Hemodynamic monitoring
in
Heart Transplantation

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HTX in Masih Daneshvari Hospital

- Numbers of HTx : 247
- Heart – Lung TX : 1
- Heart – Kidney : 2
- My experience as cardiac a anesthetist : 156 cases

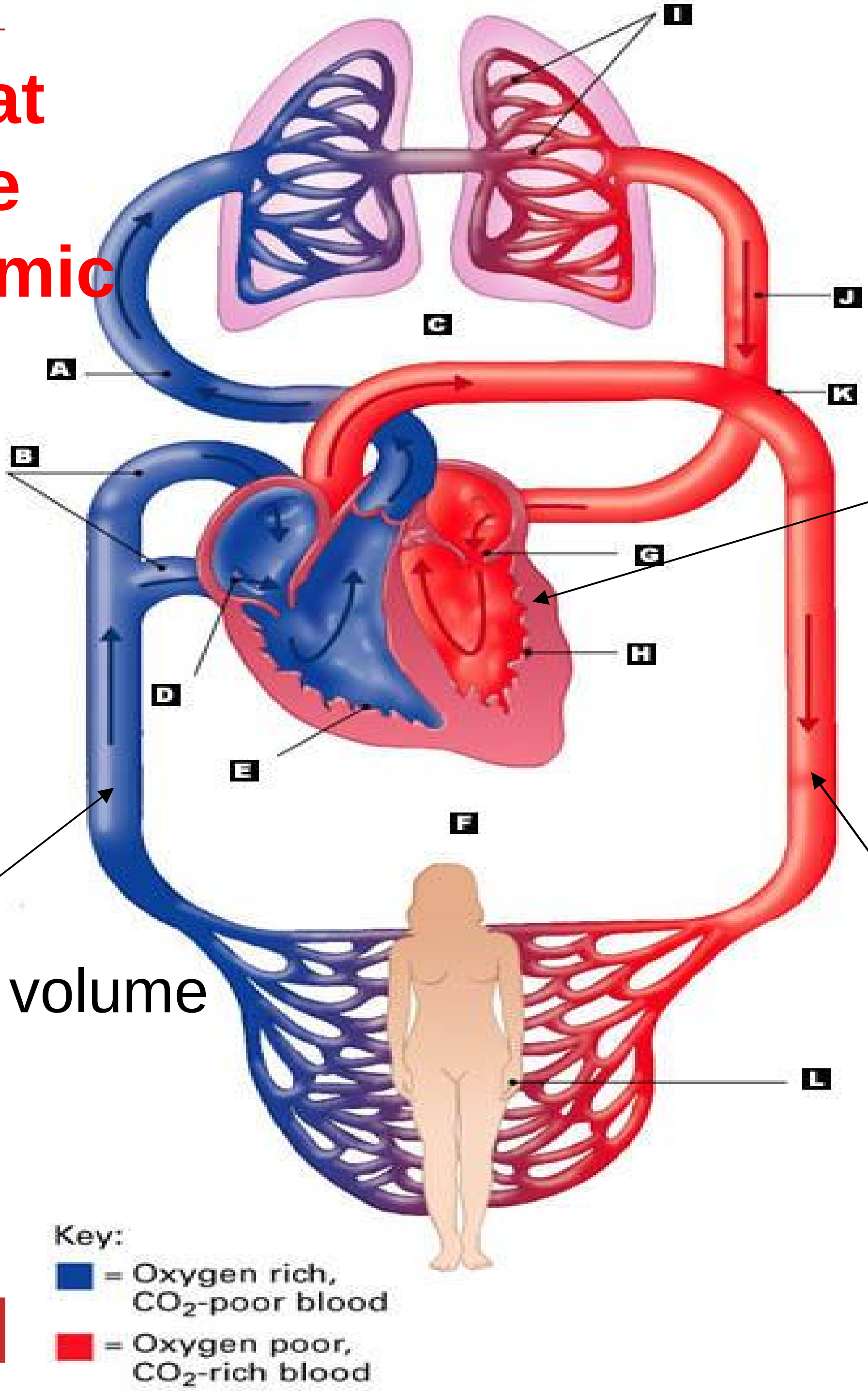
Methods of hemodynamic monitoring in HTx

- Invasive arterial blood pressure
- Central venous pressure
- Pulmonary artery catheter
- Cardiac output measurement
- Volume management
- TEE

Post-CPB period

- **Hemodynamic goals:**
- HR : 90 to 110 beats/min
- MAP : more than 65-70 mm Hg
- CVP : 8-12mm Hg
- PCWP : 6 to 14 mm Hg

3 factors that affecting the haemodynamic conditions



Myocardial contraction and heart rate

Vasoactivity

Intravascular volume

Oxygen Delivery is the Goal

- **What are we really worried about?**

  "Tissue Hypoperfusion"

- **What do we really want to monitor?**

  "Adequate Oxygen Delivery"

inadequate organ perfusion

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organ dysfunction

Renal failure

Respiratory failure

Cerebral dysfunction

Hepatic malfunction

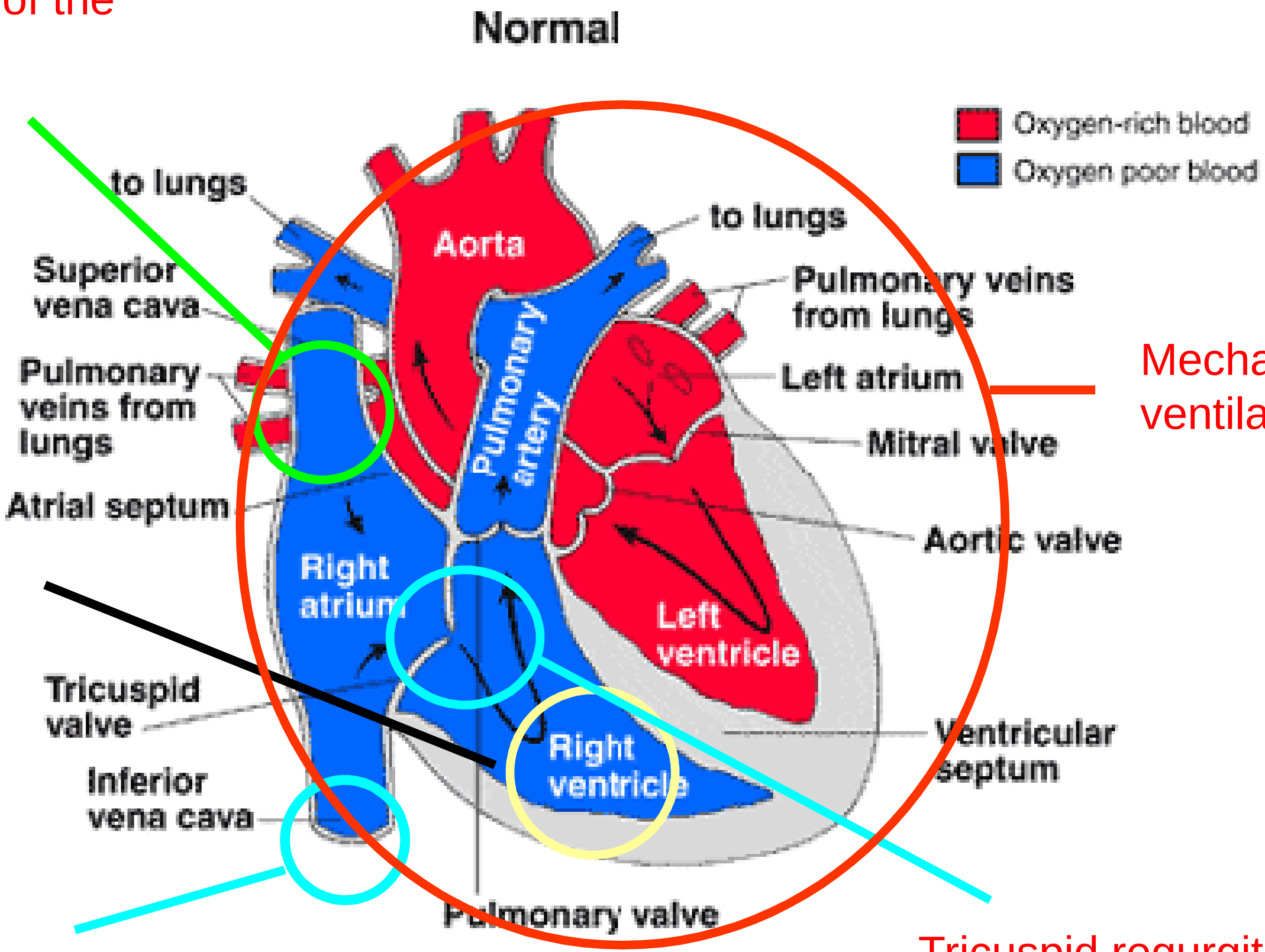
G.I dysfunction

Limitations of Arterial Catheterization

- Pressure does not accurately reflect flow when vascular impedance is abnormal
  - Artifacts:
    - Underdamping
    - Overdamping
  - Mean pressure is more accurate
  - Femoral arterial line

