PICCO -

USES AND PITFALLS

$\boxed{\text{Cardiac output}}$ x Hb x % Sat O2

Preload

Effective blood
volume
Capacitance
Obstruction
Septal shift
IV fluid
    volume
    C.O.P.

Pump failure

Arrhythmias
Ischaemia
Valvular problems
Septal shift

Afterload

RAA adaptaion
Sepsis
Valvular problems
Pulmonary embolism
Hypertension
Shunts

Heart rate

Anaemia

Fe def
Dilutional
Inflammatory
Vitamin
deficiency
Aplastic

Abnormal Hb

Sickle cell
Thalassaemia
met Hb
CO Hb

Hemolysis

free Hb and NO
Pulmonary
hypertension

Hyperviscosity

PRV
Acclimatisation

Inspired O2

Altitude
Hyperbaric O2

Hypoventilation

Decreased respiratory drive
    drug induced
CVA
Fatigue (asthma)
Obstruction
    Sleep apnoea syndrome
    Decreased consciousness

Ventilation/perfusion abnormalities

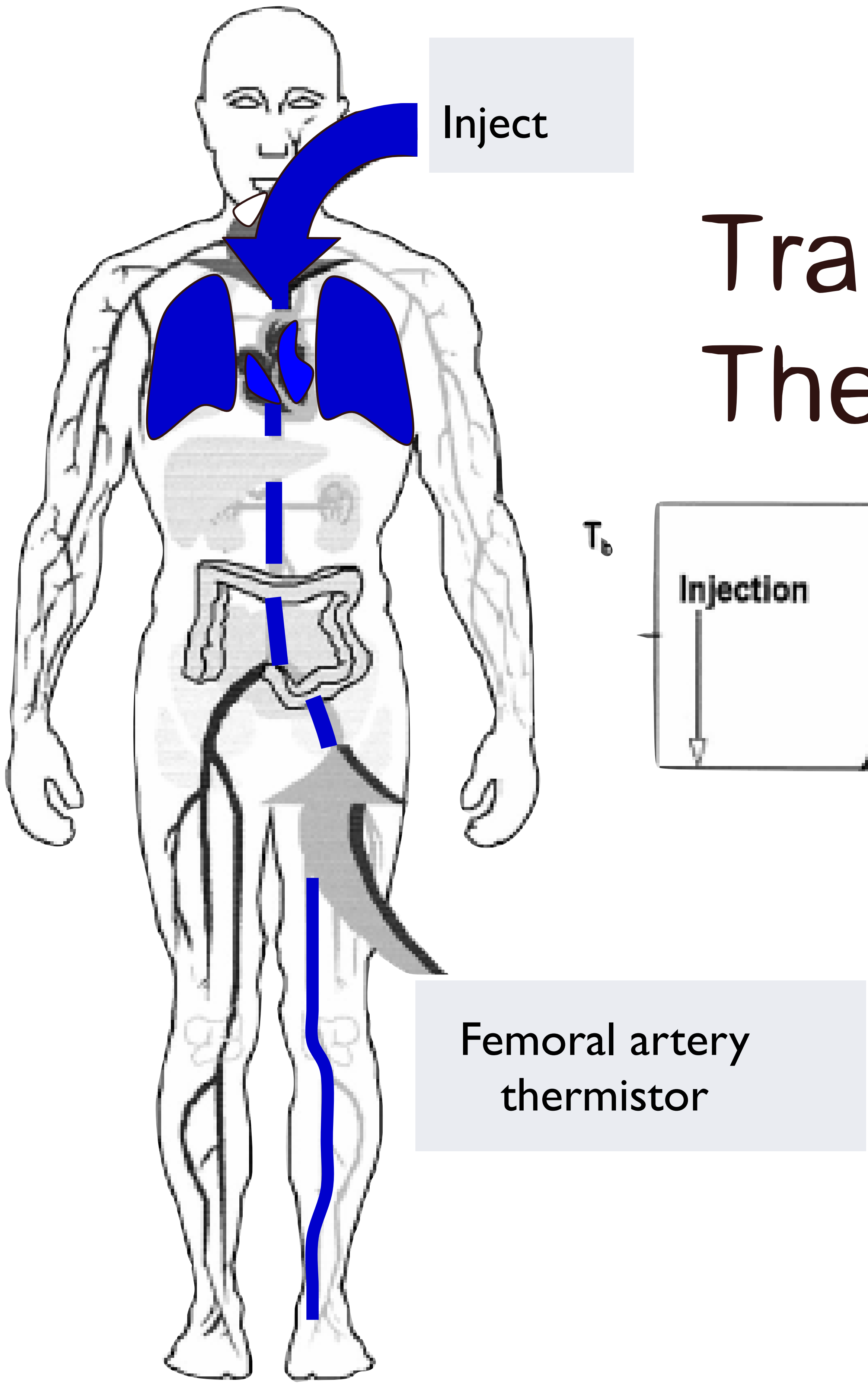
Shunt
    Pneumonia
    Pulmonary oedema
Dead space
    Pulmonary embolism
    Fat embolism
Mixed
    COPD
    Asthma

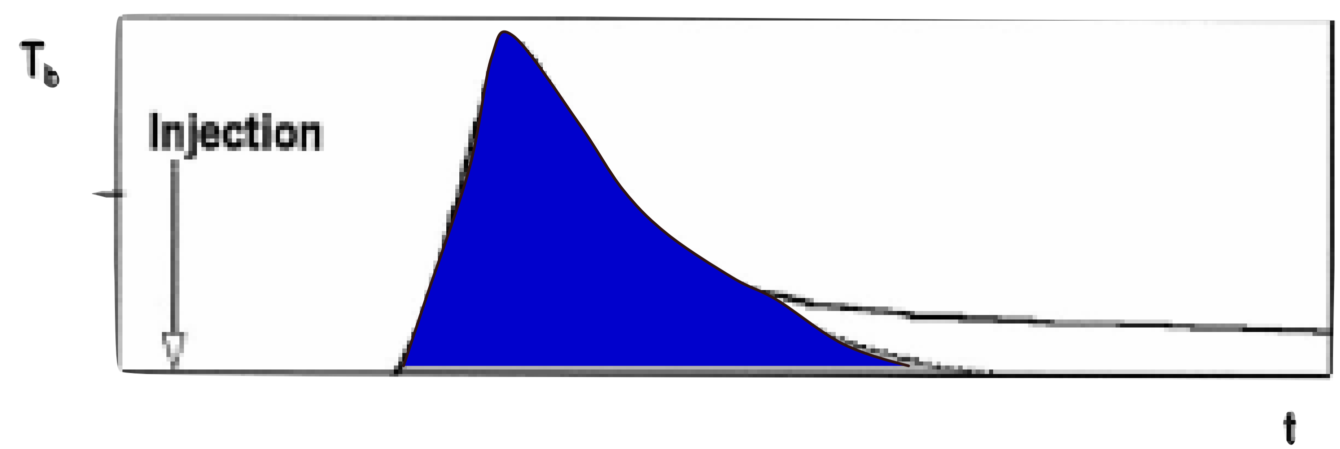
PICCO -

USES AND PITFALLS

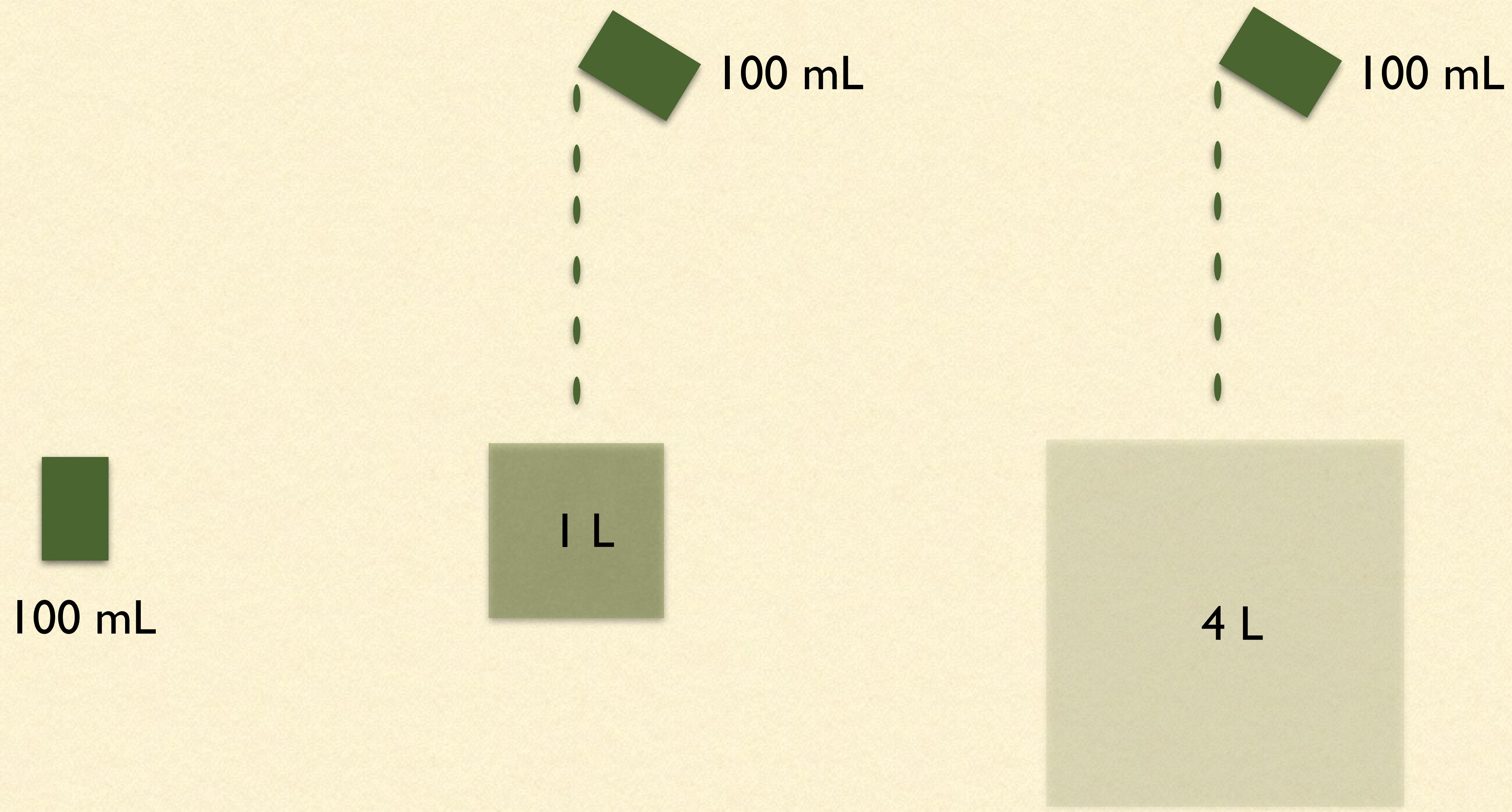
MEASUREMENTS

Transpulmonary Thermodilution



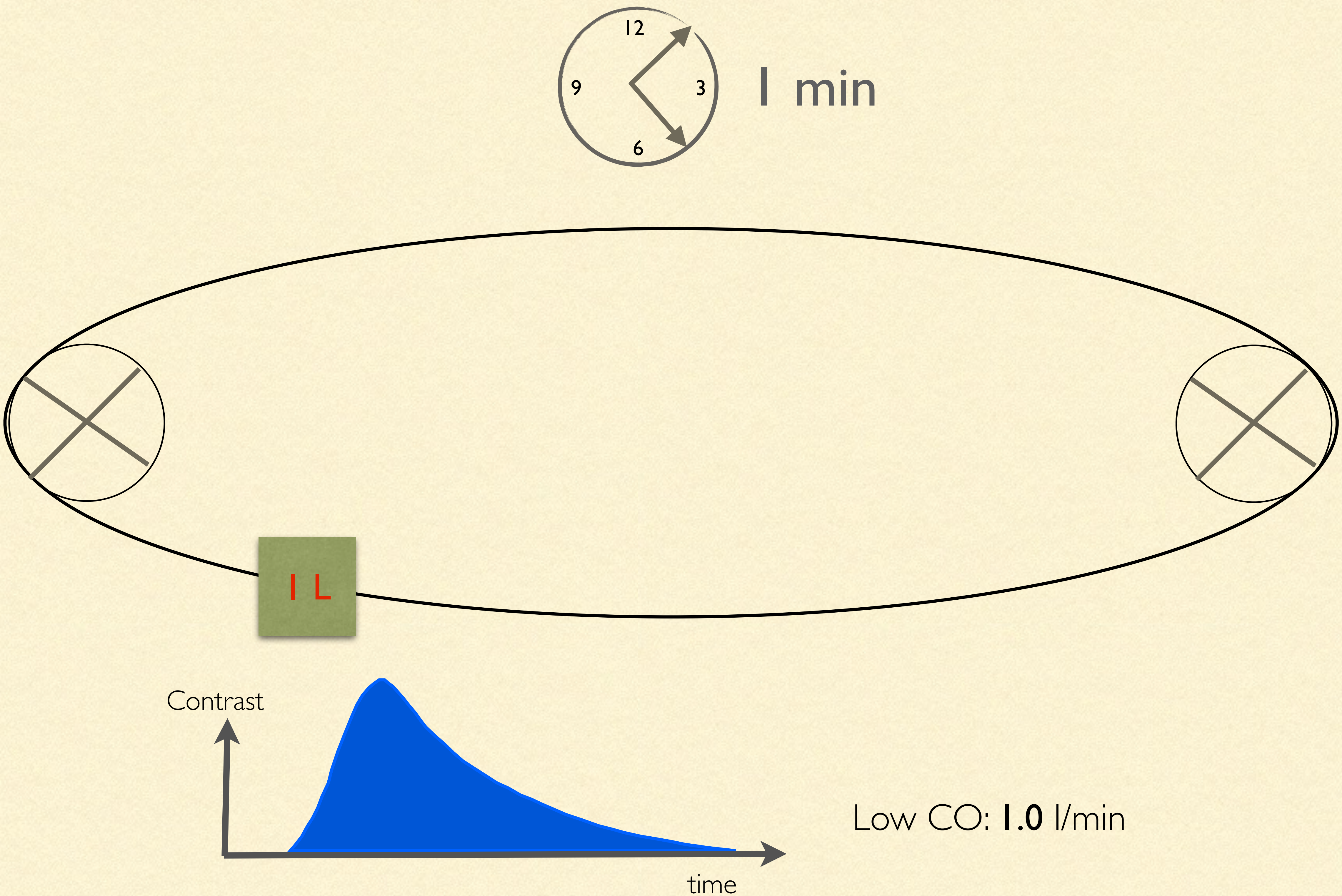


Determination of Thermodilution Cardiac Output



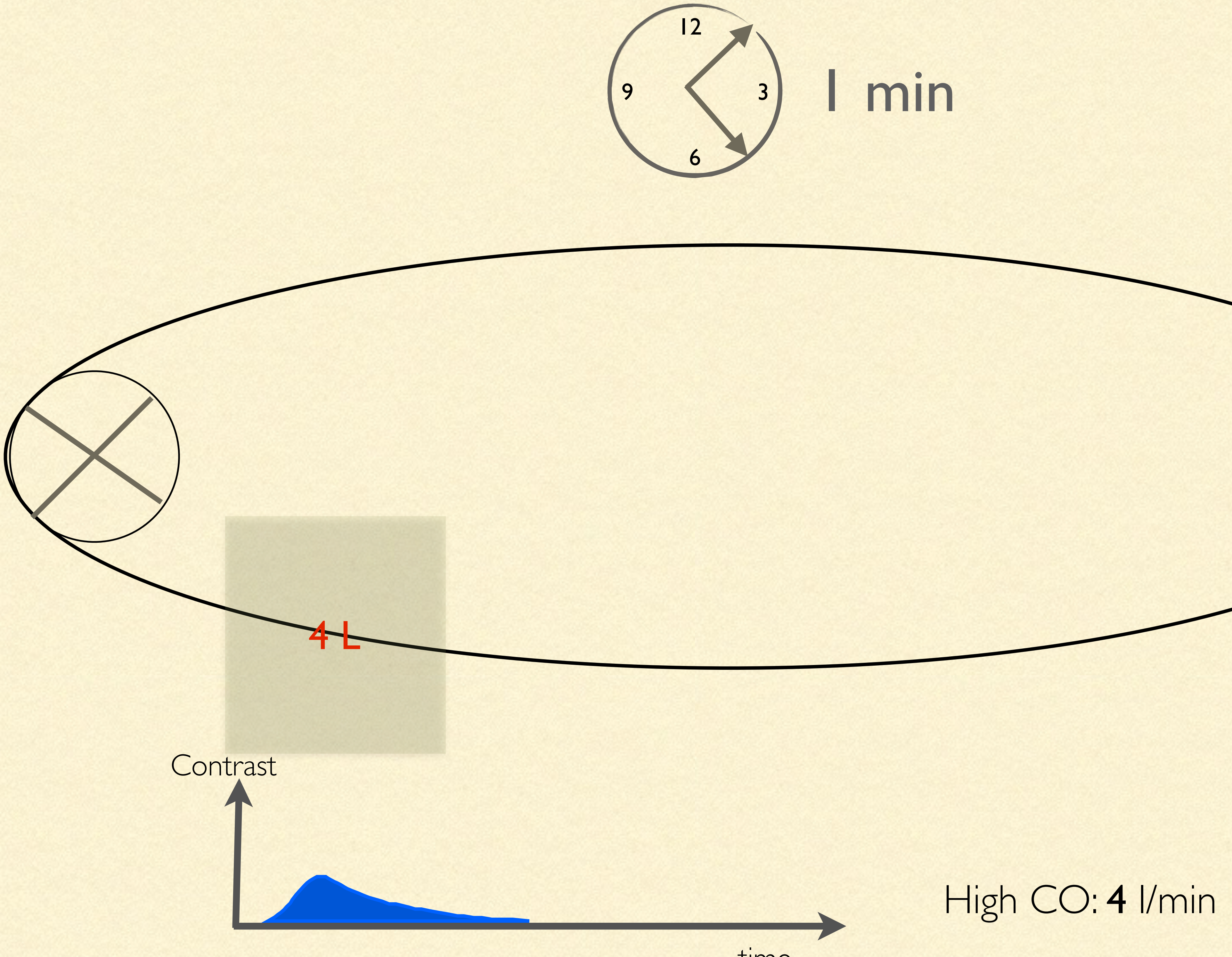
The more dilute the "dye", the larger the volume

Determination of Thermodilution Cardiac Output



Volume per time = cardiac output = 1L/min

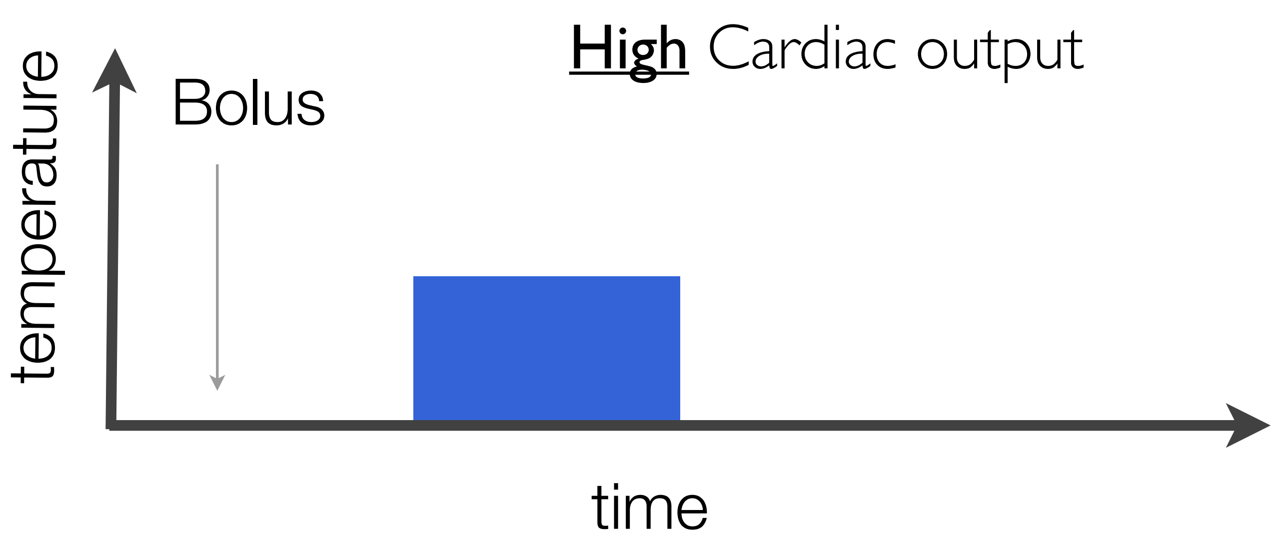
Determination of Thermodilution Cardiac Output



