Hemodynamics monitoring and Ventilator management

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29/3/25

Outline

- Hemodynamics monitoring and management
- Ventilator monitoring and management

Hemodynamics

- Cardiac pressure
- Shock
- Fluid management
  - Fluid compartment
  - Fluid selection
  - Fluid responsiveness

Mechanical Ventilator

- Hypoxia & Hypoxemia
- Respiratory failure
- Basic mechanical ventilator
- MV waveform

Hemodynamics monitoring and management

A 27-year-old man has lost of conscious suddenly. His colleagues perform basic life support and bring him to emergency department. ECG shows PEA initially. After ROSC, Swan ganz catheter was done and hemodynamic parameter show as below.

Parameter	Value	Normal value
BP /MAP, mmHg	85/54 (64)	(>65)
Rt. Atrial pressure, mmHg	15	0-6
Pulmonary artery pressure/mPAP, mmHg	28/16 (20)	<20
Pulmonary artery occlusion pressure, mmHg	15	<12
Cardiac output, L/m	2.5	3.5-5.5
SVR, dynes.sec.cm^{-5}	1600	800-1200

Which one is the most initial management in situation?

A. Blood transfusion 2 unit

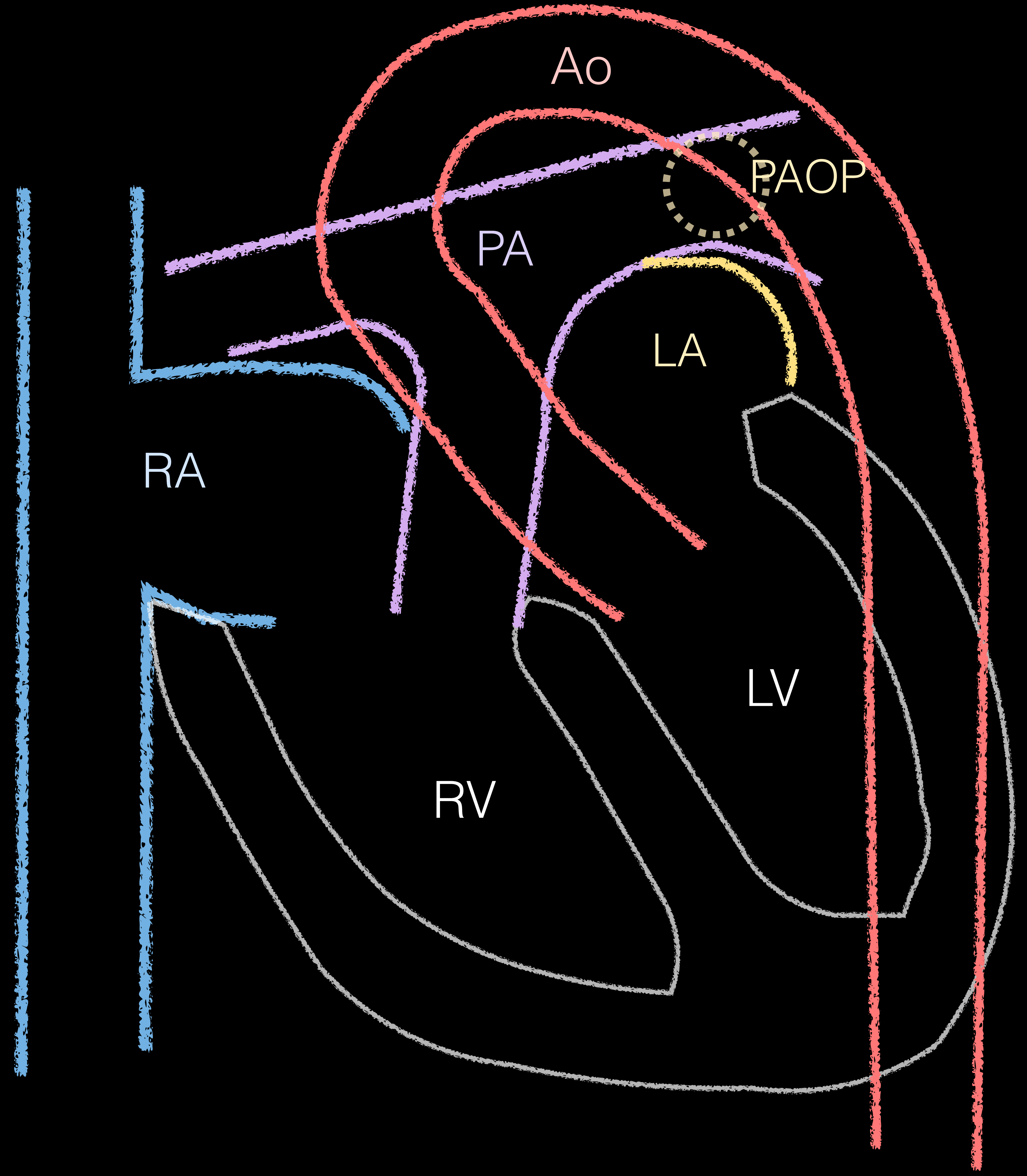
B. Norepinephrine continuous intravenous drip

C. Coronary angiogram

D. Echocardiogram and pericardiocenthesis

E. CT pulmonary artery emergency

Cardiac Pressure

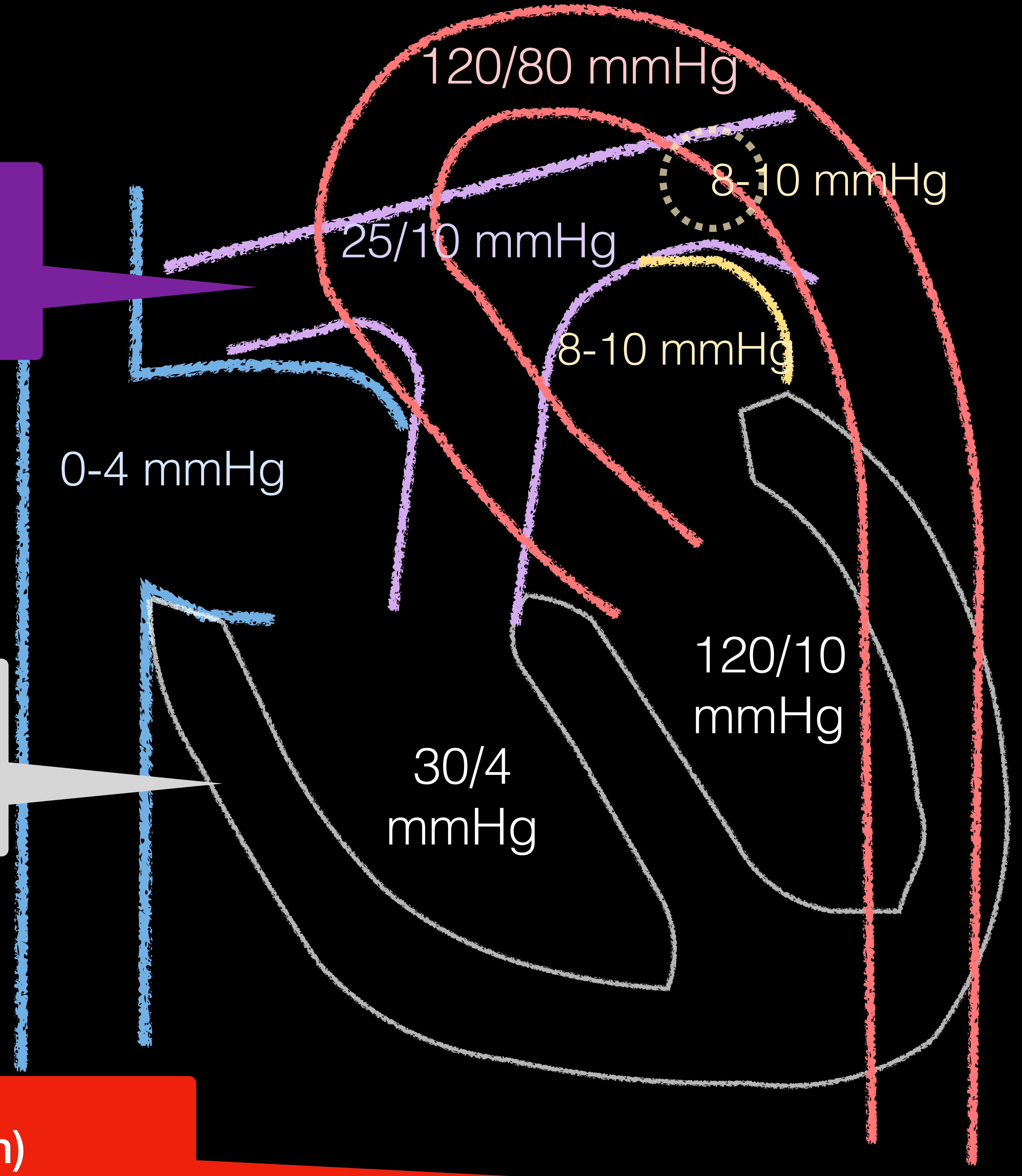


Cardiac Pressure

PVR ~ 1-2 WU (mmHg/L/min)
80-120 dyne/sec/m^{-5}

CO 4-8 L/min

SVR ~ 10-20 WU (mmHg/L/min)
900-1200 dyne*sec/cm^{5}



Blood Pressure

- Systolic BP (SBP)
- Diastolic BP (DBP)
- Mean arterial pressure (MAP)
- Pulse pressure (PP)

Cardiac contractility
Sympathetic tone

Vascular resistance

= DBP + 1/3 PP

65-75 mmHg

= SBP - DBP

~1/2 SBP

Blood Pressure

SV x HR

BP = CO x SVR(TPR)

EF

$$SV = \frac{LVEDV - LVESV}{LVEDV} \times LVEDV$$

BP = LVEDV x EF x HR x SVR(TPR)

BP = LVEDV x EF x HR x SVR(TPR)

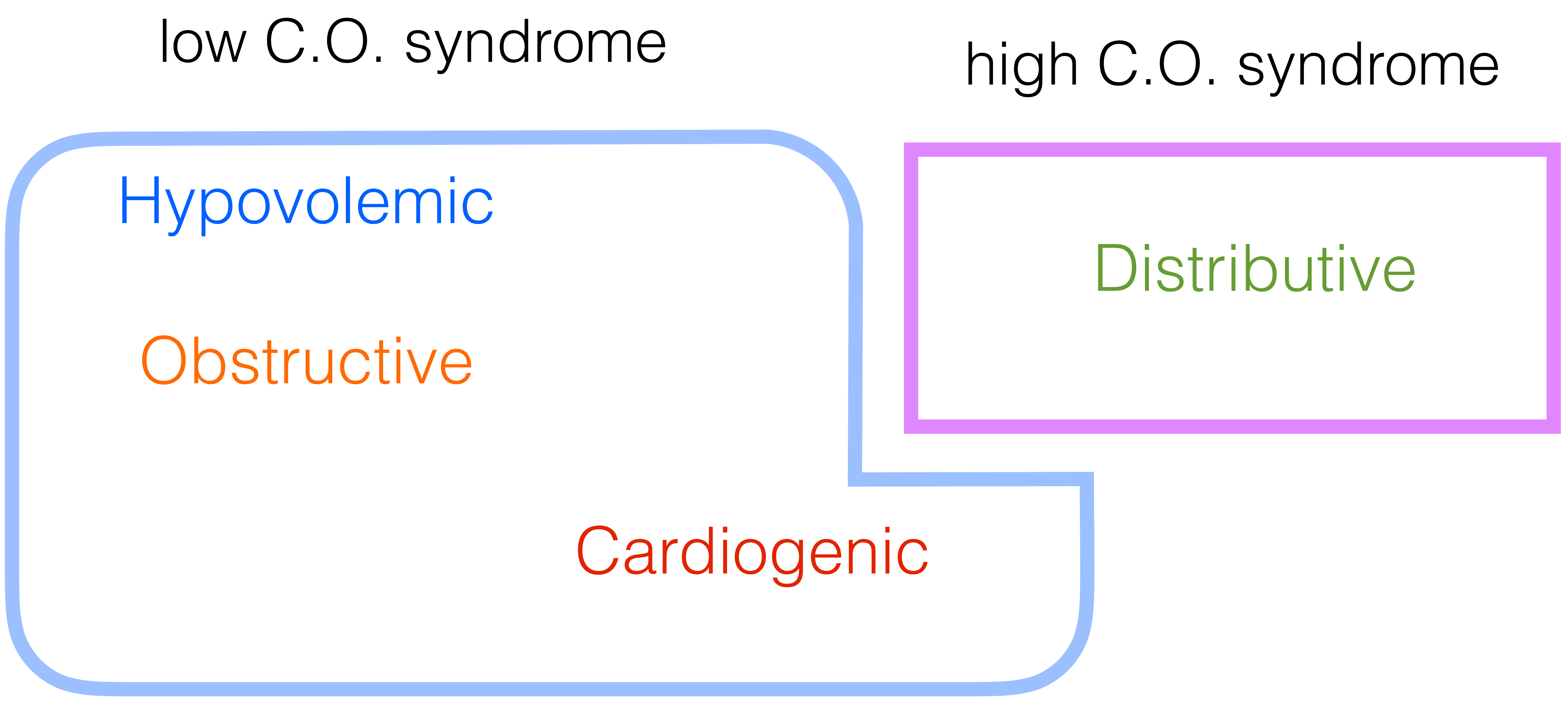
Preload
น้ำ (fluid)

Contractility/
chronotropy
ปั๊ม (cardiac output)

Afterload
แรงต้านในหลอดเลือด

Shock

$$BP = LVEDV \times EF \times HR \times SVR(TPR)$$



$$BP = CO \times SVR(TPR)$$

$$LVEDV \times EF \times HR \times SVR(TPR)$$

Type		pulse pressure	capillary refill	JVP	heart	lungs
Distributive	high CO	กว้าง มากกว่าครึ่งของ SBP	เร็ว เท่าผู้ตรวจ	ต่ำหรือปกติ	-	ได้ทุกแบบ
Hypovolemic	low CO	แคบ น้อยกว่าครึ่งของ SBP	ช้ากว่าผู้ตรวจ (หรือมากกว่า 2 วินาที)	ต่ำ	เสียง S1 เบา	clear
Obstructive				สูง	เสียง P2 ดัง หรือ distance HS	clear*
Cardiogenic				สูง	S3 or S4 gallop	late crepitation

A 23 year-old man without underlying disease, presented with high grade fever and productive cough for 3 weeks. He was intubated due to hypoxemic respiratory failure and his sputum examination showed positive result for AFB. His vital signs were, T 38.9 C, P 135/min, BP 78/66 mmHg, RR 28/min. After 3 liters of crystalloid intravenous infusion in 3 hours, a PA catheter was inserted for hemodynamic monitoring. The hemodynamic parameters measured from PA catheter were as the following:

Central venous pressure	=	20 mmHg
Pulmonary artery pressure	=	45/27(mean 33) mmHg
Pulmonary capillary wedge pressure	=	16 mmHg
Systemic artery blood pressure	=	85/67(mean 73) mmHg
Cardiac index	=	2.0 L/min/m^2
Pulmonary vascular resistance	=	680 dyne/sec/cm^{-5}
Systemic vascular resistance	=	2,120 dyne/sec/cm^{-5}

What is the most likely cause of shock in this patient?

A. Hypovolemic shock

B. Septic shock

C. Acute left ventricular failure

D. Acute right ventricular failure

E. Cardiac tamponade

A 50-year-old man, alcoholic cirrhosis Child C, presented with massive hematemesis for 6 hours. Physical examination revealed afebrile, tachycardia, BP 80/60 mmHg and drowsiness. He also had mildly pale, moderate jaundice, leg edema, mild ascites and splenomegaly. Active bleeding was noted from nasogastric lavage. Laboratory investigations showed Hb 10 g/dL, Hct 30%, platelets 90,000/mm3, BUN 25 mg/dL, Cr 0.7 mg/dL, PT 19 sec, PTT 32 sec.

Which one is the most appropriate initial management?

A. Crytalloid free flow and restrictive blood transfusion

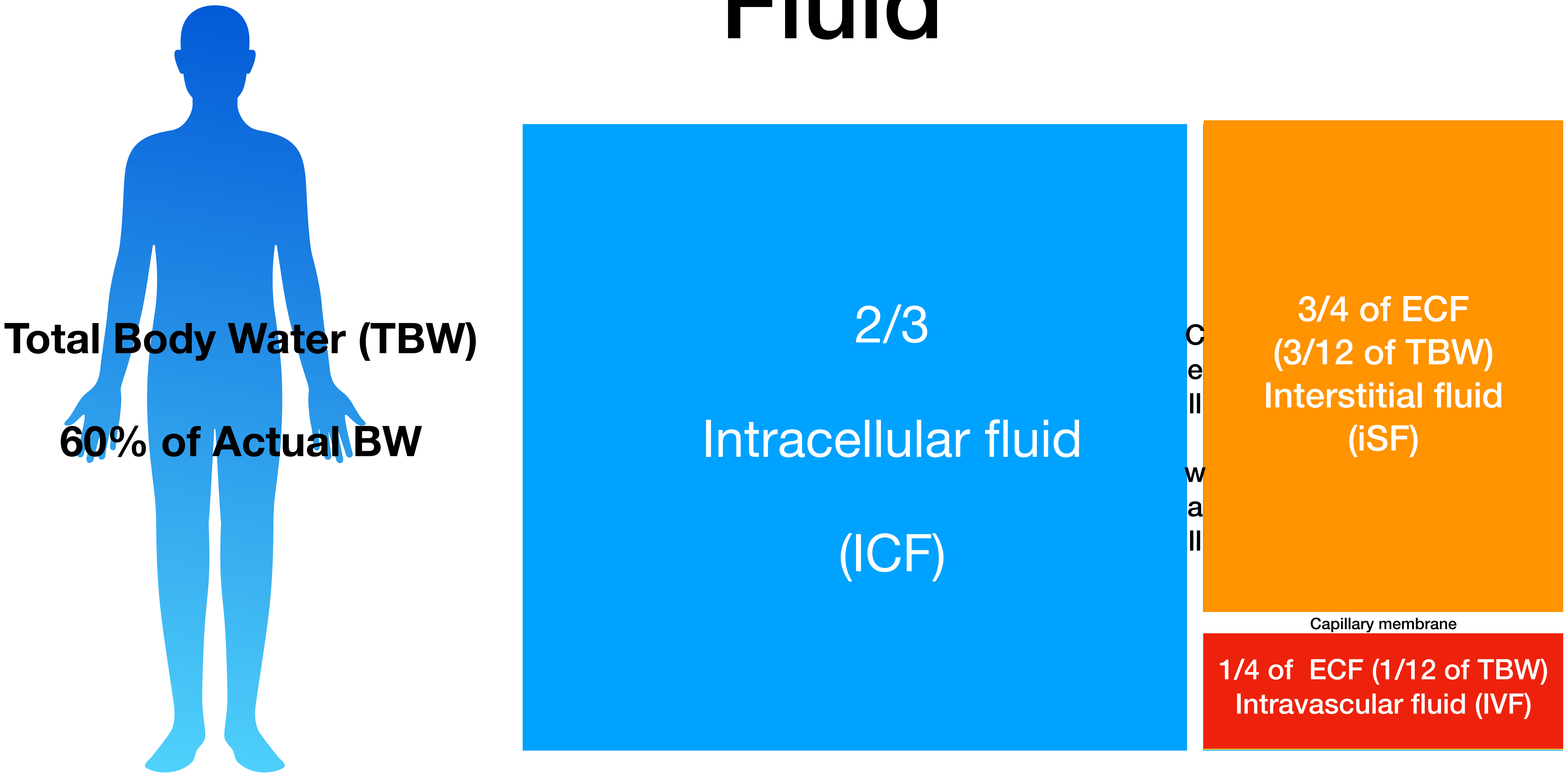
B. FFP and platelets transfusion

C. Omeprazole continuous intraveous infusion

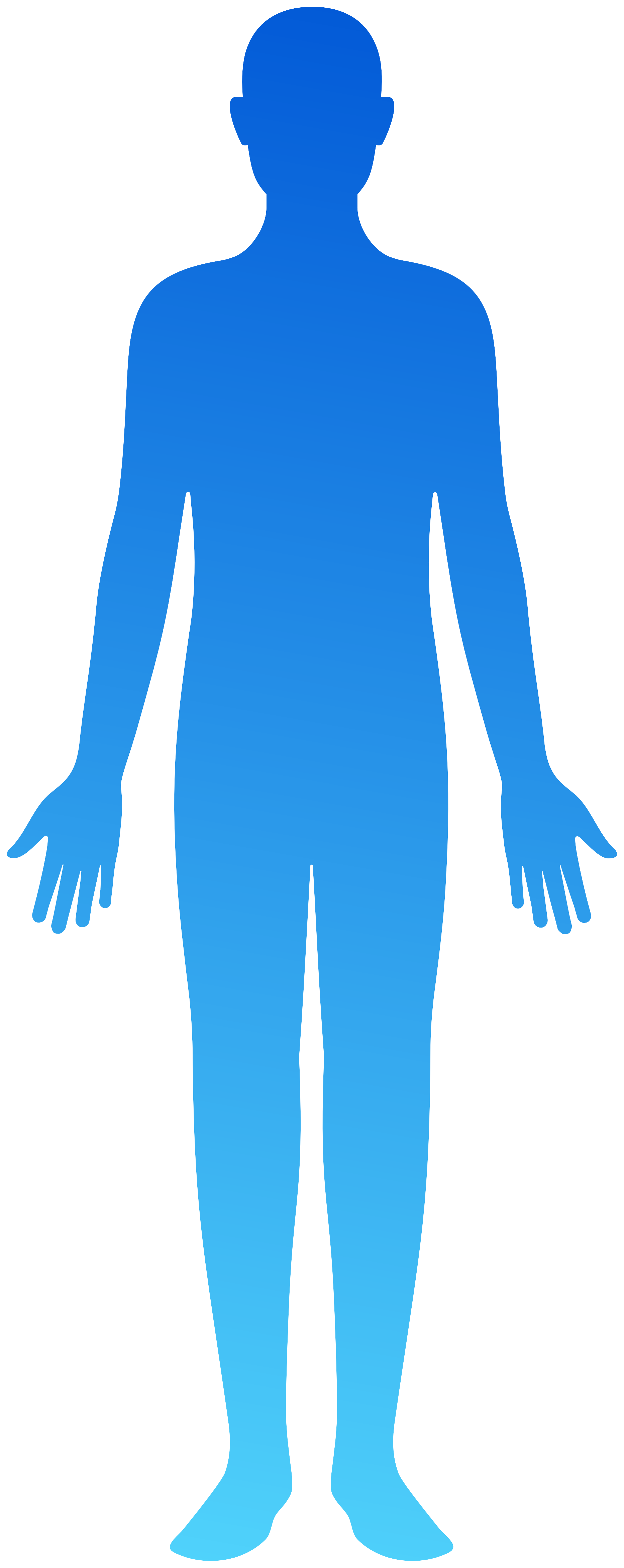
D. Lactulose 30 cc per oral stat

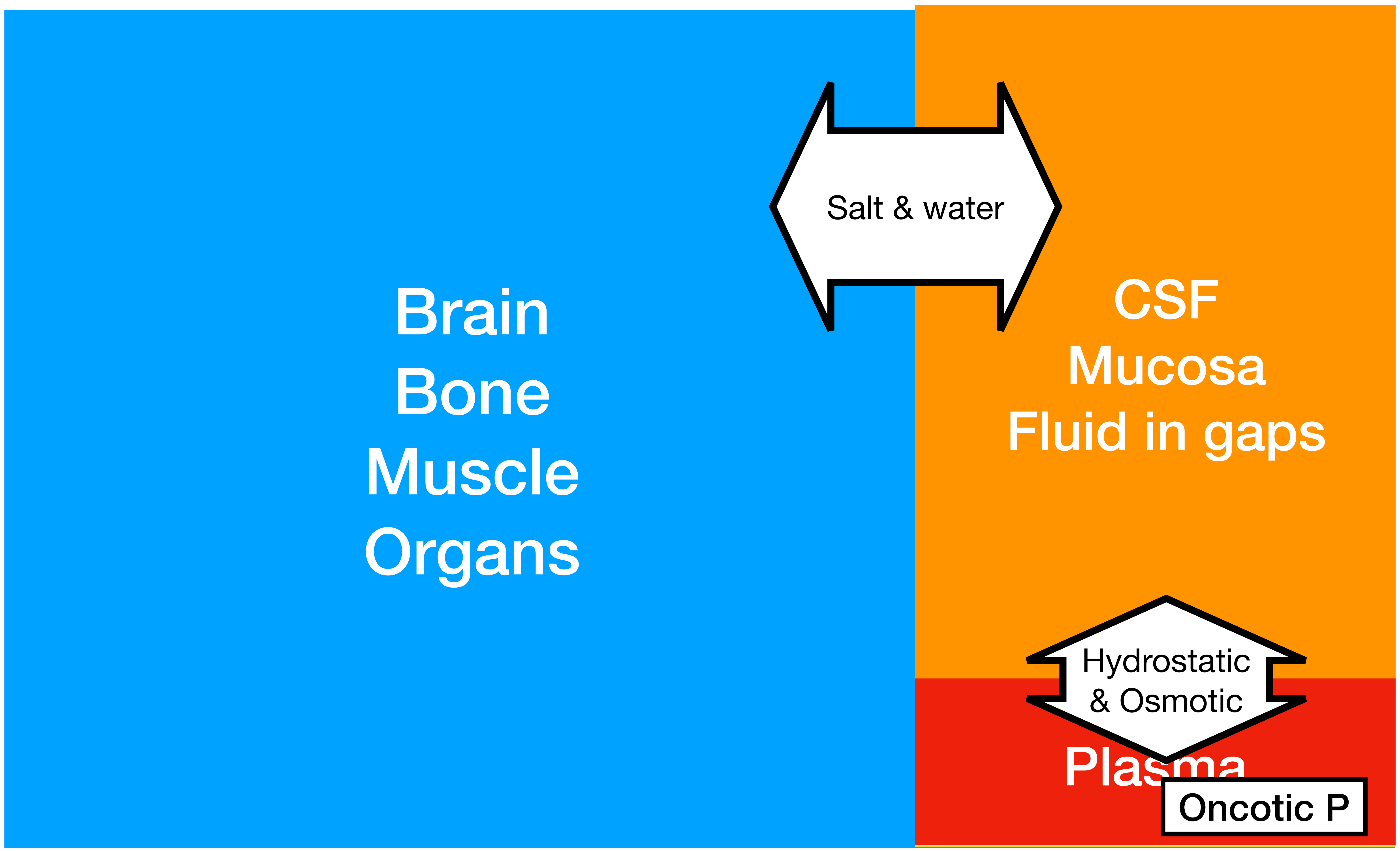
E. Intravenous ceftriaxone 1 g stat

Fluid

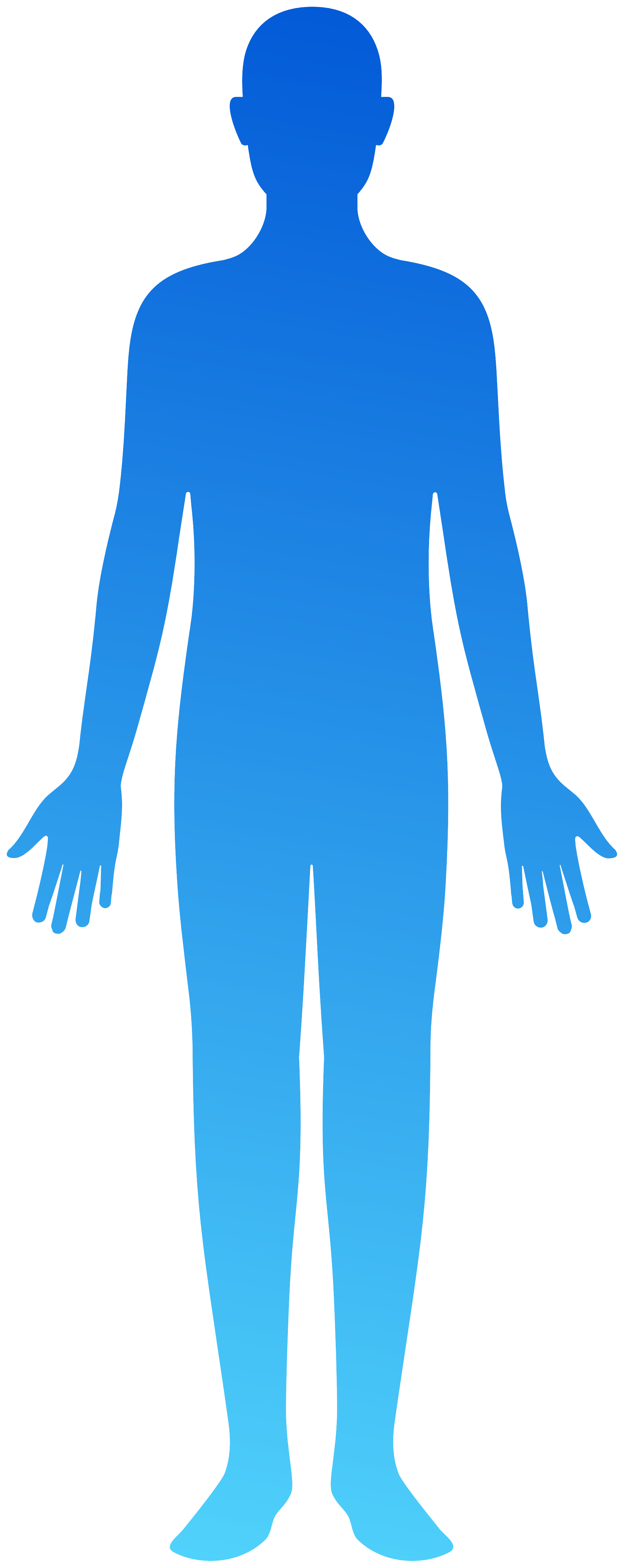

Total Body Water (TBW)
60% of Actual BW
2/3
Intracellular fluid
(ICF)
Cell wall
3/4 of ECF
(3/12 of TBW)
Interstitial fluid
(iSF)
Capillary membrane
1/4 of ECF (1/12 of TBW)
Intravascular fluid (IVF)