Limitation of CVP

Obstruction of the great veins



Mechanical ventilation

Decrease right ventricular compliance

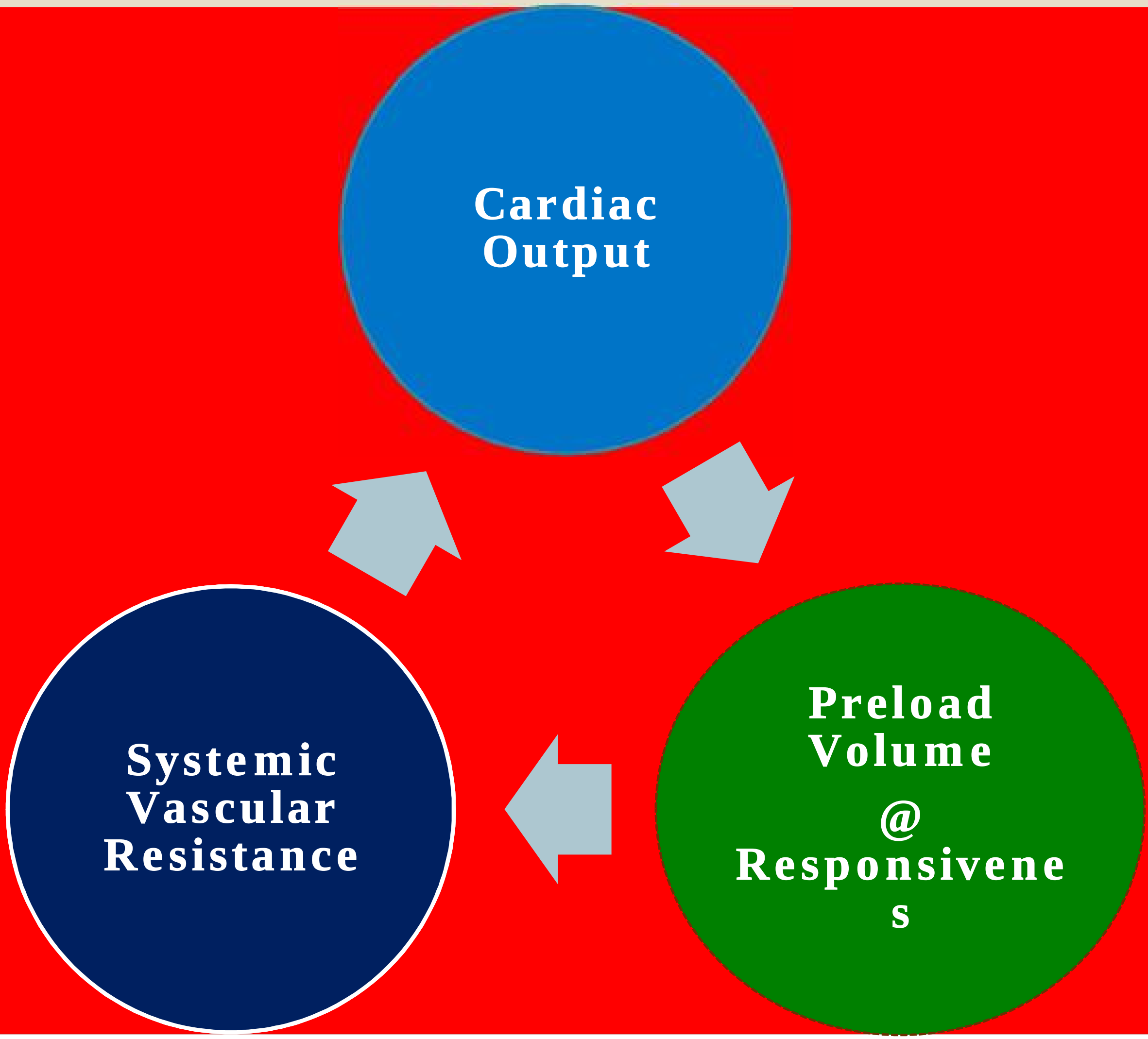
Tricuspid regurgitation

Systemic venoconstriction

The standard parameters do not give enough information in unstable patients

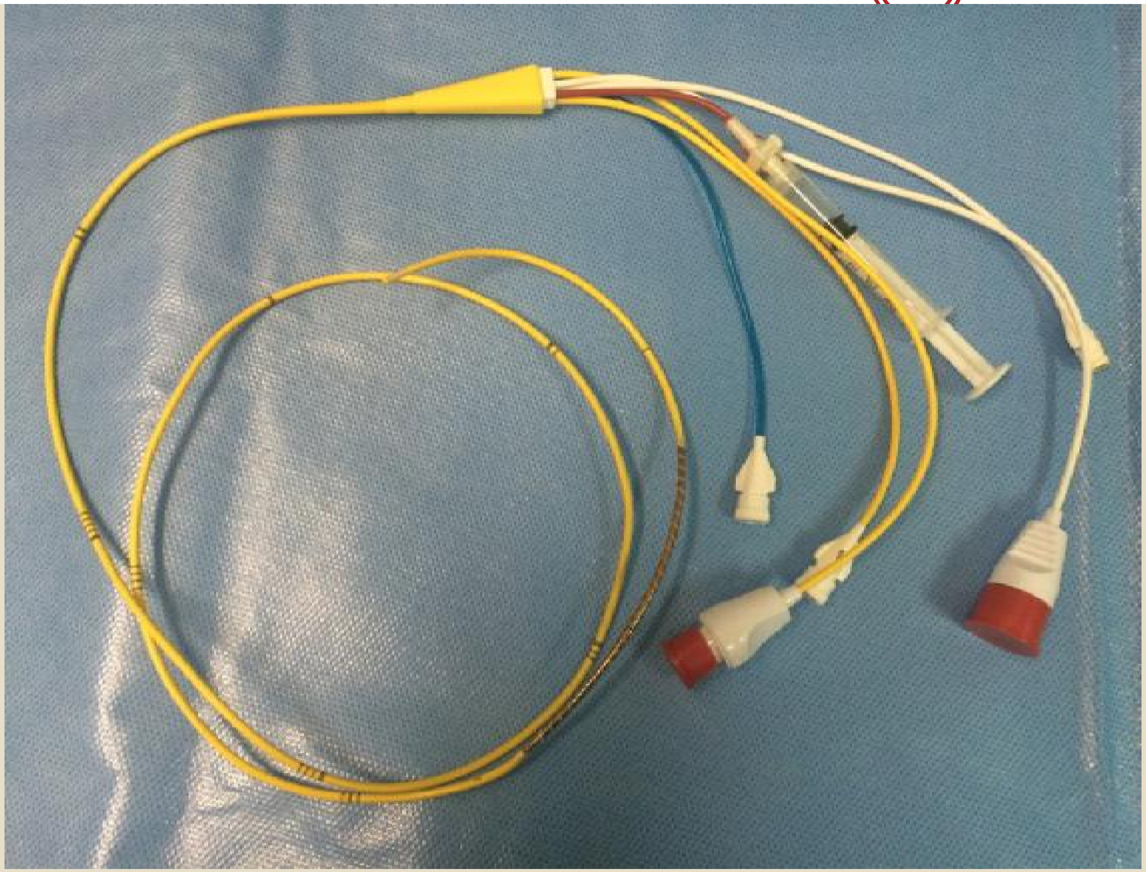
What other parameters do I need?

