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Canadian Anesthesiologists' Society

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# Advanced Hemodynamics

DUANE J. FUNK

ASSOCIATE PROFESSOR OF ANESTHESIOLOGY AND MEDICINE

UNIVERSITY OF MANITOBA

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  - University of Manitoba Department of Anesthesiology
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# Case Based Medicine

- 73 year old female.  Hypertensive, hypercholesteremia, maybe ischemic heart disease, having an open colectomy, GA (sevoflurane 1.4%) + Epidural (bupivacaine 0.25% @ 5cc/hr).
- Hypotensive, 86/50, HR 78. Urine output 30 cc last hour.
- How do we fix the blood pressure?

# Answer?

- Give some fluid?
- Give a bolus dose of vasopressor (ephedrine, phenylephrine)?
- Start a vasopressor infusion?

# H.L. Mencken

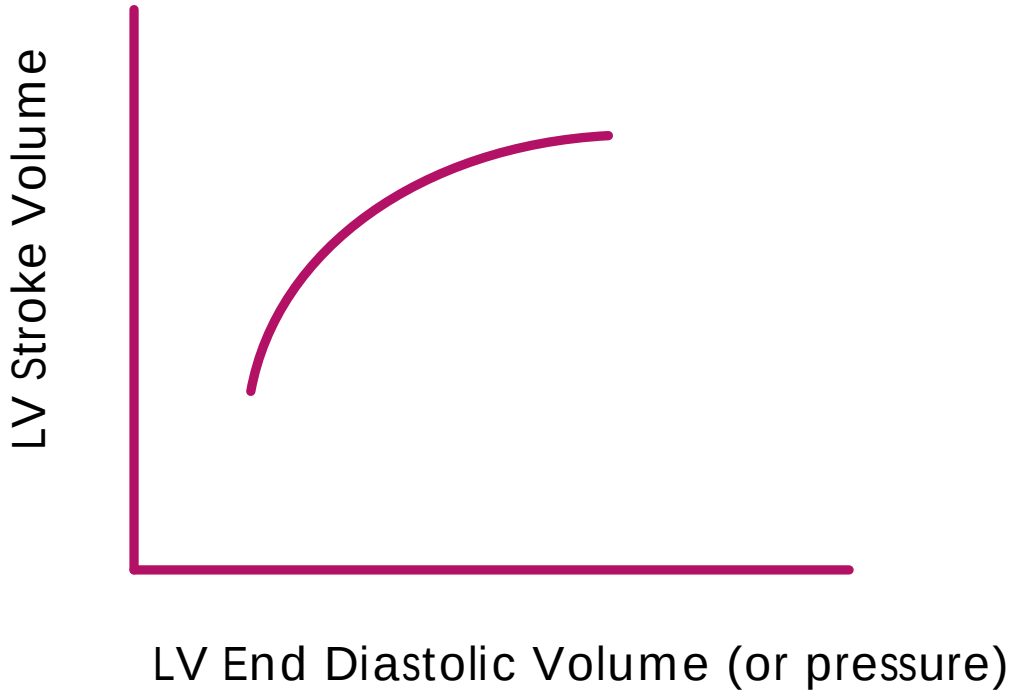
- ‘For every complex problem there is an answer that is clear, simple, and wrong’

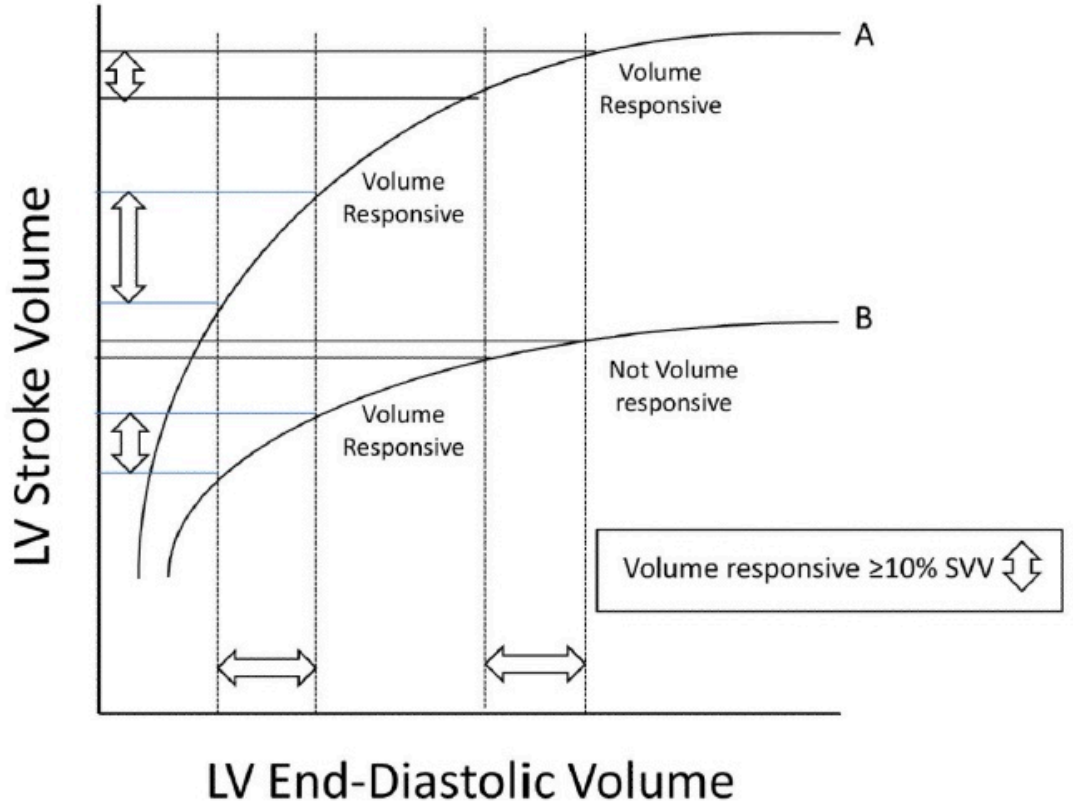
# 3 Questions

1. Will blood flow to the body increase if the patient's intravascular volume is increased?
2. Is any decrease in arterial pressure due to loss of vascular tone or merely due to inadequate blood flow?
3. Is the heart capable of maintaining an effective blood flow with an acceptable perfusion pressure without going into failure?

# Will blood flow to the body increase?

- Preload: The filling pressure of the heart at the end of diastole.
- So, if we increase preload, increase cardiac output.



