

# NAVIGATING PRELOAD ASSESSMENT

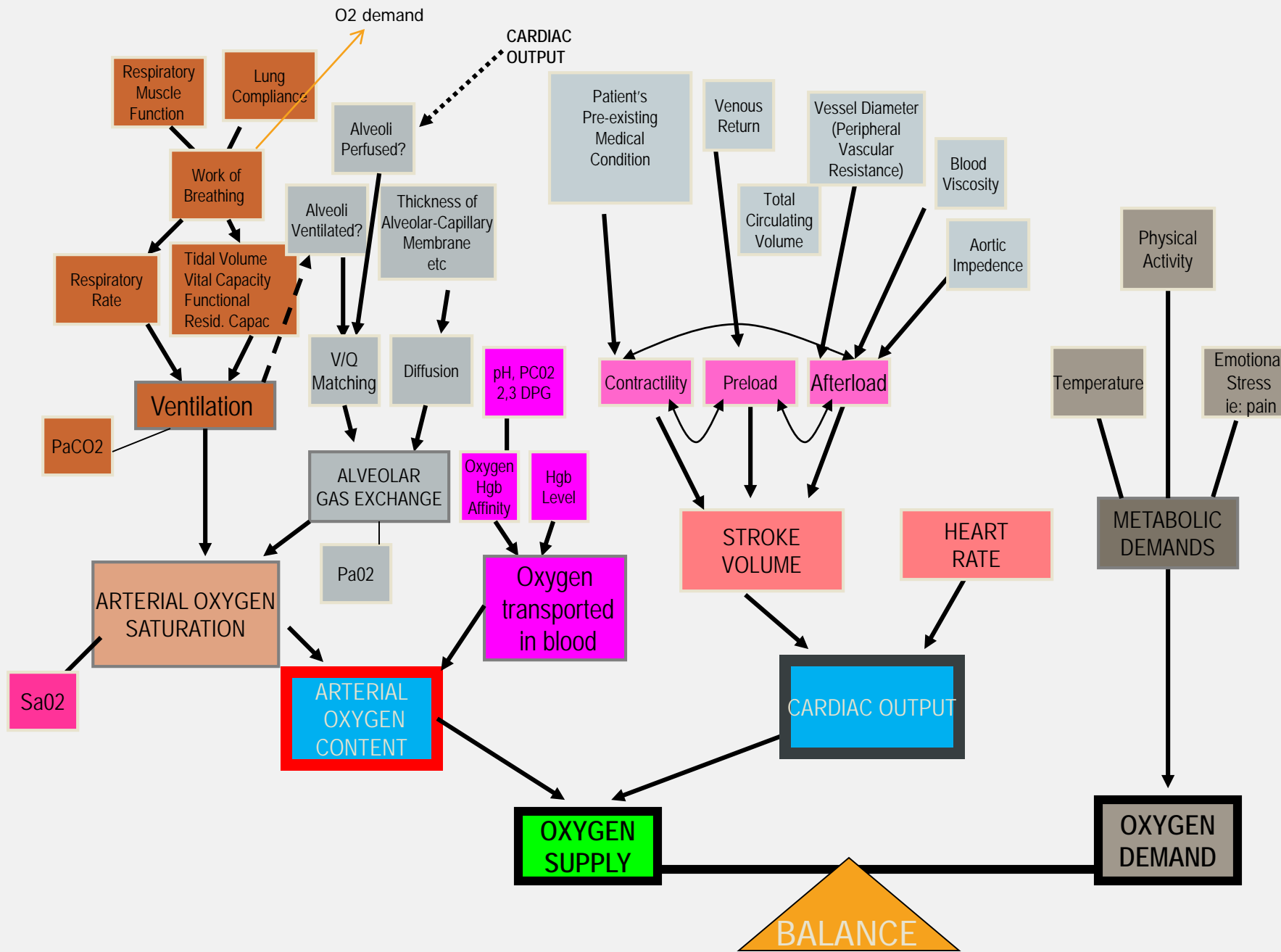
## CHOOSING THE RIGHT PATHWAY

Cecilia Baylon & Sarah Neville



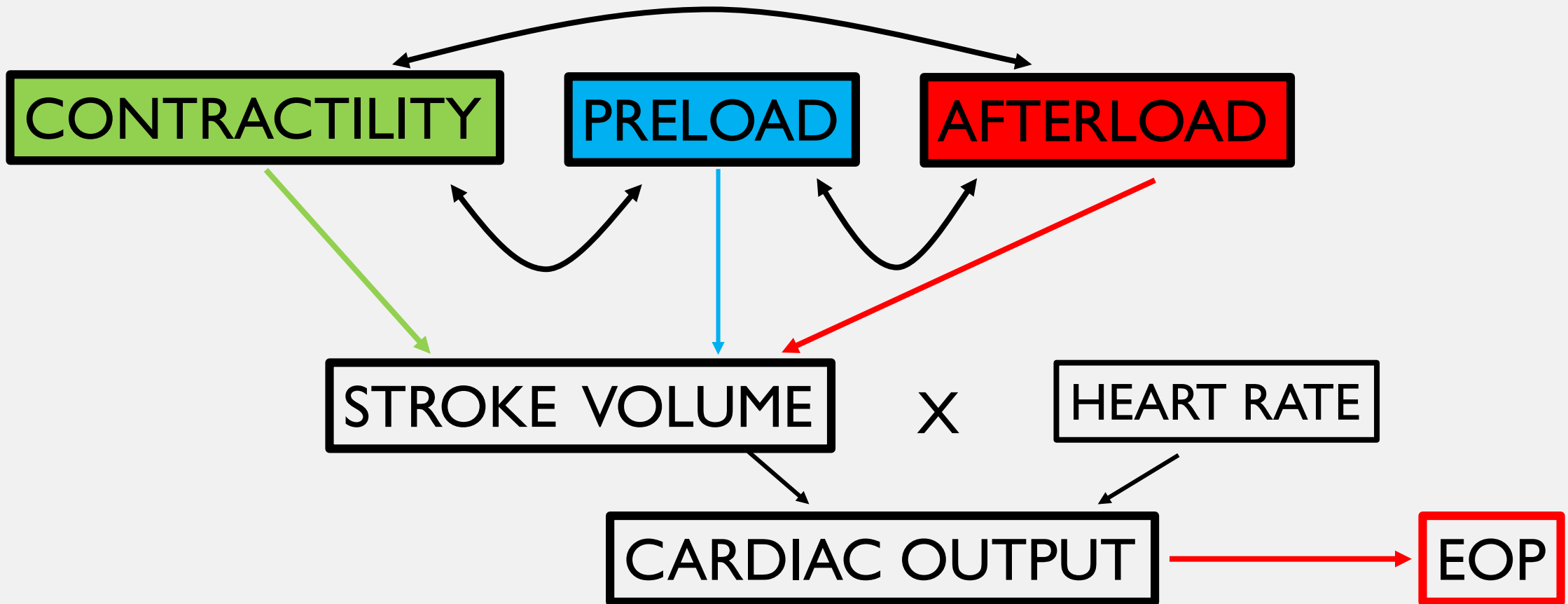
## LEARNING OBJECTIVES

- Explain the relationship between preload and fluid responsiveness (FR)
- Review the different methods of assessing preload and FR
- Analyze the current research in regard to their use in the critical care setting

