Hemodynamics in the Cath lab and ICU

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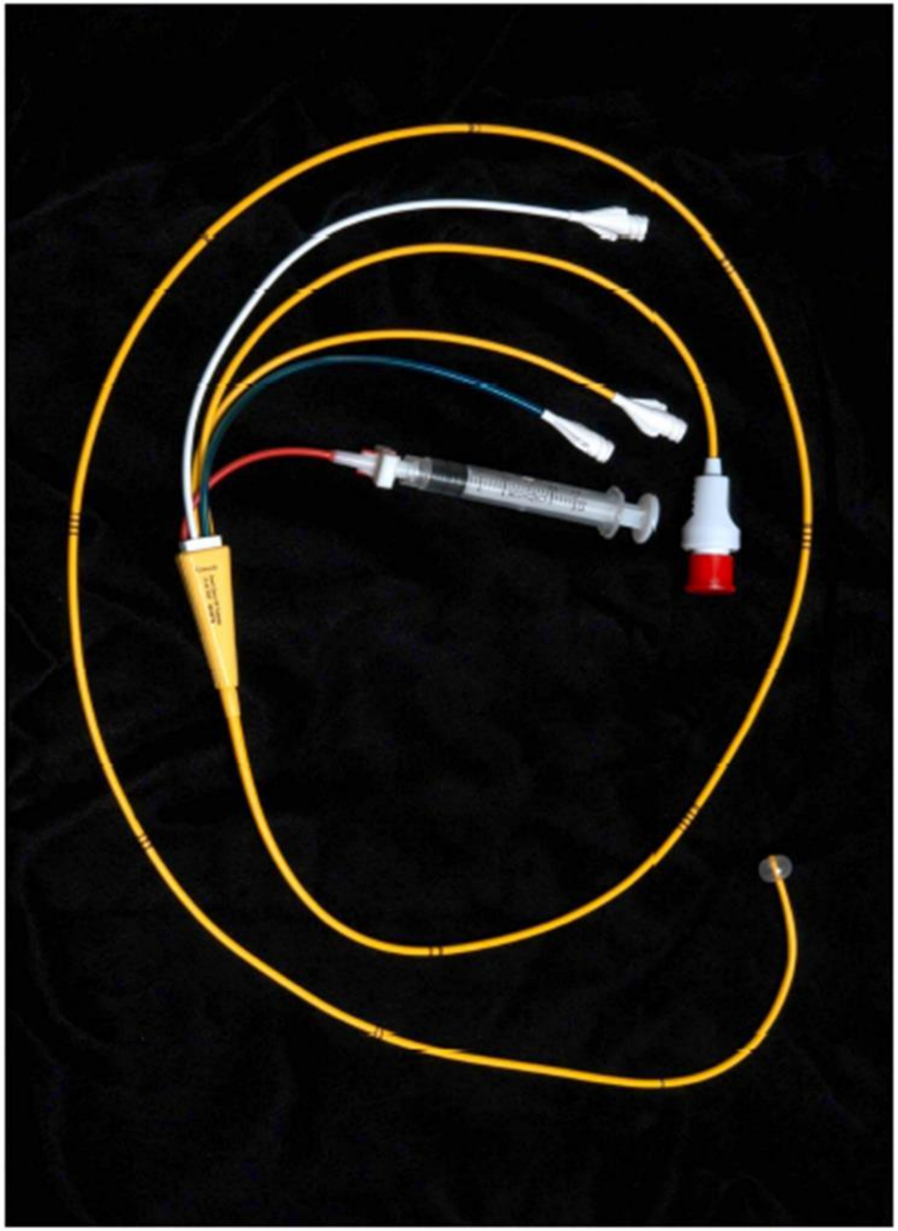
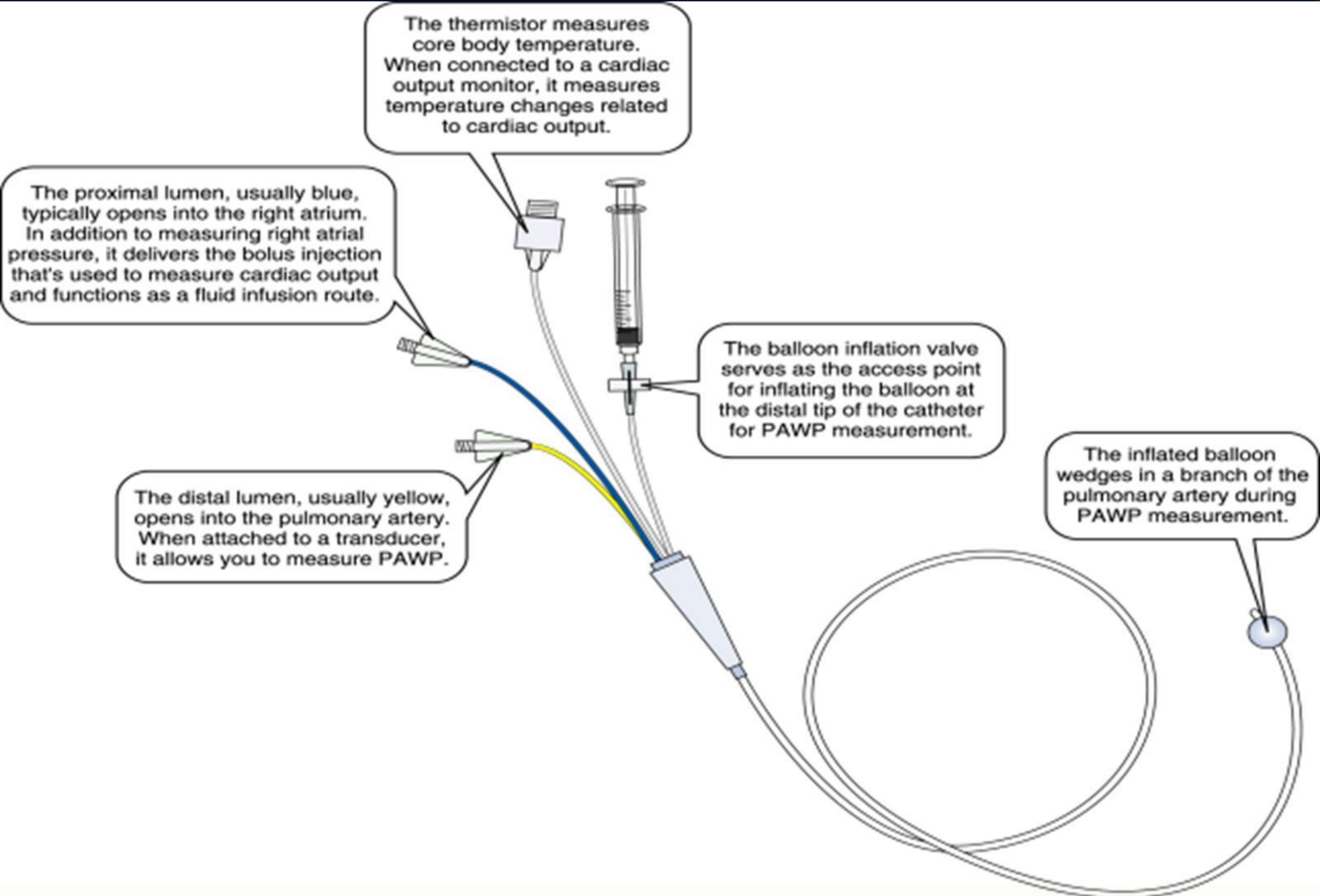
H Jeremy C Swan

Respected cardiologist and co-inventor of the Swan-Ganz catheter. He was born on Jan 1, 1922, in Sligo, Ireland; he died on Feb 7, 2005, after a heart attack in Los Angeles, CA, USA, aged 82 years.



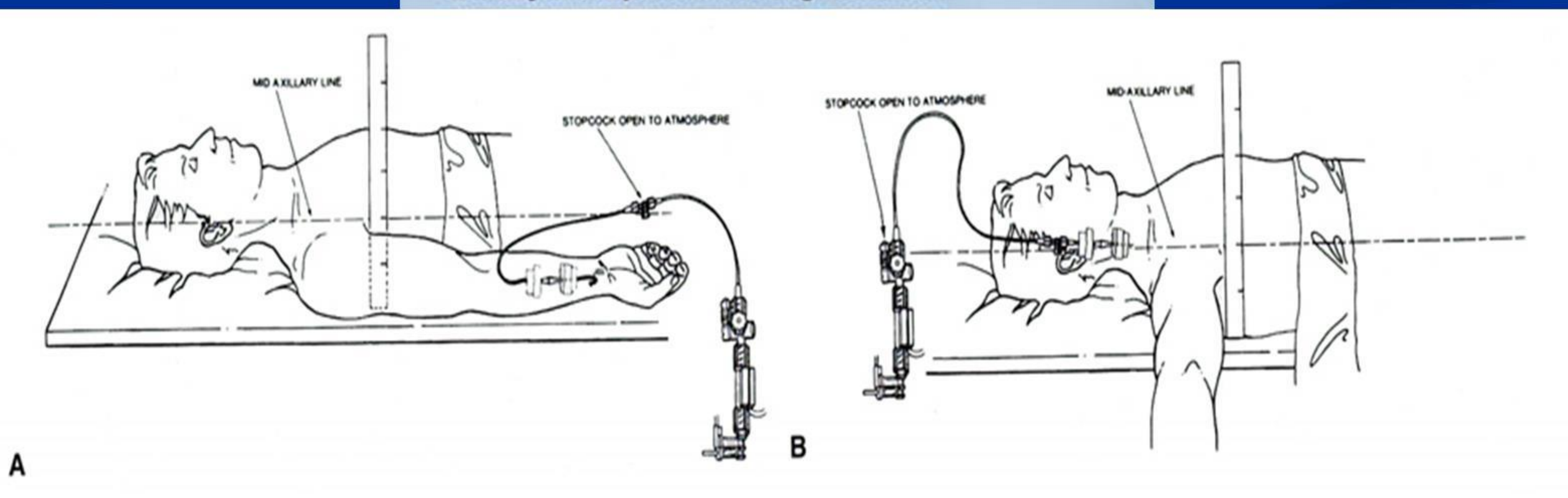

The thermistor measures core body temperature. When connected to a cardiac output monitor, it measures temperature changes related to cardiac output.
The proximal lumen, usually blue, typically opens into the right atrium. In addition to measuring right atrial pressure, it delivers the bolus injection that's used to measure cardiac output and functions as a fluid infusion route.
The balloon inflation valve serves as the access point for inflating the balloon at the distal tip of the catheter for PAWP measurement.
The inflated balloon wedges in a branch of the pulmonary artery during PAWP measurement.
The distal lumen, usually yellow, opens into the pulmonary artery. When attached to a transducer, it allows you to measure PAWP.

Before you start

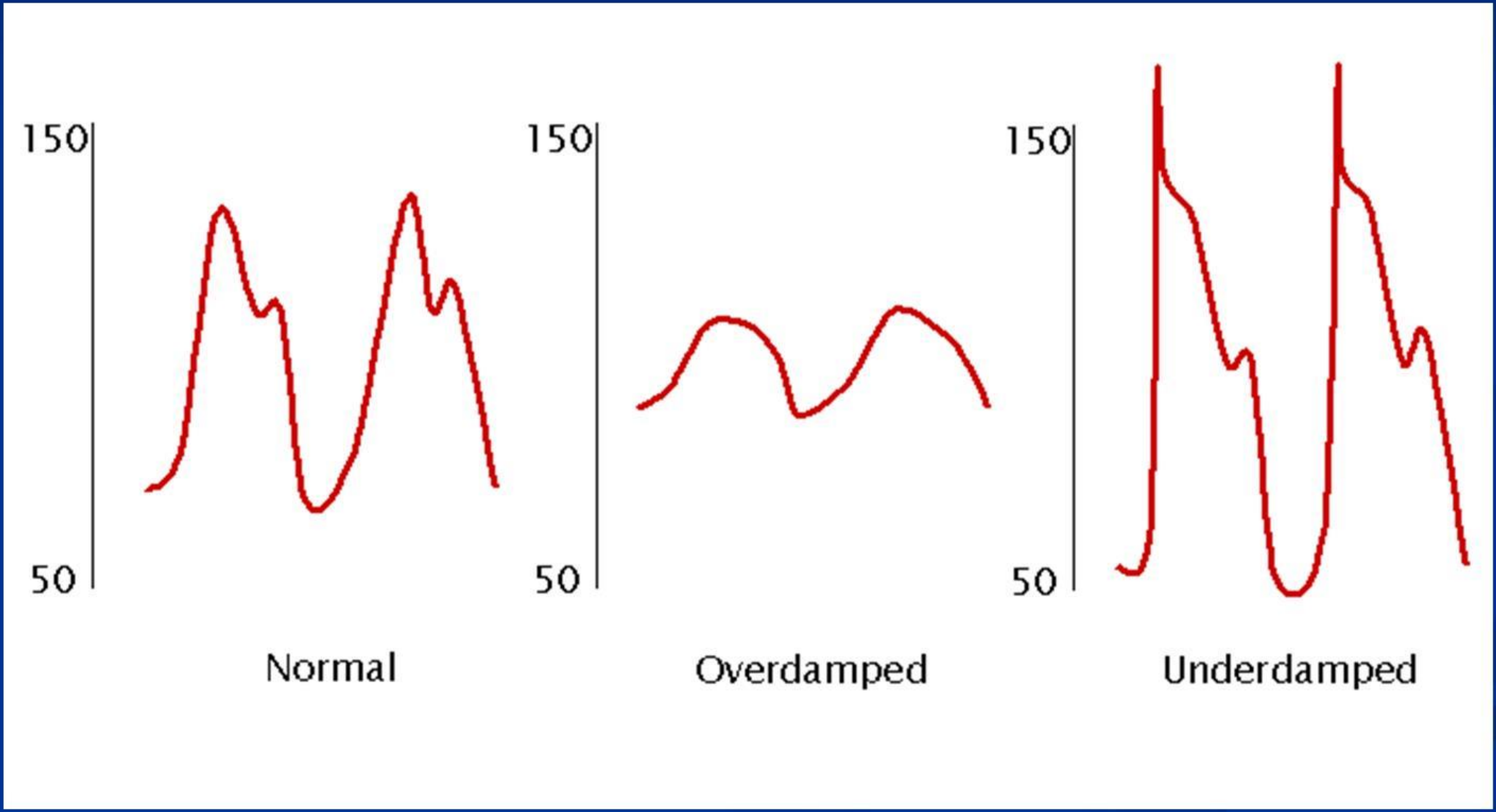
- Is a right heart catheterization planned?
- What kind of catheter is requested? Will it stay in?
- Which access site is planned?
  - Femoral? Internal Jugular? Brachial?
- How many transducers are requested?
- Flush all of the ports and connect yellow (distal port) to transducer. Use 3-way stopcocks
- Zero all of the transducers.
- Level all of the transducers to the phlebostatic level