We should be able to monitor



Cardiac Output Monitoring

– C.O monitoring ,Swan Ganz Catheter



CLINICAL APPLICATIONS

1.Direct Measurements:

- **Pulmonary Artery Pressures**
  - -PASP: reflects the pressure generated by the RV during systole
  - -PADP: reflects the higher diastolic pressure in the pulmonary vasculature
  - -PAWP: left atrial pressures are reflected

- **Right Atrial Pressure**
  - obtained by using the RA lumen of the catheter
  - provides information about RV function

- **Cardiac Output**
  - Through the use of a thermodilution catheter, C.O determinations can be made at the bedside with relative ease and accuracy

– Svo2

-Mixed venous oxygen saturation *(SvO2)* is the percentage of oxygen bound to hemoglobin in blood returning to the right side of the heart.

- $SvO2 = SaO2 - VO2 / 13.9 \times Q \times [Hb]$

2. Derived Parameters:

- **Cardiac Index**

  -CI = (CO/BSA)= 2.5 to 4.0 1/min/m2

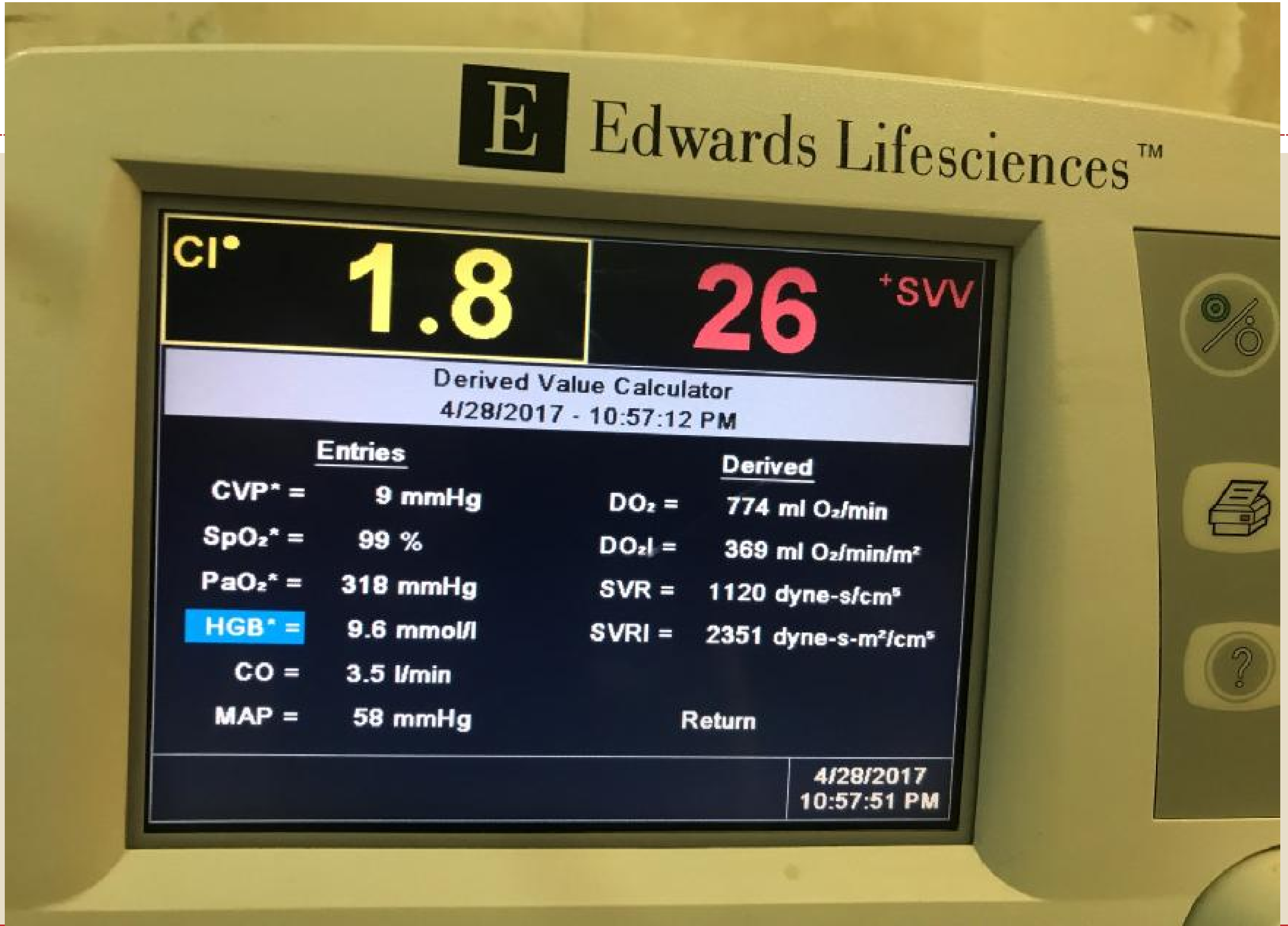
- **Stroke Volume**

  -SV = (CO/HR) x 1000 ml/L= 60 to 100 ml/beat

- **Stroke Volume Index**

  -SVI = (SV/BSA)= 33 to 47 mm/Beat/m2

- **Systemic Vascular Resistance**
  - -SVR =(MAP – RAP) /CO x 80
- **Pulmonary Vascular Resistance**
  - -PVR =(MPAP - PAWP) /CO x 80
- **Stroke Work**
  - -SW =(MAP - LVEDP) x SV x 0.0136