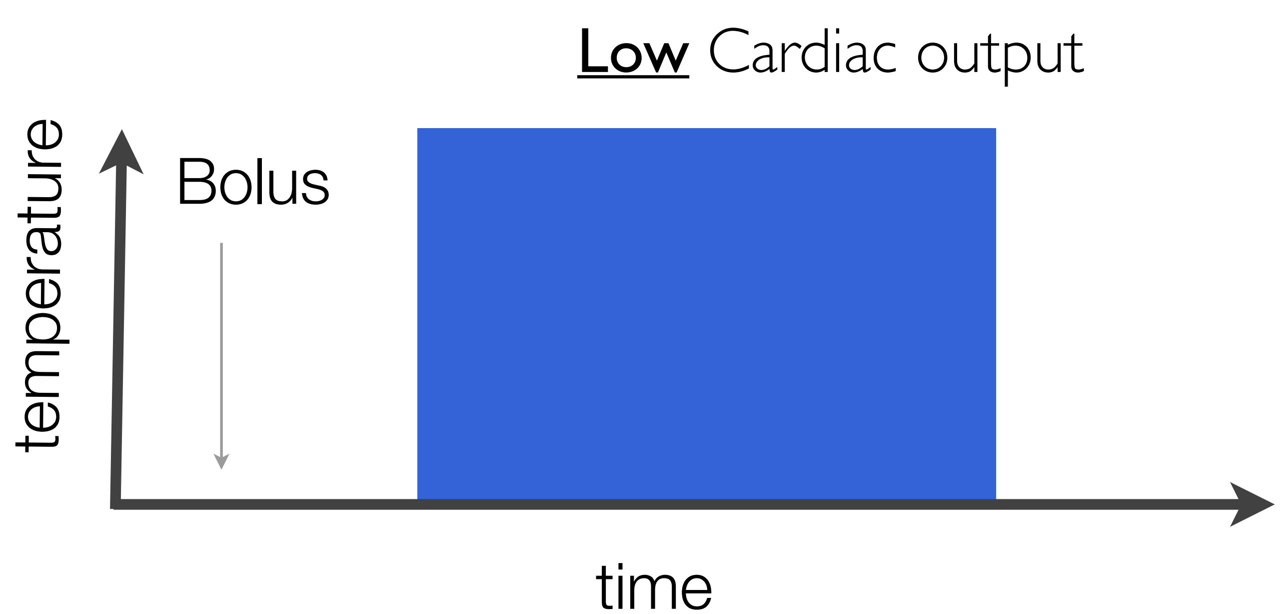
Volume per time = cardiac output = 4 L/min

Determination of Thermodilution Cardiac Output

Cardiac output calculated by thermodilution curve.
Central venous injection of cold indicator,
Thermistor at the tip of the arterial catheter measures the temperature change downstream.

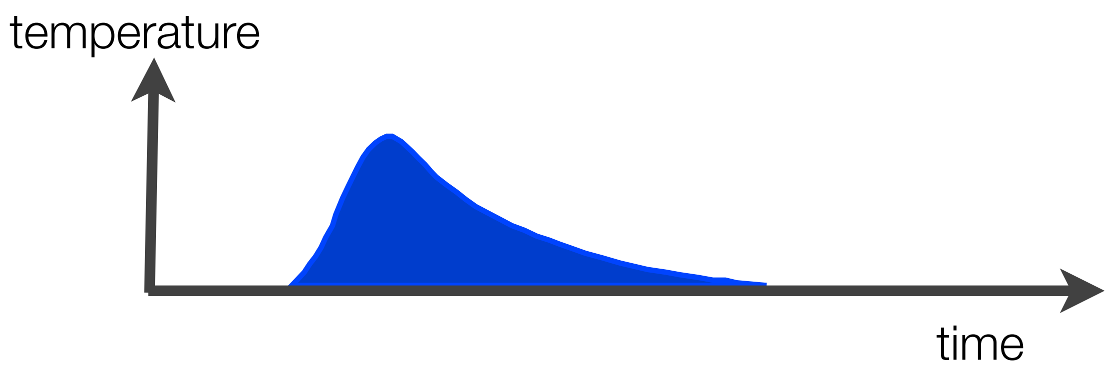


Cardiac output relates ***inversely*** to the diluted indicator **concentration** and its transit **duration**

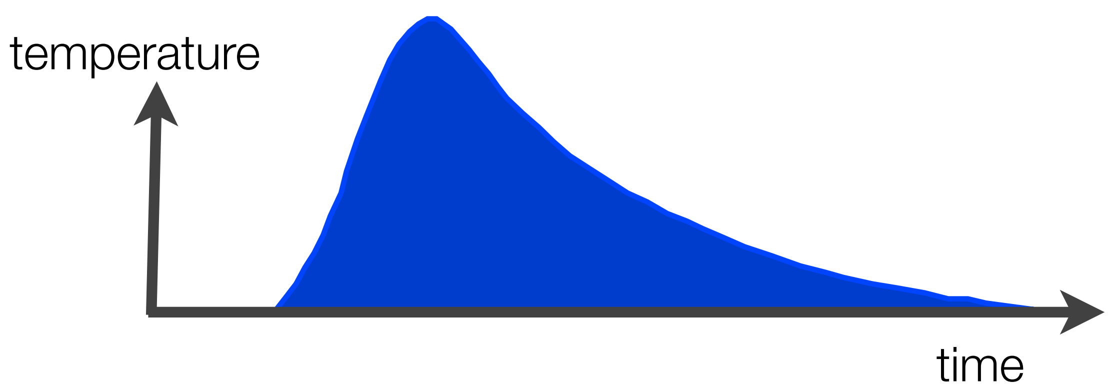


Area under the thermodilution curve is **inversely** proportional to **CO**

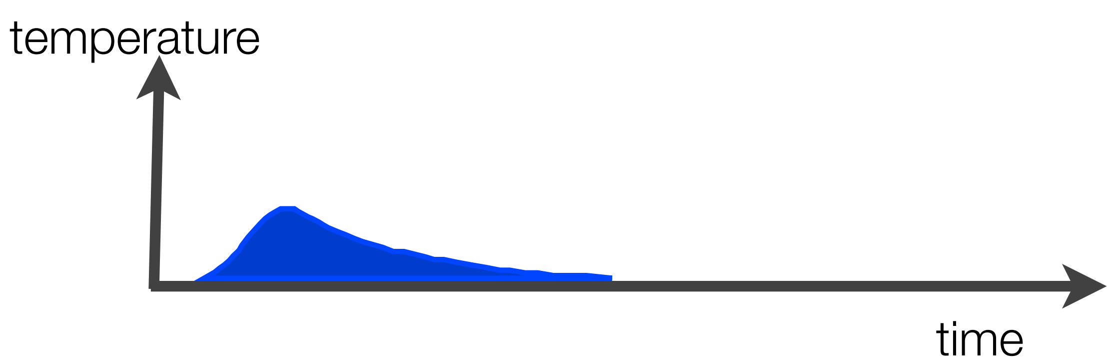
The Area under the curve is inversely proportional to the C.O.



Normal CO: **5** l/min



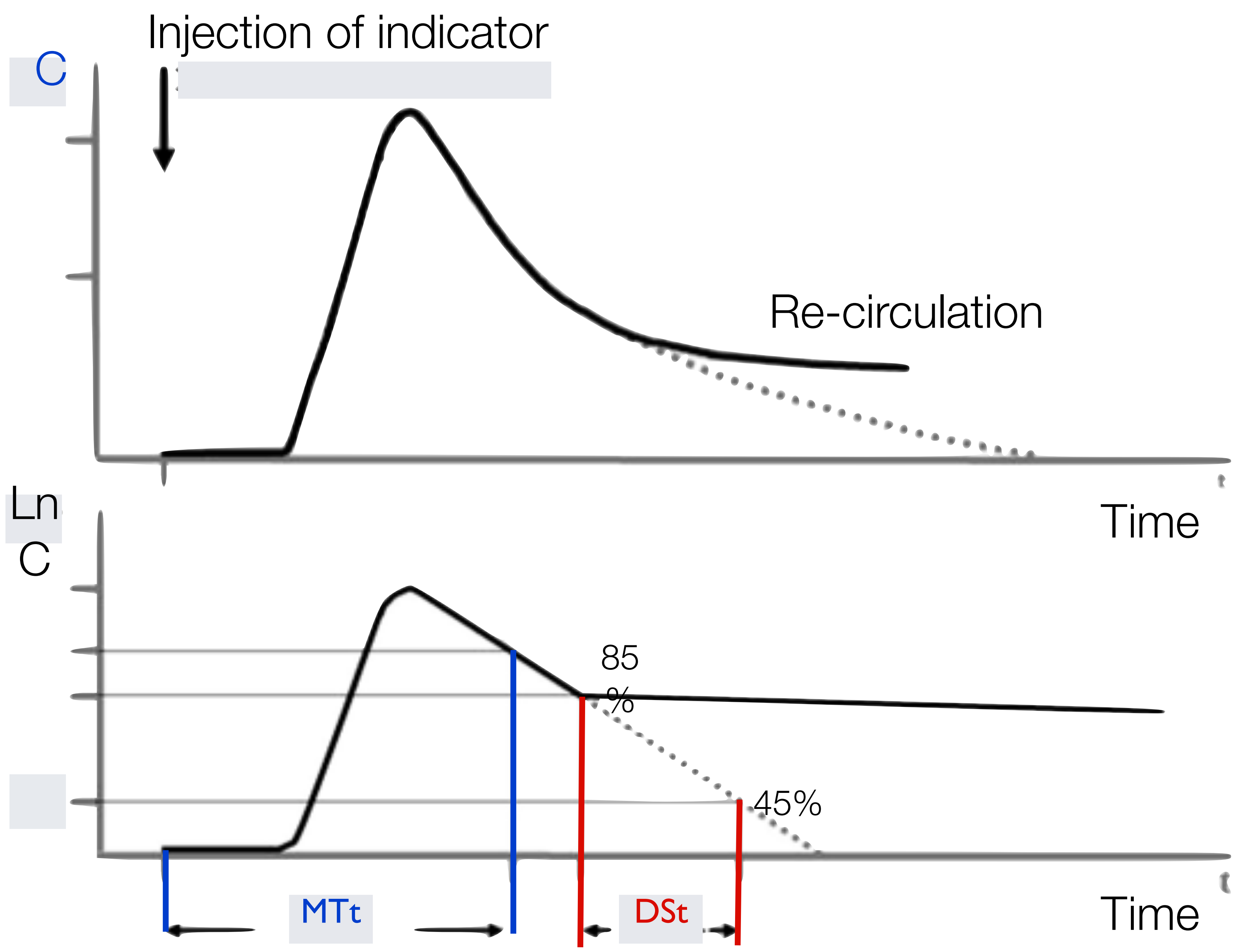
Low CO: **1.9** l/min

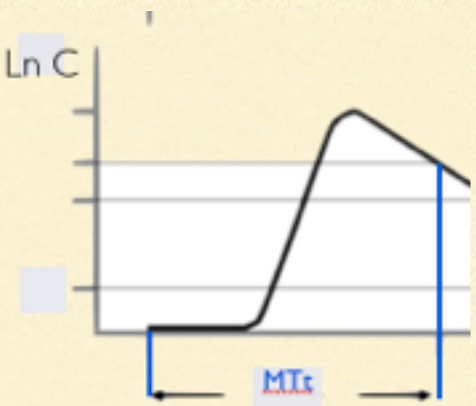


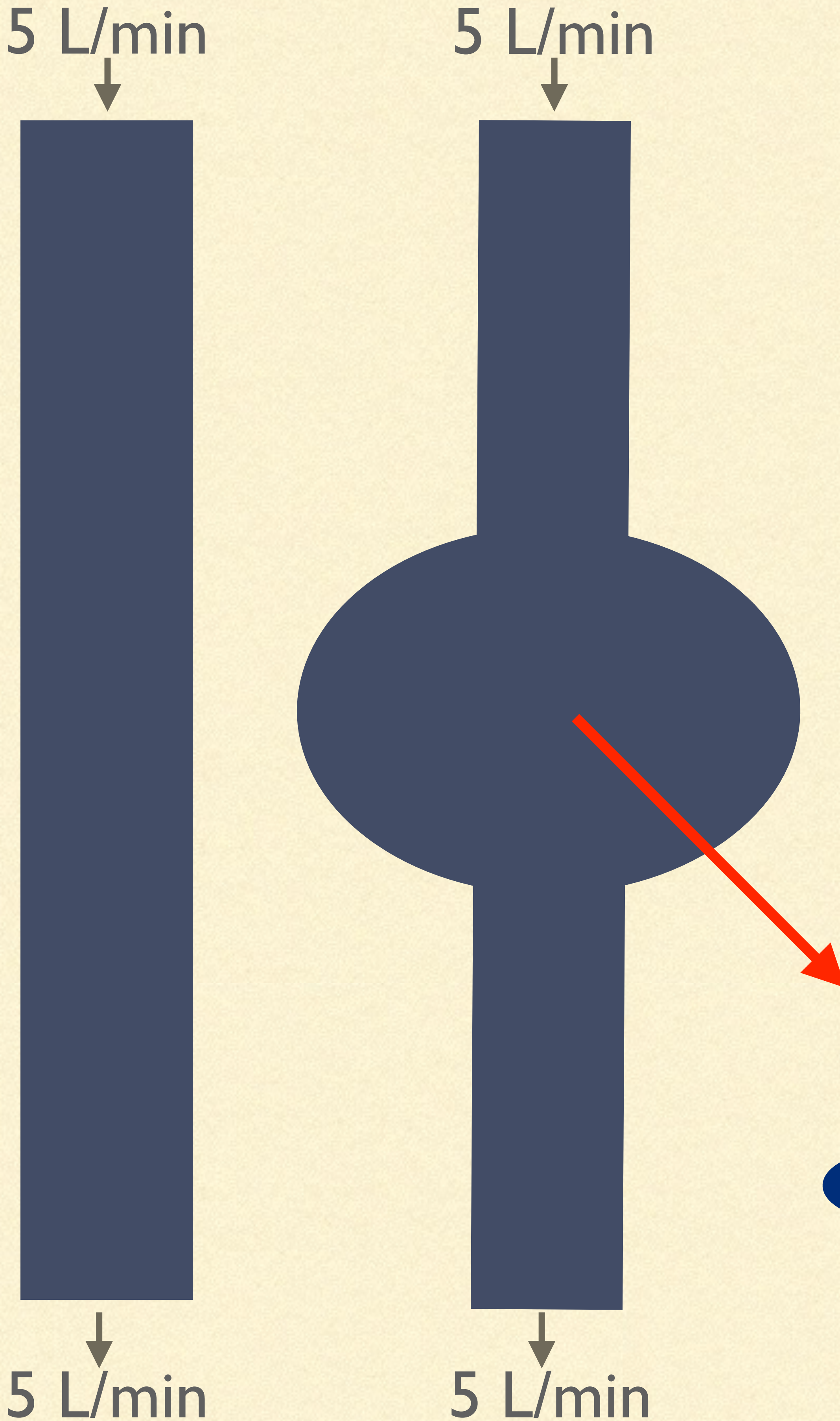
High CO: **12** l/min

CALCULATIONS

Calculation of ITTV and PTV

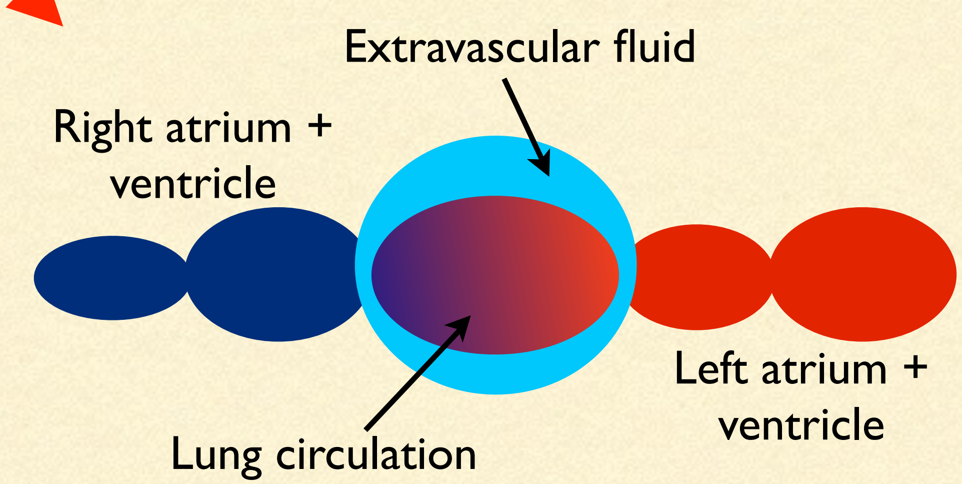




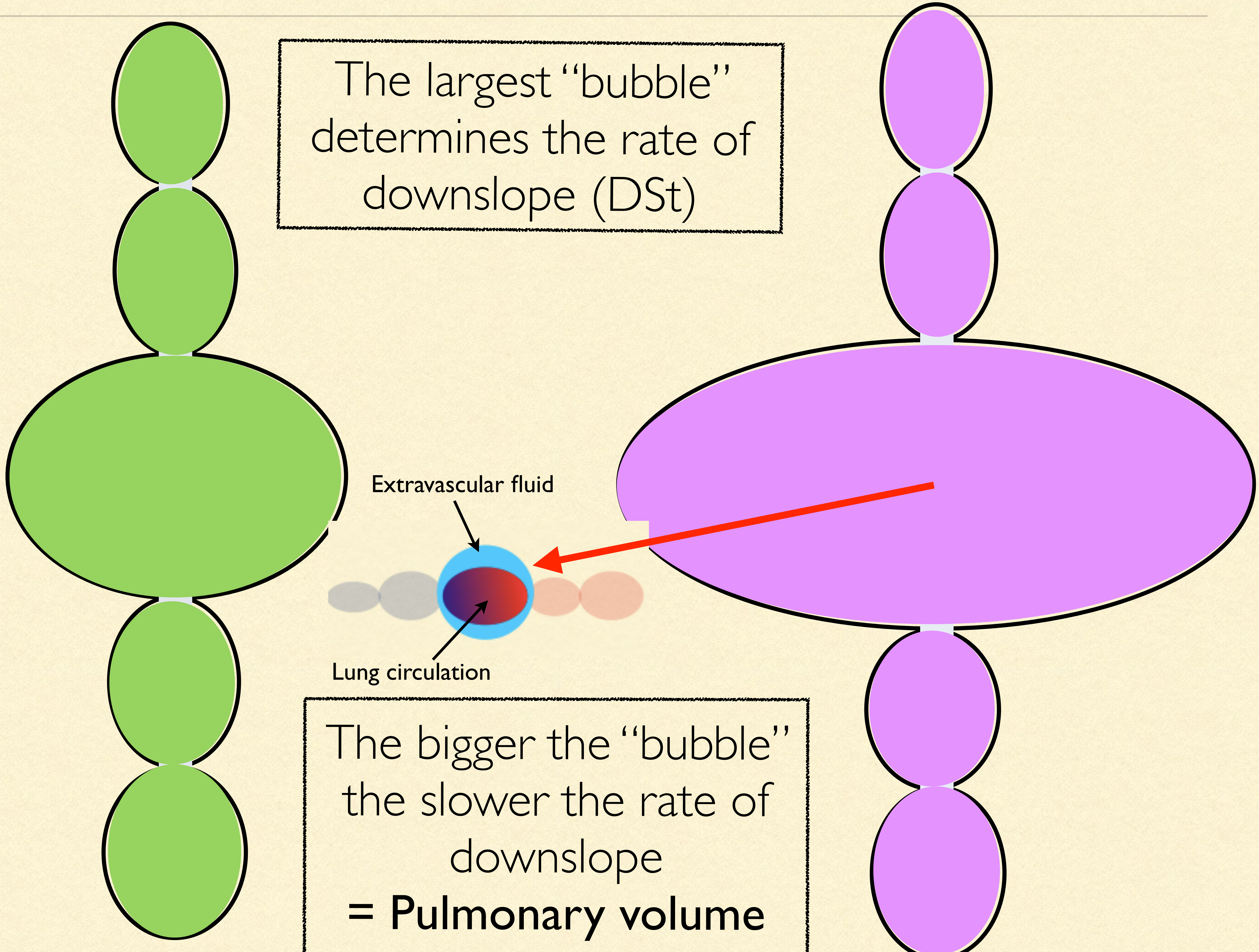


The **larger** the "bubble" the **longer** the Mean Transit Time (MTt)