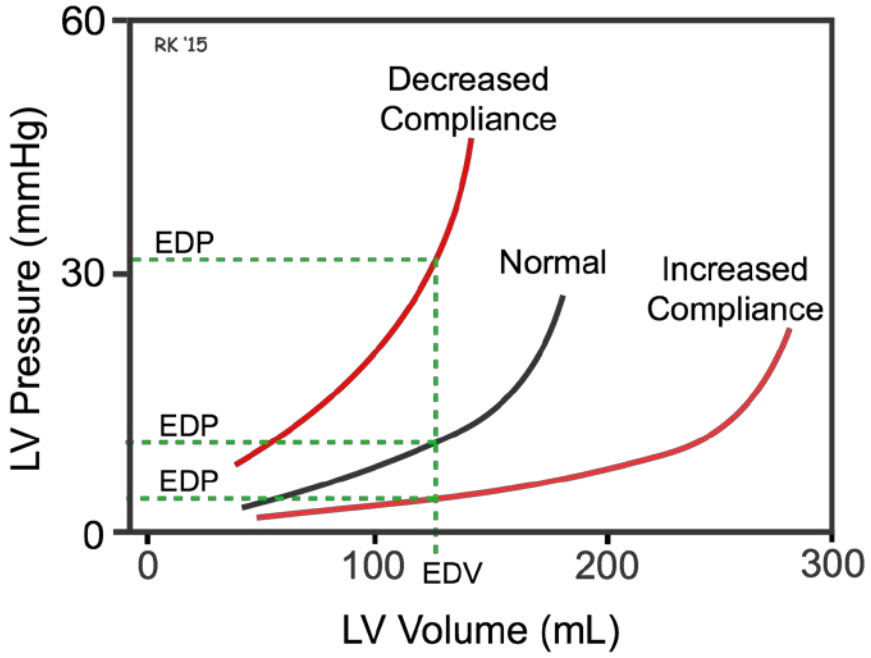

A
Volume
Responsive
Volume
Responsive
B
Not Volume
responsive
Volume
Responsive
Volume responsive ≥10% SVV
LV Stroke Volume
LV End-Diastolic Volume

- How do we best measure preload?
  - CVP
  - Wedge pressure from a PA catheter?
  - Other?

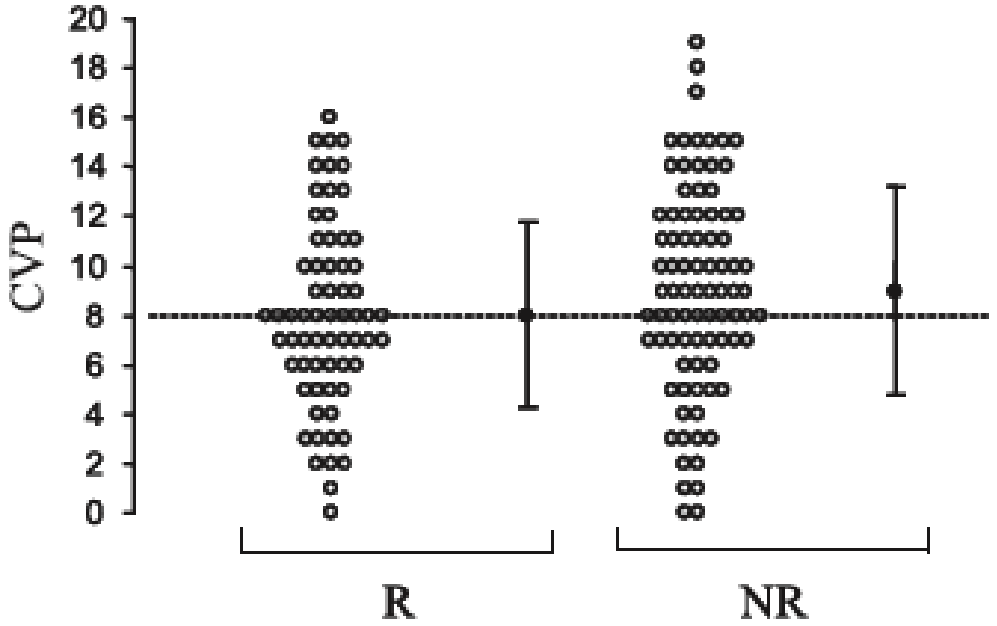
- Does CVP predict fluid responsiveness?