Edwards Lifesciences™
CI 1.8
26 +SVV
Derived Value Calculator
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Entries
CVP* = 9 mmHg
SpO₂* = 99 %
PaO₂* = 318 mmHg
HGB* = 9.6 mmol/l
CO = 3.5 l/min
MAP = 58 mmHg
Derived
DO₂ = 774 ml O₂/min
DO₂I = 369 ml O₂/min/m²
SVR = 1120 dyne-s/cm⁵
SVRI = 2351 dyne-s-m²/cm⁵
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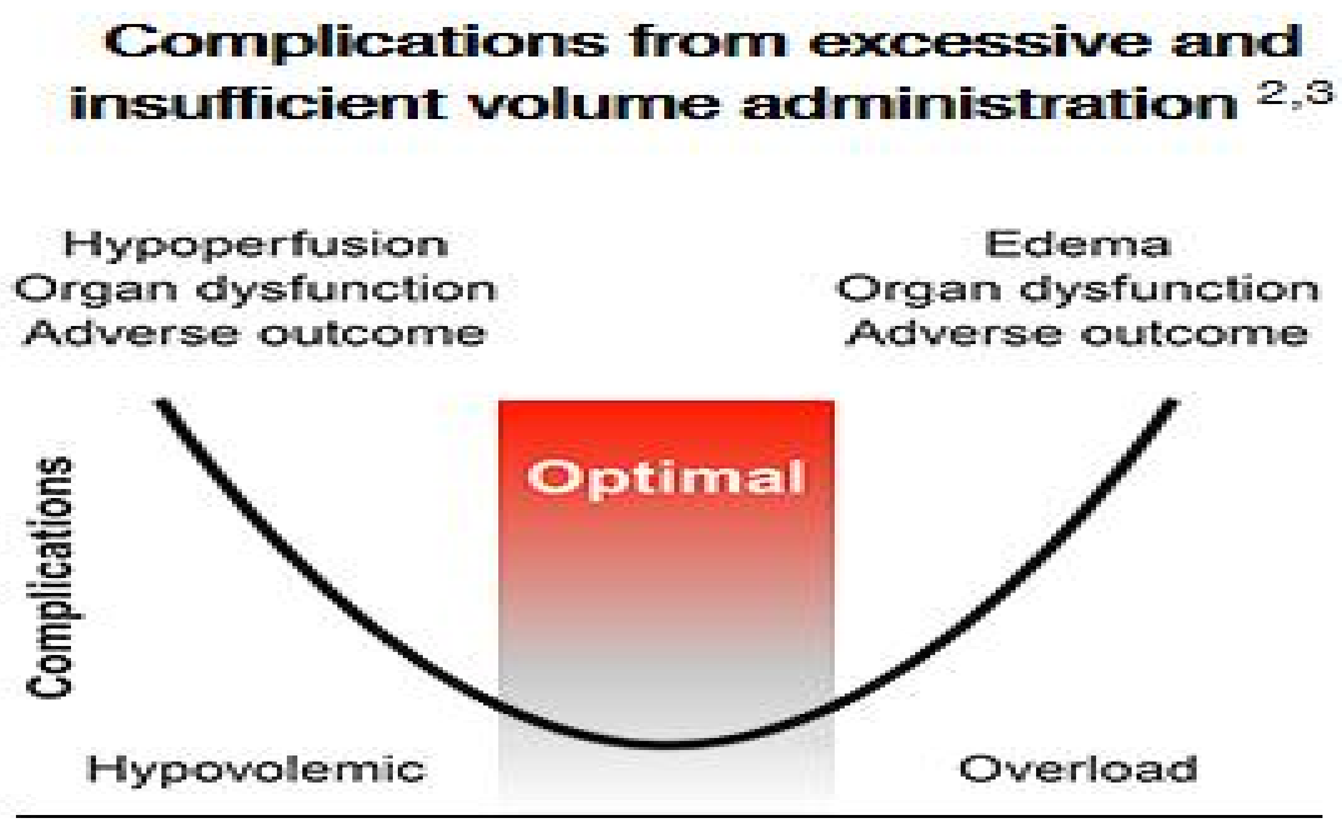
Preload assessment

Where do you want to be?