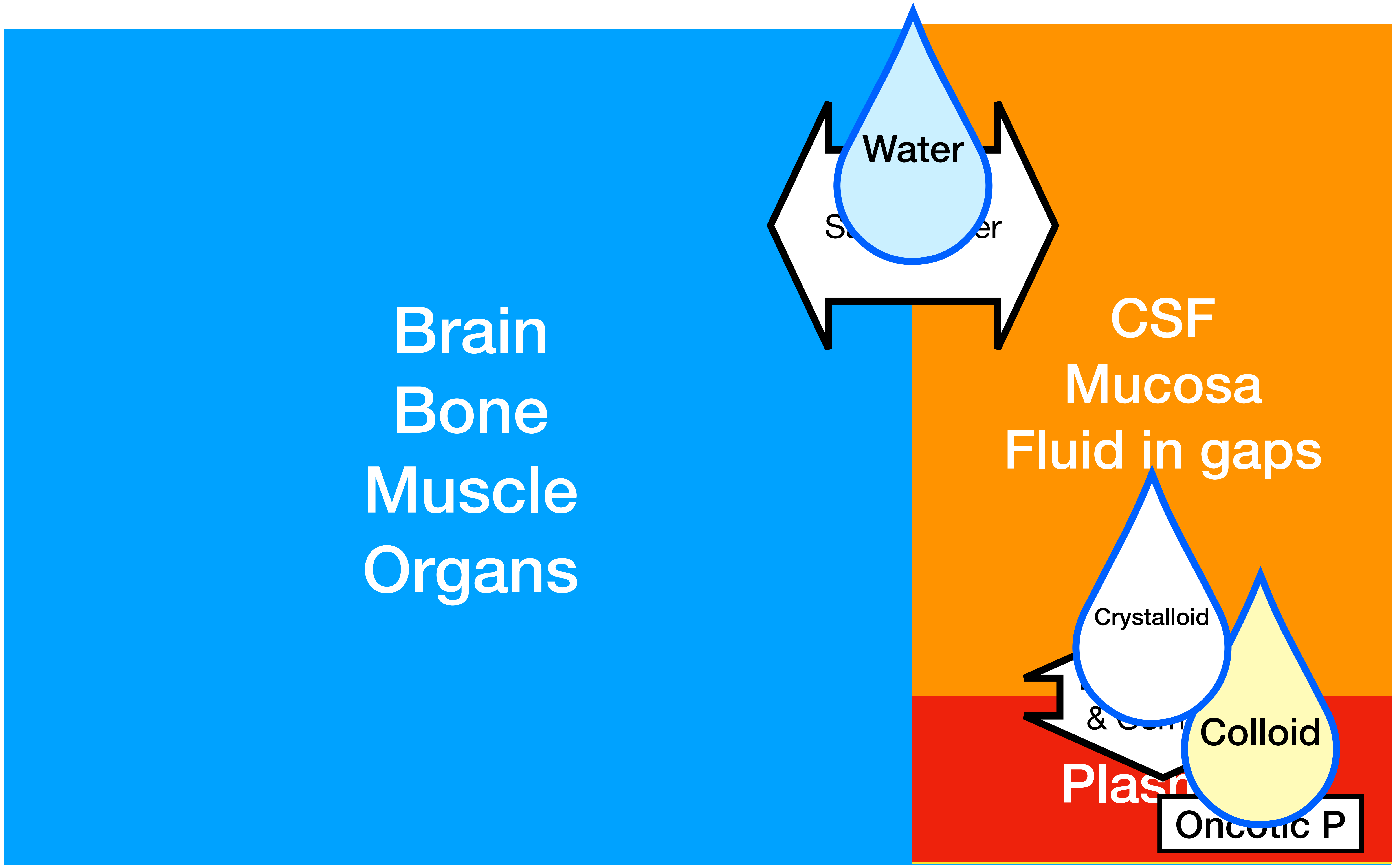
Fluid




Brain
Bone
Muscle
Organs
Salt & water
CSF
Mucosa
Fluid in gaps
Hydrostatic
& Osmotic
Plasma
Oncotic P

Fluid selection





A 54-year-old COVID-19 man presented with sudden cardiac arrest in ward, PE: BP 70/45 mmHg, HR 125/min, RR 24/min, JVP up to mandible, delayed capillary refill, cannot heard chest.

What is the best next step?

A. Call CPR team

B. Use ultrasound for thoracic examination

C. Wait for CXR portable

D. Give IV fluid 500 mL load

E. Start norepinephrine

CVS / Hemodynamic

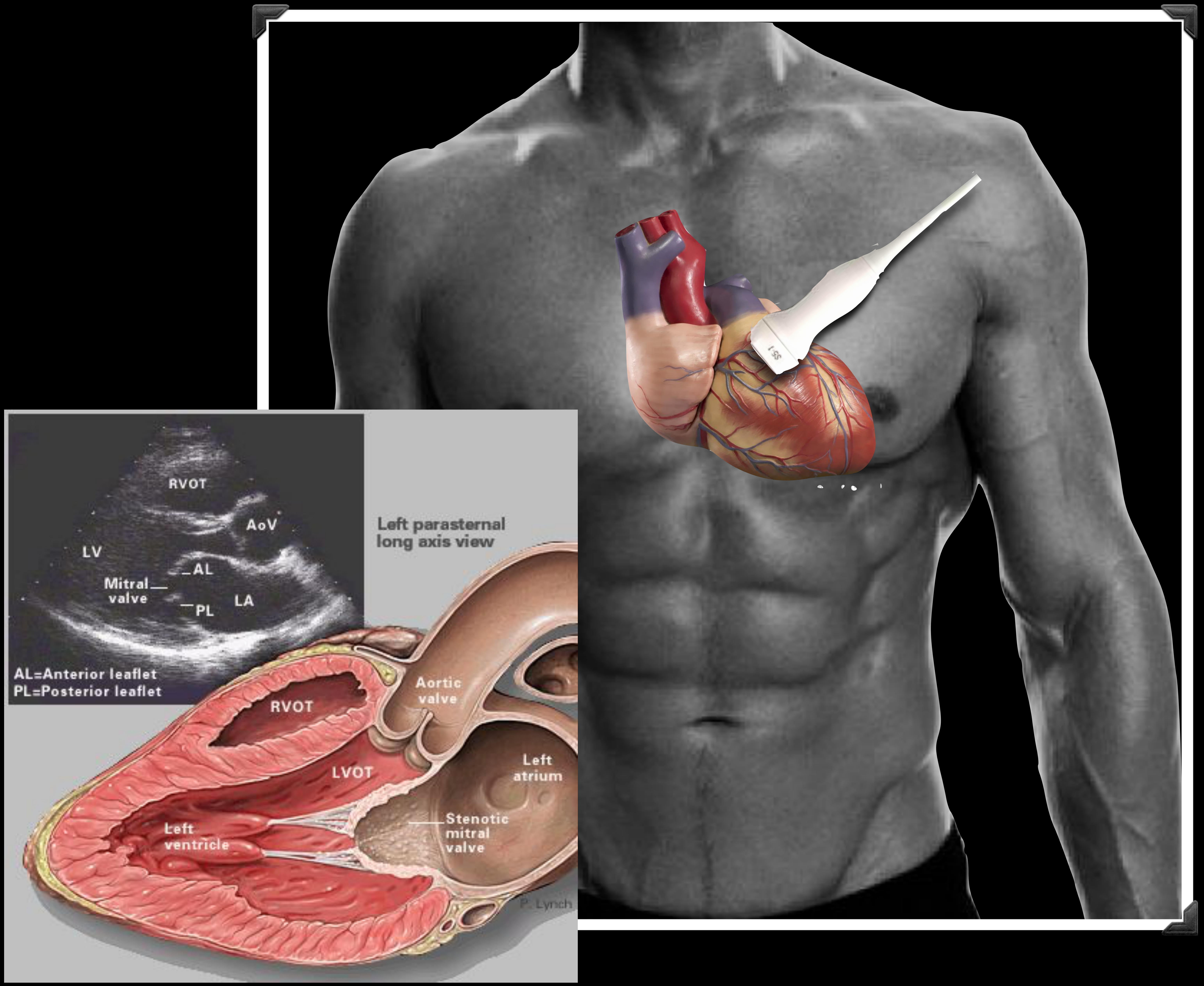
- Invasive monitoring
- Less-invasive monitoring
- Noninvasive monitoring

Aim for
Continuous monitoring
Fluid responsiveness

Focus on
Accuracy
Harmless

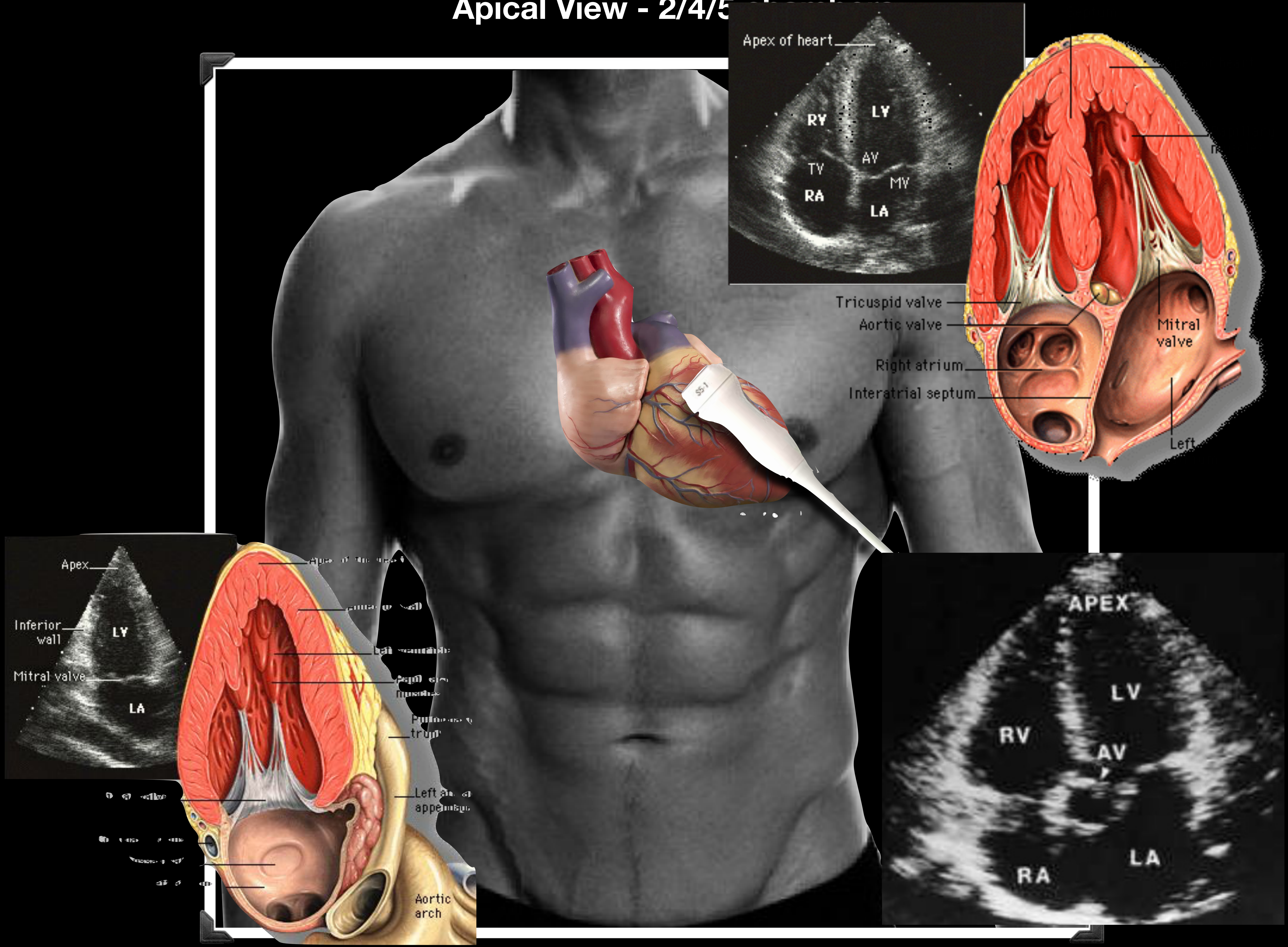
Thoracic ultrasonography

Parasternal Long Axis View - PLAX

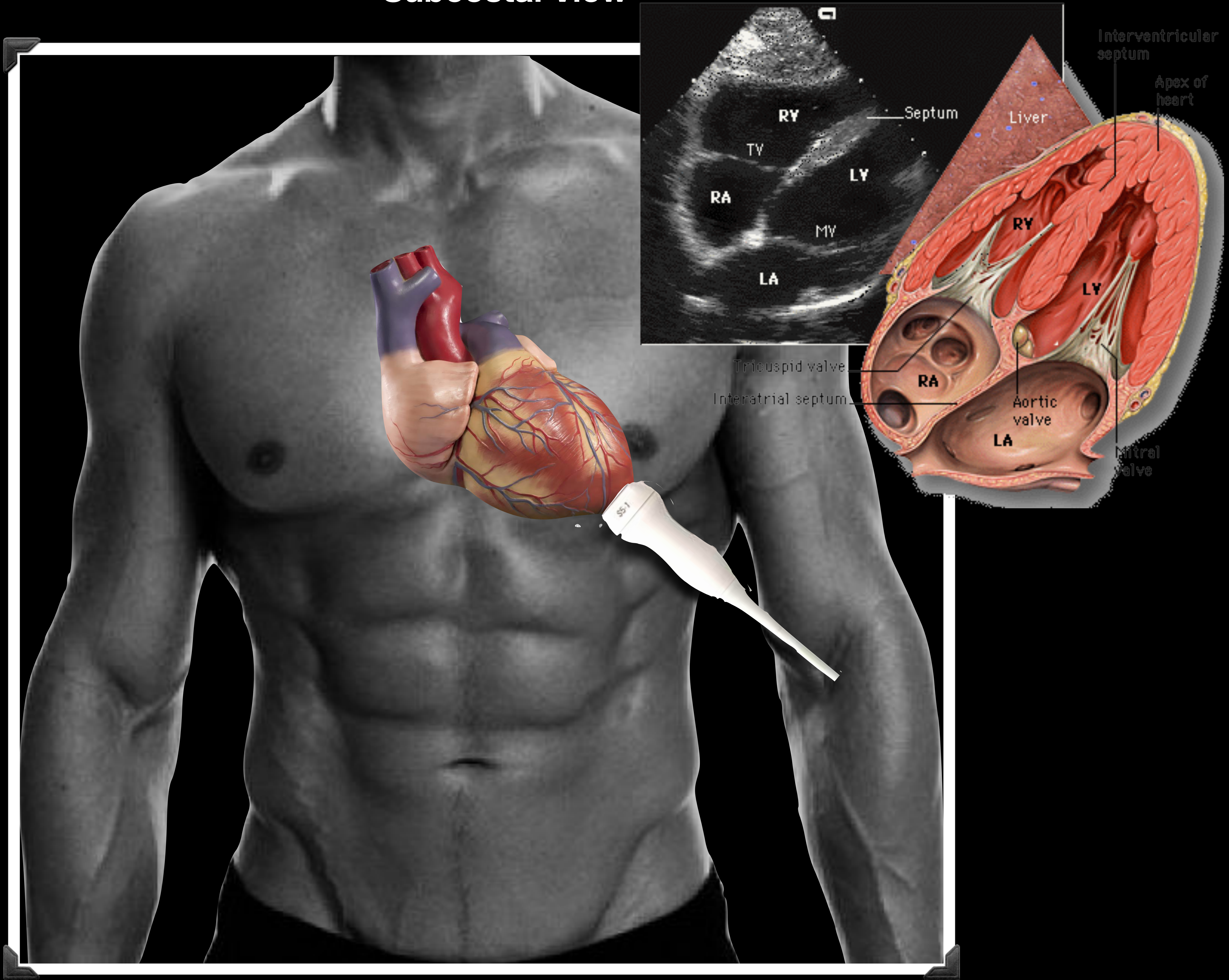


Parasternal Short Axis View - PSAX

Apical View - 2/4/5



Subcostal View



Subcostal View

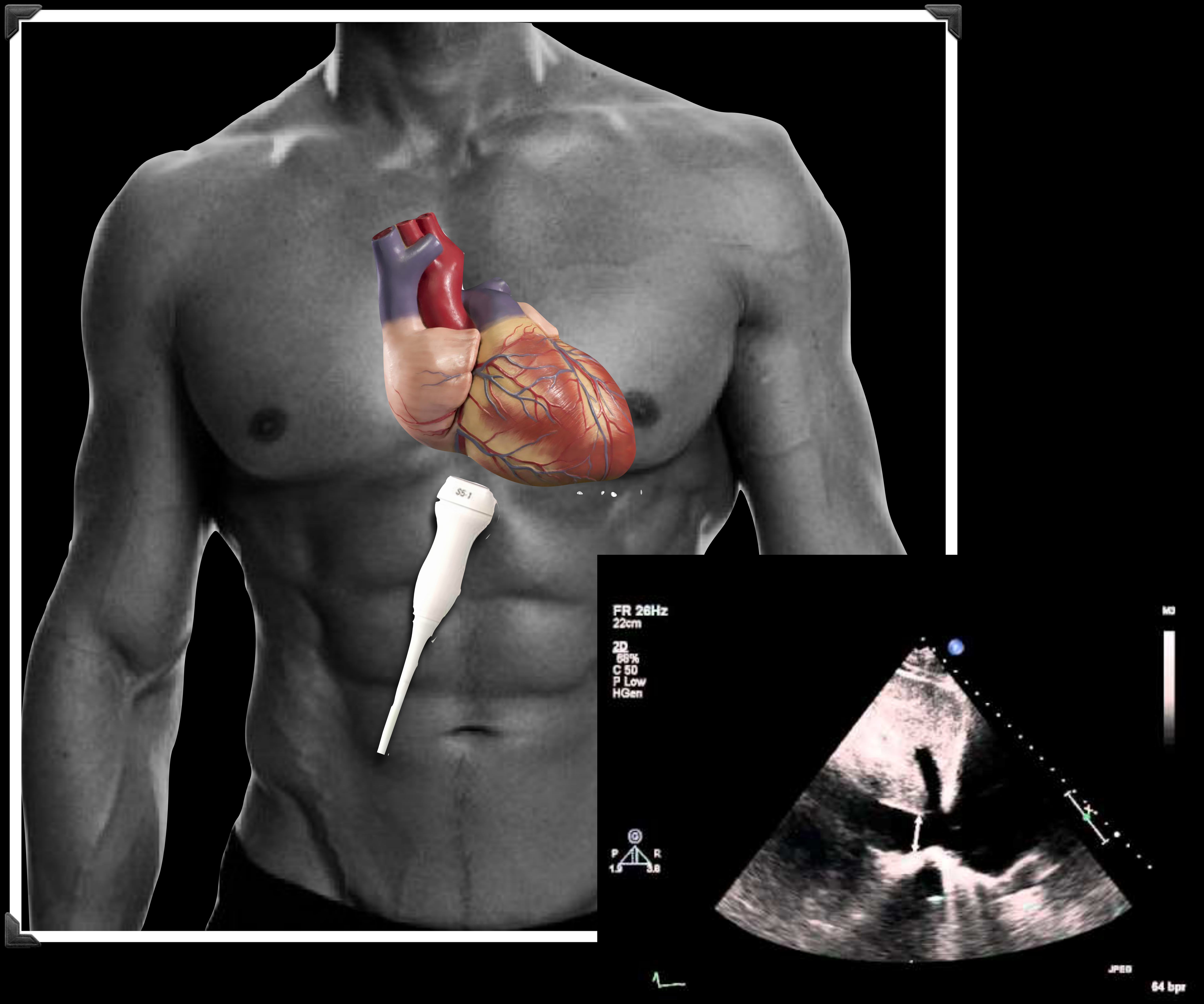
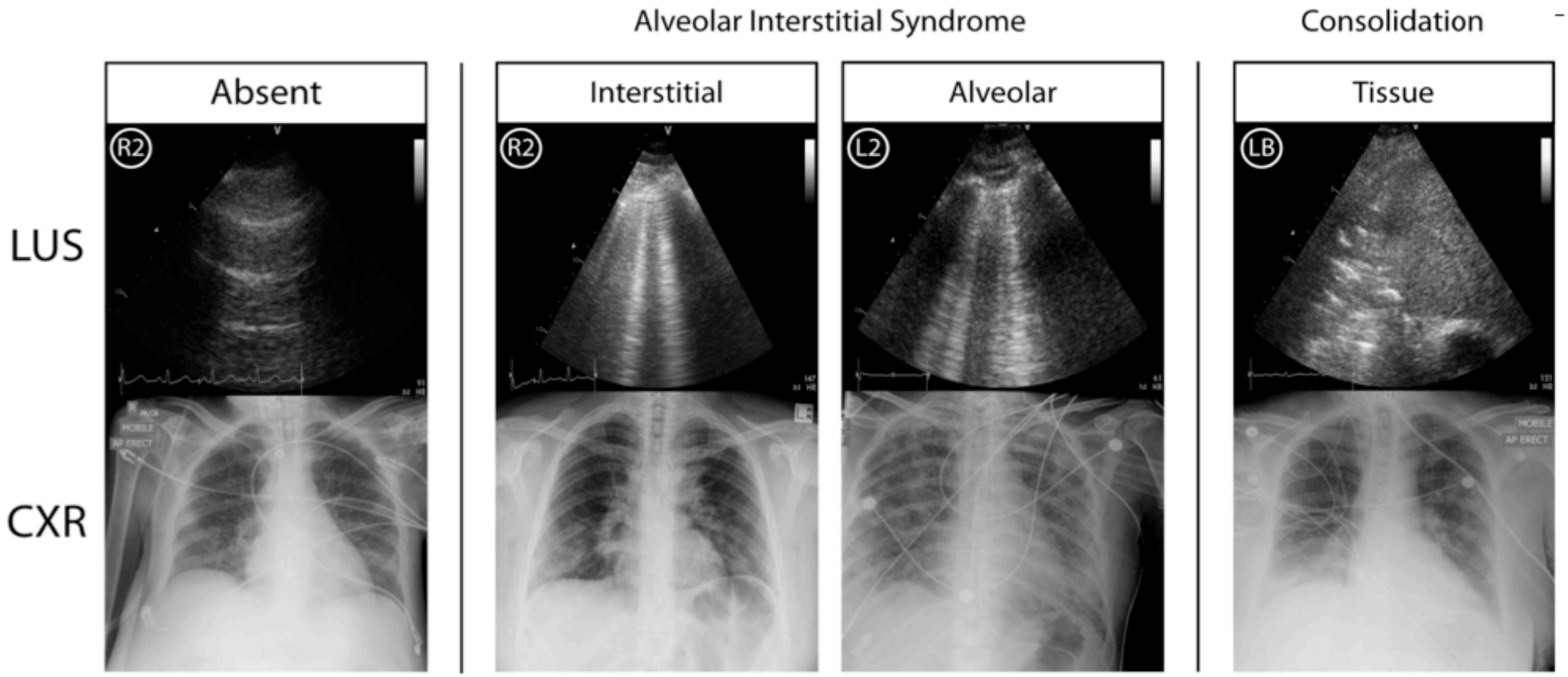
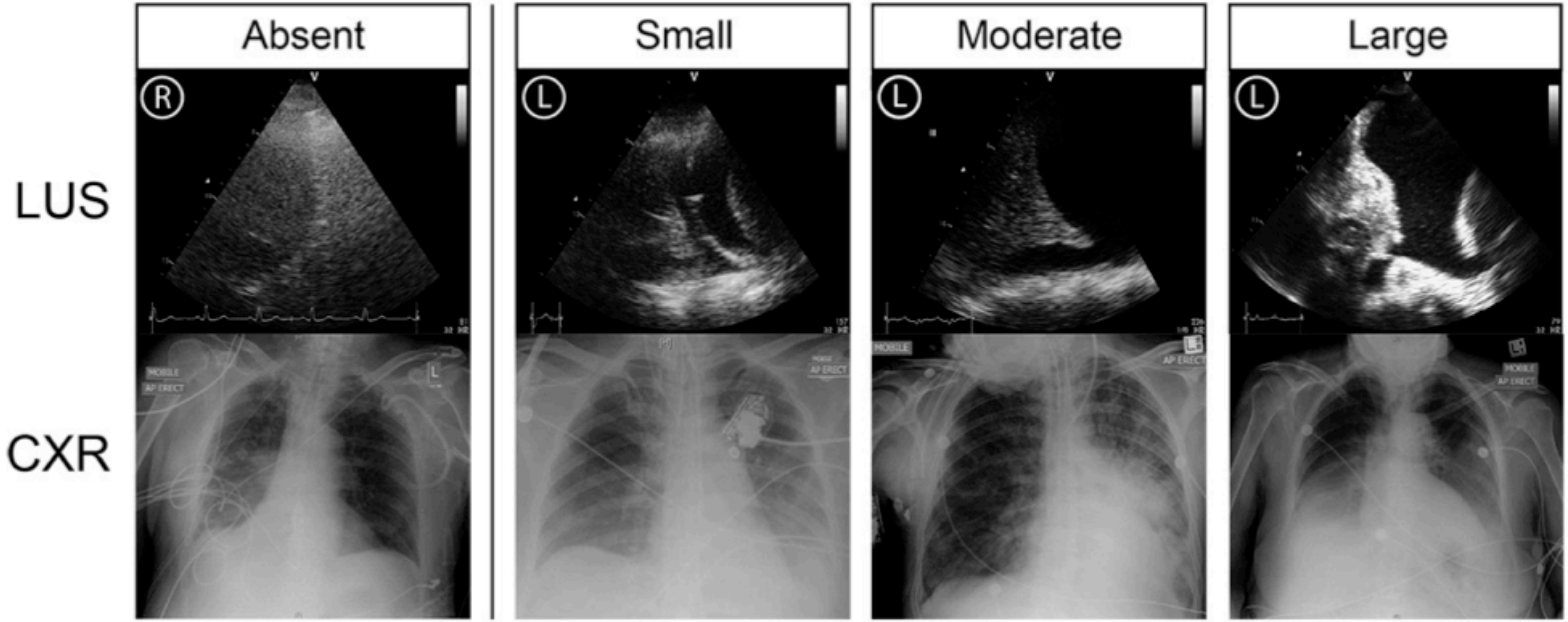


Figure 2. Lung ultrasound and radiological analysis of consolidation and alveolar interstitial syndrome



LUS = lung ultrasound. CXR = chest x-ray. Absent = images of normal lungs. LUS probe positions: R2 = right second intercostal space, mid-clavicular line; L2 = left second intercostal space, mid-clavicular line; LB = left basal lung region, mid-axillary line.

Figure 1. Lung ultrasound and radiological analysis of pleural effusion



LUS = lung ultrasound. CXR = chest x-ray. Absent = images of normal lungs. Small, moderate, large = volume of pleural effusion. R = right-sided LUS probe position. L = left-sided LUS probe position, in basal lung region, mid-axillary line.

A 78-year-old woman presented with high grade fever with RUQ pain. He was diagnosed toxic cholangitis. Her BP 92/55 mmHg, HR 130/min, RR 28/min, abdominal distension, CVP 5 mmHg. After crystalloid loading 500 mL, she was intubated due to pulmonary edema, BP 89/32 mmHg, HR 90/min, CVP 15 mmHg. Urine output 120 mL.

What is the best next step?