The "bubble" = **Intra-thoracic volume**



The largest "bubble" determines the rate of downslope (DSt)

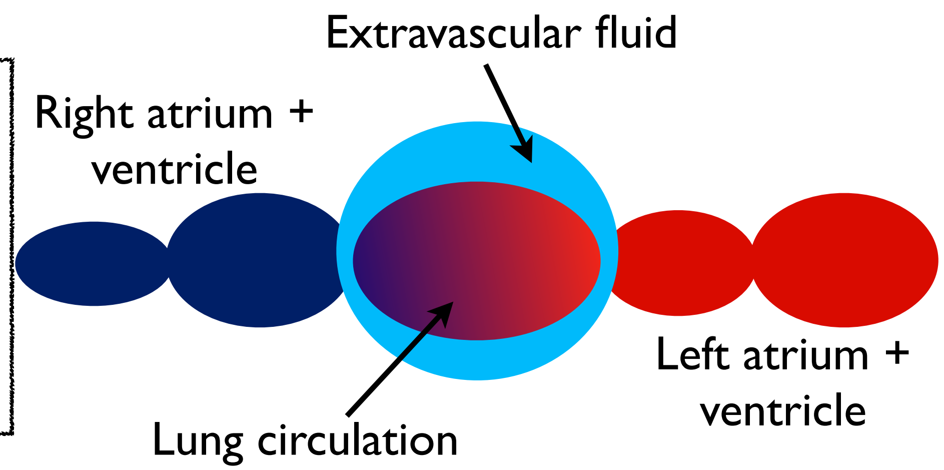


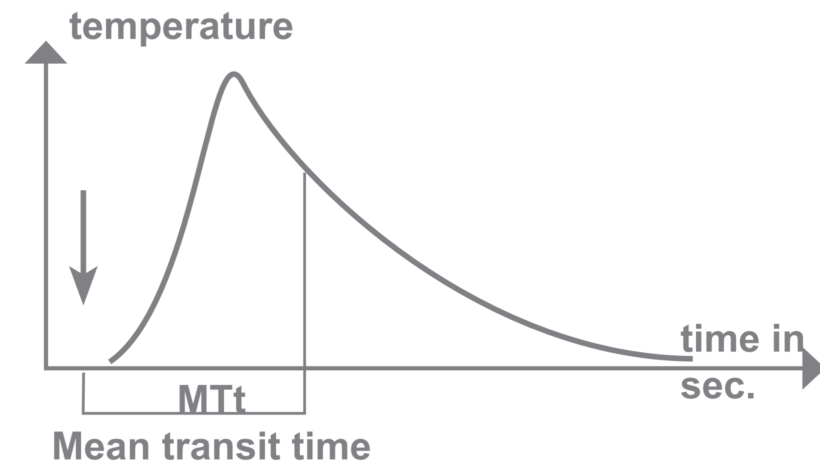
The bigger the "bubble" the slower the rate of downslope

= Pulmonary volume

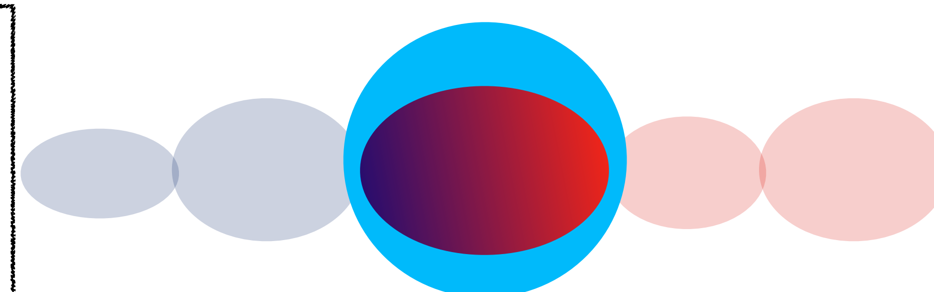
Calculation of Volumes

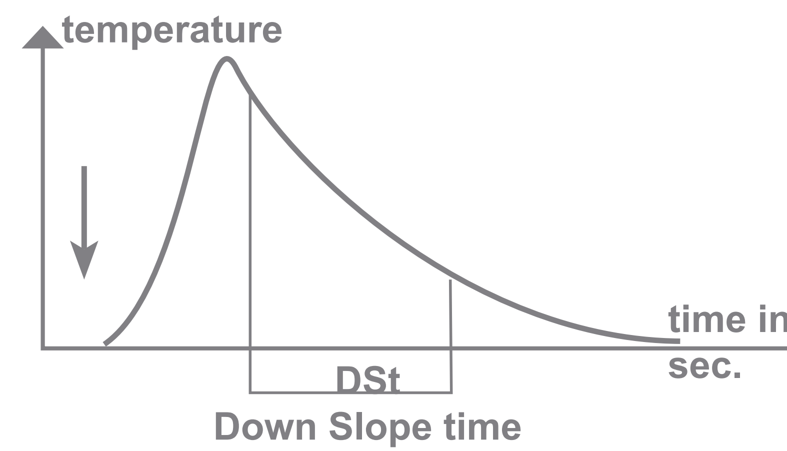
Intra-thoracic Thermal Volume
ITTV=CO x MTt



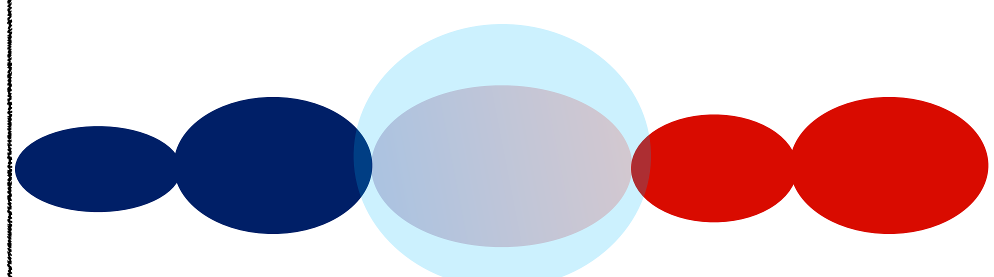


Pulmonary Thermal Volume
PTV=CO x DSt





Global End Diastolic Volume
GEDV =ITTV-PTV



Intrathoracic Volumes

ITTV = thermal volume of chest

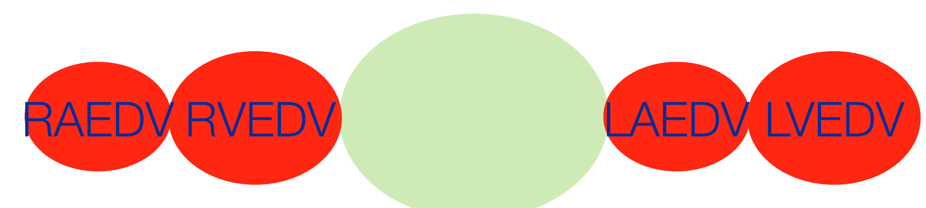
= CO x MTt

PTV = thermal volume of lung

= CO x DSt

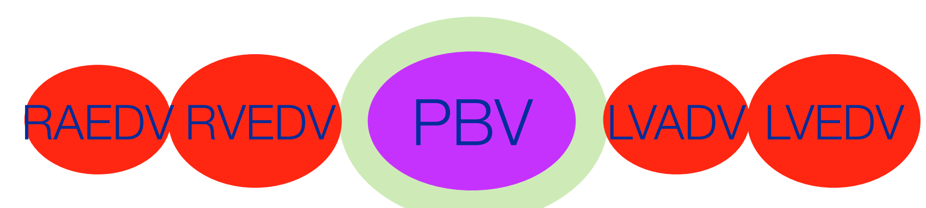
GEDV = volume of blood in heart

= ITTV - PTV

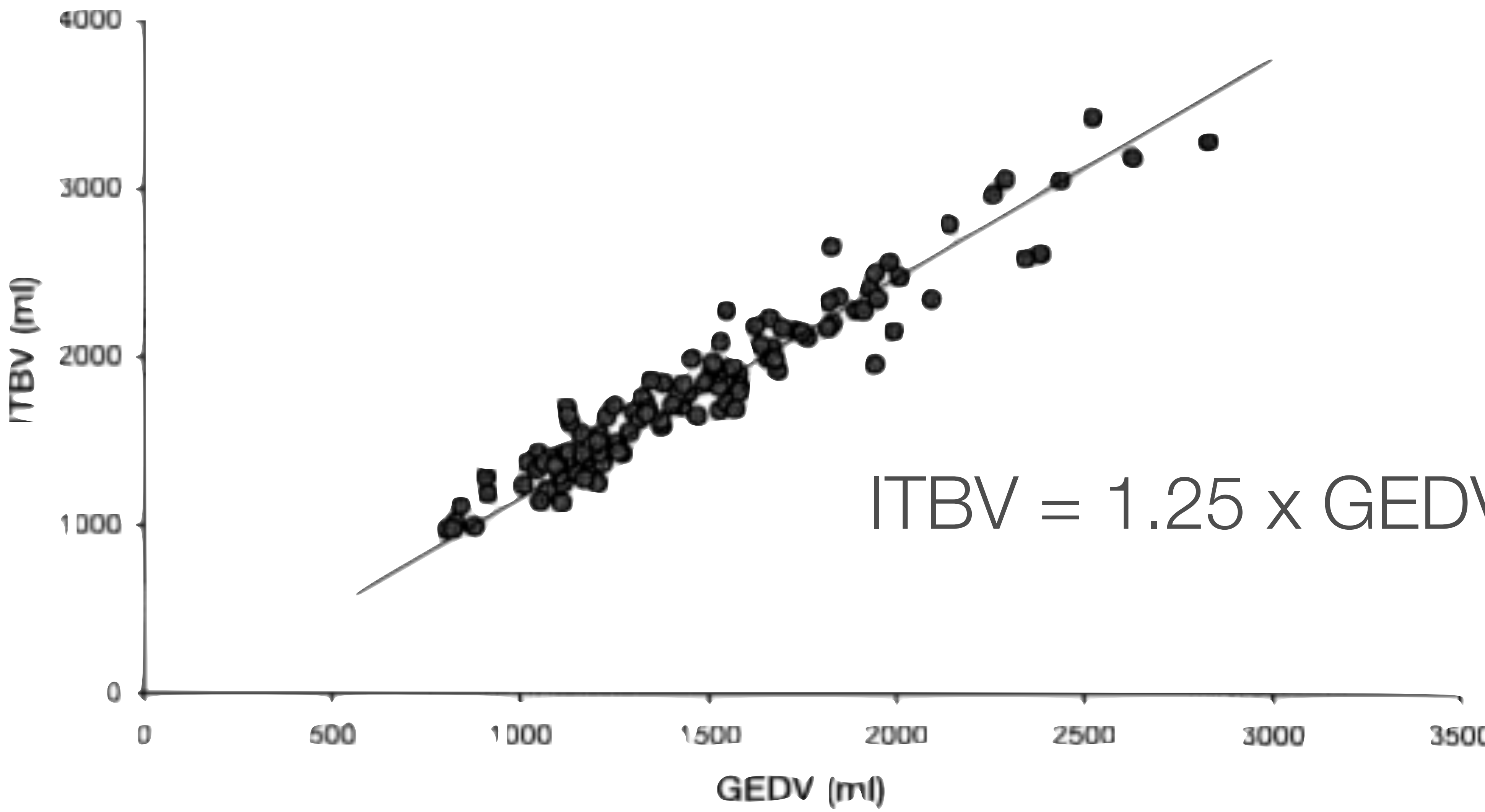


ITBV = volume of blood in chest

= 1.25 x GEDV



Volumetric preload parameters - ITBV



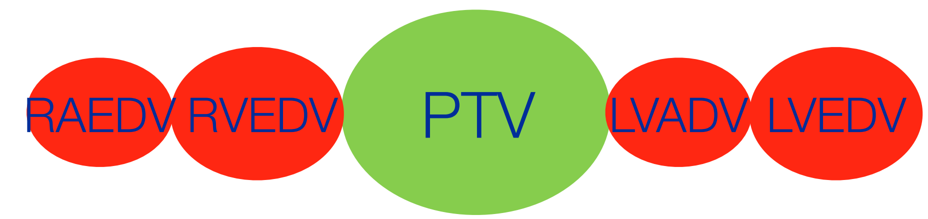
ITBV = 1.25 x GEDV

Intensive Care Med (2000) 26: 180±187

Intrathoracic Volumes

ITTV = thermal volume of chest

= CO x MTt

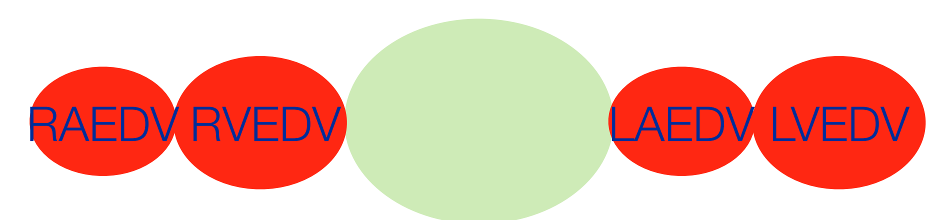


PTV = thermal volume of lung

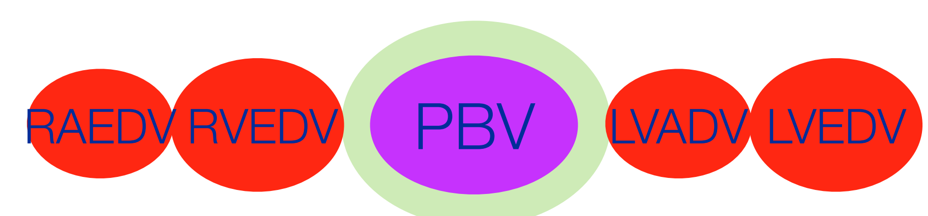
= CO x DSt

GEDV = volume of blood in heart

= ITTV - PTV



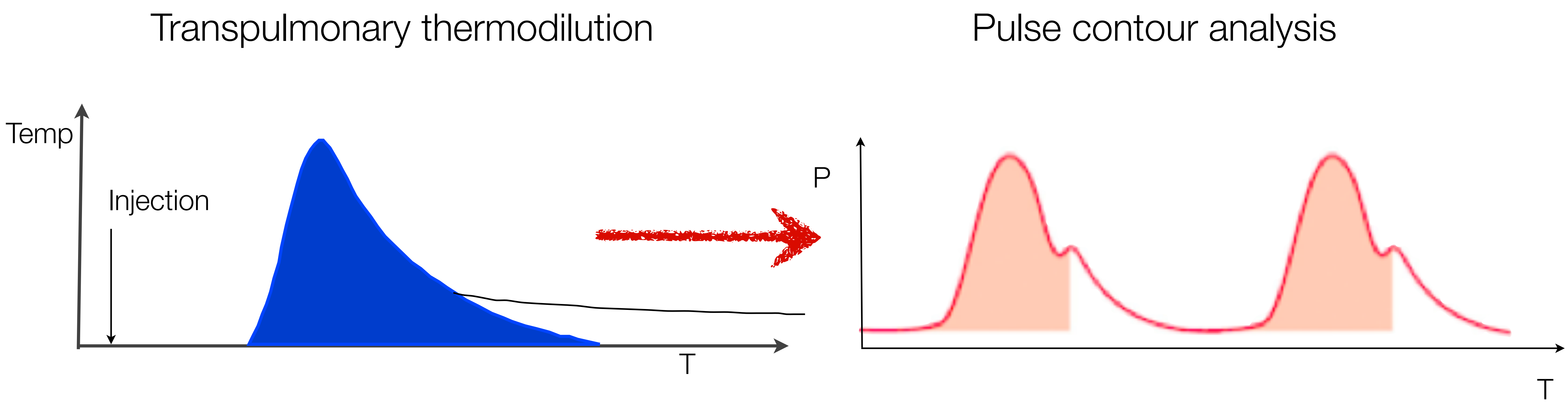
ITBV = volume of blood in chest = 1.25 x GEDV



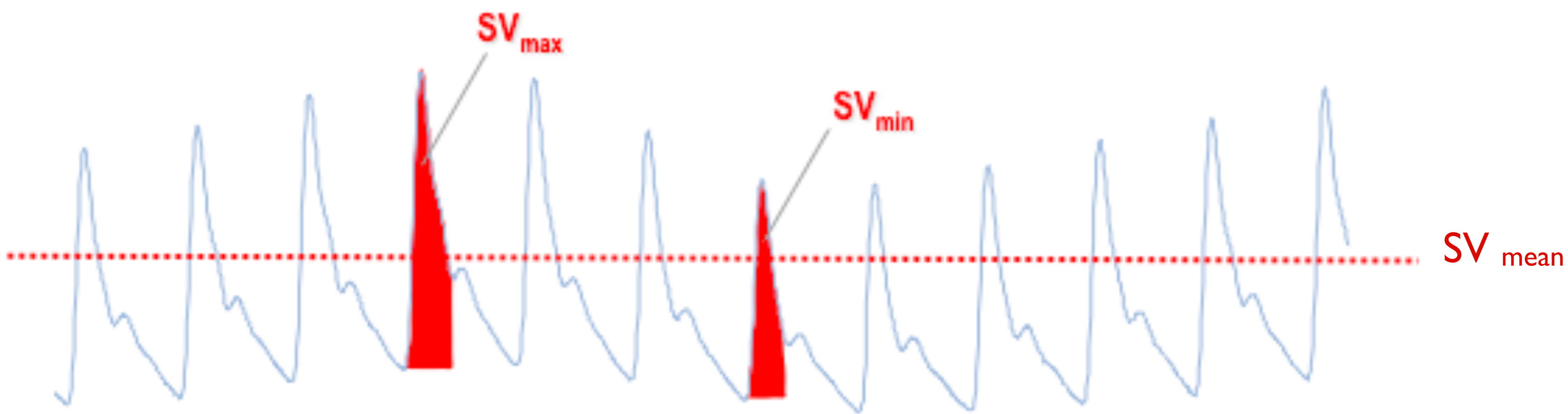
EVLW = ITTV - ITBV

Calibration of the Pulse Contour Analysis

The PCA is calibrated through the transpulmonary thermodilution
and is a beat to beat real time <u>analysis</u> of the arterial pressure curve



Dynamic tests of fluid responsiveness
- Stroke Volume Variation (SVV)

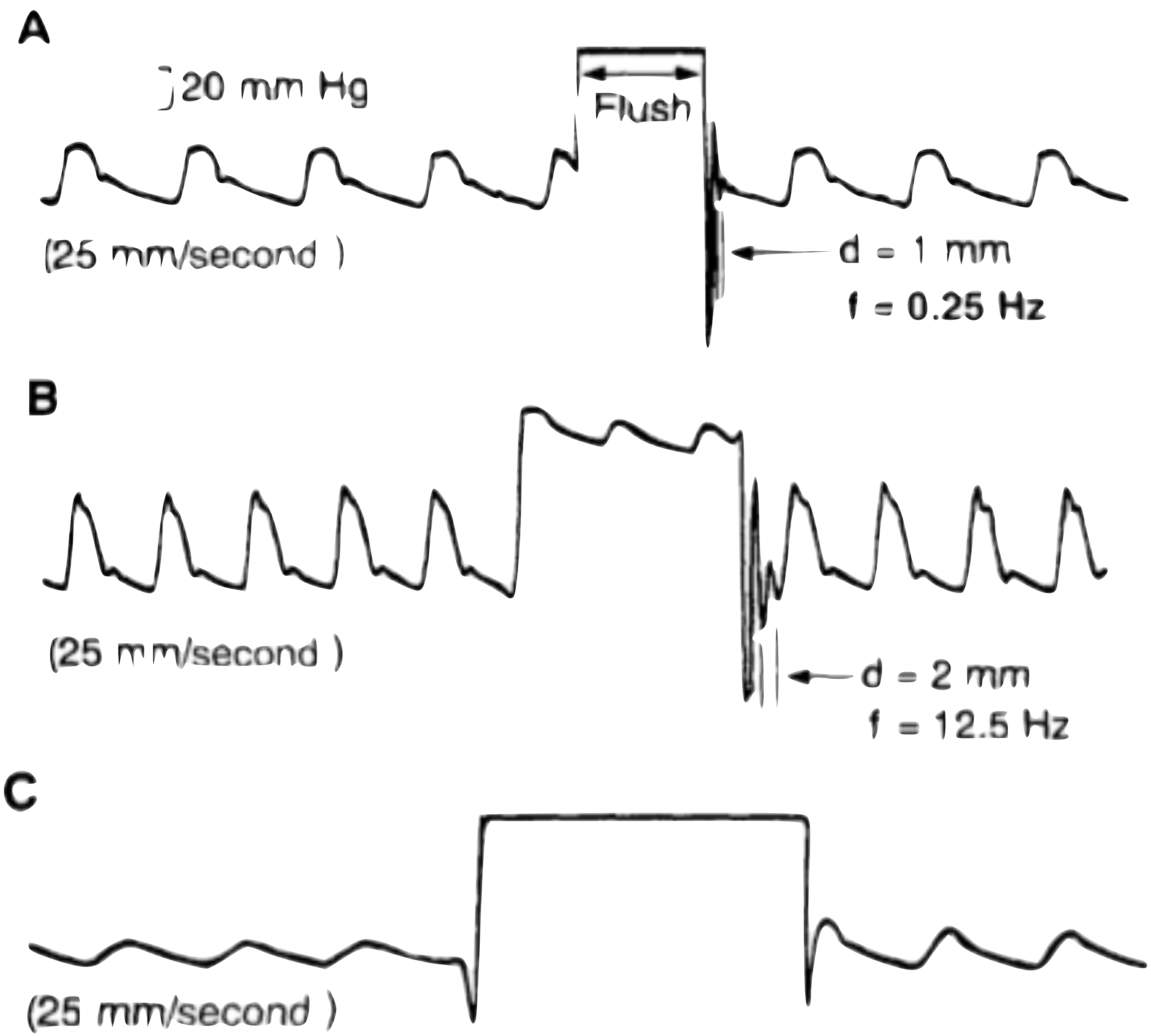


$SVV = SV_{max} - SV_{min} / SV_{mean}$

The SVV is the variation in stroke volume over the ventilatory cycle.