Volume Assessment

- Filling Pressures
- Volumetric Preload Parameters
- Volume Responsiveness

Volumetric Preload Parameters, Volume Responsiveness and Filling Pressures

Preload

Filling Pressures

CVP / PCWP

Volumetric

Preload parameters

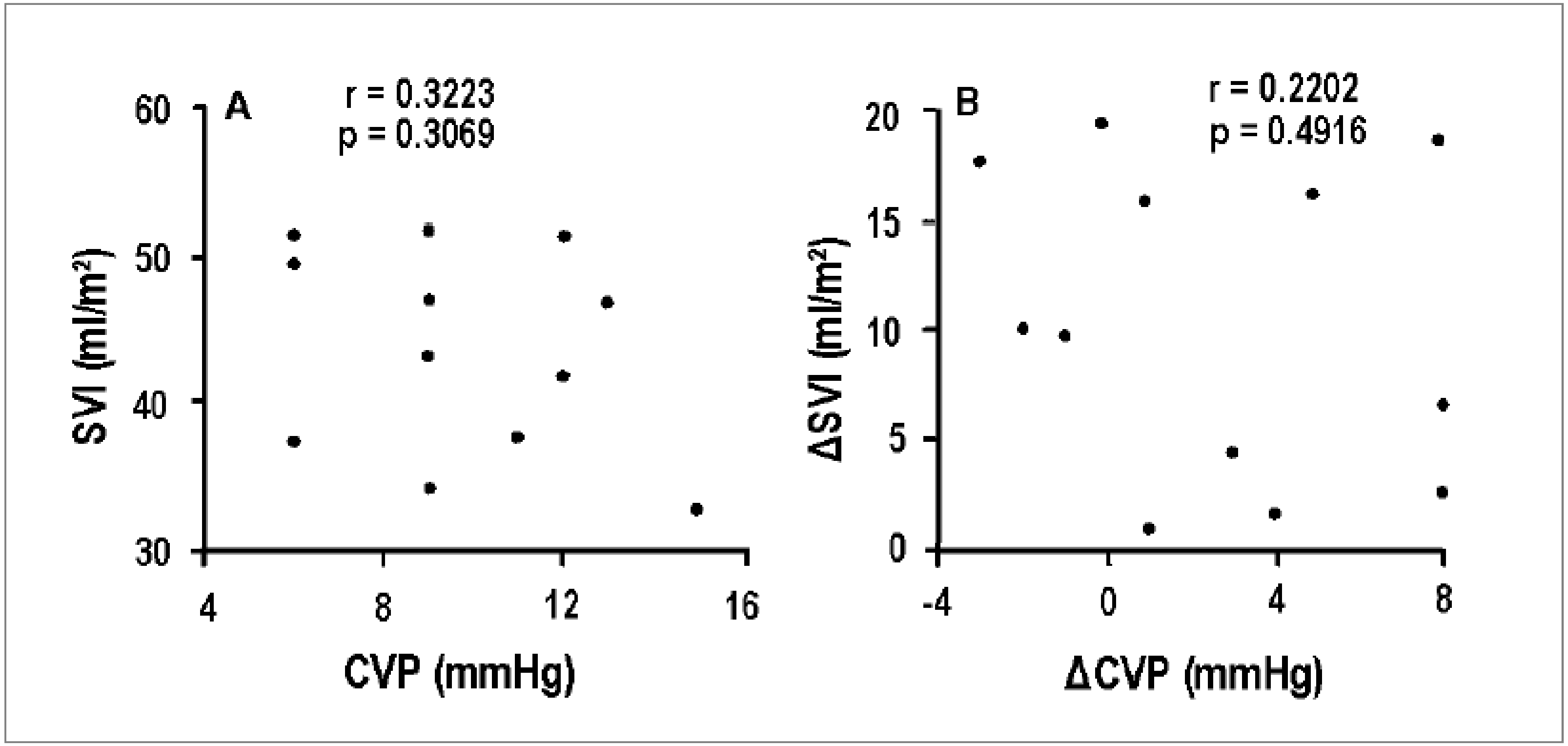
GEDV / ITBV

Volume Responsiveness

SVV / PPV

Role of the filling pressures CVP / PCWP

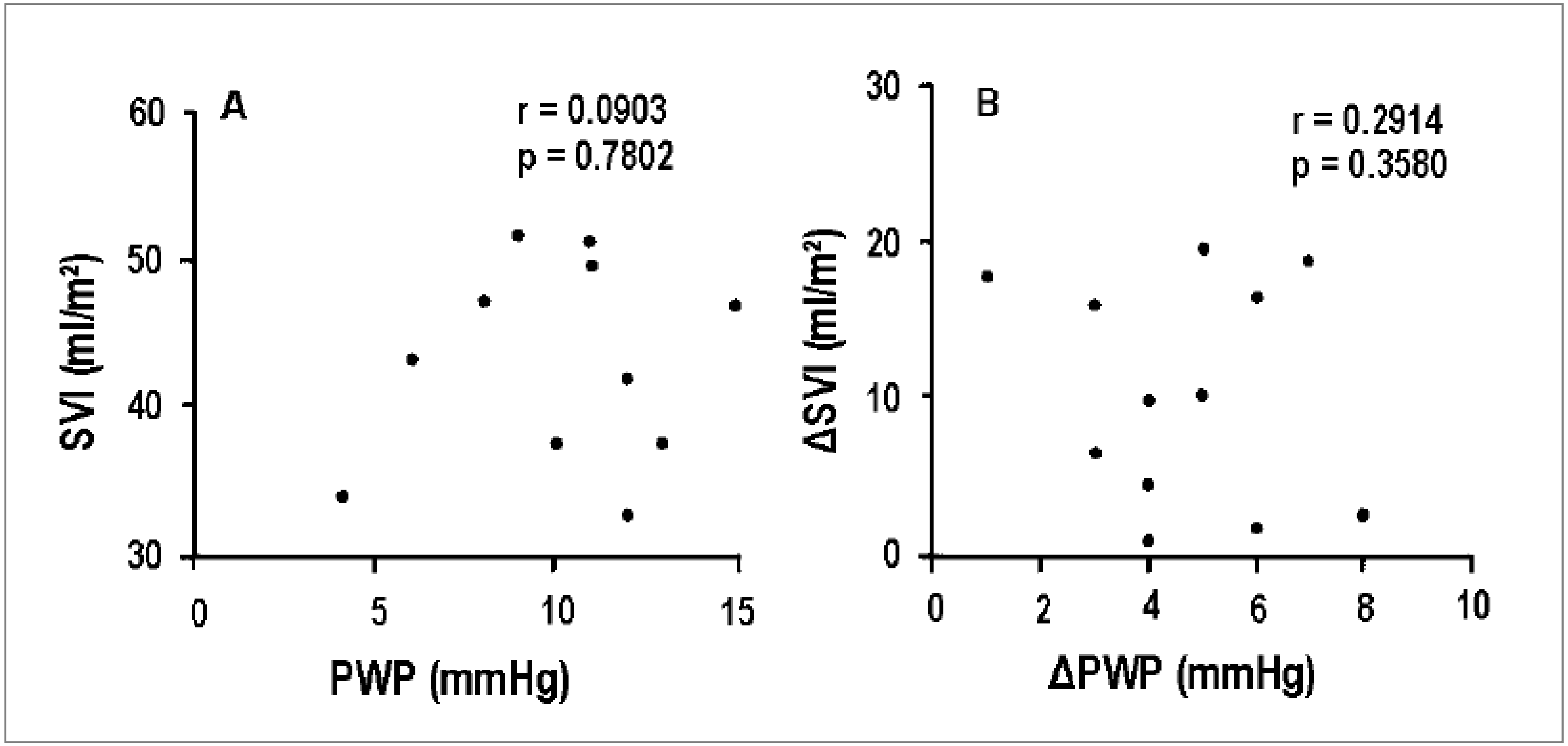
Correlation between CVP and Stroke Volume



Kumar et al., Crit Care Med 2004;32: 691-699

Role of the filling pressures CVP / PCWP

Correlation between PCWP and Stroke Volume



Kumar et al., Crit Care Med 2004;32: 691-699

Role of the filling pressures CVP / PCWP

The filling pressures CVP and PCWP do not give an adequate assessment of cardiac preload.

The PCWP is, in this regard, not superior to CVP

Pressure is not volume!

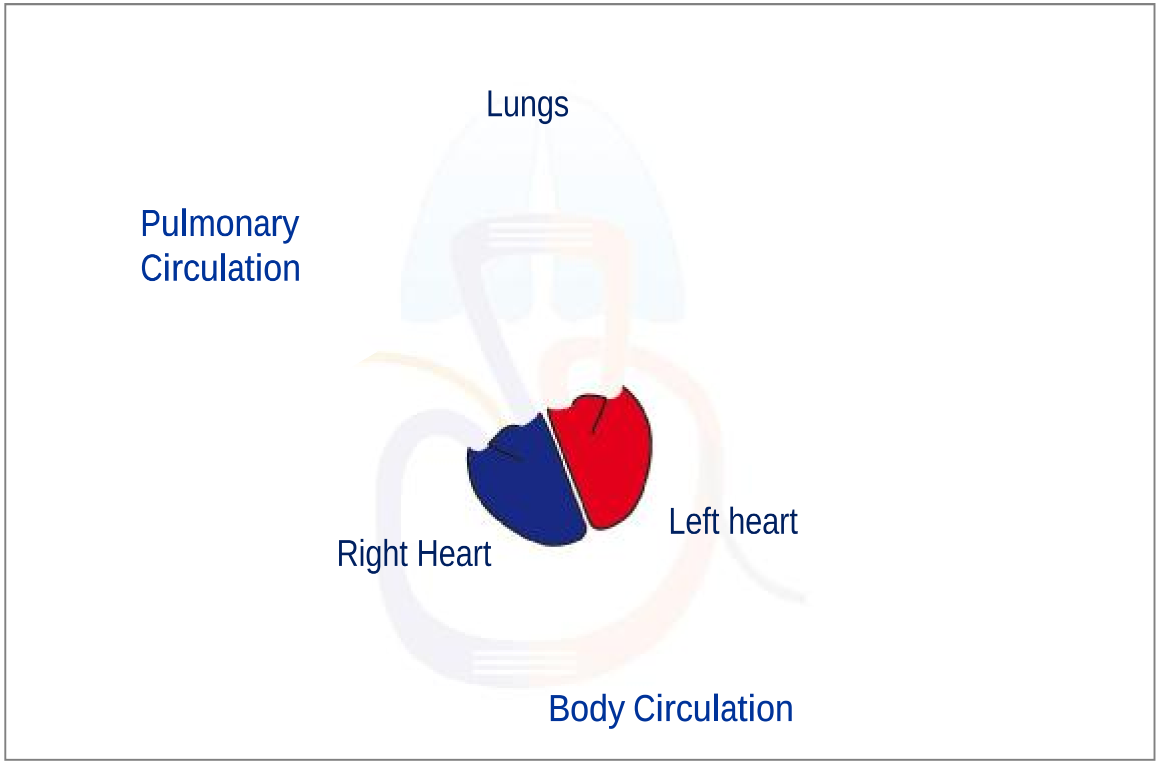
Role of the volumetric preload parameters GEDV / ITBV

Preload

Filling Pressures CVP / PCWP	Volumetric Preload parameters GEDV / ITBV	Volume Responsiveness SVV / PPV

