac Output	4-8 L/min
Cardiac Index	2.5-4.0 L/min/m2
SVR	800-1200 dynes sec/-cm5
PVR	<250 dynes sec/-cm5
MAP	70-110 mmHg

Derived parameters from cardiac output

Parameter	Calculation	Normal values
Stroke Volume (index)	$Cardiac\ output \times 1000 \div heart\ rate$ (using cardiac index will give the stroke volume index)	60 – 100 ml/ beat (33 - 47 ml/m^2/beat)
Systemic Vascular Resistance (index)	$\frac{(MAP - RAP) \times 80}{Cardiac\ Output\ (index)}$	1000 -1500 dyne s/ cm^5 (1970 - 2390 dyne s/cm^5/m^2)
Pulmonary Vascular Resistance (index)	$\frac{(MPAP - PAWP) \times 80}{Cardiac\ output\ (index)}$	<250 dyne s/cm^5 (255 - 285 dyne s/cm^5/m^2)
Left Ventricular Stroke Work (index)	$(MAP - PAWP) \times SV\ (SVI) \times 0.0136$	58 - 104 gm-m/beat (50 - 62 gm-m/m^2/beat)
Right Ventricular Stroke Work (index)	Cardiac output (index)	8 - 16 gm-m/beat (5 - 10 gm-m/m^2/beat)

MAP= mean arterial pressure; RAP = right atrial pressure (or CVP); PAWP = pulmonary artery wedge pressure; MPAP = mean pulmonary artery pressure (pulmonary systolic pressure +(2 x pulmonary diastolic pressure)/ 3); 80 and 0.10136 are the numbers required for conversion to the units of measurement