Phlebostatic Axis

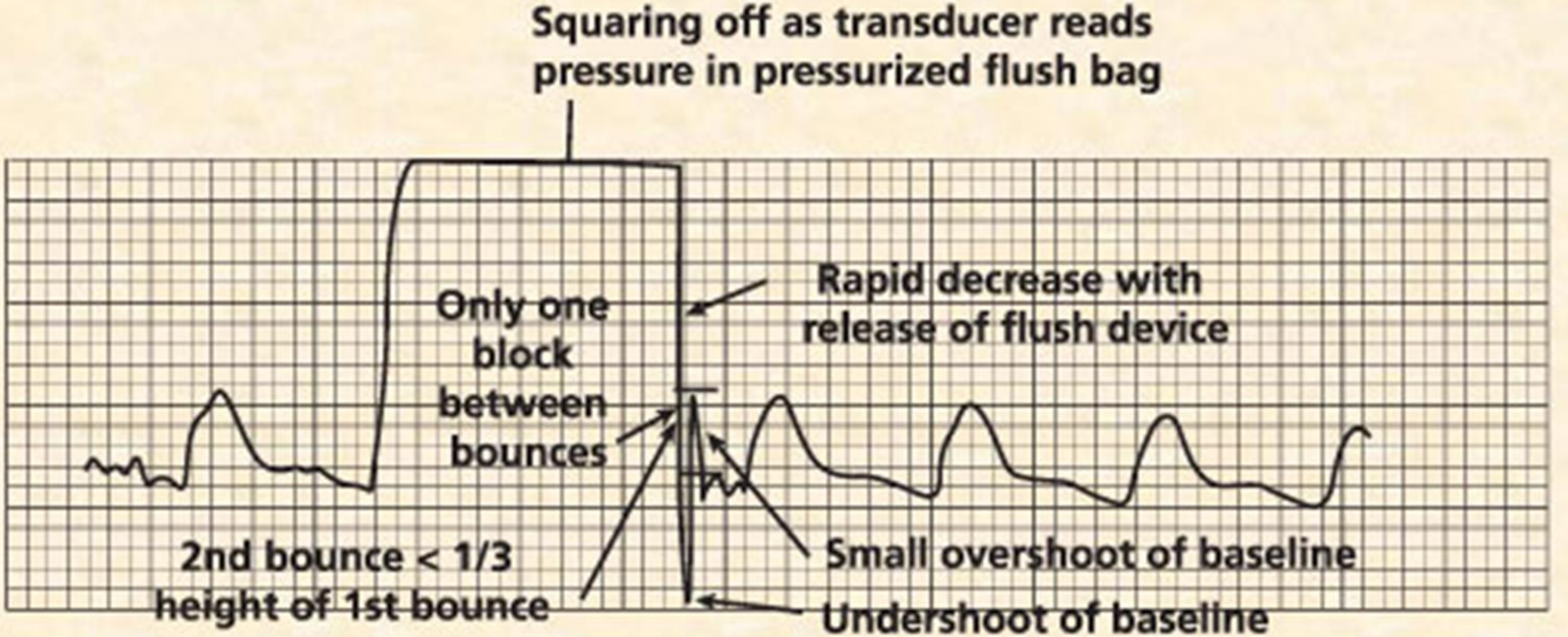
Figure 3: **The phlebostatic axis, marked on the patient's chest, is the precise anatomical point of origin of the hemodynamic pressures being measured.**

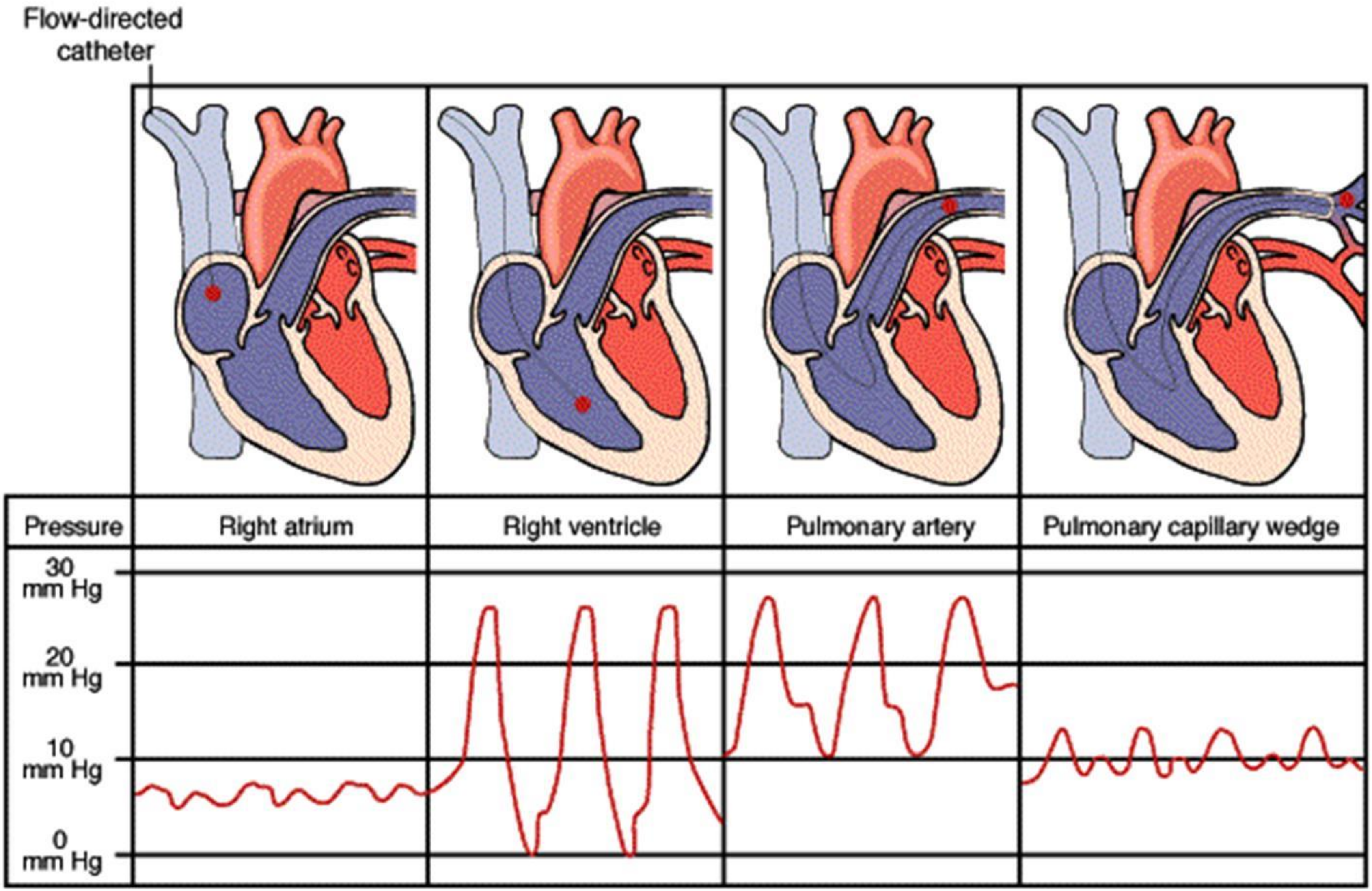


Damping

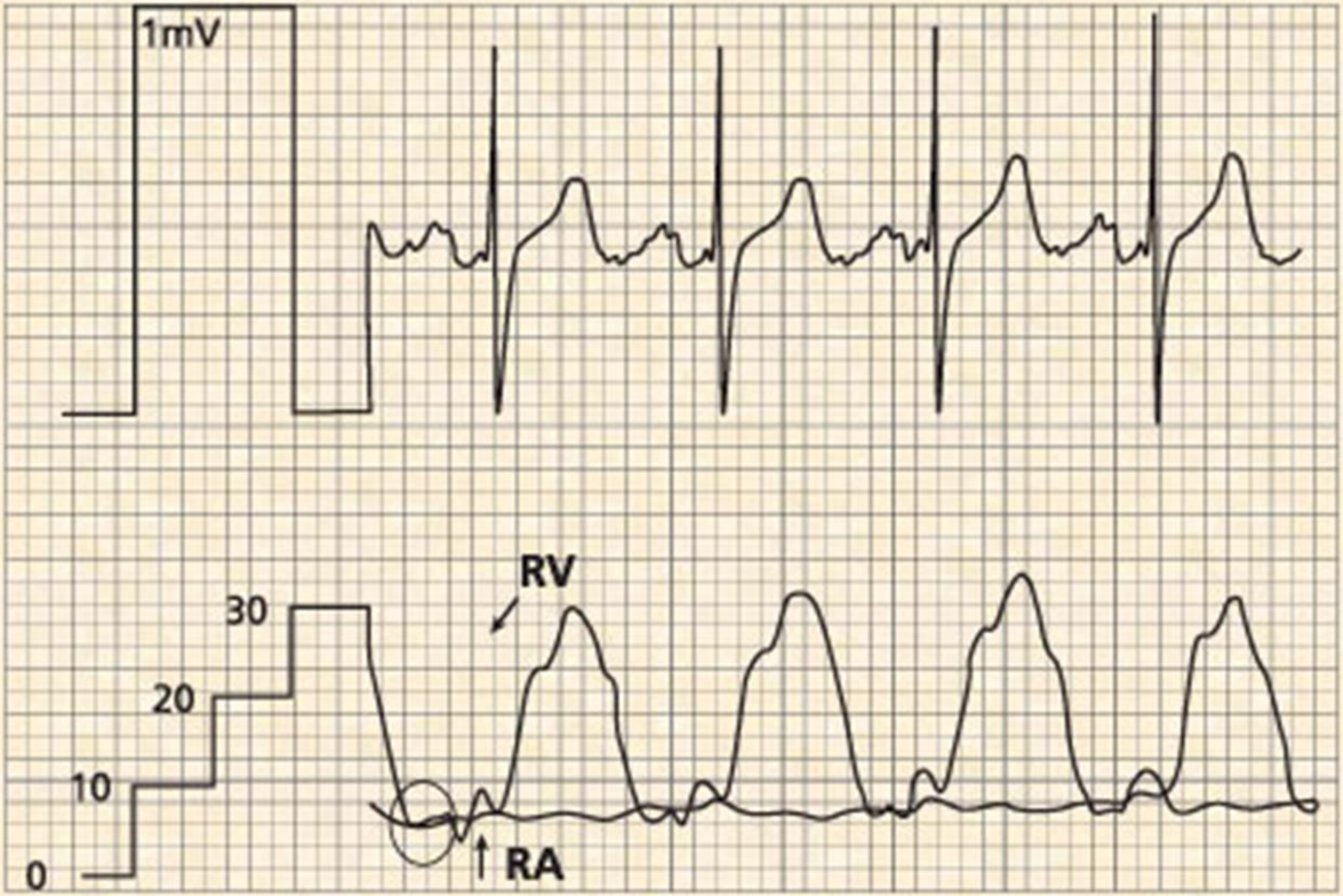


Optimal Damping Example

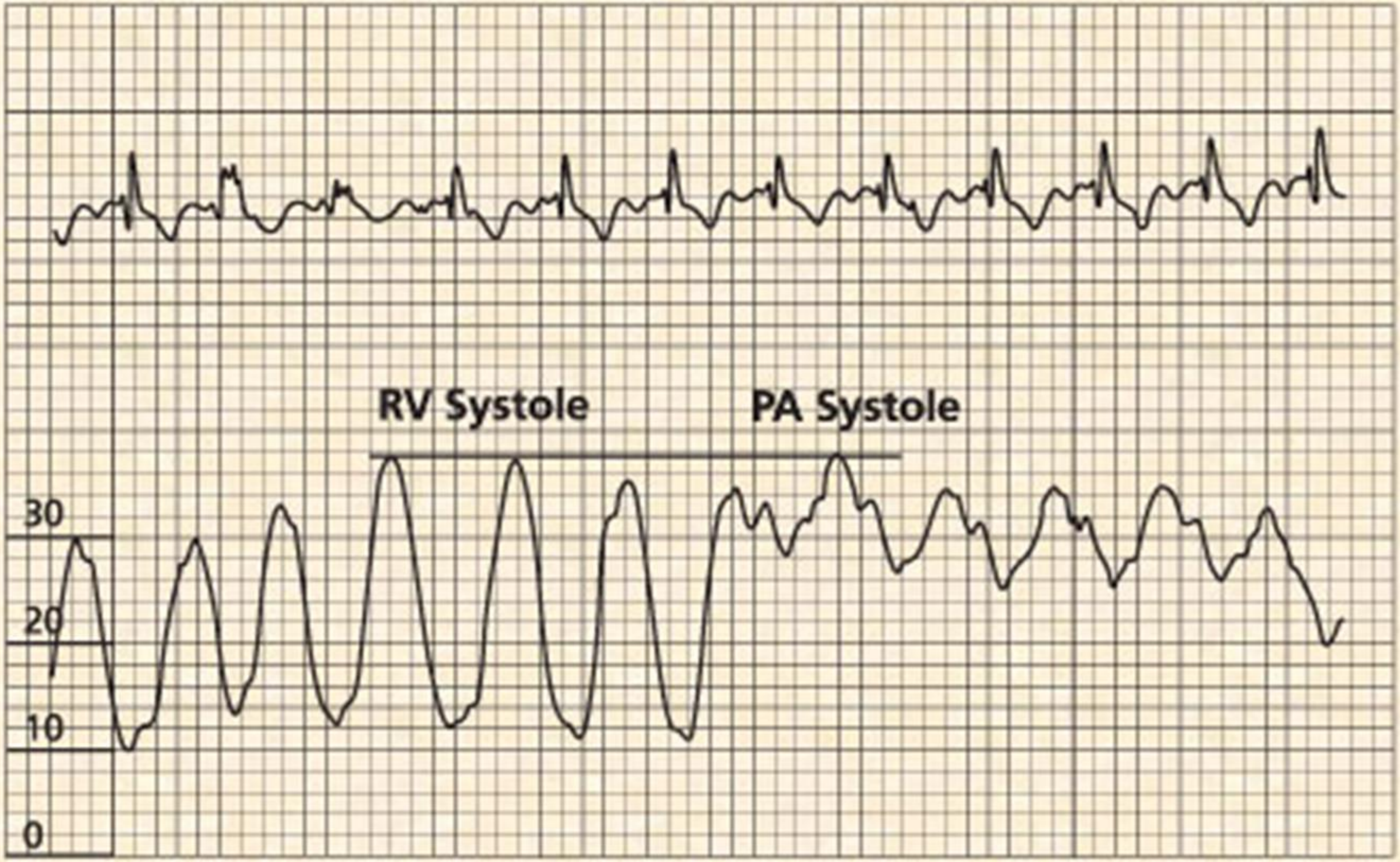



Flow-directed catheter
Pressure
Right atrium
Right ventricle
Pulmonary artery
Pulmonary capillary wedge
30 mm Hg
20 mm Hg
10 mm Hg
0 mm Hg