Role of the volumetric preload parameters GEDV / ITBV

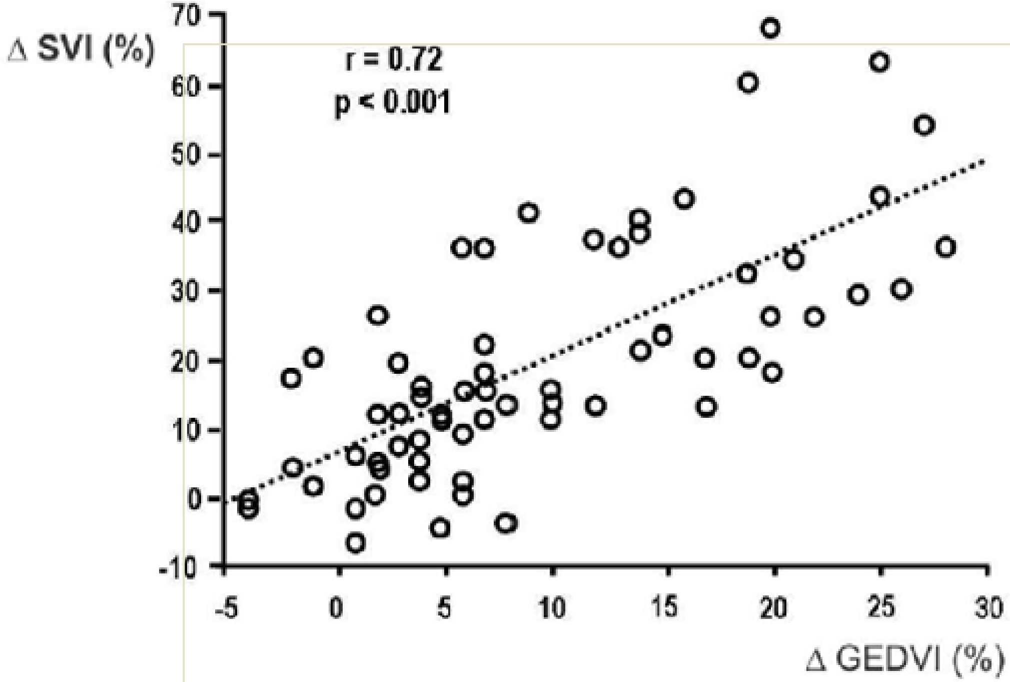
GEDV = Global End diastolic Volume



Total volume of blood in all 4 heart chambers

Role of the volumetric preload parameters GEDV / ITBV

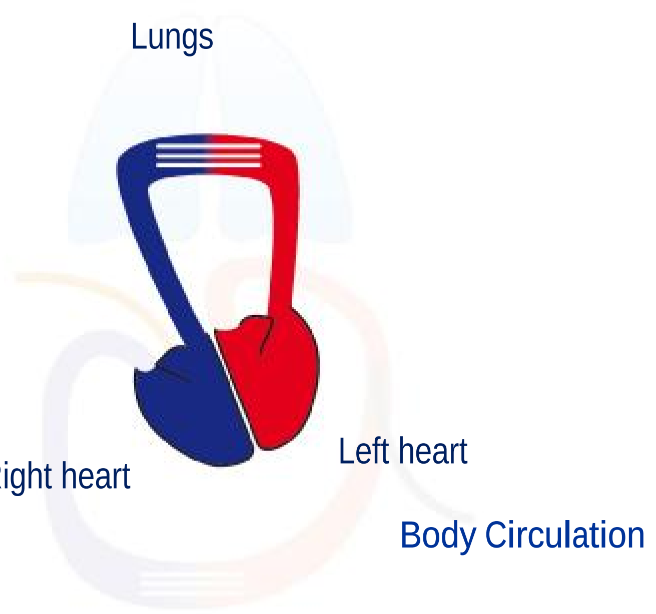
GEDV shows good correlation with the stroke volume



Michard et al., Chest 2003;124(5):1900-1908

Role of the volumetric preload parameters GEDV / ITBV

ITBV = Intrathoracic Blood Volume

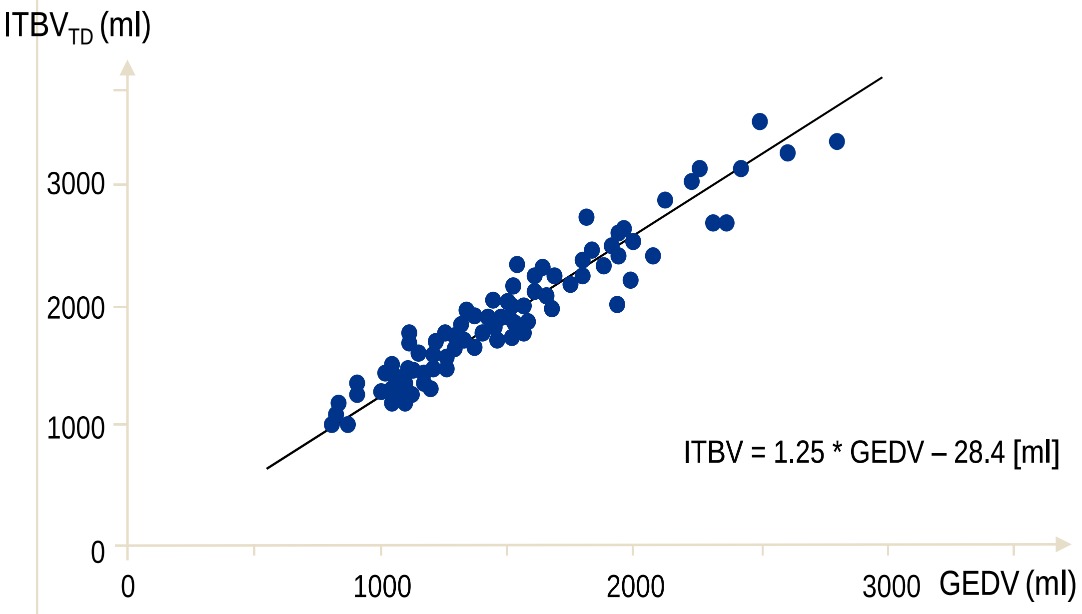


ITBV =GEDV + PBV

Total volume of blood in all 4 heart chambers plus the pulmonary blood volume

Role of the volumetric preload parameters GEDV / ITBV

ITBV is normally 1.25 times the GEDV



GEDV vs. ITBV in 57 Intensive Care Patients

Role of the volumetric preload parameters GEDV / ITBV

The static volumetric preload parameters GEDV and ITBV

- Are superior to filling pressures for assessing cardiac preload
- Are, in contrast to cardiac filling pressures, not falsified by other pressure influences (ventilation, intra-abdominal pressure)

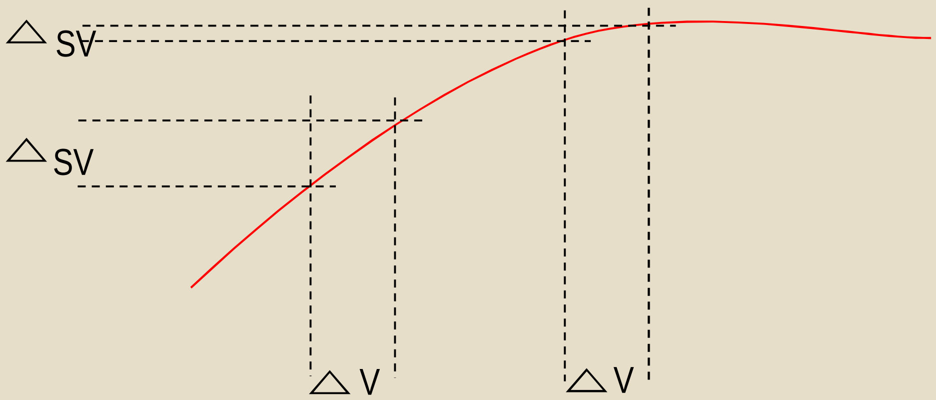
Role of the dynamic volume responsiveness parameters SVV / PPV

Preload

Filling Pressures	Volumetric Preload parameters	Volume Responsiveness
CVP / PCWP	GEDV / ITBV	SVV / PPV

