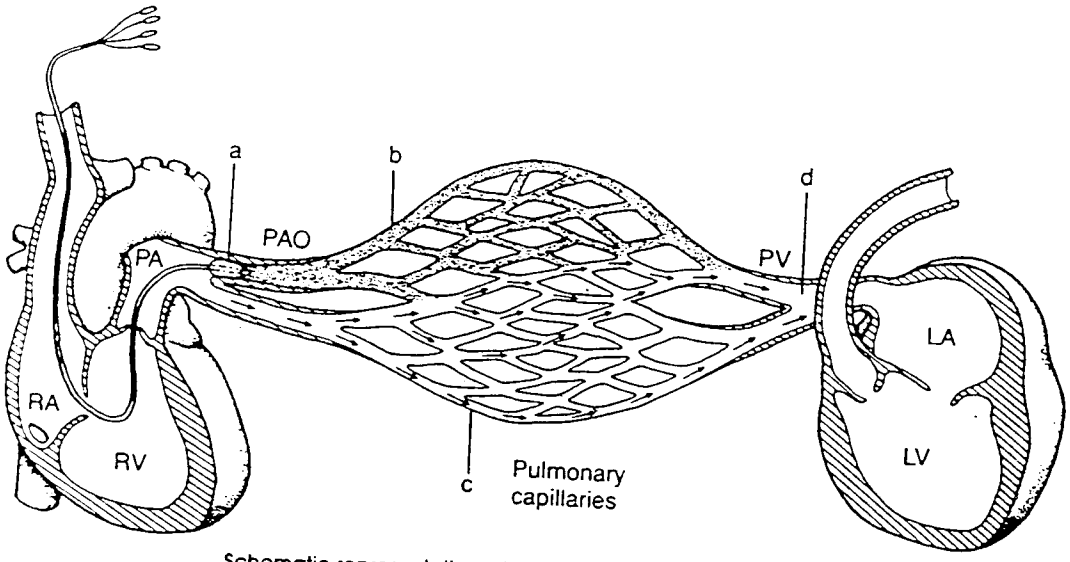


Schematic representation of the pulmonary artery catheter in the wedged position. From its position in a small occluded segment of the pulmonary circulation, the pulmonary artery catheter in the wedged position allows the electronic monitoring equipment to "look through" a nonactive segment of the pulmonary circulation to the hemodynamically active pulmonary veins and left atrium.

a. Description

(1) Proximal port - closest to skin/transducer

(a) RA (CVP) readings

(b) Port for cardiac output injectate boluses

(c) Infusion of IVs

(2) Distal port - farthest from transducer

(a) PA and PAWP readings

(b) Must be continuously monitored

(3) Thermistor connector

(a) Connects to cardiac output module of monitor

(b) Needs the connected or covered at all times to prevent microshock

(4) Thermistor

(a) Proximal to balloon

(b) For sensing temperature of blood in PA

(5) Balloon inflation valve - inflates balloon at catheter tip

b. Indications

(1) Monitoring of cardiac output and its determinants in low cardiac output states

(2) Differential diagnosis of low cardiac output states

(3) Guide to therapies directed at manipulating determinants of cardiac output

(4) Provides best indirect measure of LV preload--PAWP

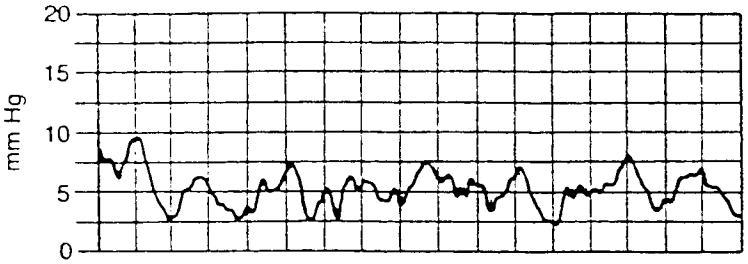
c. Limitations

(1) Doesn't reflect LV function when obstruction between catheter tip and LV at end diastole

(2) Accuracy of measurement operator dependent

d. Pressure and waveforms

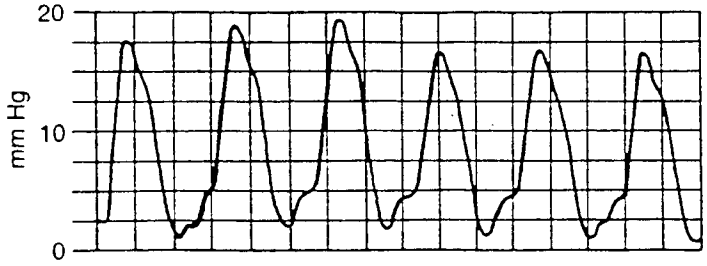
(1) Right atrial (same as CVP)



The right atrial waveform.

(2) Right ventricular pressures

(a) Normal: systolic - 20-30 mm Hg
diastolic < 5 mm HG



The right ventricular waveform.