Always test your measuring system

Flush test



Normal

Under damped

Over damped

Pitfalls in Measurement

- Loss of indicator **before** injection:
    - if 10 ml was "expected" and only 9 ml actually injected, overestimate CO by 11%
- Loss of indicator **after** injection:
    - Conductive rewarming more pronounced in low flow states or when distances are longer (ex. femoral injection).
    - Mass diversion:
        - R-L shunt
        - VV extracorporeal circulation
        - Valvulopathy
        - Femoral to femoral transfer of indicator if catheters placed together
- Fluctuations of baseline temperature:
    - Therapeutic hypothermia

Anesth Analg 2010;110:799–811

Pitfalls in Measurement

Consider:

Sources of error of CO MTt and DSt are all <u>calculated</u> from the same graph and the volumes all use CO.

All this <u>**magnifies**</u> any error.

Anesth Analg 2010;110:799–811

CLINICAL CASES

Clinical Case

21 yr old pregnant woman with Swine Flu

CO - 3.9l/min

P/F of 11

EVLW increasing rapidly (7->35!)

SVV - 17

Later needed renal dialysis

Given her poor lung state, where would you cannulate?

Effect on PICCO readings?

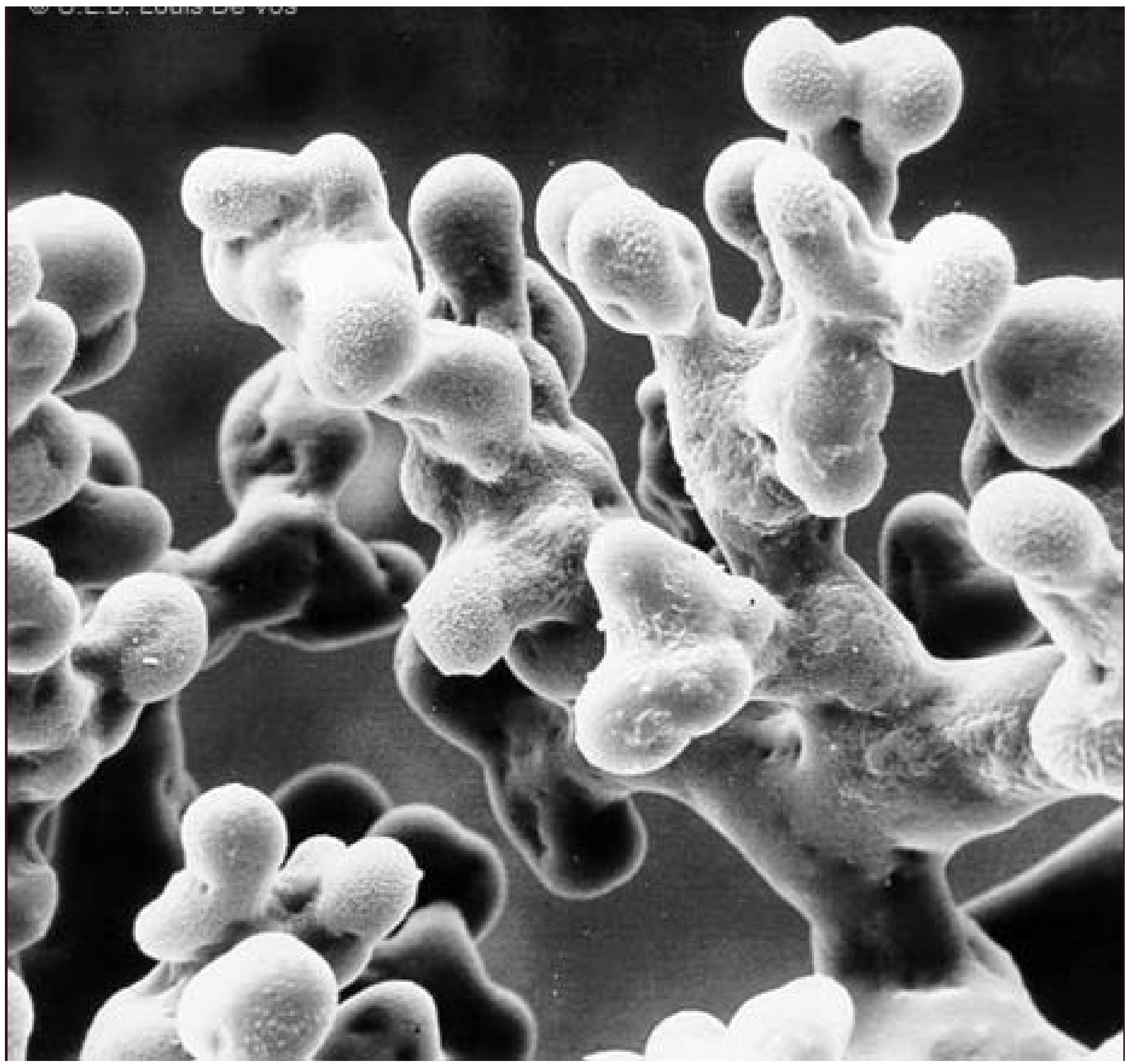
EVLW - How much?

- 7-10 ml/kg predicted body weight
- 50 kg person - 1/2 of a liter
- 1/2 liter = 0.9 pints

The lung is dry and dry is good

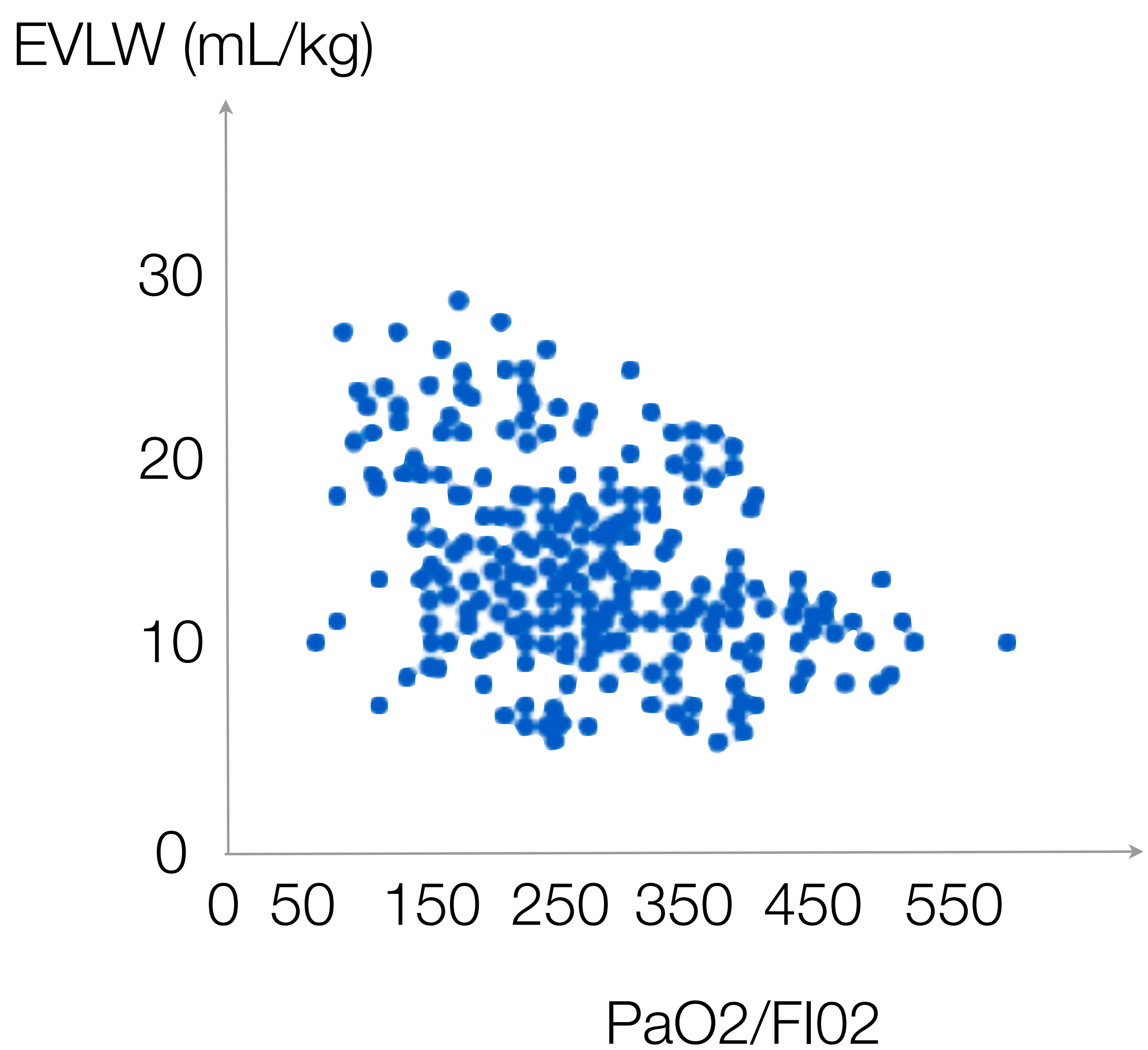
- Lung is a dry place
- Increase EVLW by only 200- 300 ml - your drowning
- In ALI, mortality approaches 100% if EVLW >14 ml/kg on day 1

Alveolar surface area covers a tennis court



Normal volume of lung water

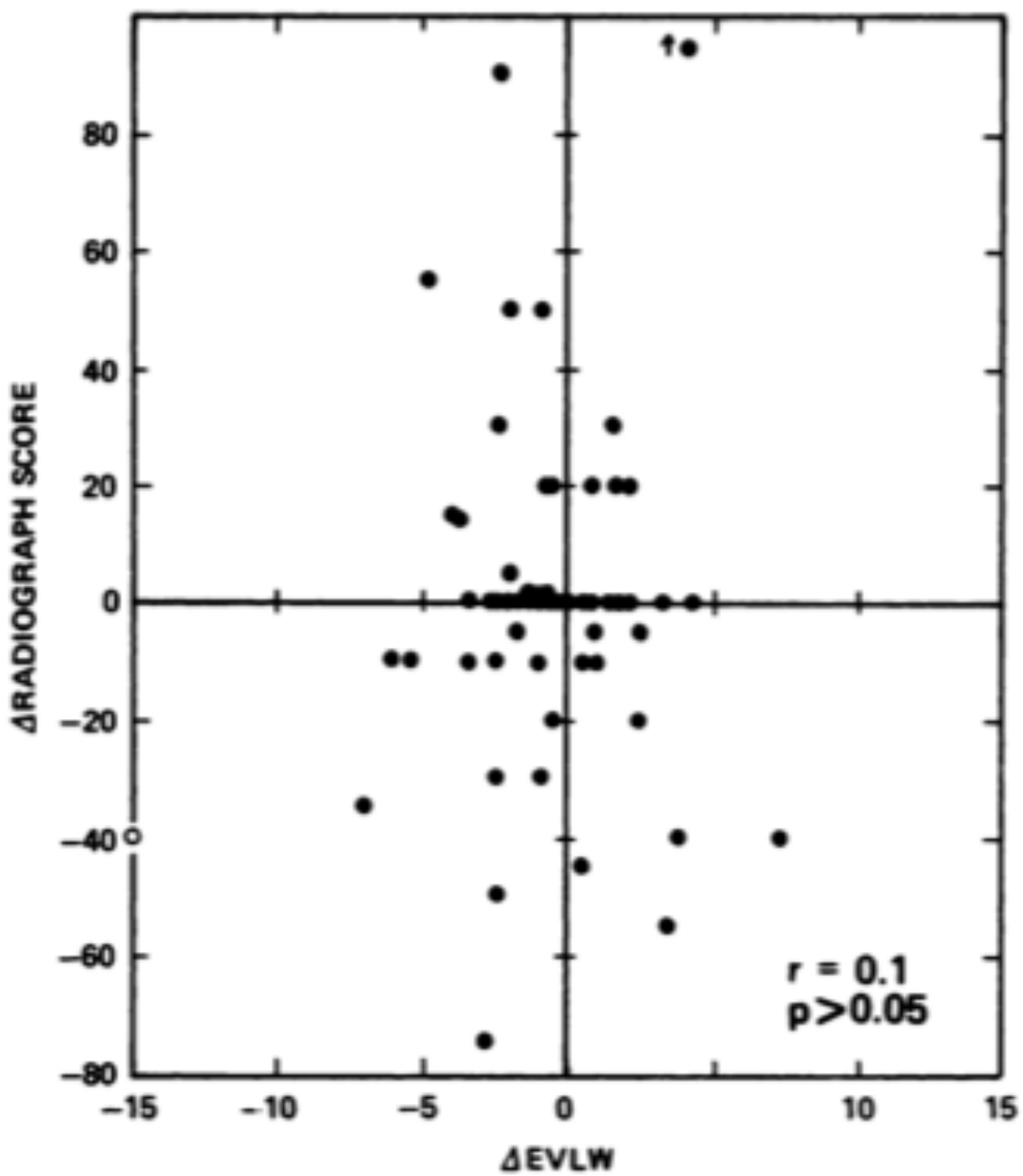
High EVLW is not reliable identified by blood gas analysis



Boeck J, J Surg Res 1990; 254-265

EVLW as a quantifier of lung oedema

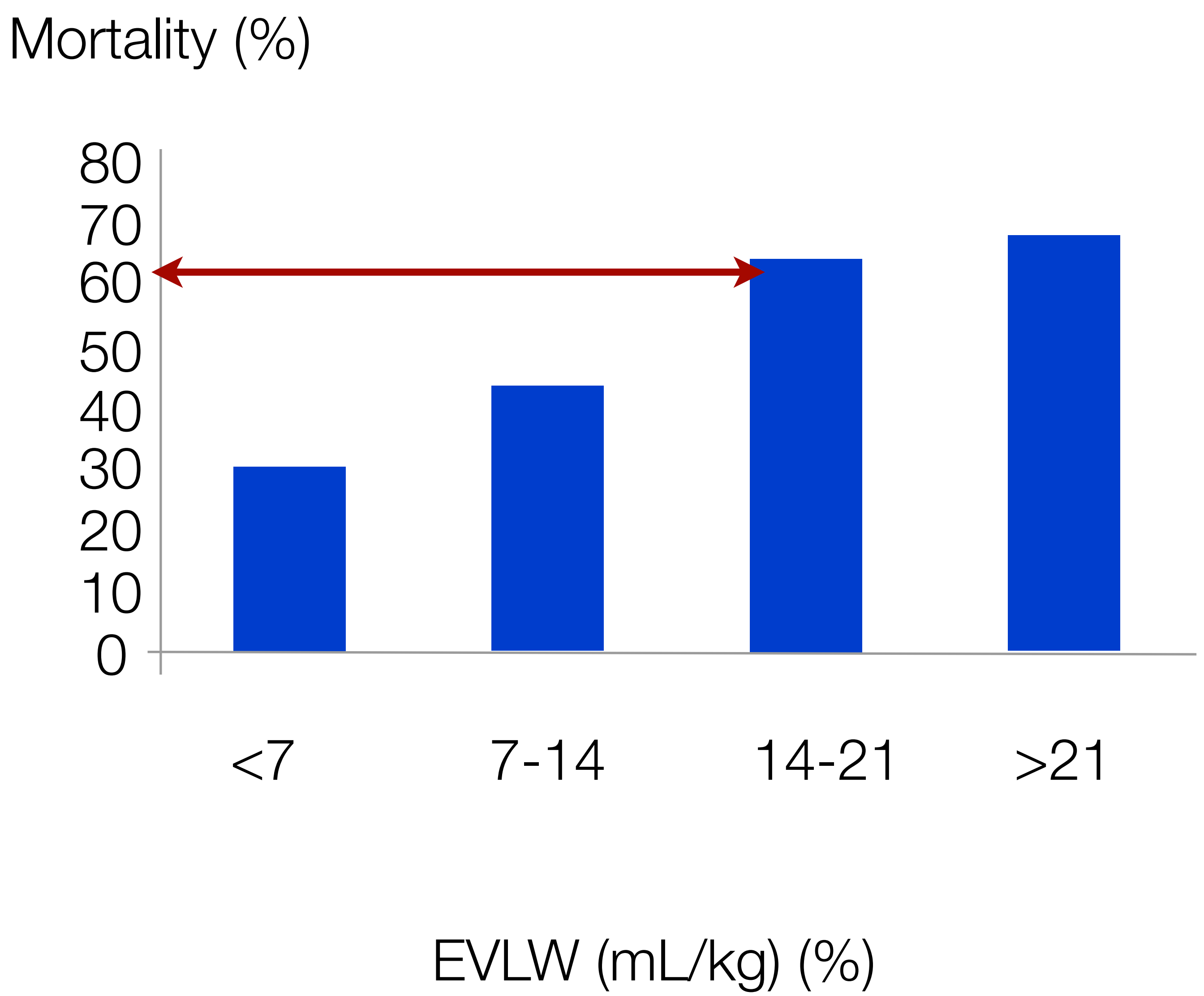
Evaluation of the Portable Chest Roentgenogram for Quantitating Extravascular Lung Water in Critically Ill Adults*