A. PA catheter insertion

B. Arterial line

C. IVC ultrasound

D. CVP monitoring

E. Monitor urine output

Hemodynamic monitoring

Goal : to assess the adequacy of perfusion (perfusion pressure & oxygen delivery)

- invasive & non-invasive
- static & dynamic

Blood Pressure

BP = LVEDV x EF x HR x SVR(TPR)

preload	Static: CVP, PCWP, IVC Dynamic: FCT, PLRT, PPV, SVV, IVCv
pump	Echocardiogram
chrono	ECG monitoring
afterload	SVR calculation from devices

Hemodynamic parameters

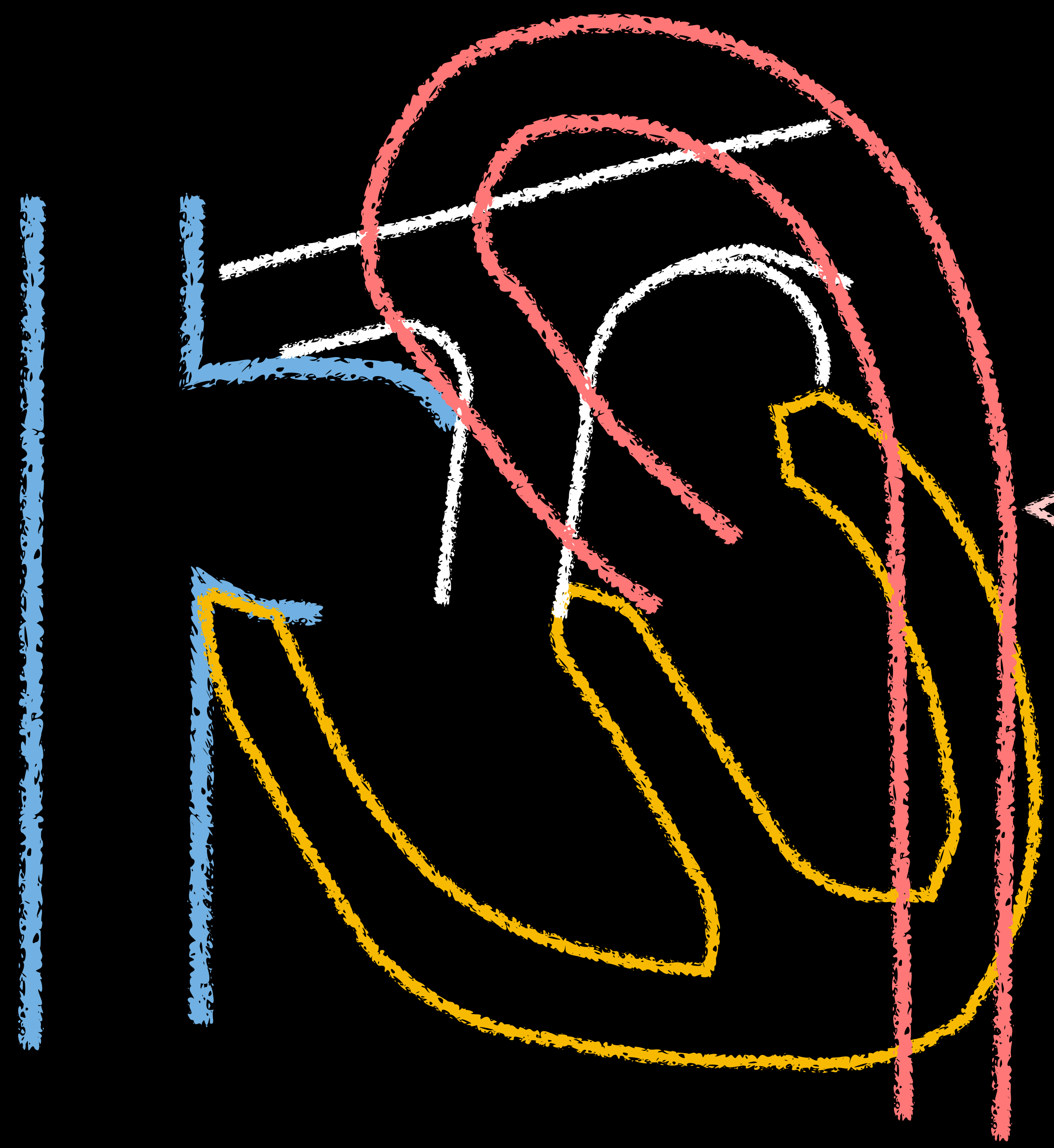
	Clinical assessment	Static assessment	Dynamic assessment
Preload	JVP, skin turgor, lungs sound	CVP, PCWP	PPV, SVV, PLRT, etc.
Pump	Heart sound	Echocardiography	Echocardiography
Chronotropy	Heart rate	ECG	ECG
Afterload	Pulse pressure, capillary refill	SVR (calculate)	vascular impedance

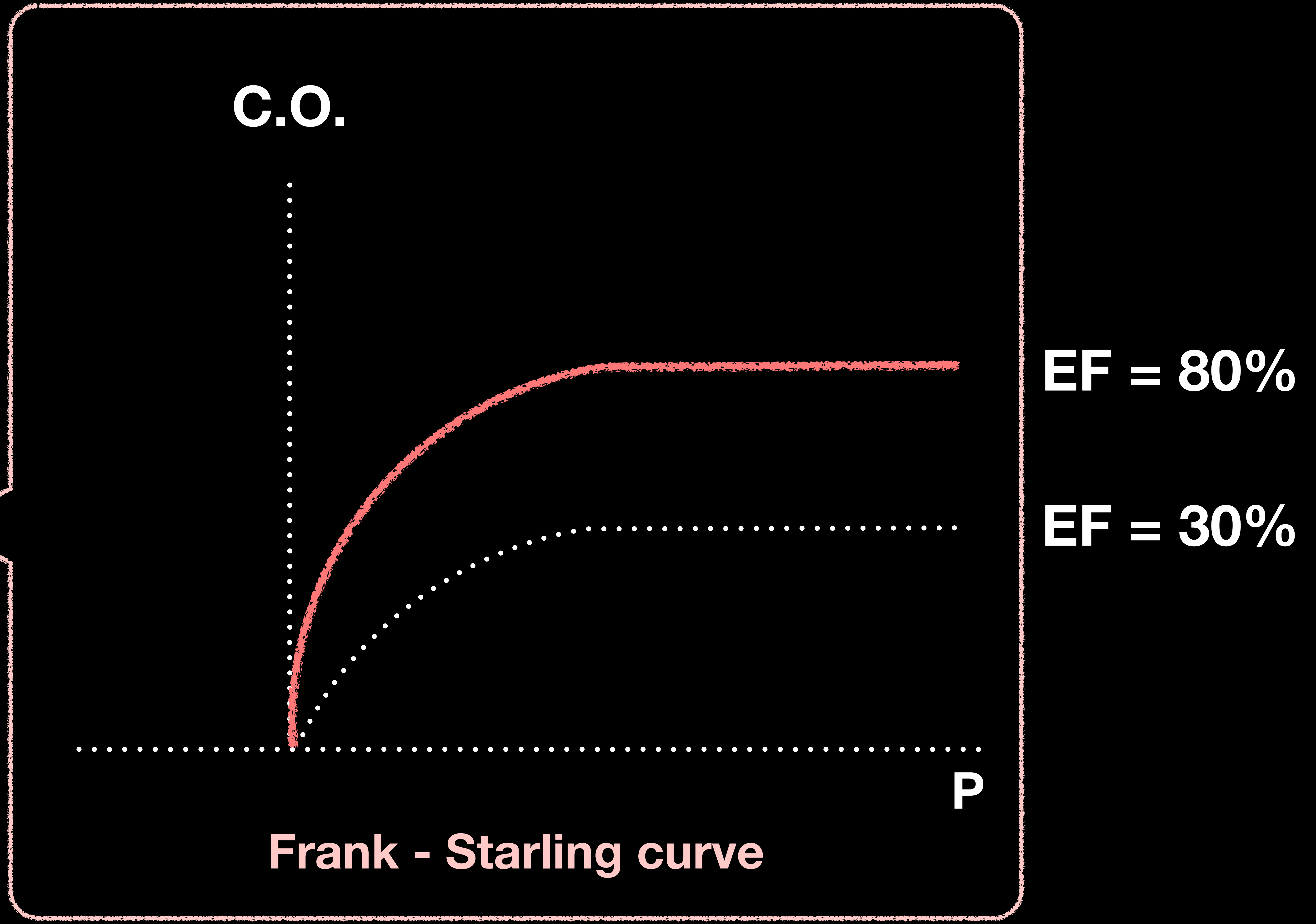
Hemodynamic monitoring in ICU

- for observation & hemodynamic support
- for predicted fluid responsiveness

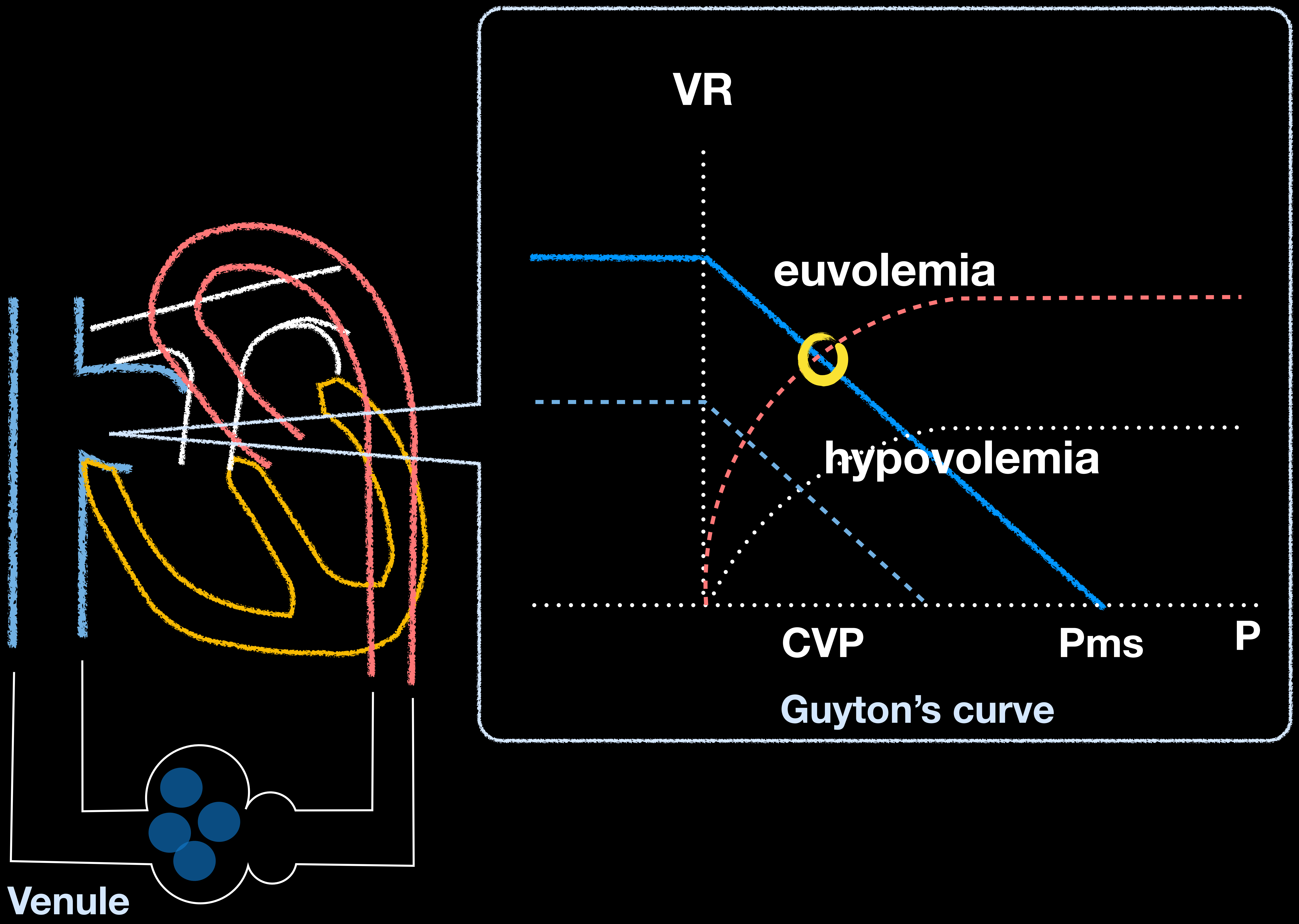
Fluid responsiveness : an increase of stroke volume of 10-15% after the patient receives 500 ml of crystalloid over 10-15 minutes (defined by Paul Marik)