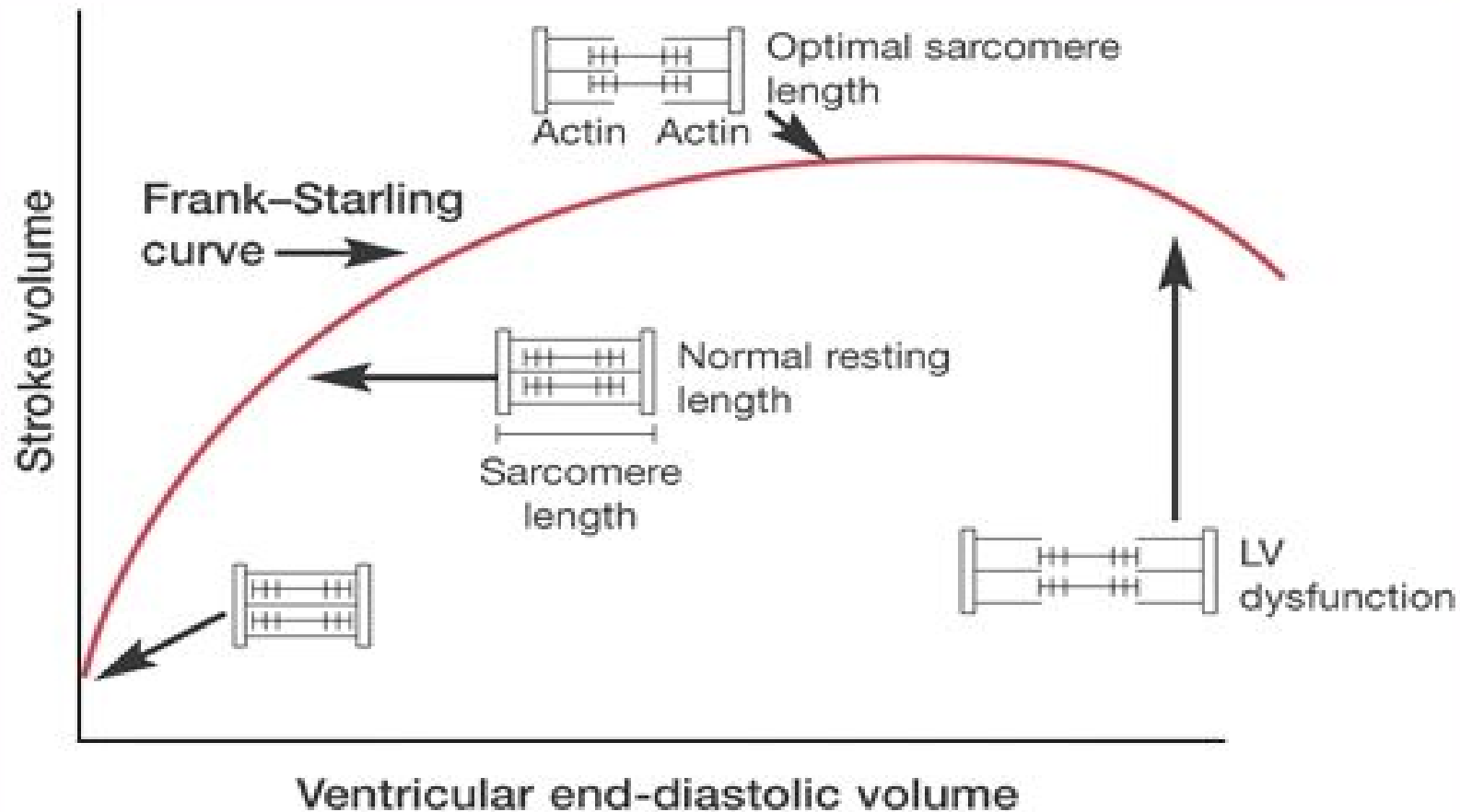


End organ perfusion

# OXYGEN SUPPLY & DEMAND (HEMODYNAMIC) FRAMEWORK



# FRANK-STARLING'S LAW



## FRANK-STARLING'S LAW

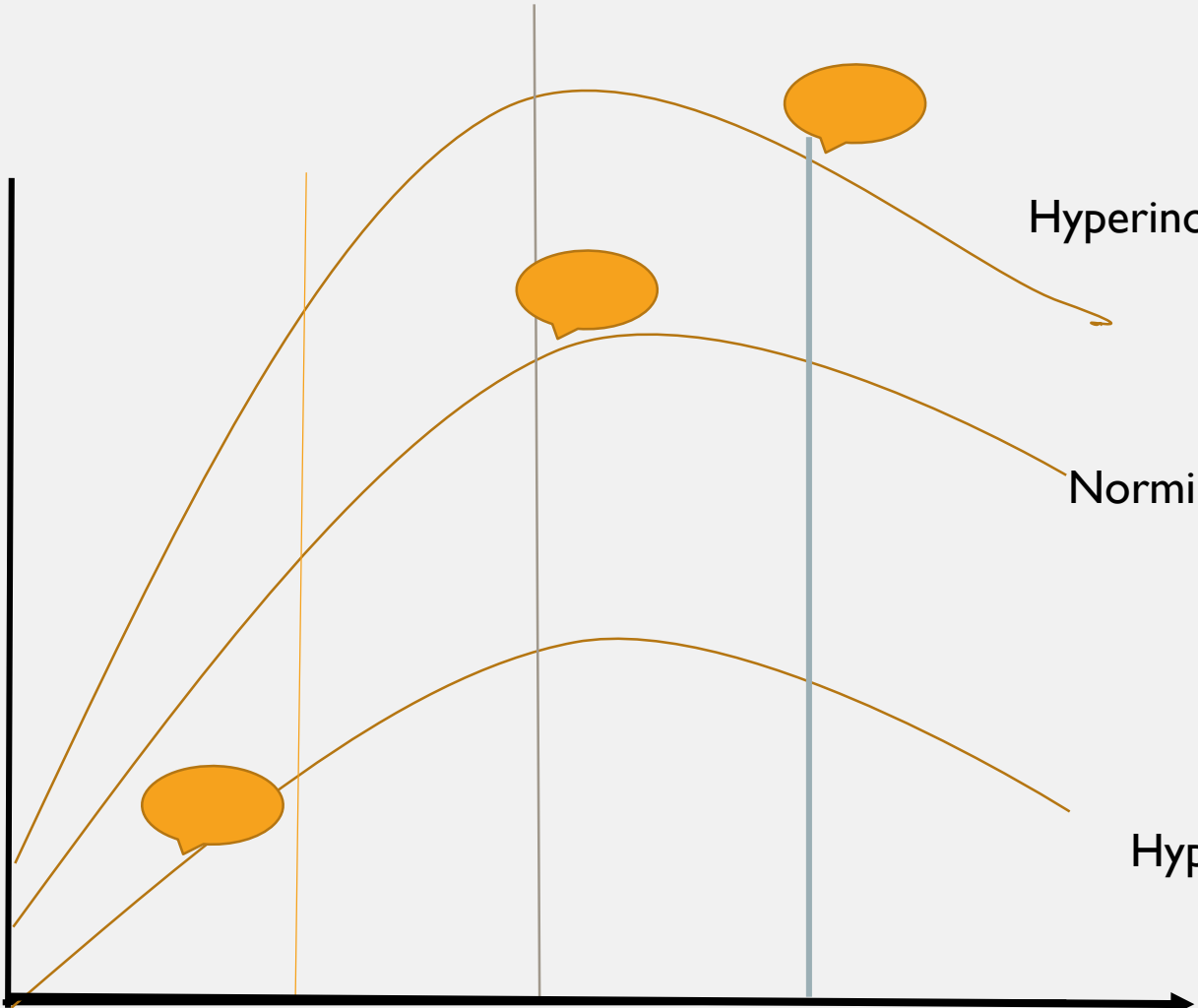
- “the force of ventricular ejection is directly related to...”

VOLUME IN THE VENTRICLE AT END-DIASTOLE (PRELOAD)