# CVP/Preload relationship: Not So Fast!

CVP ≈ RVEDP ≈ PAEDP ≈ LAP ≈ LVEDV



# CVP=RNG (Random number generator)

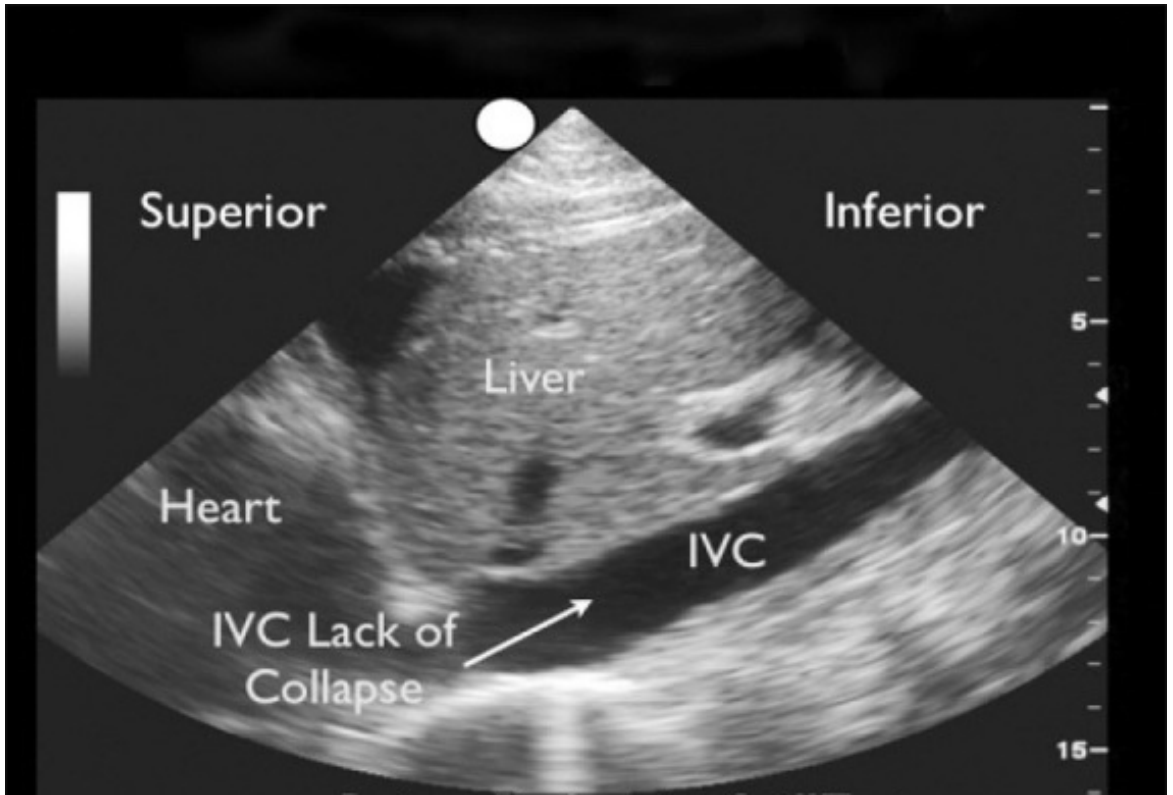


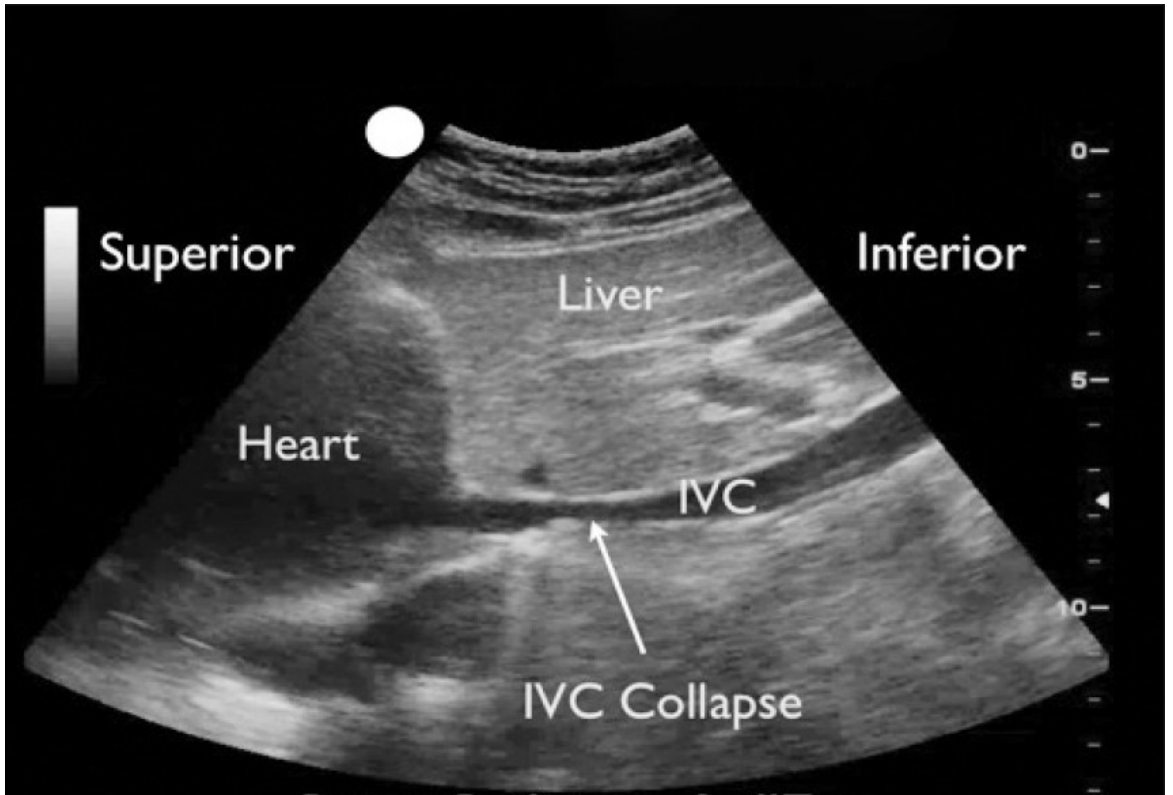

**Does Central Venous Pressure Predict Fluid Responsiveness?**

Paul E. Marik, Michael Baram and Bobbak Vahid

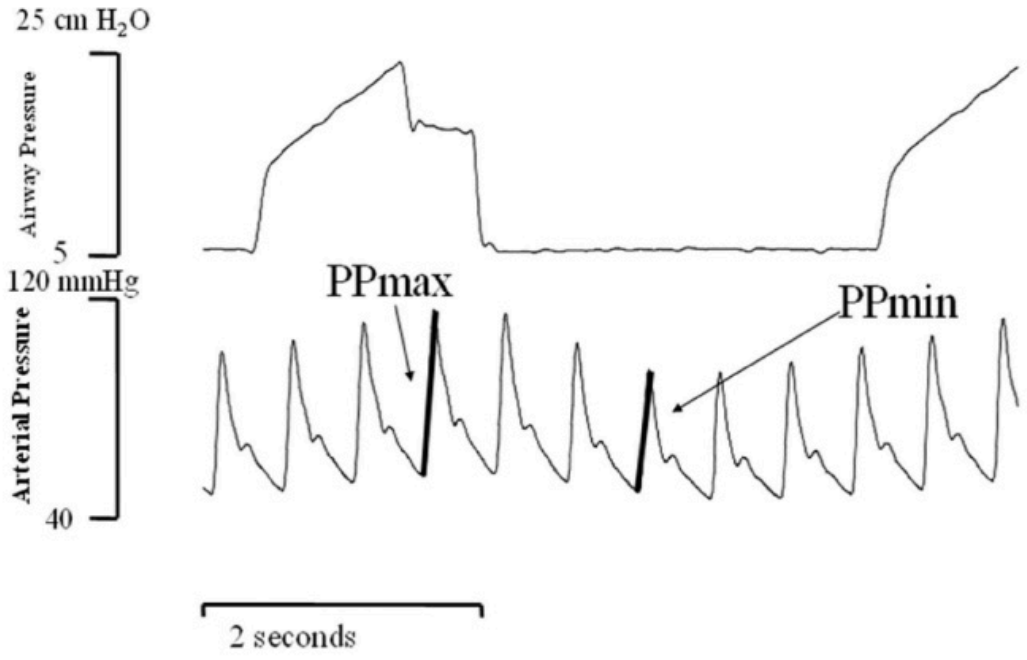
*Chest* 2008;134;172-178

# IVC Diameter: The $60,000 CVP



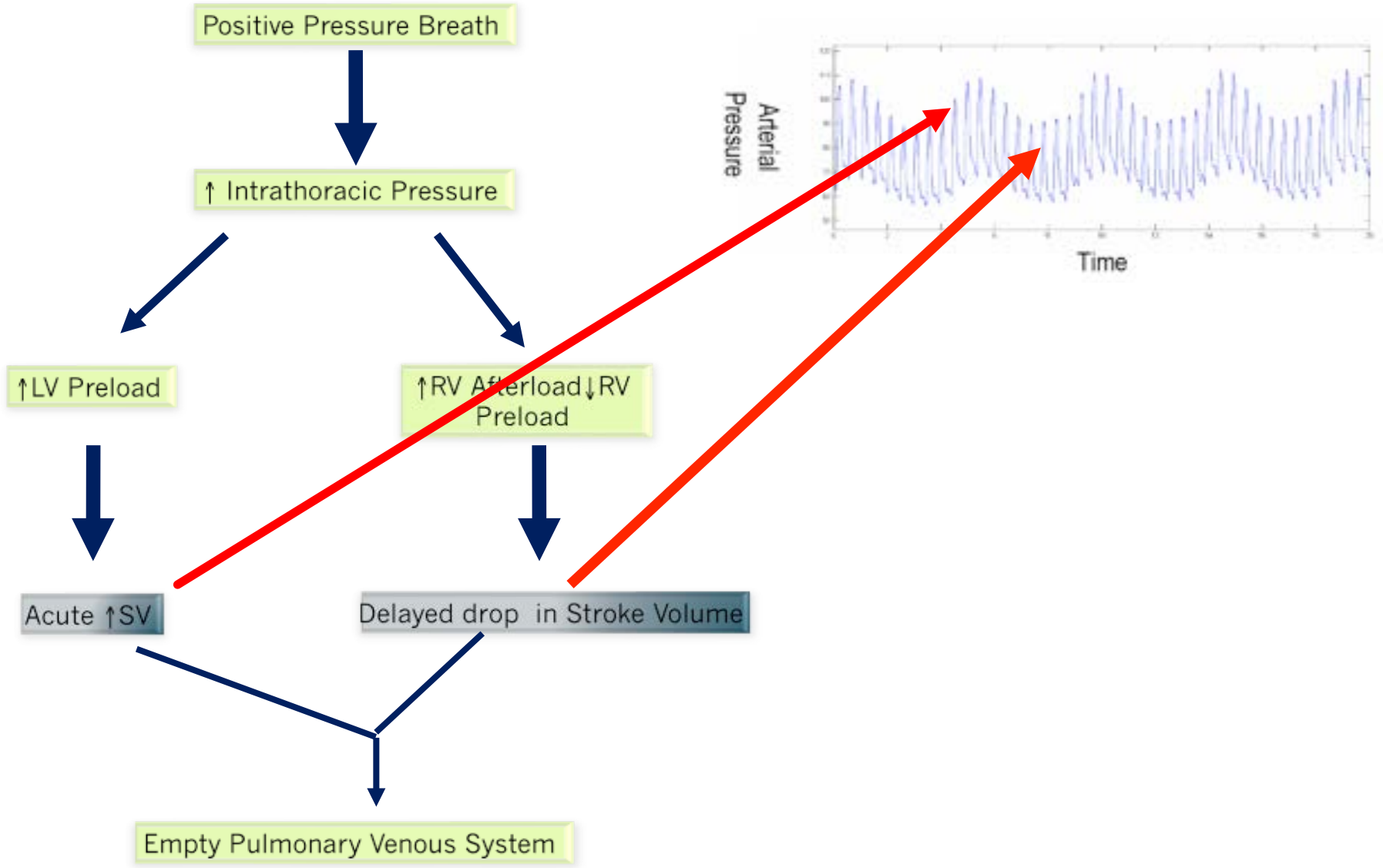



# Pulse Pressure Variation

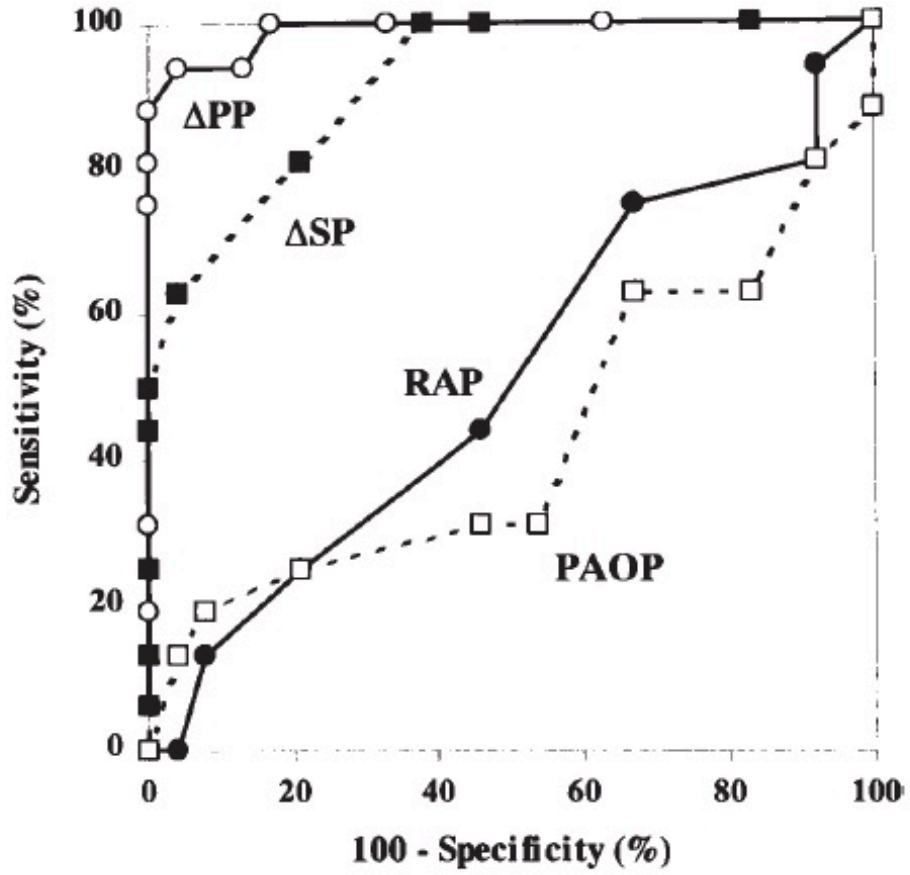



**Δ Pulse Pressure (PP) = PPmax-PPmin**

**ΔPP Variation (PPV) = (PPmax-PPmin)/PPmean**


Positive Pressure Breath
↑ Intrathoracic Pressure
↑LV Preload
↑RV Afterload↓RV Preload
Acute ↑SV
Delayed drop in Stroke Volume
Empty Pulmonary Venous System
Arterial Pressure
Time