Cardiac function & Return function

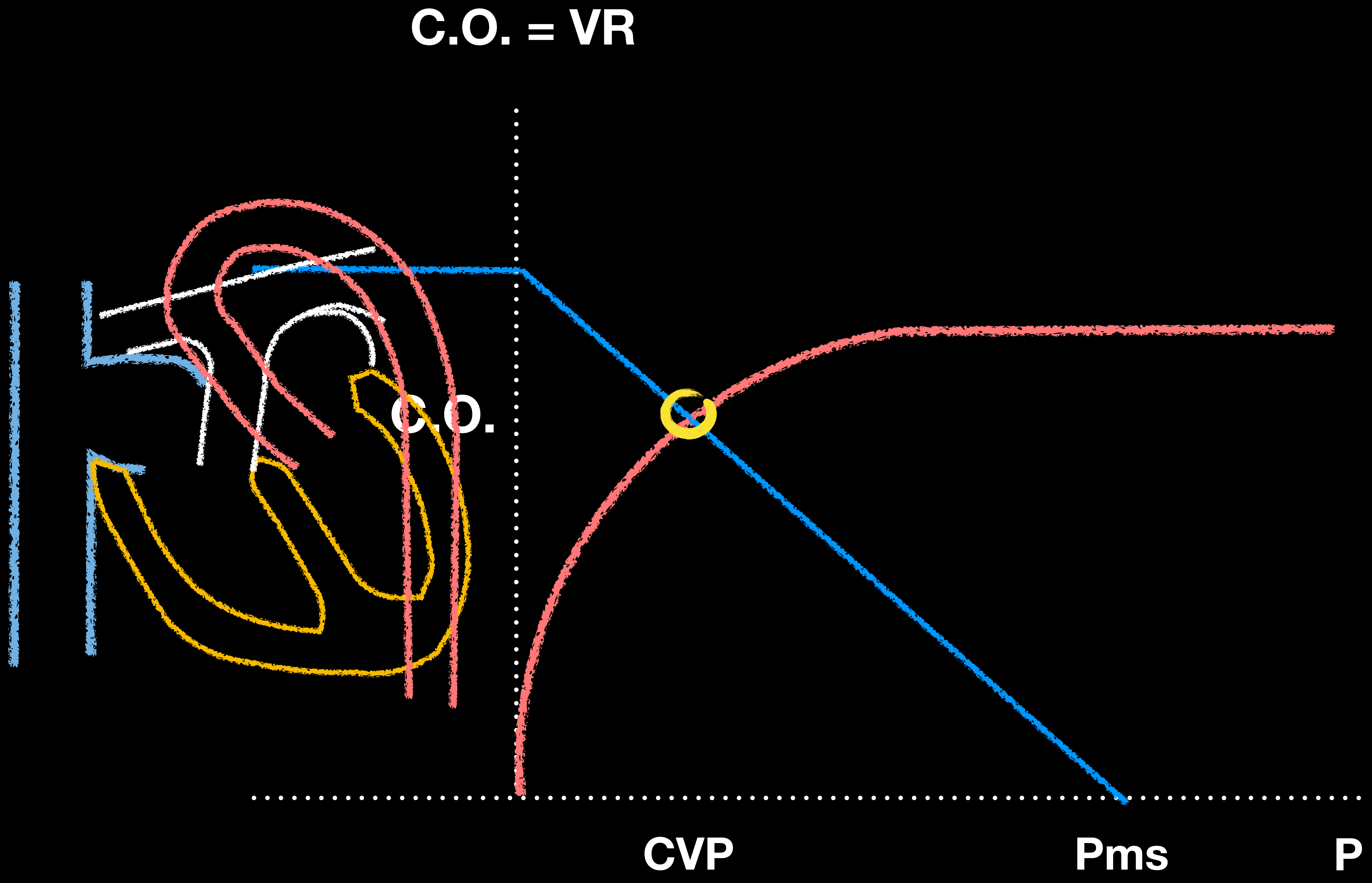




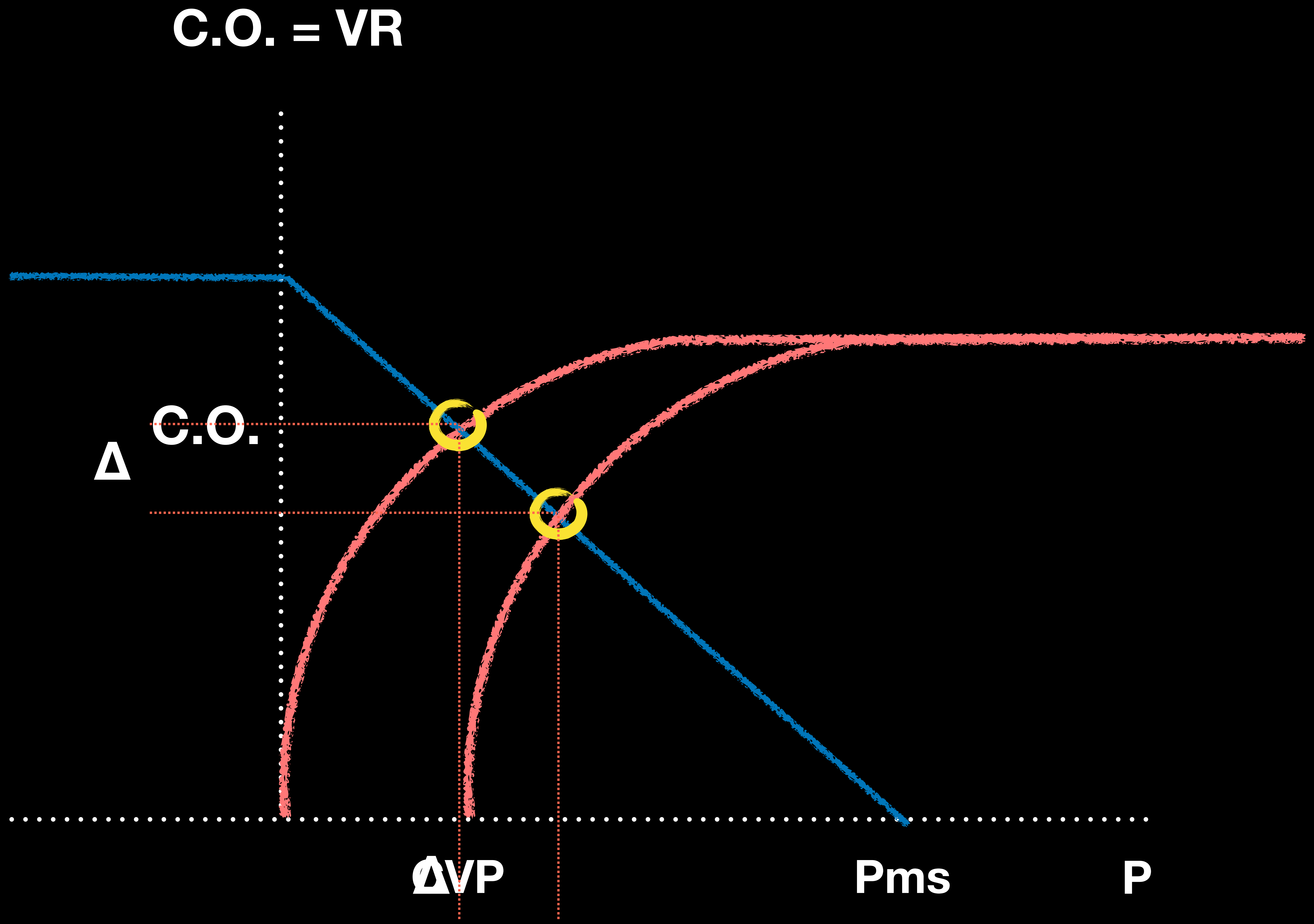
Cardiac function & Return function



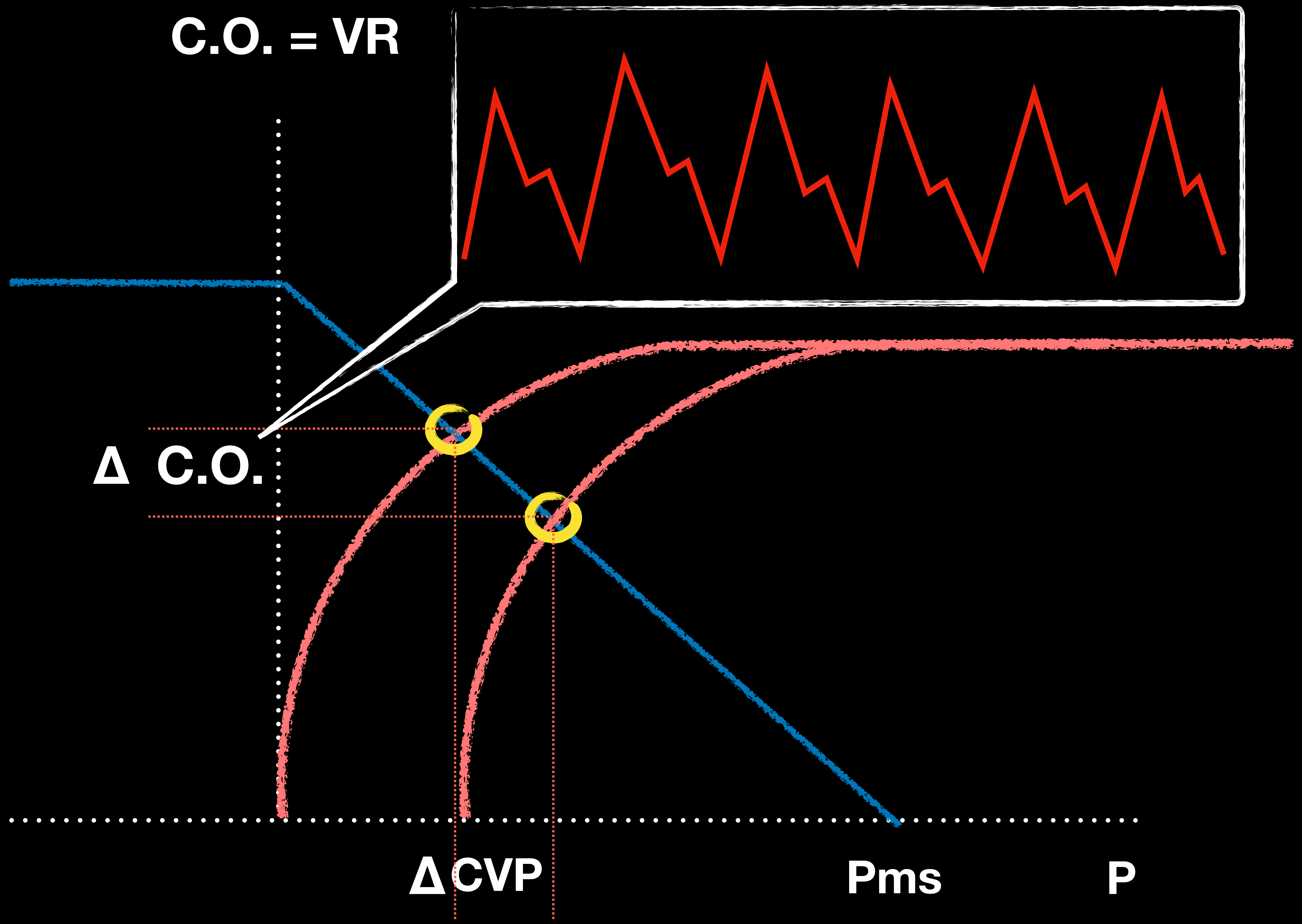
Cardiac function & Return function



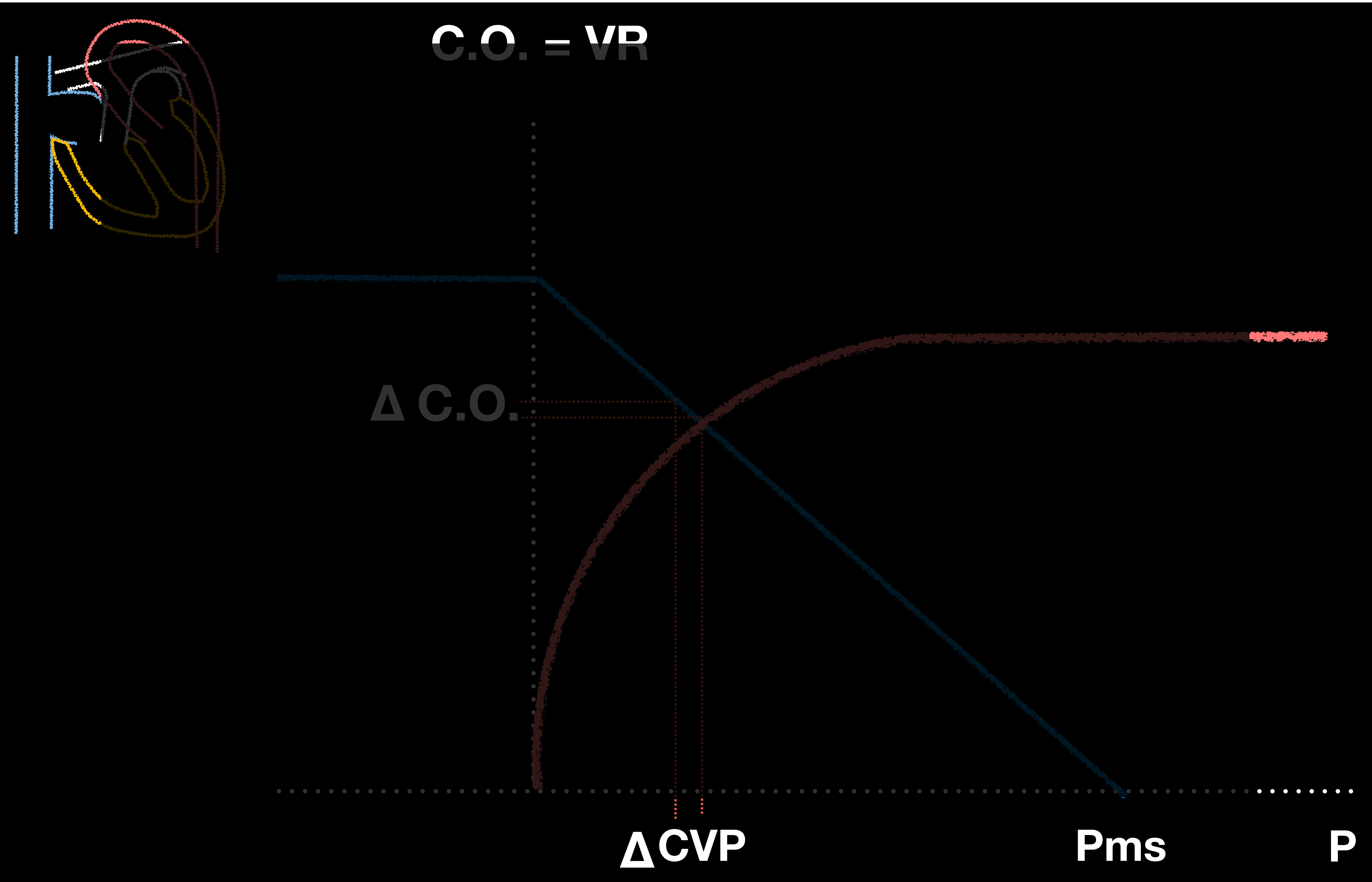
Heart & Lung interaction



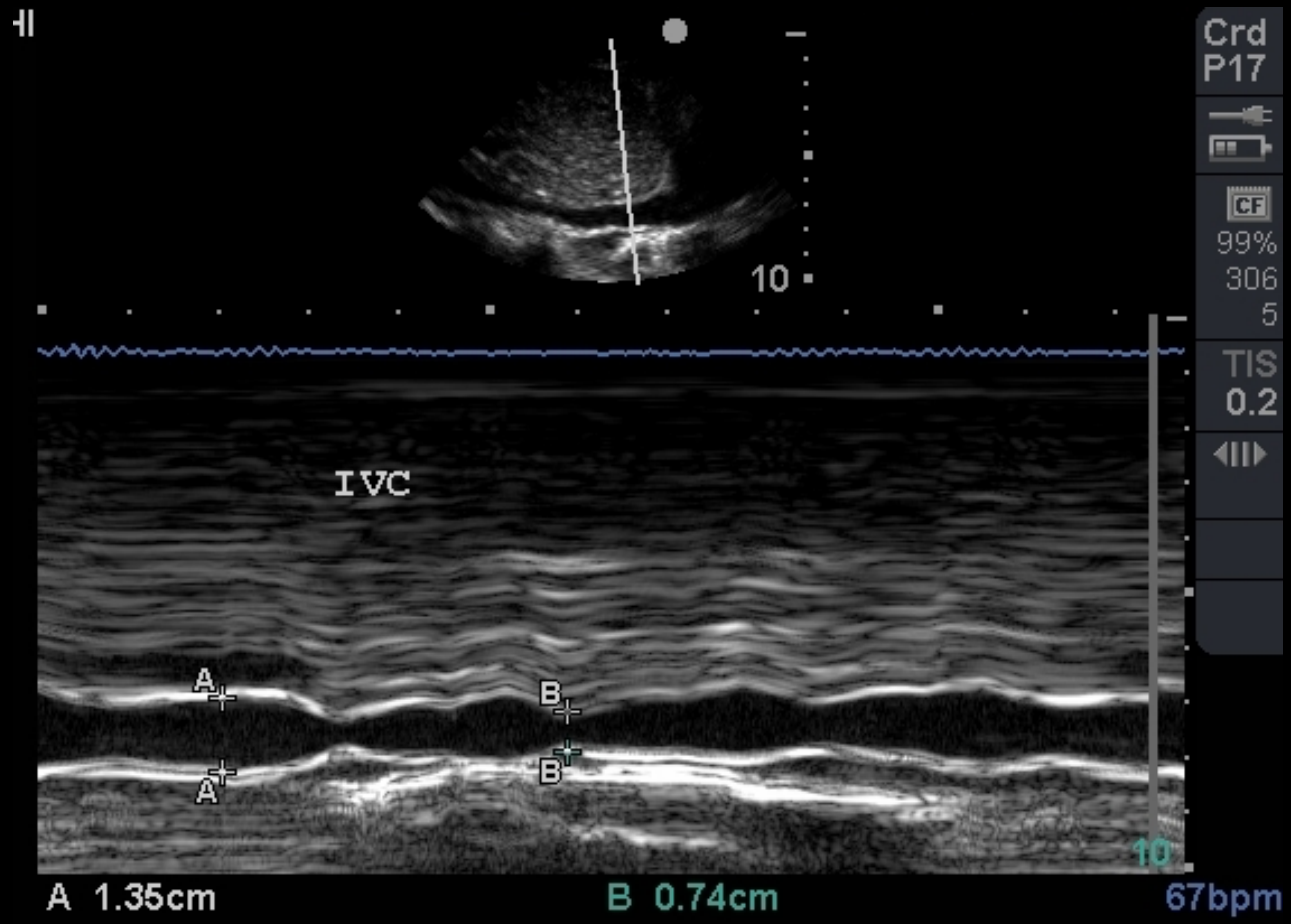
Heart & Lung interaction



CVP variation



IVC variation



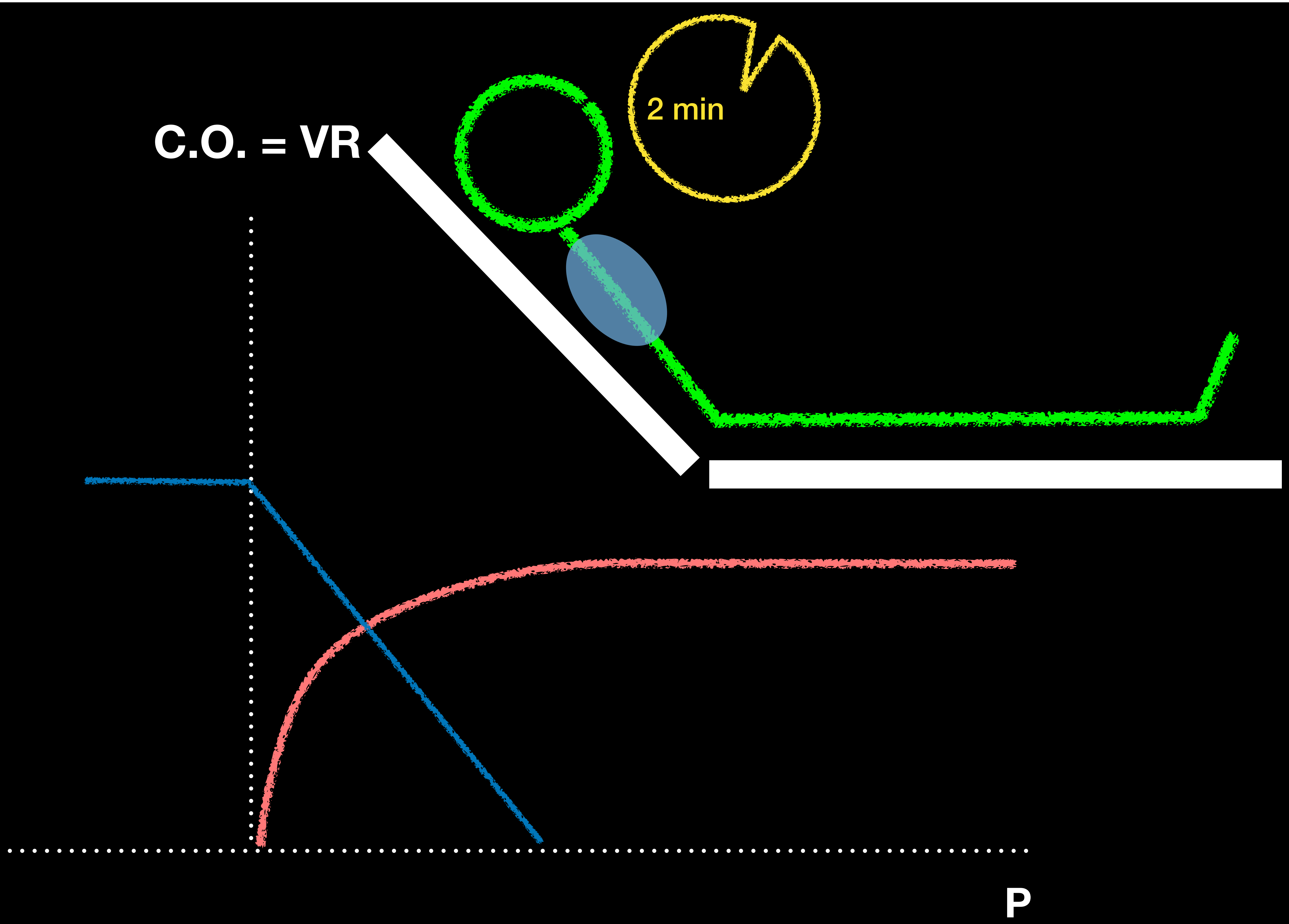
Fluid challenge test

Fluid challenge test

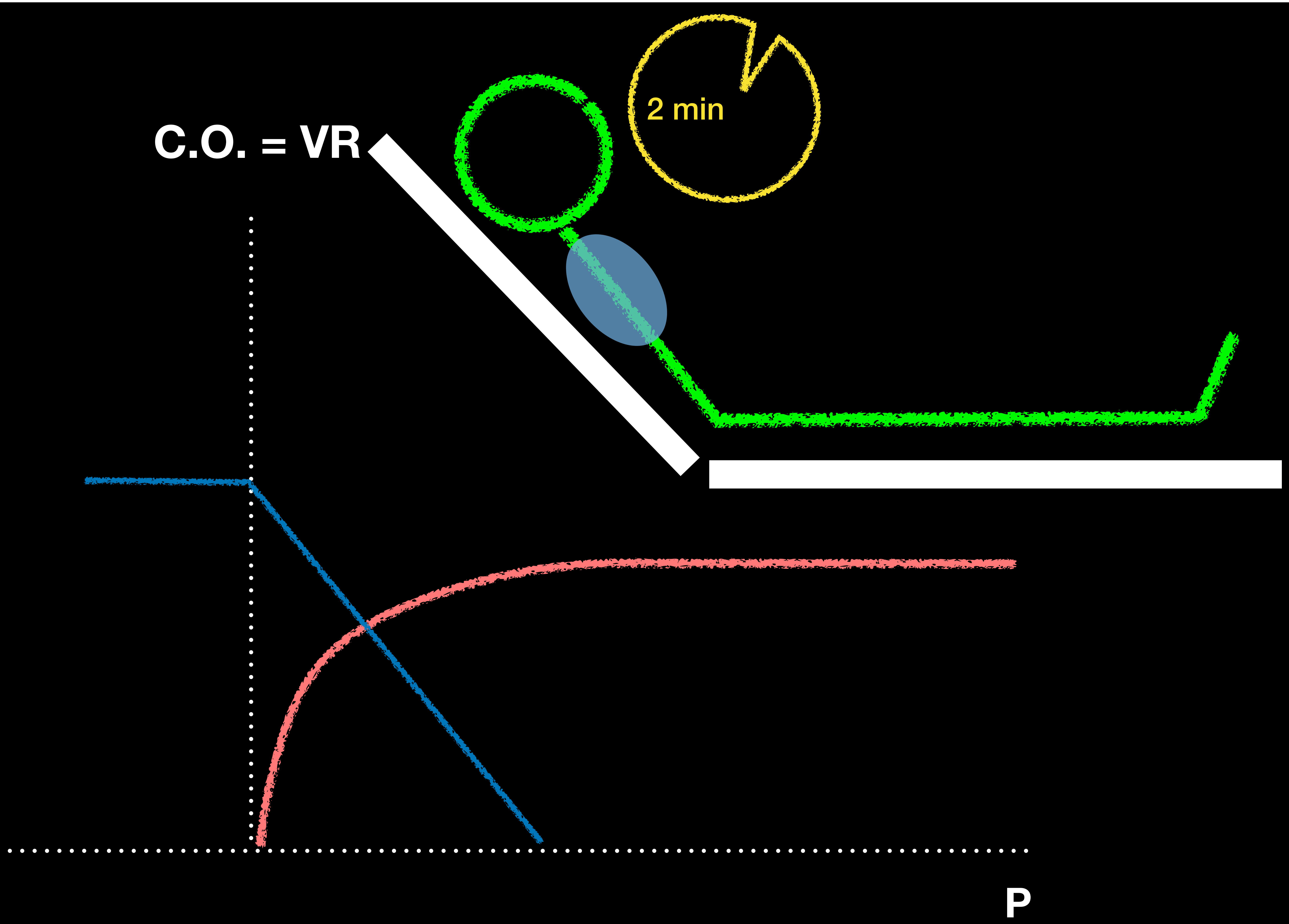
	CVP (cmH_2O)	PAOP (mmHg)	Fluid therapy
During	Δ> 5	Δ> 7	Stop
After bolus	Δ< 2 Δ2-5 Δ> 5	Δ< 3 Δ3-7 Δ> 7	continue with 10 mins stop
After 10 mins	still Δ> 2 Δ< 2	still Δ> 3 Δ< 3	stop repeat infusion

Weil MH. Henning RJ. Anesth Analg 1979:58;124-132

Passive Leg Raising Test

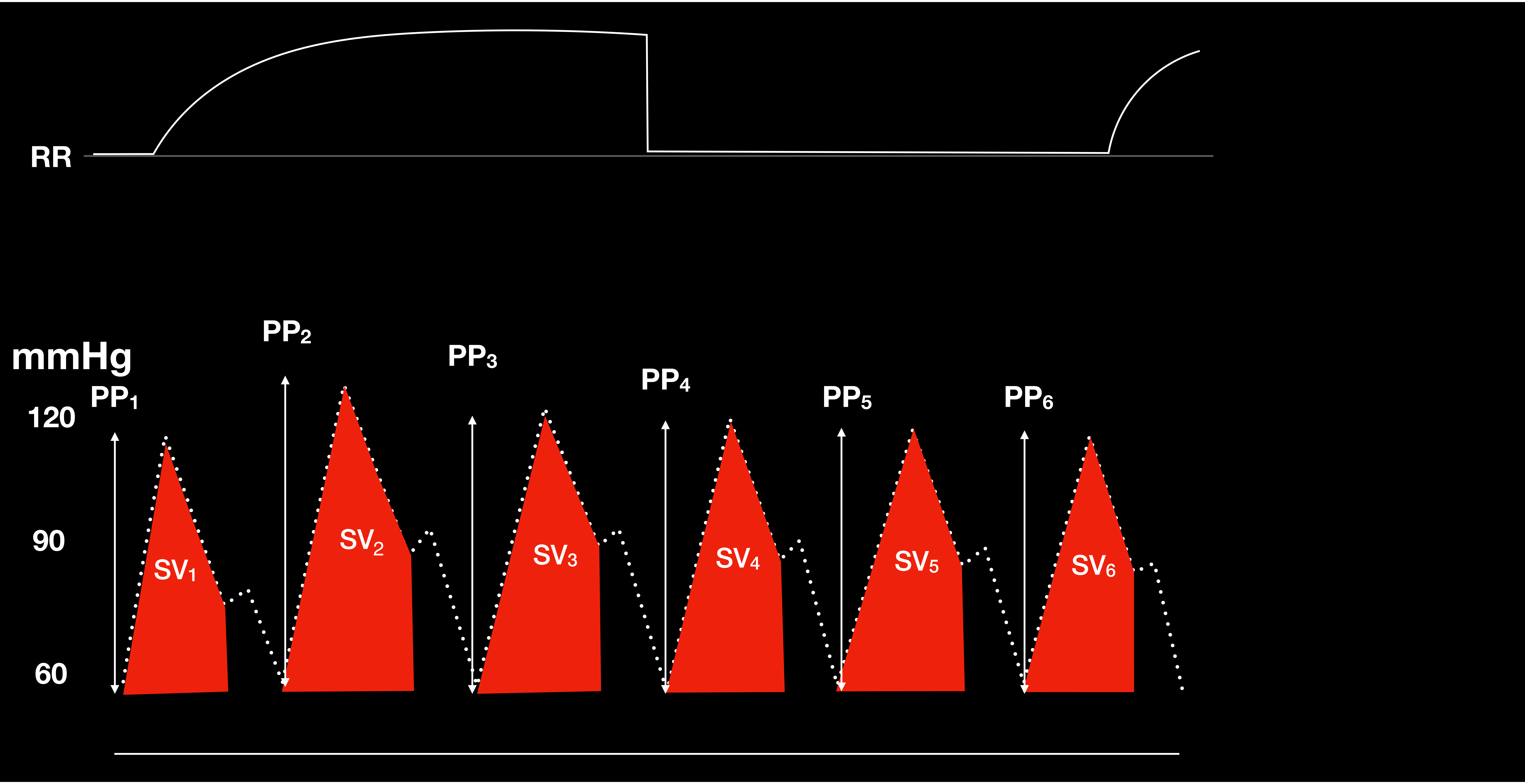


Passive Leg Raising Test

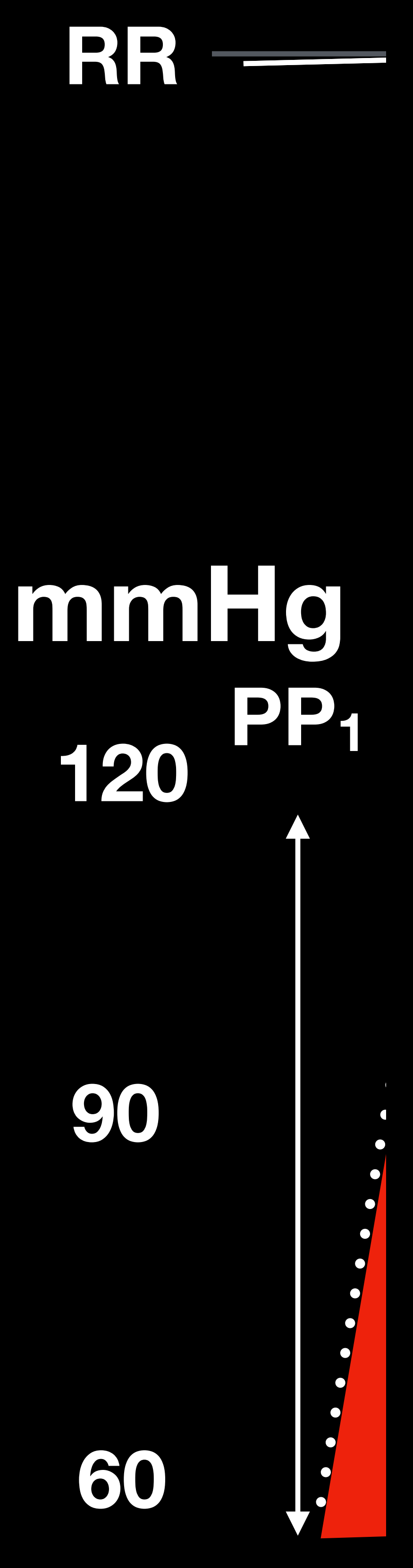


Arterial line

Arterial line



Stroke volume variation
Pulse pressure variation

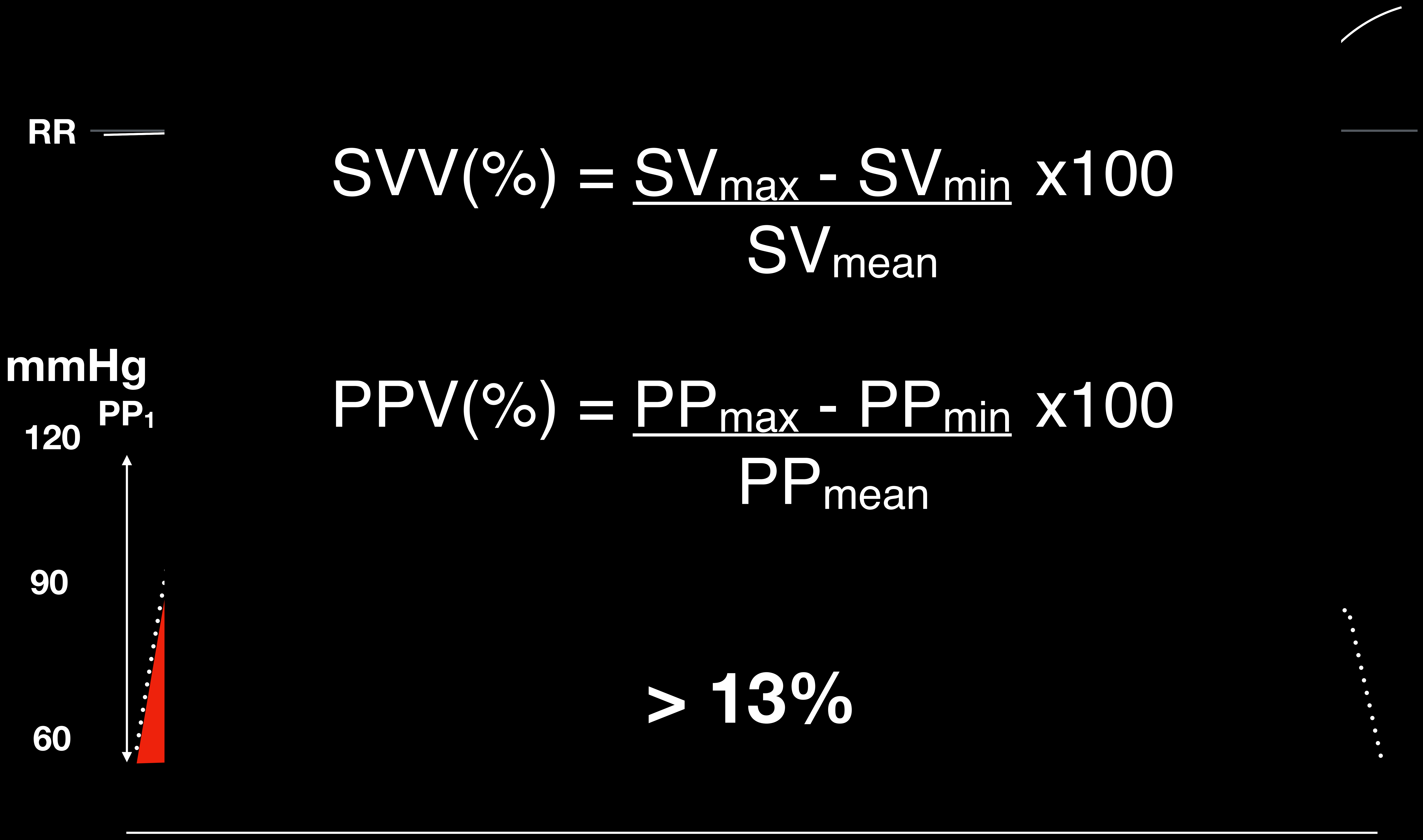


$$SVV(\%) = \frac{SV_{max} - SV_{min}}{SV_{mean}} \times 100$$

$$PPV(\%) = \frac{PP_{max} - PP_{min}}{PP_{mean}} \times 100$$

> 13%

Stroke volume variation
Pulse pressure variation

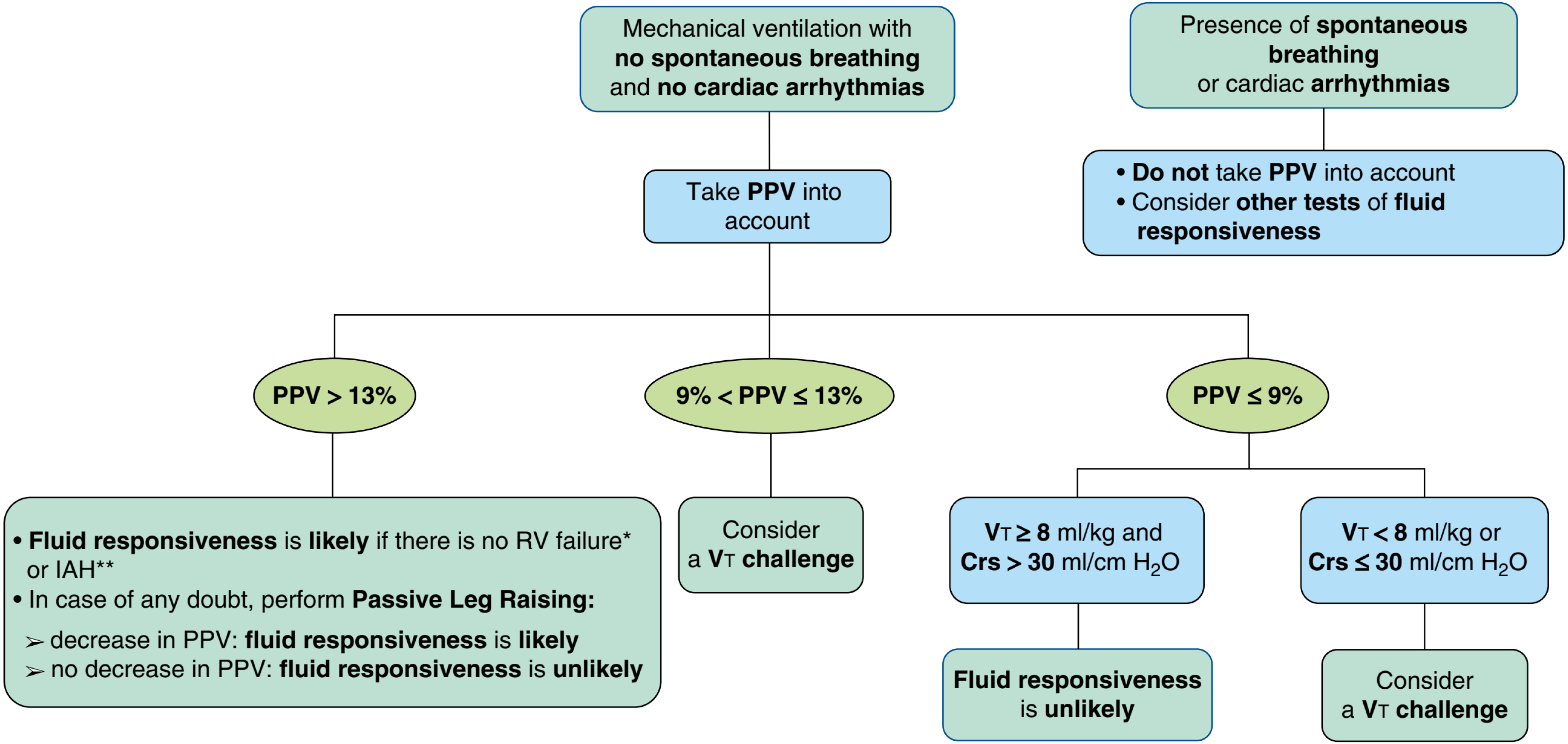


$$SVV(\%) = \frac{SV_{max} - SV_{min}}{SV_{mean}} \times 100$$

$$PPV(\%) = \frac{PP_{max} - PP_{min}}{PP_{mean}} \times 100$$

> 13%

		False positive	False negative
L	**Low** HR/RR ratio (Extreme bradycardia or high frequency ventilation)		✓
I	**Irregular** heart beats	✓	
M	**Mechanical** ventilation with low tidal volume		✓
I	**Increased** abdominal Pressure (Pneumoperitoneum)	✓	
T	**Thorax** open		✓
S	**Spontaneous** breathing	✓	✓



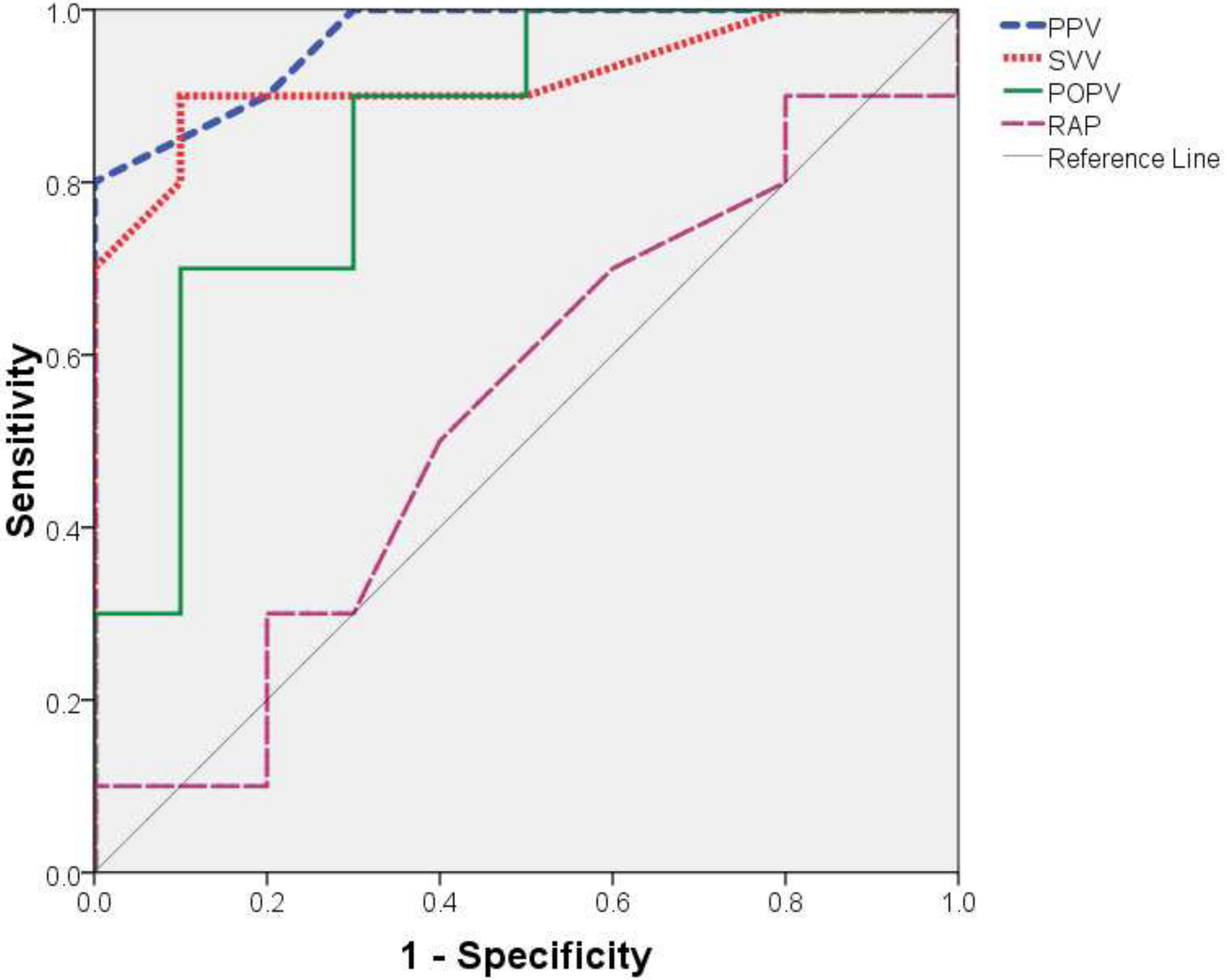
Mechanical ventilation with no spontaneous breathing and no cardiac arrhythmias
Presence of spontaneous breathing or cardiac arrhythmias
Take PPV into account
• Do not take PPV into account
• Consider other tests of fluid responsiveness
PPV > 13%
9% < PPV ≤ 13%
PPV ≤ 9%
• Fluid responsiveness is likely if there is no RV failure* or IAH**
• In case of any doubt, perform Passive Leg Raising:
➢ decrease in PPV: fluid responsiveness is likely
➢ no decrease in PPV: fluid responsiveness is unlikely
Consider a VT challenge
VT ≥ 8 ml/kg and Crs > 30 ml/cm H2O
VT < 8 ml/kg or Crs ≤ 30 ml/cm H2O
Fluid responsiveness is unlikely
Consider a VT challenge

Table 1 Summary of methods predicting preload responsiveness with diagnostic threshold and limitations

Method	Threshold	Main limitations
Pulse pressure/stroke volume variations [22]	12%	Cannot be used in case of spontaneous breathing, cardiac arrhythmias, low tidal volume/lung compliance
Inferior vena cava diameter variations [44]	12%	Cannot be used in case of spontaneous breathing, low tidal volume/lung compliance
Superior vena caval diameter variations [44]	36%*	Requires performing transesophageal Doppler Cannot be used in case of spontaneous breathing, low tidal volume/lung compliance
Passive leg raising [55]	10%	Requires a direct measurement of cardiac output
End-expiratory occlusion test [75]	5%	Cannot be used in non-intubated patients Cannot be used in patients who interrupt a 15-s respiratory hold
"Mini"-fluid challenge (100 mL) [84]	6%**	Requires a precise technique for measuring cardiac output
"Conventional" fluid challenge (500 mL) [81]	15%	Requires a direct measurement of cardiac output Induces fluid overload if repeated

* Thresholds from 12 to 40% have been reported

** 10% is more compatible with echography precision. Citations indicate the most important reference regarding the test



Crit Care 2009,13(S1):p208

Table 1. Overview of monitoring methods.

