EDUCATION
FOR A COMPLEX WORLD.

BCIT

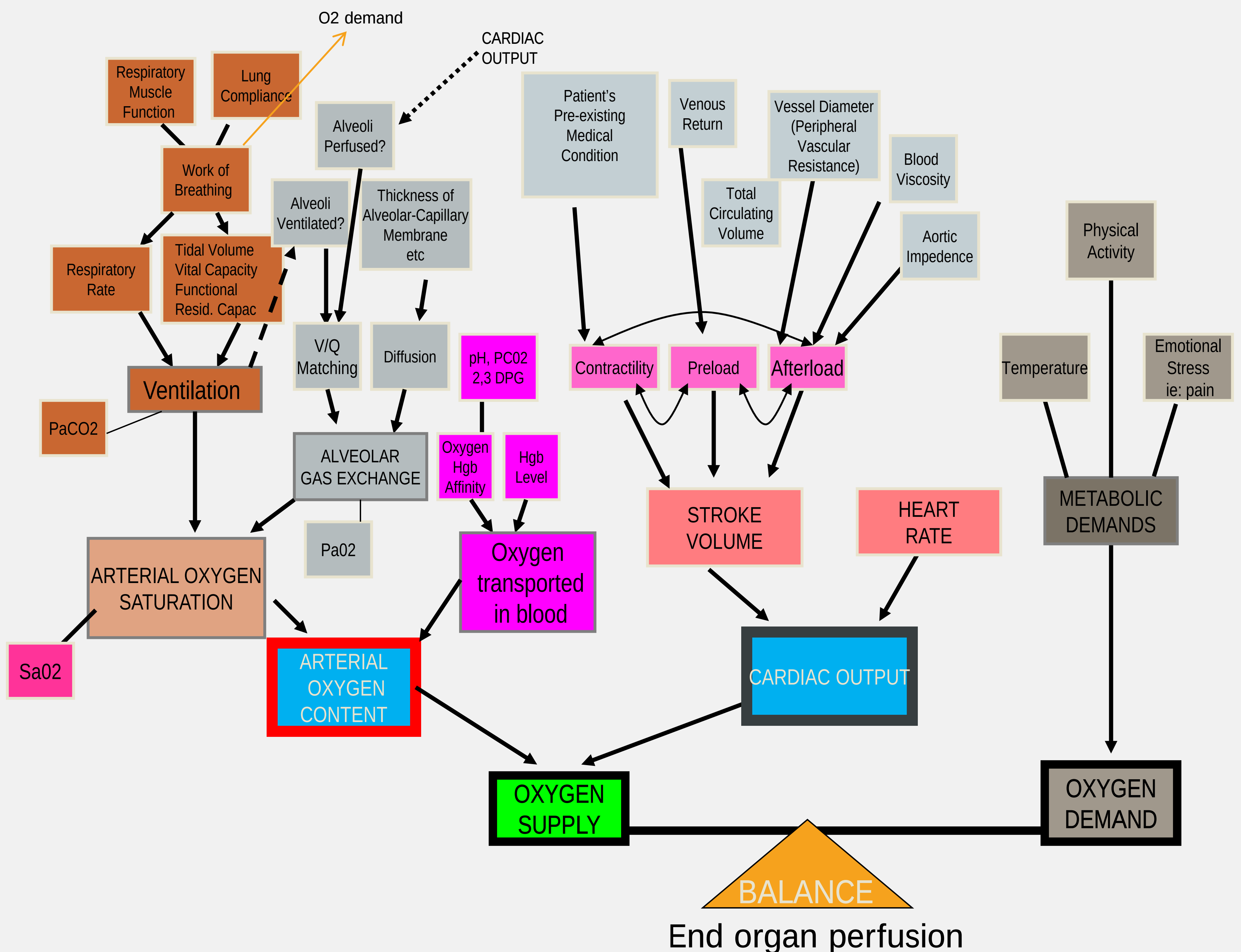
NAVIGATING PRELOAD ASSESSMENT

CHOOSING THE RIGHT PATHWAY

Cecilia Baylon & Sarah Neville

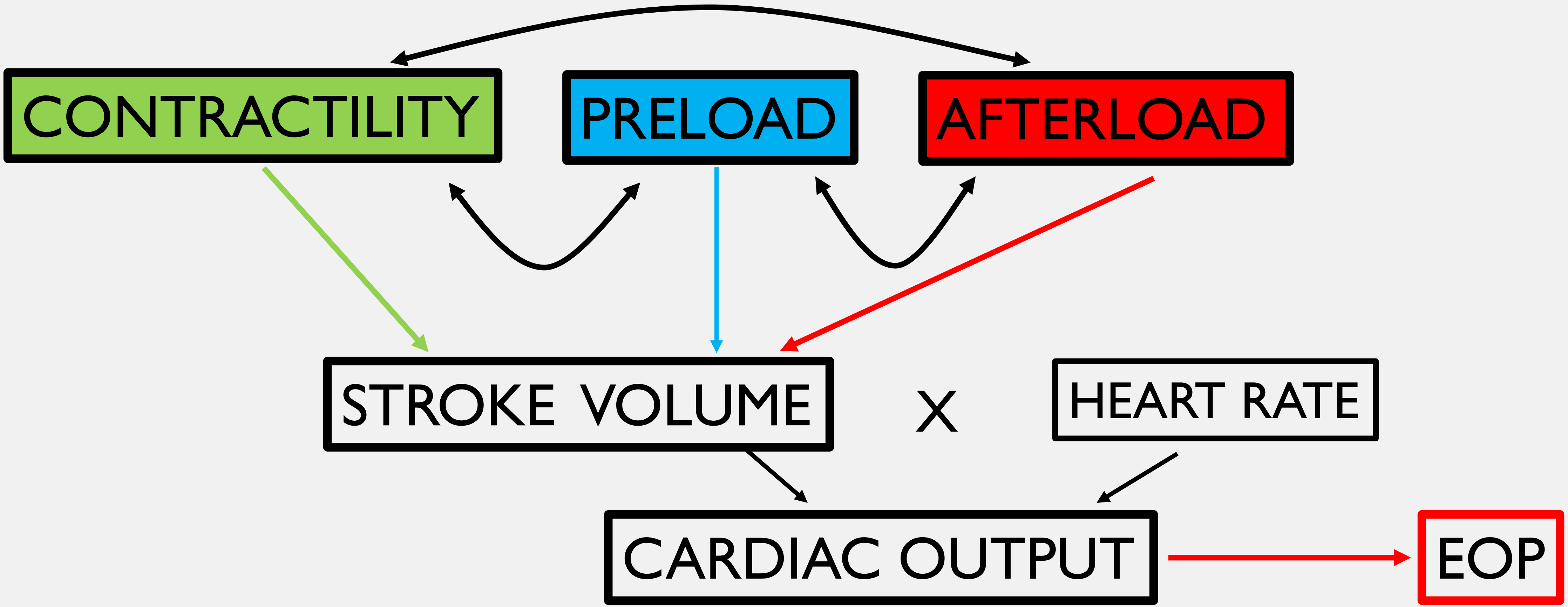
LEARNING OBJECTIVES

- 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

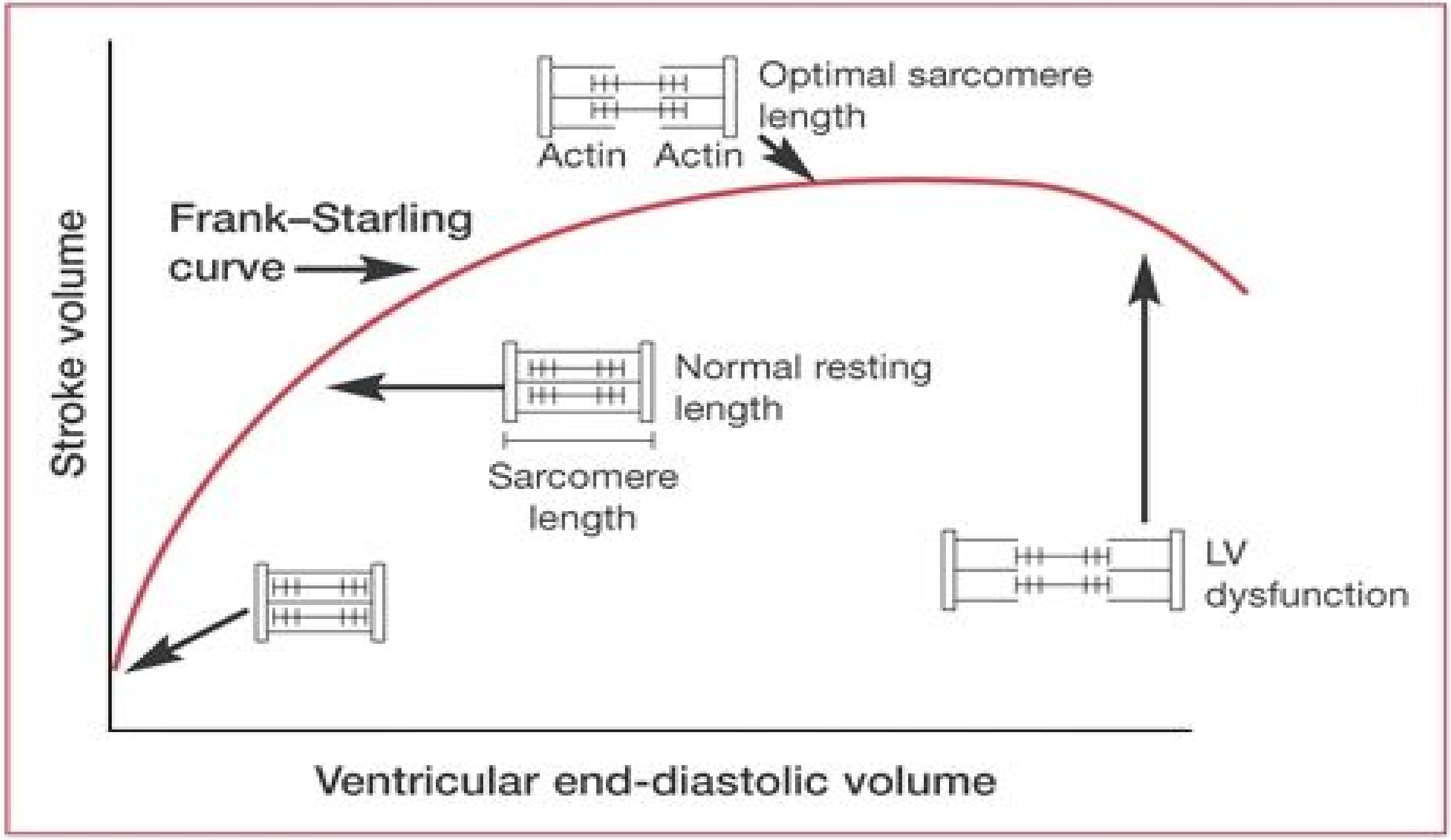


O2 demand
CARDIAC OUTPUT
Respiratory Muscle Function
Lung Compliance
Work of Breathing
Alveoli Perfused?
Alveoli Ventilated?
Thickness of Alveolar-Capillary Membrane etc
Respiratory Rate
Tidal Volume Vital Capacity Functional Resid. Capac
V/Q Matching
Diffusion
pH, PC02 2,3 DPG
Ventilation
PaCO2
ALVEOLAR GAS EXCHANGE
Oxygen Hgb Affinity
Hgb Level
Pa02
ARTERIAL OXYGEN SATURATION
Oxygen transported in blood
Sa02
ARTERIAL OXYGEN CONTENT
Patient's Pre-existing Medical Condition
Venous Return
Vessel Diameter (Peripheral Vascular Resistance)
Blood Viscosity
Total Circulating Volume
Aortic Impedence
Physical Activity
Contractility
Preload
Afterload
Temperature
Emotional Stress ie: pain
STROKE VOLUME
HEART RATE
METABOLIC DEMANDS
CARDIAC OUTPUT
OXYGEN SUPPLY
OXYGEN DEMAND
BALANCE
End organ perfusion