CXR does **not** reliably **quantify** pulmonary oedema

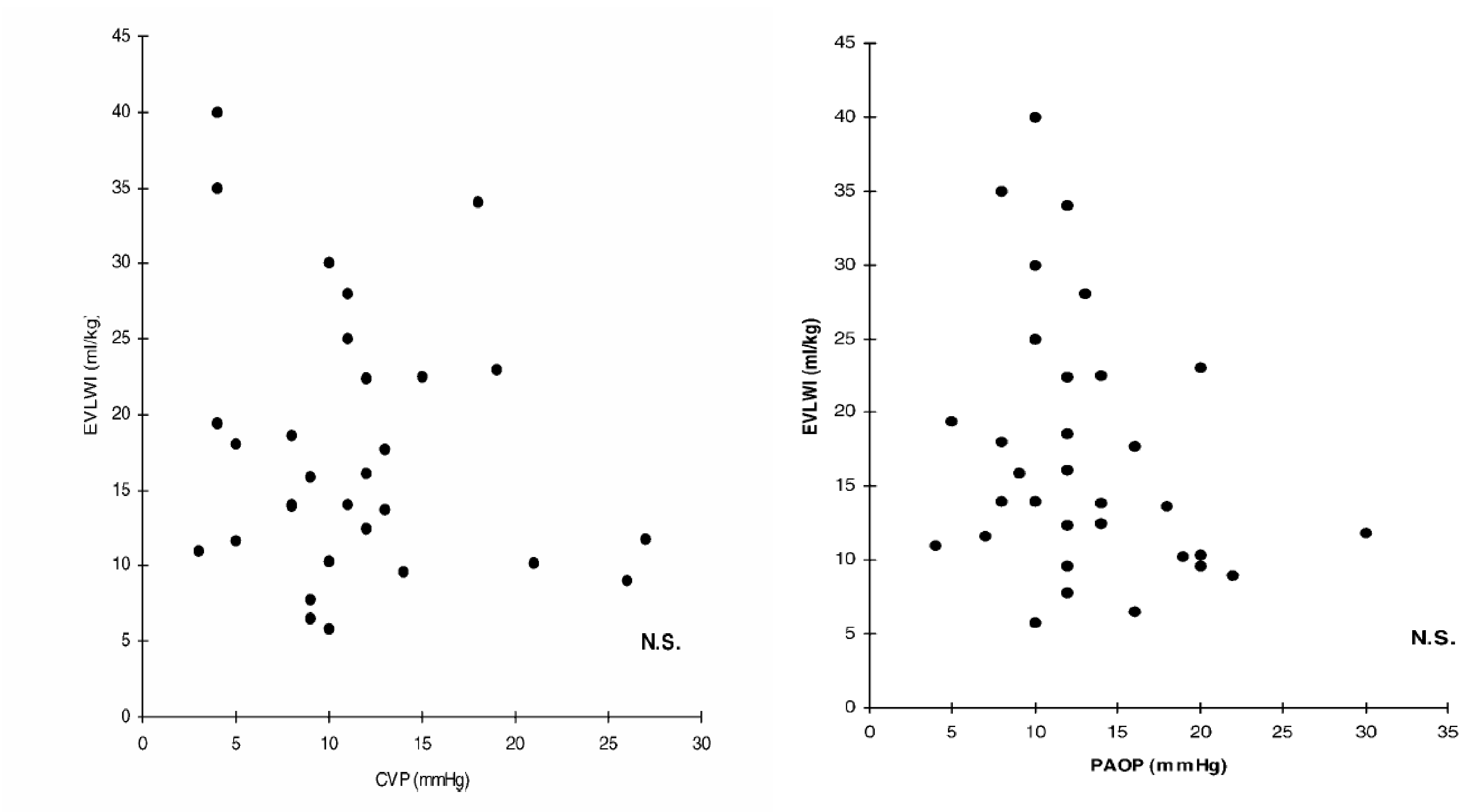
CHEST I 88 I 5 I NOVEMBER, 1985

Amount of EVLW is a predictor for mortality



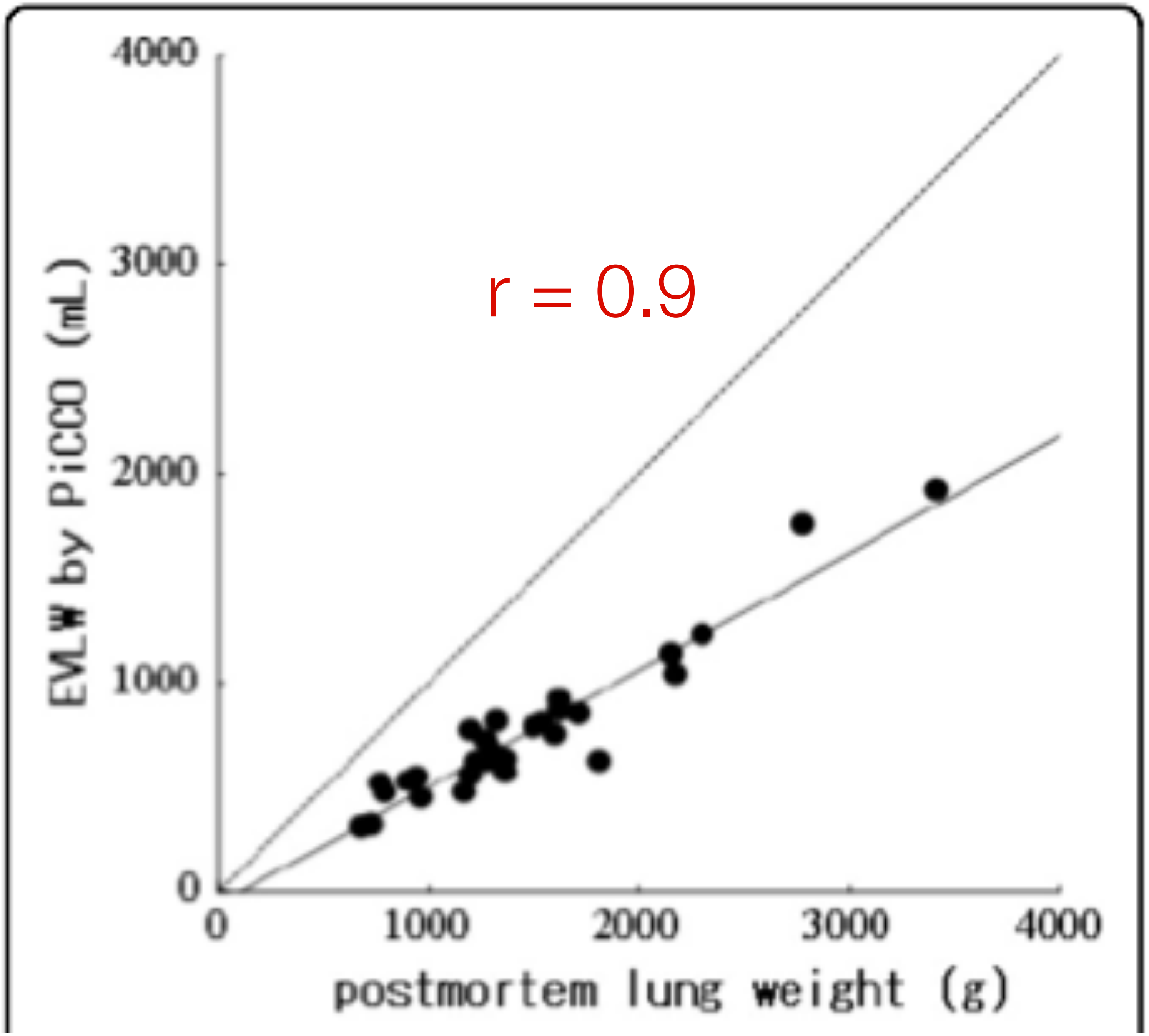
CHEST / 122 / 6 / DECEMBER, 2002

CVP and PAOP do not correlate with development of lung water



Boussat Intensive Care Medicine 2002;28

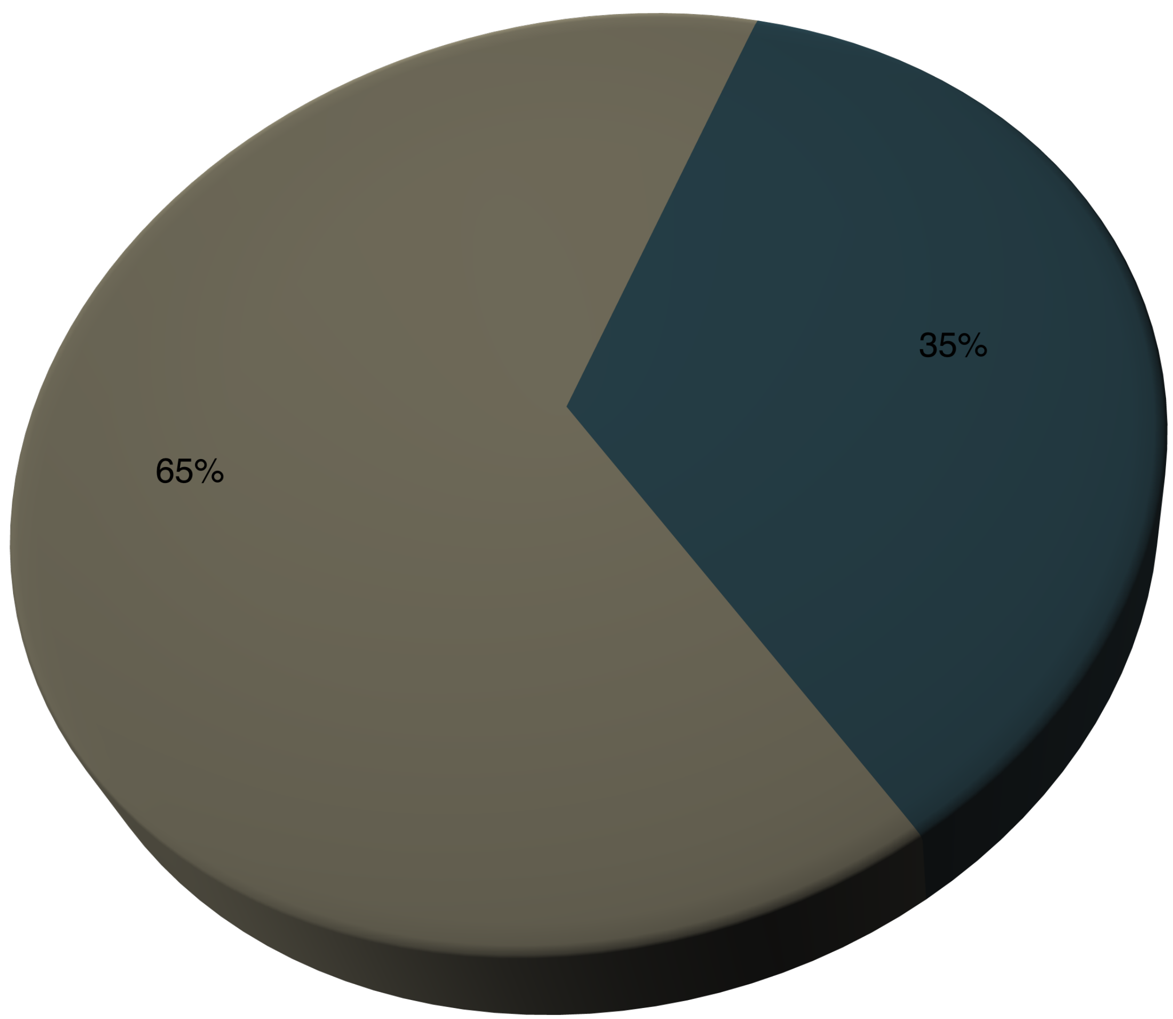
Validation of extravascular lung water measurement: human autopsy study



Critical Care 2010, 14:R162

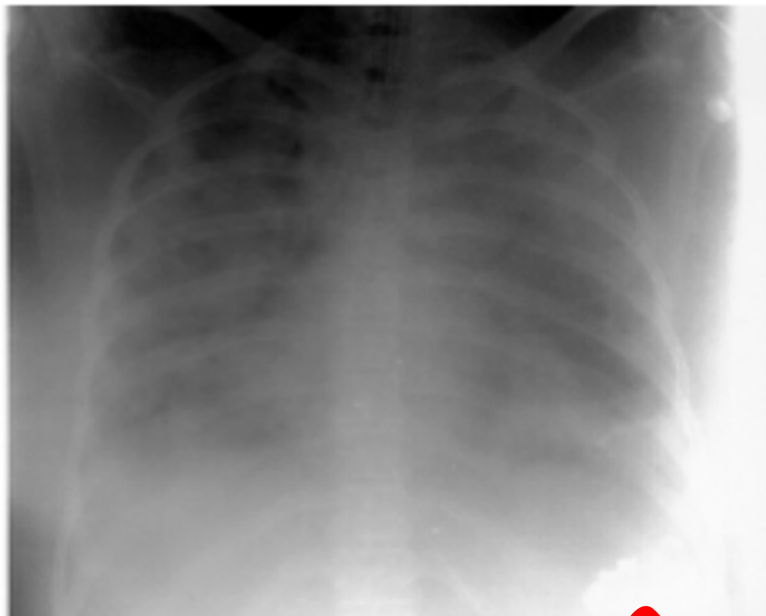
Not all cases of ARDS/ALI have a high EVLW

All cases of ARDS/ALI as defined by the European/ US consensus definition.



Chest 2004; 125:1166-1167

EVLW as a quantifier of lung oedema



EVLW= 19mL/kg

Pulmonary oedema

EVLW= 14mL/kg

Extravascular lung water index (EVLW) normal range:
3-7 mL/kg

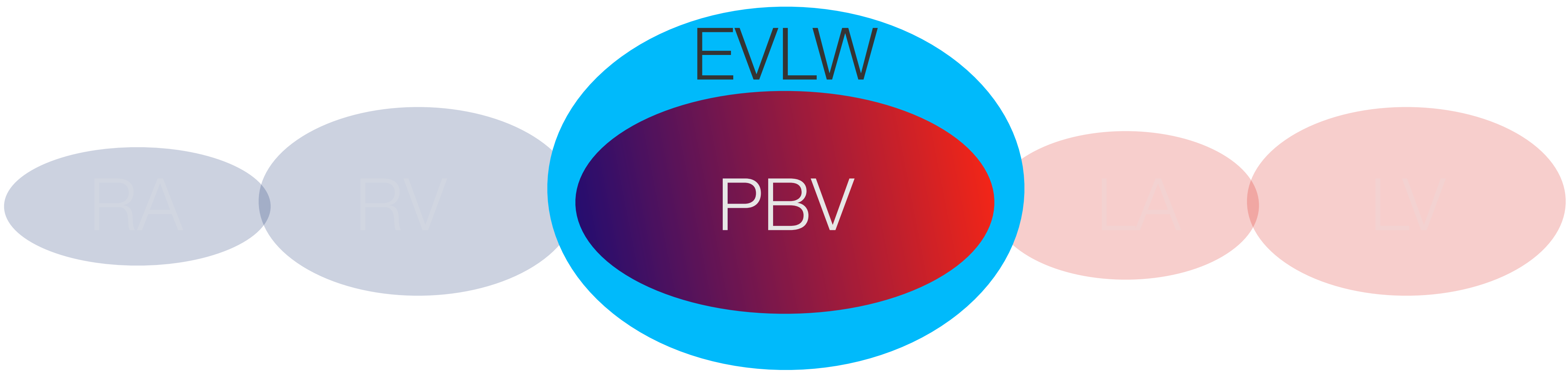
EVLW= 7 mL/kg

Normal range

EVLW= 8 mL/kg

Differentiating Lung Oedema

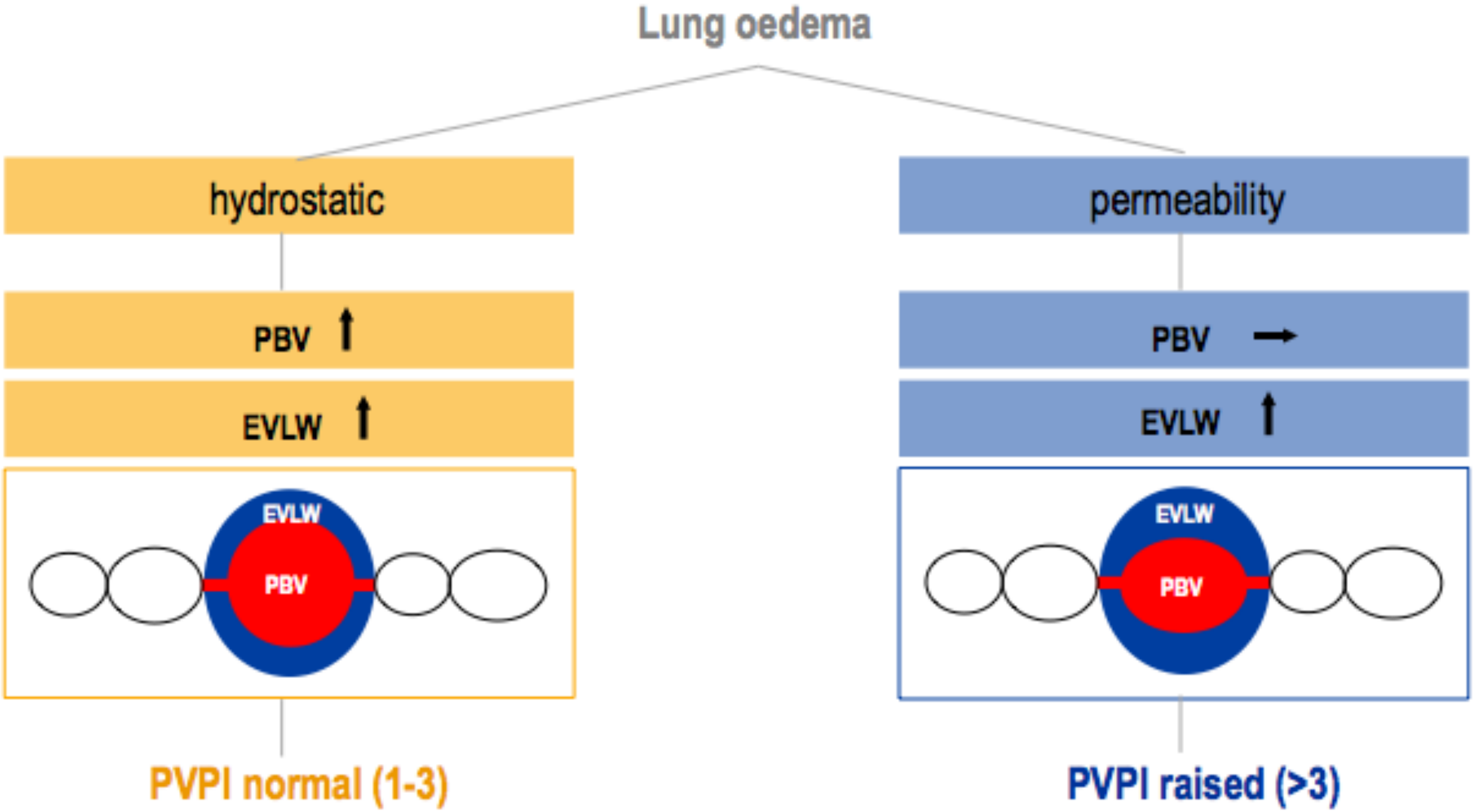
Pulmonary Vascular Permeability Index (PVPI)
= EVLW / PBV



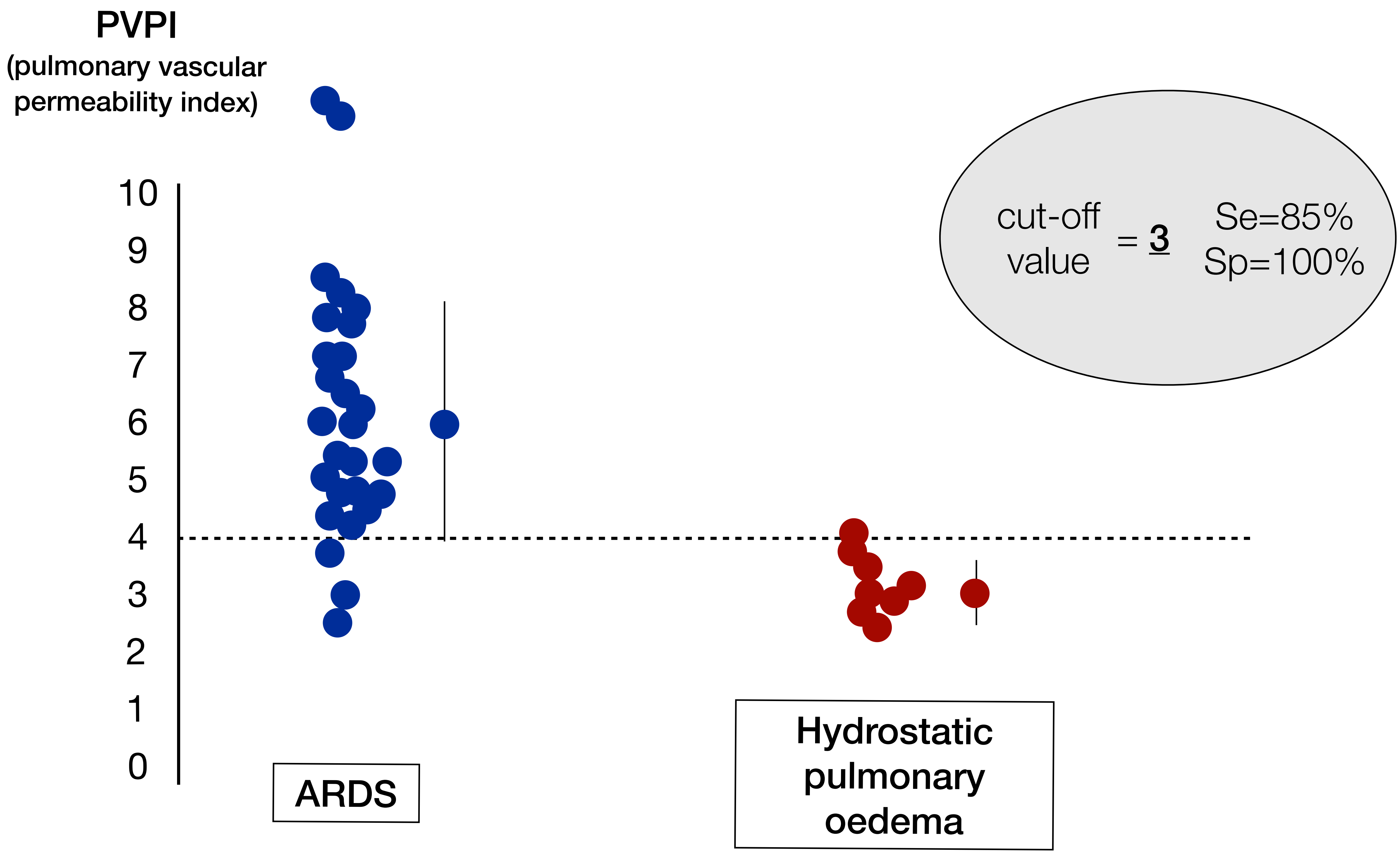
- ❖PVPI is the ratio of EVLW to Pulmonary Blood Volume
- ❖Differentiates transudate from exudate