Method	Examples of commercial name	Calibrated or not	Major advantages	Major disadvantages
Invasive methods				
Pulmonary artery catheter		Calibrated	Direct measurements in right atrium and pulmonary circulation	Delay in determining CO, most invasive, and risks involved
Less-invasive methods				
Transpulmonary thermodilution	PiCCO® VolumeView®/EV1000® LiDCO®	Calibrated	Intermittent and continuous CO, added variables	Need for specialized arterial and central venous line, LIMITS (PiCCO® system)
Ultrasound flow dilution	COstatus®	Calibrated	Continuous CO, added variables, can detect intracardiac shunts	Requires AV loop
Pulse contour and pulse pressure variation	FloTrac®/Vigileo® ProAQT®/Pulsioflex® LiDCOrapid®/pulseCO® Most Care®/PRAM	Non-calibrated	Continuous CO	Lack accuracy in unstable patients or during use of vasoactive drugs
Partial CO2-rebreathing	NiCO®	Non-calibrated	No need for intravascular devices	Only in sedated patients under volume control ventilation, interference from pulmonary disease
Transesophageal echocardiography		Operator dependent	Real-time images of the cardiac structures and blood flow	Learning curve, (low) risk of complications
Esophageal Doppler		Operator dependent	Real-time CO and afterload data, added variables	Risk of dislocation
Non-invasive methods				
Transthoracic echocardiography		Operator dependent	Direct measurement of CO and visualization of cardiac structures	Ultrasound characteristics often suboptimal in ICU patients
Non-invasive pulse contour systems	T-line® ClearSight®/Nexfin®/ Physiocal® CNAP®/VERIFY®	Non-calibrated	Non-invasive, simple tool	Less accurate, needs more validation
Bioimpedance		Non-calibrated	Simple tool, providing data concerning CO and fluid overload	Changes intrathoracic fluid content and SVR influence measurements
Estimated continuous cardiac output®	esCCO®	Non-calibrated	Uses widely available variable to estimate CO	Is only estimate, inadequate accuracy
Ultrasonic cardiac output monitoring®	USCOM®	Non-calibrated	Short learning curve and only few risks	Only estimate, uses standard valve areas which can differ in patients

AV loop, arteriovenous fistula; CO, cardiac output; ICU, intensive care unit; SVR, systemic vascular resistance.

Which method is the best?

Equipment	Parameter	Benefits	Disadvantage	Condition	Sensitivity
PAC	CVP, PCWP	nearly true C.O.	static, non cardiac	Cardiac cause	low
CVC	CVP	…	static, many confounder, high risk infection	as available	low
A-line	BP monitor, SVV, PPV	minimal invasive, dynamic measurement	…	MV, reg HR	high
Echo	LVEF, IVC, CO, VTI	non invasive	operator dependent	any	+/-

A 40-year-old woman with lupus nephritis, diabetes mellitus, and hypertension developed dyspnea for 3 days. She received prednisolone, furosemide, calcium, dapsone, and folic acid. Physical examination showed mild pallor, mild jaundice, mild pitting edema both feet, normal lung sound. SpO_2 (room air) = 80%. Arterial blood gas showed pH 7.45, PaO_2 = 98 mmHg, $PaCO_2$ = 35 mmHg, HCO_3 = 24 mmol/L.

What is the most likely mechanism of dyspnea?

A. Ventilation-perfusion mismatch

B. Intrapulmonary shunt

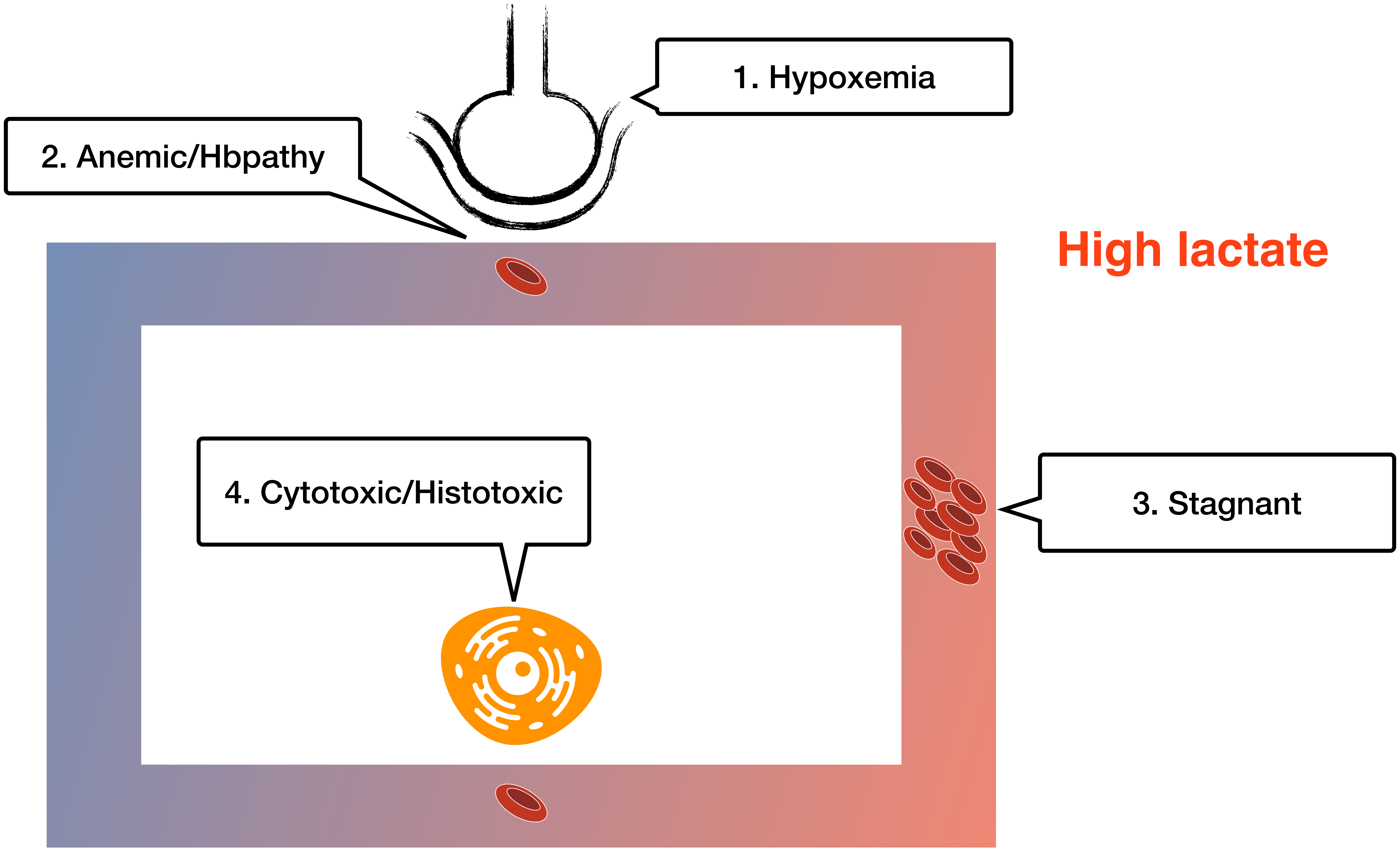
C. Oxygen-dissociation curve shift to the right

D. Inability to carry oxygen by ferric ion

E. Intracardiac shunt

Oxygen

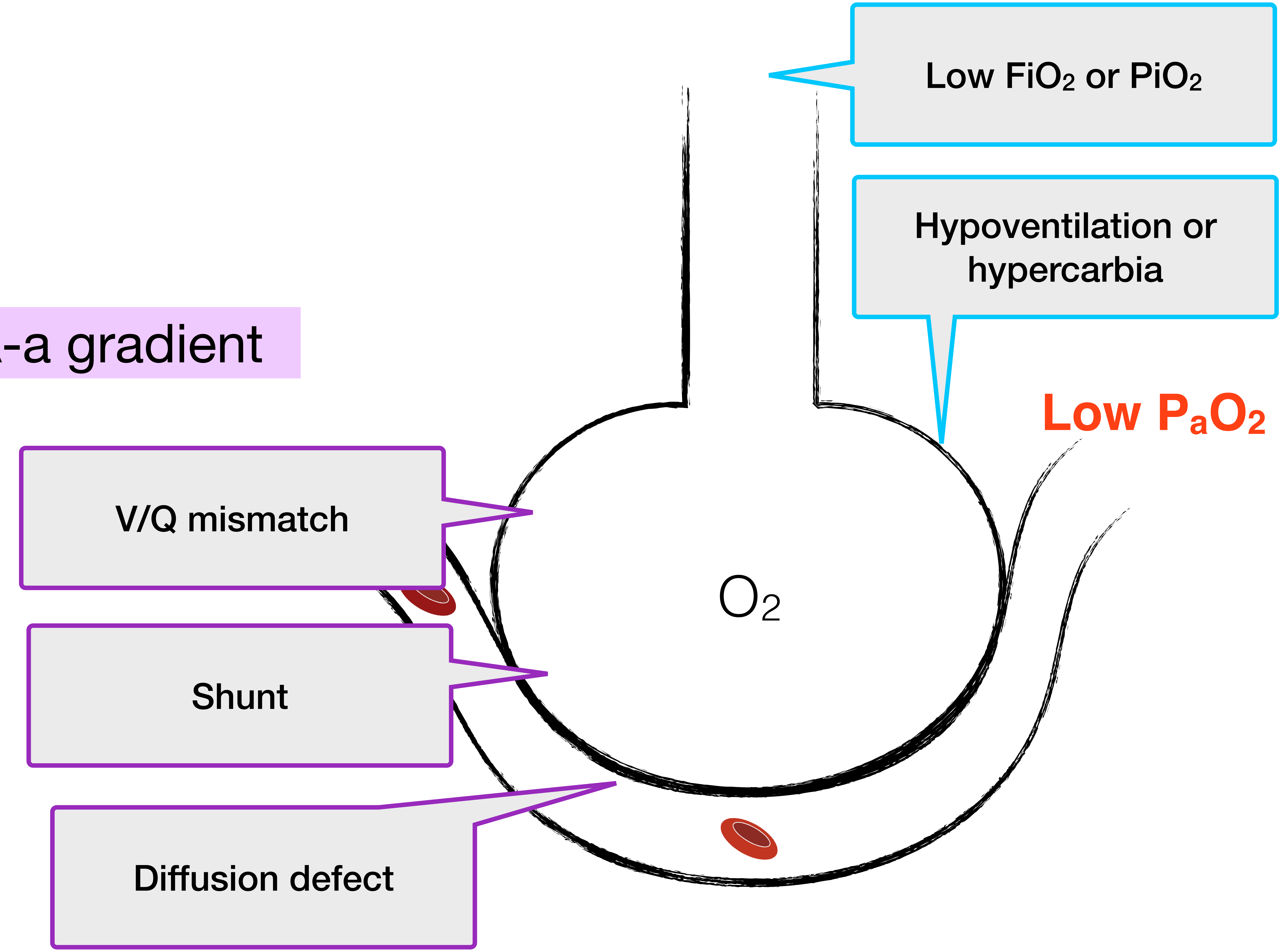
Hypoxia


1. Hypoxemia
2. Anemic/Hbpathy
High lactate
4. Cytotoxic/Histotoxic
3. Stagnant

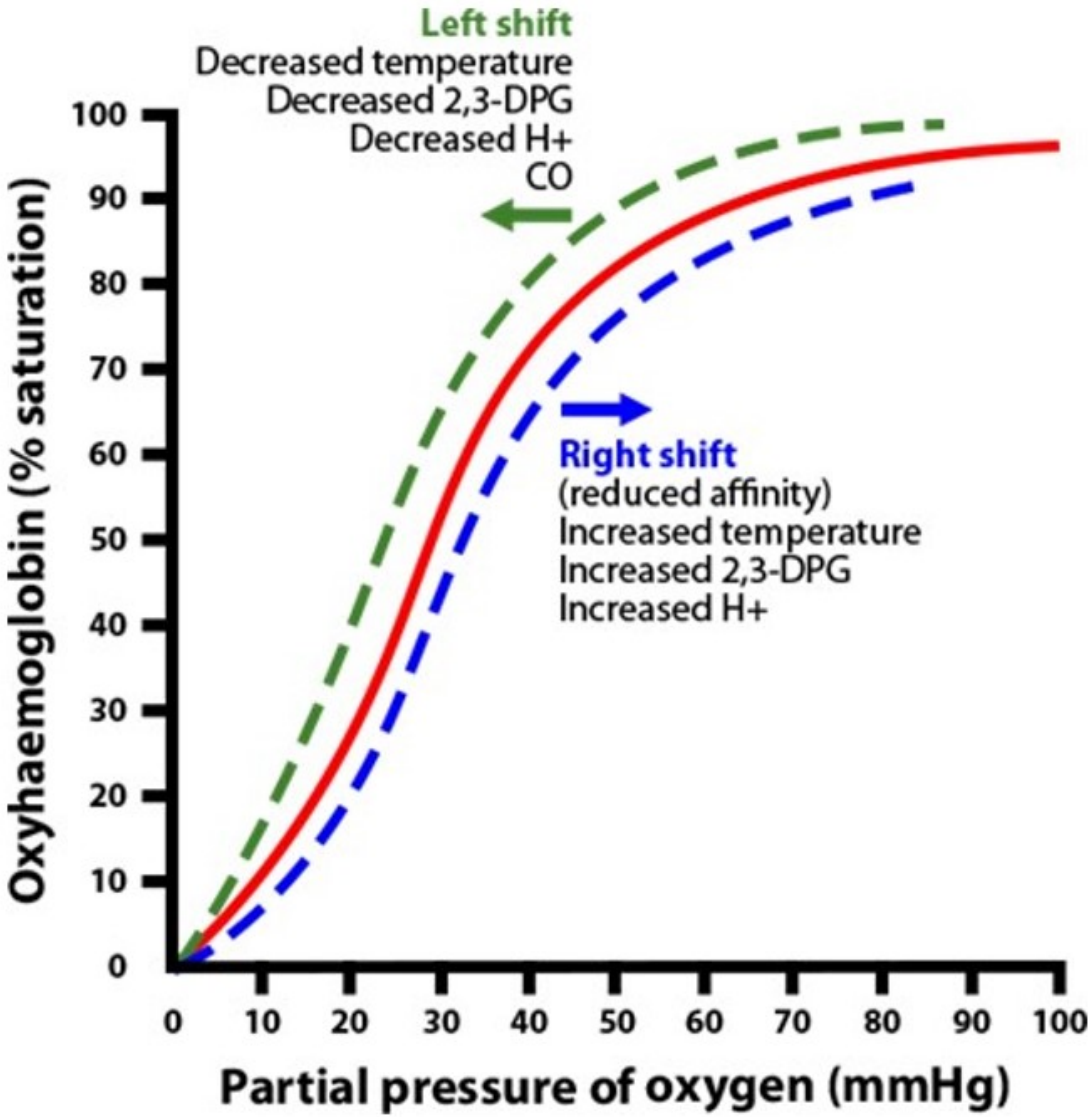
Hypoxemia

Normal A-a gradient

Wide A-a gradient



Oxygen dissociation curve



Respiratory

- RR
- Ventilator waveform
- End tidal CO2 (EtCO2)
- Electrical Impedance Tomography (EIT)
- Esophageal probe (TPP, diaphragm function)
- Imaging (CXR, CT)

Aim for
Lung mechanics monitoring
Gas exchange monitoring
Another abnormal patterns

Focus on
Lung mechanics change

A 43-year-old type2 diabetes woman presented with fever and acute dyspnea. She was diagnosed COVID-19 pneumonia. Her vital sign showed T 38^{o}c, BP 124/48 mmHg, HR 124/min, RR 30/min. 20 hours later she developed ARDS. MV was setting with protective lung strategy (Vt 6 mL/kg - BW 60 kg), RR 30/min, Ti 0.9 sec, PEEP 12 cmH_2O. ABG showed pH 7.14, pO_2 110 mmHg, pCO2 80 mmHg, HCO_3 30 mg/dL, FiO2 1.0, $EtCO_2$ 60 mmHg.
Which is the best new MV setting for pH 7.3?

A. Rise RR to 35/min

B. Recruitment manoeuvre and PEEP titration

C. Rise Vt to 450 mL

D. Rise Ti to 1.2 sec

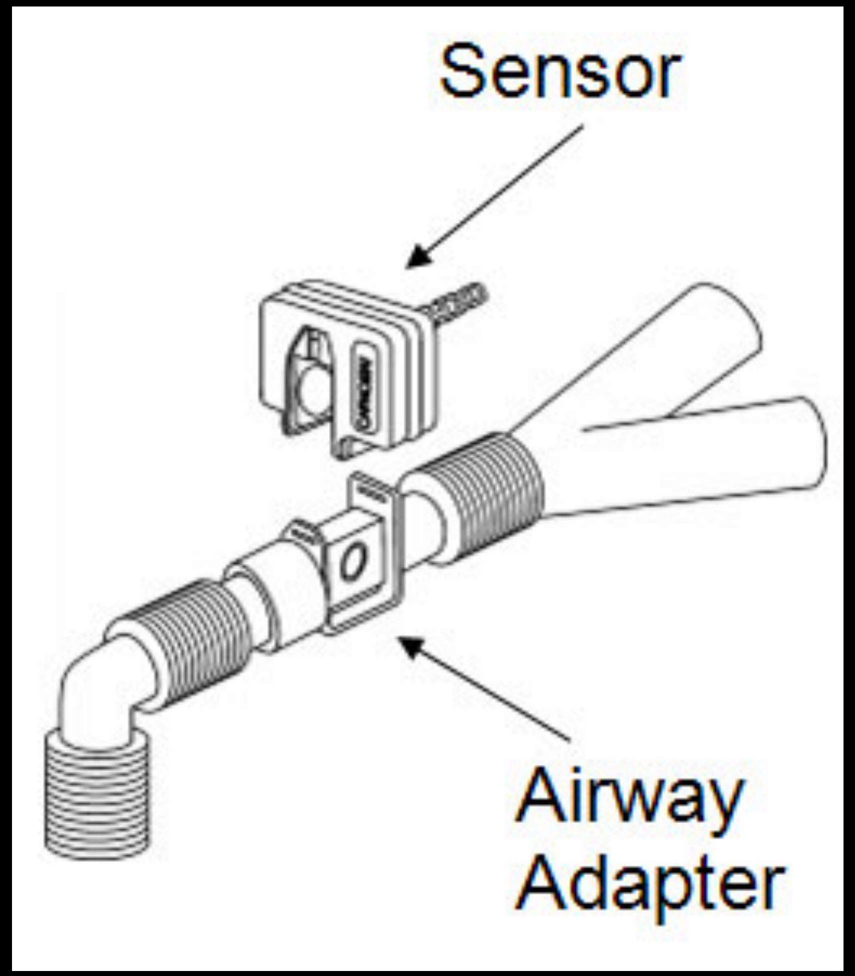
E. Give sodiumbicarbonate

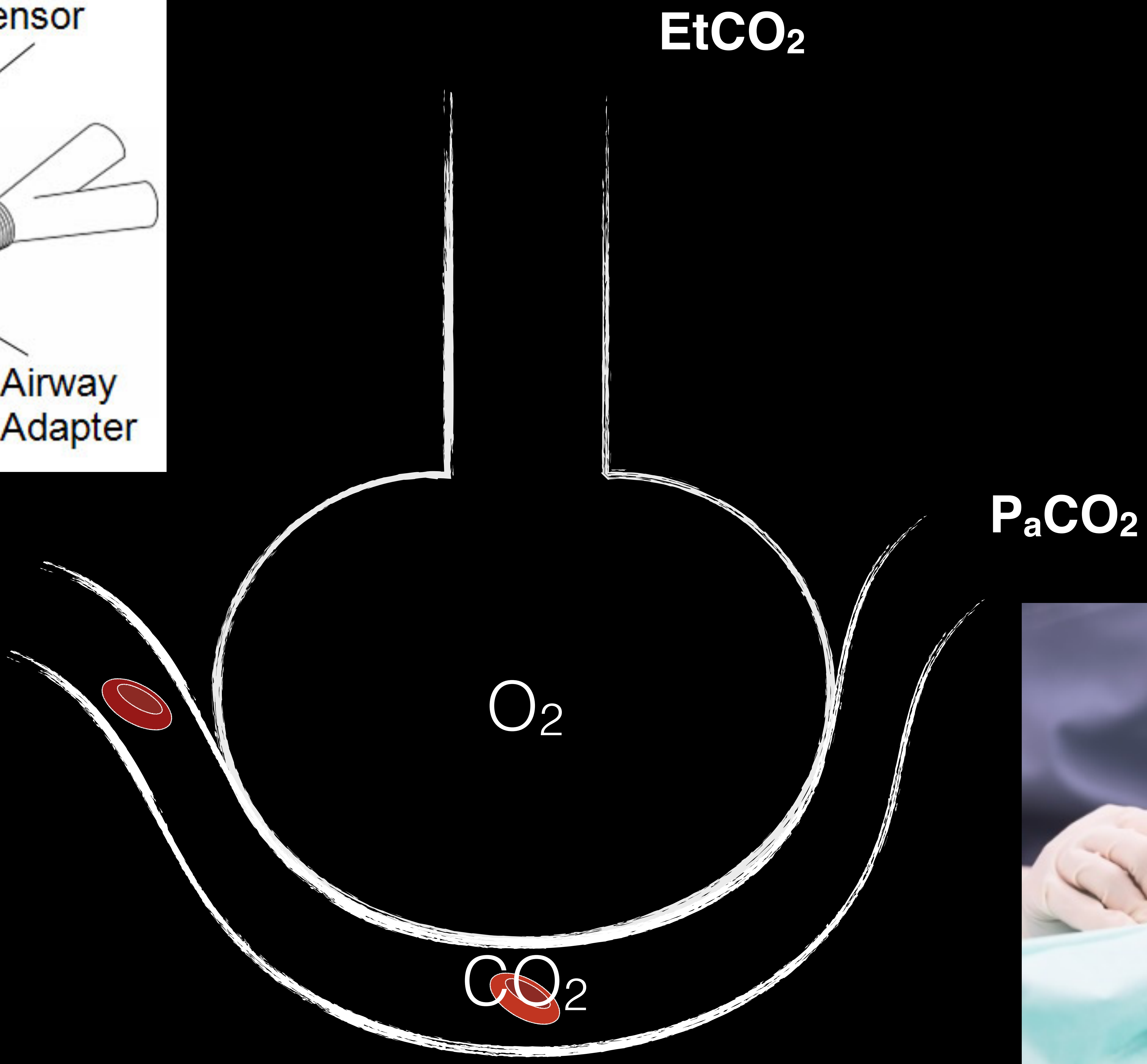
$PaCO_2$

$$PaCO_2 = k \times \frac{CO_2 \text{ production}}{\text{Alveolar ventilation}}$$

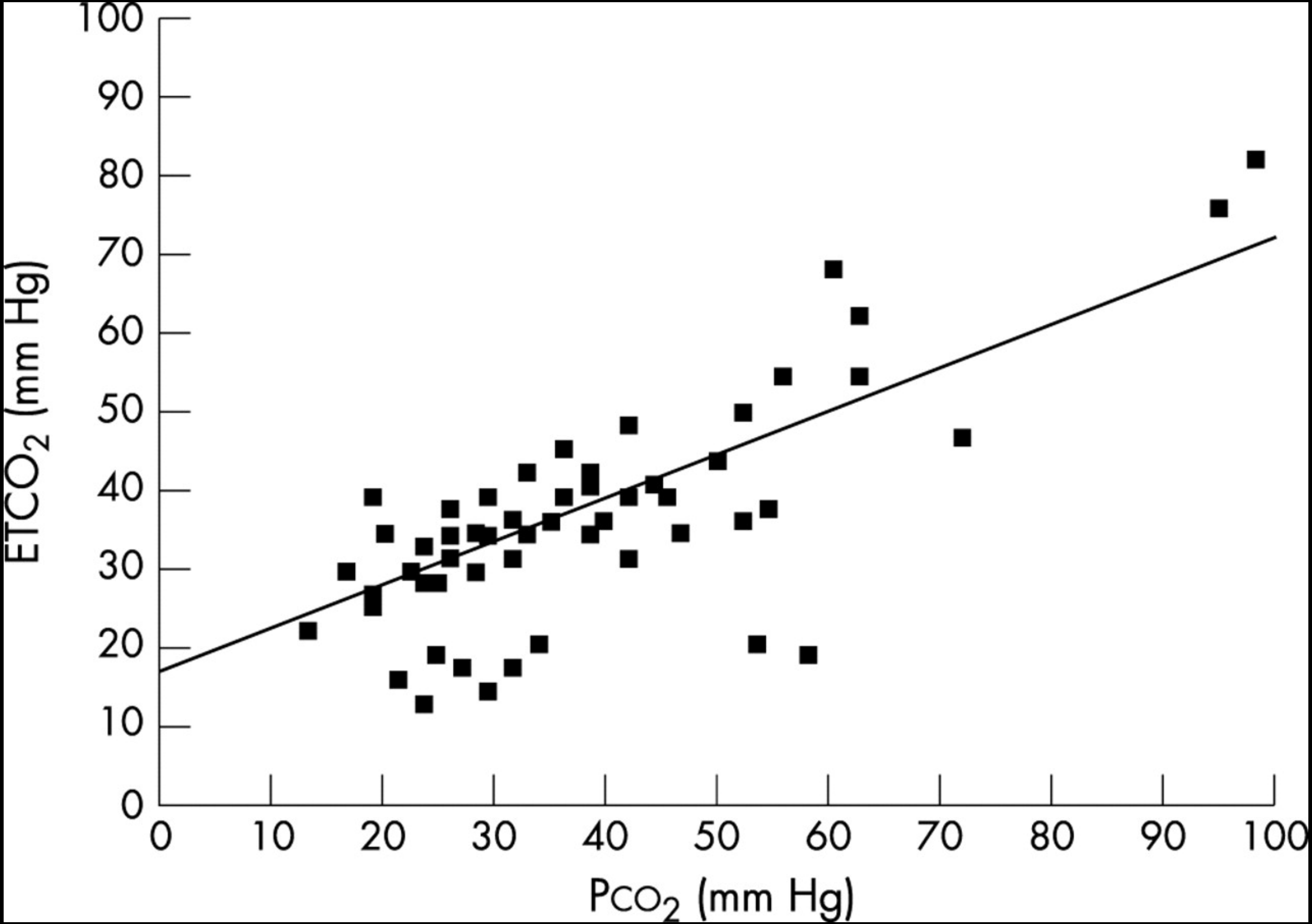
Hypoventilation	> 40 mmHg	metabolic acidosis, burn, sepsis, acute pancreatitis, obese	low Vt, RR high Vd
Hyperventilation	< 40 mmHg	metabolic acidosis, psychogenic	high Vt, RR low Vd

$PetCO_2$ ($EtCO_2$)