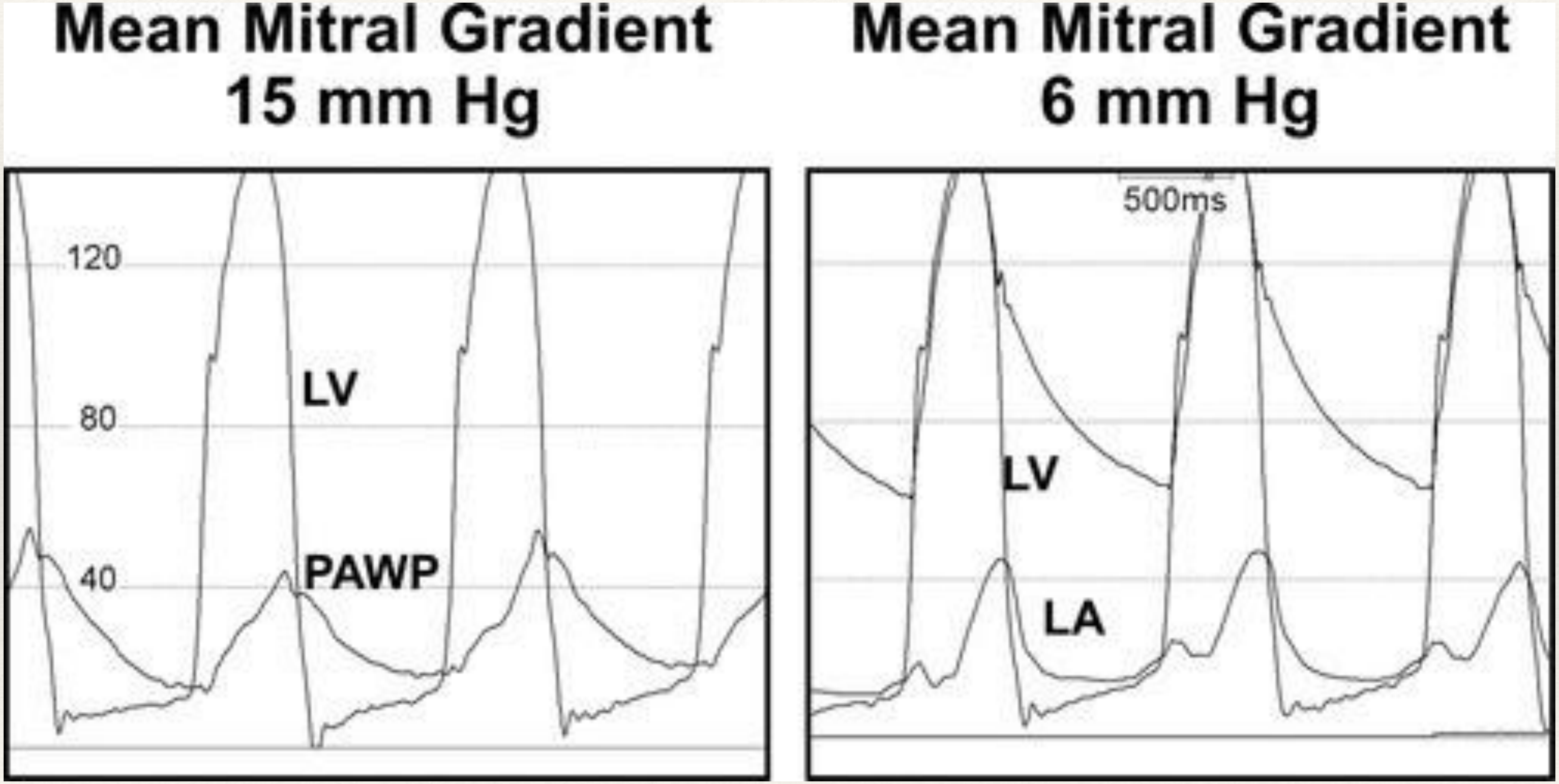
Common RHC findings: Shock

(Table 1) *Hemodynamic Profile of Shock States*

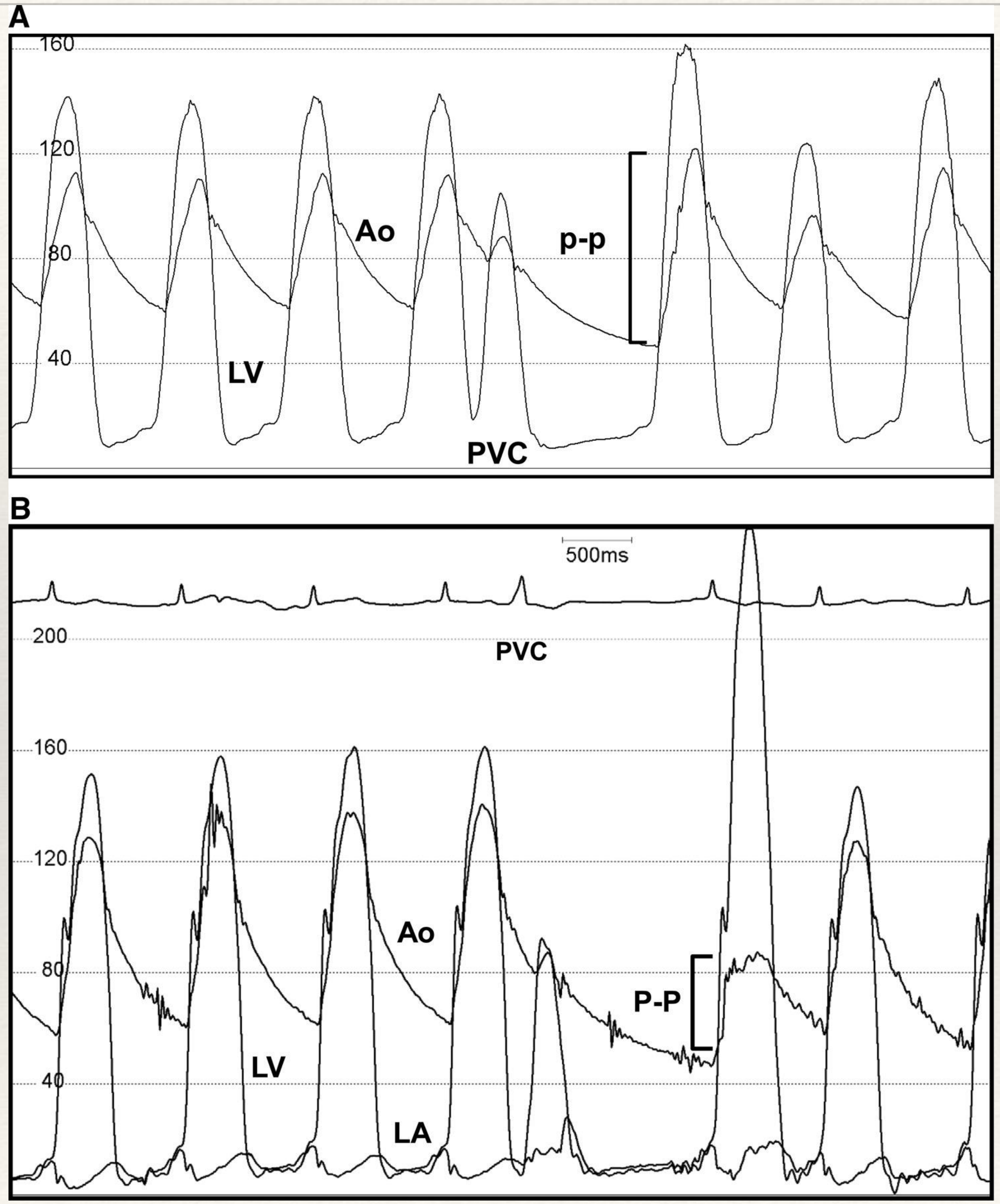
Physiologic Variable →	Preload	Pump Function	Afterload
Clinical Measurement →	Central Venous Pressure *	Cardiac Output	Systemic Vascular Resistance
Hypovolemic	↓	↓	↑
Cardiogenic	↑	↓	↑
Distributive**	↓ or ↔	↑	↓