(b) Phases and mechanical correlation

1) Initial rapid rise in pressure - isovolumetric contraction, i.e., tricuspid and pulmonary valves are closed and volume within RV remains constant while pressure increases

2) Pressure in RV exceeds PA pressure and pulmonary valve opens. Blood is then ejected from the RV into the PA. Right ventricular systole is represented by the peak of the waveform.

3) The pulmonary valve closes and the RV pressure rapidly decreases. The tricuspid valve opens and RV passively fills with blood from the RA. The lowest point on the waveform represents RV end-diastole.

(c) Abnormal pressures

1) Increase in systolic RV pressures

a) Pulmonary HPTN any cause (PE, pneumo, hypoxemia, ARDS)

b) Pulmonic valvular stenosis

2) Increase in RV diastolic pressures

a) RV failure

b) Constrictive pericarditis

c) Cardiac tamponade

3) Decreased in hypovolemia, distributive shock

(d) Not monitored routinely

1) Presence on monitor screen indicative of PA catheter migration backwards

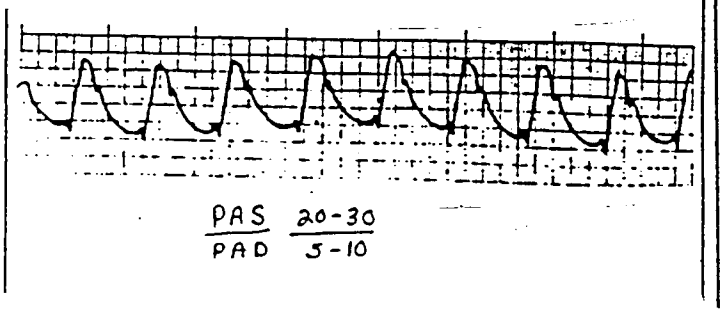
2) Sudden start of ventricular ectopy in patient with PA catheter - be sure to check waveform on screen - catheter probably displaced into RV and pattern reflective of this

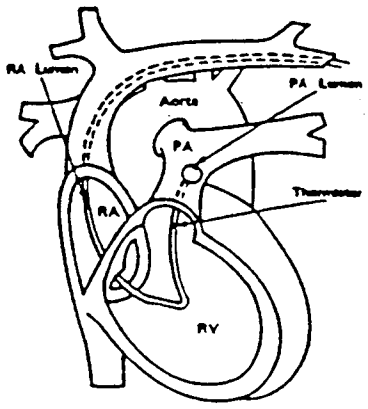
(e) Right ventricular stroke work index - (RVSWI) - work performed by the right ventricle to generate pressure per beat, adjusted for body size. Normal range: 8.5 - 12 g-m/m^2

(3) Pulmonary arterial pressures

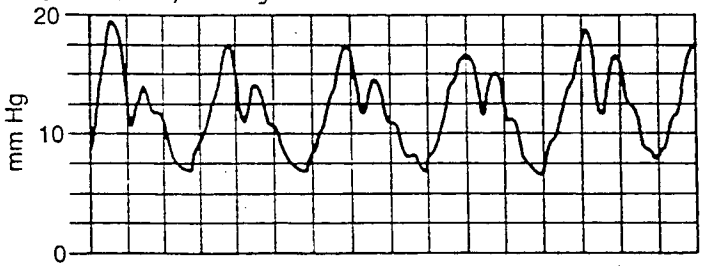
(a) Normal pressures 20-30 mm HG
8-15 mm Hg

PA mean < 20 mm Hg





Pulmonary Artery Waveform



(b) Phases and mechanical correlation

1) Rapid rise in waveform represents RV ejection

2) The dicrotic notch in the downward slope represents pulmonary valve closure

(c) Abnormal pressures

1) Increased

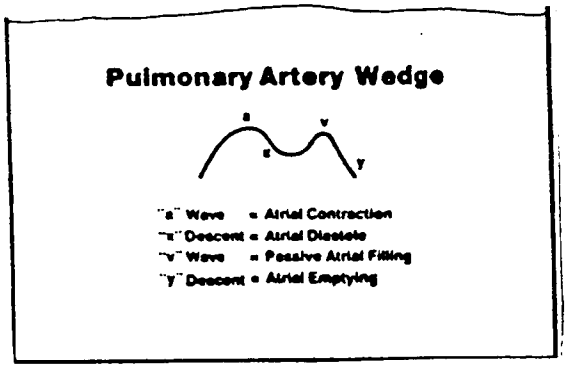
a) Increased pulmonary blood flow

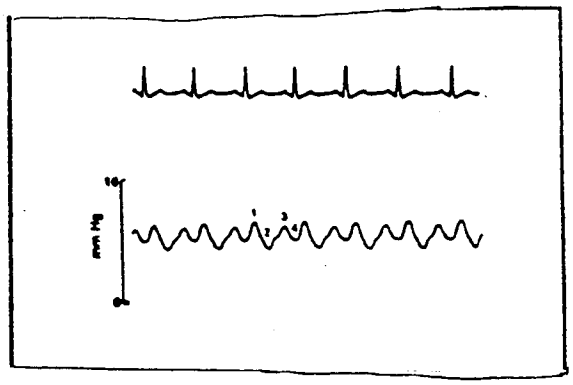
b) Increased pulmonary vascular resistance