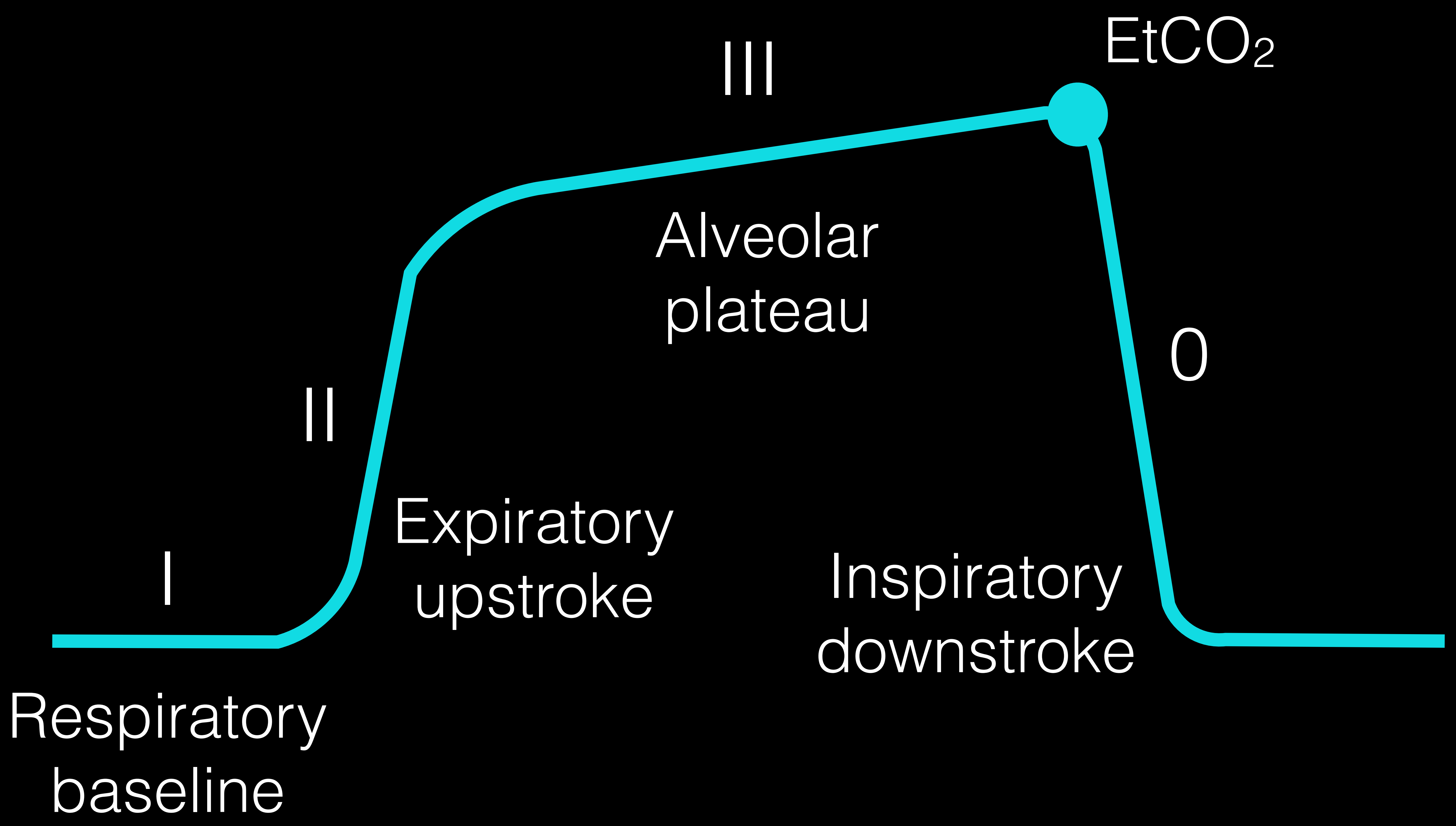




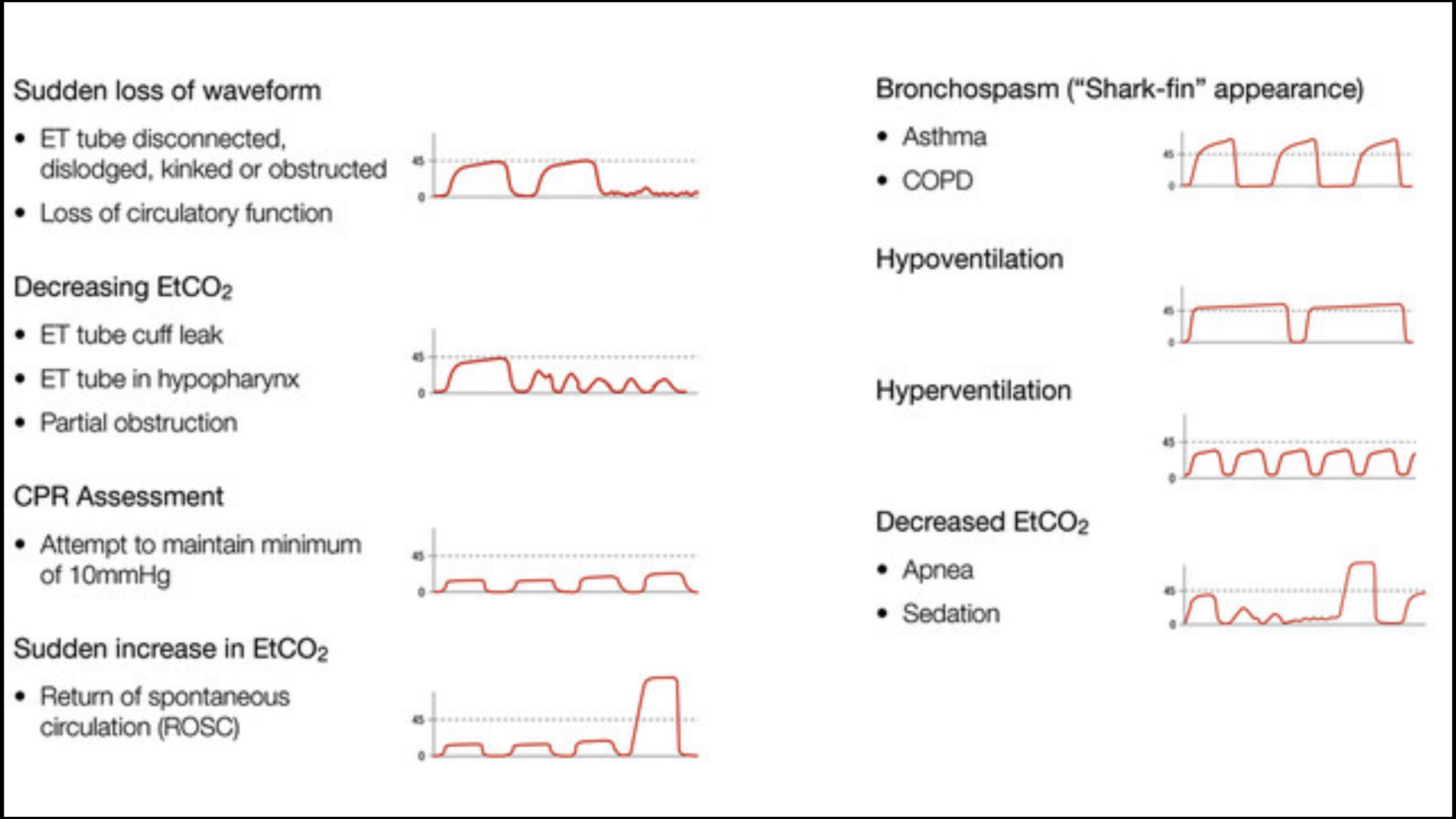
$PaCO_2$ - $EtCO_2$



Phase of $EtCO_2$



$EtCO_2$ interpretation



Carbondioxide : ventilation

- $PaCO_2 \propto V[CO_2] / VA$
- $VA = RR (Vt - Vd)$

$$PaCO_2 = \frac{V[CO_2]}{RR (Vt - Vd)}$$

Carbondioxide : ventilation

- $Vd/Vt = (PaCO_2 - EtCO_2) / PaCO_2$
- C1V1 = C2V2 : $(PaCO_2)_1 \times VA_1 = (PaCO_2)_2 \times VA_2$
- $(PaCO_2)_1 \times (RR_1 \times (Vt_1\text{-}Vd)_1 = (PaCO_2)_2 \times (RR_2 \times (Vt_2\text{-}Vd)_2$

A 43-year-old type2 diabetes woman presented with fever and acute dyspnea. She was diagnosed COVID-19 pneumonia. Her vital sign showed T 38°c, BP 124/48 mmHg, HR 124/min, RR 30/min. 20 hours later she developed ARDS. MV was setting with protective lung strategy (Vt 6 mL/kg - BW 60 kg), RR 30/min, Ti 0.9 sec, PEEP 12 cmH_2O. ABG showed pH 7.14, pO_2 110 mmHg, pCO2 80 mmHg, HCO_3 30 mg/dL, FiO_2 1.0, $EtCO_2$ 60 mmHg. Which is the best new MV setting for pH 7.3?

$$(PaCO_2)_1 \times (RR_1 \times (Vt_1 - Vd)_1 = (PaCO_2)_2 \times (RR_2 \times (Vt_2 - Vd)_2$$

Vd/ 360 = (80 - 60) / 80 90

(1) 80 x 30 = 60 x 40

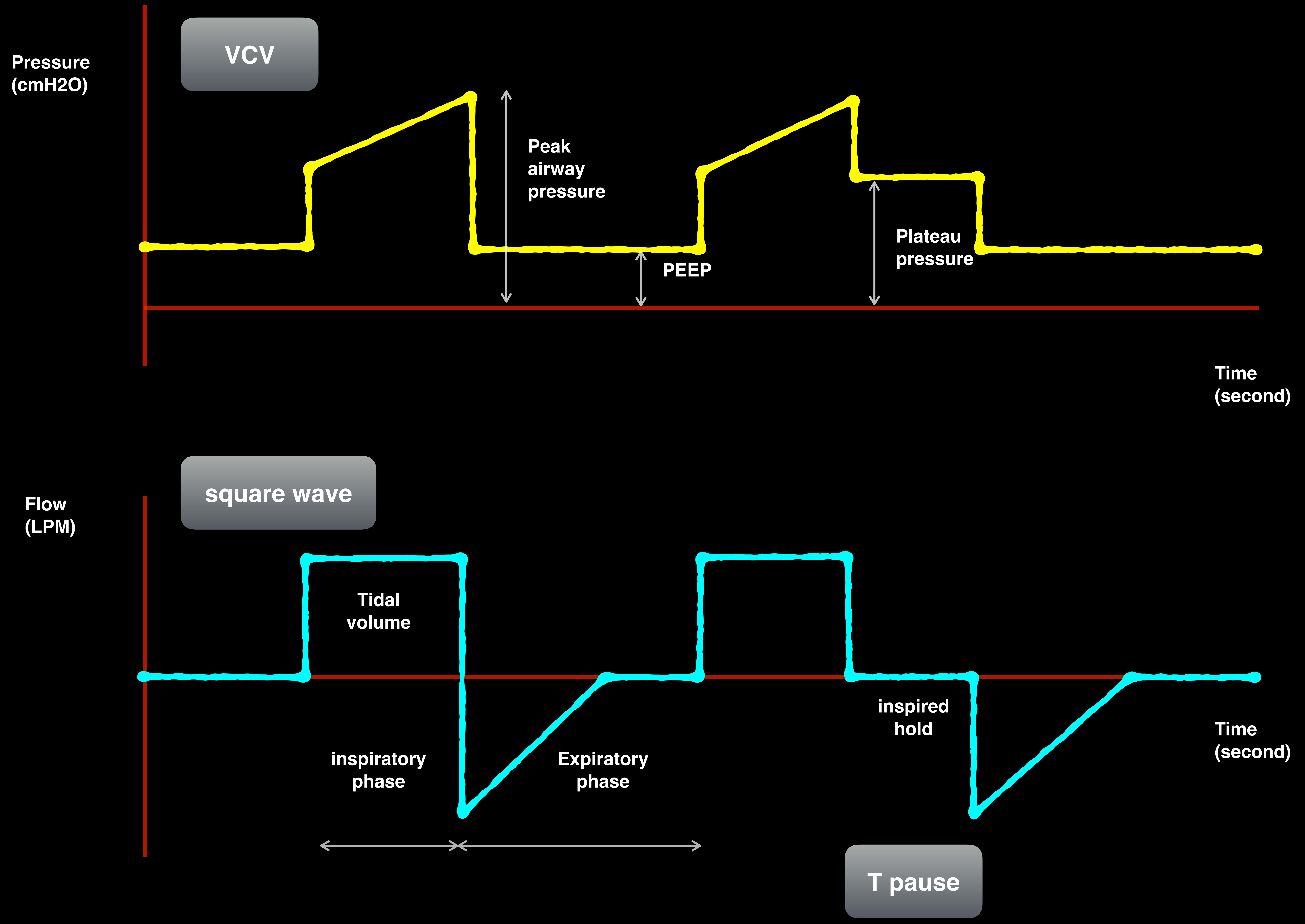
(2) 80 x 360 - 90 = 60 x 450 - 90

A 66-year-old COPD man was diagnosed COPD A/E. He was intubated and MV setting VCV Vt 360 mL, RR 16/min, PIF 60 LPM, PEEP 5 cmH_2O, FiO_2 0.24, His Paw was 40 cmH_2O and Ppl 18 cmH_2O. 3 hours later, MV alarm Paw changed to 60 cmH2O and Ppl 45 cmH_2O.
What is the possible cause of alarm?

A. Secretion obstruction
B. Bronchospasm
C. Pneumonia
D. Pneumothorax
E. One lung intubation

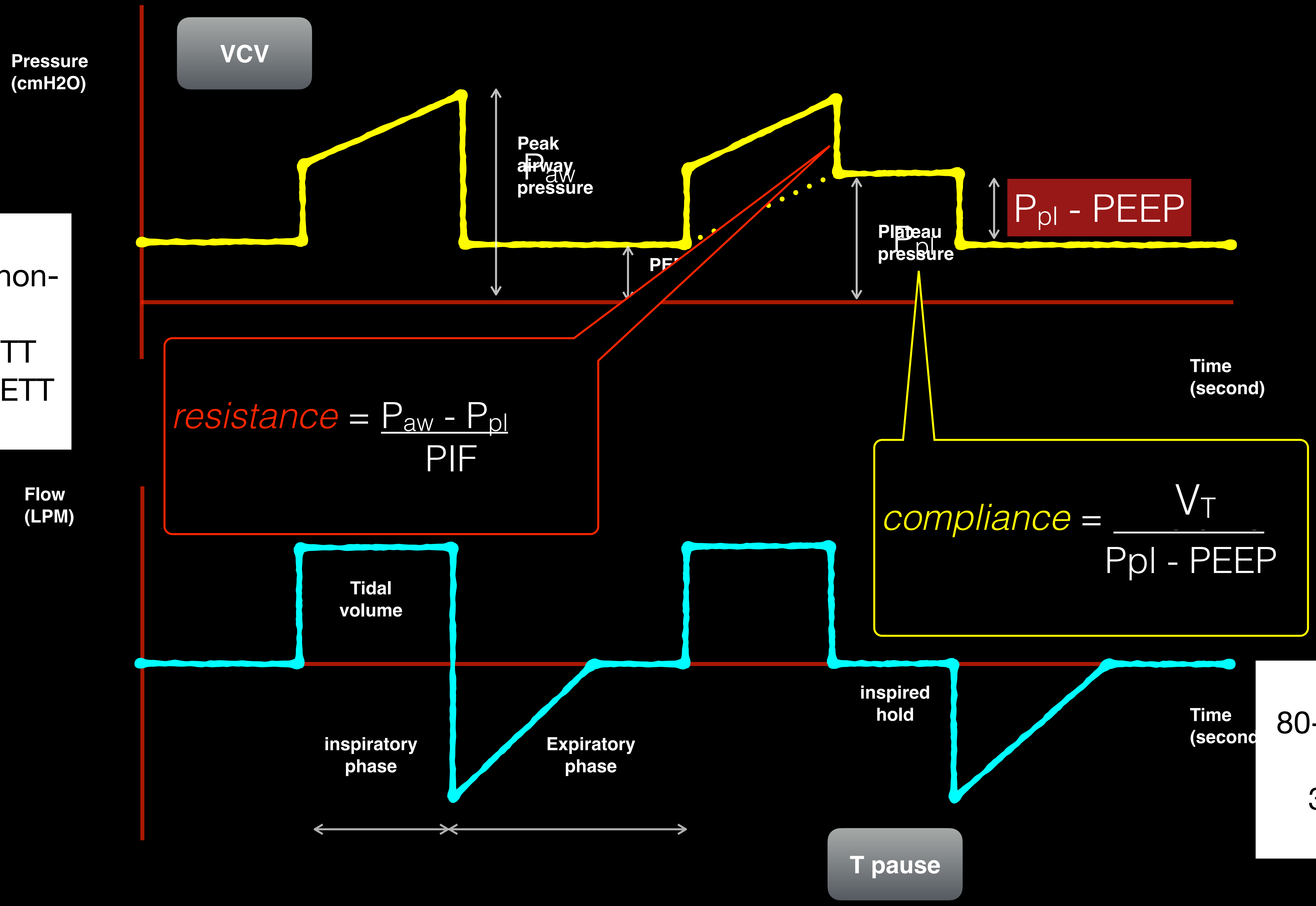
Ventilator Waveform

Ventilator waveform (VCV)



Ventilator waveform (VCV)

normal R
5-10 $cmH_2O/L/S$ in non-intubate
3-5 $cmH_2O/L/S$ in TT
8-10 $cmH_2O/L/S$ in ETT

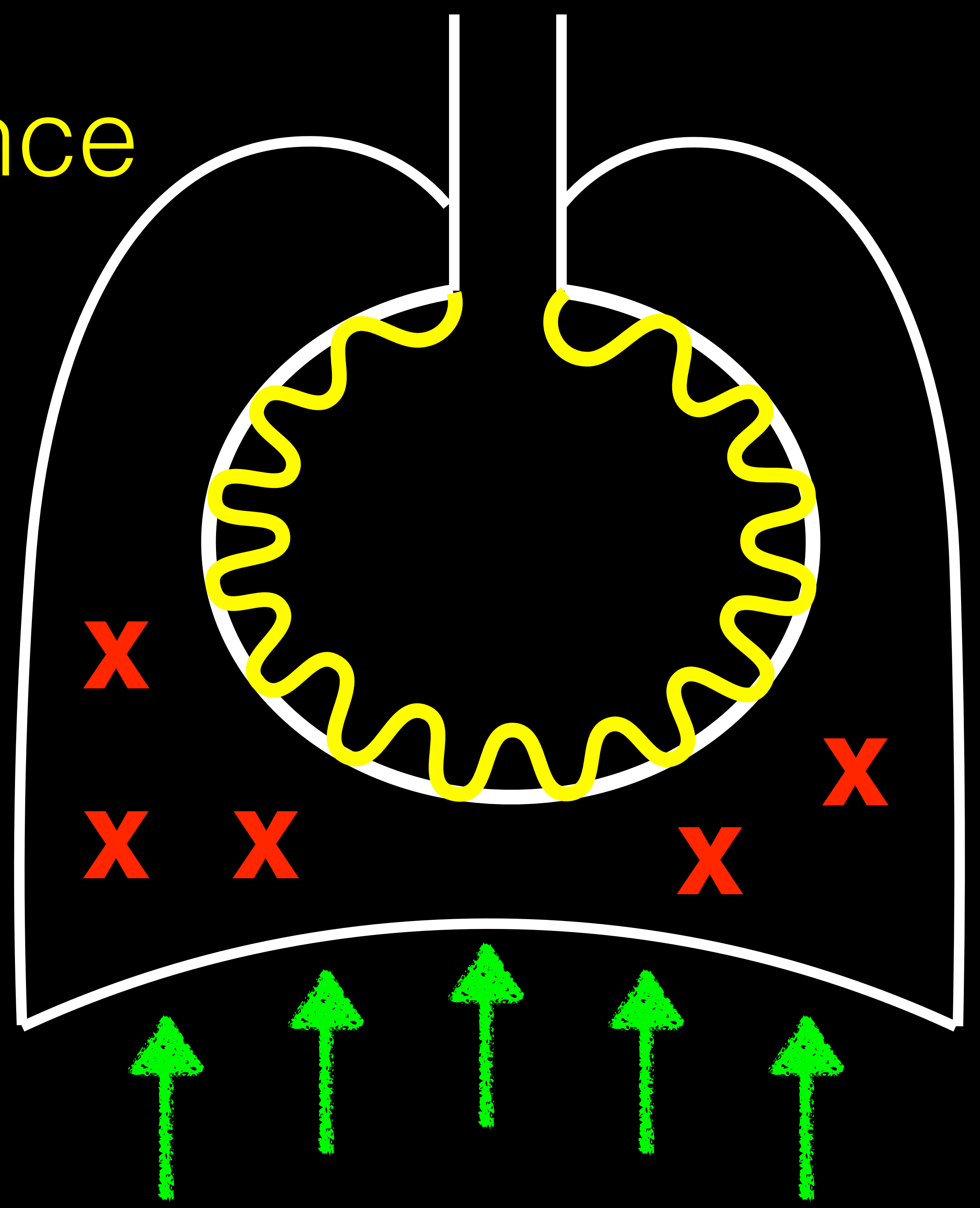


normal C
80-100 mL/cmH_2O in non-intubate
30 mL/cmH_2O in critically illness

Increased P_{aw} and P_{pl}

change elastance / compliance

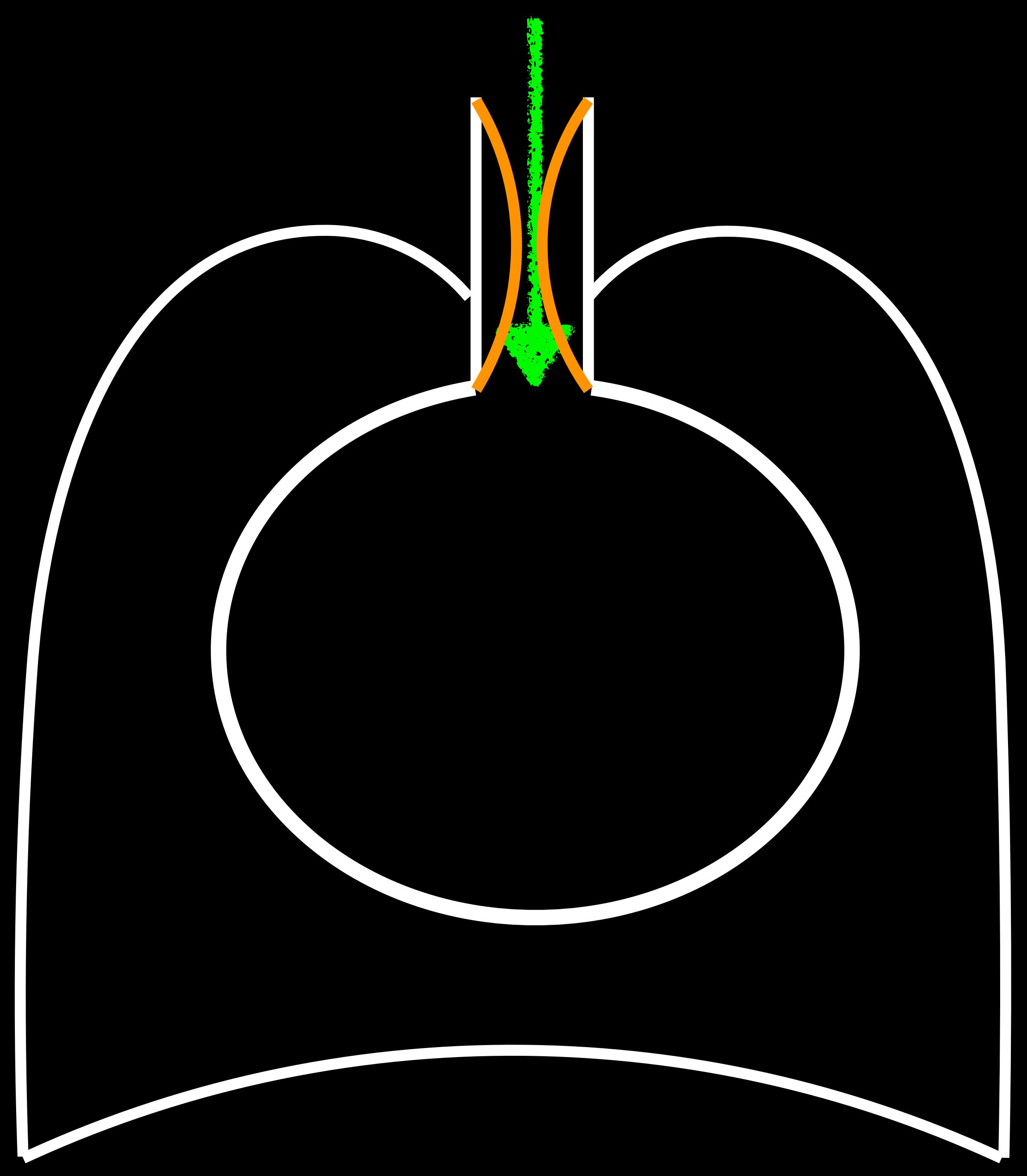
- Increased tidal volume
- Decreased pulmonary compliance
  - Parenchymal diseases
  - Pleural diseases
  - Abdominal pressure
  - Endobronchial intubation



Increased P_{aw} and unchanged P_{pl}

- Increased inspiratory gas flow rate
- Increased airway resistance
- Kinked ET tube Secretions
- Foreign body aspiration
- Bronchospasm
- Airway compression
- ET tube cuff herniation

change resistance

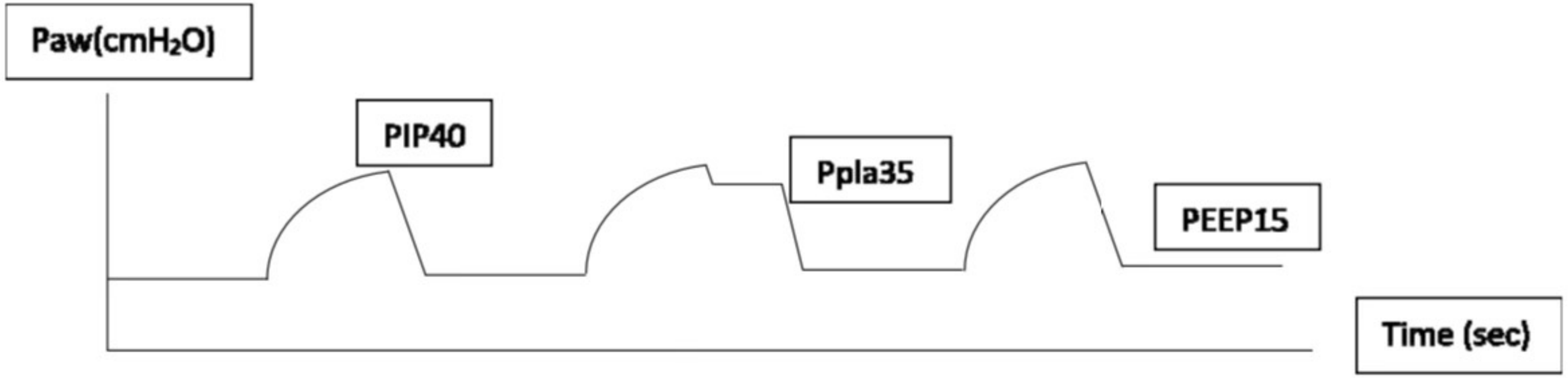


CH63. A 19-year-old woman had acute respiratory distress syndrome with urosepsis and on mechanical ventilator support. She was receiving FiO_2 of 0.5 and a tidal volume of 0.8 L. Inspiratory flow rate is 100 L/min, positive end expiratory pressure is 5.0 cmH_2O. The peak and plateau airway pressure are 35 and 31 cmH_2O respectively. Suddenly, the patient begins repeatedly exceeding the cycling and alarm pressure limit of 50 cmH_2O and 33 cmH_2O.

Which is the most likely diagnosis?

1. Pneumonia
2. Tension pneumothorax
3. Worsening pulmonary edema
4. Excessive secretion within the airway
5. Dislocation of the endotracheal tube into the right main bronchus

A 45-year-old woman was intubated by paramedics after dyspnea at home. Chest film shown ground gas opacity both lung fields. Rapid Flu-A test was positive. Mechanical ventilator setting as the following: V-CMV mode, Flow 30 Liters/min, Vt 420 ml (7 ml/kg predicted weight by height), square wave form, RR 25 PEEP 15 cmH_2O FiO2 100 % and Pressure-Time wave form as below:



What is the best parameter that associated with mortality outcome in ARDS?

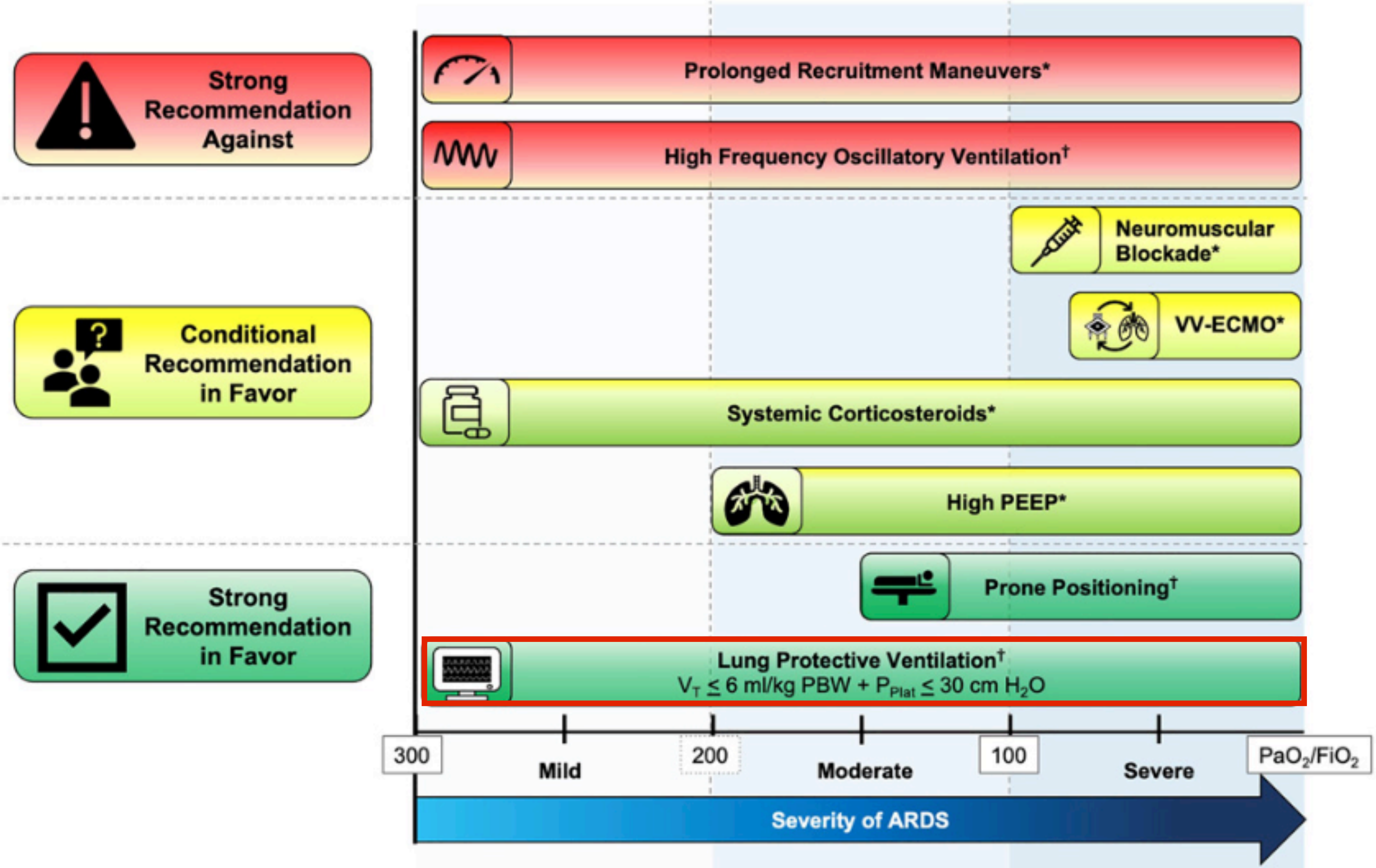
A. High Ppeak 40 cmH2O

B. High Ppla 35 cmH2O

C. Static Driving pressure 20 cmH2O

D. High PEEP 15 cmH2O

E. Vt 7 ml/kg



* New or updated recommendations in current guideline.
† Recommendations addressed in 2017 guideline.