OXYGEN SUPPLY & DEMAND (HEMODYNAMIC) FRAMEWORK



FRANK-STARLING'S LAW



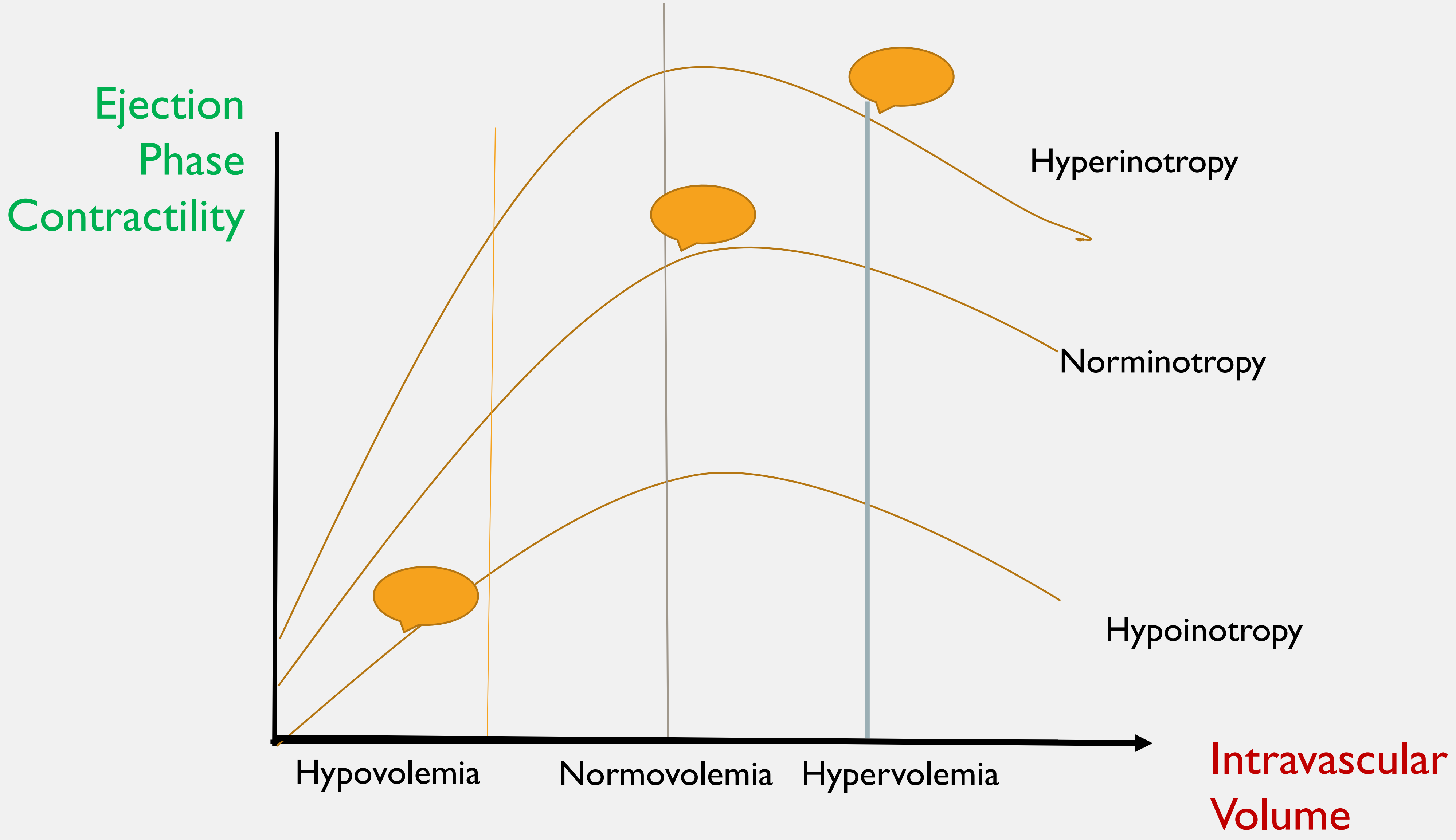
FRANK-STARLING'S LAW

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

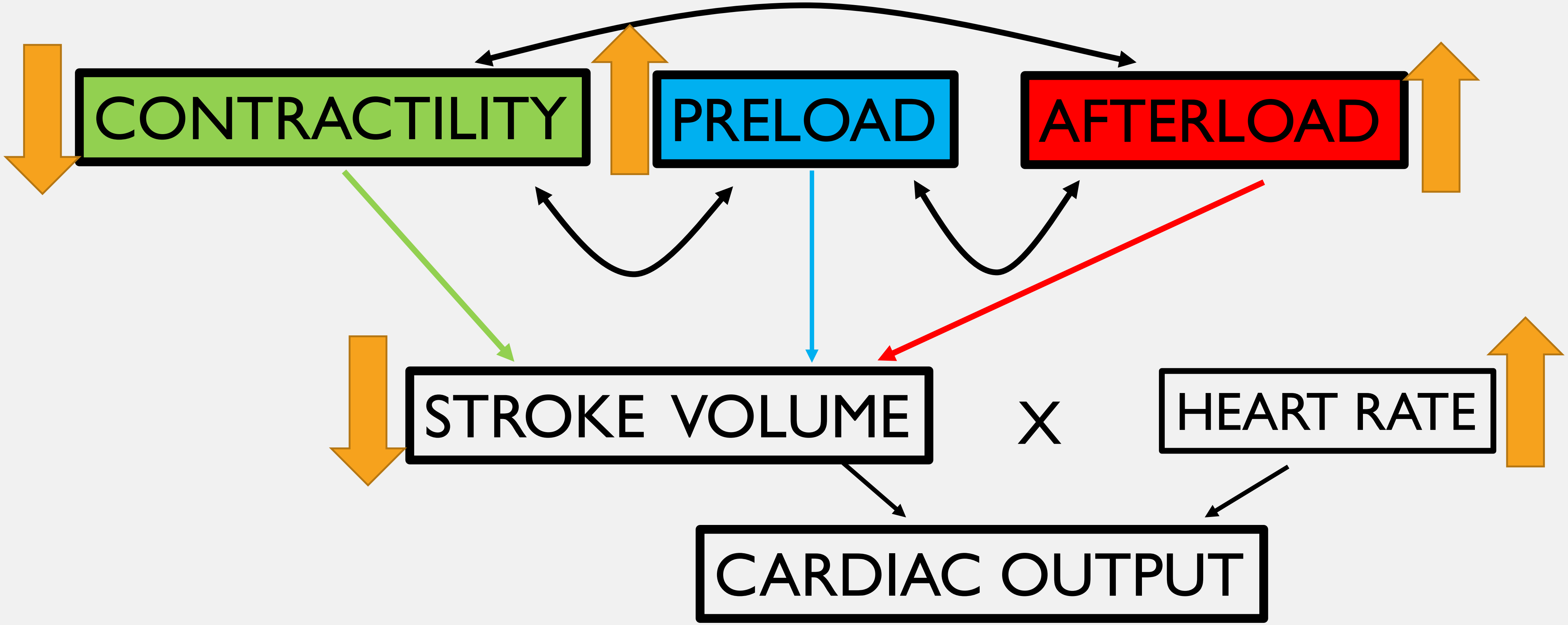
VOLUME IN THE VENTRICLE AT END-DIASTOLE (PRELOAD)

AMOUNT OF MYOCARDIAL STRETCH PLACED ON THE VENTRICLE AS A RESULT

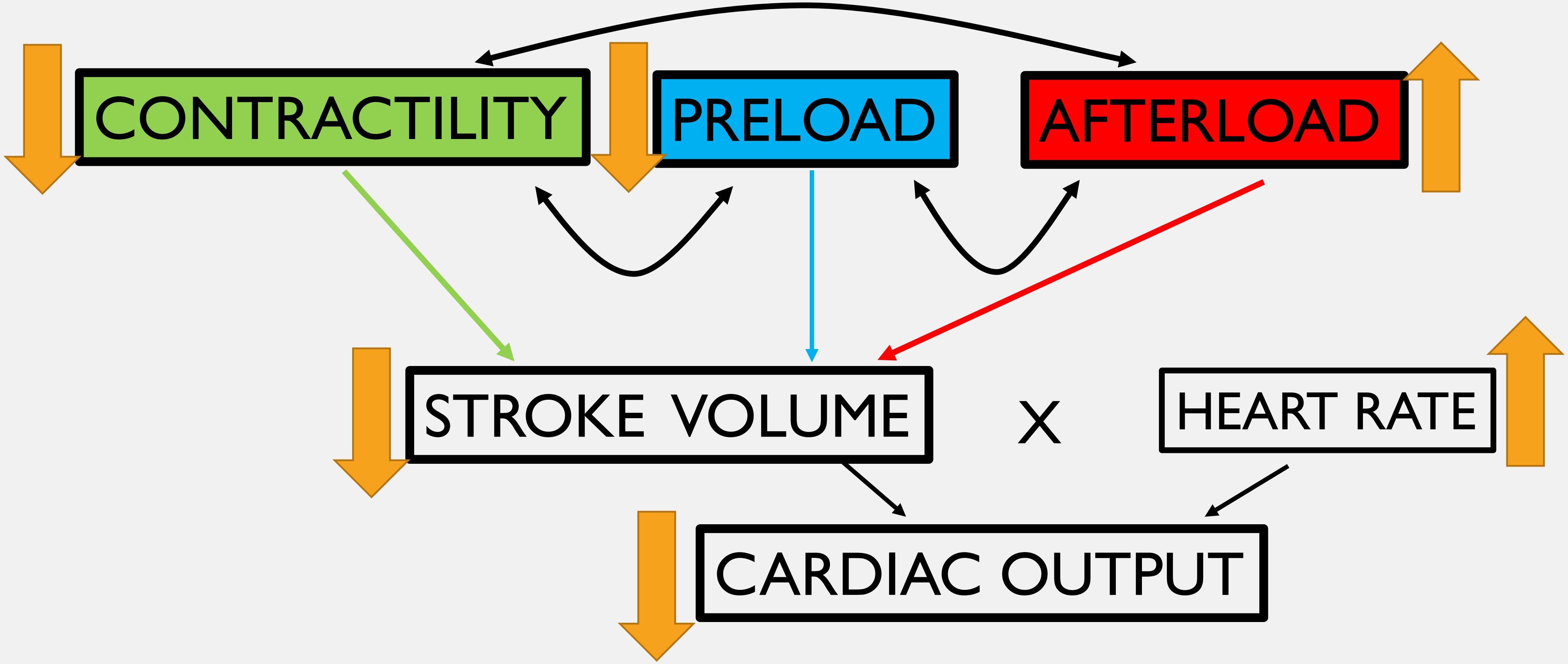
Urden, Stacy, Lough (2018), p. 214


Ejection
Phase
Contractility
Hyperinotropy
Norminotropy
Hypoinotropy
Hypovolemia
Normovolemia
Hypervolemia
Intravascular
Volume