hysiology of the dynamic parameters of volume responsiveness

Fluctuations in stroke volume throughout the respiratory cycle



Mechanical Ventilation

Intrathoracic pressure fluctuations

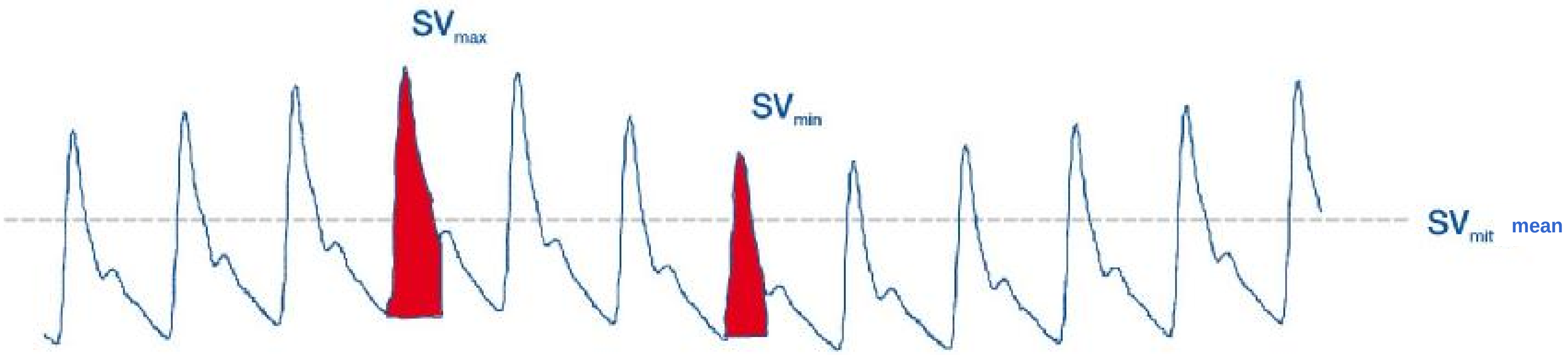
Changes in intrathoracic blood volume

Preload changes

Fluctuations in stroke volume

Role of the dynamic volume responsiveness parameters SVV / PPV

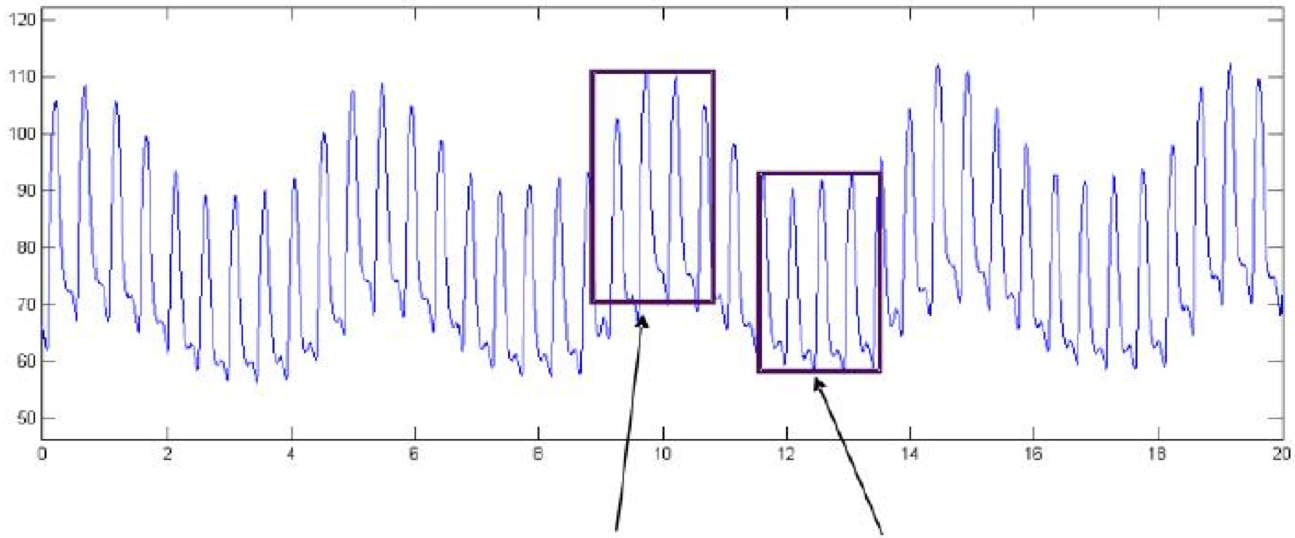
V = Stroke Volume Variation



- The variation in stroke volume over the respiratory cycle
- Correlates directly with the response of the cardiac ejection to preload increase (volume responsiveness)

FloTrac Vigileo –

Stroke Volume Variation



$$SVV = \frac{SV_{max} - SV_{min}}{SV_{mean}}$$

Stroke Volume Variation

- Can be used as a tool for volume responsiveness in low CO states.
- **SVV > 13% =Volume Responsive**
- **"SVV and PPV are more effective indicators for Volume Responsiveness then static indicators of preload (CVP, PAOP)."[7]**
- Limitations:

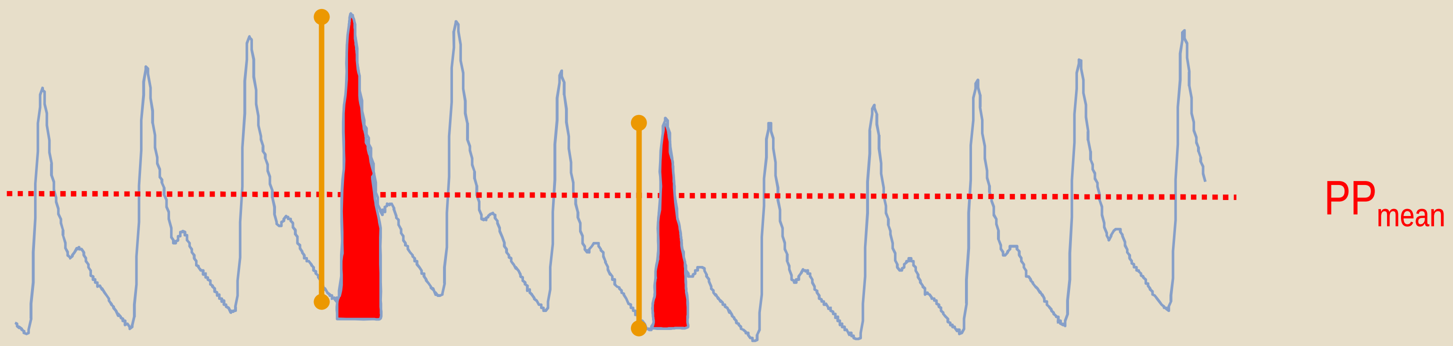
  Pt needs to be on 100% Controlled Mechanical Ventilation.

  Spontaneous Ventilation & SVV ?

  Arrhythmias can affect SVV.

Role of the dynamic volume responsiveness parameters SVV / PPV

V = Pulse Pressure Variation

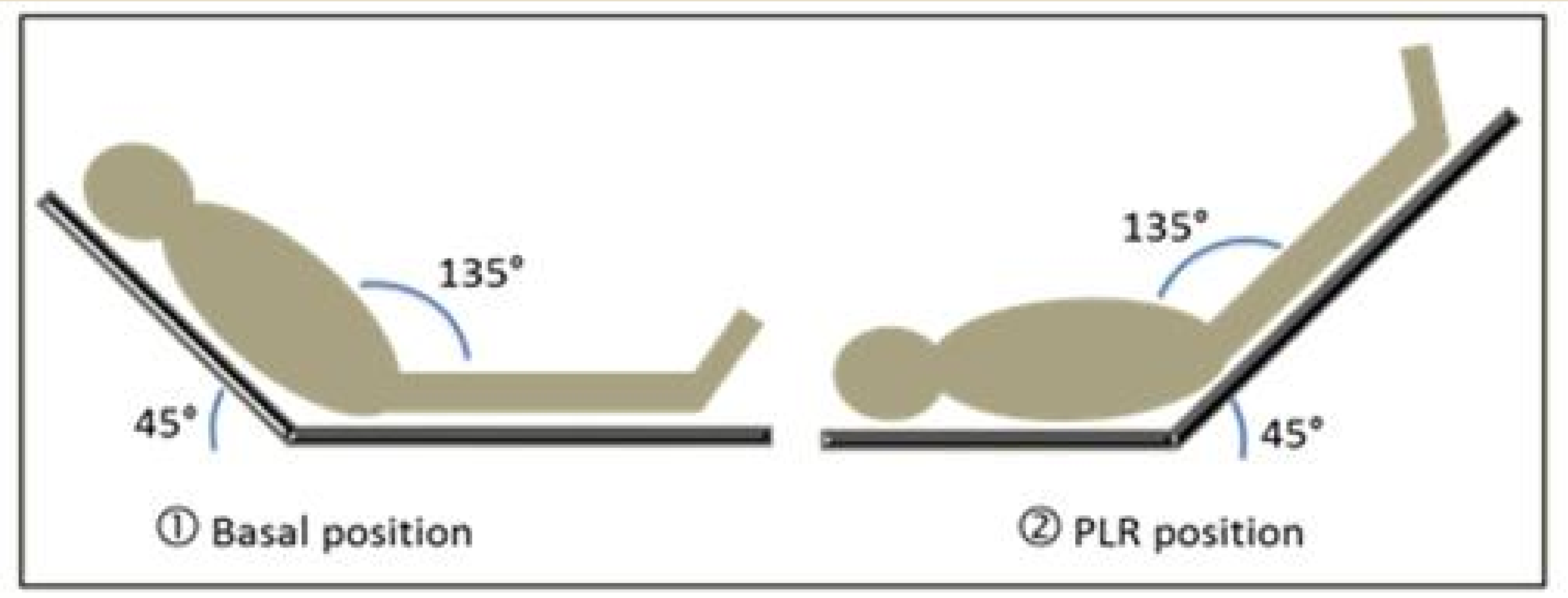


- The variation in pulse pressure amplitude over the respiration cycle
- Correlates equally well as SVV for volume responsiveness