AMOUNT OF MYOCARDIAL STRETCH PLACED ON THE  
VENTRICLE AS A RESULT

Urden, Stacy, Lough (2018), p. 214

Ejection  
Phase  
Contractility



Hypovolemia

Normovolemia

Hypervolemia

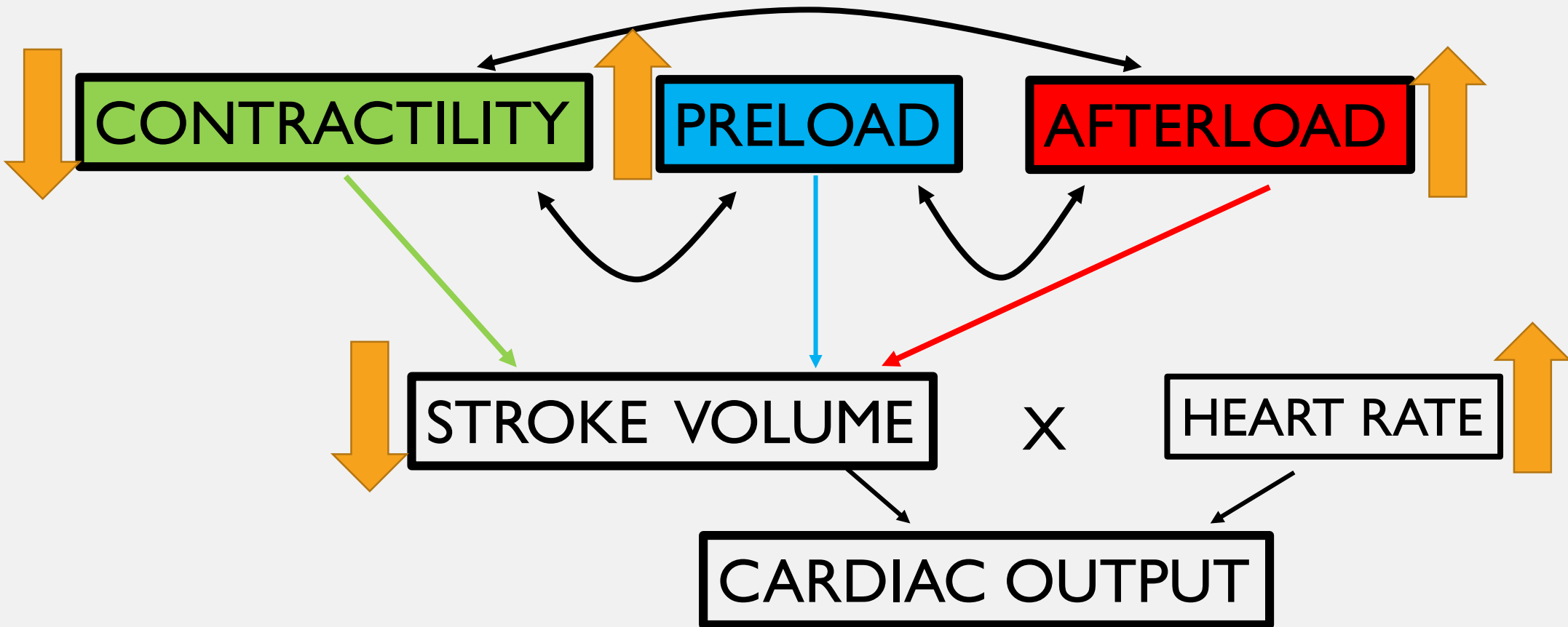
Hyperinotropy

Norminotropy

Hypoinotropy

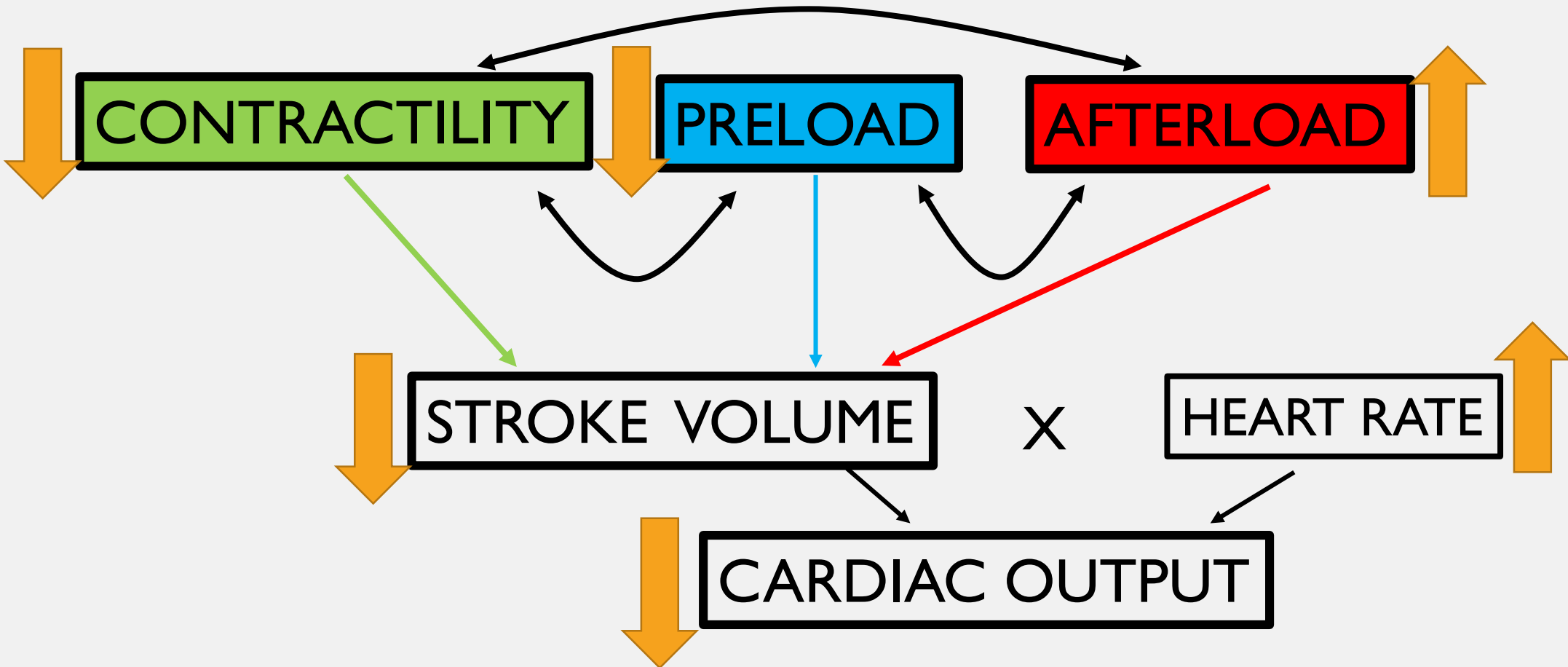
Intravascular  
Volume

# OXYGEN SUPPLY & DEMAND (HEMODYNAMIC) FRAMEWORK

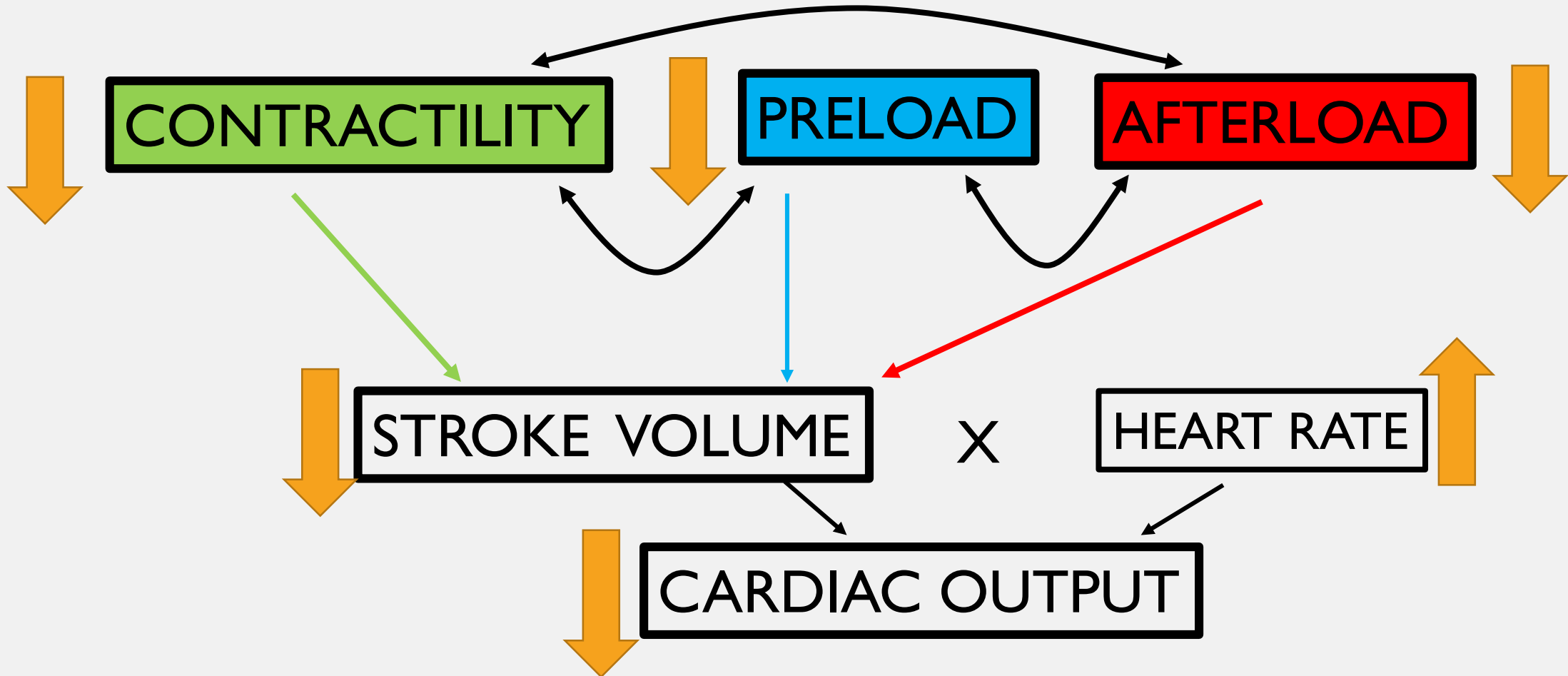




# OXYGEN SUPPLY & DEMAND (HEMODYNAMIC) FRAMEWORK



# OXYGEN SUPPLY & DEMAND (HEMODYNAMIC) FRAMEWORK



## FLUID RESPONSIVENESS

- Change in **cardiac output** of 15% or greater in response to a 500 ml fluid challenge

(Pinsky, 2015)

- Changes in **CO or SV** of more than 10 – 15% after fluids

(Carsetti, et al, 2015; Ceconi, et al, 2015)