c) Increased pulmonary venous pressure

2) Decreased - hypovolemia and distributive shock

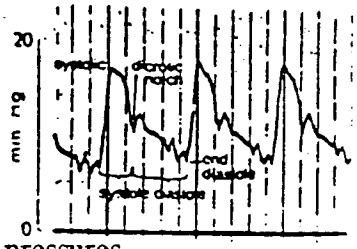
(4) Pulmonary arterial wedge pressure



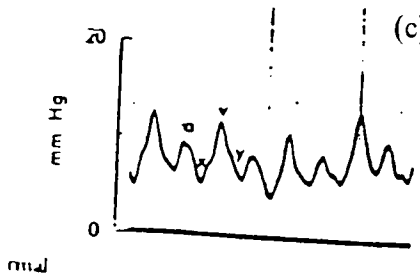


(a) PAWP primary measurement

(b) Provides indirect measurement of LV function by indirect measurement of LV preload --> LVEDP



(c) PAD>PAWP>LAP>LVEDP



1) Normal pressures: 8-12 mm Hg

2) Phases and mechanical correlation similar to RA pressures

3) Abnormal pressures

a) Increased

- LV failure
- Mitral stenosis
- Mitral insufficiency
- Constrictive pericarditis
- Volume overload

b) Decreased - hypovolemia and distributive shock

(d) "Laws" of PAWP monitoring

1) Catheter tip must be in the pulmonary artery

2) There can be no obstruction between the transducer and the vascular system at the tip of the catheter

3) There can be no obstruction between the catheter tip and the LV at end-diastole

(e) Miscellaneous

1) 18-20 mm Hg beginning of pulmonary congestion

2) > 30 mm Hg severe pulmonary edema

3) 15-19 mm Hg may be necessary in hyperdynamic patient

4) PADP normally equal to PAWP or 2-4 mm HG>PAWP except when patient has pulmonary hypertension or heart rate is greater than 130

NOTE: PAWP should NEVER be greater than PADP.

5) Accurate readings essential for appropriate medical care

6) You must be aware that may not get flattened waveform on wedging balloon, there is a problem

7) Accuracy of readings on which medical therapies based dependent on nursing management

(5) Left ventricular stroke work index (LVSWI) work performed by the left ventricle to generate pressure per beat, adjusted for body size. Normal range: 35-85 g-m/m2

(f) Primary complications of placement

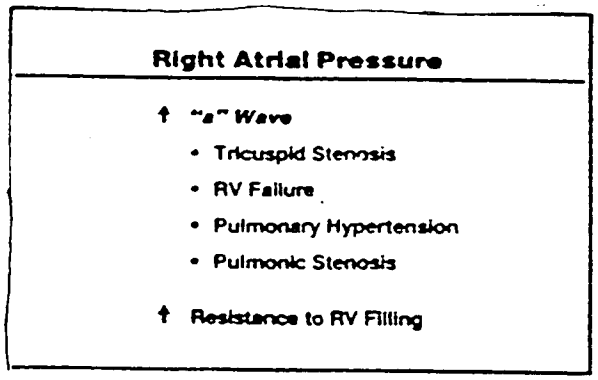
Complication	Causative Factors	Prevention/Treatment
More Common		
Arrhythmia	Endocardial irritation from catheter tip Prolonged catheterization	Fully inflate balloon
Thrombosis		Continuous flushing with heparinized solution Heparin bonding of catheter shaft
Infection	Inadequate aseptic technique Frequent catheter manipulation Prolonged catheterization	Strict sterile technique should be used for insertion Plastic sleeve Remove catheter at first sign of infection; replace with a new site if continued hemodynamic monitoring is indicated
Pulmonary Infarction	Distal migration with peristent wedging Thrombosis Forced flushing	Vigilant monitoring for wedging Withdraw catheter and reposition Obtain x-ray films daily to check catheter position
Balloon rupture	Repeated inflations Excessive inflation volumes Prolonged catheterization Prolonged shelf life or absorption of lipoporteins resulting in weakened structural integrity of the balloon	Do not inflate the balloon if a rupture is suspected Use pulmonary artery diastolic pressure whenever possible, because diastolic pressure measurements do not require balloon inflation
Less Common		
Pulmonary artery	Distensive occlusion of the pulmonary artery Balloon inflation with fluid Escess catheter looping Pulmonary hypertension	Inflate the balloon slowly under continuous pulmonary arterial monitoring Discontinue inflaiton once pulmonary capillary wedge pressure is obtained Keep wedge time to a mimimum (<8 to 15 seconds)