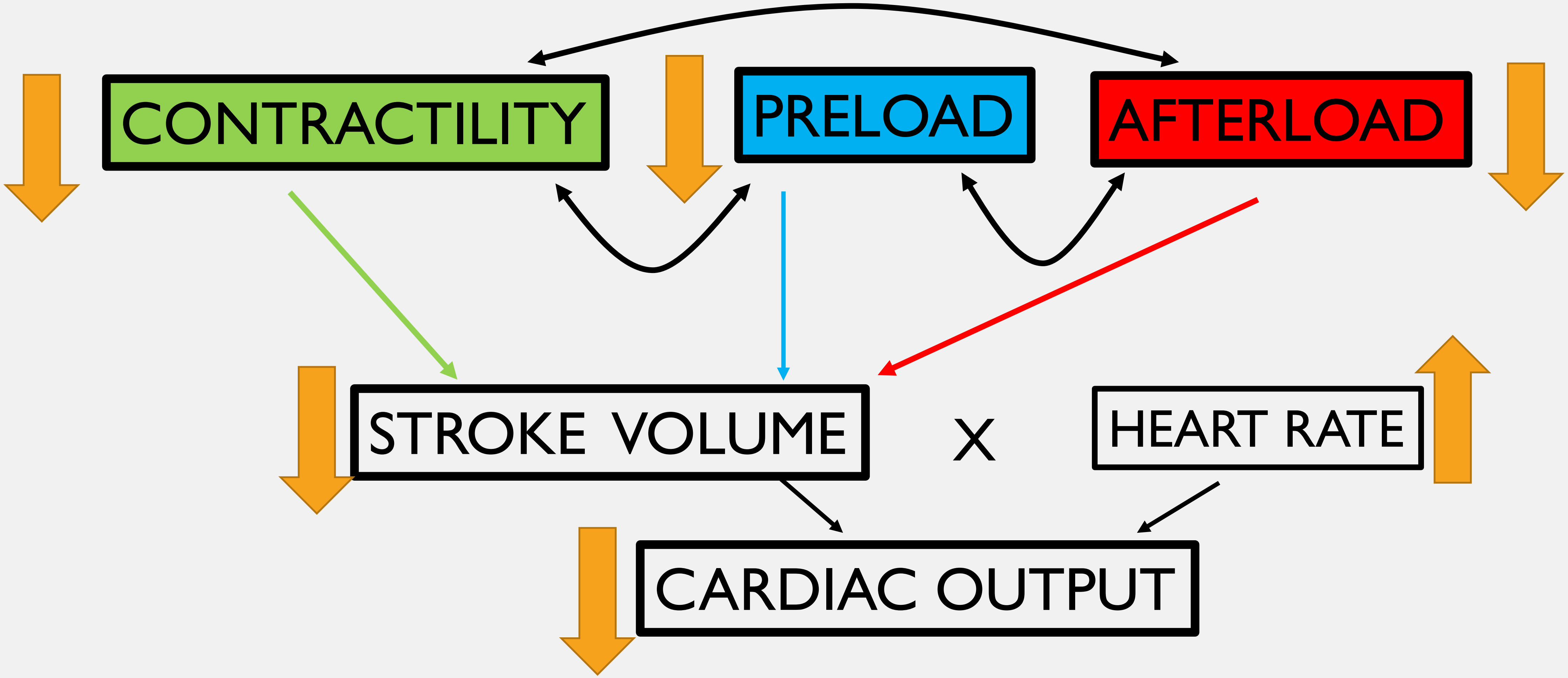
OXYGEN SUPPLY & DEMAND (HEMODYNAMIC) FRAMEWORK



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)

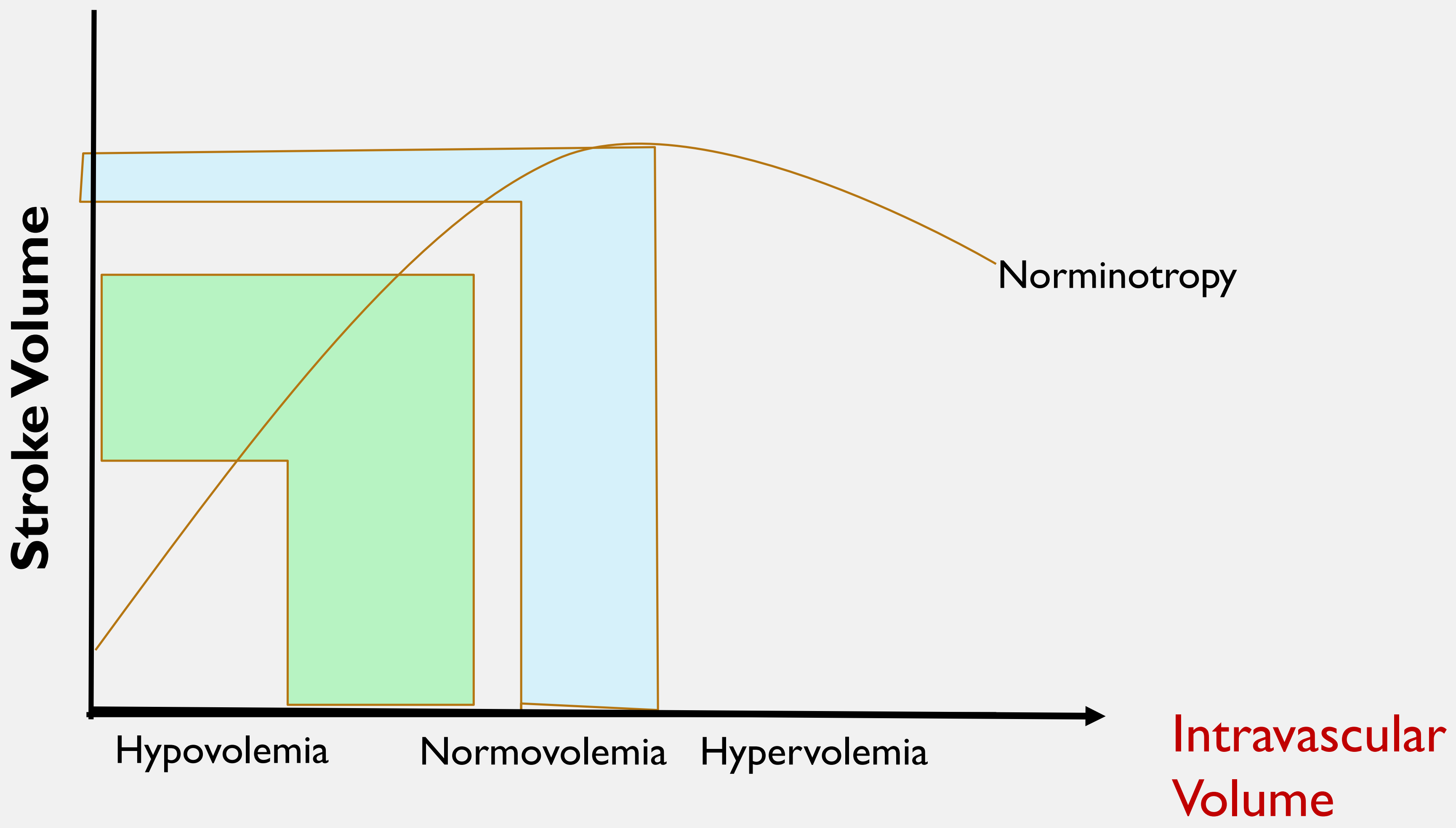
- More than 15% increase in arterial pressure after volume expansion

(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


Stroke Volume
Norminotropy
Hypovolemia
Normovolemia
Hypervolemia
Intravascular Volume

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 **EXTRA**VASCULAR 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

URDEN, STACEY & LOUGH (2018)

NURSING ASSESSMENT
PRELOAD

AUSCULTATION

HEART SOUNDS

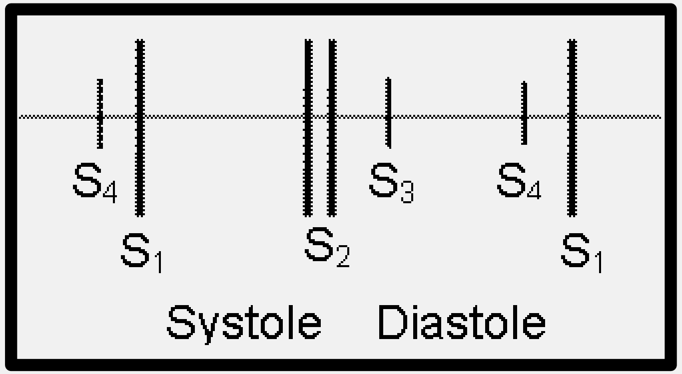
- S3 – ventricular gallop

  indicator of heart failure -

  ventricle with fluid overload

- S4 – atrial gallop

  atrial contraction when the ventricle is stiff



URDEN, STACEY & LOUGH (2018)

NURSING ASSESSMENT
PRELOAD

AUSCULTATION

Lung Sounds

- Bibasilar crackles or rales (inspiratory)