Mean RA ≈ RVedp

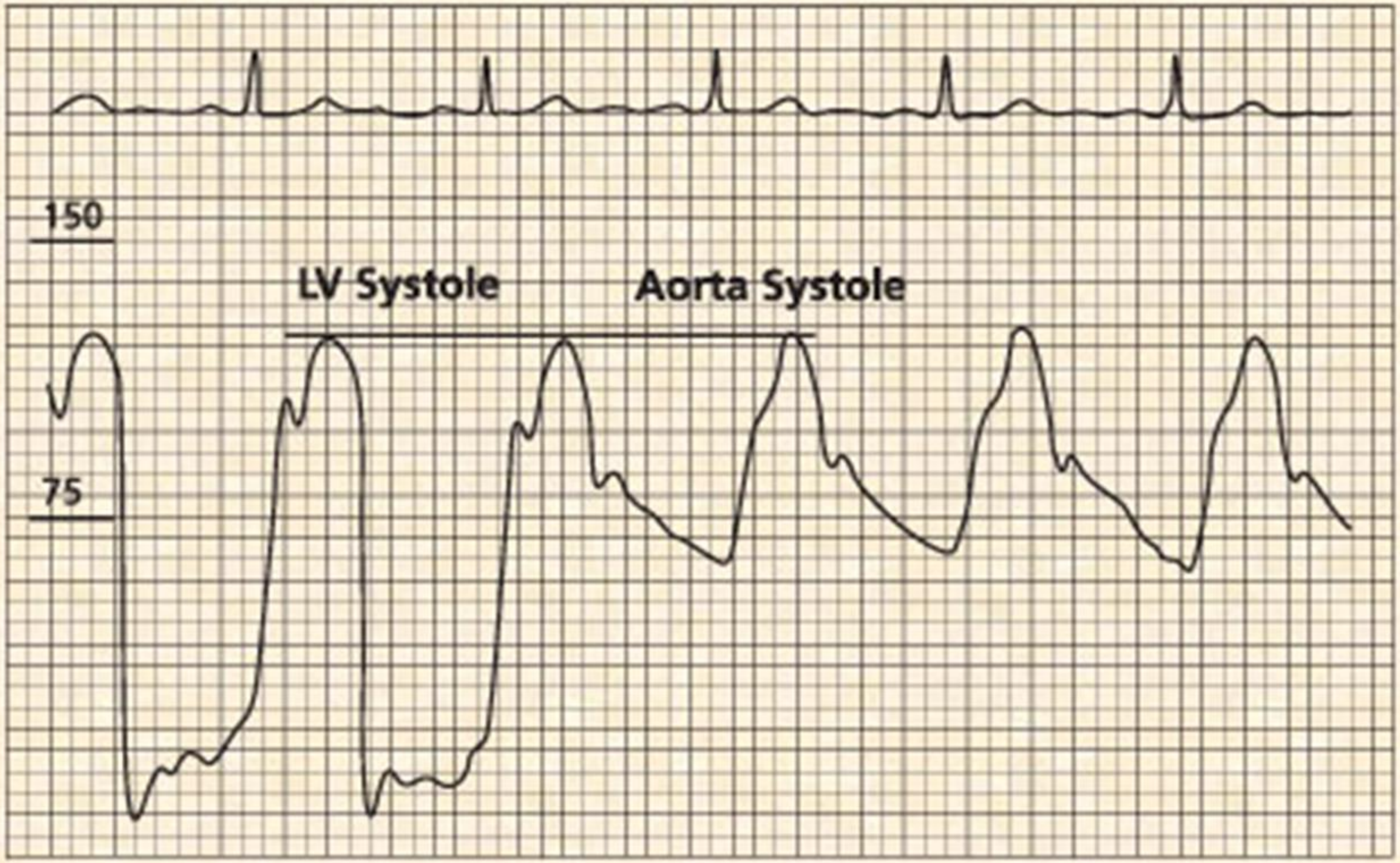


PA Systolic Pressure ≈ RV Systolic



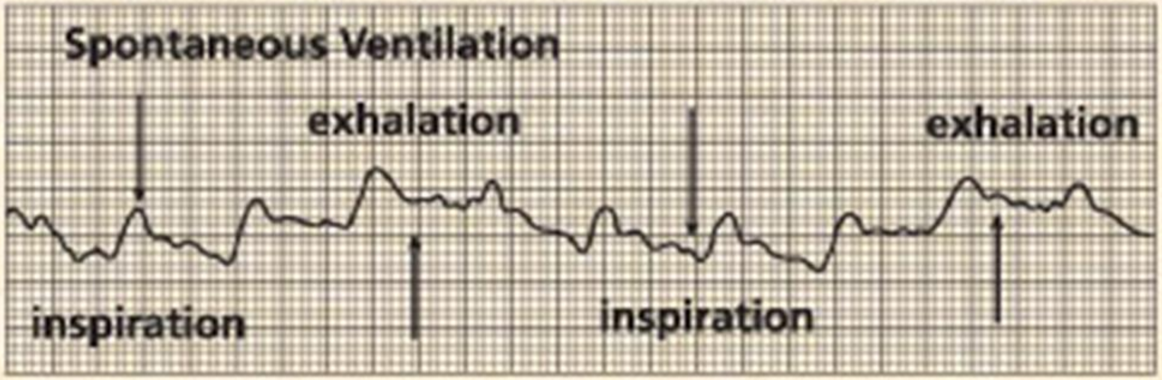
PAedp and PAOP ≈ LVedp

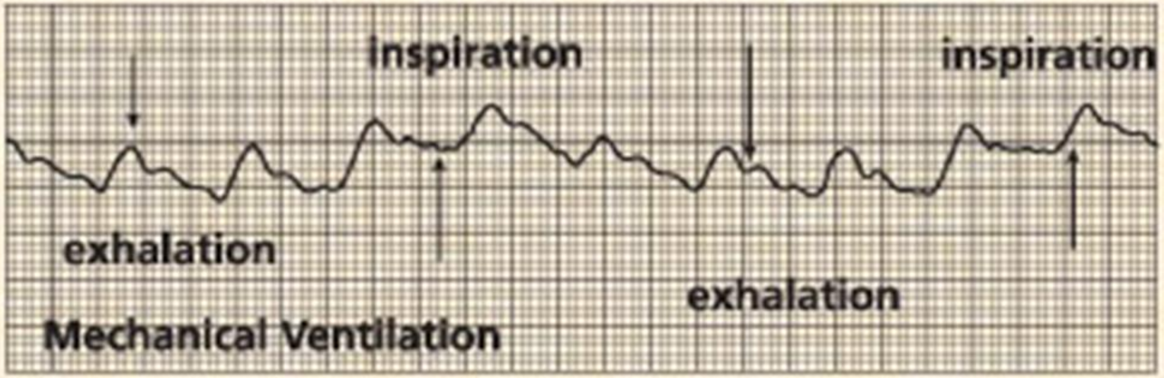
Aortic Systolic Pressure ≈ LV Systolic Pressure



Effects of Respiration on Waveforms

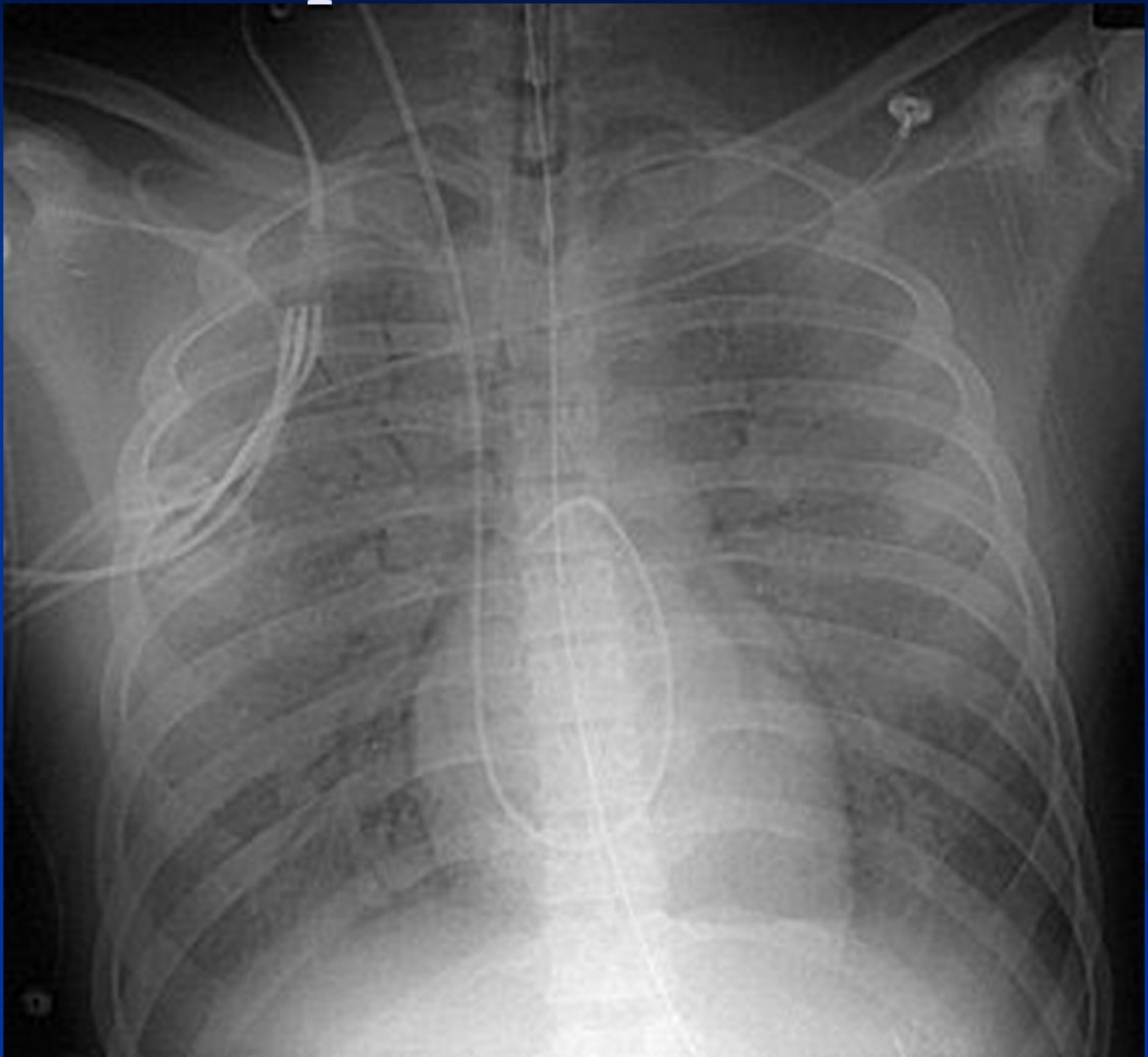
Spontaneous Ventilation



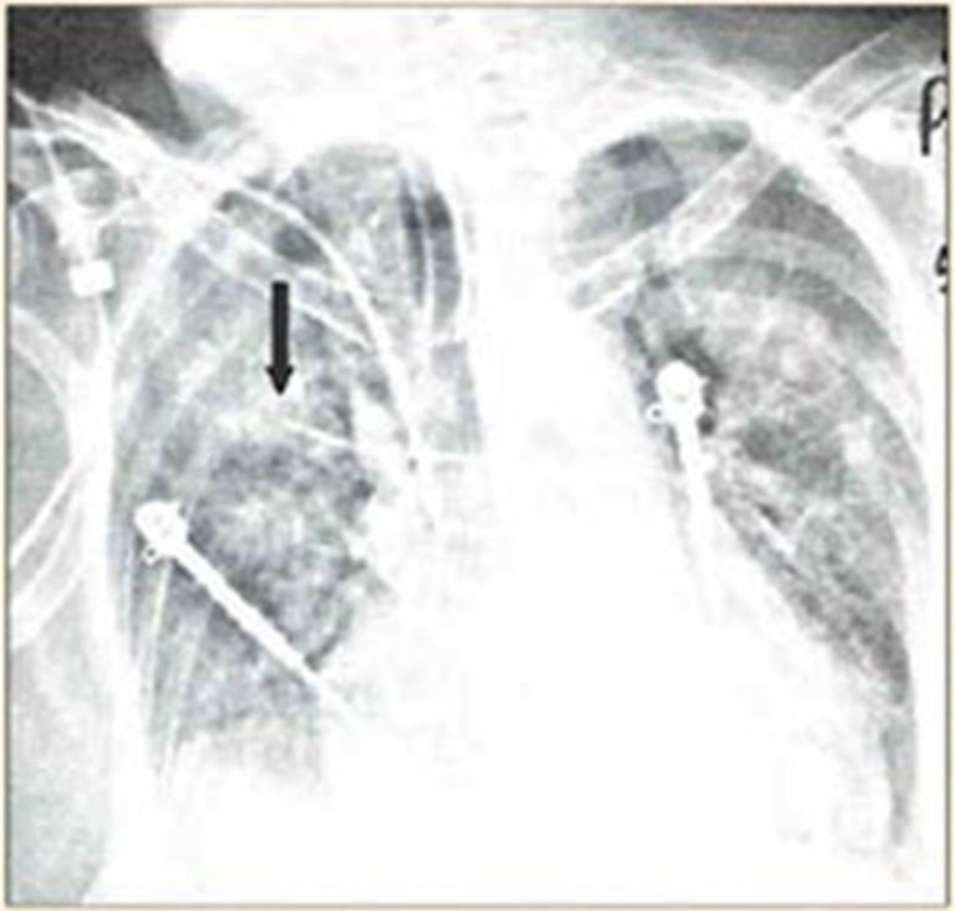


ALWAYS MEASURE VALUES AT END-EXPIRATION!