# End of Story




AUC 0.56 for CVP

AUC 0.94 for PPV

# PPV Caveats

- PPV false positives: PPV >15%, but not volume responsive
  - Spontaneous ventilation
  - Right heart failure
  - High PEEP
  - Atrial fibrillation or PVCs

# PPV caveats

- PPV false negatives:  PPV <15% but volume responsive
  - Intra-abdominal hypertension
  - Small tidal volumes (<8 mL/kg)
  - Bronchospasm

# Getting back to our patient:

- If hypotensive and high PPV (>15%), give some fluid, cardiac output will increase.
- But remember all the caveats!
- Ignore the CVP and urine output.
- Blood pressure response: a different story.

# Why is the blood pressure low?

- Fluid boluses (500 cc of Lactated Ringers x 2).
- Hypotensive, 86/50, HR 78.
- Now what?

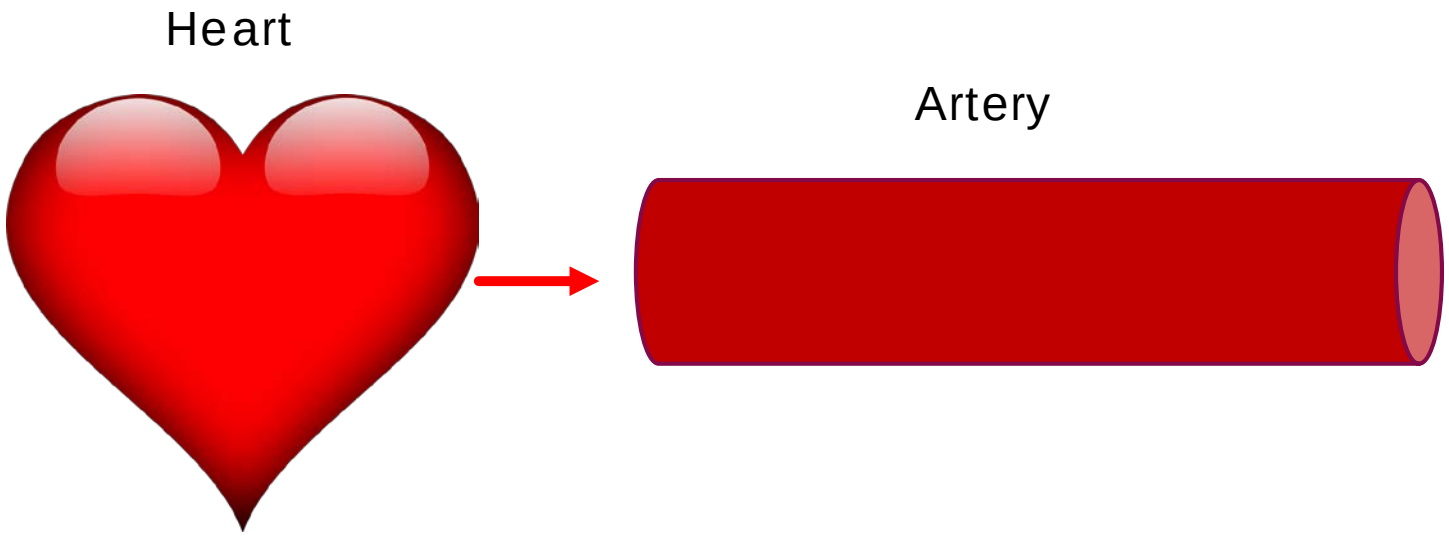
# Why is the blood pressure low?