NURSING PHYSICAL ASSESSMENT

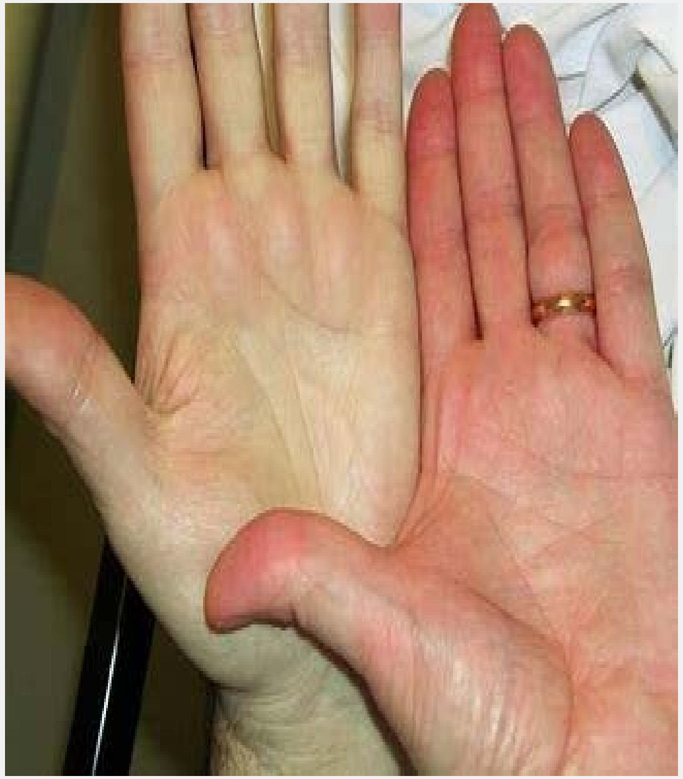
Integration

- 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

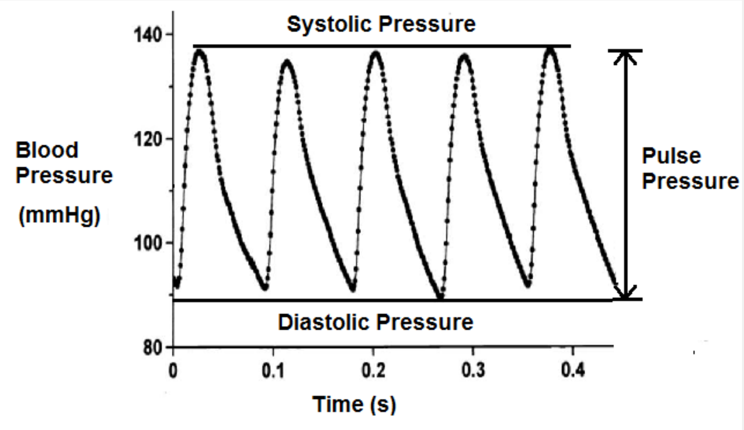
PALPATION

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

URDEN, STACEY & LOUGH (2018)

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 PaO2, elevated PaCO2
- 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

$ScvO_2$/SVO_2 : provide balance between O_2 transport & demand

Venoarterial CO_2 difference (pCO_2 gap) >6 mmHg

Cecconi, De Backer, Antonelli, et al., (2014)

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

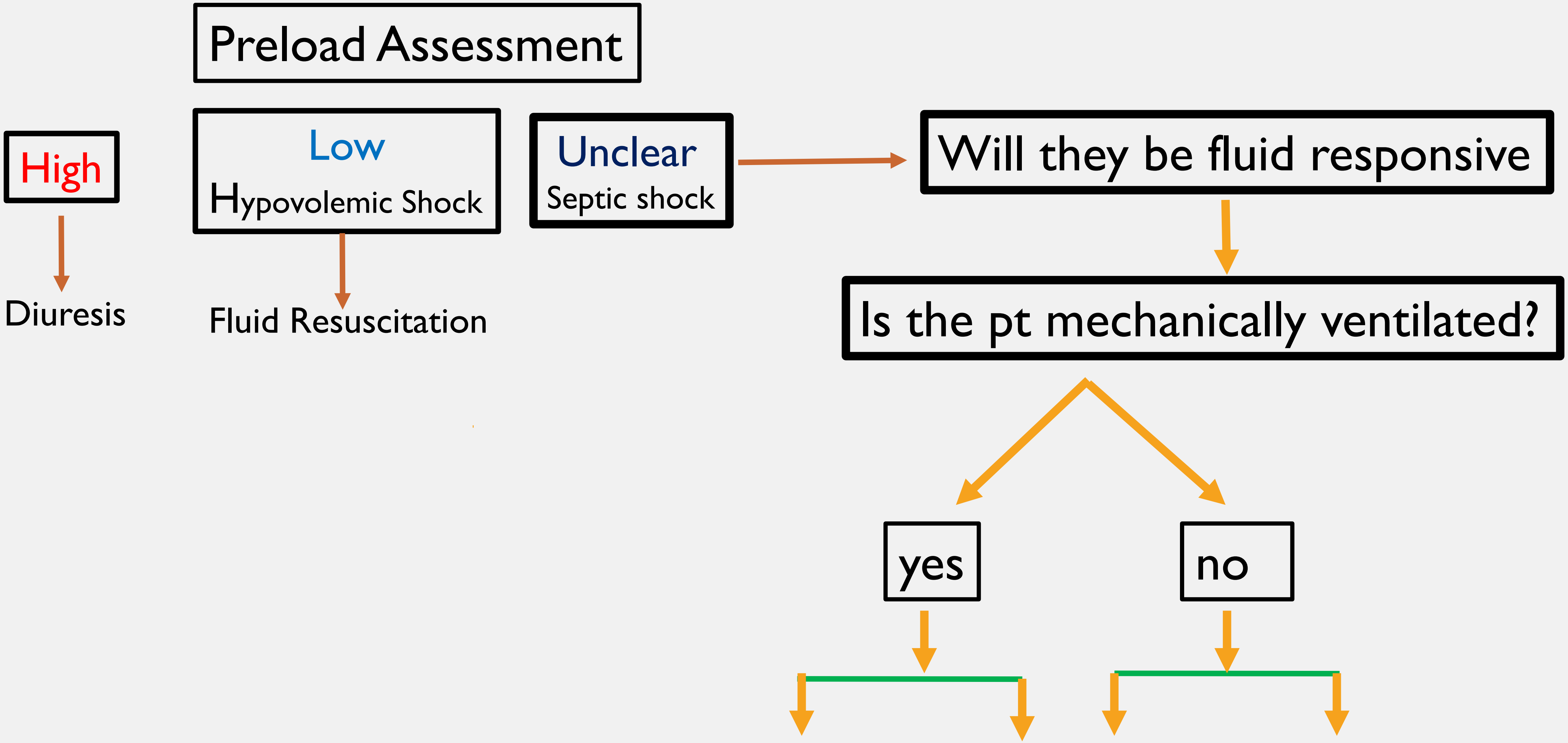
CENTRAL VENOUS PRESSURE (CVP)

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 EV1000 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)*

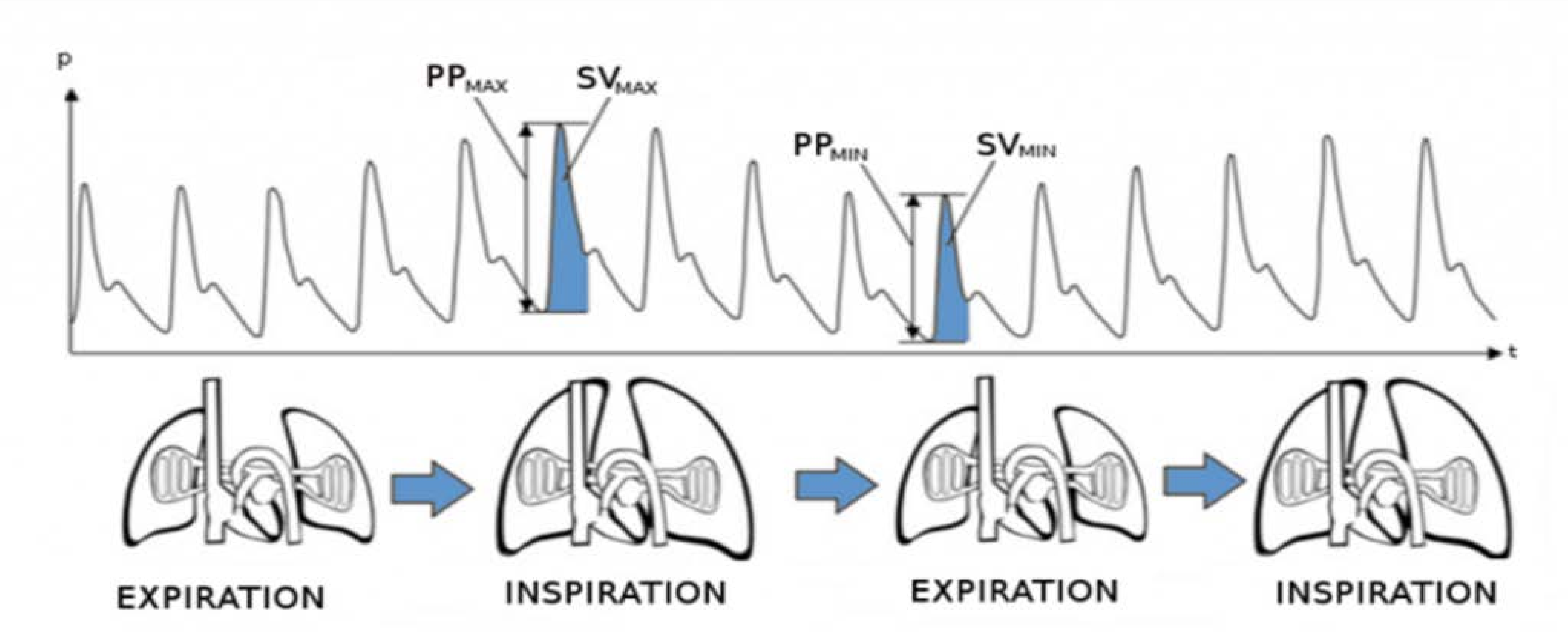
Increase in ITP -> reduces venous return (ascending portion of the curve)-> reduces RV output (by 20-70%)**