Figure 1: Hemodynamic profile of shock states.

Common RHC findings: Mitral Stenosis



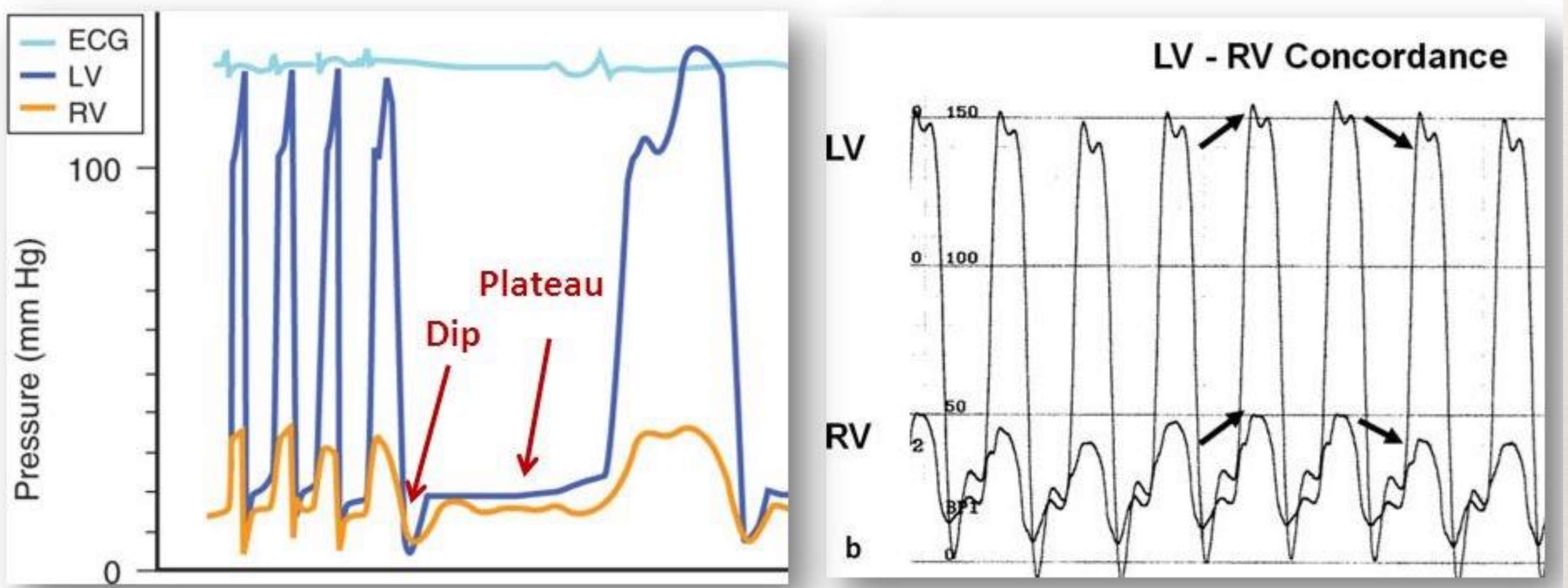
Common RHC findings: AS vs HOCM



- Aortic stenosis: fixed obstruction
- HOCM: dynamic obstruction (Brockenbrough phenomenon)