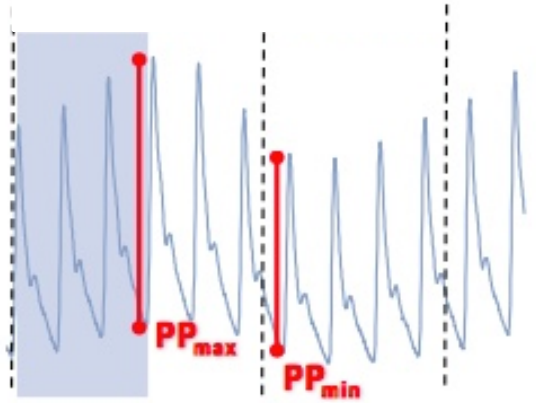
- Is any decrease in arterial pressure due to loss of vascular tone or merely due to inadequate blood flow?

# Why is the blood pressure low?

- PPV only tells you about cardiac output response to fluids
- Tells you nothing about the blood pressure response

# Arterial Elastance



- Arterial pressure rise with ventricular contraction is a function of:
  - LV stroke volume
  - Arterial elastance (or tone, Ea)

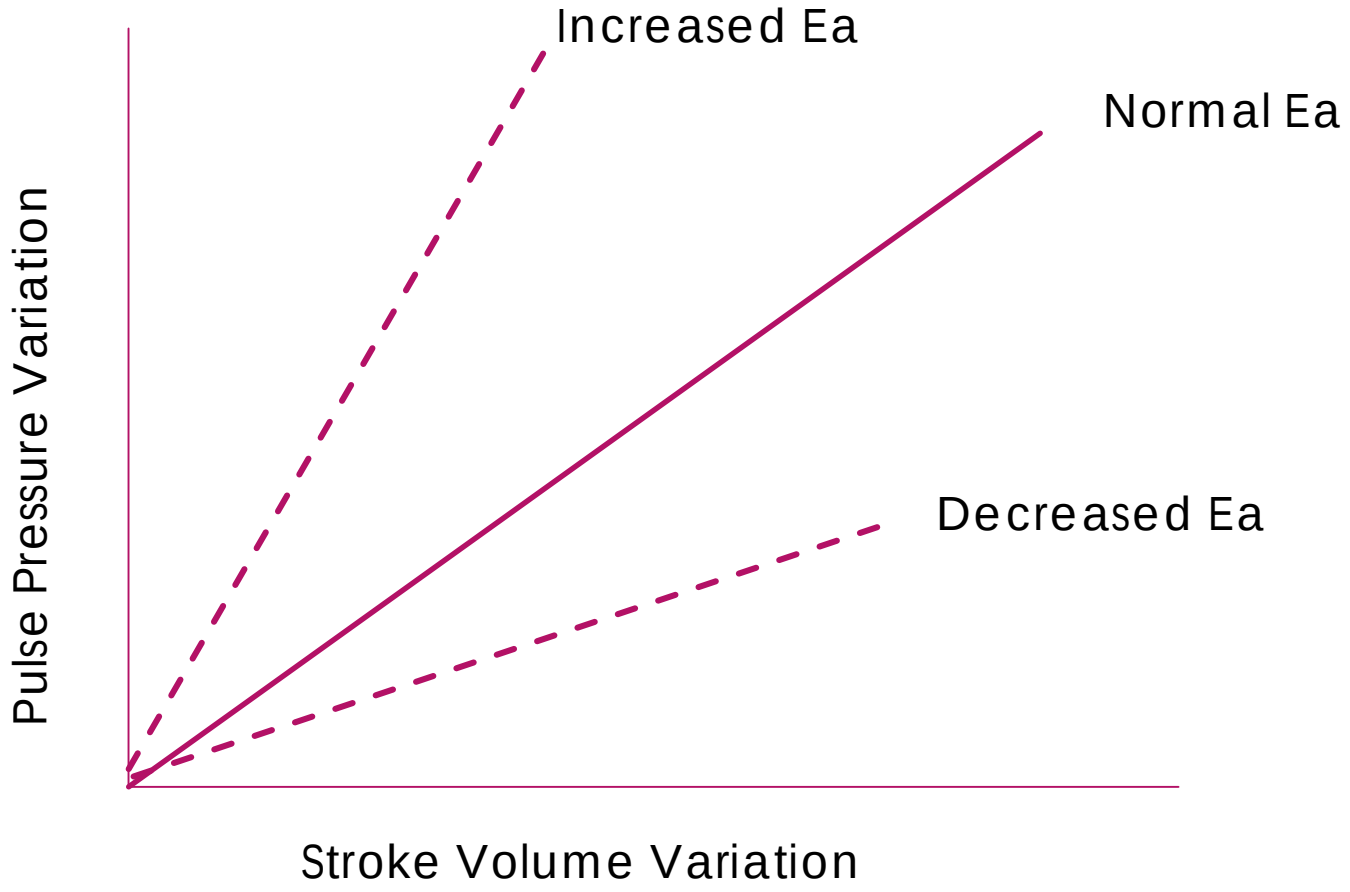
$$Arterial\ Elastance(Ea) = \frac{\Delta Pressure}{\Delta\ Volume}$$

- Arterial Elastance is the dynamic relationship between pulse pressure vs. stroke volume.