Am J Respir Crit Care Med [online ahead of print] 30 Nov 2023

Table 2

The variable assignment of influence factors for survival in ARDS patients

Variable	Assignment instructions
Age (years)	≤40=0, >40–65=1, >65=2
Gender	Male =0, female =1
APACHE II score	≤20=0, >20=1
Severity of ARDS	Mild =0, moderate =1, severe =2
Infection site	No =0, pulmonary =1, extrapulmonary =2
Number of organ failure	No =0, one =1, multiple =2
MAP (mmHg)	≥65=0, <65=1
Plateau pressure (cmH_2O)	≤30=0, >30=1
Driving pressure (cmH_2O)	<15=0, ≥15=1
Lung compliance (mL/cmH_2O)	≤30=0, >30=1
PaO_2/FiO_2 (mmHg)	≤100=0, >100–200=1, >200=2
Lactate level (mmol/L)	≤2=0, >2=1
Survival	Survivors =0, non-survivors =1

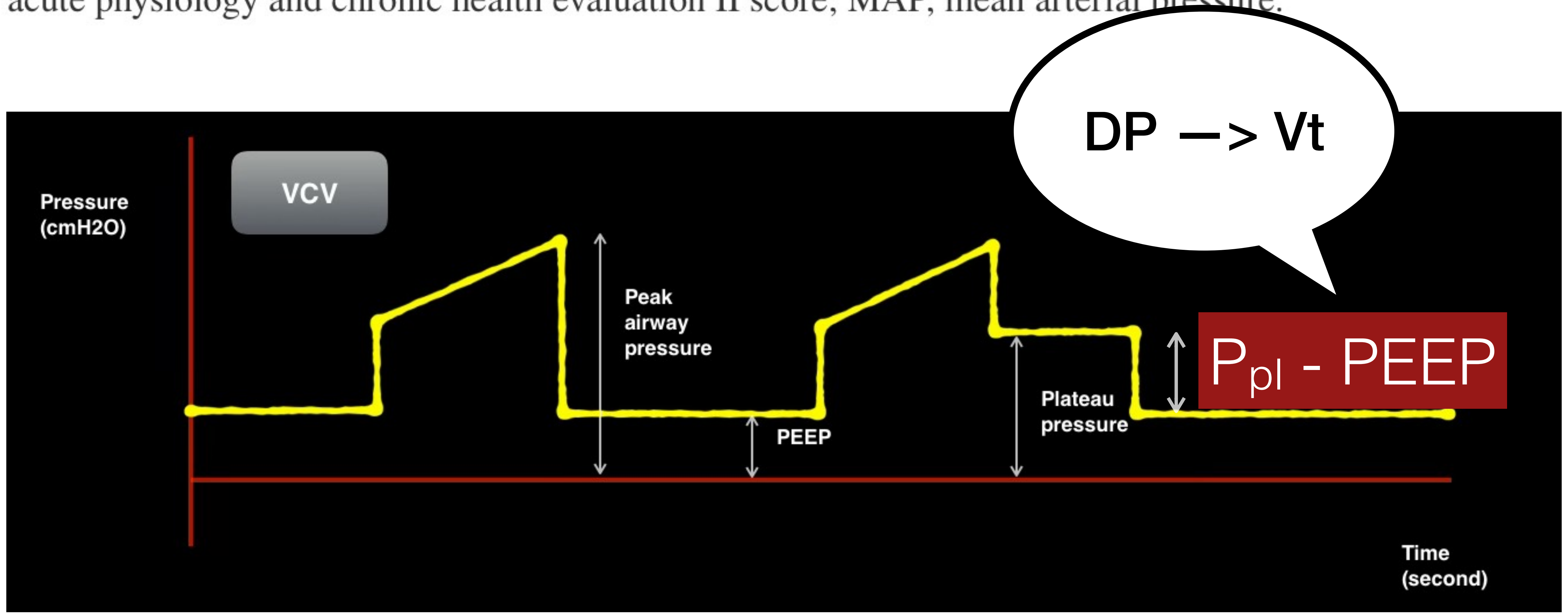
ARDS, acute respiratory distress syndrome; APACHE II score, acute physiology and chronic health evaluation II score; MAP, mean arterial pressure.

Table 3

Influence factors for survival in ARDS patients by multivariate logistic regression analysis

Variable	b	S_b	Wald χ^2	P	OR (95% CI)
APACHE II score	1.2330	0.4902	6.3278	0.0119	3.4316 (1.3130–8.9686)
Number of organ failure	1.2507	0.2902	18.5687	<0.0001	3.4928 (1.9775–6.1693)
MAP	1.6302	0.5230	9.7176	0.0018	5.1049 (1.8317–14.2274)
Driving pressure	1.7920	0.5180	11.9701	0.0005	6.0017 (2.1746–16.5641)
Lactate level	1.4050	0.4734	8.8080	0.0030	4.0754 (1.6114–10.3068)

ARDS, acute respiratory distress syndrome; OR, odds ratio; CI, confidence interval; APACHE II score, acute physiology and chronic health evaluation II score; MAP, mean arterial pressure.



J Thorac Dis. 2019 Mar; 11(3): 673–685. doi: 10.21037/jtd.2019.02.84

A 45-year-old man with heavy alcohol drinking presented with fever and d 2 days. His chest radiograph revealed bilateral alveolar infiltrates. He was intubated and received mechanical pneumonia support. He receives volume-assist control ventilation with a TV 300 mL, RR 30/min, PEEP of 8 cmH2O, and FiO2 0.4, His plateau airway pressure is 23 cmH2O, pH is 7.34, PaCO2 is 45 mmHg, and Pa02 is 70 mmHg. The patient's body weight is 60 kg (predicted body weight 50 kg). He received treatment with ceftriaxone + azithromycin. 24 hours later, hemoculture yielded Streptococcus pneumoniae. What is the MOST appropriate next step management?

A. Increase TV to 350 mL

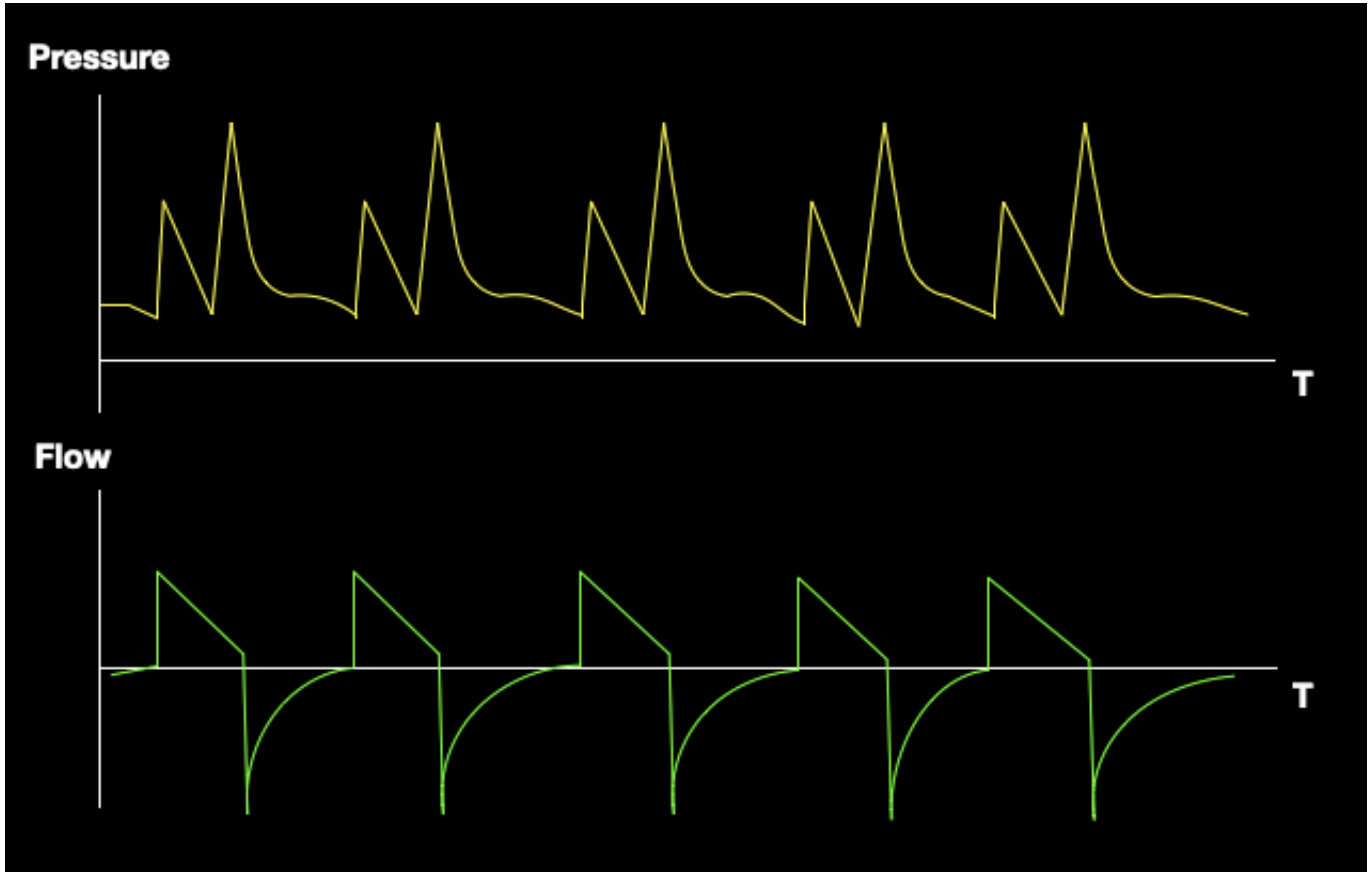
B. Start cis-atracurium

C. Recruitment maneuver

D. Prone position

E. Continue current treatment

A 25-year-old man presented with acute asthmatic attack. He was intubated and on MV. MV was setting with VCV: Vt 400 mL, RR 20/min, PIF 40 LPM, PEEP 5 cmH_2O, FiO_2 0.3. His MV waveform as showed.



What is the most likely diagnosis?

A. Delayed termination

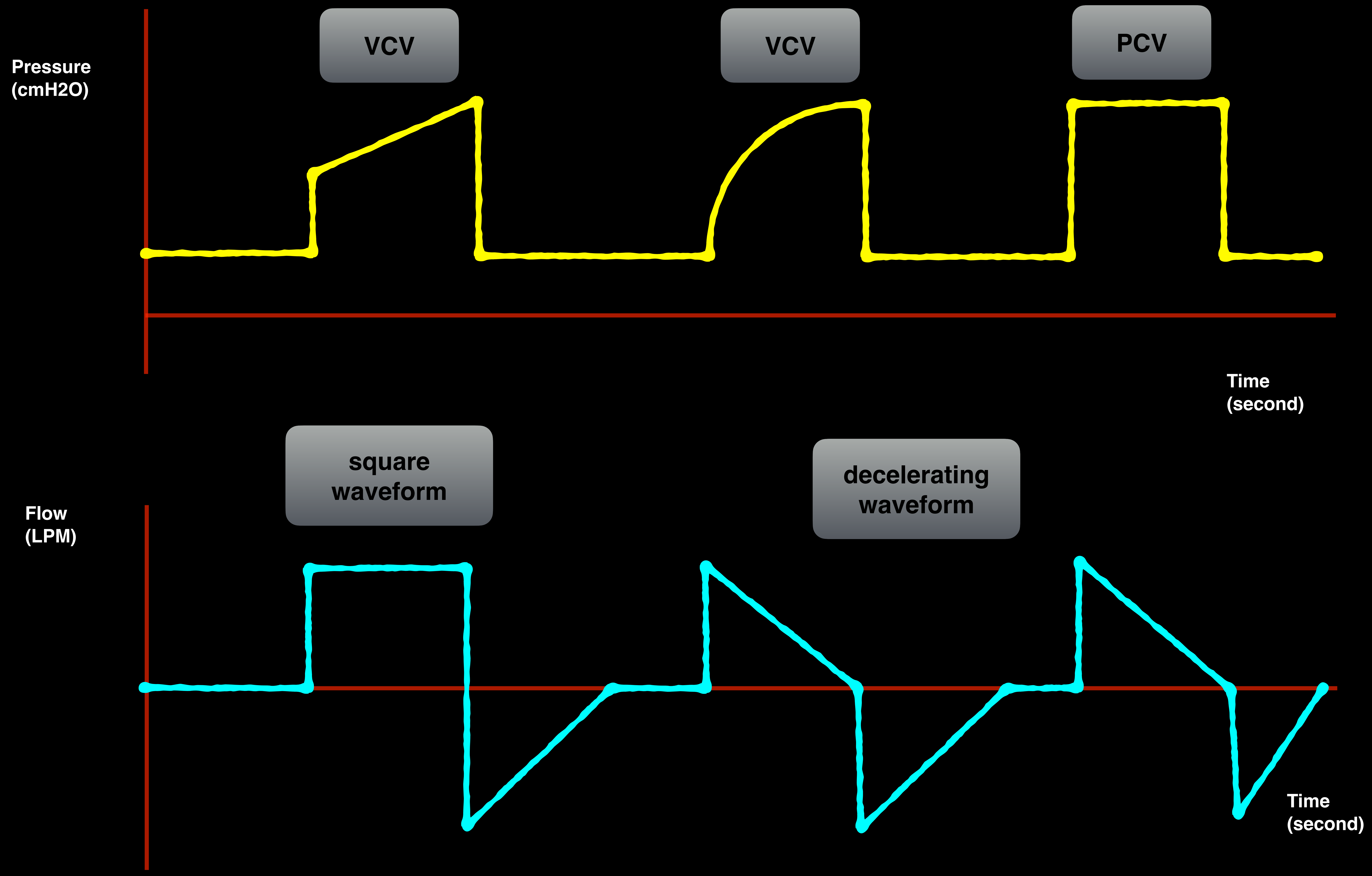
B. Auto triggering

C. Double triggering

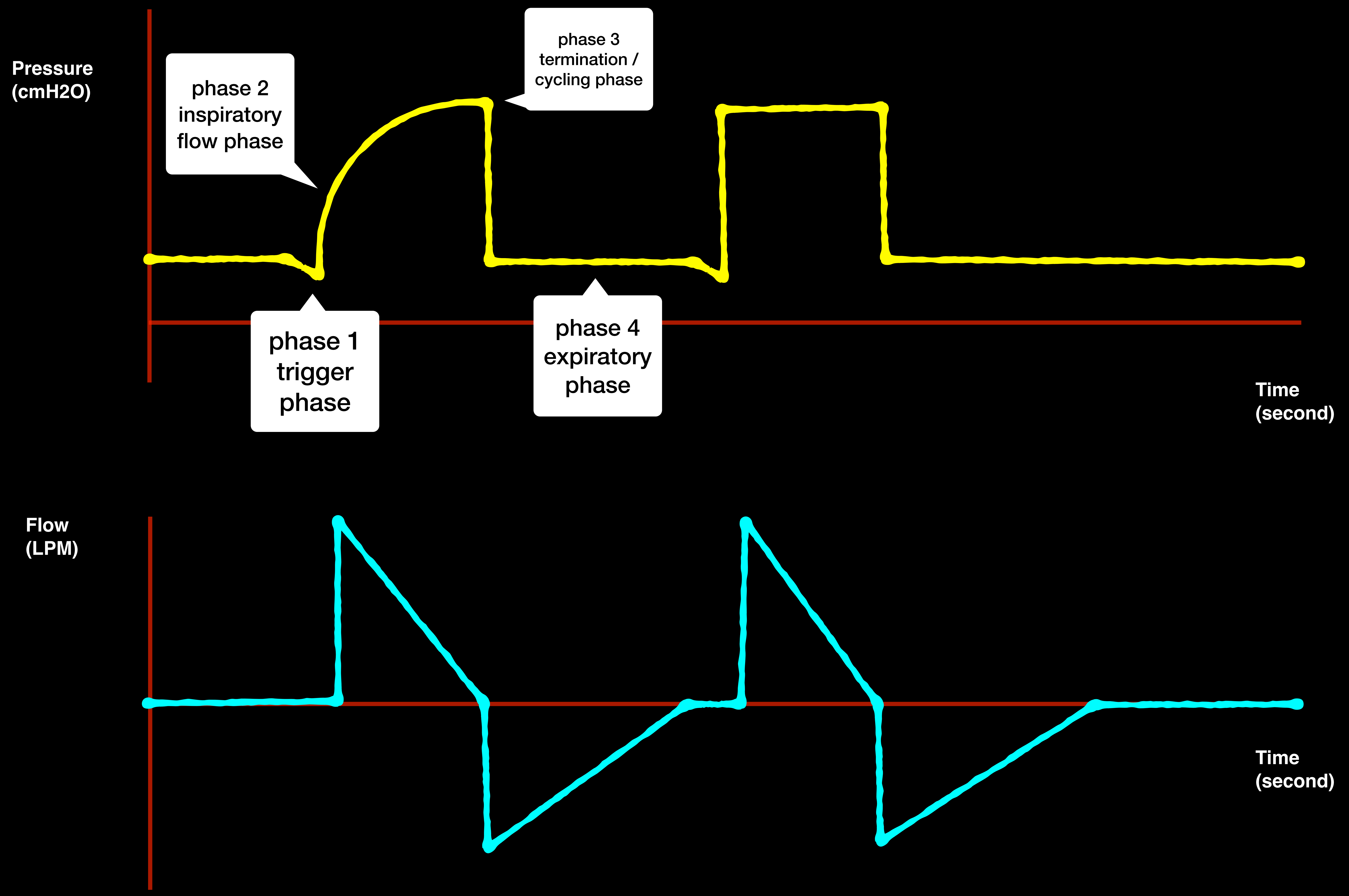
D. Flow starvation

E. Early termination

Ventilator waveform

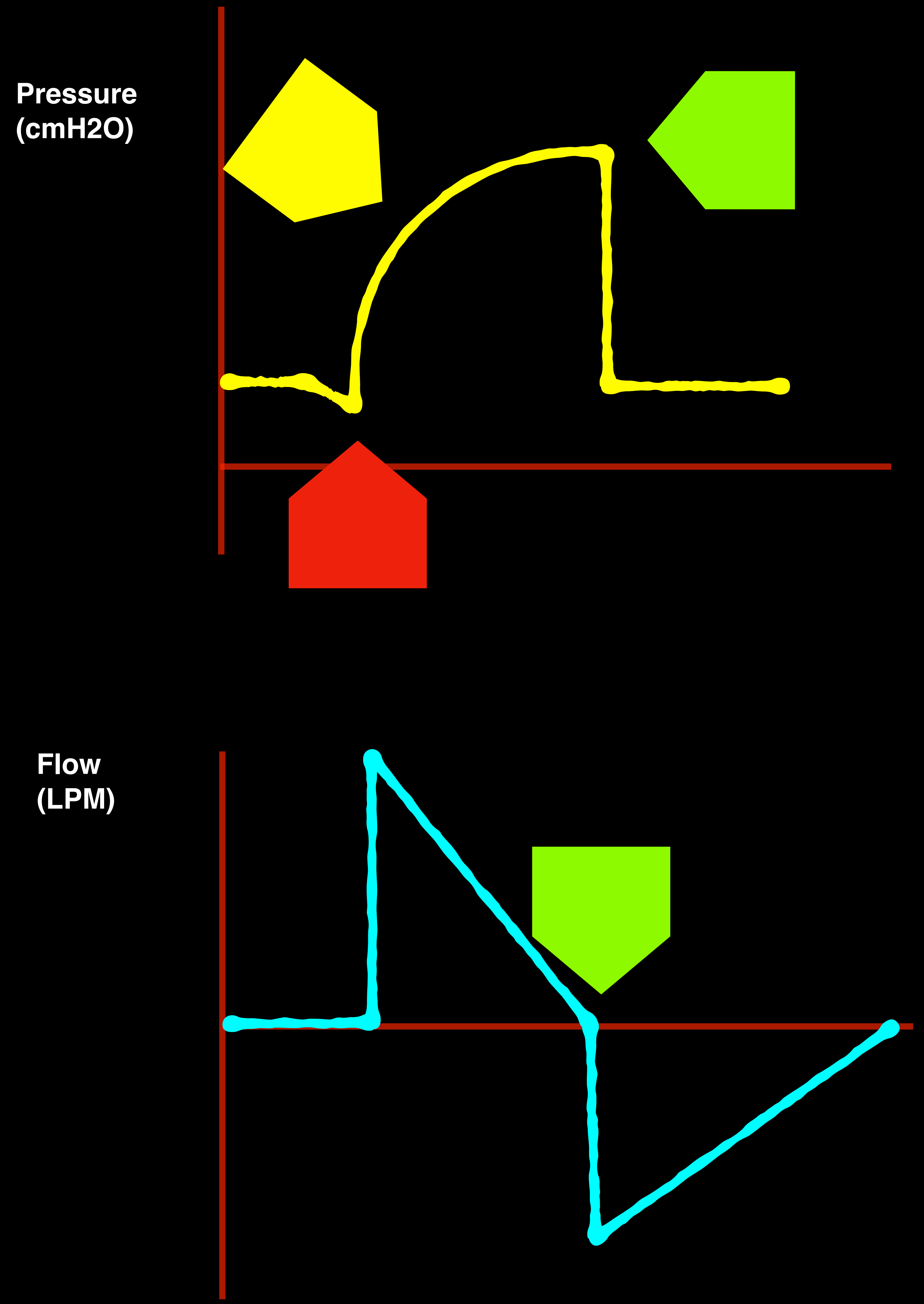


Ventilator waveform

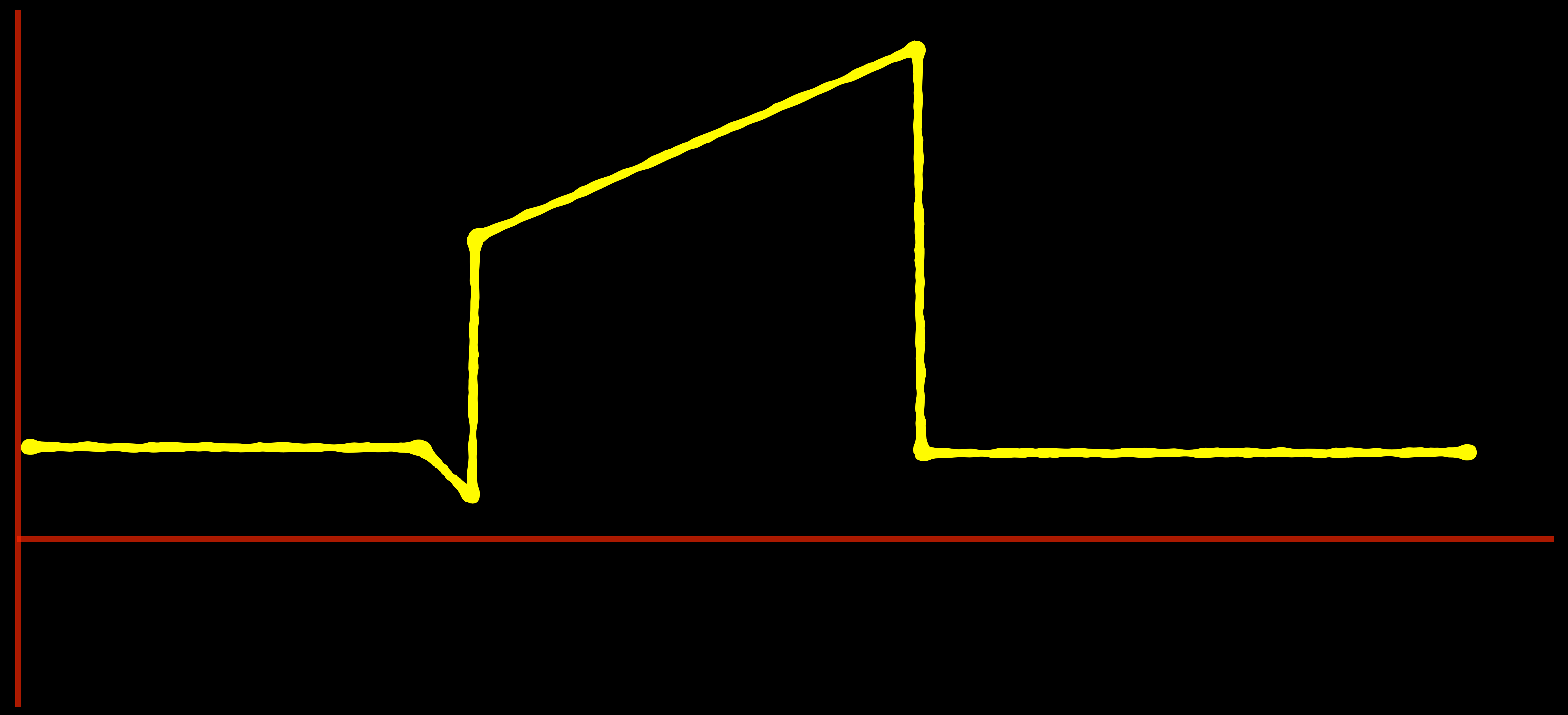


Waveform interpretation

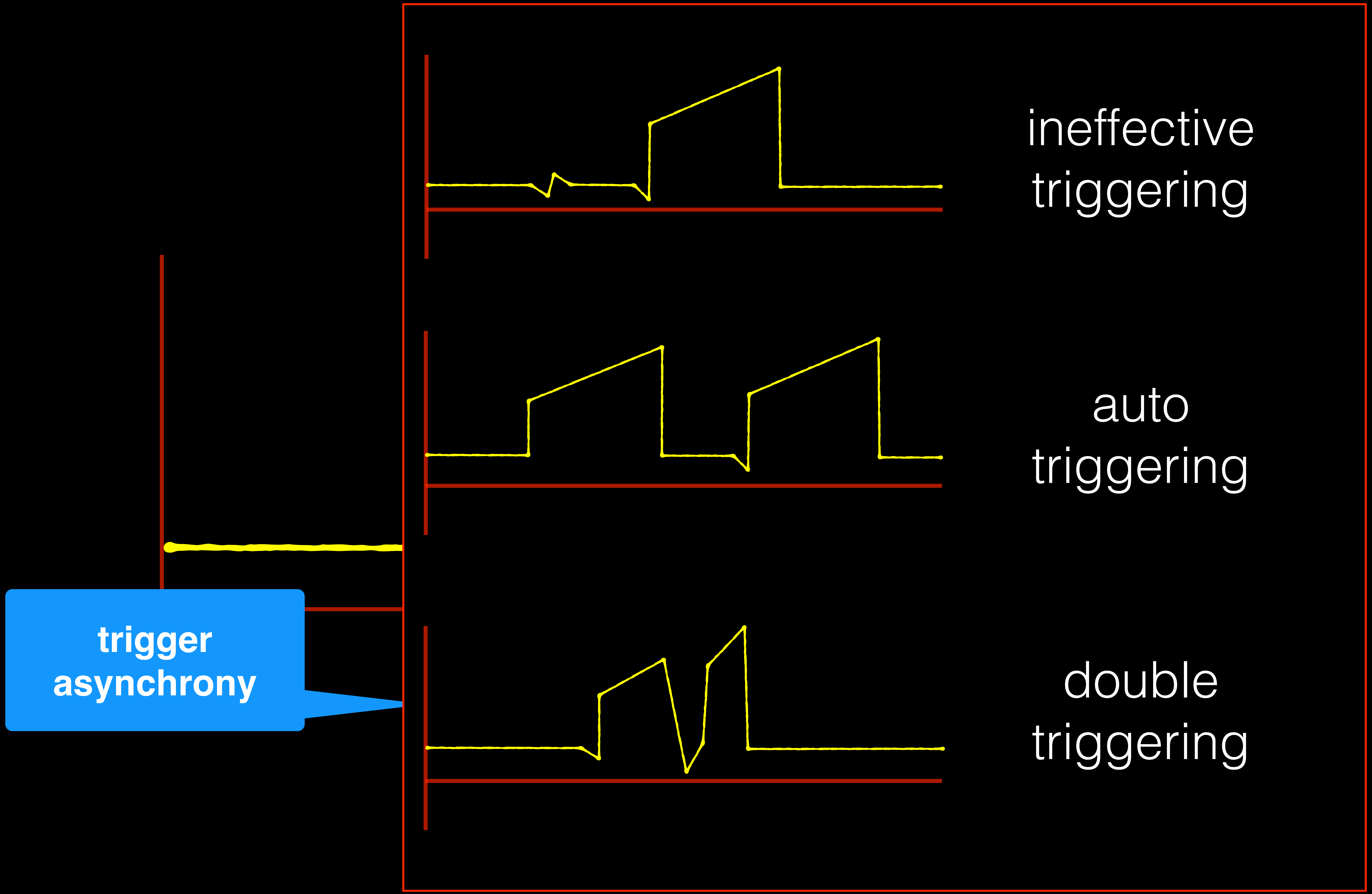
1. Mode อะไร (volume & pressure)
2. มี Trigger ไหม
3. Flow พอไหม
4. Termination หยุดตอนไหน