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



www.deltexmedical.com/decision_tree/stroke-volume-variation-svv-and-pulse-pressure-variation-ppv/

FLUID RESPONSIVENESS ASSESSMENT

Dynamic assessments

PROCEDURES/DIAGNOSTICS - **DYNAMIC**

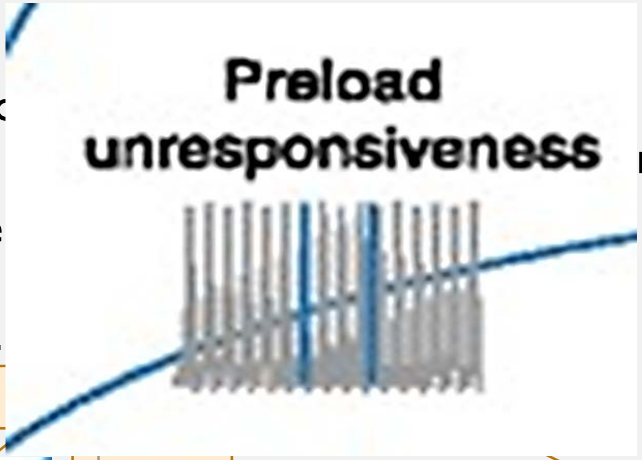
Stroke volume variation (SVV)

Systolic pressure variation (SPV)

Pulse pressure variation (PPV)

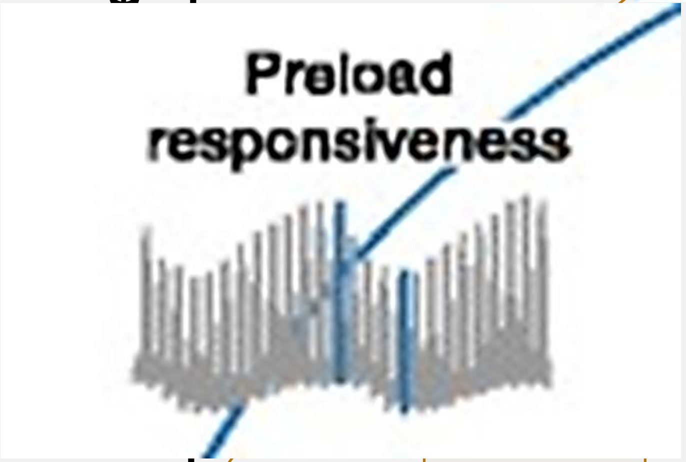
- info as to whether an increase in preload will also lead to an increase in SV