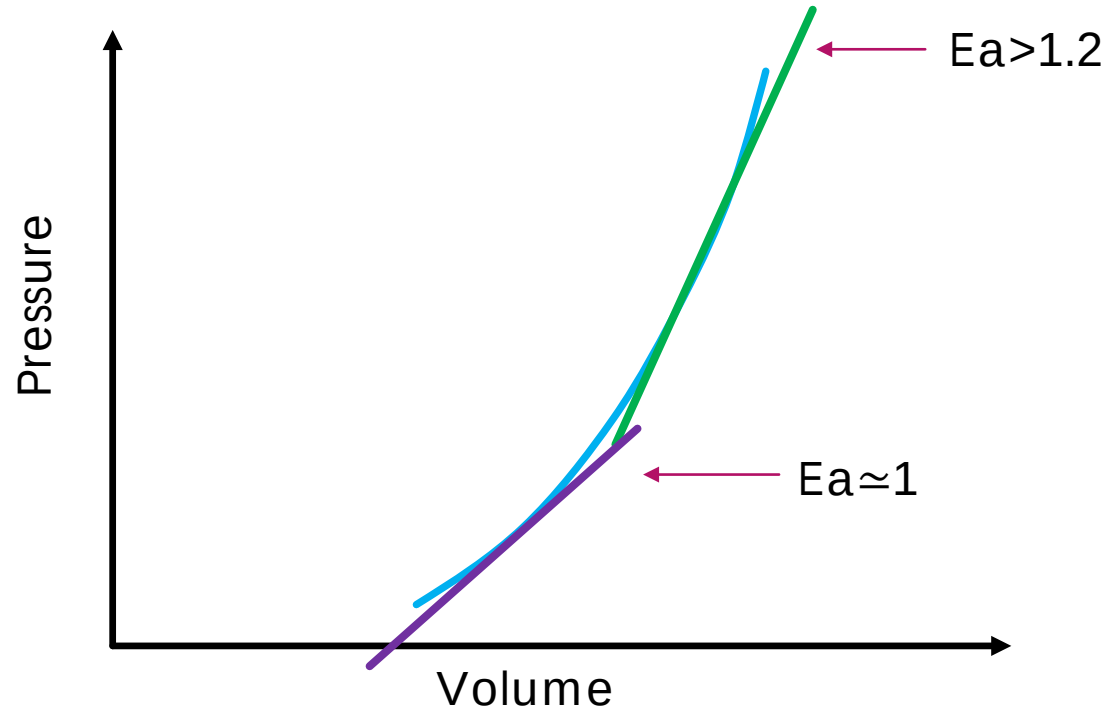
- In normal people, Increasing LV stroke volume increases arterial pressure proportionally.

# Arterial Elastance

- Our patients aren't 'normal'.
- Change in arterial elastance:
  - Anesthetic drugs
  - Regional Anesthesia
  - Atherosclerosis
  - Sepsis



# Dynamic Arterial Elastance



# Dynamic Arterial Elastance

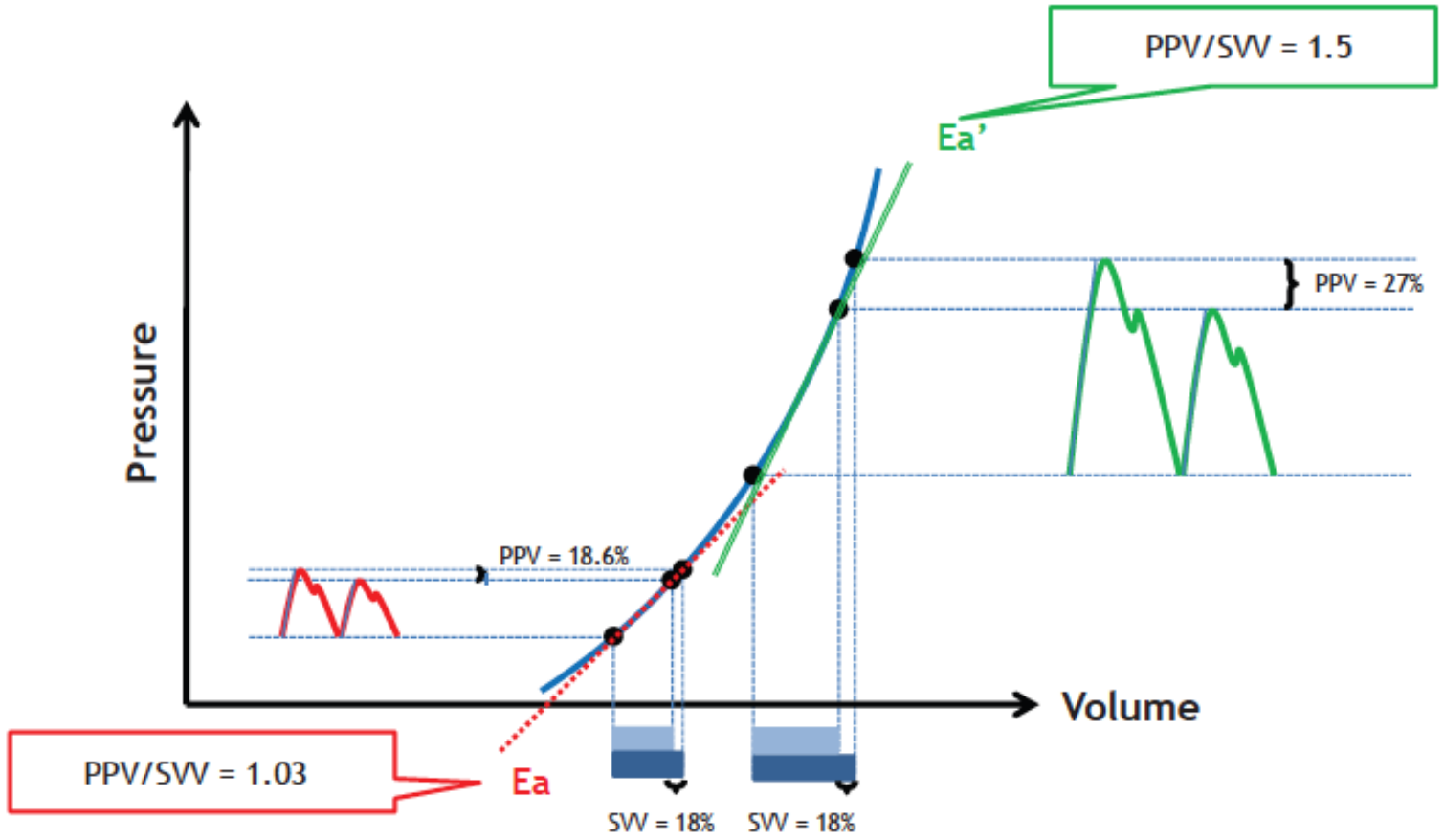



**Figure 1. Model of two different arterial elastances (Ea and Ea') on the pulse pressure variation (PVV) relationship curve, with the same stroke volume variation (SVV) value.**

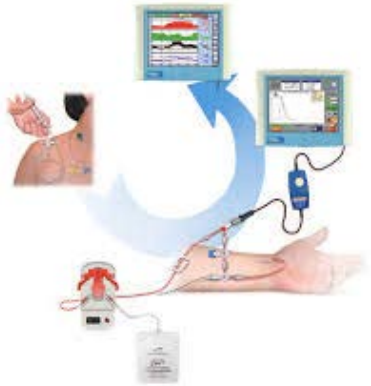
# Dynamic Arterial Elastance

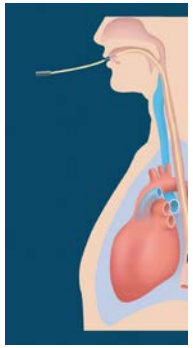
- Physiology is sound and well known
- One problem: Need to know stroke volume variation
- Not typically available

# Stroke volume measurement


The FloTrac sensor

EV1000 clinical platform



**PLAX Systole**

LVOT diameter = 2.0 cm

**5 chamber LVOT PW**

LVOT VTI = 19 cm

# Question #3

- Is the heart capable of maintaining an effective blood flow with an acceptable perfusion pressure without going into failure?