Classification of Lung Oedema with the PVPI

Difference between the PVPI with hydrostatic and permeability lung oedema:

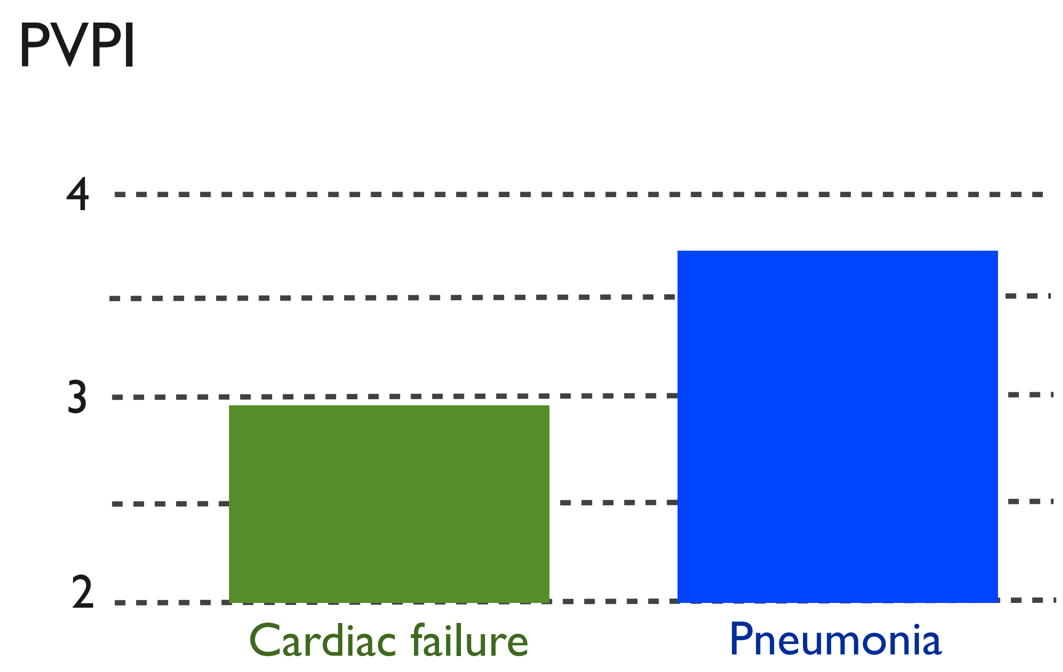


Differentiation of hydrostatic pulmonary oedema from ARDS



ICM 2007; 33: 448

Validation of the PVPI



16 patients with congestive heart failure and pneumonia.
In both groups the EVLW was 16 ml/kg

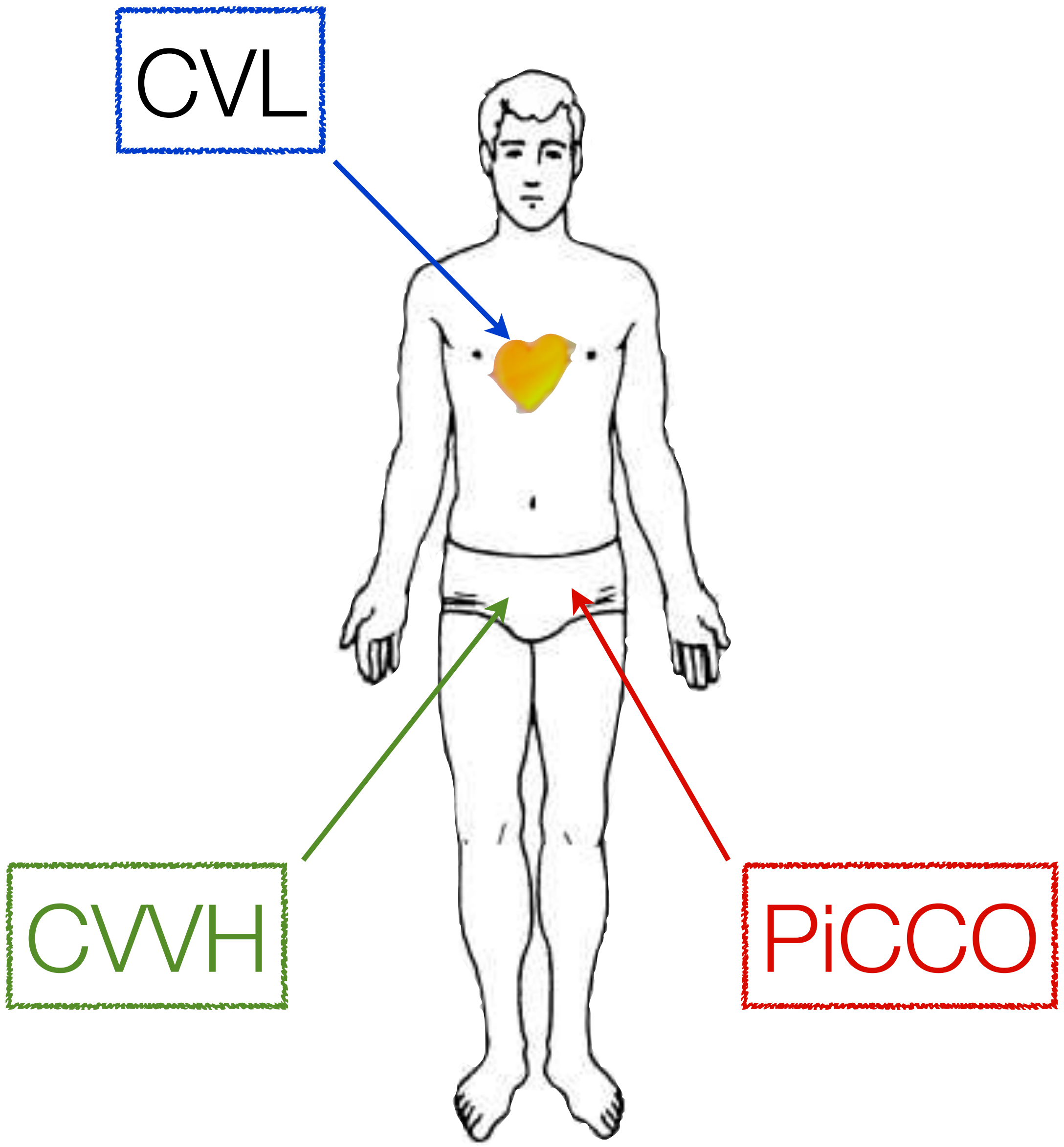
Benedikz et al ESICM abstract 2003

EFFECT OF CATHETER SITE

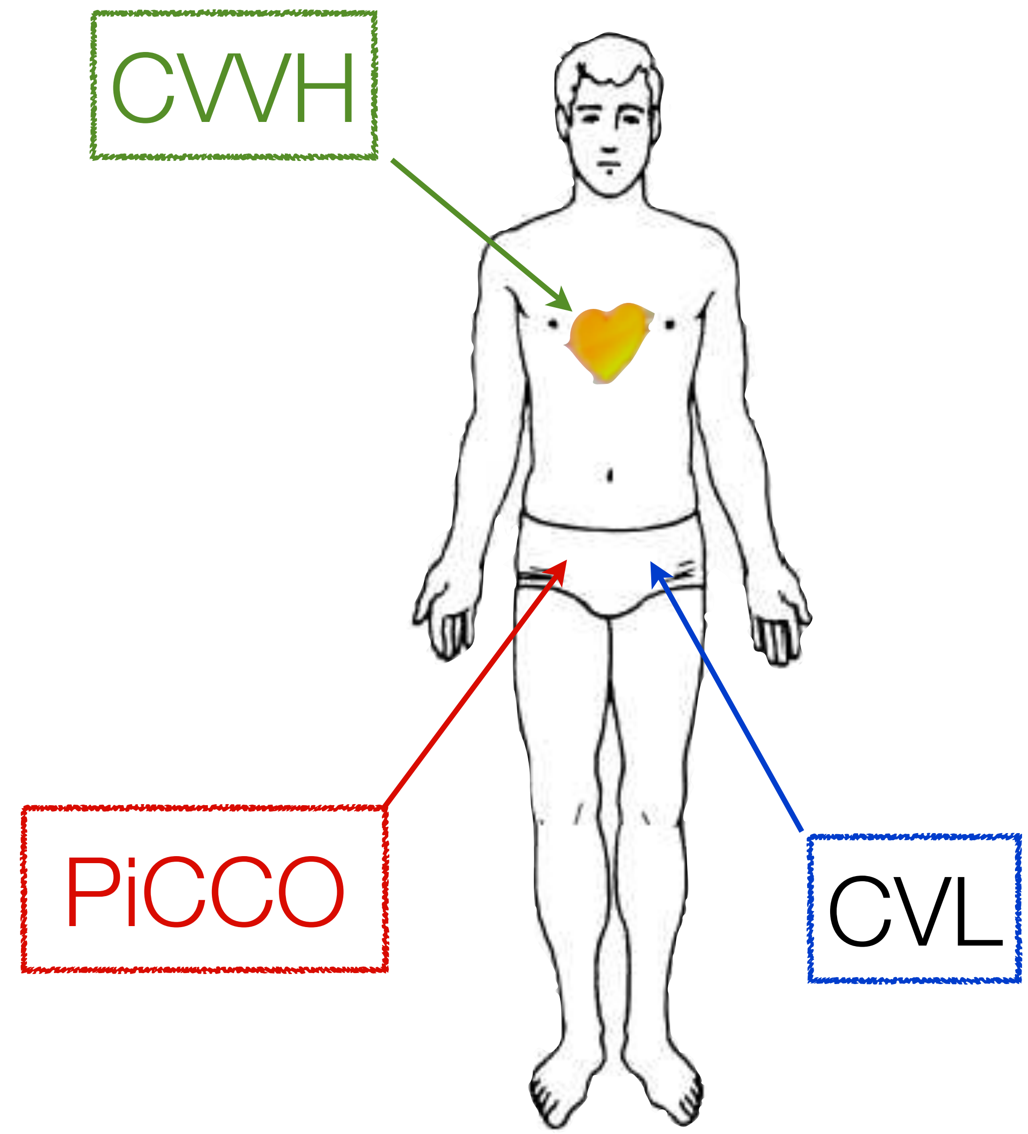
	Subclavian or Jugular	Femoral
CI (L/min/m2)	4.3	↑ 5.1
GEDVi (ml/m2)	835.6	↑ 1043
EVLWi (ml/kg)	12.5	↑ 15.1

Malbrain M et al ESICM 2010

Correct Position



Wrong Position



FAULTY CATHETER POSITION:
DIALYSIS CATHETER IS PLACED IN **BETWEEN** THERMODILUTION INJECTION AND DETECTION SITE

Malbrain M et al ESICM 2010

EFFECT OF CATHETER POSITION + CVVH ON PICCO PARAMETERS

	Correct catheter position		Faulty catheter position	
	without CVVH	with CVVH	without CVVH	with CVVH
CI (L/min/m2)	4	↓ 3.6	5.1	↓ 4.1
GEDVi (ml/m2)	895	↓ 802	1178	↓ 920
EVLWi (ml/kg)	10.8	11.6	12.3	13.9

Drop in CI and GEDVi and increase in EVLWi during CVVH is more pronounced in faulty catheter position

Malbrain M et al ESICM 2010

Clinical Case

32 yr old woman with acute viral myocarditis

GEDI - 500

CO - 3.9 l/min

SVV - 7

EVLW - 10

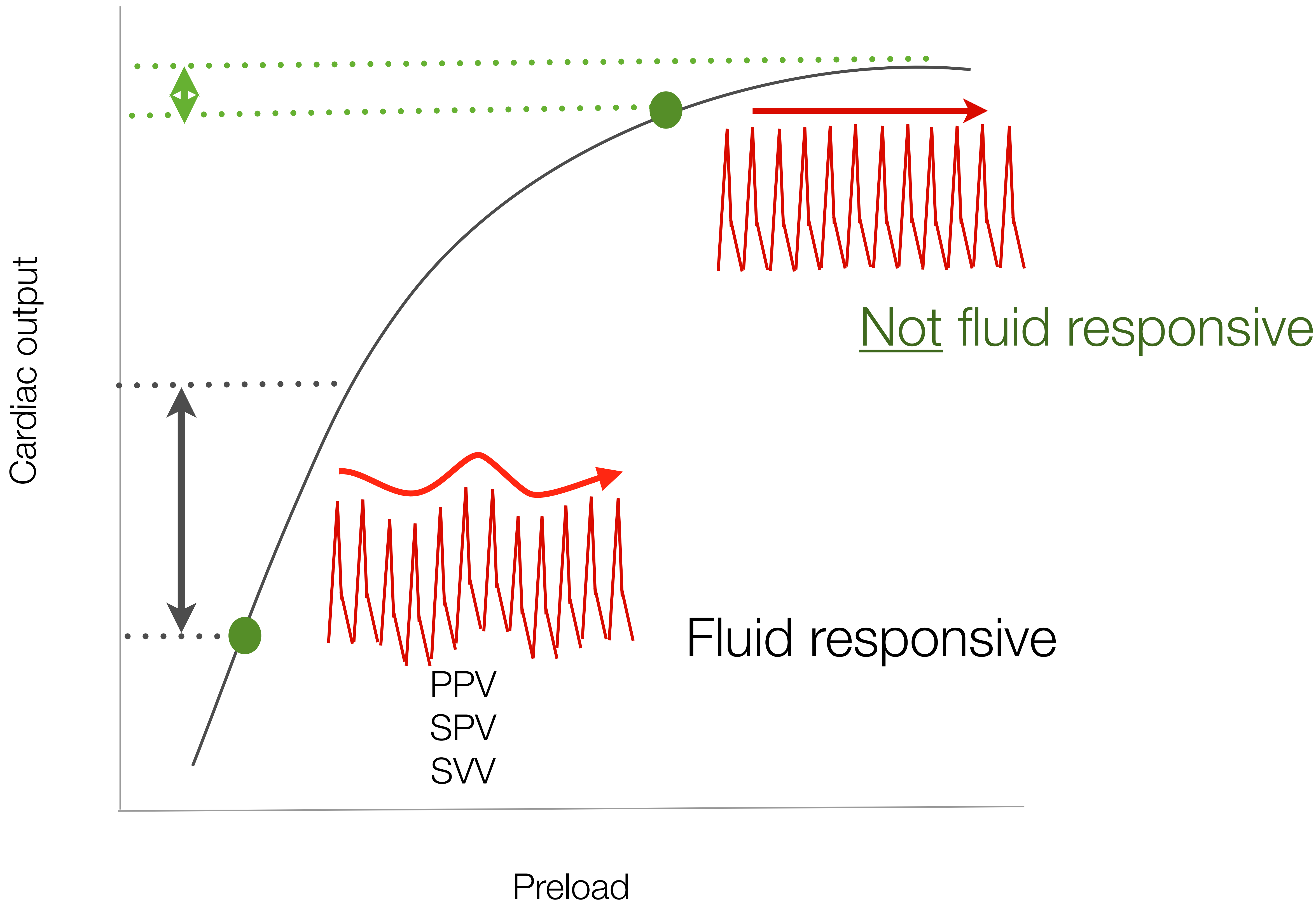
P/F - 23

IPPV and PEEP

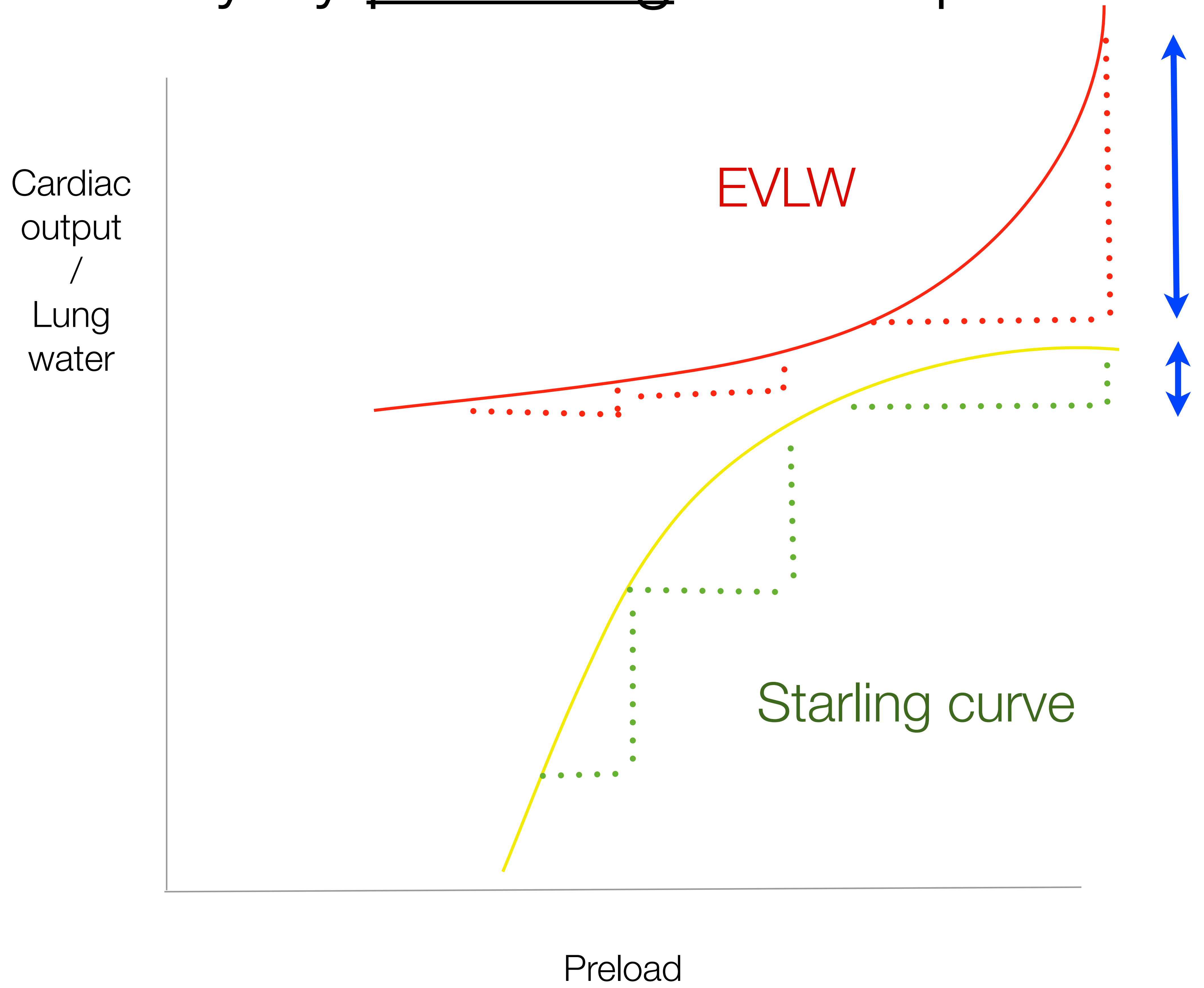
A double hump was noticed on calibration of PICCO

Found to have mitral regurgitation on ECHO

Response to IPPV tells you where you are on Starling Curve



Why try <u>predicting</u> fluid responsiveness?