- More than 15% increase in **arterial pressure** after volume expansion

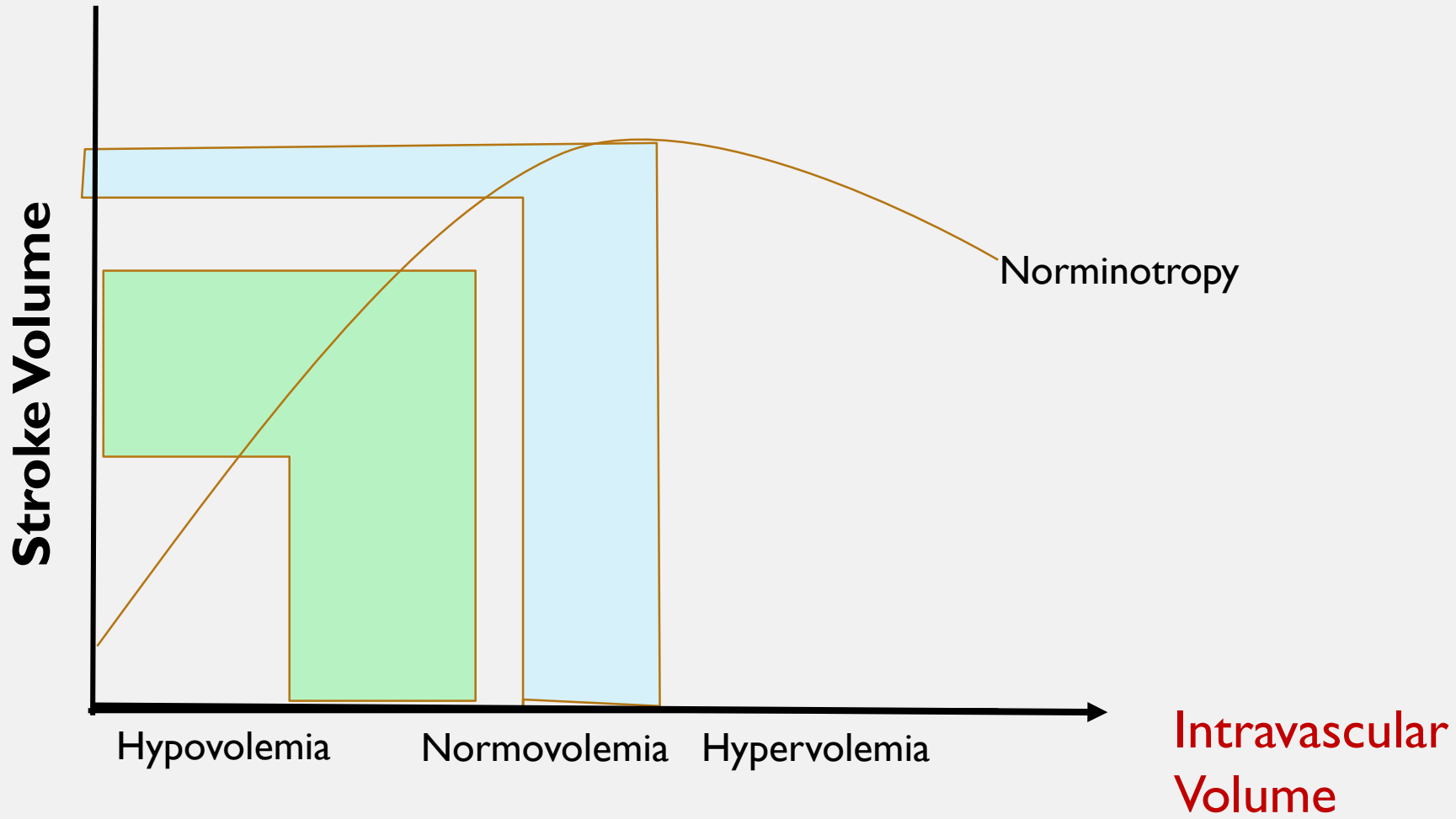
(Grassi, Nigro, Battaglia, et al, 2013)

## PRELOAD

VS

## FLUID RESPONSIVENESS

- End diastolic volume
  - Influenced by:
    - venous return
    - ventricular compliance
    - venous capacitance
  - Static measurement
- Potential for changes in CO and/or SV in relation to fluid
  - Considers changes in preload, that would impact contractility, afterload, & HR



## PRELOAD VS FLUID RESPONSIVENESS

- Your assessments will change depending on what you are looking for. Is it preload strictly or fluid responsiveness?
- Preload assessment is the start – but more testing is required to determine if they are fluid responsive
- Preload assessment is usually more effective when trying to determine if preload is too high or too low.
- Less effective when preload status is unclear ie in septic patients – edematous but intravascularly dry

# PRELOAD ASSESSMENT

## Comprehensive Physical Assessment

Inspection

Sputum

Daily weights

JVD

Mucous membranes

Palpation

Edema

Auscultation

Heart sounds

Lung sounds

## Physician Driven

Inferior Vena Cava  
Diameter

## Invasive Assessments

CVP

PCWP

PICCO

## COMPREHENSIVE ASSESSMENT

**First:** Combination of history, chest x-ray, lab data & physical examination

+

**Second:** Technological assisted devices (TAD)



# NURSING PHYSICAL ASSESSMENT

Physical assessment - informs our clinical  
care directly; humanizes our practice

(Metkus, 2015)

***Ideal:*** assessment can guide the use of TAD  
(technological assisted devices).

## NURSING PHYSICAL ASSESSMENT

Physical assessment - “immediately available, rapid and repeatable, relatively inexpensive, safe, and non-invasive.”

(Elder, et al, 2016, p. 11)

## NURSING COMPREHENSIVE ASSESSMENT STARTS WITH...

- Patient history
  - Admitting diagnosis (decompensated HF, sepsis or hypovolemic shock)
  - History of fluid loss or gains (N&V, diarrhea, bleeding, excessive fluid intake)
  - History of heart failure or kidney failure
  - Diabetes (new or uncontrolled)
  - Liver failure

# NURSING ASSESSMENT

## PRELOAD

Do a systems review or head to toe assessment.

Then...

Categorize data together...

# PHYSICAL ASSESSMENT

## PRELOAD

### Inspection

- Jugular venous distention
- Daily weights
- Mucous membranes
- Sputum type – thin pink frothy

# NURSING ASSESSMENT

## PALPATION

- EDEMA
  - FLUID ACCUMULATION IN THE **EXTRAVASCULAR SPACES OF THE BODY**
    - dependent
    - unilateral or bilateral
    - pitting or non-pitting
  - Not the most reliable indicator of preload especially in critically ill patients
- SKIN TURGOR

# NURSING ASSESSMENT

## PRELOAD

### AUSCULTATION

#### HEART SOUNDS

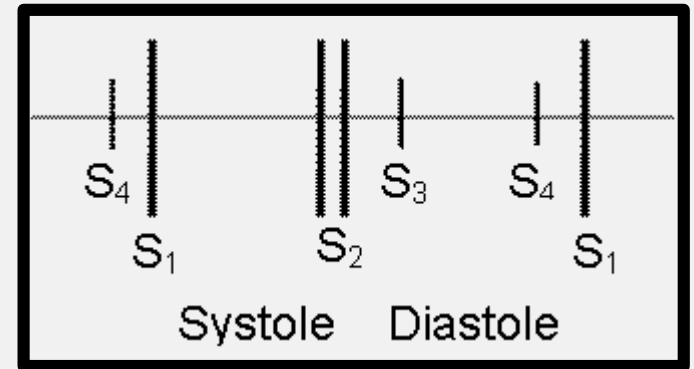
- S3 – ventricular gallop

indicator of heart failure -

ventricle with fluid overload

- S4 – atrial gallop

atrial contraction when the ventricle is stiff



# NURSING ASSESSMENT

## PRELOAD

### AUSCULTATION

#### Lung Sounds

- Bibasilar crackles or rales (inspiratory)





# NURSING PHYSICAL ASSESSMENT

## Integration

- It is important to look at the whole picture as noted with the framework concepts, so we will also look at assessment parameters for afterload and contractility.

# NURSING ASSESSMENT

## AFTERLOAD

### INSPECTION

- Limb colour





# NURSING ASSESSMENT

## AFTERLOAD

### PALPATION

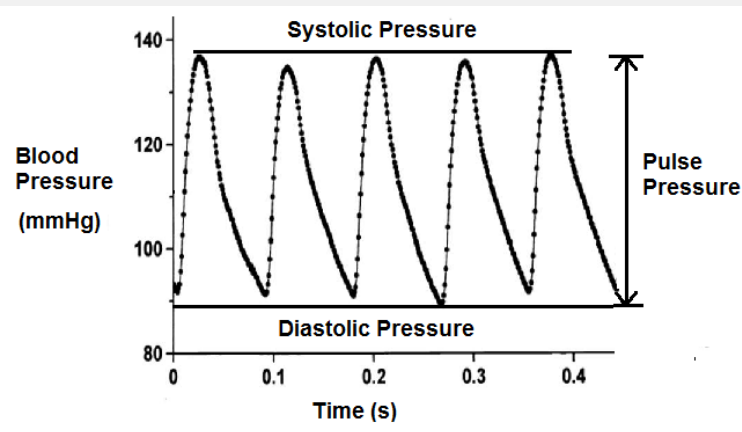
CAPILLARY REFILL -  $> 3$  secs / delayed : indicative of vasoconstriction

PULSES - decreased/+dopplers: indicative of vasoconstriction  
- bounding: indicative of vasodilation

SKIN TEMPERATURE - cool peripheries: indicate vasoconstriction,  
- warm peripheries indicate vasodilation

MORTON & FONTAINE (2013)





# NURSING ASSESSMENT AFTERLOAD

## AUSCULTATION

- PARAMETERS:

DIASTOLIC BP -  $< 60$  mmHg is low

PULSE PRESSURE - normal 40 mmHg

- Low DBP and wide PP indicative of vasodilation = low afterload
- High DBP and narrow PP indicative of vasoconstriction = high afterload

# NURSING ASSESSMENT

## CONTRACTILITY

### PRELOAD CONCLUSION

- based on Frank-Starling's law

### CARDIAC HISTORY

- heart failure, MI/ST segment changes or q waves
- ejection fraction, LV function on ECHO

### POINT OF MAXIMAL IMPACT

- Palpation of apex of heart – if shifted indicates increased size of left ventricle

(Gillespie, 2013)

# NURSING ASSESSMENT

## END ORGAN PERFUSION

- CNS – decreased LOC for no other discernible reason
- CVS – cardiac chest pain, ST segment changes and troponins
- RESP – increased WOB, decreased PaO<sub>2</sub>, elevated PaCO<sub>2</sub>
- GI – hypoactive/no BS, N&V, LFTs
- GU – decreased urine output (consider if pt has known kidney disorders), creatinine, BUN, and eGFR

# NURSING ASSESSMENT

## END ORGAN PERFUSION- GLOBAL PARAMETERS

Serial lactate : usual cut-off value is 2 mmol/L

ScvO<sub>2</sub>/SVO<sub>2</sub> : provide balance between O<sub>2</sub> transport & demand

Venoarterial CO<sub>2</sub> difference (pCO<sub>2</sub> gap) >6 mmHg

# PROCEDURES/DIAGNOSTICS

**Static measures**



# CENTRAL VENOUS PRESSURE

- Estimate of right ventricular filling
- Affected by valvular regurgitation, right ventricular dysfunction, pulmonary hypertension (Mikkelsen, et al, 2019; Pinsky, 2015)
- Affected by variation in intrathoracic pressure with respiration  
MV and spontaneous breathing (SB) influence static measures  
heart-lung physiologic interactions vary between MV & SB (Pinsky, 2015)
- Requires CVC, also anticipate complications

## CENTRAL VENOUS PRESSURE

“An increase in CVP or in EDV only reflects that preload was effectively manipulated not helpful in identifying patients who experience an increase in CO in response to fluid administration.”