- i.e. What is the cardiac function?

# Question #3

- The heart's only function is to take what blood it receives under a low filling pressure and transfer it to the arterial system under a higher pressure.

# Ohm's law

$$V = I \; x \; R$$

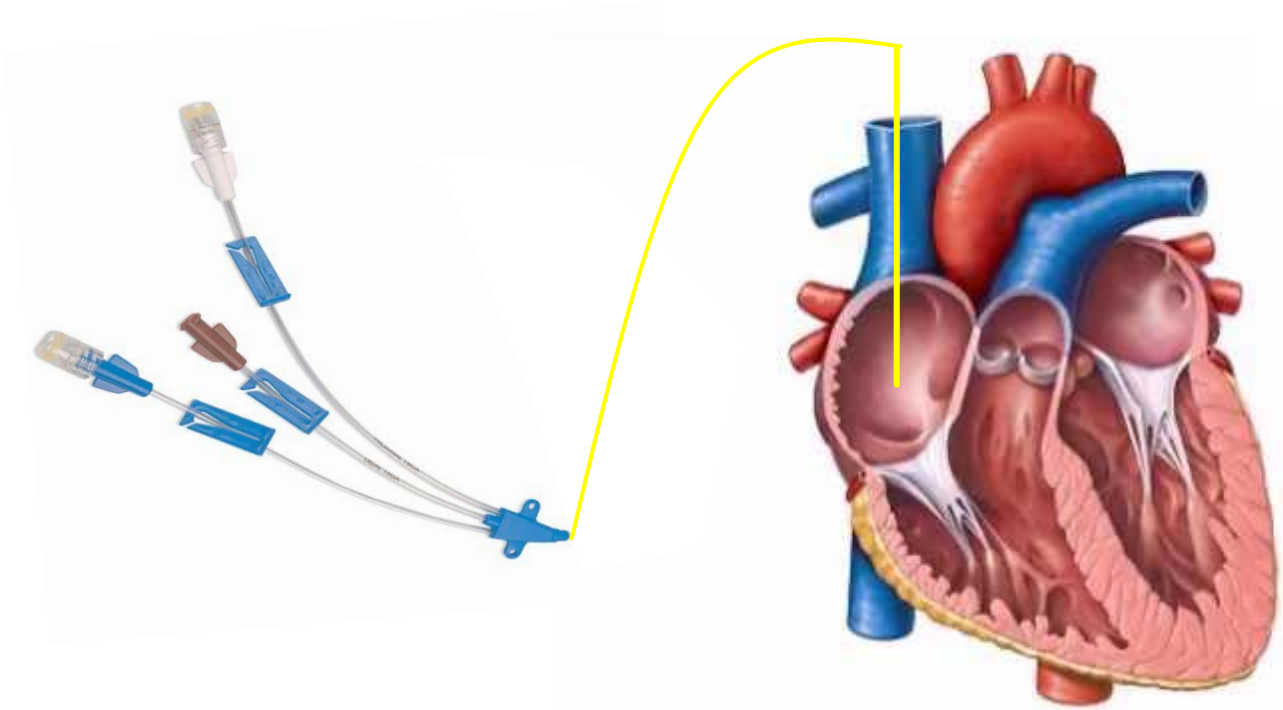
*Arterial Pressure= Cardiac Output x Systemic Vascular Resistace*

# Ohm’s law

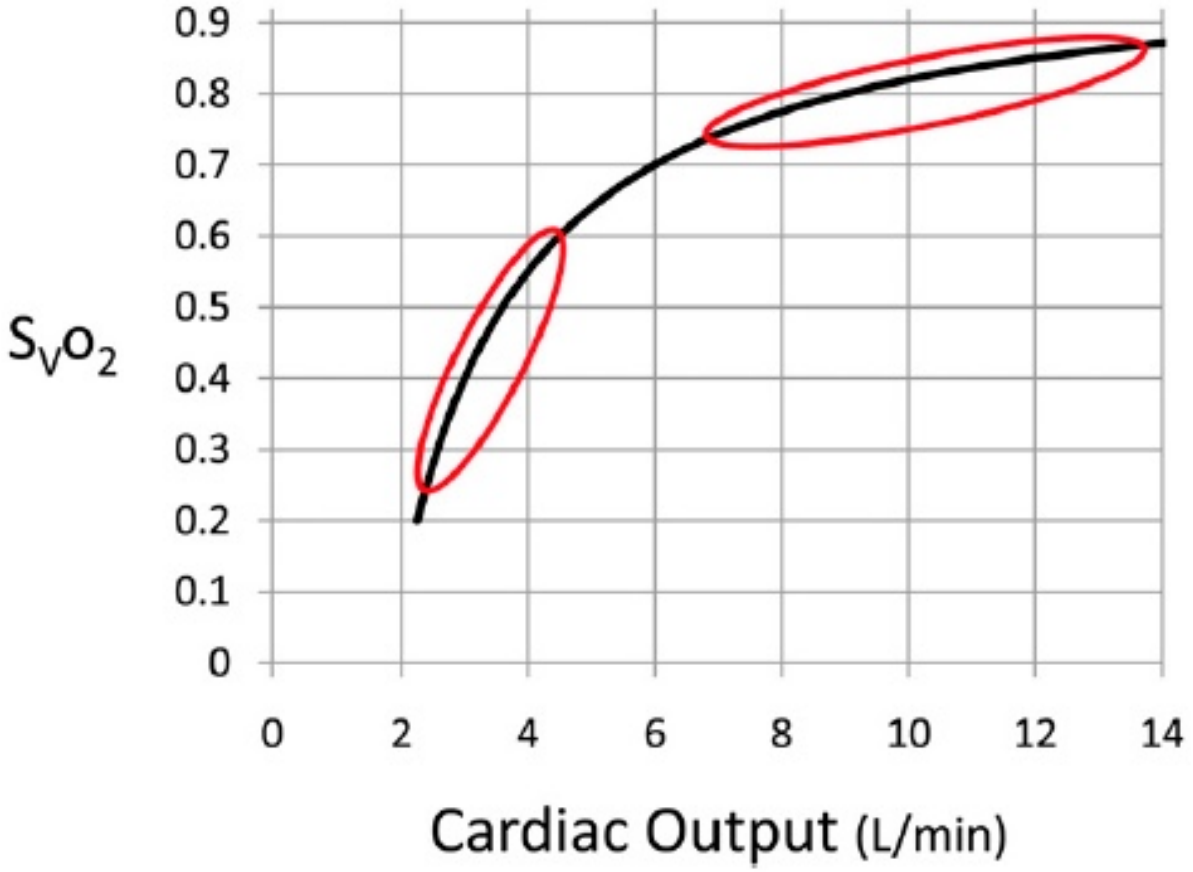
- Practically speaking, this means that the body maintains blood pressure at the expense of flow.
- We can easily (and typically) measure pressures
- It is more challenging to measure flow, and we don’t typically do it.
- Only looking at half the equation!