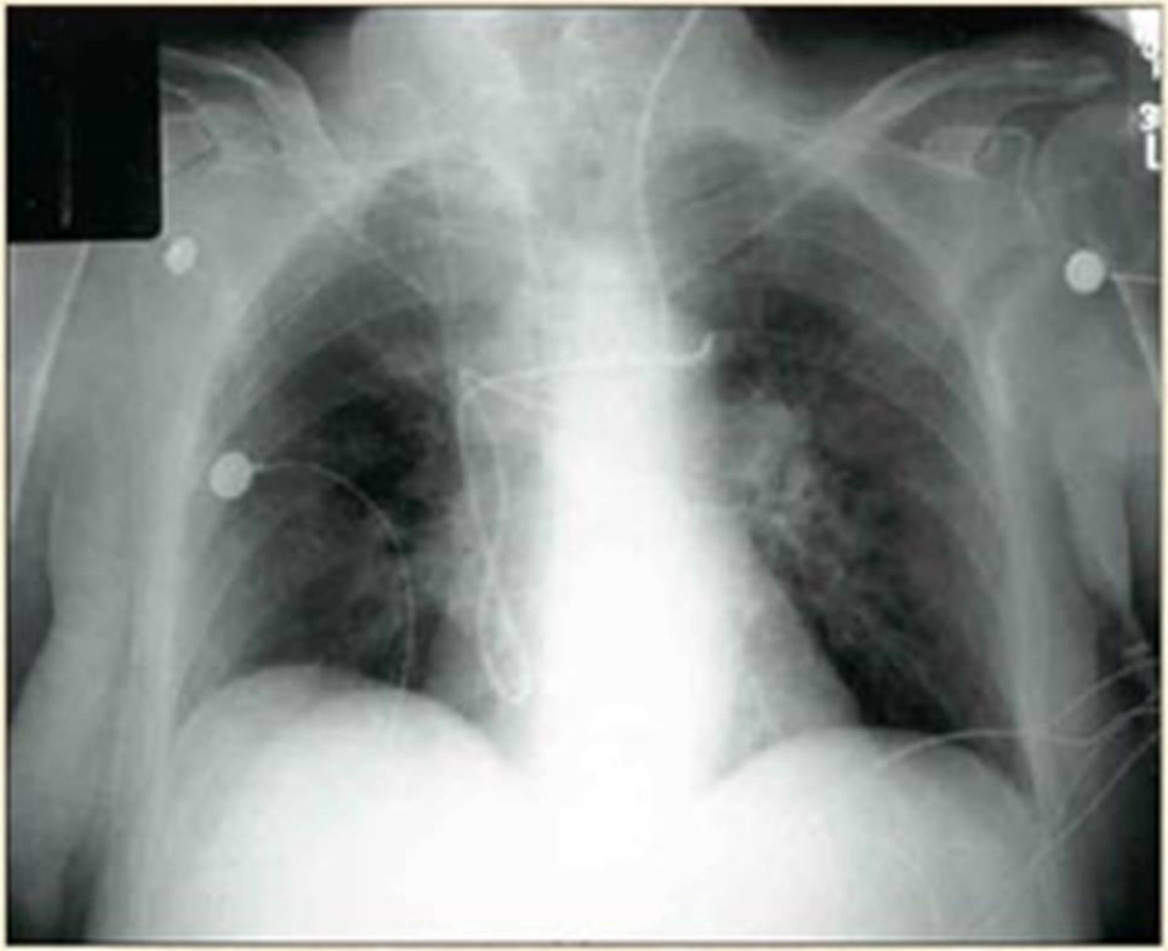
Proper Swan Position



Distal PAC Position



Coiled PAC



Cardiac Output

- Cardiac output by Thermodilution
  - Cold or room temp fluid is injected into the CVP port of the catheter. The temperature of the fluid is measured by the thermistor on the distal port of the catheter.
  - Cardiac output is inversely proportional to the mean concentration of the indicator.

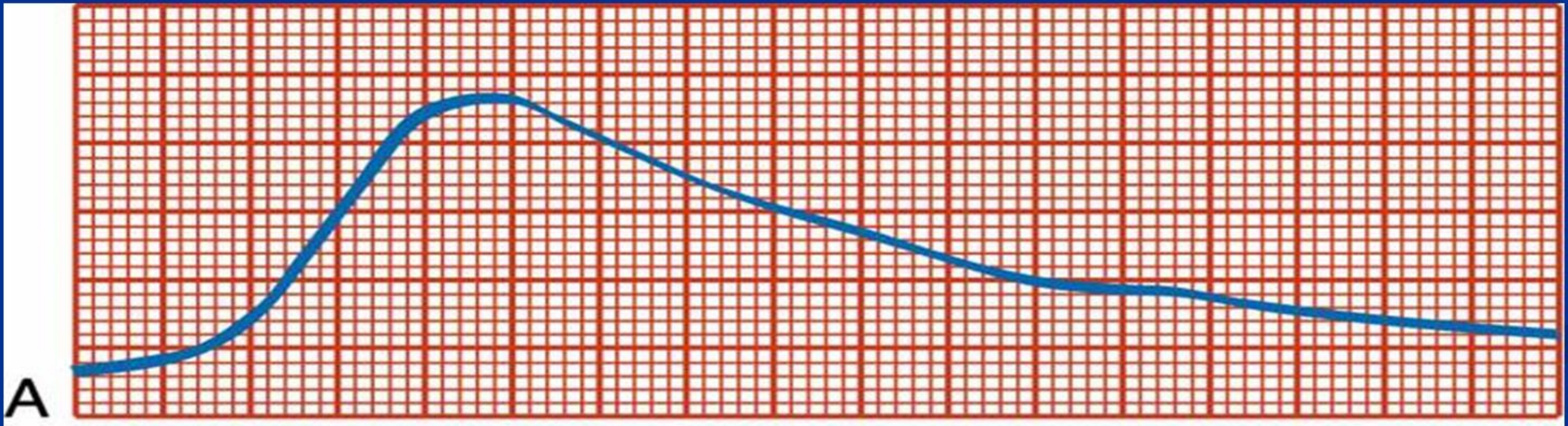
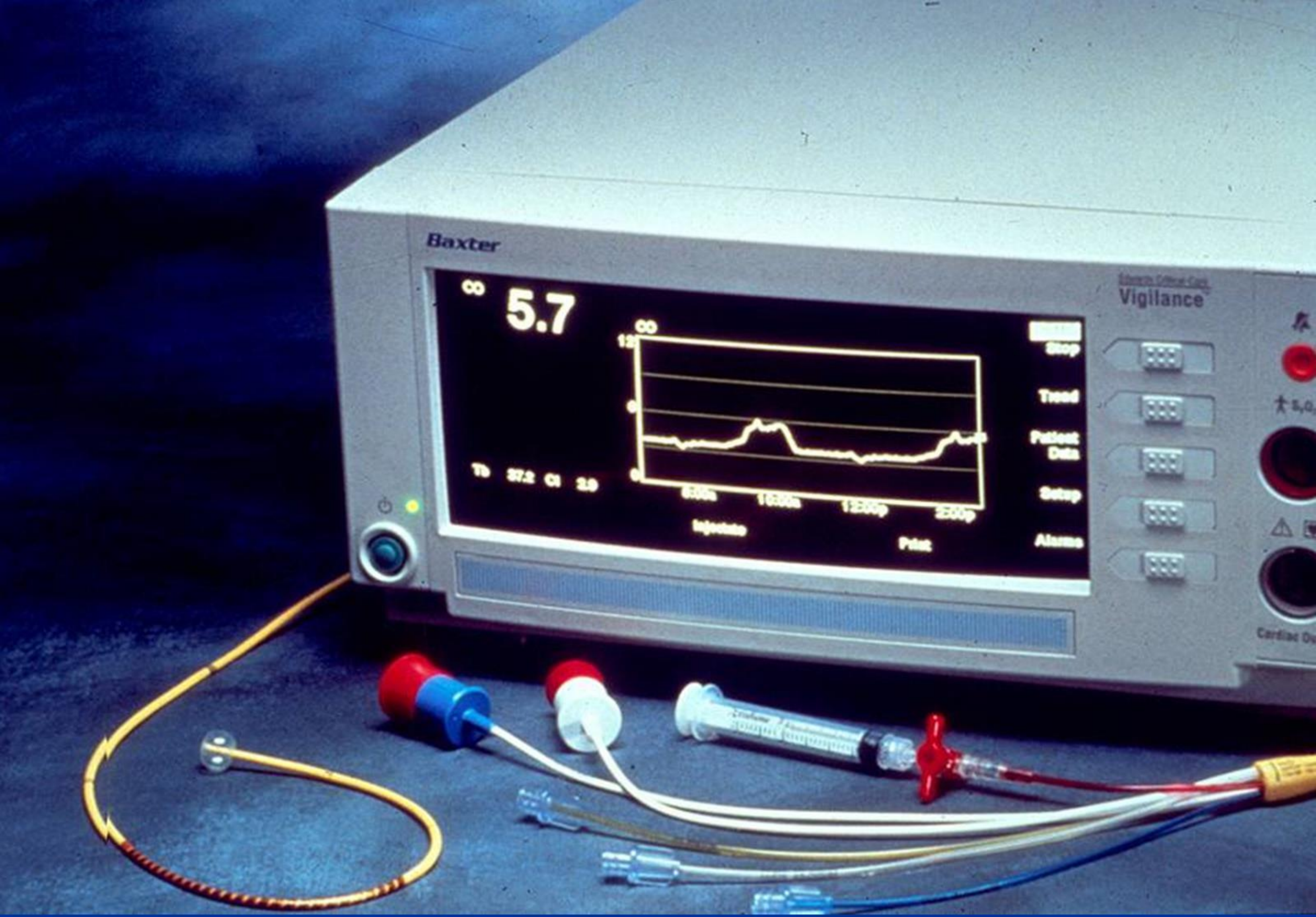


Figure 17-62A Thermodilution curves produced on a strip chart recorder. (A) Smooth recording is accurate.

Cardiac Output Curve Evaluation

Delete Curves That are Notched or Irregular

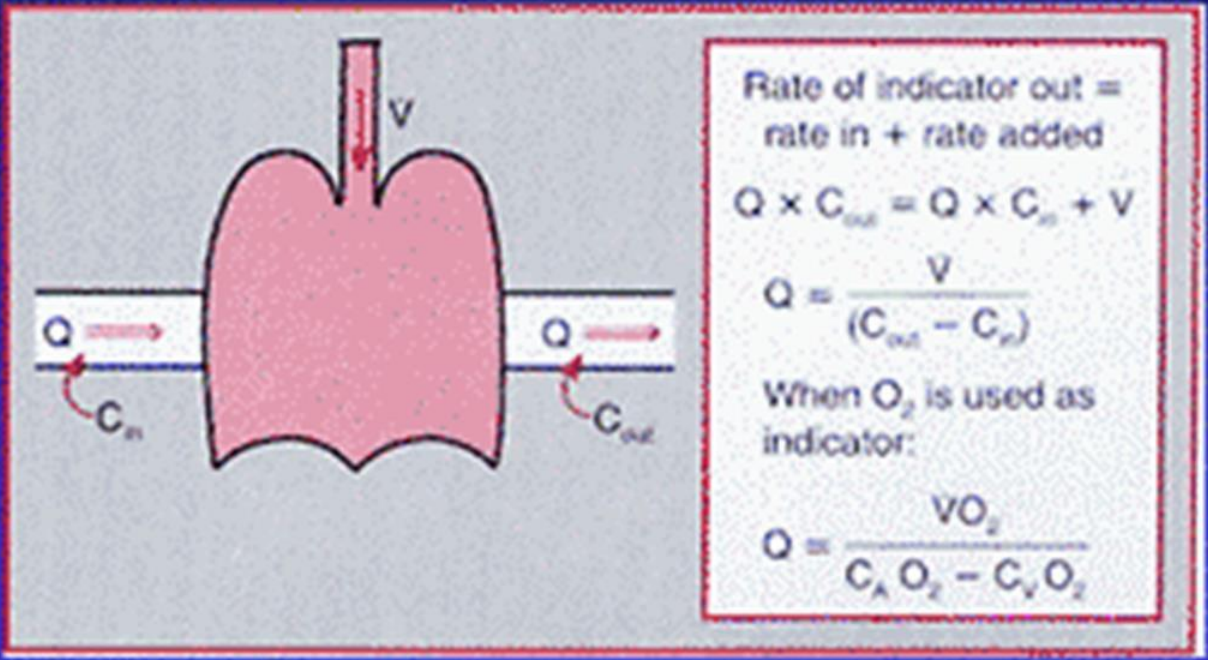

Baxter
CO
5.7
Vigilance
Stop
Trend
Patient Data
Setup
Alarms

Cardiac Output: Technical Problems

- Variations in respiration:
  - Use average of 3 measures
- Blood clot over thermistor tip: inaccurate temp
- Cardiac Shunts:
  - R->L reduced peak, rapid washout, CO overestimated
  - L->R dilution of injectate, reduced peak, CO overestimated
- TR: attenuated peak and prolonged washout of signal, CO underestimated
- Computation constants:
  - Varies for each PAC, check package insert + manually enter

Cardiac Output:

The Fick Equation

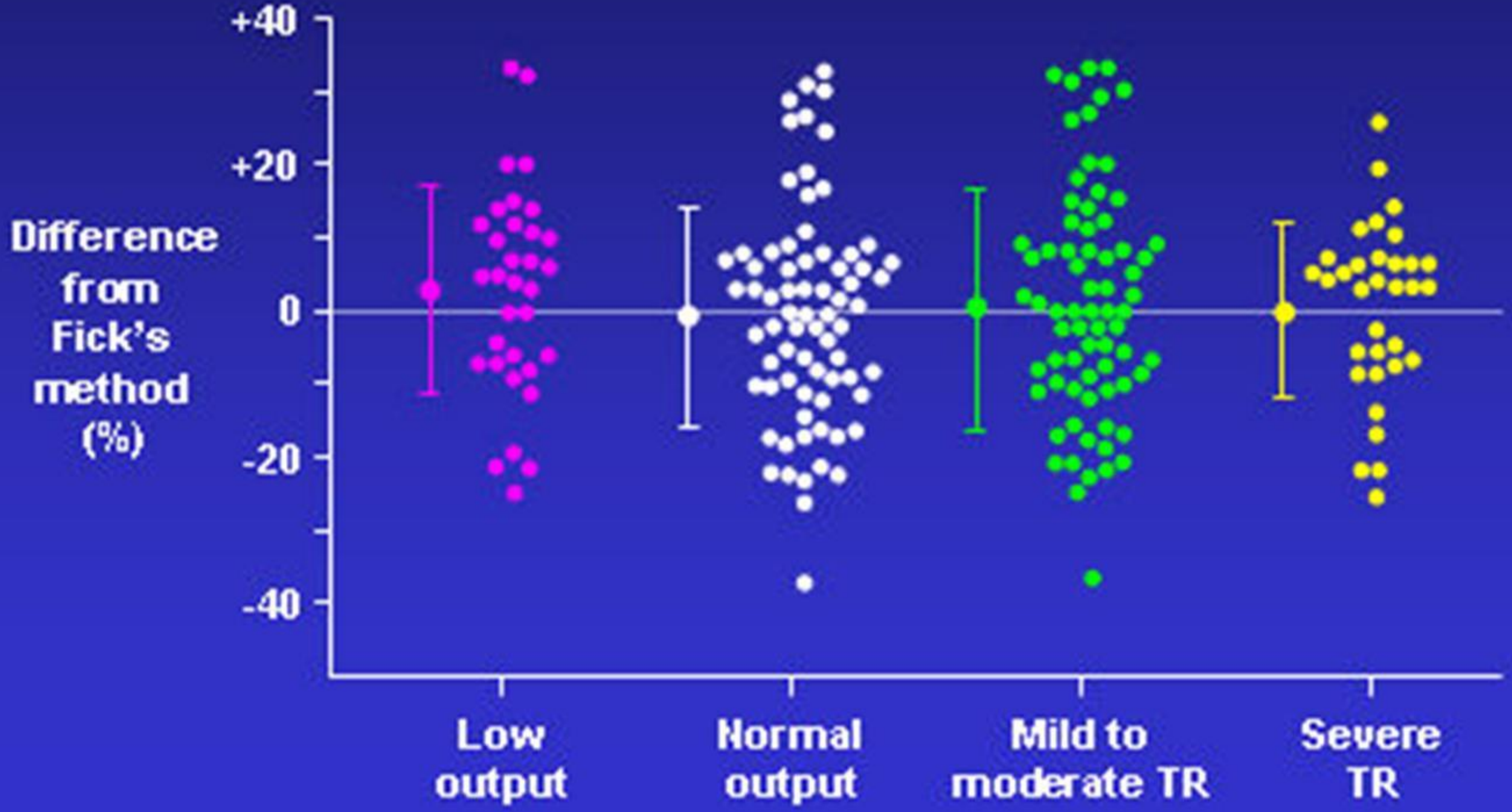


Direct Fick : VO2 measurement

Indirect Fick: VO2 estimate (3.5ml/kg)

Murali, Medscape CME: Confirmation of PAH

Cardiac Output
Thermodilution vs Fick



Murali, Medscape CME: Confirmation of PAH

Limitations of Fick

- VO2 is often estimated by body weight (indirect method) rather than by spirometry (direct methods)
- Large errors possible with small differences in saturations, hemoglobin.
- Patients should be on room air.
- Samples must be processed quickly/accurately

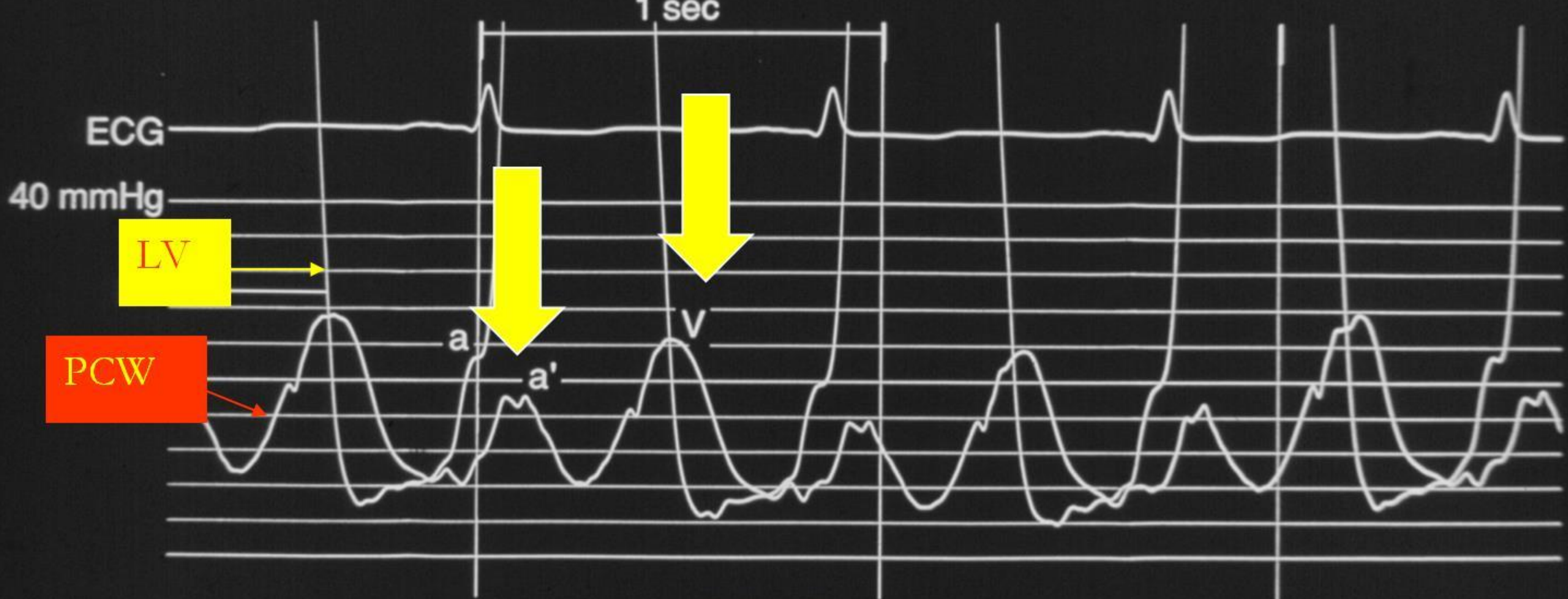
Typical Cath lab hemodynamics: Left and Right heart Cath

- Measurements of right heart pressures and cardiac output, for calculation of valve areas

$$\text{Valve area} = \frac{\text{Cardiac output}}{\sqrt{\text{Mean gradient}}}$$

- Measurement of LVEDP = ? CHF
- Measurement of LV/PCWP gradient = ?MS
- Measurement of LV/Ao gradient = ?AS
- Measurement of LV/RV response to inspiration = ?pericardial constriction

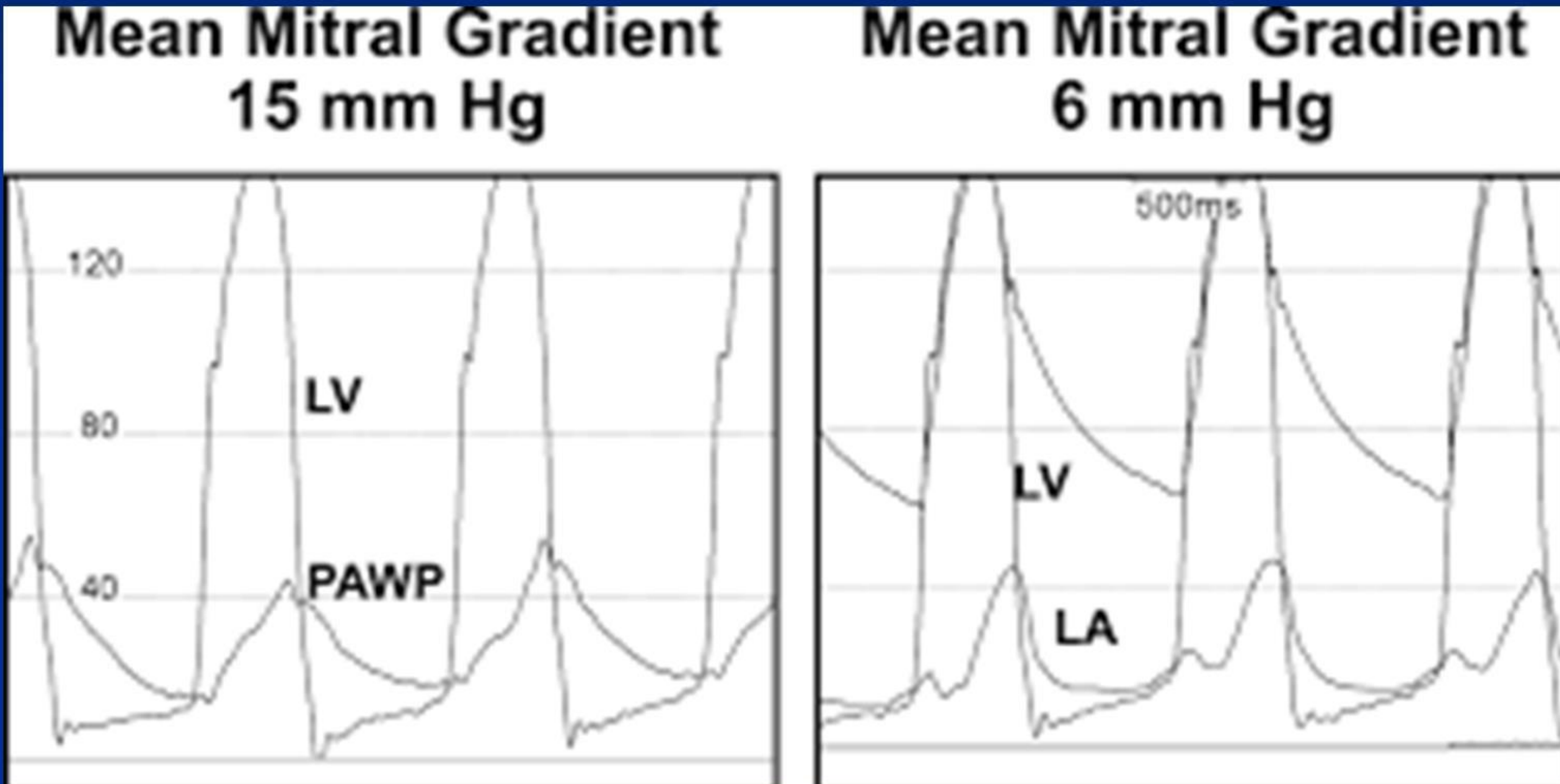
Most common technique for Mitral Gradients
PCW and LV