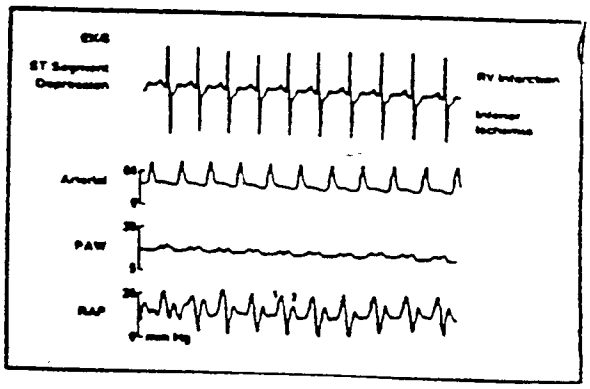
Complication	Causative Factors	Prevention/Treatment
Complete heart block	Preexisting left bundle-branch block Loop tightening (exerts direct pressure on the conduction system)	?Prophylactic pacemaker
Cardiac tissue	Forcible catheter withdrawal without deflated balloon Inadequate balloon inflation	Always deflate the balloon when withdrawing the catheter
Catheter knotting	Repeated catheter manipulation Catheter insertion with deflated balloon Large, dilated right ventricle	Avoid catheter redundancy Use estimates of average insertion lengths when catheterizing a patient without fluoroscopic guidance

4. Abnormal waveform analysis

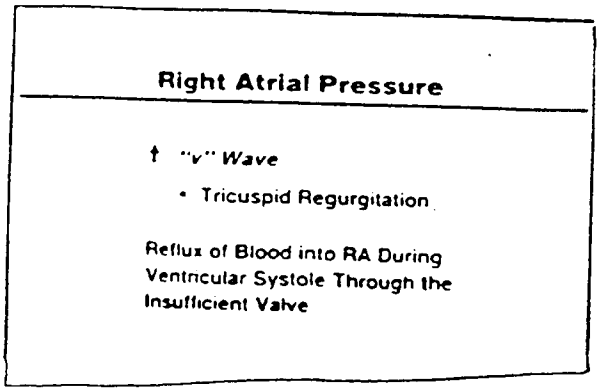
   a. Abnormal right atrial pressure waveforms