(Pinsky, 2015)

# CENTRAL VENOUS PRESSURE

CVP alone cannot evaluate fluid responsiveness

= sufficient fluid is given to achieve a minimal increase in CVP (up to 2 mmHg)

with a concomitant increase in CO = fluid responsive

- increase in CVP without increase in CO = further fluids not indicated

(Carsetti, Cecconi, & Rhodes, 2015).

# PULMONARY WEDGE CAPILLARY PRESSURE

- Estimate of left ventricular filling
- Normal range: 5-12 mmHg (Urden, Stacy & Lough, 2018)
- Need pulmonary artery catheter; potential for complications.
- Challenges in interpreting intravascular pressures from PACs (Mikkelsen et al, 2019; Pinsky, 2015)

# PROCEDURES/DIAGNOSTICS

## STATIC PRESSURES

CENTRAL VENOUS PRESSURE (CVP)

PULMONARY CAPILLARY WEDGE PRESSURE (PCWP/PAOP)

- poor predictive value for predicting fluid responsiveness (Lakhal et al, 2010; Mikkelsen, et al, 2019)
- not good predictors of preload or the change in SV or CO to fluid challenge  
(Carsetti, et al, 2015)
- do not identify those patients who will increase their CO in response to fluid loading  
(Pinsky, 2015)

## OTHER STATIC MEASURES OF PRELOAD

- Global end-diastolic volume –using a PICCO or EVI000 system
- Inferior vena cava diameter

# Preload Assessment

High

Diuresis

Low  
Hypovolemic Shock

Fluid Resuscitation

Unclear  
Septic shock

Will they be fluid responsive

Is the pt mechanically ventilated?

yes

no

# HEART-LUNG INTERACTIONS

Change in intra-thoracic pressure (ITP)

- related directly to the ventilator applied tidal volume
- related indirectly to the compliance of the chest wall



# HEART-LUNG INTERACTIONS

During mechanical **inspiration** -> Initial increase in SBP (reverse pulsus paradoxus)\*

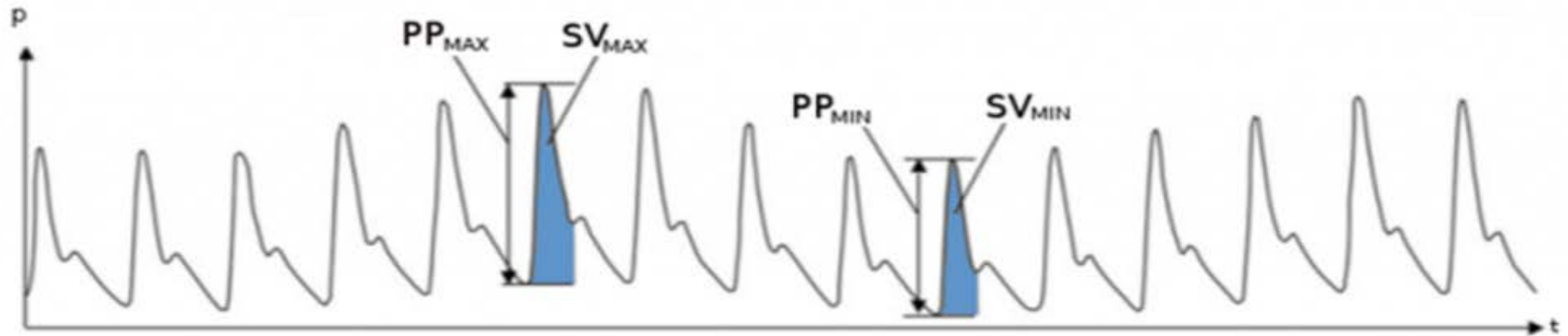
Increase in ITP -> reduces venous return (ascending portion of the curve)-> reduces RV output  
(by 20-70%)\*\*

**2-3 cardiac cycles later ...**

During mechanical **expiration** -> an inspiratory reduction in RV output reaches the LV -> reduces LV output  
-> expiratory reduction in aortic systolic pressure

This allows for a beat –to-beat evaluation of LV SVV

# DYNAMIC PRESSURES



EXPIRATION

INSPIRATION

EXPIRATION

INSPIRATION

# FLUID RESPONSIVENESS ASSESSMENT

Dynamic assessments

## PROCEDURES/DIAGNOSTICS - **DYNAMIC**

Stroke volume variation (SVV)

Systolic pressure variation (SPV)

Pulse pressure variation (PPV)

- info as to whether an increase in preload will also lead to an increase in SV

Preload dependent zone

Area of curve where  
Are still responsive  
CO increase of >10-

**Preload  
unresponsiveness**

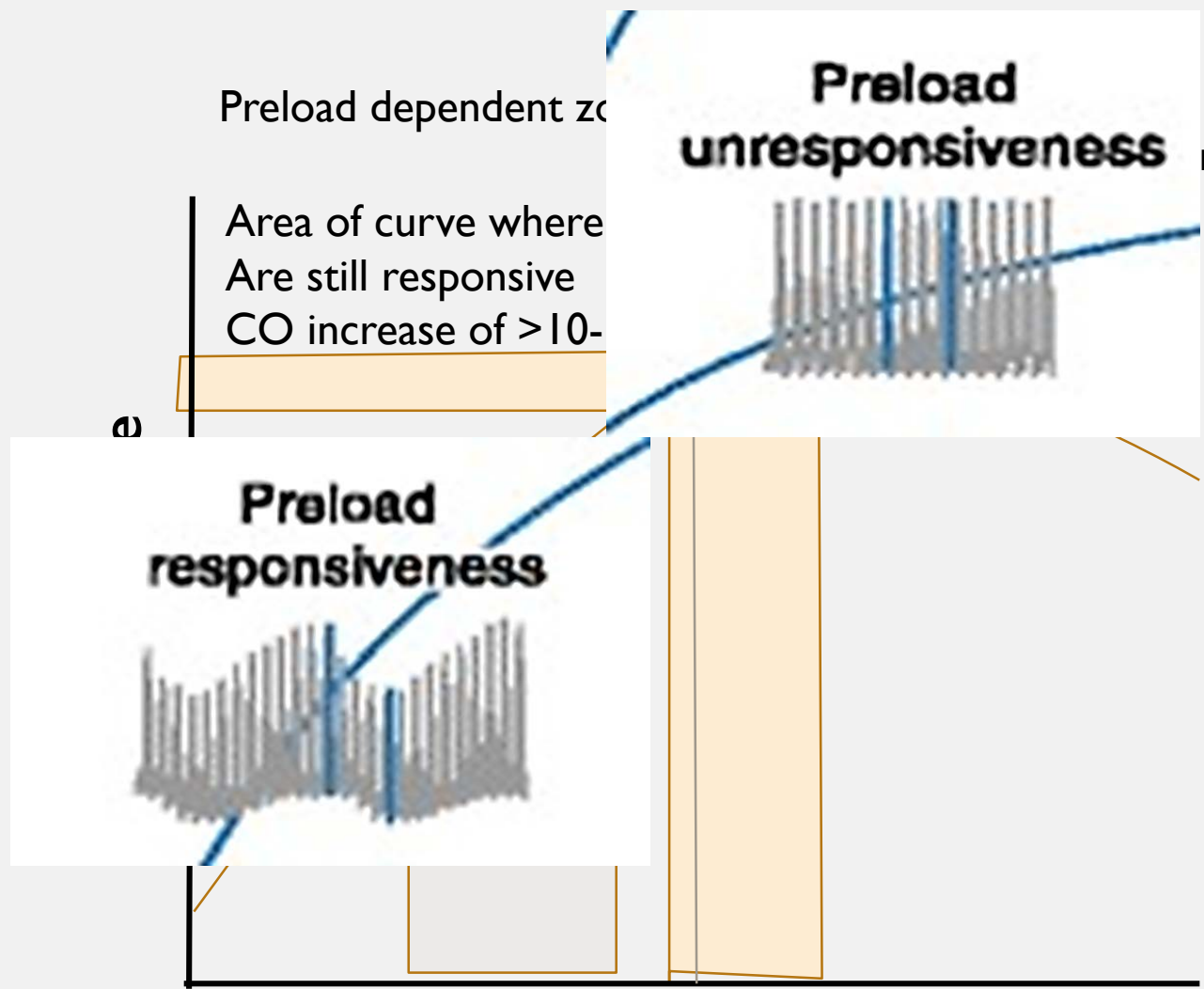
are no longer fluid responsive

a)