Role of the dynamic volume responsiveness parameters SVV / PPV

- Good predictors of a potential increase in CO due to volume administration
- Only valid with patients who are fully ventilated and who have no cardiac arrhythmias

Passive Leg Raising maneuver (PLR)



PLR

Reversible increase in preload (200-300 mL)

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Increases stroke volume in potential fluid responders

Tradditinal form

need to detected within minutes

Continuous cardiac output measurement, and thus stroke volume, by **PAC** requires **8 to 10 min of delay**

Minimally invasive systems

Maximal effect = 30-90 seconds
Will reach 10- 15 % increase in SV

PLR

More than 10% increase in SV

↓

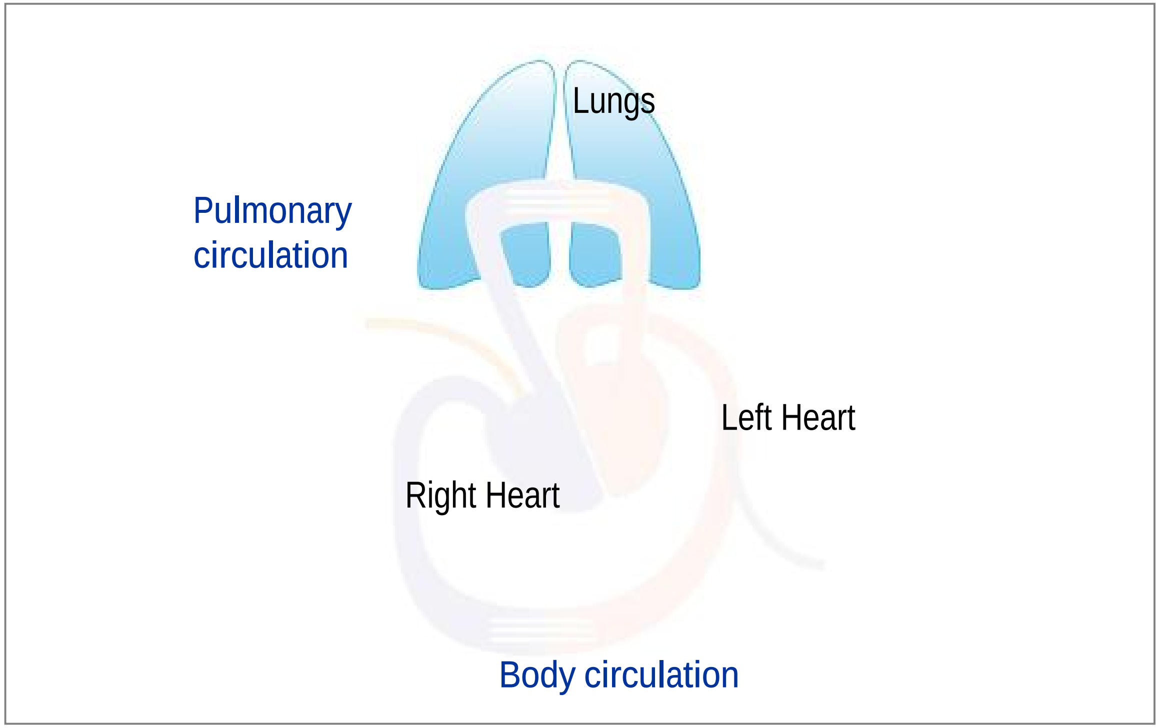
Good sensitivity & specificity

PLR limitations

- Neurologic problems
- ALI,ARDS
- Increased Abdominal Pressure
- Who are wearing elasic compression stockings
- Pain @Agitation

Role of extravascular lung water EVLW

EVLW = Extravascular Lung Water



Extravascular water content of the lung

Role of extravascular lung water EVLW

The Extravascular Lung Water EVLW

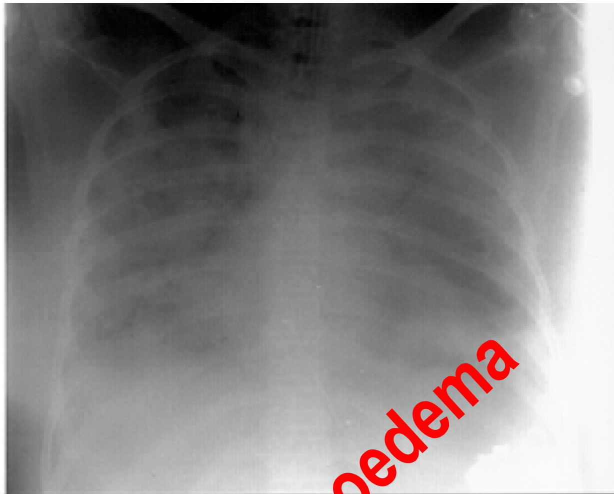
- Useful for differentiating and quantifying lung edema

The only parameter available at the bedside

- Functions as a warning parameter for fluid overload

EVLW as a quantifier of lung oedema

Pulmonary oedema



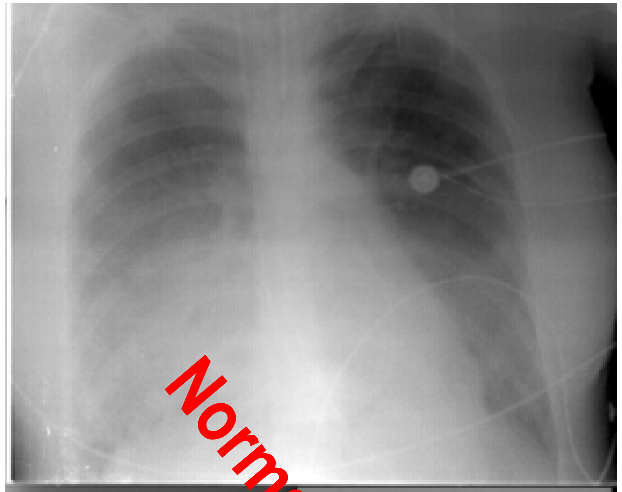
ELWI = 19 ml/kg

ELWI = 14 ml/kg

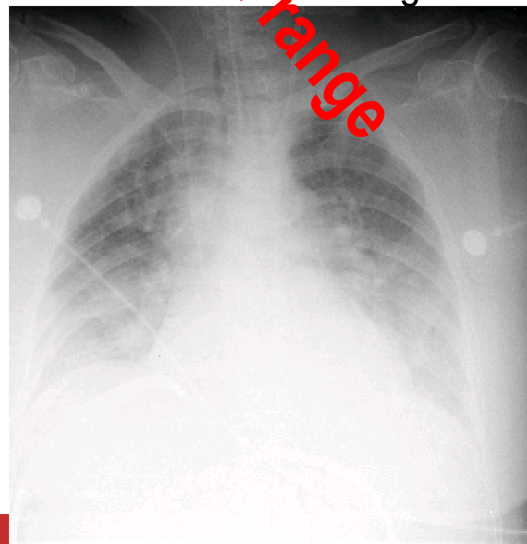
Extravascular lung water index (ELWI) normal range:

3 – 7 ml/kg

Normal range



ELWI = 7 ml/kg



ELWI = 8 ml/kg

Afterload parameter

$$SVR = \frac{(MAP - CVP) \times 80}{CO}$$

Mixed venous O2 saturation (SvO2)

- *SvO2* is the percentage of oxygen bound to Hb in blood returning to the right side of the heart

- Measured with PA catheter
- Normal is 65-75%
- Low SvO2 may indicate inadequate tissue O2 delivery (even if arterial O2 is OK)

Assessment of Adequate Oxygen Delivery

Clinical Estimation

- Tachycardia
- Tachypnea
- Prolonged Capillary Refill
- Increased Temperature Difference
- Reduced Level of Consciousness
- Decreased Urine Output

Diaphoresis
Cool Peripheries

Lab Values

- Lactate
- Base Excess

Measurement of CO and/or SvO2%

- Invasive & Noninvasive
- New vs. Old

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