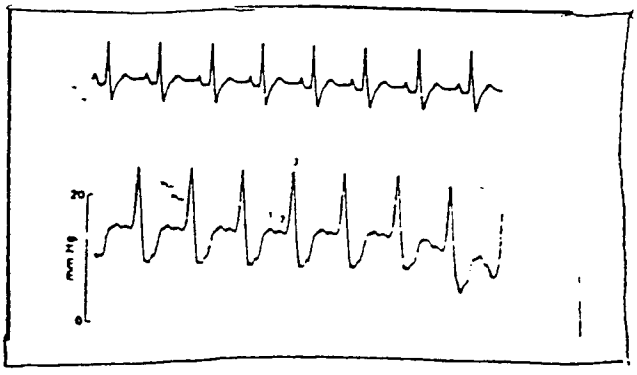
      (1) Elevated "a" waves



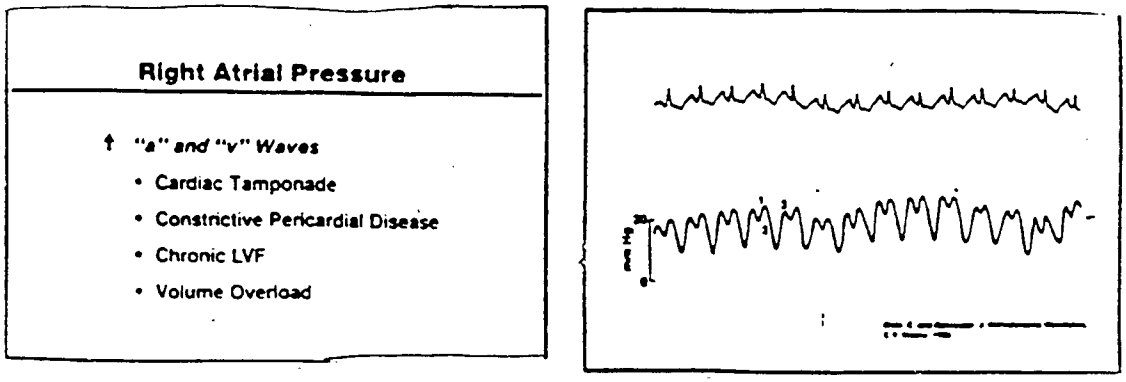


      (2) Elevated "v" waves

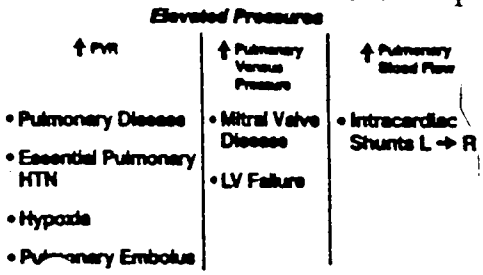


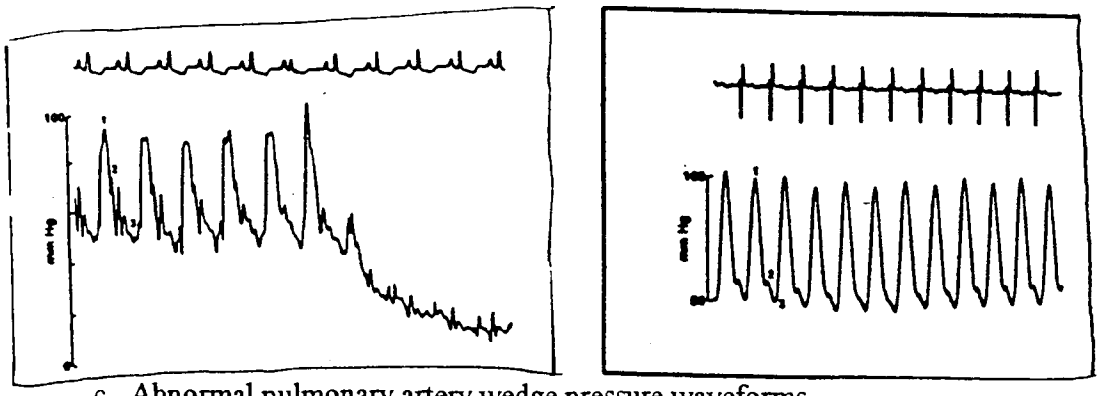


(3) Elevated "a" and "V" waves



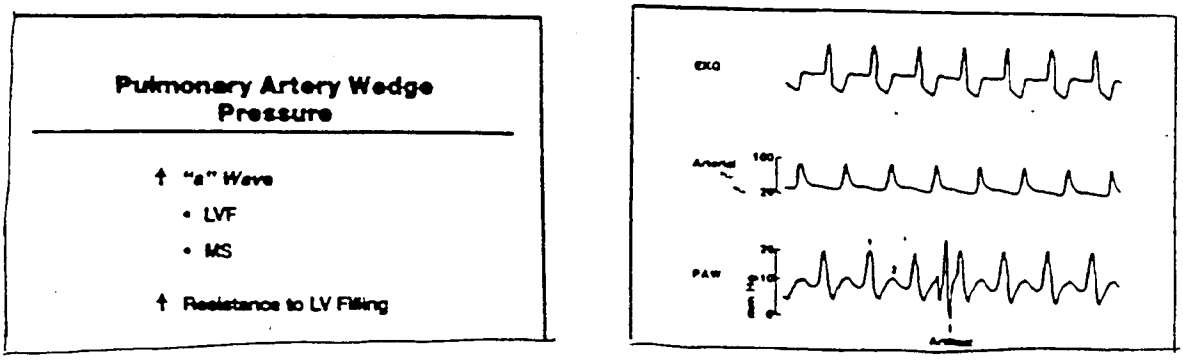
b. Abnormal pulmonary artery pressure waveforms - elevated pressures