**Preload  
responsiveness**

**Ventricular Preload**

**Intravascular  
Volume**

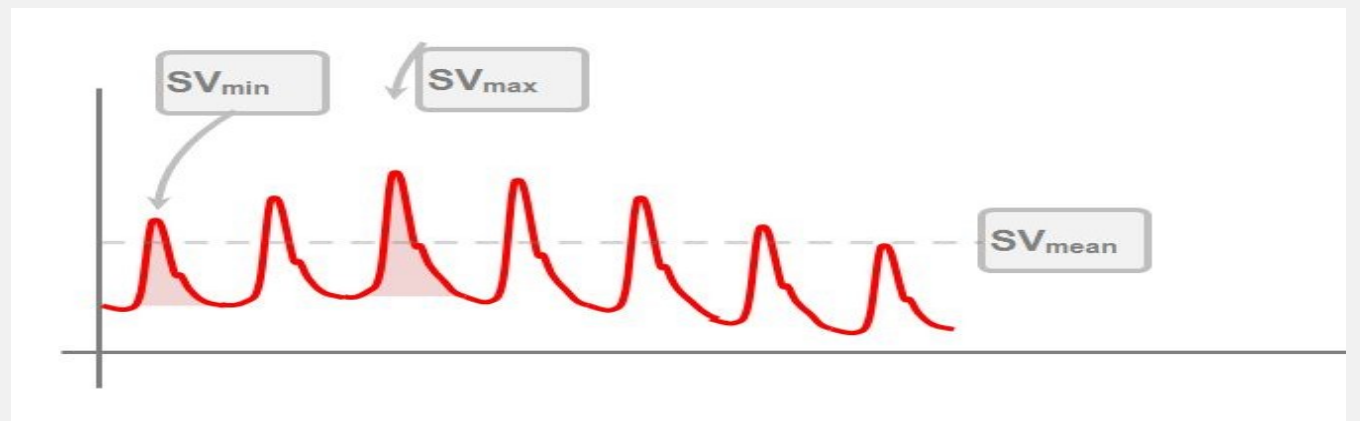
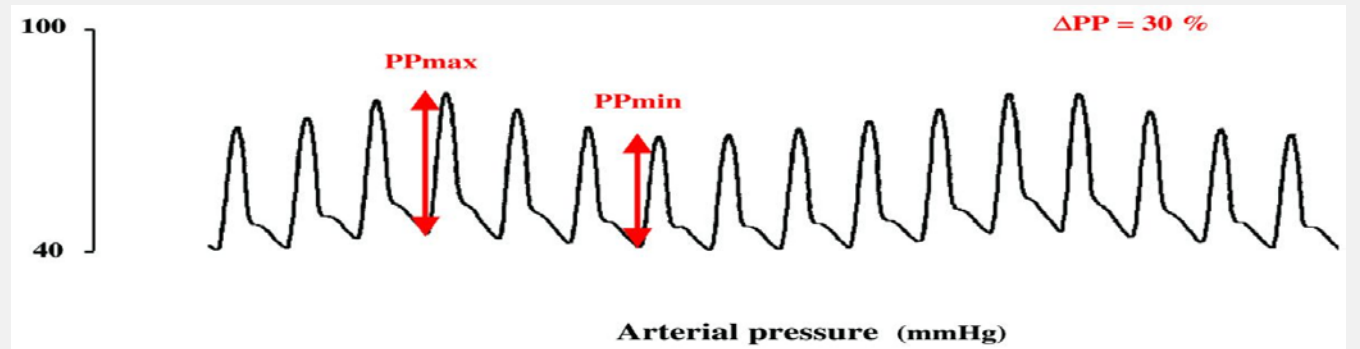


# PPV AND SVV

Normal range:  $< 10\% \text{ ml/m}^2$

PPV  $> 13-15\%$

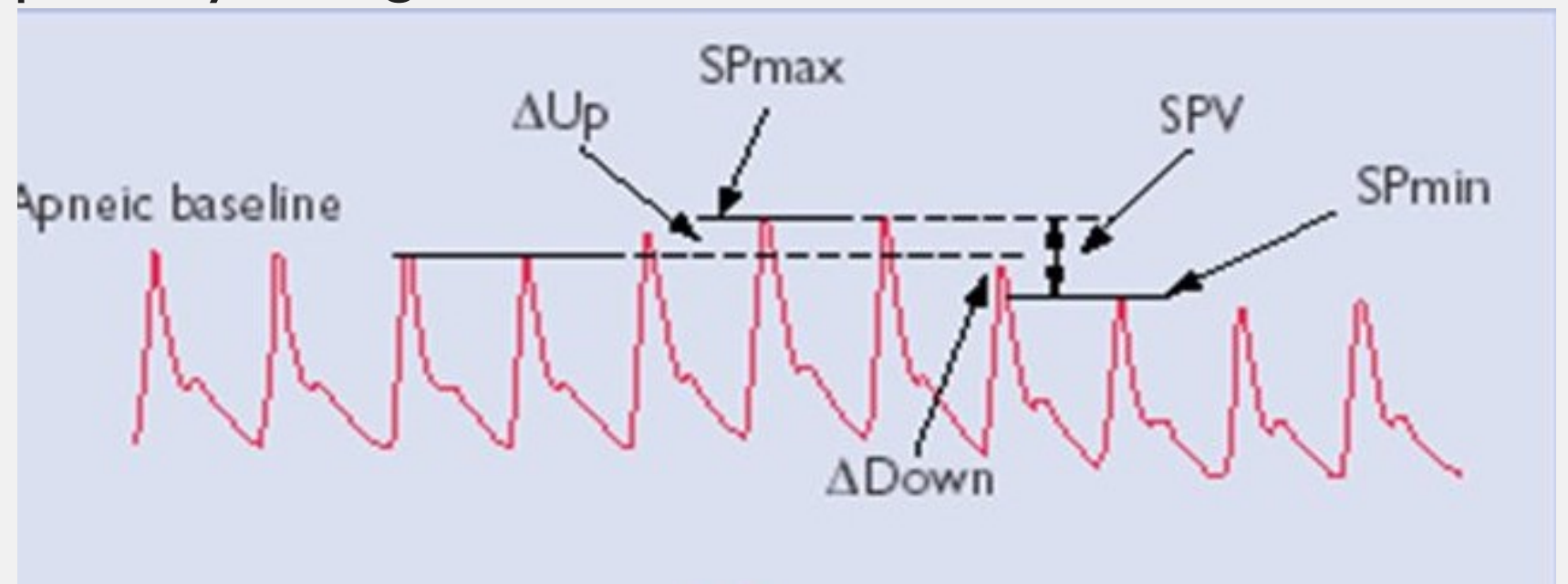
SVV  $> 10\%$



## SYSTOLIC PRESSURE VARIATION (SPV)

$SPV \text{ [mmHg]} = SBP \text{ max} - SBP \text{ min}$

Looks for respiratory changes in the ABP



## **SVV AND PPV**

For this data to be useable patients must:

be fully mechanically on a volume control mode

tidal volume  $\geq 7-8$  ml/kg

heart rate – resp rate ratio  $\geq 4$

no arrhythmias

arterial line



## SVV AND PPV

Valid clinical criteria: **consider**

PEEP: higher PEEP - higher variations

open abdomen: reduces SVV/PPV by 40 – 50%

Δ in lung or chest compliance, patient position

left or right ventricular dysfunction

pneumoperitoneum

## PPV AS A PREDICTOR OF FLUID RESPONSIVENESS (AN OBSERVATIONAL STUDY)

Grassi, Nigro, Battaglia, Barone, Testa & Berlot, (2013)

- Good accuracy even in MV pts who **actively trigger** the ventilator
- Used SPV (instead of flow-based indices CO or SV)
- Set inspiratory & expiratory triggers

## PULSE PRESSURE VARIATION (PPV)

### Tidal volume challenge (TVC)

Temporarily increasing TV from 6 ml/kg to 8 ml/kg for 1 min and noting changes in measurements

$\Delta\text{PPV} > 3.5\%$  predicts FR with high accuracy (Jalil & Cavallazi, 2018)

PROCEDURES/DIAGNOSTICS  
**DYNAMIC**  
**HEMODYNAMIC MANEUVERS**

Fluid challenge

Passive leg raise

End expiratory occlusion test

## FLUID CHALLENGE

A dynamic test of the CVS that assesses the preload reserve of the patient ( Carsetti, Cecconi & Rhodes, 2015)

- Usually 250 ml or 3 ml/kg of crystalloids
- OR 500 ml  
OR 100 ml over 1 min (mini-challenge)
- Infused over a short period of time (5-10 min)

## FLUID CHALLENGE

- Fluid responsive if SV or CO increases more than 10-15 %
- Need to remember that:
  - ✗ blood pressure alone is not a good indicator (BP dependent on CO & elastance)

(Carsetti, Cecconi & Rhodes, 2015)

✗ MAP & CVP alone are not accurate (Chen, 2018)

✗ CVP & urine output (Ahrens, 2010)

## FLUID CHALLENGE

“defining [fluid] responsiveness by giving small volumes of fluid is not the same as fluid resuscitation”

Fluid challenges merely document [fluid] responsiveness.