Static measures

British Journal of Anaesthesia **94** (**3**): 318–23 (2005)
doi:10.1093/bja/aei043 Advance Access publication December 10, 2004
BJA

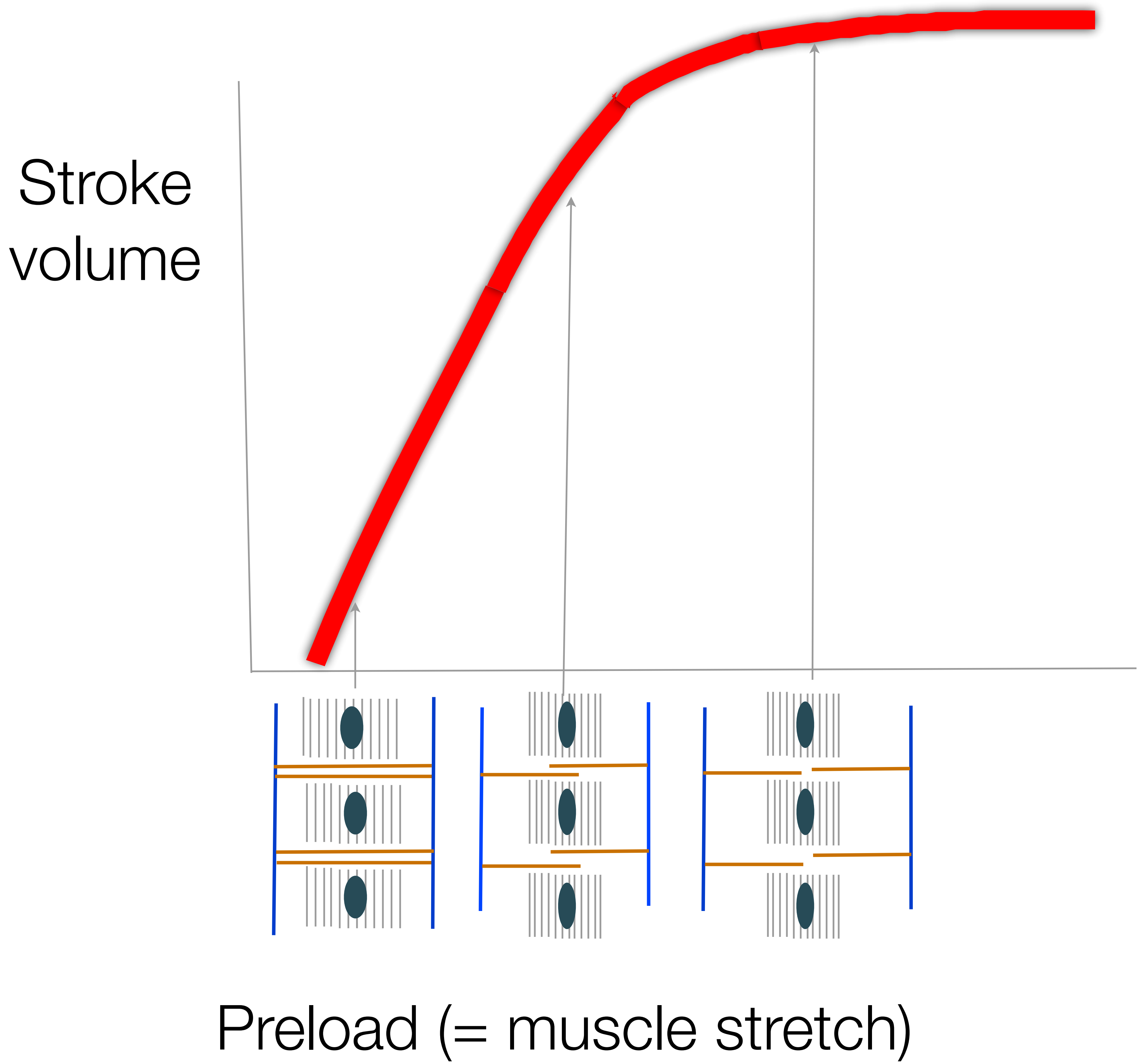
Assessing fluid responsiveness during open chest conditions

D. A. Reuter[1]*, M. S. G. Goepfert[1], T. Goresch[1], M. Schmoeckel[2], E. Kilger[1] and A. E. Goetz[1]

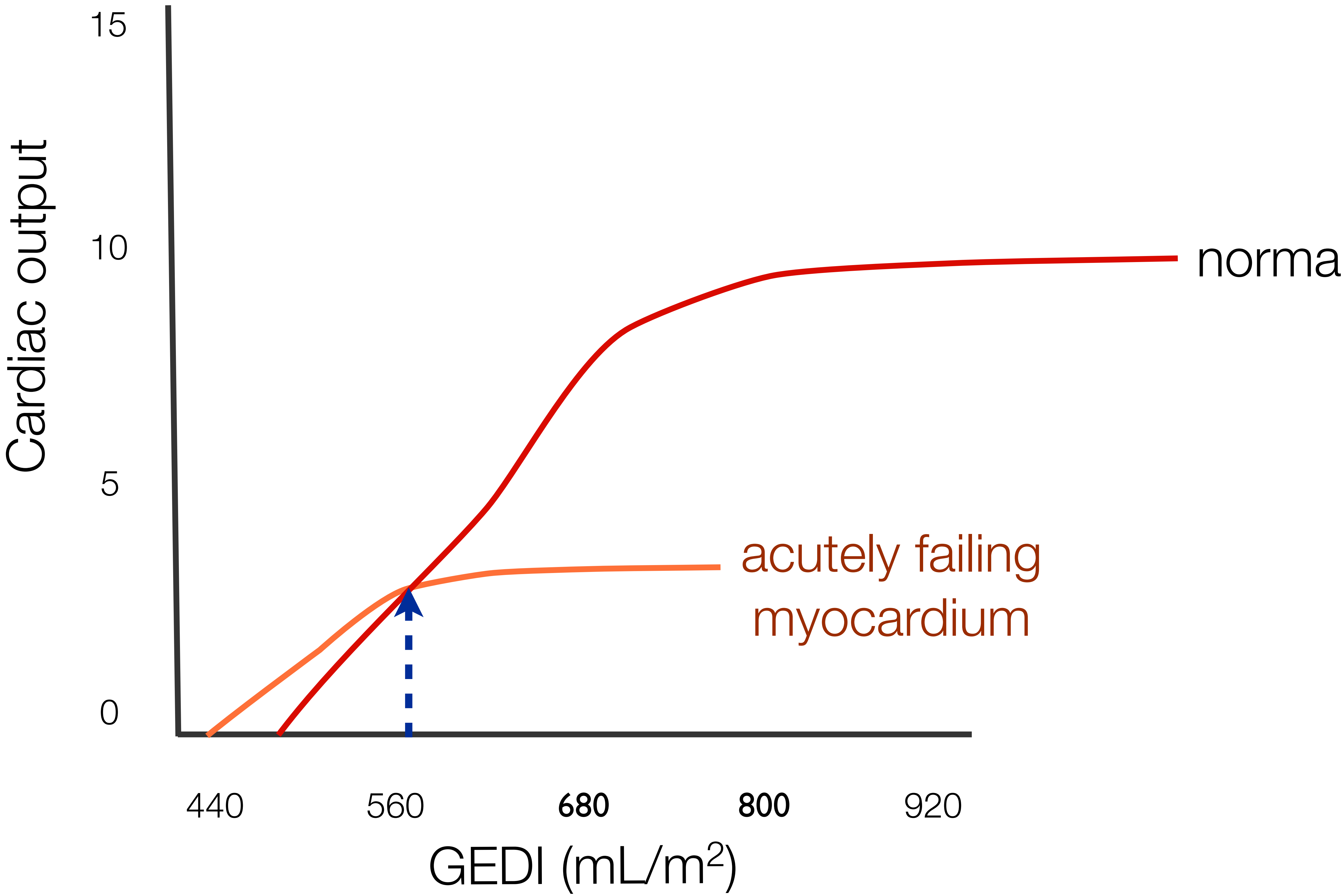
"**No correlation** between values of global end-diastolic volume (GEDI) nor left ventricular end-diastolic area (ECHO) and response to fluid loading."

Preload is not the same as **preload responsiveness**!

What is Preload?



Ventricular Failure



Valvular regurgitation-effect on PICCO

Tends to overestimate CO

increased transit times (increases its dissipation)

or

Flat prolonged curve gives an underestimation of CO (i.e., large area under curve)

INCREASES IN **CALCULATED** VOLUMES :

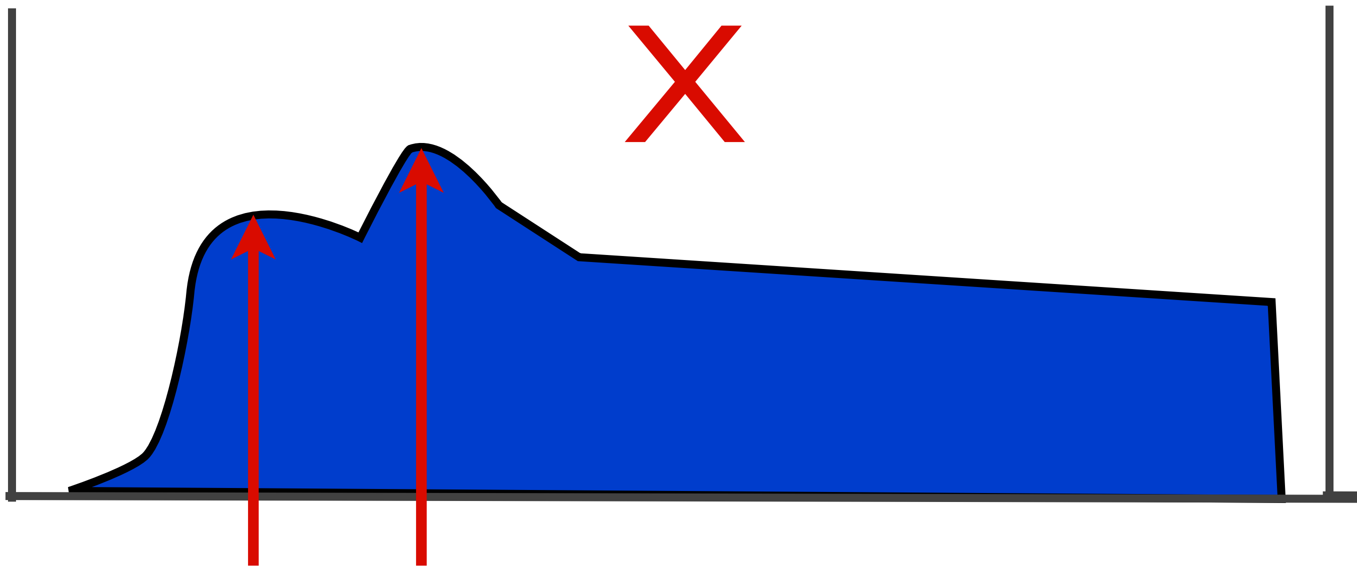
ITBV

GEDVI

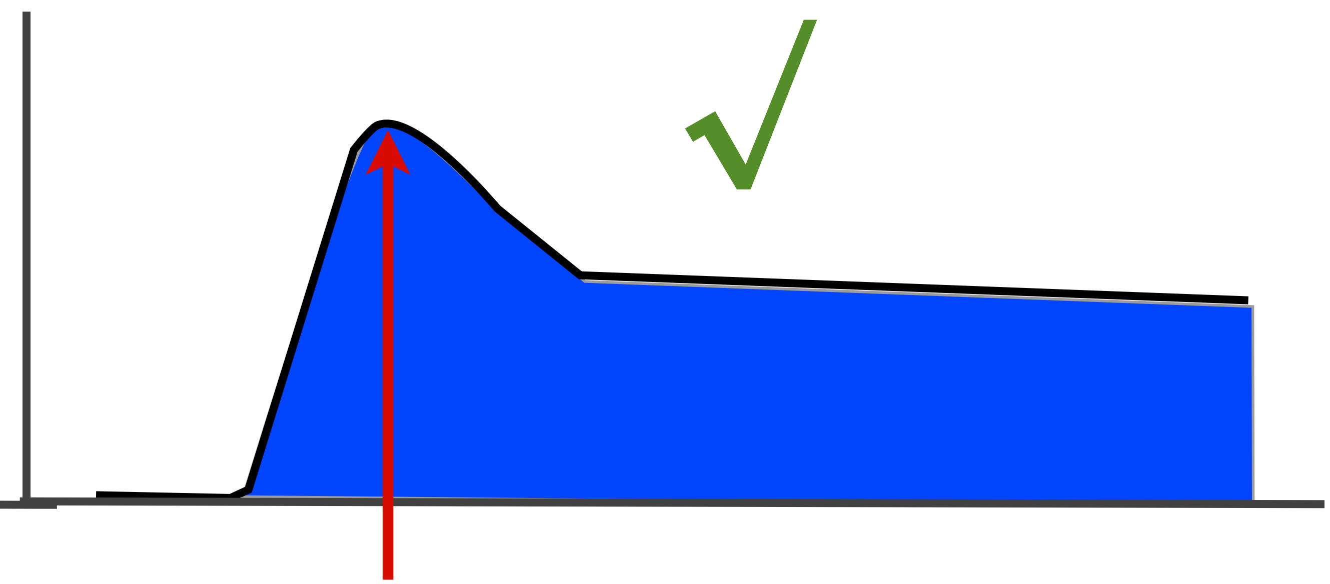
EVLW

Anesth Analg 2010;110:799–811

Watch that TPTD Curve
Premature hump?



C.I. 5.37
GEDVi 1155

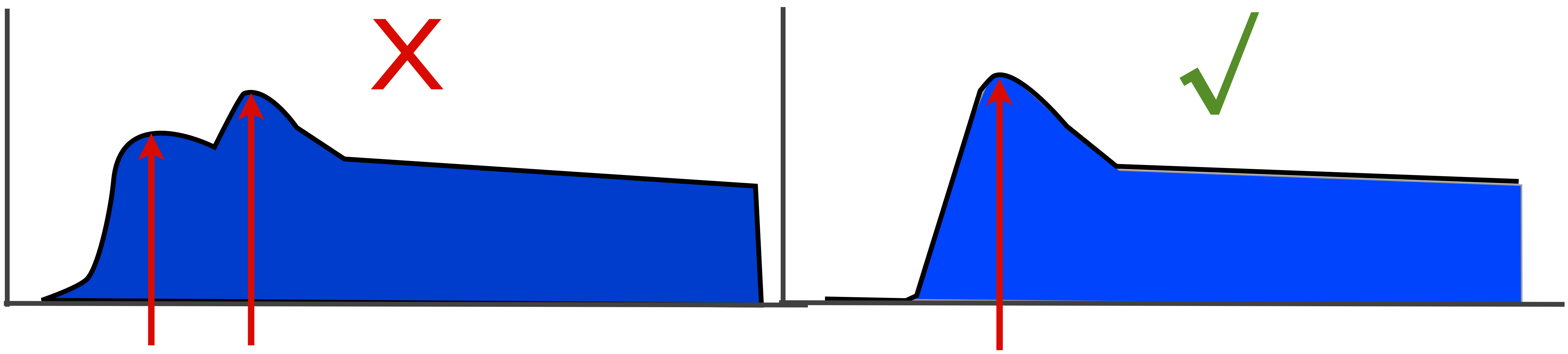


C.I. 5.01
GEDVi 660

PREMATURE HUMP

- Bolus interrupted
- Bolus mixing
- Cross talk
- R/L shunt

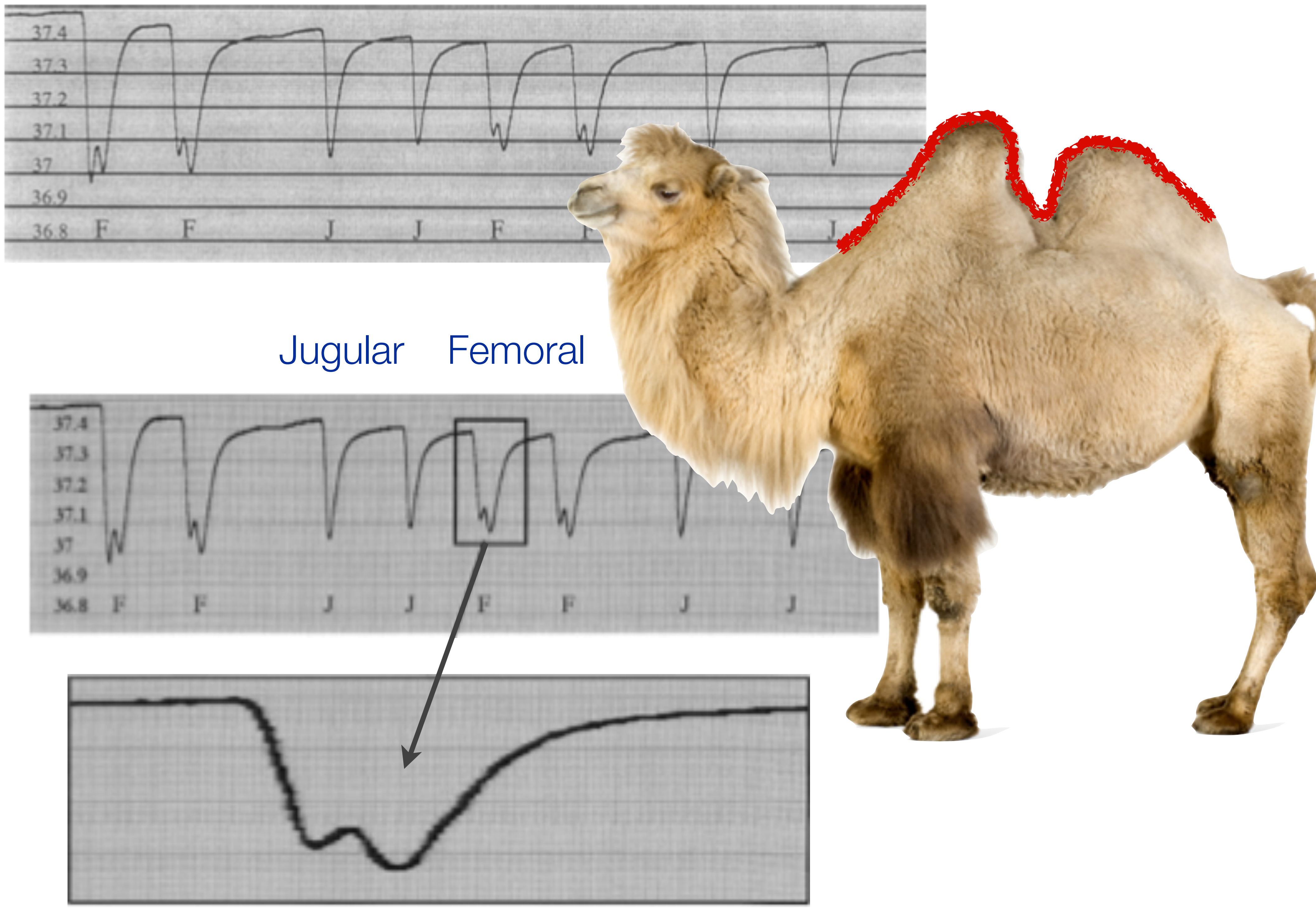
Cross talk Phenomenon



Injection and detection femoral

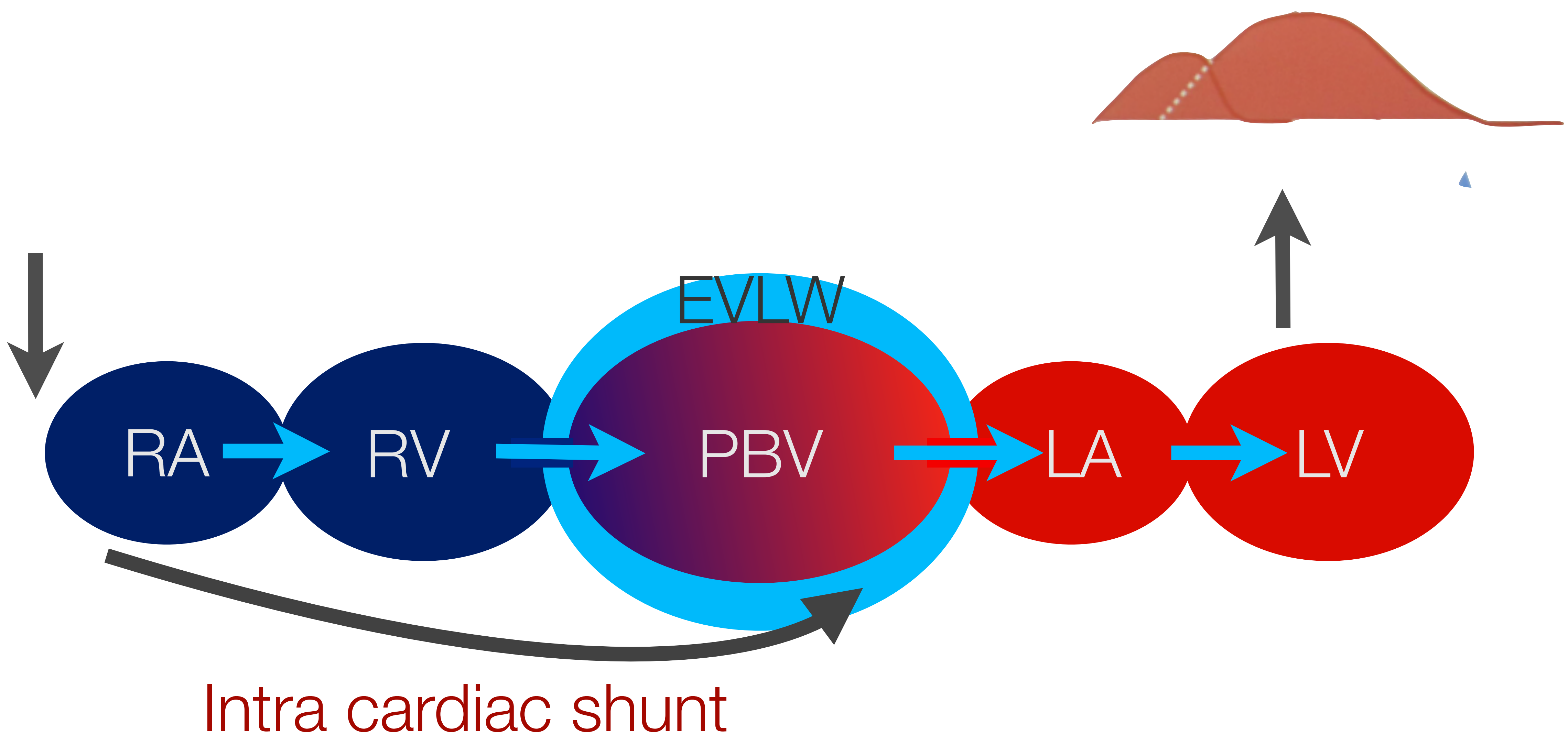
Injection subclavian
and detection femoral