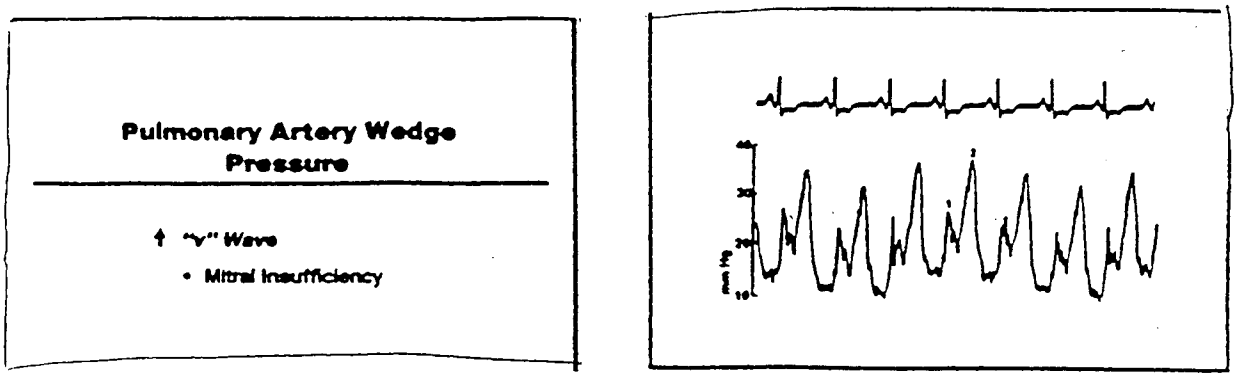


c. Abnormal pulmonary artery wedge pressure waveforms

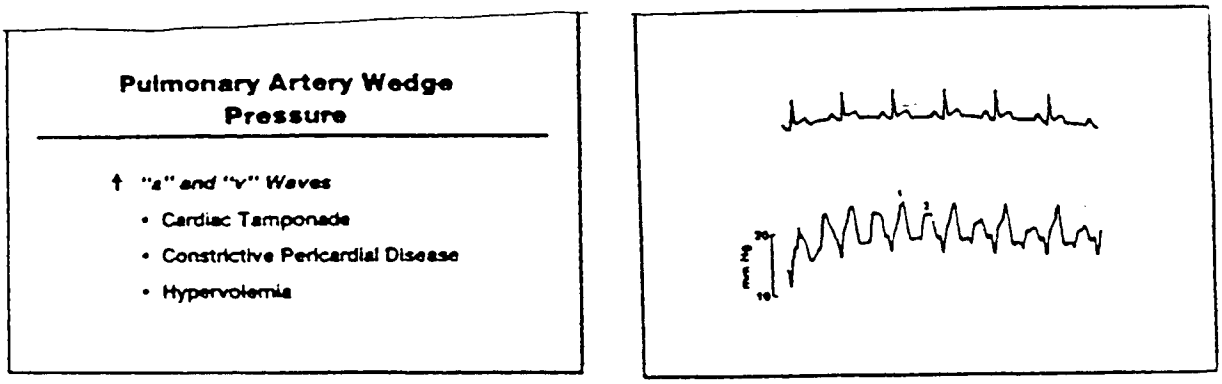
(1) Elevated "a" waves



(2) Elevated "v" waves



(3) Elevated "a" and "v" waves



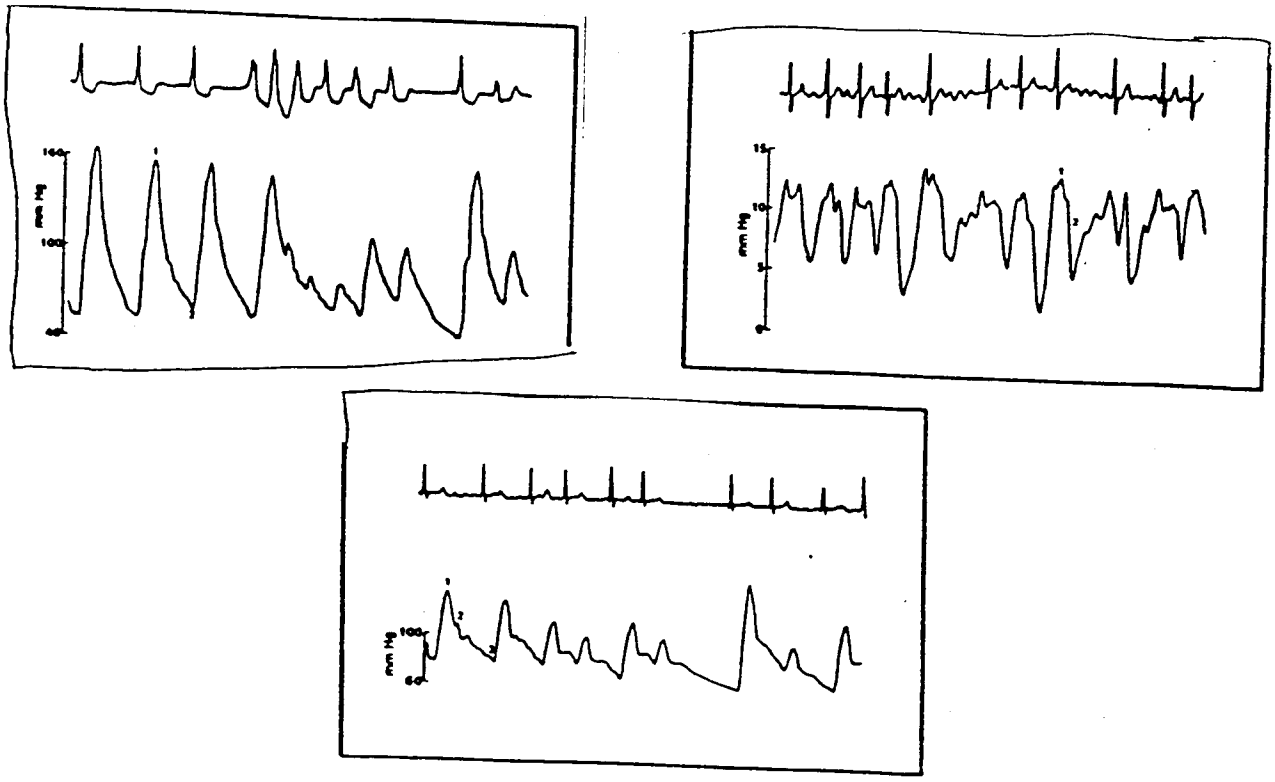
d. Abnormal arterial pressure waveforms

(1) Elevated arterial pressure waveforms

(2) Decreased arterial pressure waveforms

5. Troubleshooting waveform analysis

a. Arrhythmias



b. Mechanical problems altering waveforms

(l) Dampened waveform

Damped Waveform

WAVEFORM ABNORMALITIES

Problem	Cause	Corrective Action
Dampened waveform	Underinflated pressure bag	Inflate pressure bag to 300mm Hg
	Air bubbles in tubing	Flush air bubbles from system
	Disconnected or loose tubing	Tighten all stopcocks and connections
	Blood stasis in tubing	Aspirate blood from tubing
False low readings	Tip of catheter against arterial wall	Flush catheter with flush mechanism or reposition catheter
	Catheter bent under dressing	Check under dressing for kinked catheter
	Transducer height is higher than phlebostatic axis	Place transducer at phlebostatic
	Disconnected or loose tubing	Tighten all stopcocks and connections
Inability to wedge	Balloon rupture	Replace with properly functioning catheter
	Improper catheter position	Reposition catheter to pulmonary artery
False high readings	Transducer level is lower than phlebostatic axis	Place transducer at phlebostatic axis
	Tip of catheter against arterial wall	Flush catheter with flush mechanism or reposition catheter
	Clotted catheter	Attempt to aspirate clot