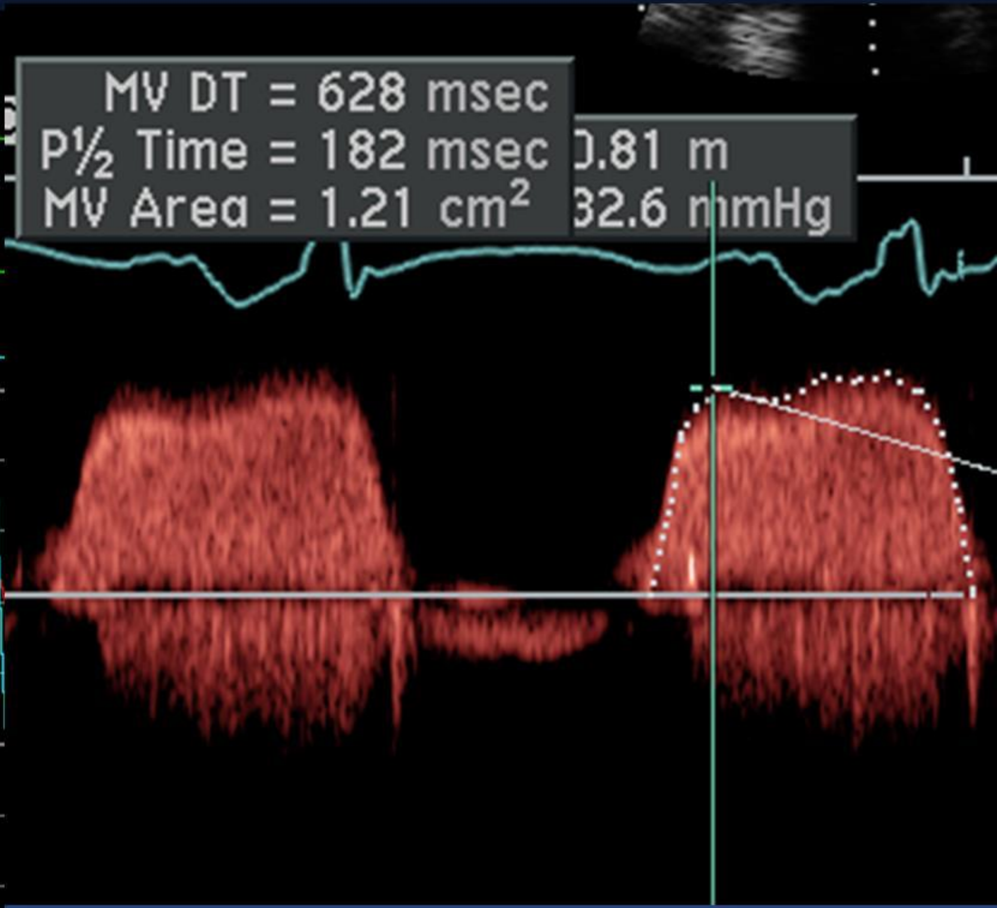
'a' wave delayed

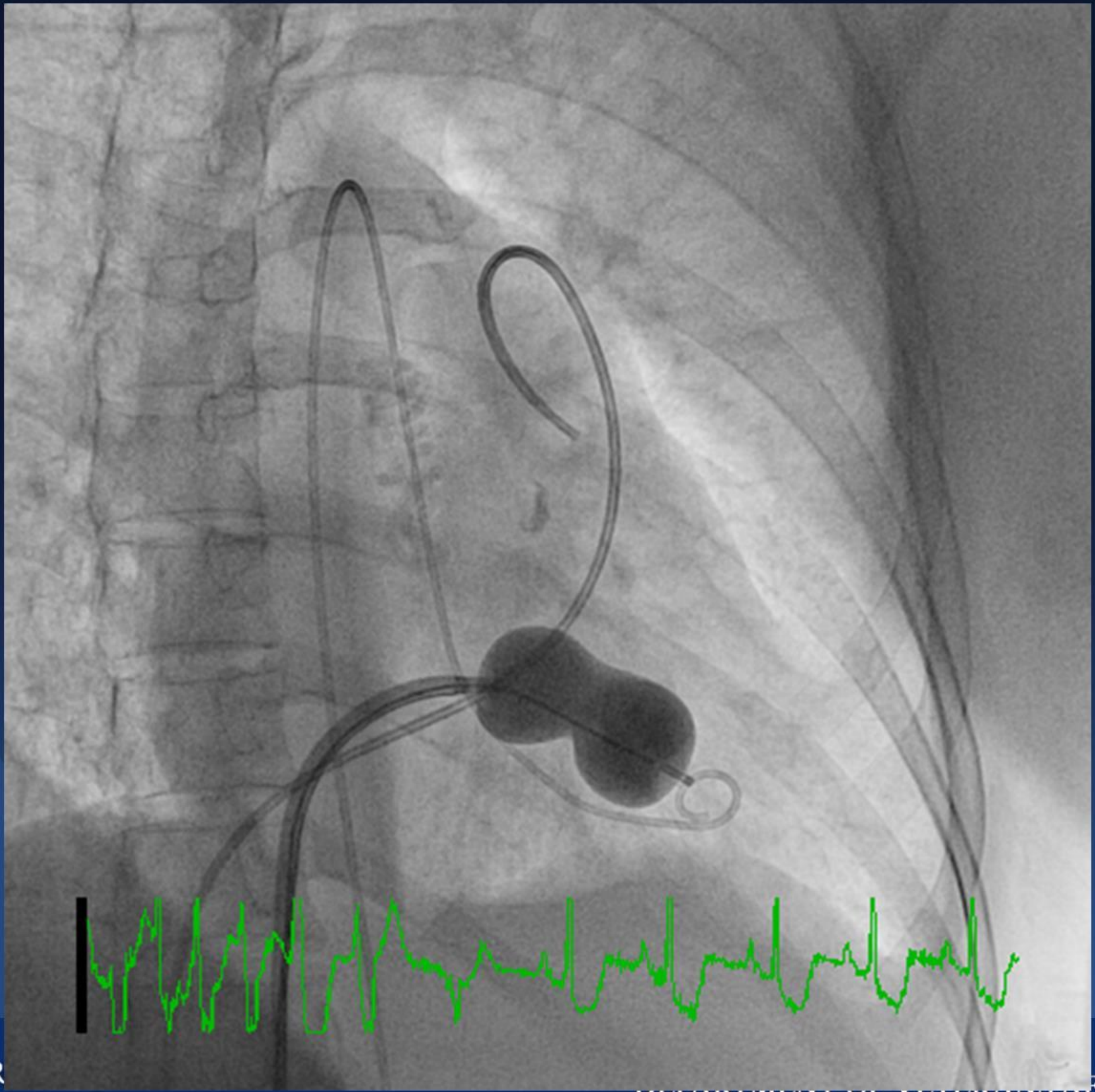
'v' wave on LV down slope

Mitral Stenosis

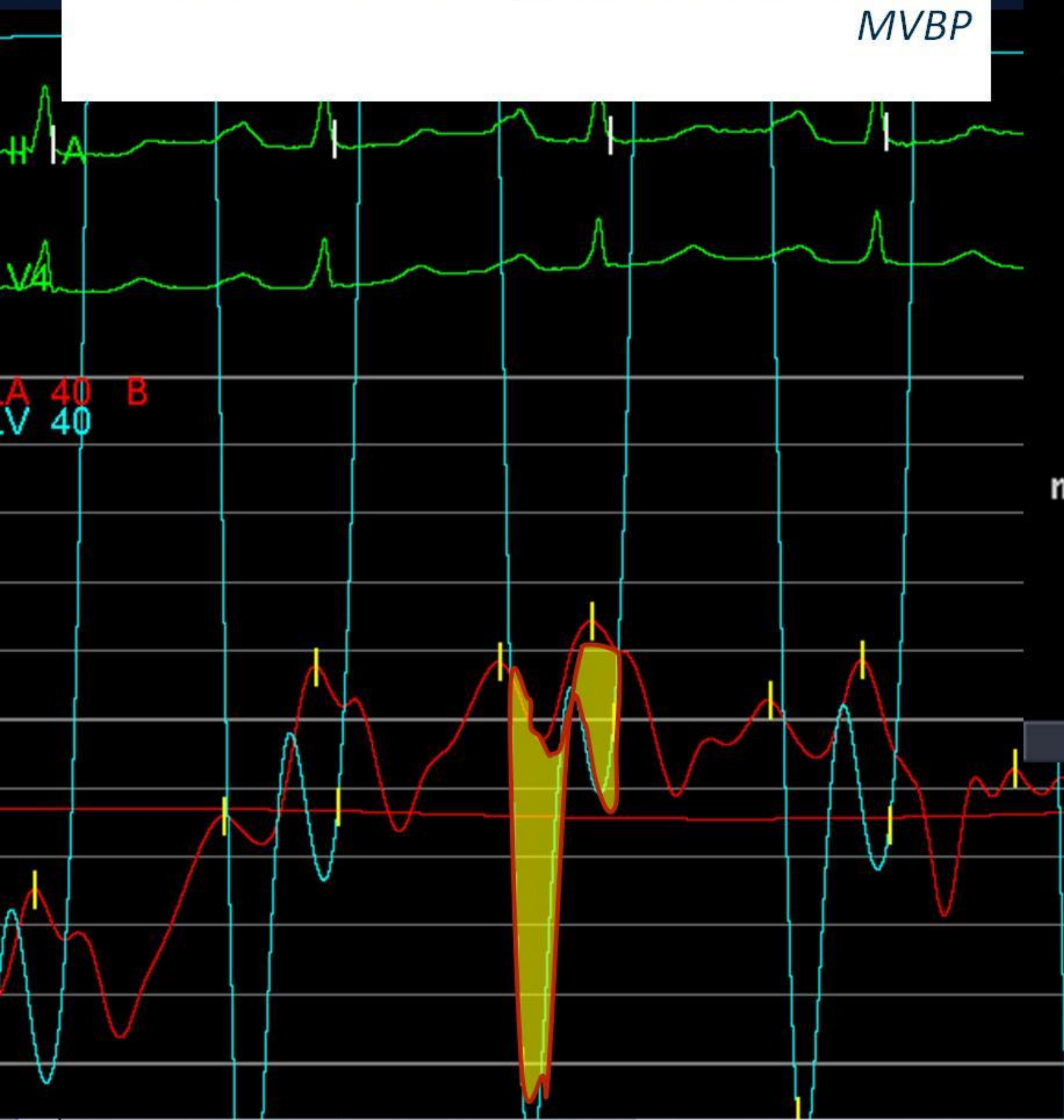


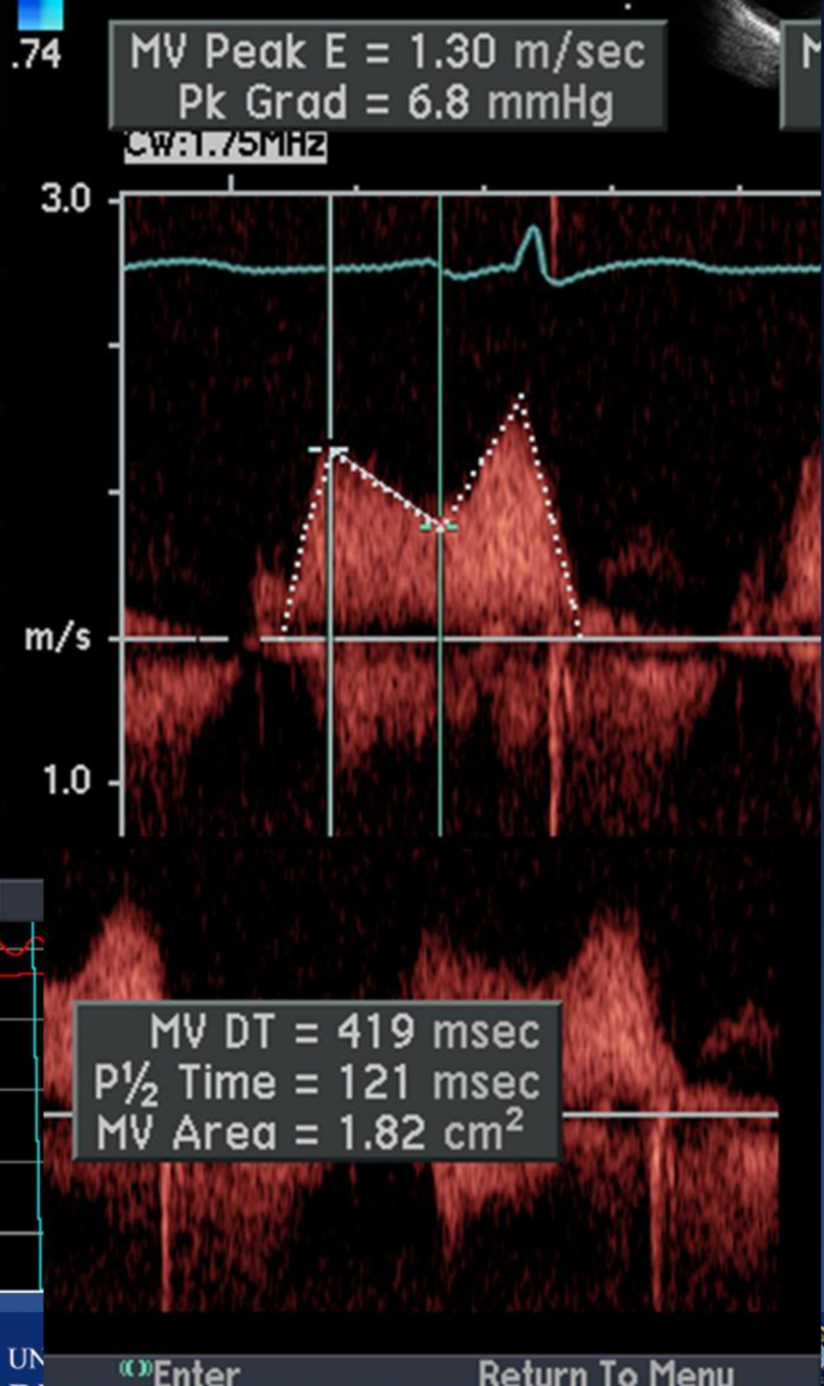
Hemodynamics and Doppler Echo findings before MVBP