Preload dependent zo



re no longer fluid responsive

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



Ventricular Preload

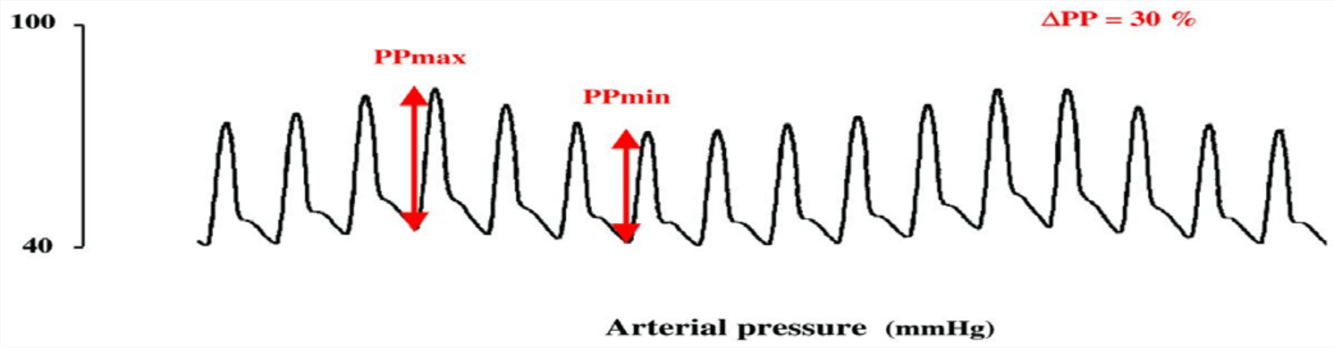
Intravascular
Volume

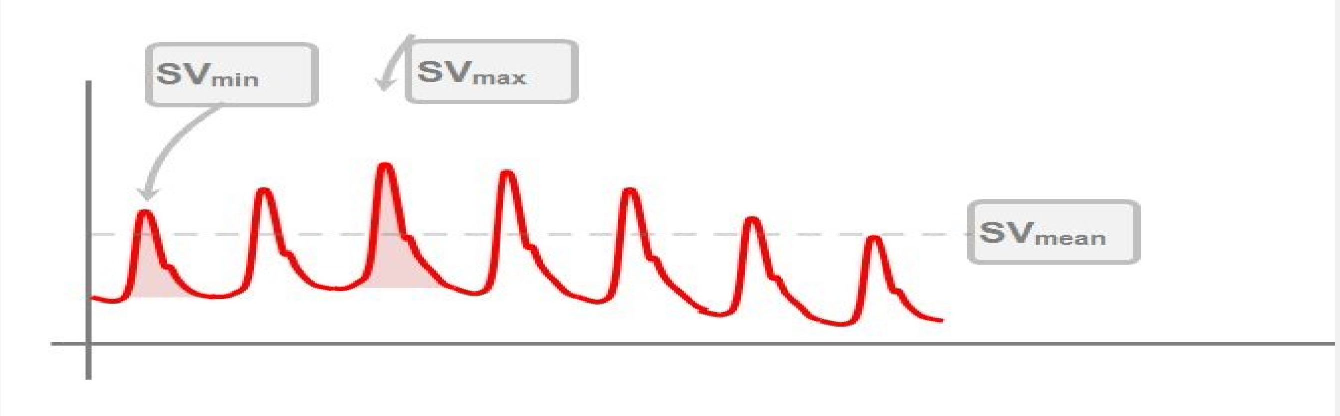
PPV AND SVV

Normal range: <10% ml/m²

PPV > 13-15%

SVV > 10%

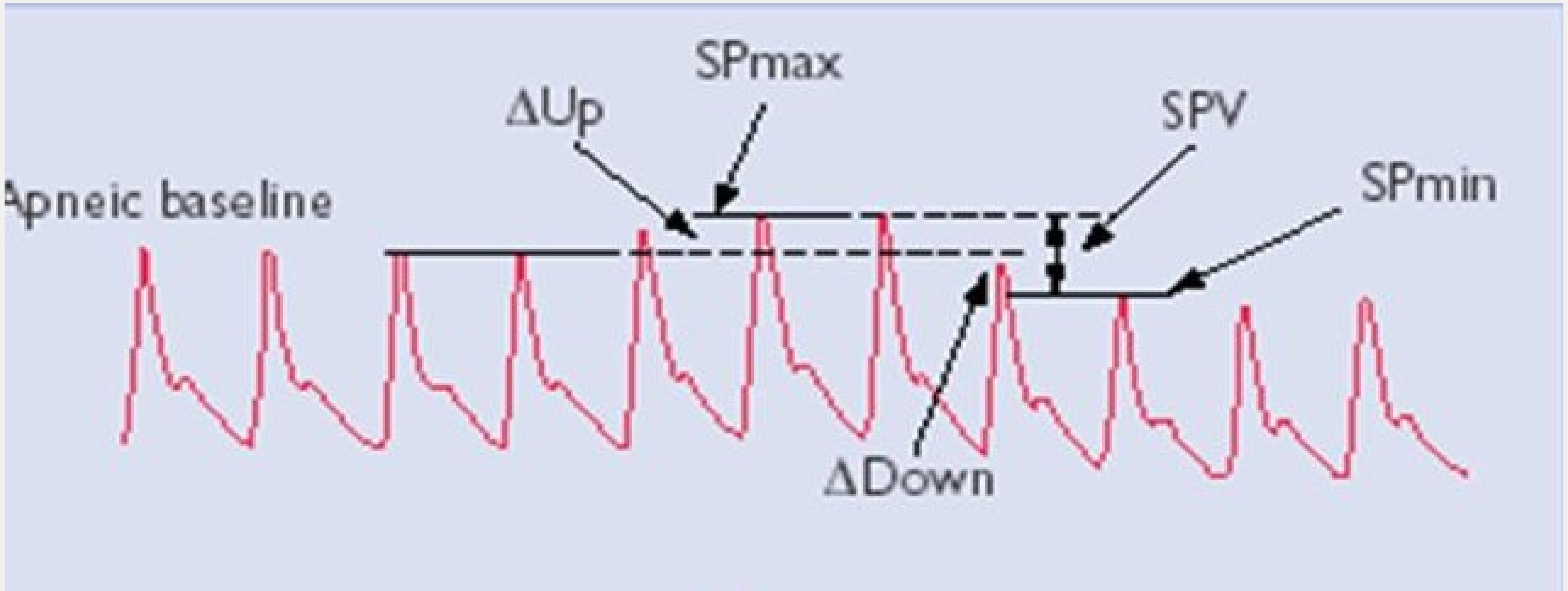




SYSTOLIC PRESSURE VARIATION (SPV)

SPV [mmHg] = SBP max – SBP 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 ≥ 7-8 ml/kg
- heart rate – resp rate ratio ≥ 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

www.deltexmedical.com/decision_tree/stroke-volume-variation-svv-and-pulse-pressure-variation-ppv/

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

ΔPPV > 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

<u>FENICE study</u> – 2213 patients in 46 countries

- Judged response to fluid challenge

  increase in BP 67%

  increase in UO 38%

  decrease in HR 24%

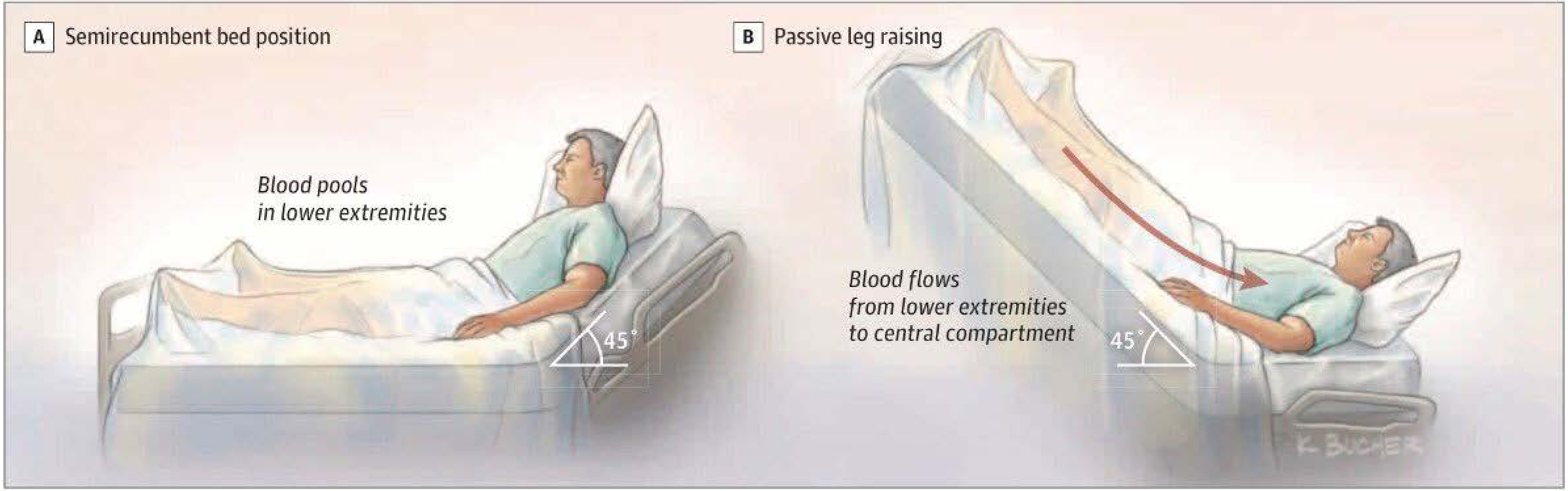
  lactate 18%

  CVP/PAOP 16%

PASSIVE LEG RAISE (PLR)

- Significance/implication
- Studies

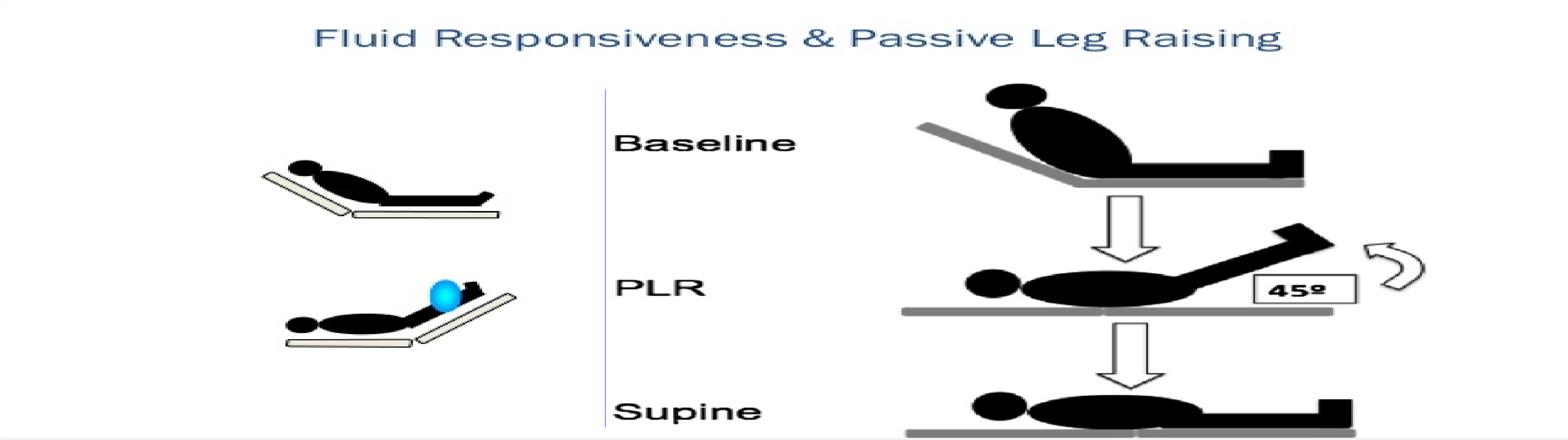
Figure 2. Performance of a Passive Leg-Raising Test



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)