	Catheter kinked under dressing	Check under dressing for kinked catheter
Overwedging	Catheter too far out in periphery	Reposition catheter
Catheter whip	Hyperdynamic right ventricle	Reposition catheter or monitor on "mean"
	Short tubing	Use tubing that is 60 cm long
Migration to right ventricle	Enlarged right ventricle	Reposition catheter into pulmonary artery
	Catheter inadvertently pulled to RV position	Reposition catheter into pulmonary artery

Problem	Cause	Corrective Action
Spontaneuous wedging	Catheter softening	Reposition catheter into pulmonary artery
Inability to flush or withdraw blood samples	Clotted lumen Catheter kinked under dressing Catheter tip up against arterial arterial wall	Attempt to aspirate clot Check under dressing for kinked catheter Reposition catheter or flush catheter with flush mechanism

ONLY PHYSICIANS REPOSITION SWAN-GANZ CATHETERS.
IF CLOT IS SUSPECTED, DO NOT FLUSH WITH SYRINGE AND NS.

(2) Catheter whip

E. Standard of Practice: Hemodynamic Monitoring: Pulmonary Artery Pressure Monitoring

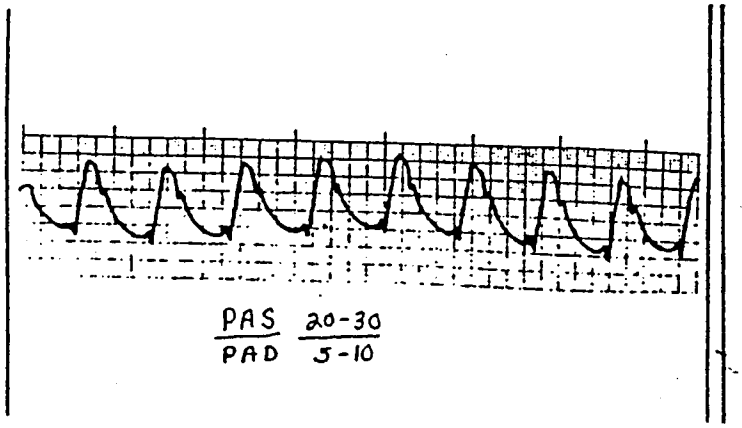
OUTCOME: Accurate assessment of the patient's cardiovascular status to ensure appropriate diagnosis and treatment by the physician.

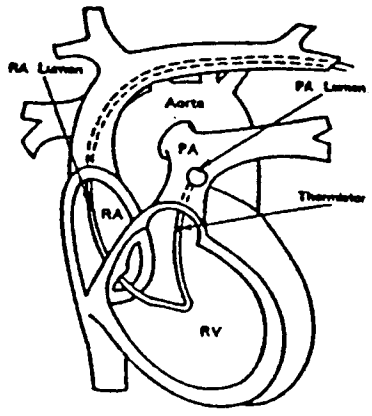
1. MONITOR:

Ratioinale. Prevention of pulmonary infarct, PVC's, ventricular tachycardia.

PA waveform should be continuously monitored.

2. CONFIRM PULMONARY ARTERIAL (PA) WAVEFORM:

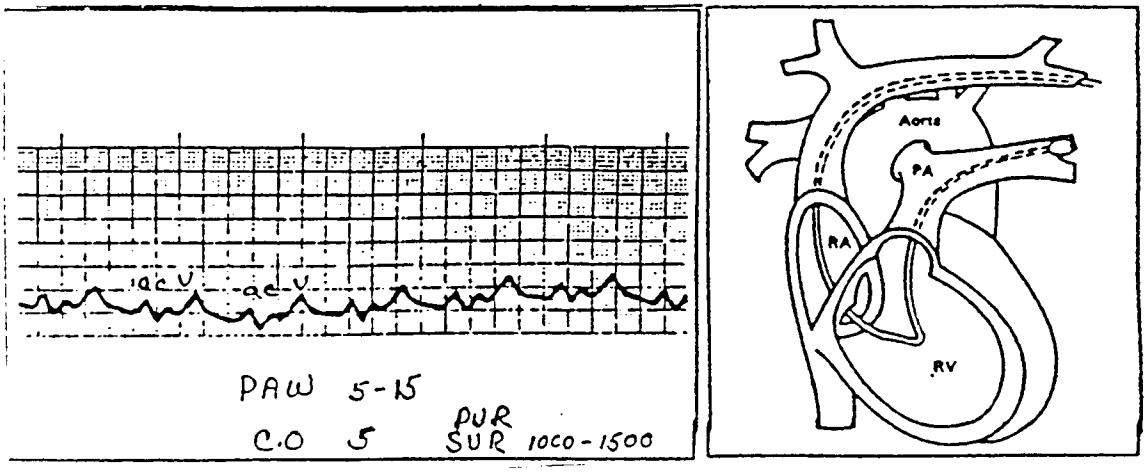




Rationale: Prevention of pulmonary infarct, PVC's, ventricular tachycardia; prevention of inaccurate measurements.