Aggressive fluid resuscitation in shock is evaluated by the reversal of organ and tissue hypoperfusion. (Pinsky, 2015)

## FLUID CHALLENGES IN INTENSIVE CARE

**FENICE study** (2015) – 2213 patients in 46 countries

- Median amount of fluid 500 ml
- Median time 24 min
- Median rate of administration 1000 ml/hr
- Crystalloids (balanced solution then NS)



# FLUID CHALLENGES IN INTENSIVE CARE

**FENICE study** – 2213 patients in 46 countries

➤ Indications: hypotension (56-60%), oliguria, weaning vasopressor, lactate

➤ Hemo variable used to predict FR:

no variable 40 – 44%

static (33-37%) vs dynamic (20 – 23%)

CVP (25%)

PPV (4%), SVV (4%)

PAOP ( 1.4%)

**PLR** (10%)

• markers of EOP <8%

# FLUID CHALLENGES IN INTENSIVE CARE

**FENICE study** – 2213 patients in 46 countries

➤ Judged response to fluid challenge

increase in BP 67%

increase in UO 38%

decrease in HR 24%

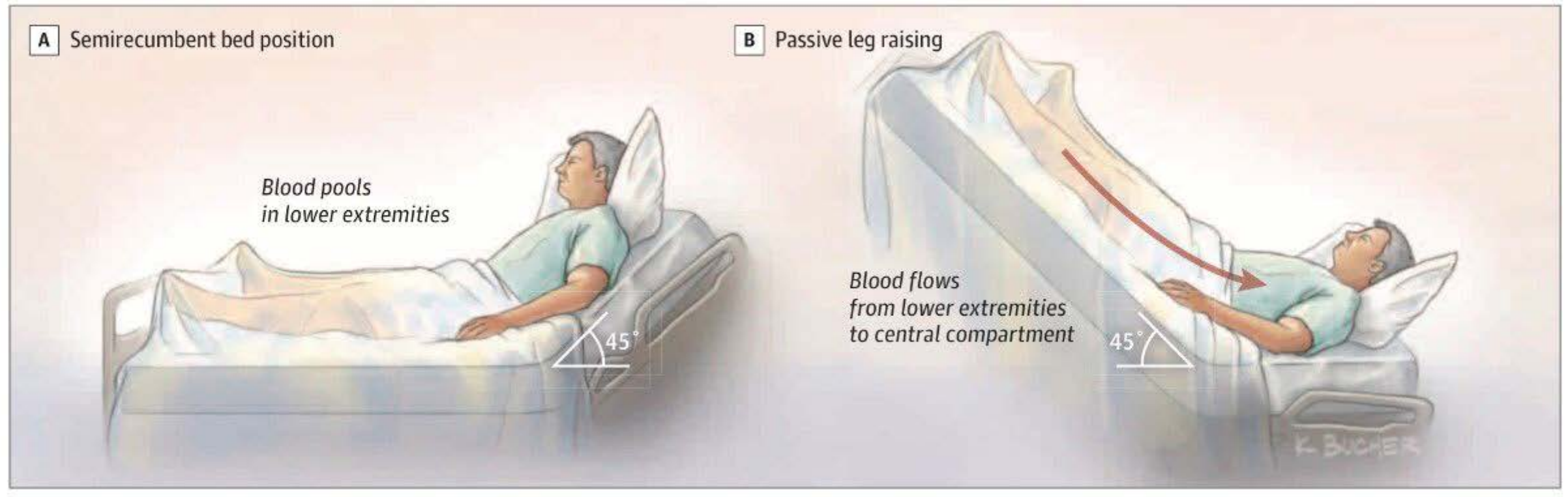
lactate 18%

CVP/PAOP 16%

## PASSIVE LEG RAISE (PLR)

- Significance/implication
- Studies

Figure 2. Performance of a Passive Leg-Raising Test

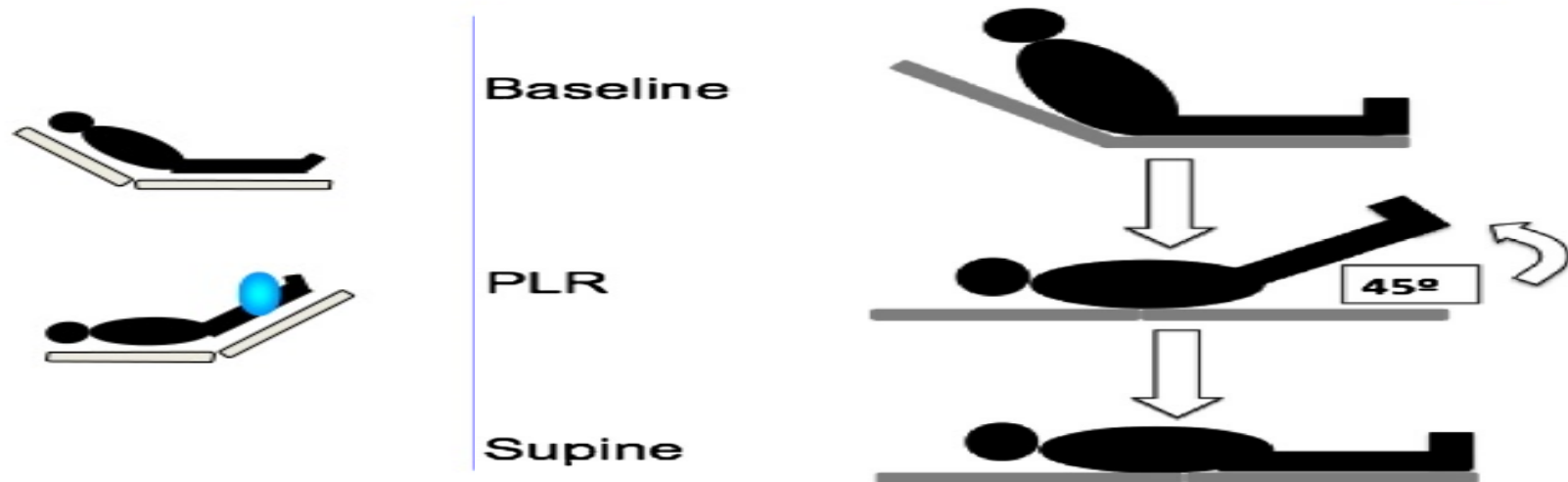


1. Start from semi-recumbent position, not supine
2. Effects must be assessed by direct measurement of CO, not by a simple measurement of BP
3. Technique used must measure CO to detect short term & transient changes
4. CO is measured before, during and after PLR
5. Pain, cough discomfort and awakening can provoke SNS response

( Monnet & Teboul, 2015)

# PASSIVE LEG RAISING (PLR)

## Fluid Responsiveness & Passive Leg Raising



Venous blood shift from legs to thoracic compartment approx. 150-300 ml

Auto fluid bolus

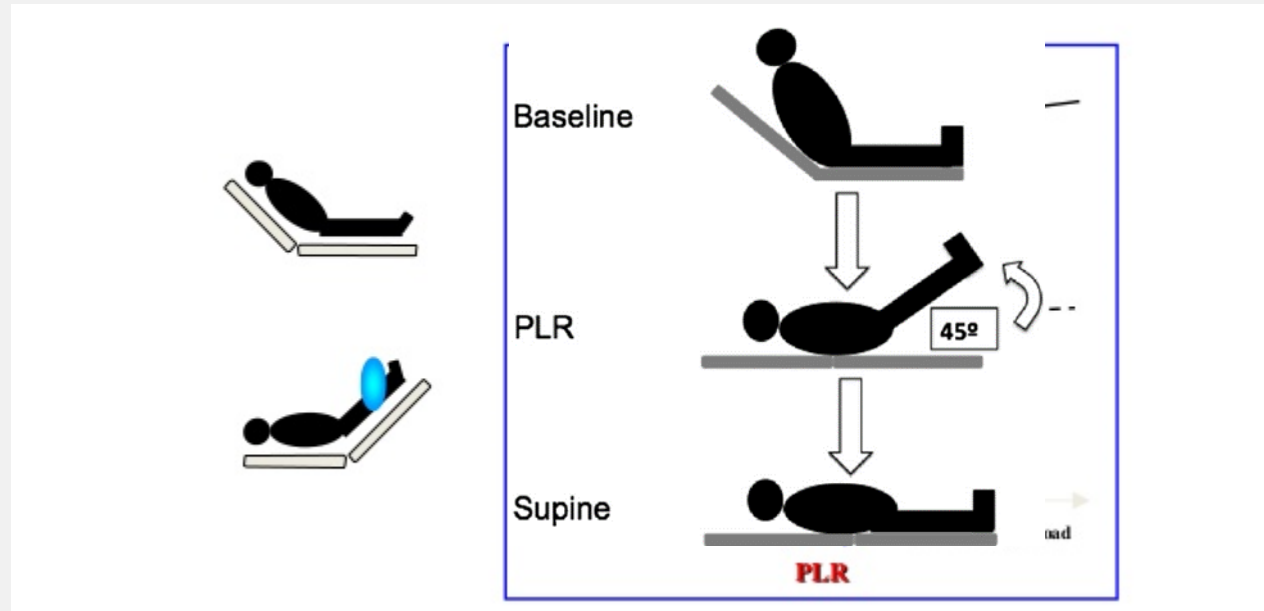
Transient and reversible effect, non-invasive, amount of fluid mobilized is proportional to body size