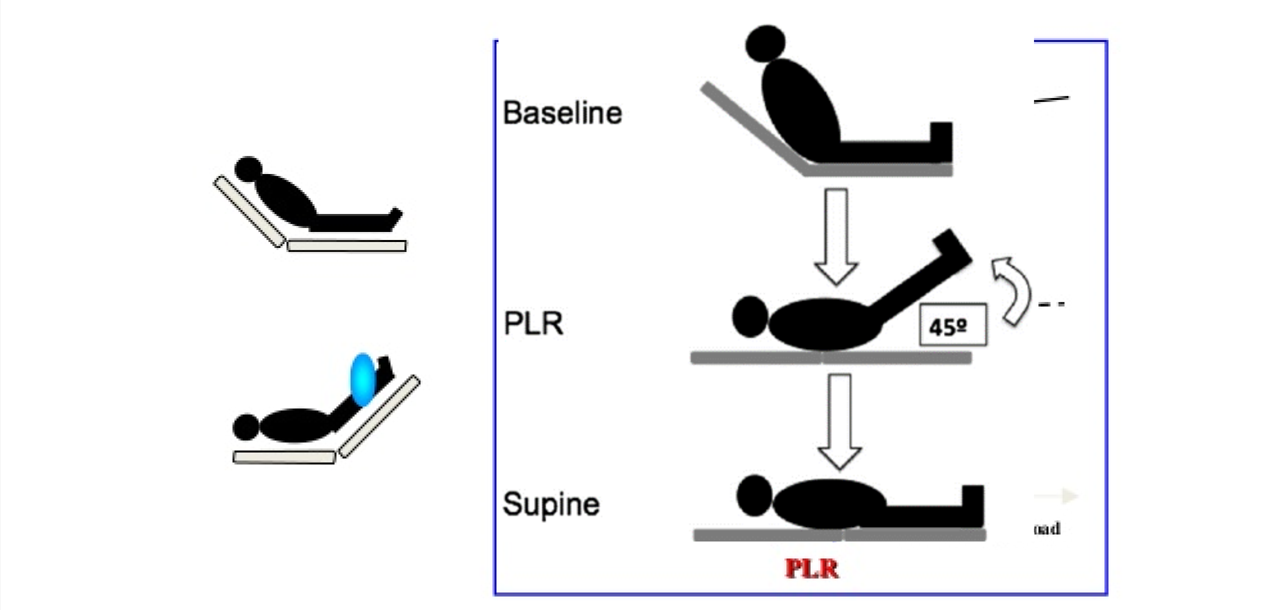


Venous blood shift from legs to thoracic compartment approx. 150-300 ml
Auto fluid bolus
Transient and reversible effect, non-invasive, amount of fluid mobilized is proportional to body size
An increase in aortic blood flow of at least 10 – 15%

PASSIVE LEG RAISING (PLR)

ADVANTAGES / BENEFITS

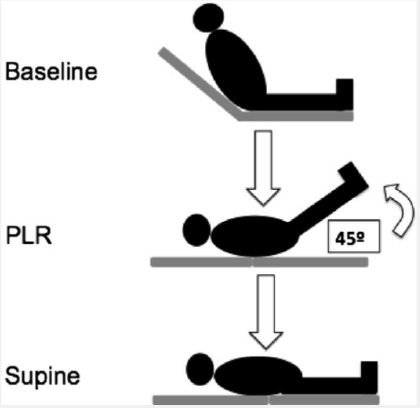
- Remains reliable when parameters based on heart-lung interactions cannot be used (Carsetti et al, 2015)
- Works better with low- respiratory system compliance (e.g. ARDS)
- Accurate in patients with arrhythmias & spontaneously breathing
- Can be used regardless of vent mode & cardiac rhythm (Cavallaro,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



<u>Disadvantages</u>

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 ≥ 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_2 variation - $\Delta EtCO_2$ = before – after $ETCO_2$ during PLR [≥2 mmHg or ≥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 ≥ 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

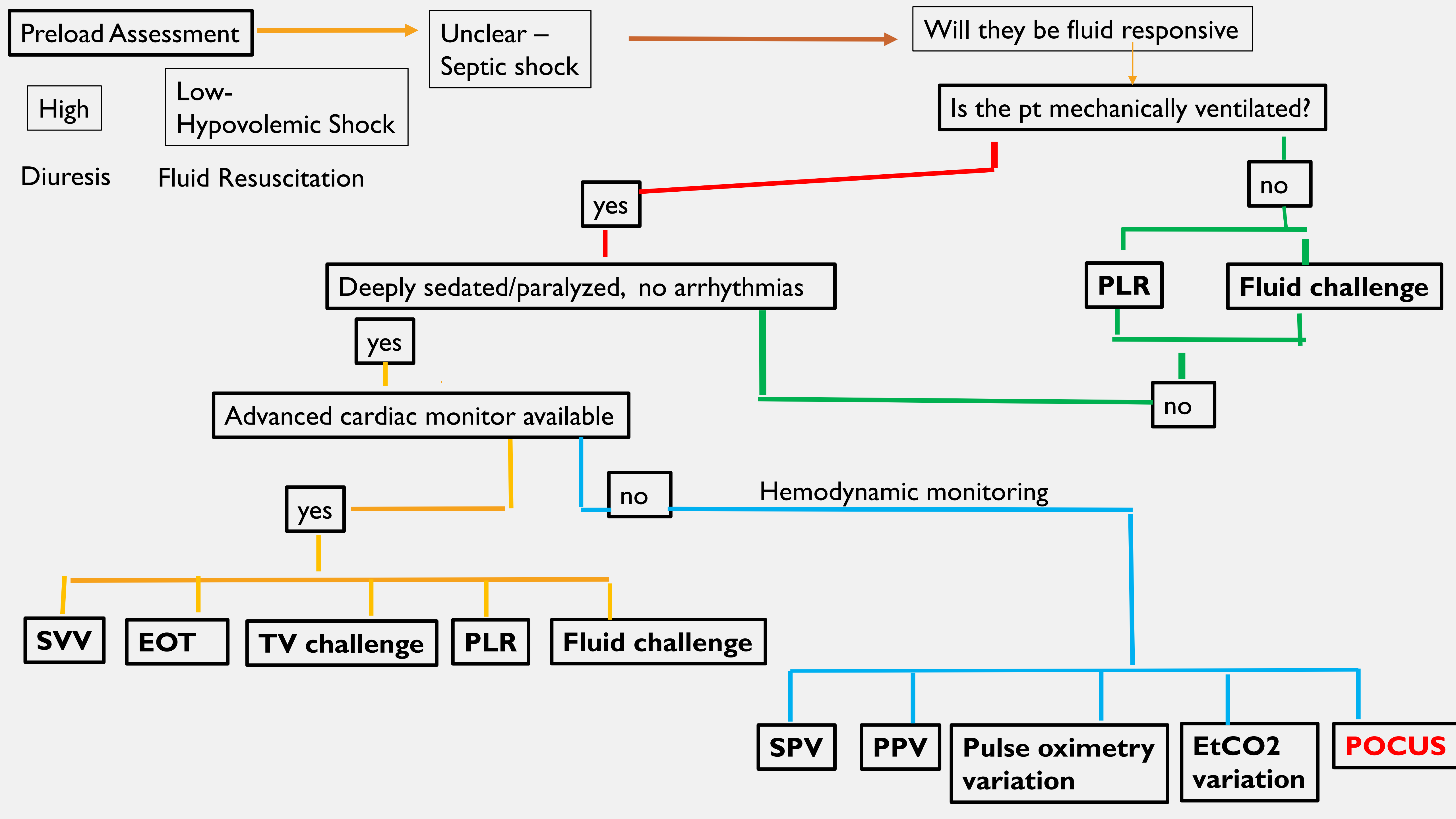
(Lee, Kory, & Arntfield, 2016; Jozwiak, Teboul & Monnet, 2015)

- 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



Preload Assessment
Unclear – Septic shock
Will they be fluid responsive
High
Low- Hypovolemic Shock
Diuresis
Fluid Resuscitation
Is the pt mechanically ventilated?
yes
no
Deeply sedated/paralyzed, no arrhythmias
PLR
Fluid challenge
yes
no
Advanced cardiac monitor available
yes
no
Hemodynamic monitoring
SVV
EOT
TV challenge
PLR
Fluid challenge
SPV
PPV
Pulse oximetry variation
EtCO2 variation
POCUS

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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