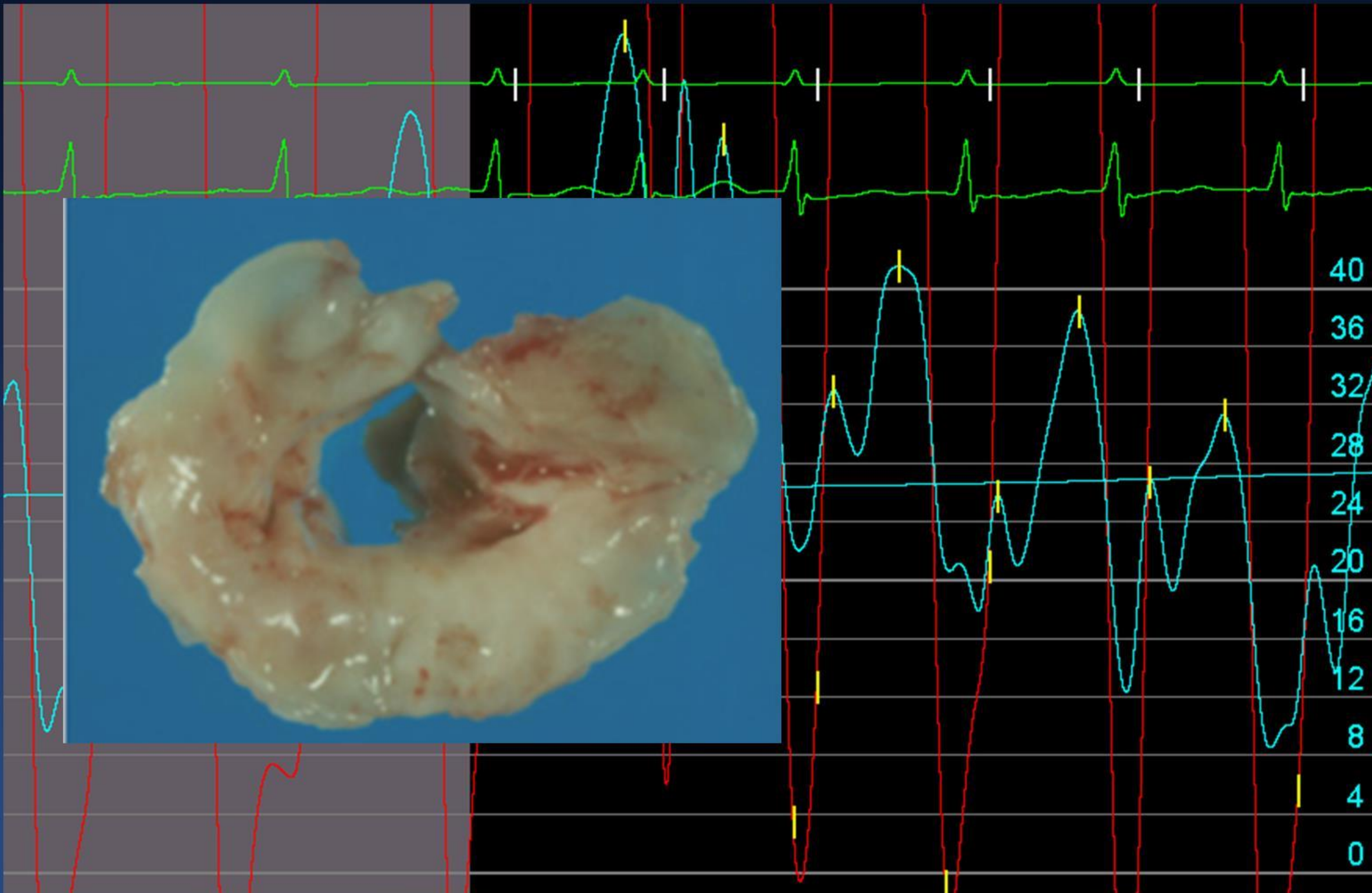




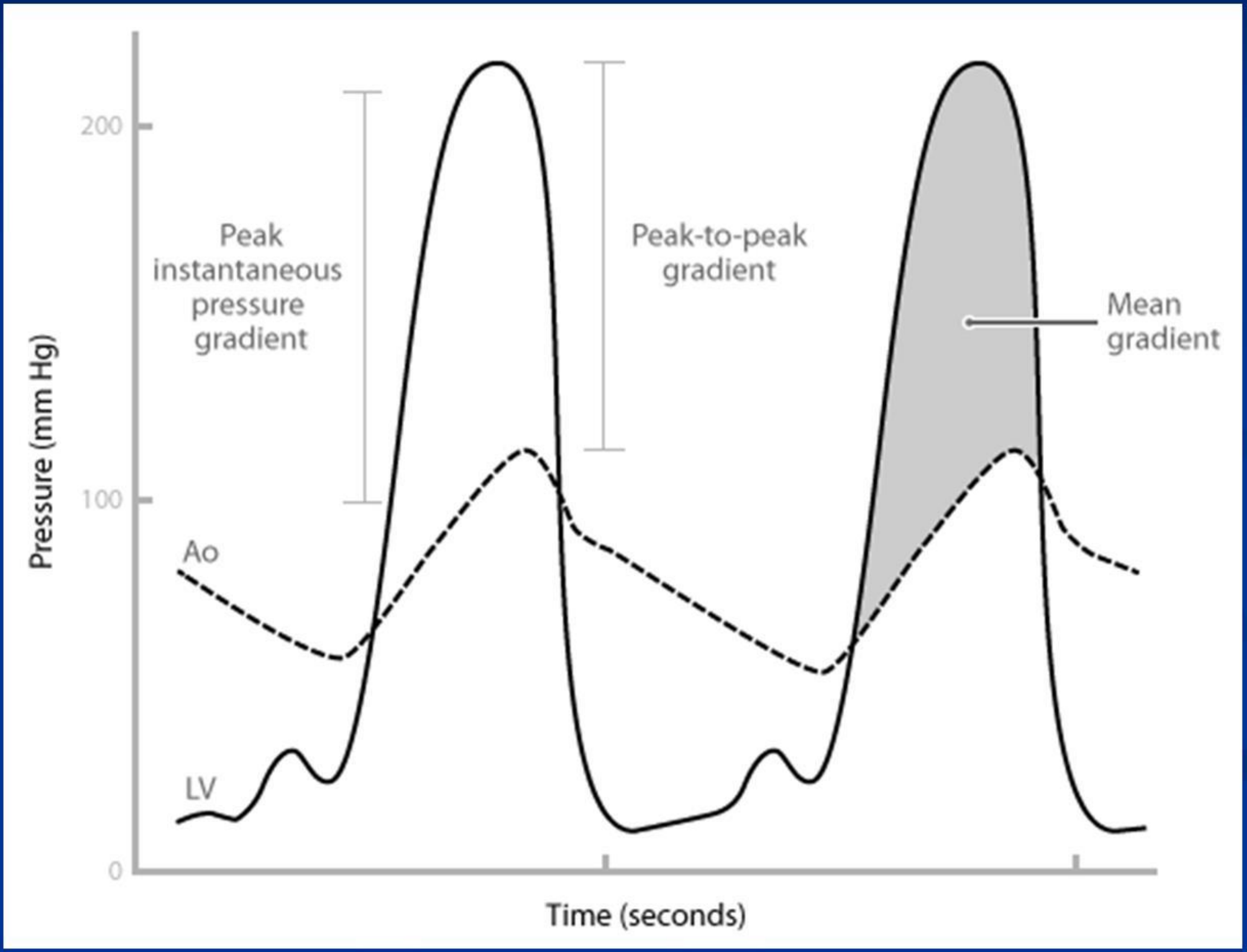
Hemodynamic and Doppler Echo findings after MVBP



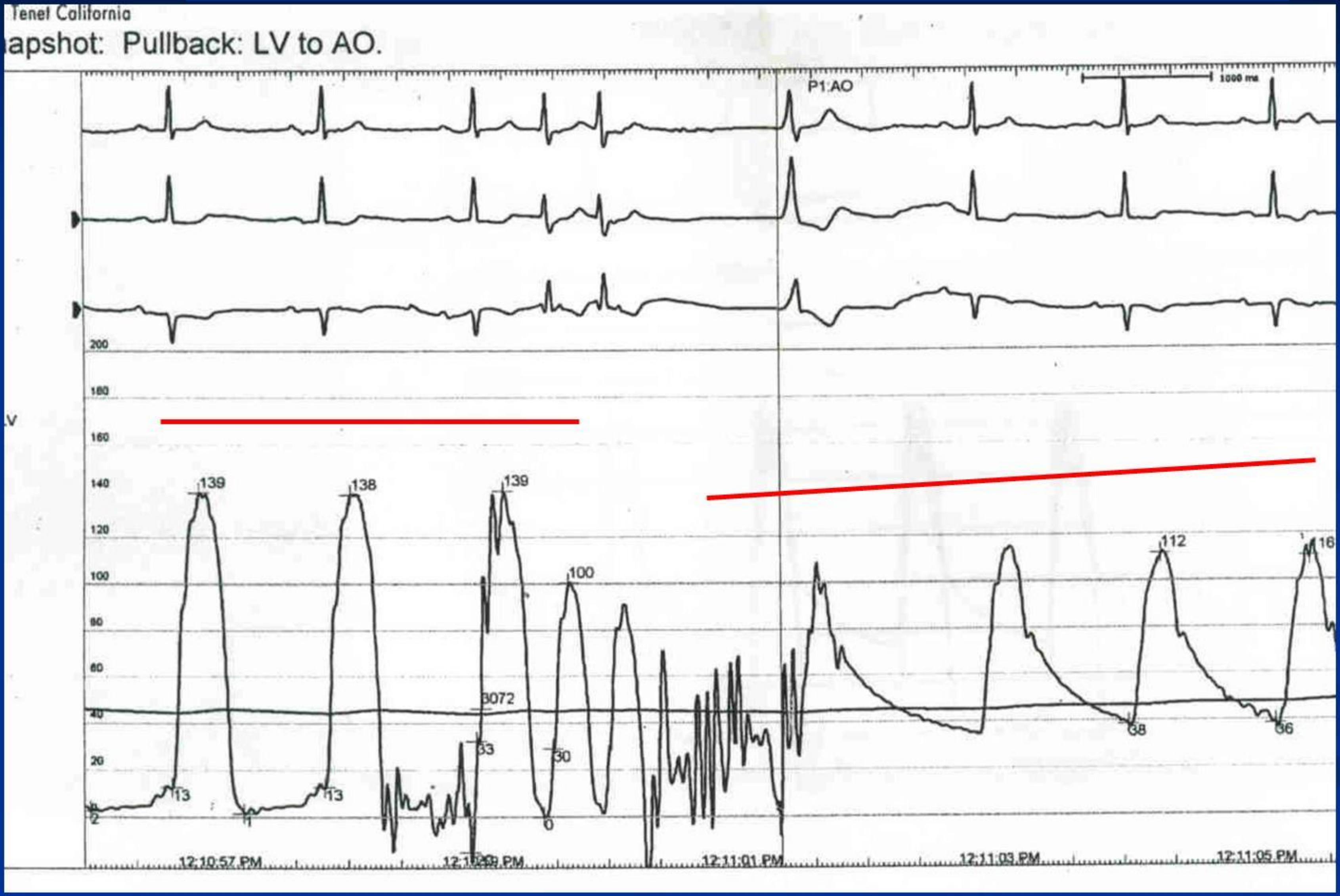



40
36
32
28
24
20
16
12
8
4
0

Aortic Stenosis

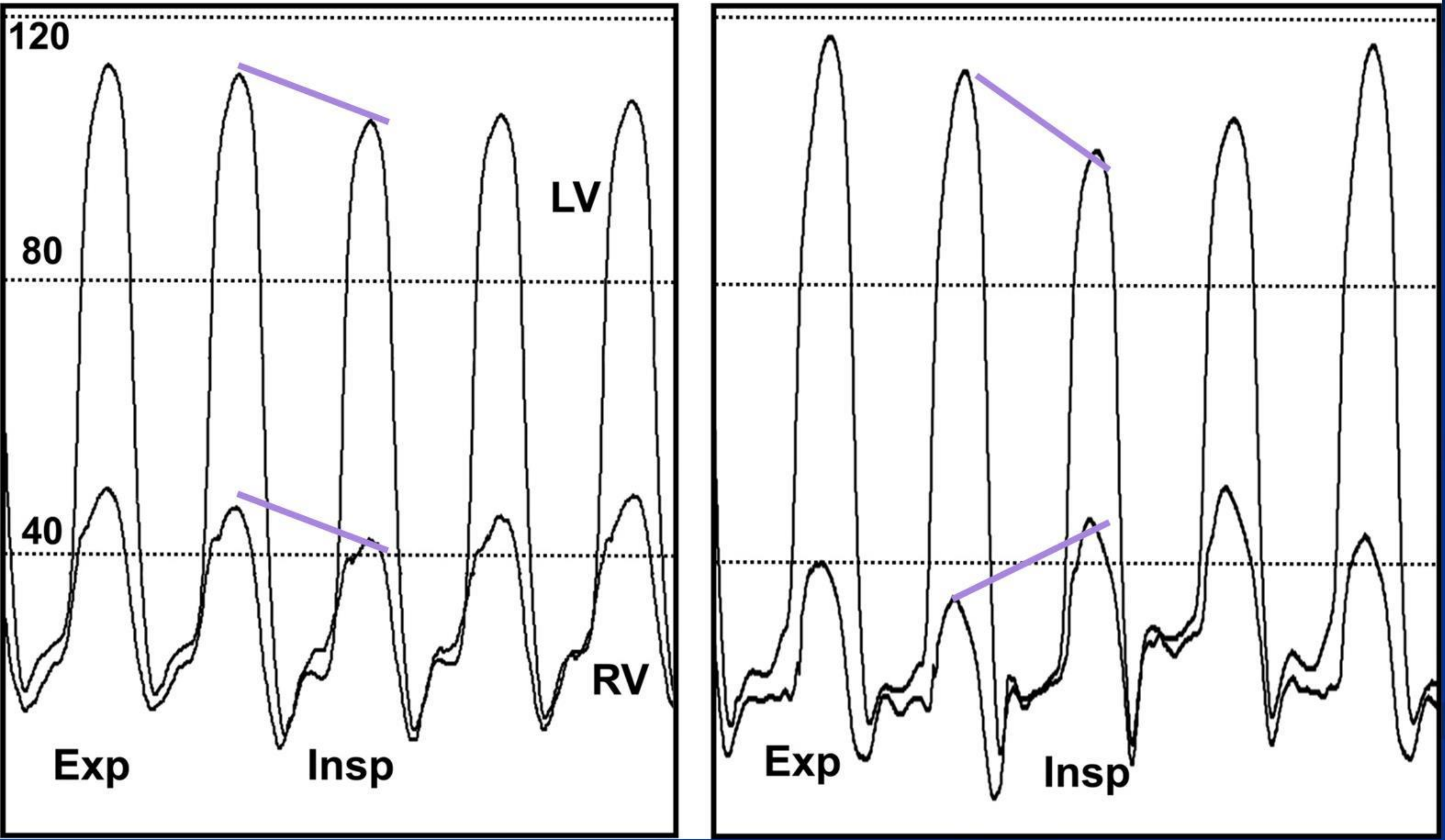


Single Catheter pullback technique is not accurate enough for AS



Restrictive Cardiomyopathy

Constrictive Pericarditis



Information Obtained from the PA Catheter

- Directly measured
  - CVP
  - PA pressure
  - PAOP/wedge pressure
  - Cardiac output
  - SvO_2
- Calculated from directly measured data
  - Stroke volume/index
  - Cardiac index
  - Systemic vascular resistance
  - Pulmonary vascular resistance
  - Oxygen delivery

Core Hemodynamic Variables

- Variable
  - Stroke volume/index
  - Cardiac output/index
  - CVP/RA
  - PAOP
  - SvO_2
- Assesses
  - pump performance
  - blood flow
  - filling pressures
  - filling pressures
  - tissue oxygenation

Normal Hemodynamic Values

SvO_2	0.60 - 0.75
Stroke volume	50-100 ml/beat
Stroke index	25-45 ml/beat/M^2
Cardiac output	4-8 L/min
Cardiac index	2.5-4.0 L/min/M^2
CVP	2-6 mm Hg
PAP	25/10 mm Hg
PAOP	8-12 mm Hg

Normal Hemodynamic Values

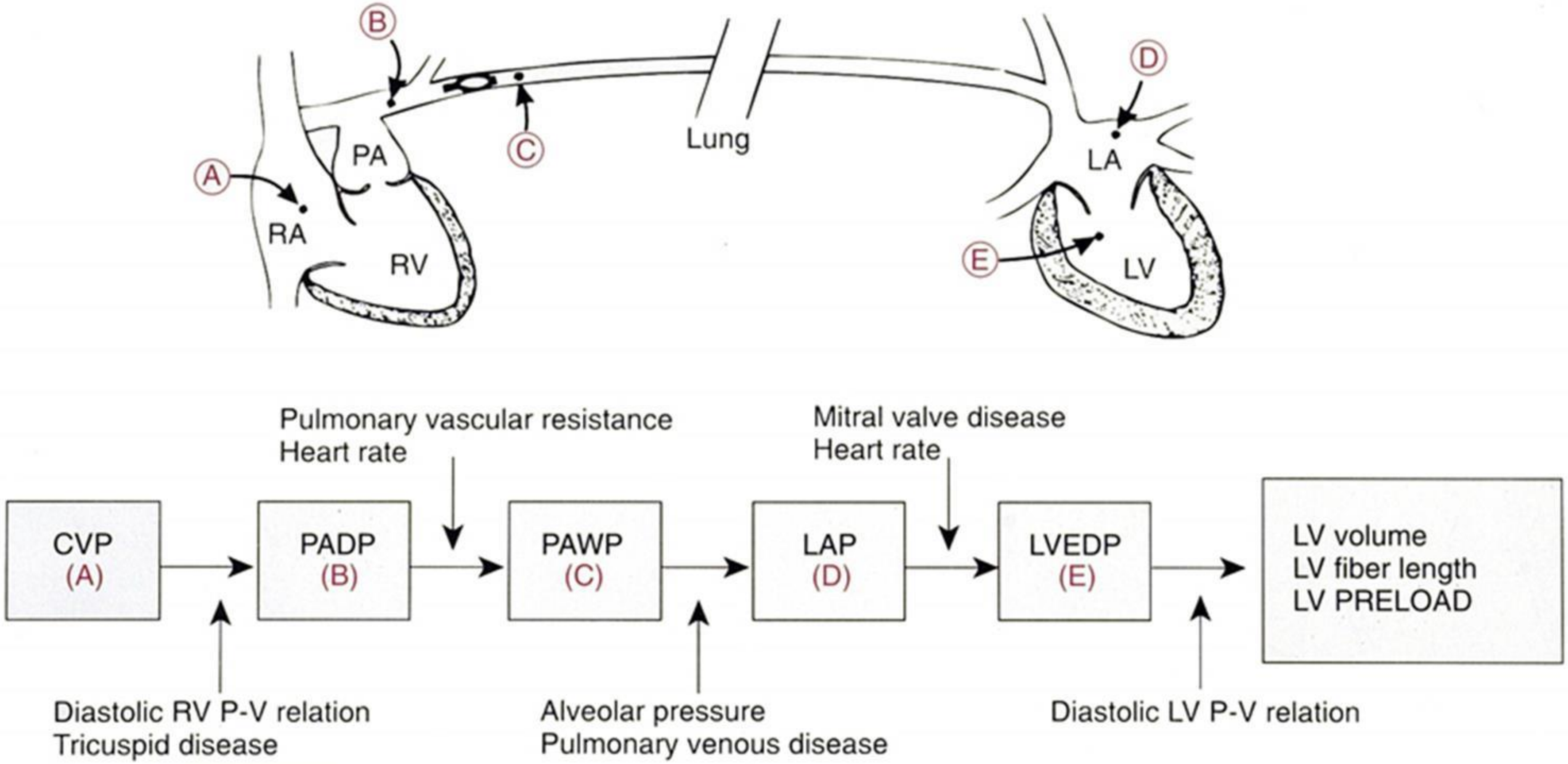
SVR	900-1300 dynes·sec/cm^5
PVR	40-150 dynes·sec/cm^5
MAP	70-110 mm Hg

What are we doing?