# Poor persons cardiac output

$ScVO_2 \approx SvO_2$



# Poor persons cardiac output

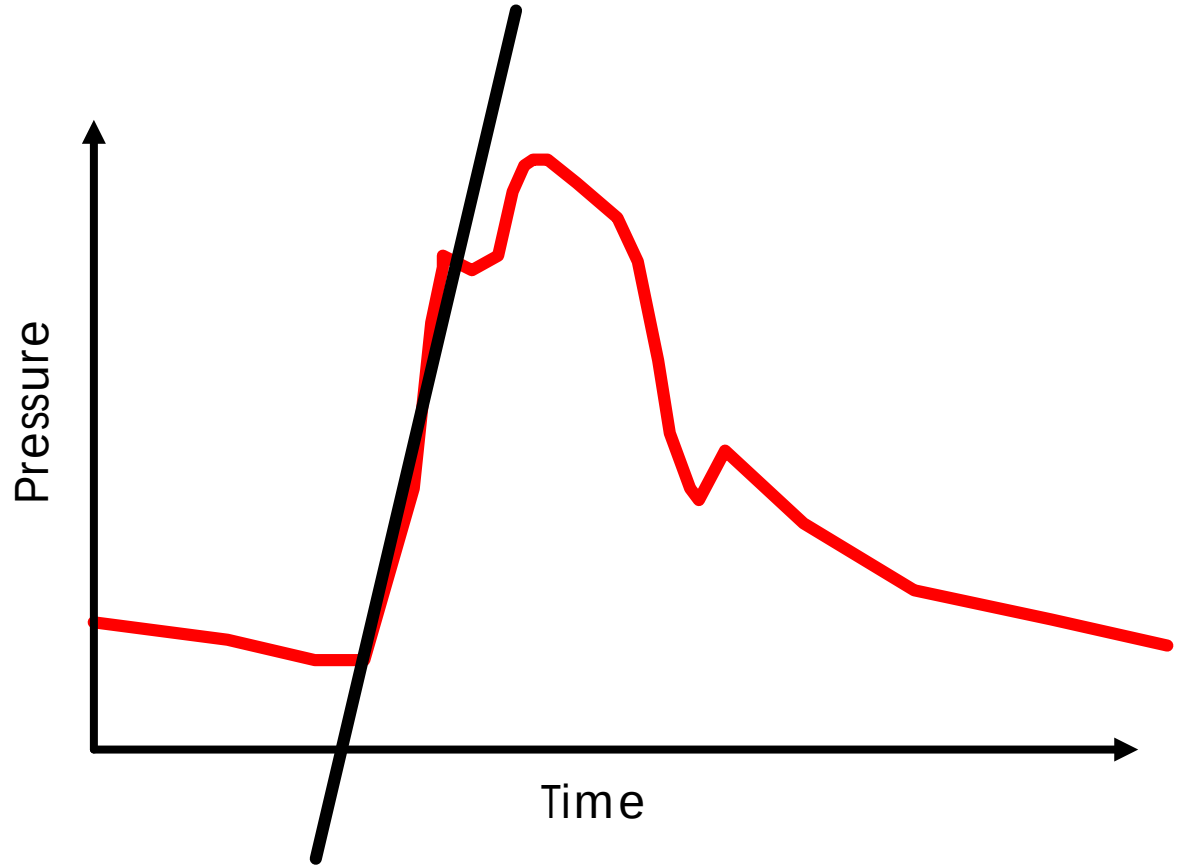


# Cardiac Function Measurement

- Contractility difficult to measure clinically.
- Preload and afterload dependent
- Ejection fraction from Echo doesn't tell you about contractility.
- Contractility: Essentially it is the change in pressure vs. time.

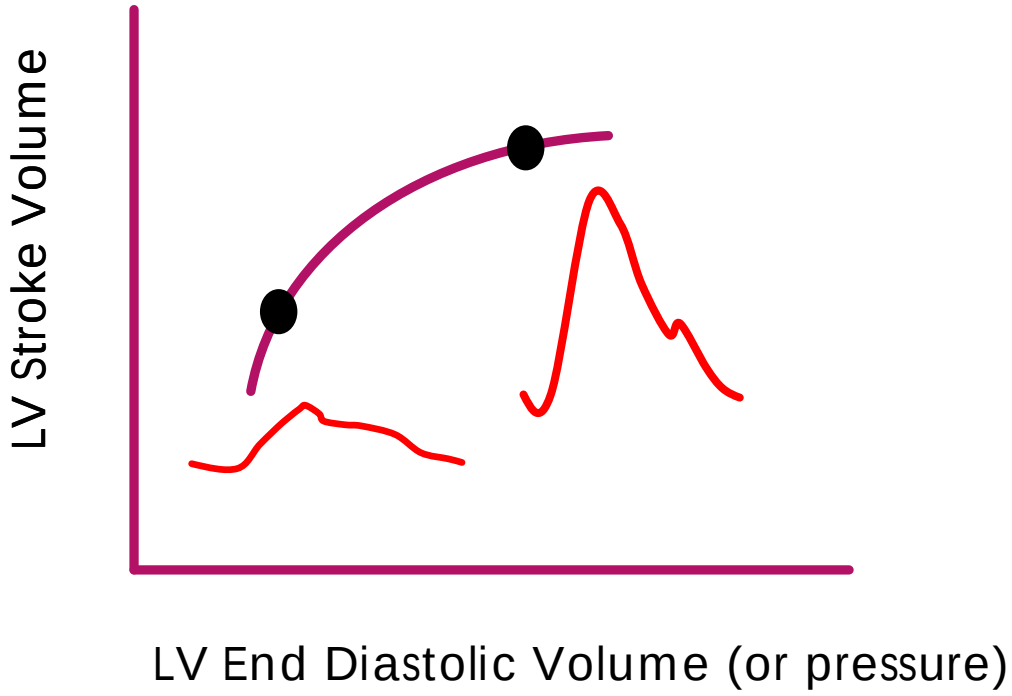
# Cardiac Function Measurement

- $\frac{dP}{dt}$



# Cardiac Function Measurement

- Preload dependent
- Hypovolemic patients will have depressed *dP/dt*
- Normal hearts can look ‘bad’ with low volume.



# Putting it all together

- 73 year old female. having an open colectomy, GA + Epidural.
- Hypotensive, 86/50, HR 78. Urine output 30 cc last hour.
- So what do we do with our patient?

# Putting it all together

PPV > 15

Controlled mechanical ventilation
$V_t$ > 6 ml/Kg
Sinus Rhythm
No spontaneous breaths

↓

500cc Fluid bolus q 10 min until PPV <12

↓

Still hypotensive: measure PPV/SVV ratio

↓

Ea > 1.2 give more fluid. Ea < 0.8 add start vasopressor

↓

Measure CO/Sc$VO_2$ , assess arterial tracing, TEE

# Putting it all together

- Hypotensive in recovery?
- Can’t use PPV
- Don’t use ultrasound for IVC diameter
- Try a passive leg raise if possible.

# Summary

- Lots of information can be gleaned from typical hemodynamic monitors that we use
- Consider advanced monitoring in high risk patients (Central line, cardiac output monitor).
- Know the limitations of the parameters you are measuring/acting upon.
- Attempt to be a sniper not a carpet bomber.

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