Common RHC findings: restriction

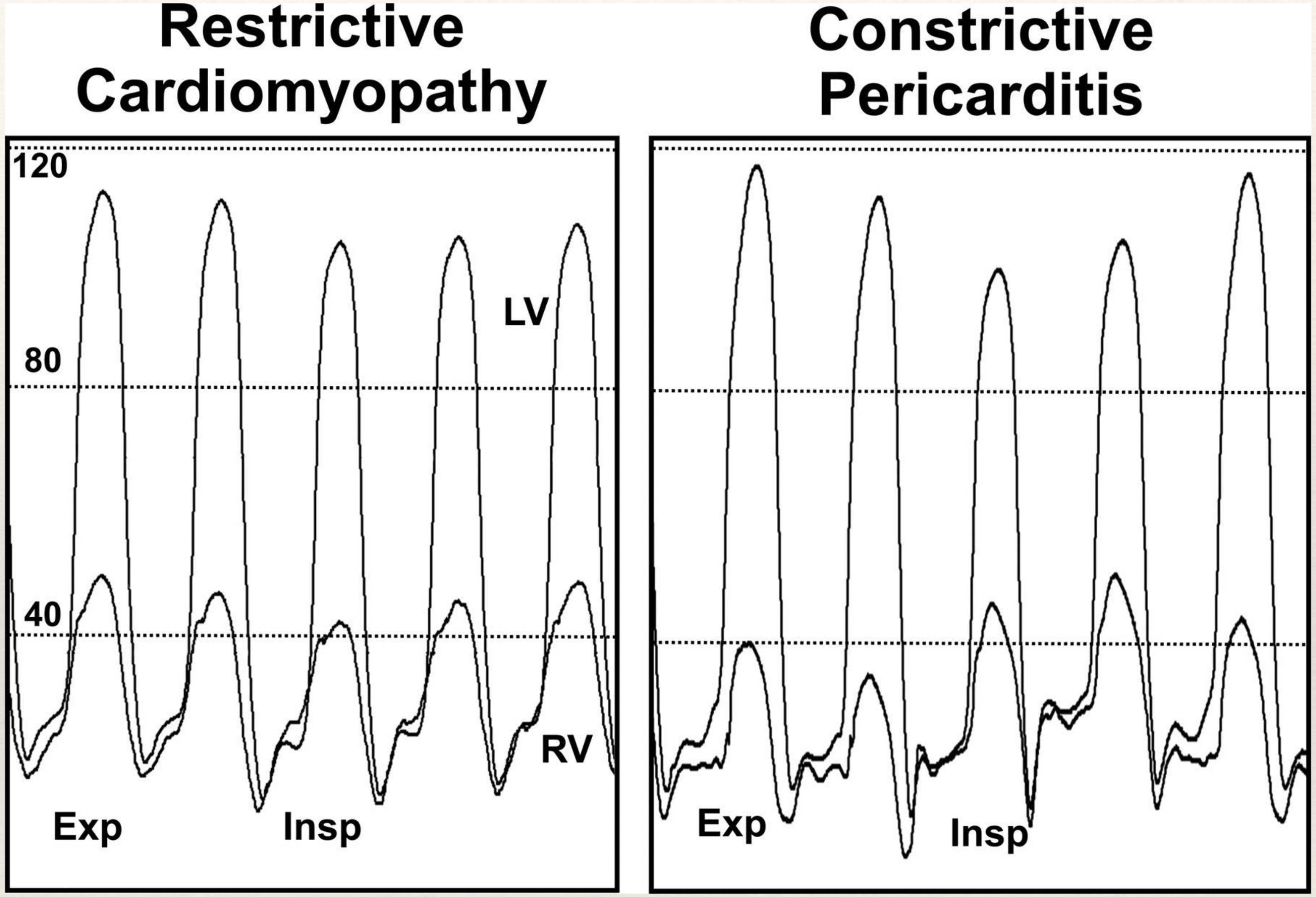
Hemodynamics of Restrictive Physiology



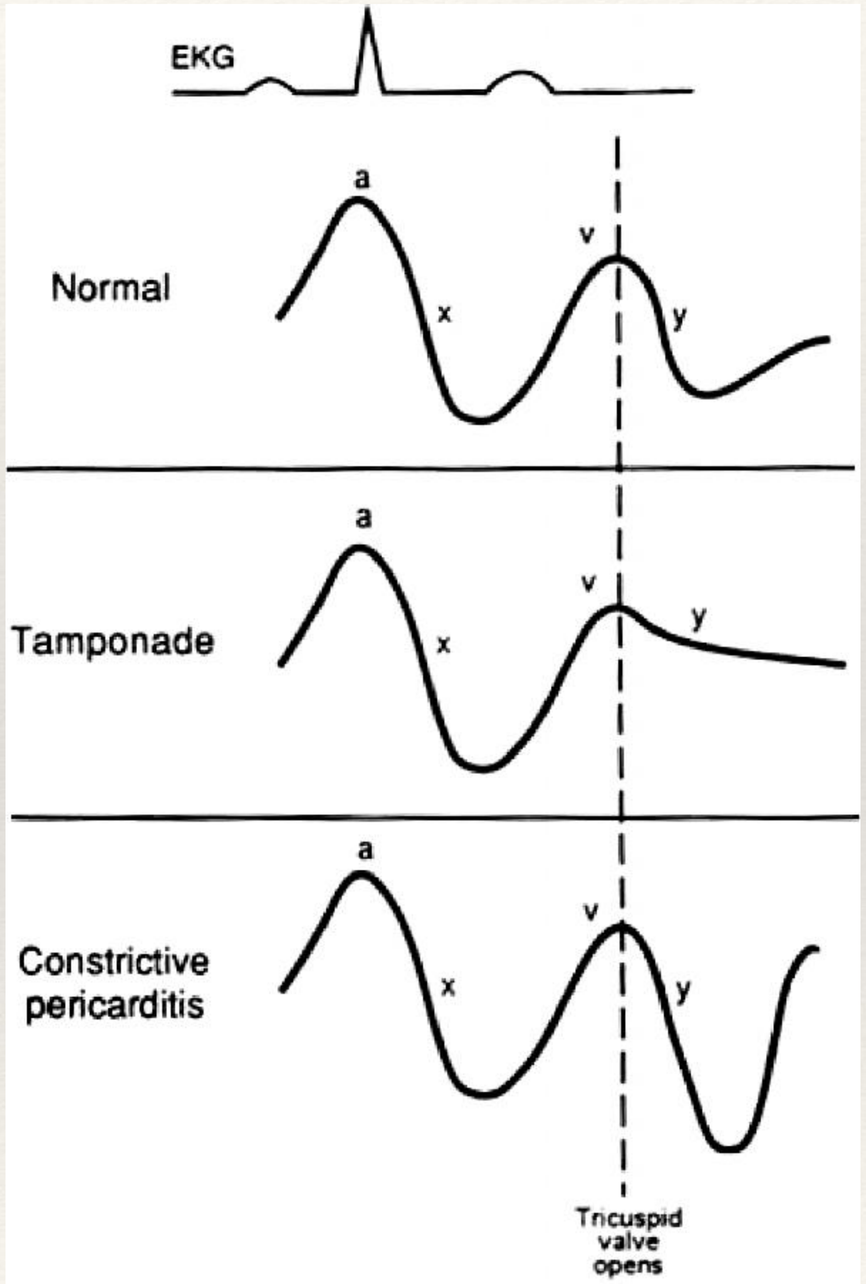
- Elevated left- and right-sided filling pressures
- “Square root” sign in ventricular pressure recordings
- LV-RV EDP diff>5mmHg
- Respiratory LV-RV systolic "concordance“

Common RHC findings: restriction vs contraction

- Restriction: concordant
- Constriction: discordant



Common RHC findings: Tamponade



Summary

- **Left** heart failure: Low CI, high **PCWP**, high **SVR**
- **Right** heart failure: Low CI, high **CVP**, high **PVR**
- **Tamponade: low CI, high PCWP= high CVP**

- **Hypotension**
- Hypovolemia: low CI, low PCWP, low CVP, high SVR
- Cardiogenic: low CI, high PCWP, high CVP, high SVR
- Sepsis: high CI, low PCWP, low CVP, low SVR

Thank you!
Stay safe!