THE CAMEL CURVE



CHEST / 127 / 4 / APRIL, 2005

Detection of right-to-left intracardiac shunt using transpulmonary indicator dilution

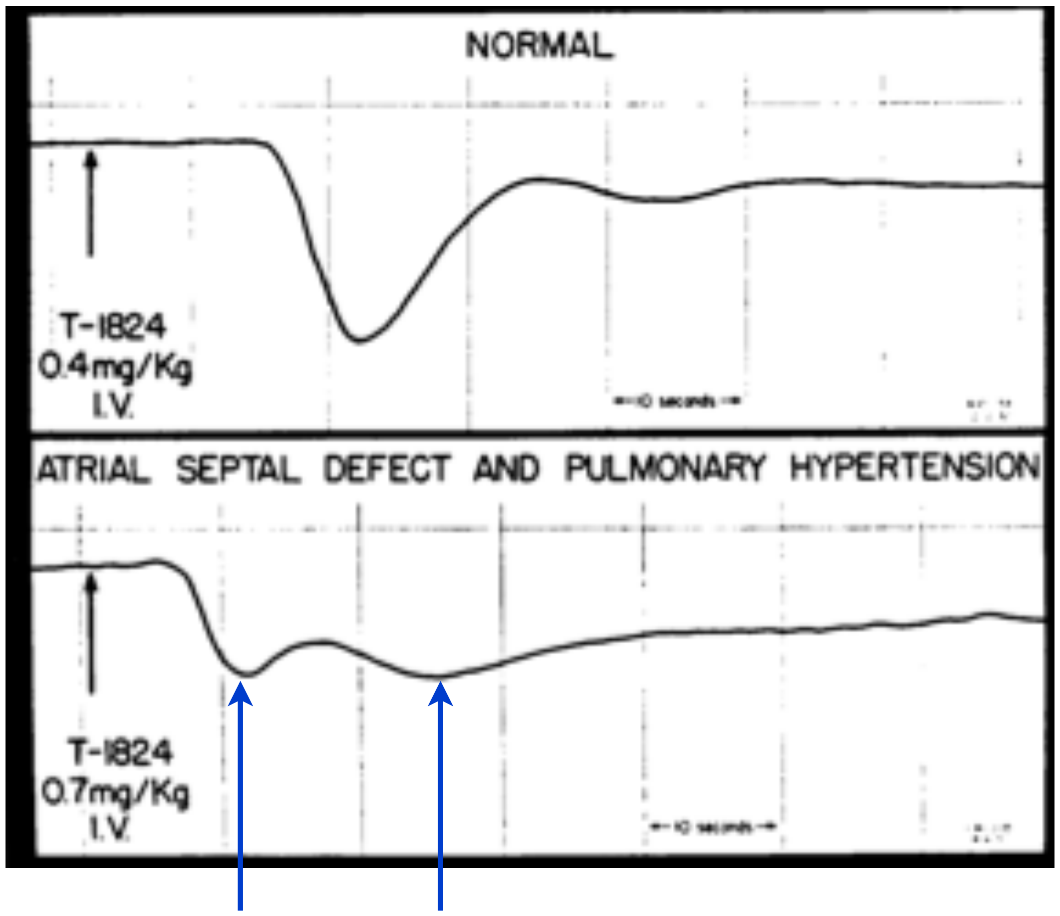


Prevalence of moderate to large PFO shunting - **19%** in ARDS and IPPV with PEEP

Crit Care Med 2010 Vol. 38, No. 9

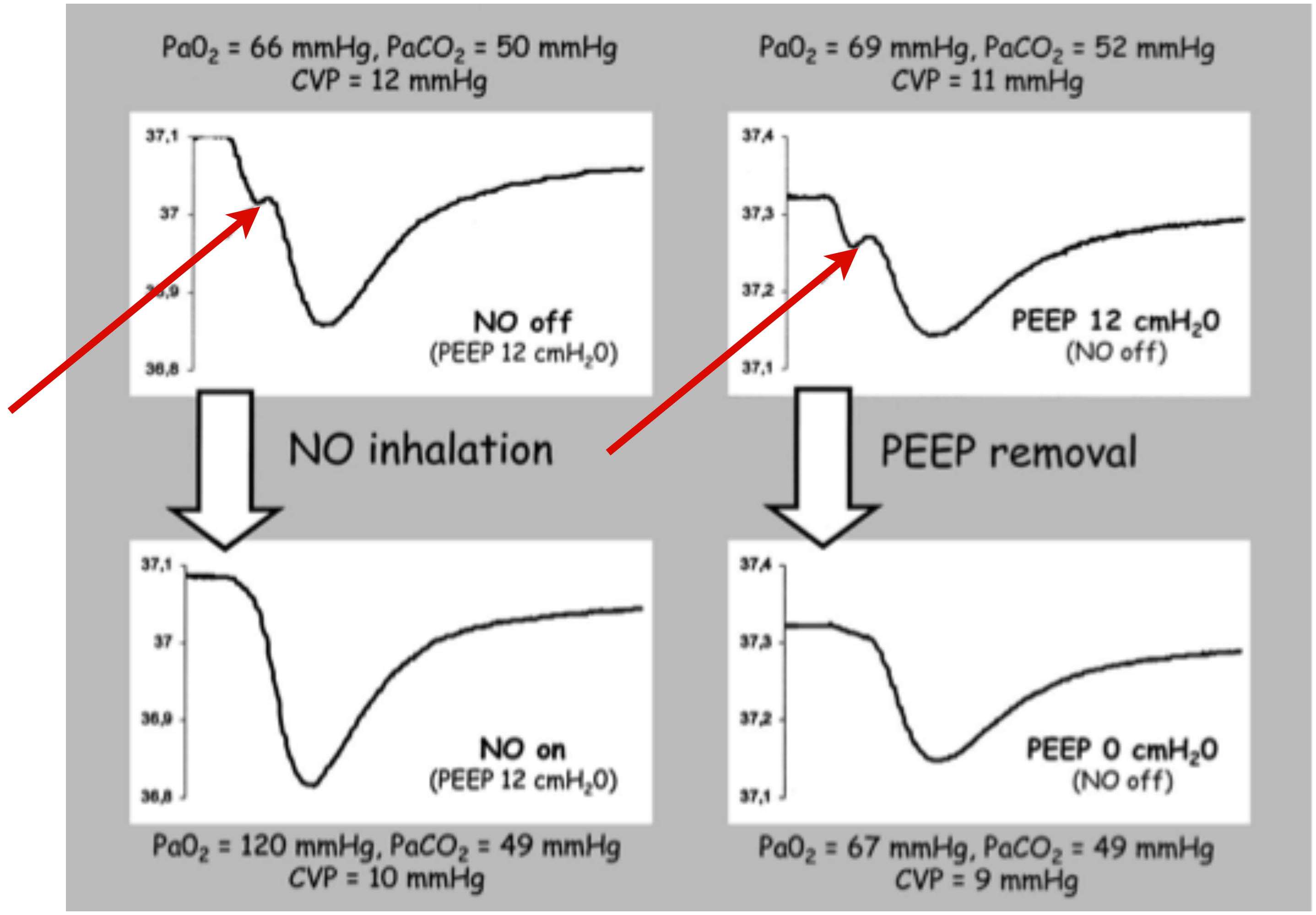
Dye Dilution Curves in Cyanotic Congenital Heart Disease

By H. J. C. SWAN, PH.D., M.B., M.R.C.P. (Lond.), J. ZAPATA-DIAZ, M.D., AND EARL H. WOOD, M.D., PH.D.



Circulation, Volume VIII, July, 1953

Monitoring Right-to-Left Intracardiac Shunt in Acute Respiratory Distress Syndrome



Crit Care Med 2004 Vol. 32, No. 1

Contractility Parameters

Cardiac Function Index (CFI)

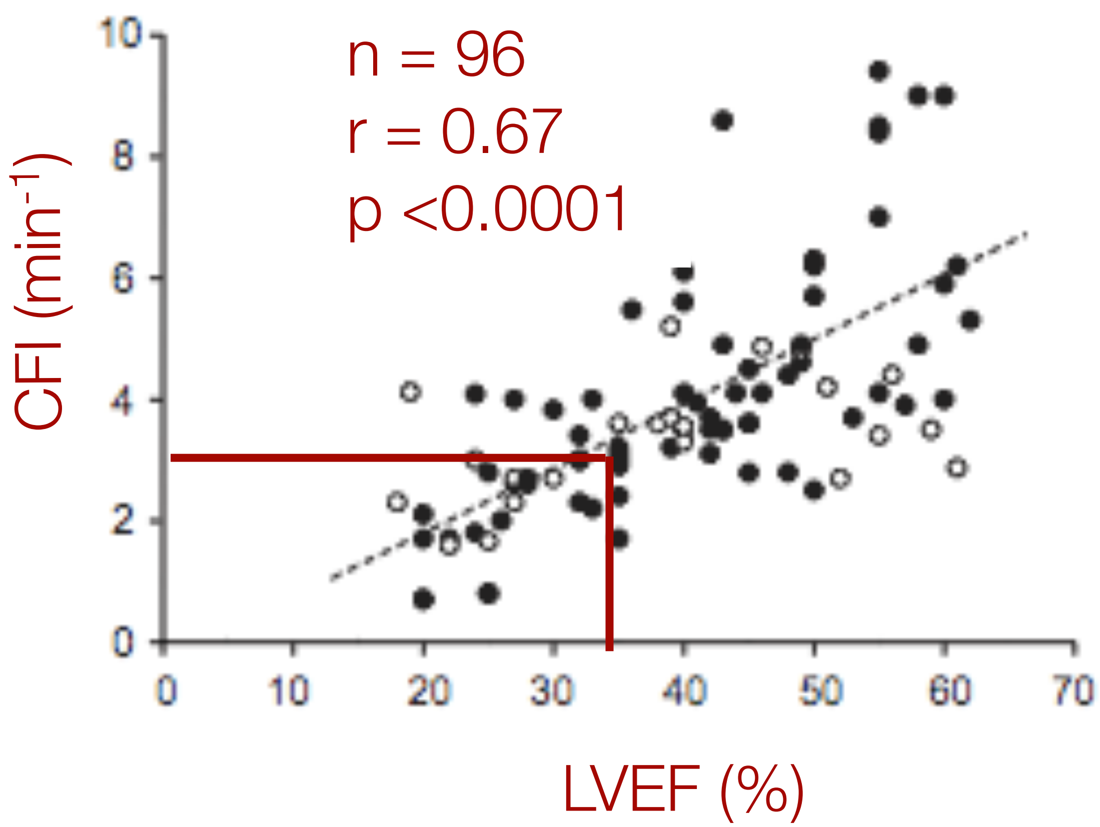
$$\boxed{CFI = CO/GEDV}$$

CFI is a parameter of both left and right ventricular contractility

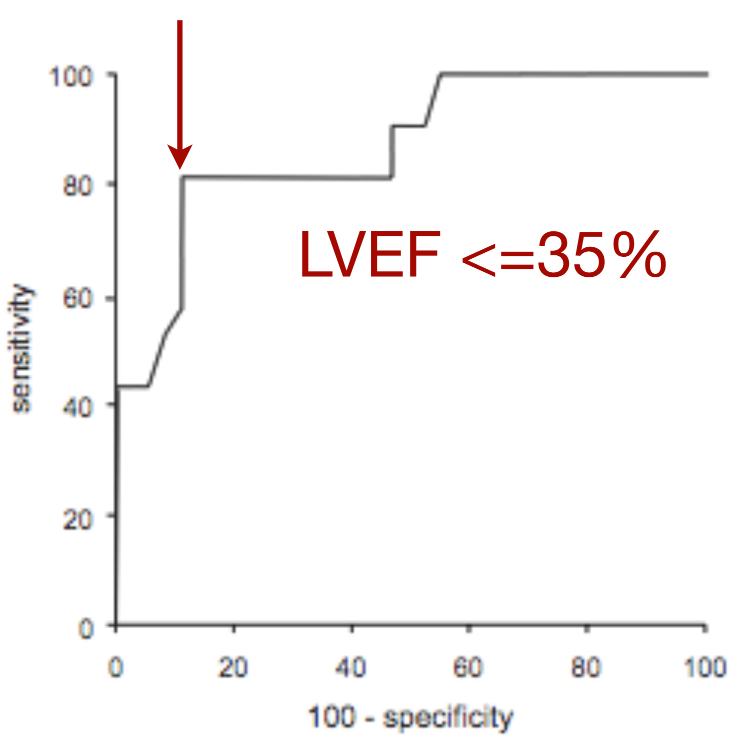
Cardiac function index (CFI) as an indicator of LV systolic function

CFI = CO / GDEV

A low CFI can alert the clinician and incite to perform an echo



3.5 min^{-1}

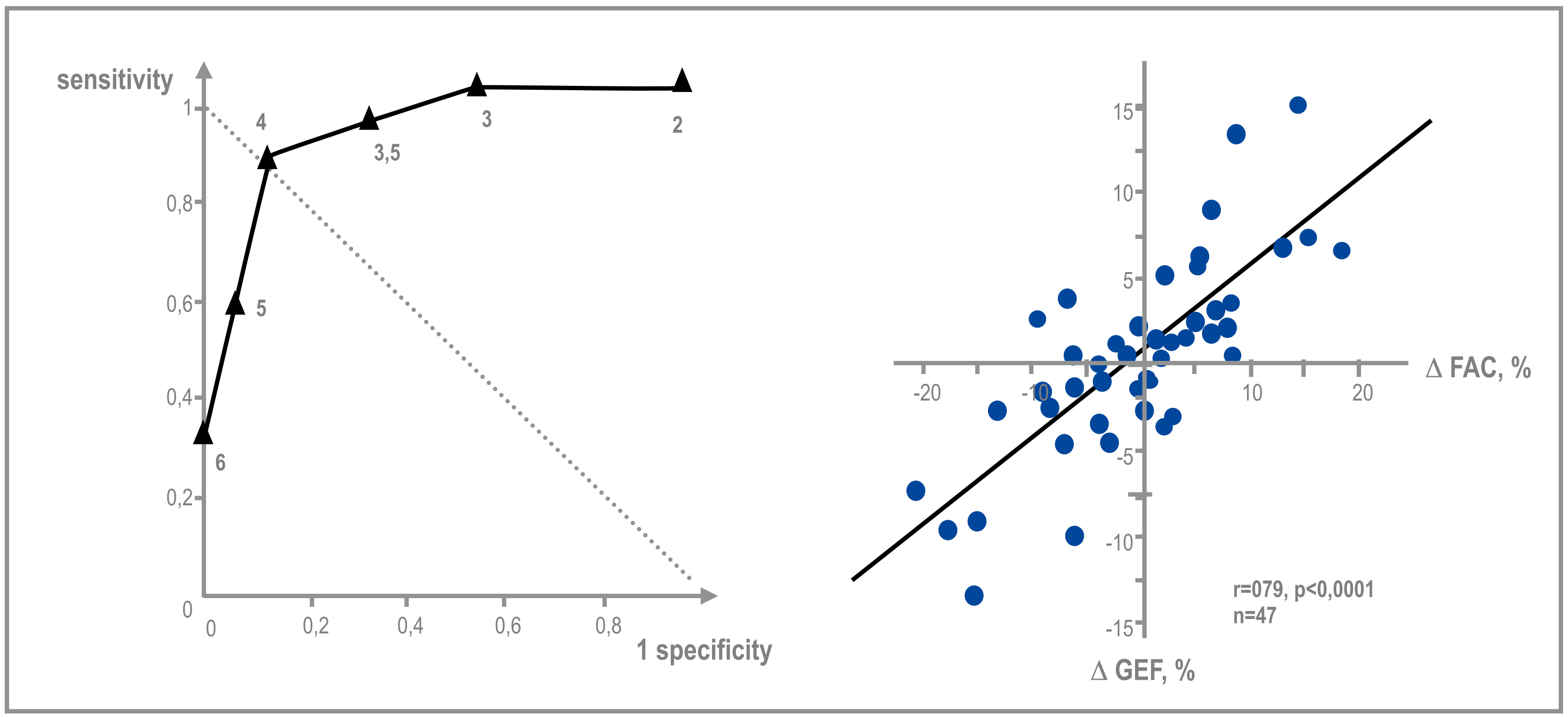


Ability of the CFI (**<3.5 min^{-1}**) to detect a LVEF <35%

Crit Care Med 2009; 37:2913–2918

Contractility parameters from the thermodilution measurement

CFI = Cardiac Function Index



Combes et al, Intensive Care Med 30, 2004

CFI was compared to the gold standard TEE measured contractility in patients without right heart failure

MATHEMATICAL PITFALLS

The mathematical analysis of the indicator- dilution curve (MTt, DSt) allows for the extrapolation of volumes (volume=flow x time)

Small errors in the determination of CO by Transthoracic Thermal Dilution which are unlikely to affect the validity of each individual measurement may acquire substantial weight when repeated in subsequent calculations.

Ex., determining the ITTV requires the use of three integrals (one from the CO and two from the MTt) obtained from the same thermodilution curve.

The mathematical derivation of the GEDV intimately ties it with the CO because CO is the “flow” term of both ITTV and PTV calculations and both MTt and DSt are calculated based on the same thermodilution curve used for the determination of the CO

Minerva Anestesiol 2010;76:945-9

WRAP IT UP

- Any measurement stands or falls with its accuracy
- Know the pitfalls of your tool!
    - Calibration
    - TPTD
    - Functional HD
- Identify the “Camel Curve”
- EVLW low + CXR white = Pleural fluid

???