An increase in aortic blood flow of at least 10 – 15%

# PASSIVE LEG RAISING (PLR)

## ADVANTAGES / BENEFITS

- Remains reliable when parameters based on heart-lung interactions cannot be used (Carsetti et al, 2015)
- Works better with low- respiratory system compliance (e.g.AARDS)
- Accurate in patients with arrhythmias & spontaneously breathing
- Can be used regardless of vent mode & cardiac rhythm (Cavallaro, 2010)
- Can avoid the risk of fluid overload (Carsetti et al, 2015)



## Disadvantages

Not used when IAH is present, TBI (Cavallaro, 2010)

Need to stop other interventions during this maneuver

Time consuming and requires SV monitoring which is also a significant limitation in the everyday critical care setting (Vistisen, 2017)

# PASSIVE LEG RAISING (PLR)

What results indicate fluid responsiveness:

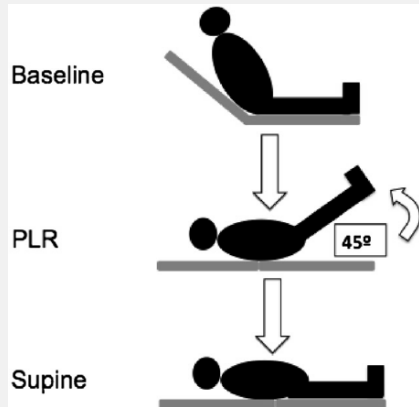
- 10% increase in CO or SV
- Reduction in SVV and PPV (Mikkelsen, et al, 2019)

PLR induced change in CVP  $\geq 2$  mmHg (Lakhal et al, 2010) in addition to changes in PP

PLR in combination with SV is currently considered superior in predicting FR in MV patients (Assadi, 2017)

Sensitivity to fluid responsiveness 86% and specificity of 92%

(Mikkelsen et al, 2019)





## OTHER DYNAMIC PARAMETERS

End tidal CO<sub>2</sub> variation -  $\Delta\text{EtCO}_2 = \text{before} - \text{after ETCO}_2$   
during PLR [ $\geq 2$  mmHg or  $\geq 5\%$ ] – small studies

## OTHER DYNAMIC PARAMETERS

Oximetric waveform variation – PVI (pleth variability index)

*“PVI and FR of hemodynamically stable patients after cardiothoracic surgery”*

Maughan (2015)

- measured PVI after PLR in pts with PACS
- not reliable

## END-EXPIRATORY OCCLUSION TEST

- 15 sec expiratory hold on MV patients (Jalil & Cavallazi, 2018)
- Not limited by cardiac dysrhythmias
- Only done in deeply sedated or paralyzed patients
- Increase in arterial pulse pressure  $\geq 15\%$

# PHYSICIAN-DIRECTED PRELOAD ASSESSMENT

Static and dynamic measures

# ECHOCARDIOGRAPHY - POCUS

- Able to give information about preload, afterload & contractility (Carsetti et al, 2015)
- Ejection fraction – contractility parameter
- Also has static and dynamic parameters
- Static parameters have the same limitations (Carsetti et al, 2015)
- Operator-dependent; requires training; mostly MD-operated at bedside

## ECHOCARDIOGRAPHIC INDICES

- Caval index - Respiratory variation of IVC diameter – distensibility index of 18%  
(Carsetti, Cecconi & Rhodes, 2015; Jalil & Cavallazi, 2018)
- Collapsibility of IVC - optimum cutoff point 25%  
(Corl, George, Romanoff et al, 2017; Perera, et al, 2014)
- Collapsibility of SVC (Cecconi et al, 2014)
- Velocity time integral (VTI) reflects changes in LV stroke volume  
(Cecconi et al, 2014)

# LUNG ULTRASONOGRAPHY

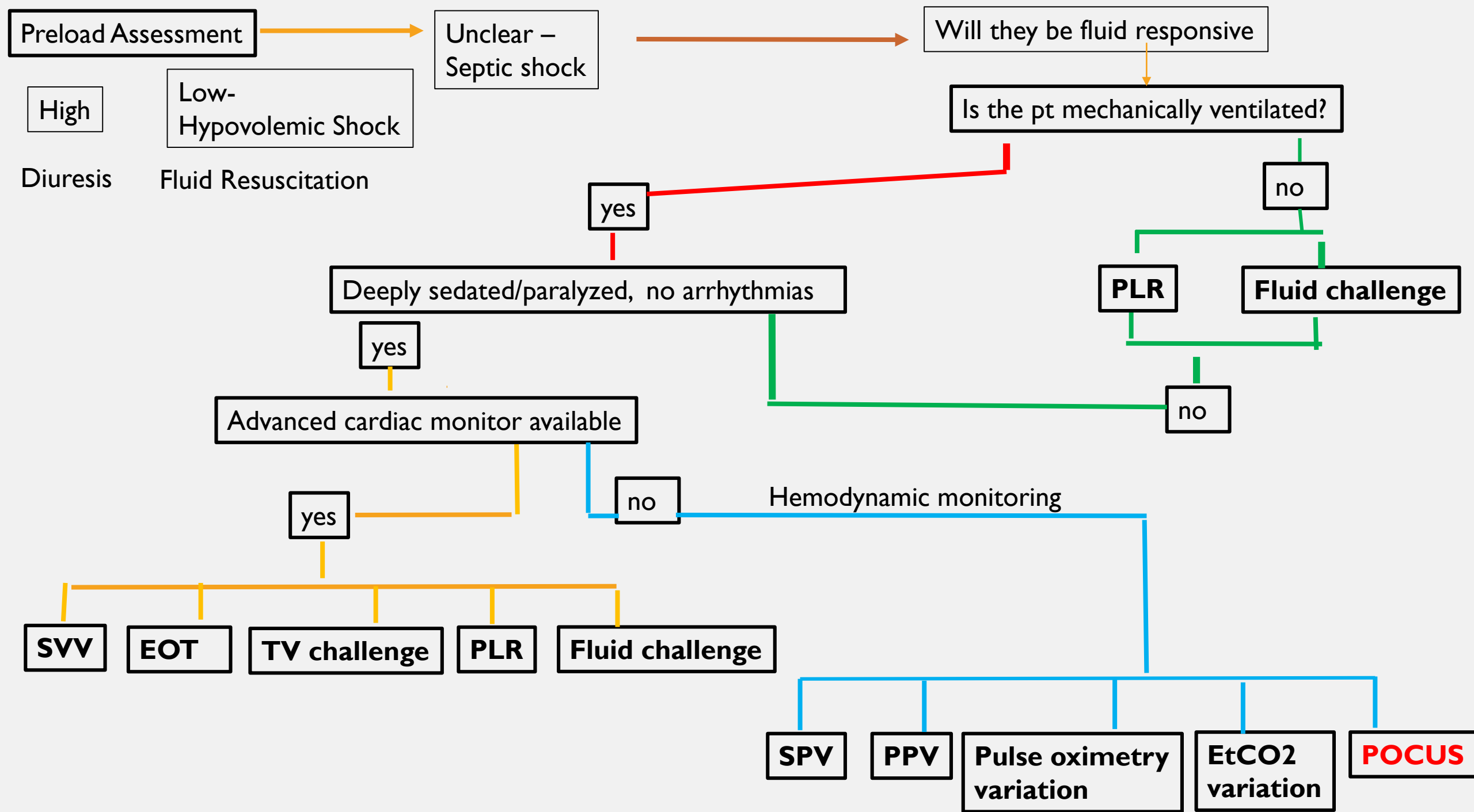
- LATE SIGNS of volume overload : Radiographic and clinical signs of pulmonary edema and clinical evidence of anasarca
  - US evidence of early volume overload:
    - B-lines – interstitial or alveolar pulmonary edema
    - EVLW measurement – extravascular lung water
- (Lee, Kory, & Arntfield, 2016; Jozwiak, Teboul & Monnet, 2015)
- Poorly studied

## ULTRASOUND EXAM BY NURSES

Feasibility and reliability of pocket-size ultrasound examinations of the pleural cavities and IVC performed by nurses in an outpatient heart failure clinic.

- *Dalen, et al., (2015). European Journal of Cardiovascular Nursing*
- Done by “specialized” nurses (median time 5 min), relook by cardiologist using a high-end scanner





## AFTER ALL THAT...

- “any measure of preload, particularly if it is a one-time measurement, should not be taken out of context with respect to the measures of other variables and the patient’s overall clinical condition. (Cecconi et al, 2014, p. 1806)
- PLR or a fluid challenge + real-time stroke volume monitoring
  - only accurate method to assess fluid responsiveness (Cavallaro, 2010)
- All techniques to measure blood flow (SV) have strengths and limitations

## SUMMARY

- Preload assessment is where you should start
- If further investigation is required – determine if patient is fluid responsive
- Need to remember to use physical assessment first as a key to guide technologically assisted devices
- There is no one answer to determine preload and fluid responsiveness
- Be aware of limitations with TAD to determine preload and fluid responsiveness

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