Confirm presence of PA waveform on monitor by observation of dicrotic notch on downslope of pressure curve.

a. Damped waveform/PAWP waveform



(l) DO NOT FLUSH CATHETER DAMPED WAVEFORM due to potential for PA rupture

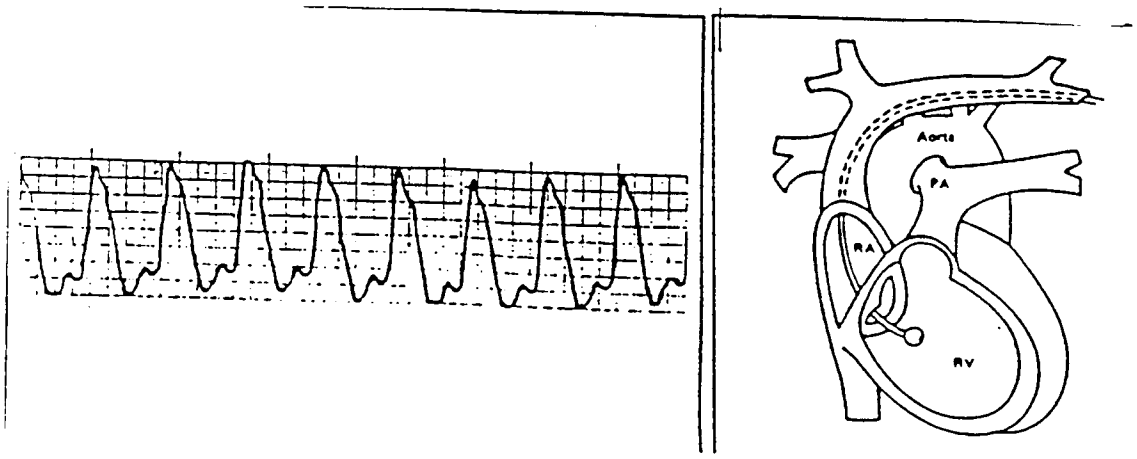
(2) Check scale to insure waveform on 0-60 scale

(3) Check the sensitivity to insure not a monitor screen problem look for dicrotic notch

(4) Aspirate blood from distal PA part - removes clot from catheter tip

(5) If above steps fail, have MD pull back swan since catheter has probably migrated to peripheral PA or been pulled back to a right atrial position

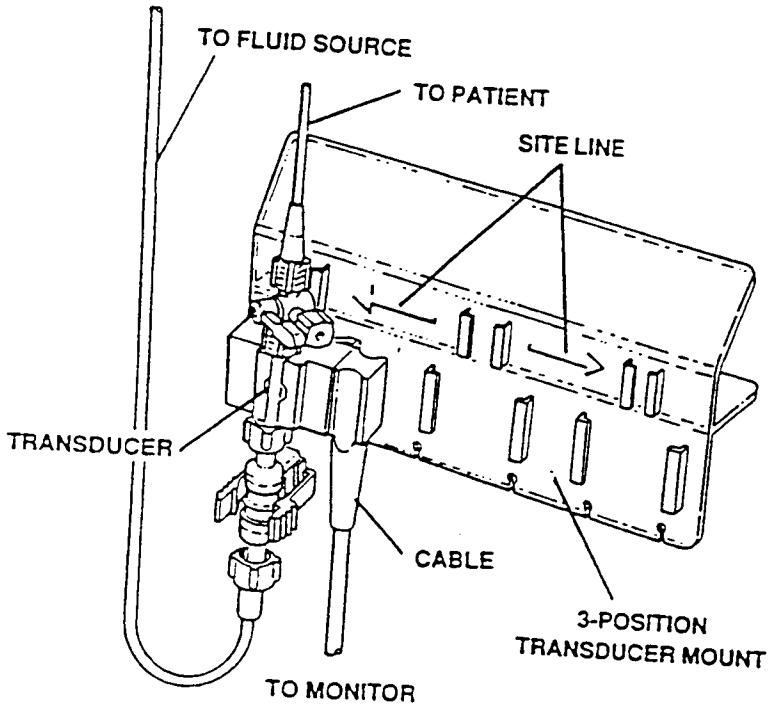
b. Right ventricular-like pattern with negative, zero, or low diastolic digital pressure measurement accompanied by increased frequency of PVC's



The physician should refloat the Swan-Ganz since the catheter is probably in an RV position

NOTE: If Swan-Ganz is not in PA, balloon inflation may lead to erroneous PAWP measurements. Wedge patterns may be obtainable on balloon inflation even though catheter tip is not in PA.

4. ZERO ONCE EVERY SHIFT AND PRN CHANGES MONITOR:



"Air Reference Stop Cock"