- Assessing adequacy of Circulation, or cause for inadequacy.

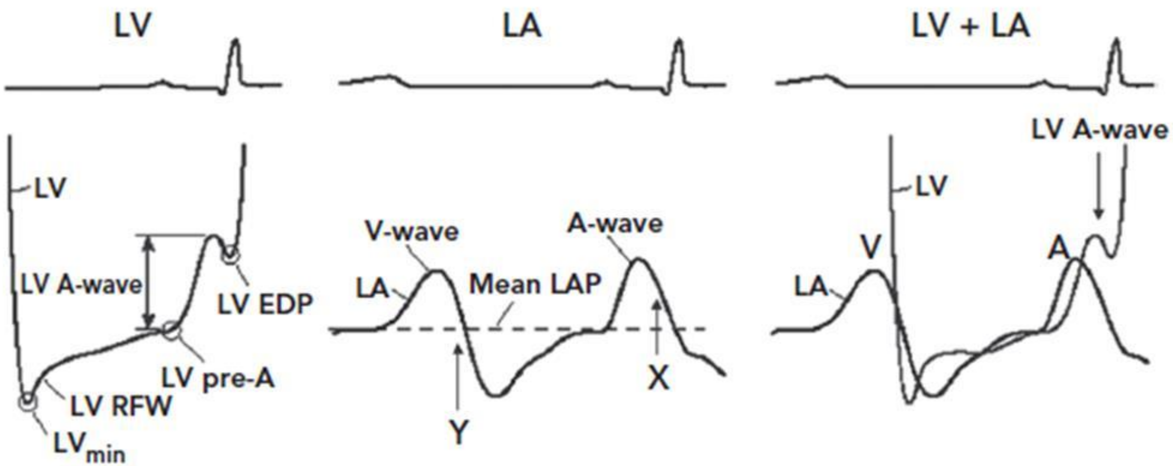
- Cardiac Output = HR x SV
- SV is a function of:
  - Preload (LVEDV, PCWP, CVP)
  - Afterload (SVR)
  - Contractility/Inotropy

Problems Estimating LV Preload



LVEDP or pre-A LVDP?

Figure 2: Differences in Left Ventricular and Left Atrial Pressure Recordings



Left panel: LV diastolic pressure recording. Arrows point to LV minimal pressure (min), LV RFW, LV pre-A pressure, A wave rise with atrial contraction and EDP. Middle panel: LA pressure recording showing V- and A-waves marked along with Y and X descent. Right panel: simultaneous LV and LA pressure recording showing differences in LVEDP and LA pressure. LA = left atrial; LV = left ventricular; LVEDP = LV end diastolic pressure; RFW = rapid filling wave. Source: Nagueh SF et al.[49] Reproduced with permission from Oxford University Press, ©2016.

In normal pts, difference between two is 1.6mmHg, so PADP, PCWP, LAP, and LVEDP and LVEDP are usually the same

In pts with MI, CHF, LVEDP may be >> LAP due to contribution of atrial contraction

LVEDP = ventricular preload

Mean LAP and pre-A LVDP better measure of pulmonary congestion, correlates with PCWP

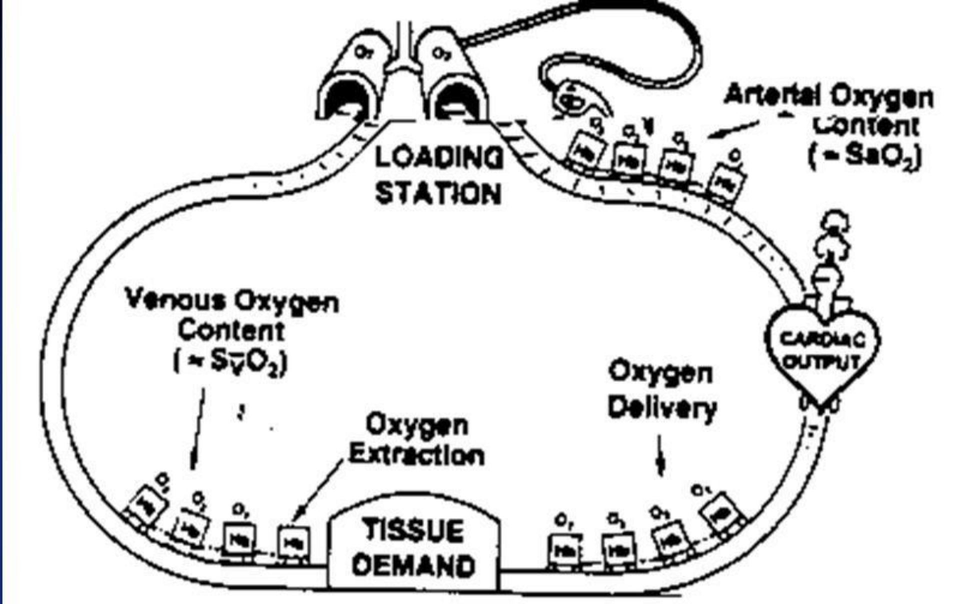
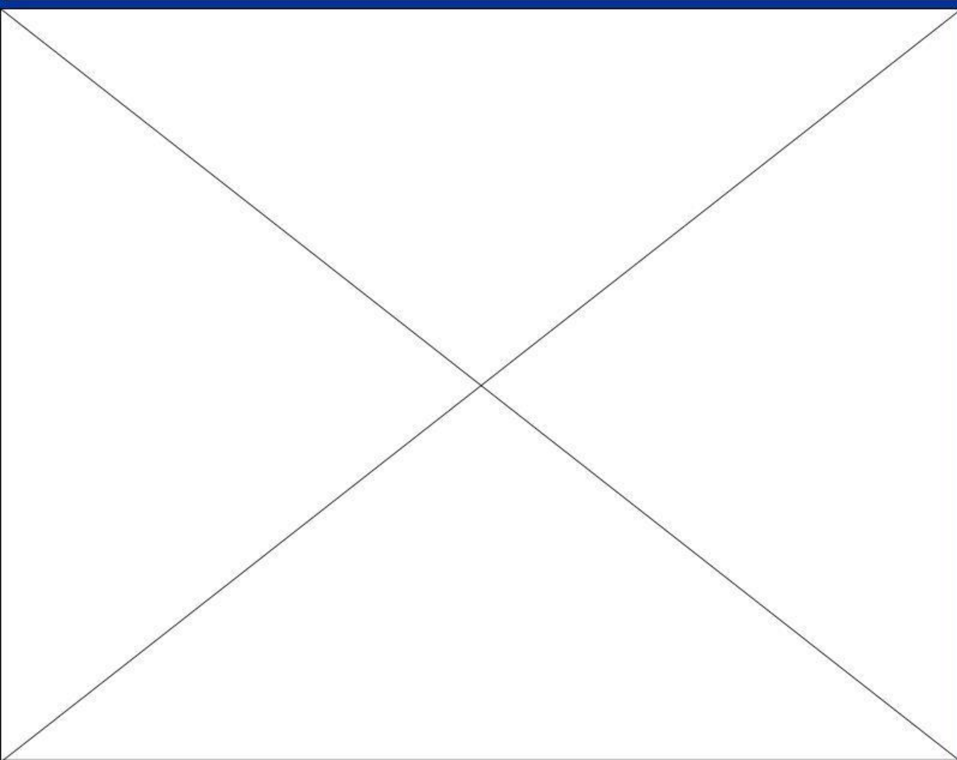


Figure 9d Mixed venous oxygen saturation.



- Fick Equation
  - $VO_2 = CO\ [CaO_2 - CvO_2]$
  - $CvO_2 \sim SvO_2$ b/c most O_2 in blood bound to Hg
- If O_2 sat, VO_2 + Hg remain constant, SvO_2 is indirect indicator of CO
- Use oximetric Swan, or send blood gas from PA
- Normal $SvO_2 \sim 65\%$
- ↓ SvO_2 [< 60%]
  - ↓ Hg- bleeding, shock
  - ↑ VO_2: fever, agitation,
  - ↓ SaO_2 : hypoxia, resp distress
  - ↓ CO: MI, CHF, hypovolemia

Etiology & Hemodynamic Changes in Shock

Etiology of shock	example	CVP/ PAOP	CO	SVR	SvO2
preload	hypovolemic	low	low	high	low
contractility	cardiogenic	high	low	high	low
afterload	distributive	low or high	high	low	low or high

Hemodynamic Therapeutic Interventions

Preload
- high → Diuretics, Venodilators
- low → Fluids

Afterload
- high → Arterial dilators, Calcium blockers, ACE inhibitors
- low → Vasopressors

Contractility
- low → Inotropic agents

Quiz

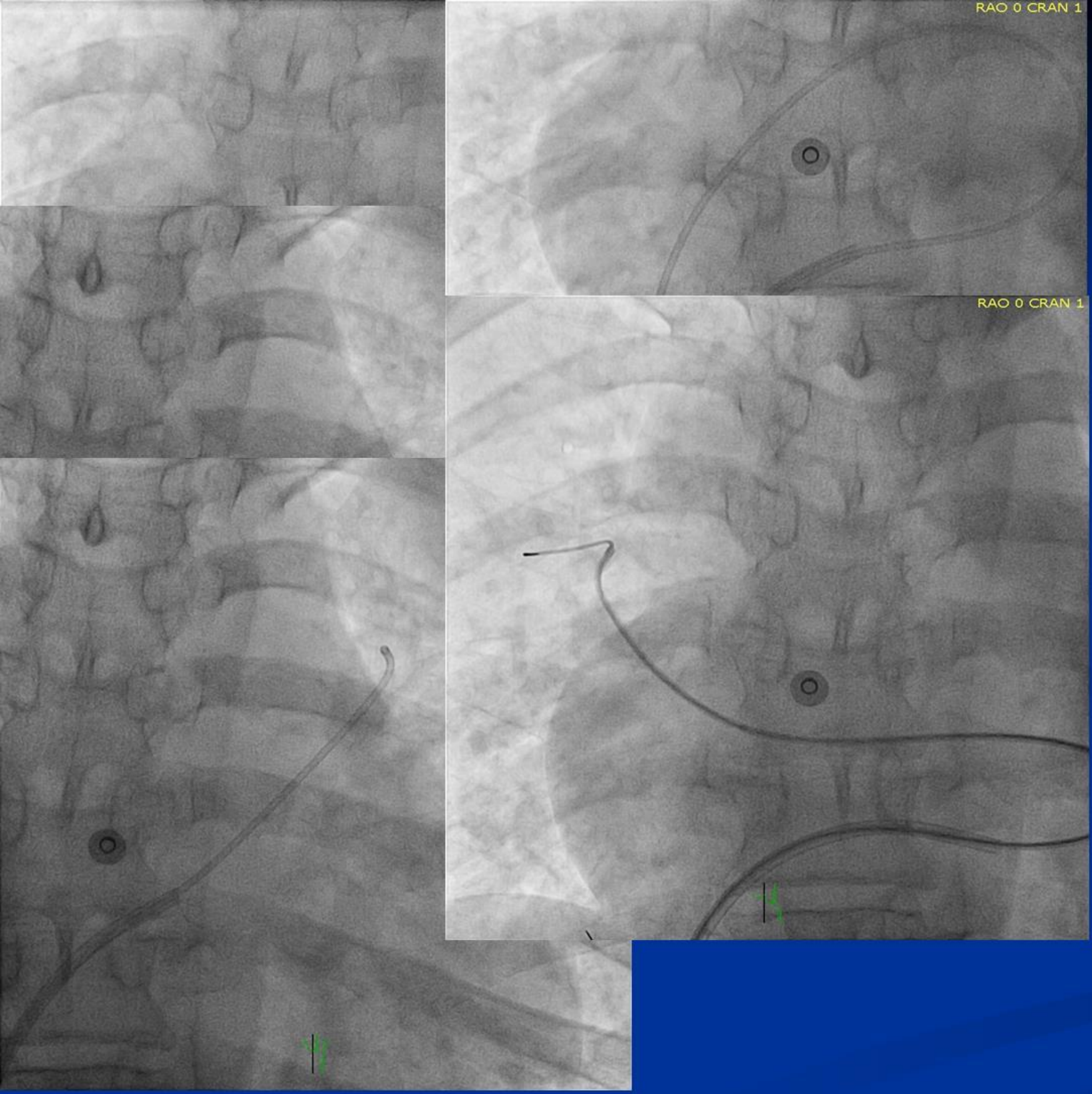
- 61 yo woman with hypotension (90/40) is admitted to the MICU and started on vasopressors. Her BP has improved to 110/70, pulse 90. She has an unexplained lactic acidosis of 5.0 mmol/L.
- Swan Values:
  - PAOP 18mmHg
  - CVP 12 mmHg
  - C.I. 2.0 L/min/m2
  - SvO2 0.45
- How would you treat her?
  - A) Bolus IV fluids
  - B) Dobutamine
  - C) Supplemental Oxygen
  - D) Antibiotics and vasopressors

Answer: Dobutamine

- Her Low SvO2 indicates severely impaired oxygen delivery
- Her low C.I. and high PAOP indicates that this is due to inadequate C.O.
- Her normal BP is due to a compensatory elevation in her SVR, which calculates to 1560!
- Echo eventually showed EF 20%.
- Stopped Dopamine, transfer to CCU.

Quiz

- A 20 yo man with a GSW to the abdomen has:
  - HR 158, MAP 68 mm Hg,
  - CVP 16 mm Hg, PCWP 20 mm Hg
  - CO 10.2 L/min, SvO2 78% , SaO2 94%
- What should he be given?
  - A) Bolus IV fluids
  - B) Dobutamine
  - C) Supplemental Oxygen
  - D) Antibiotics and vasopressors



45 yo man with systemic hypoxemia, O2 sat 80%, referred for evaluation of right to left shunt. Normal PFTs, h/o cirrhosis.

Standard shunt run?

Sats obtained from all 4 pulmonary veins show O2 sat 80%.

Dx: Intrapulmonary shunts due to cirrhosis

Rx: Liver transplant.