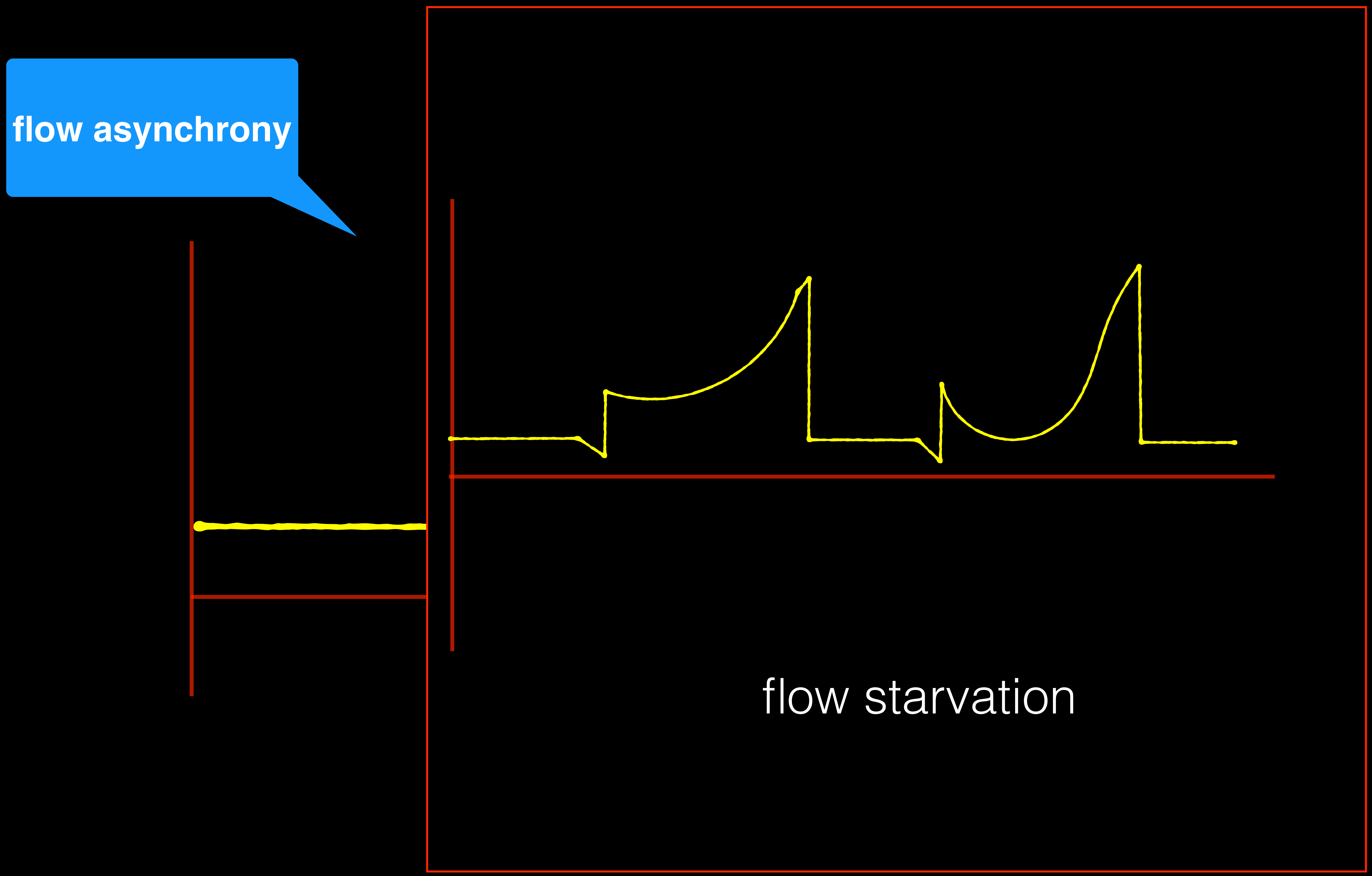
Waveform



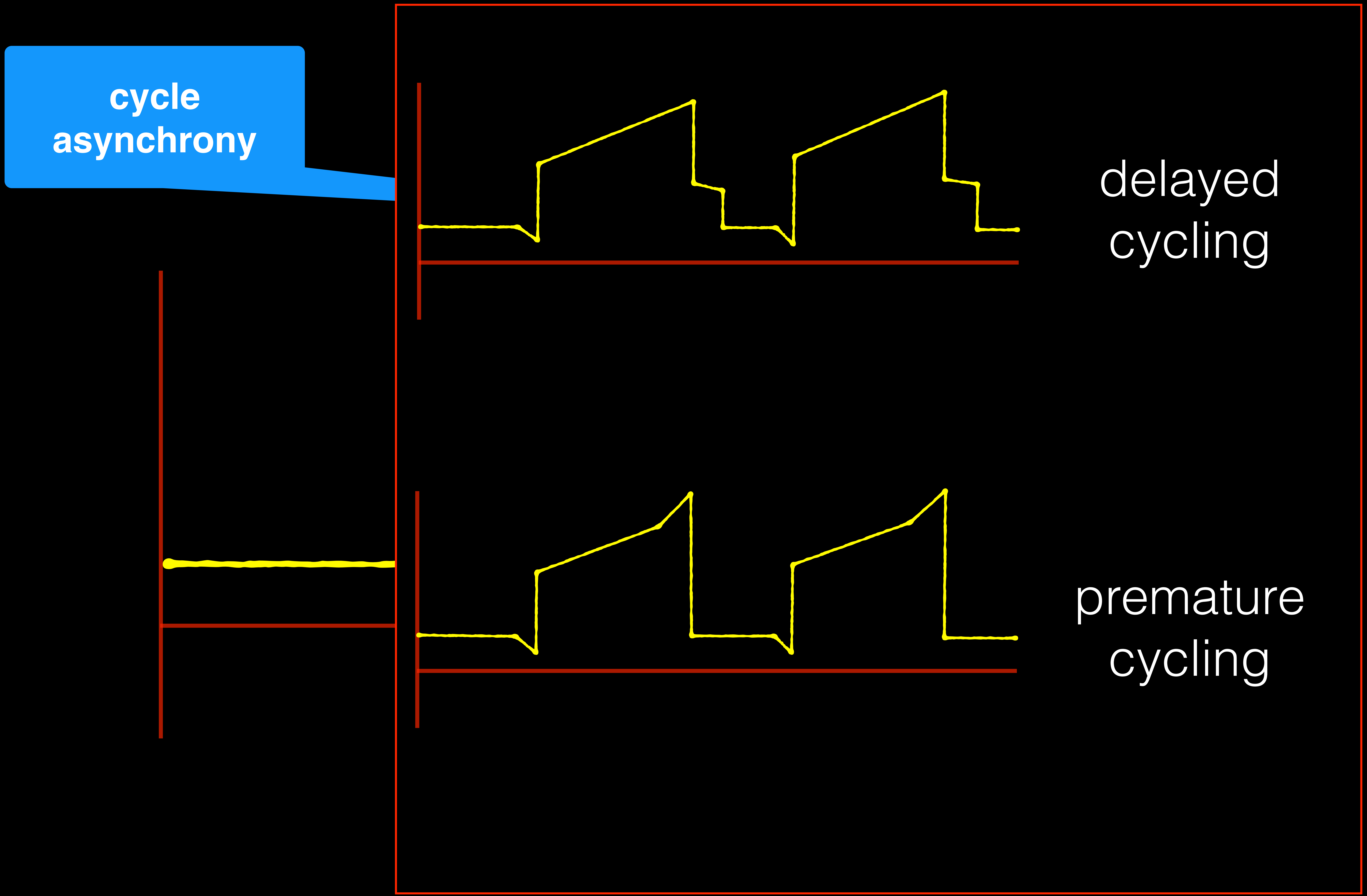
Waveform

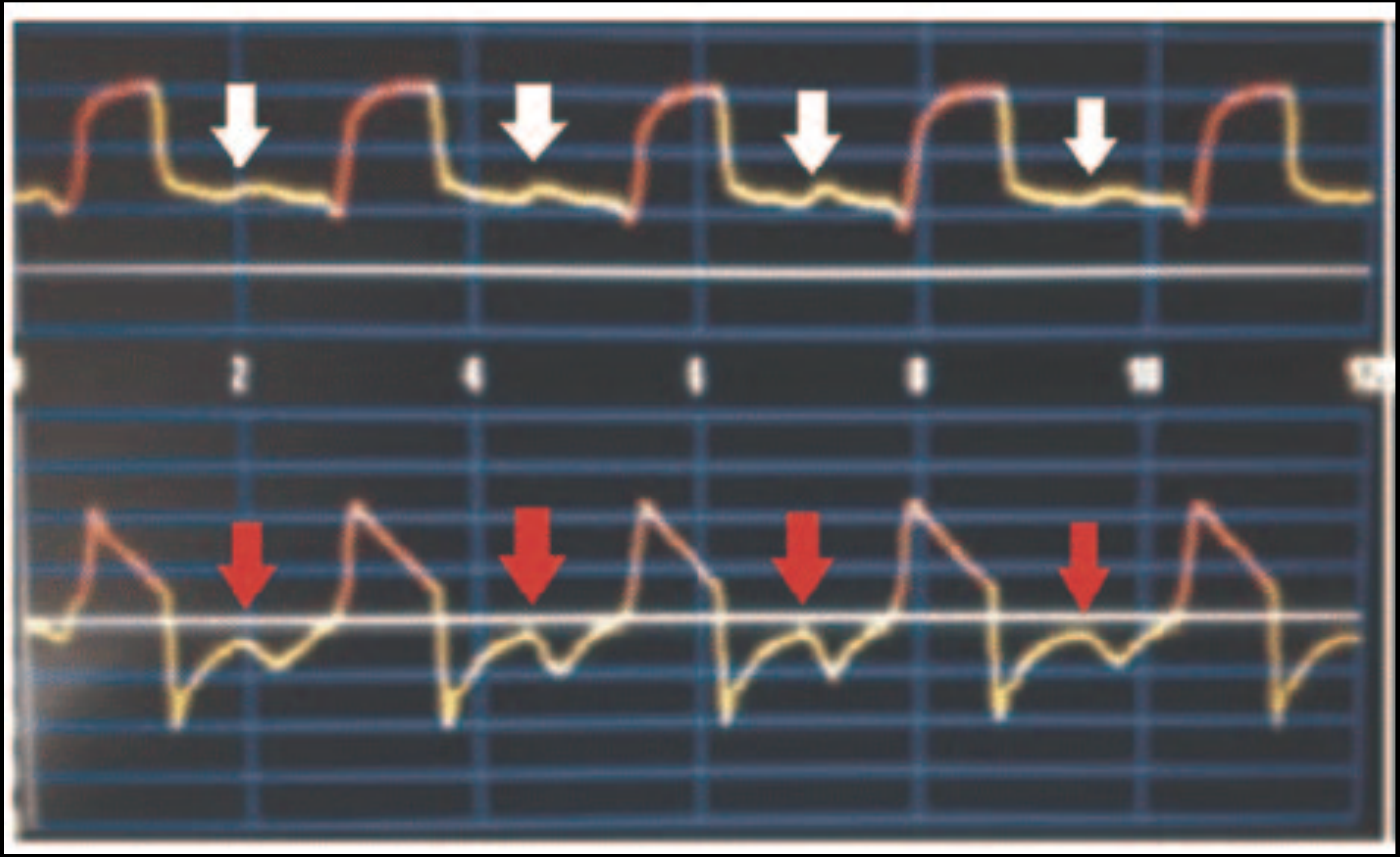

ineffective triggering
auto triggering
double triggering
trigger asynchrony

Waveform

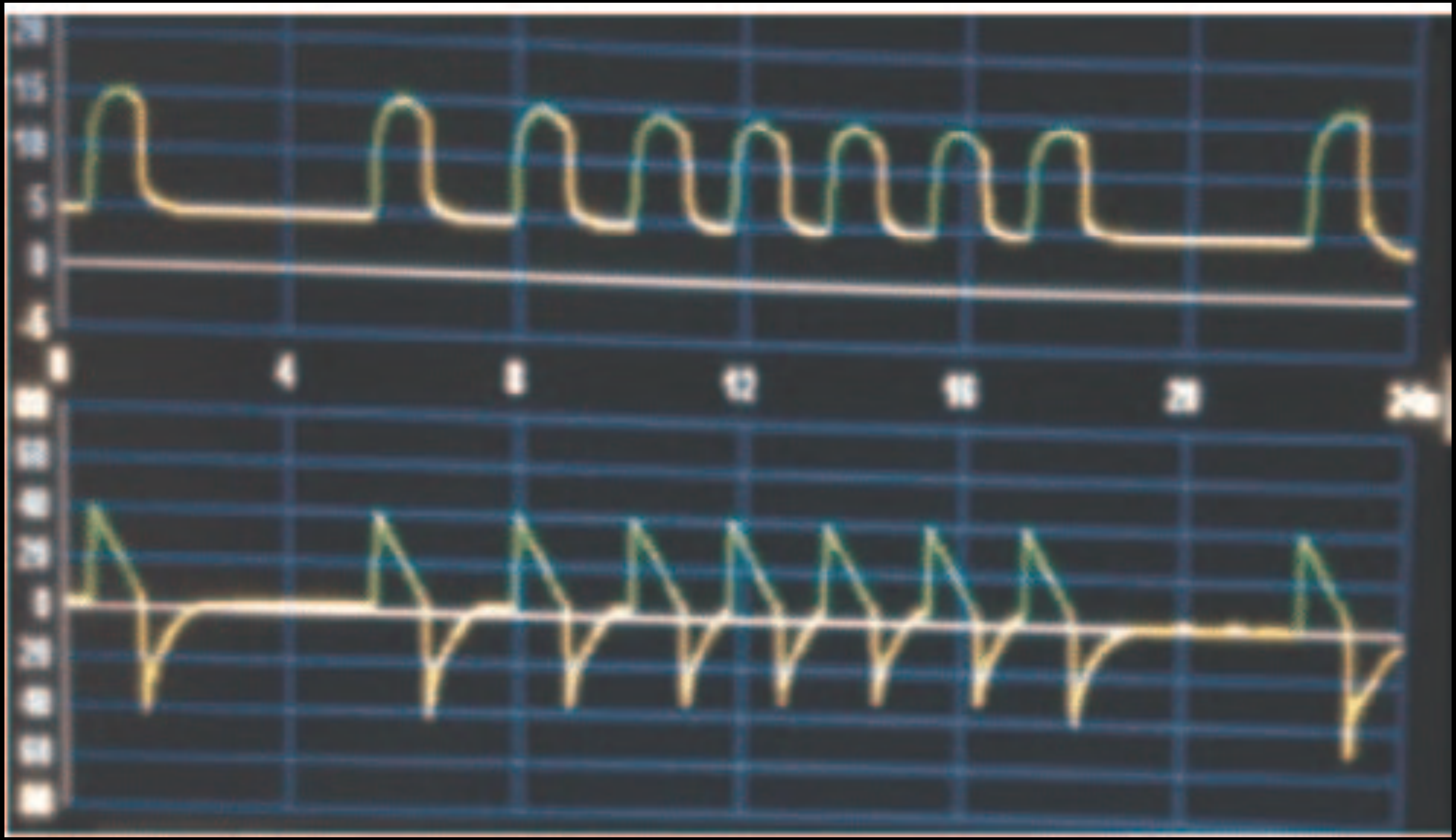


Waveform

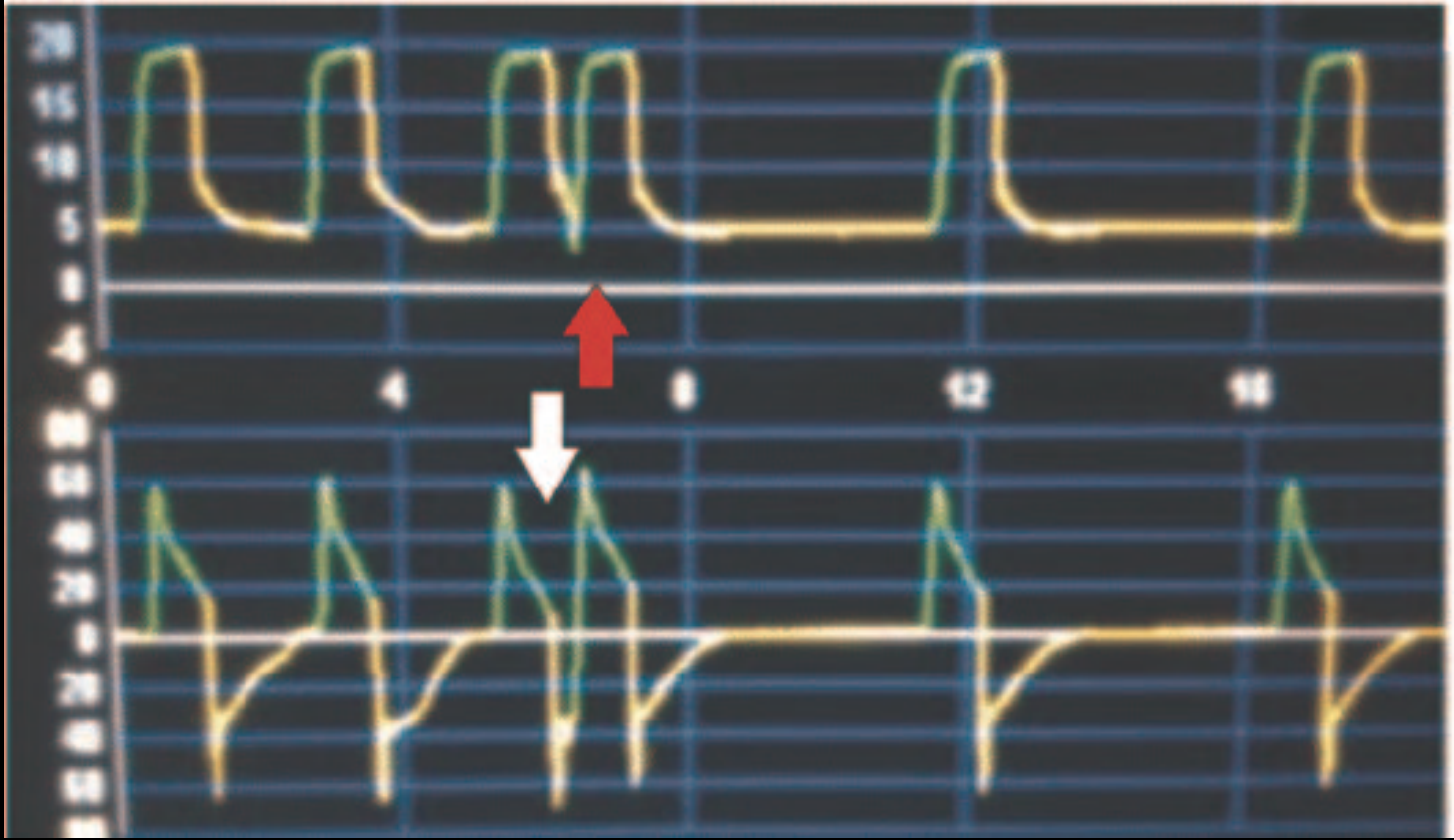




Ineffective triggering



Auto triggering

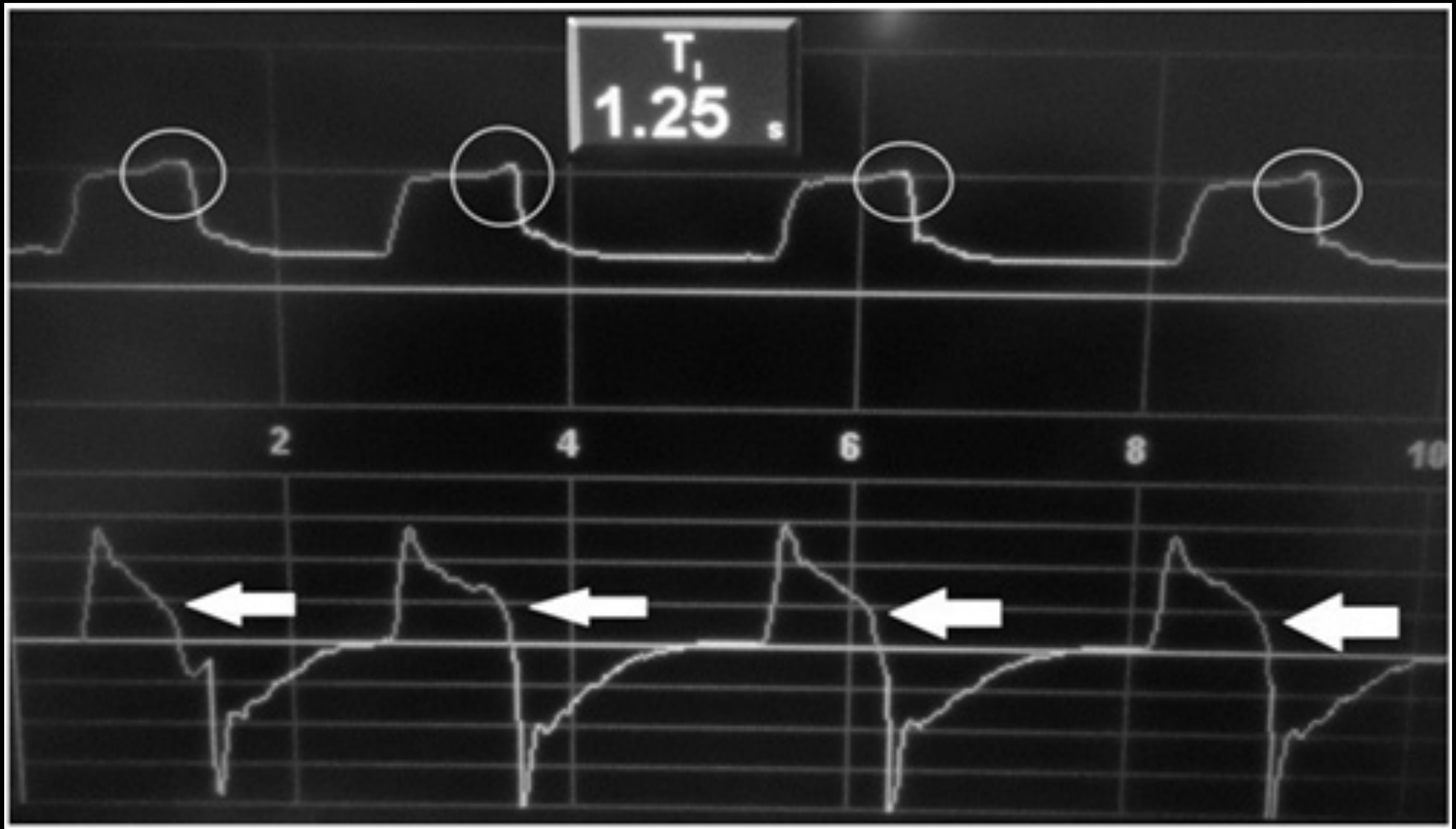


Double triggering

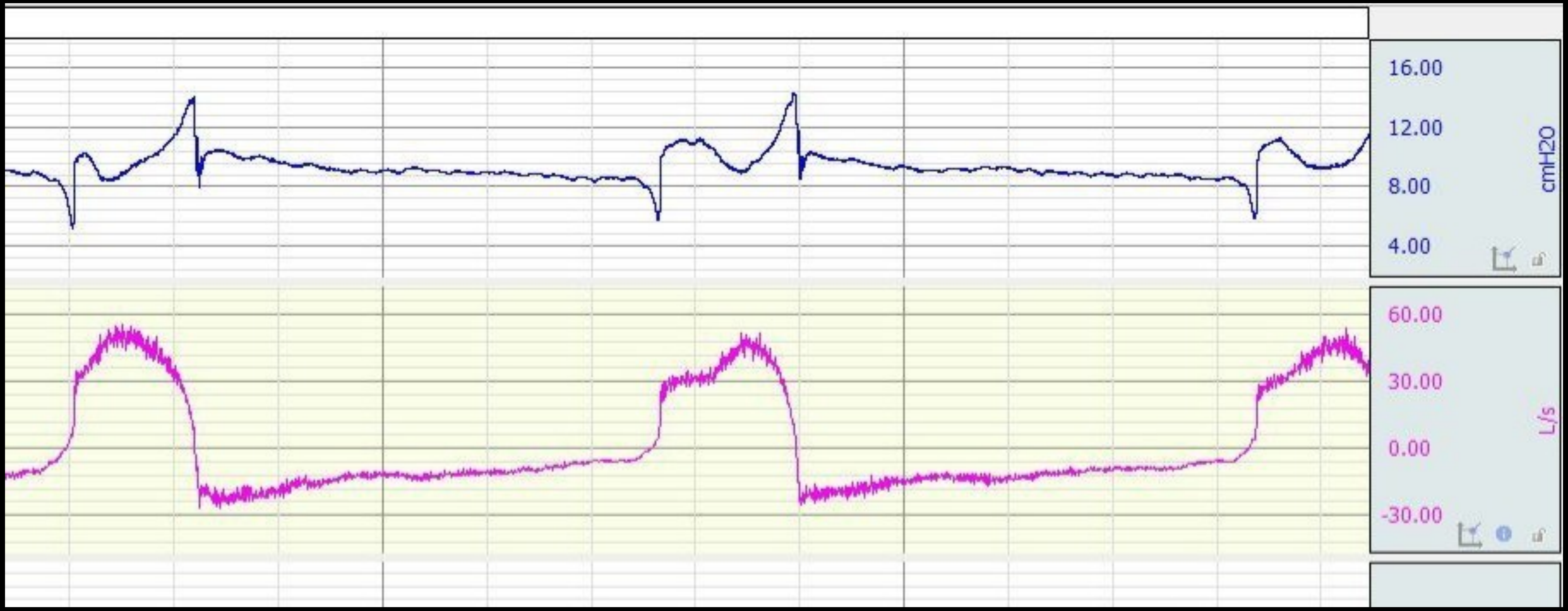
Reverse triggering

Reverse triggering is a type of dyssynchrony that occurs when a patient effort occurs after ('is triggered by') the initiation of a ventilator
triggered) breath. Usually, it is a phenomenon occurring over many consecutive breaths and also referred to as 'entrainment'

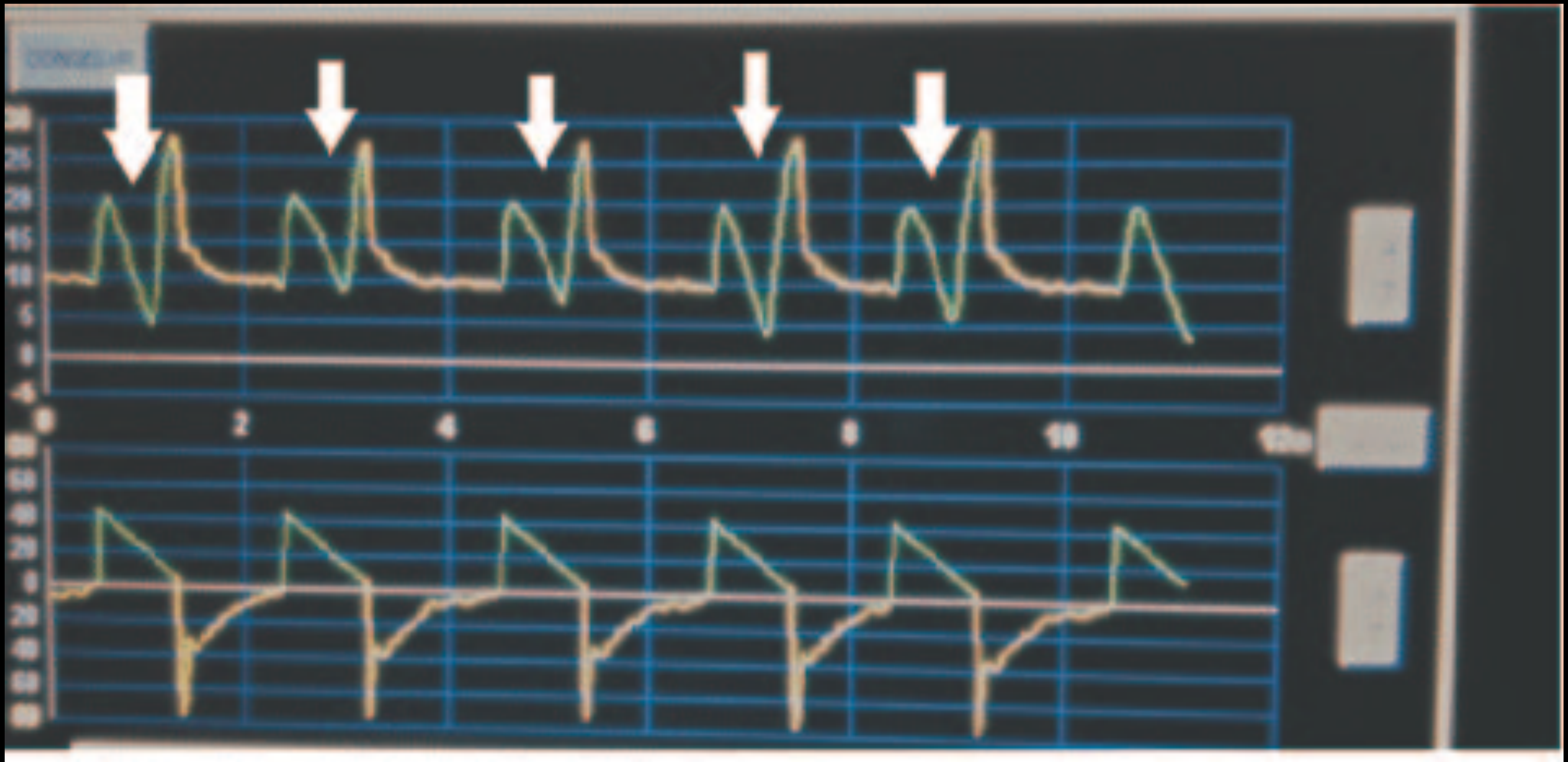
Premature cycling



Delayed cycling

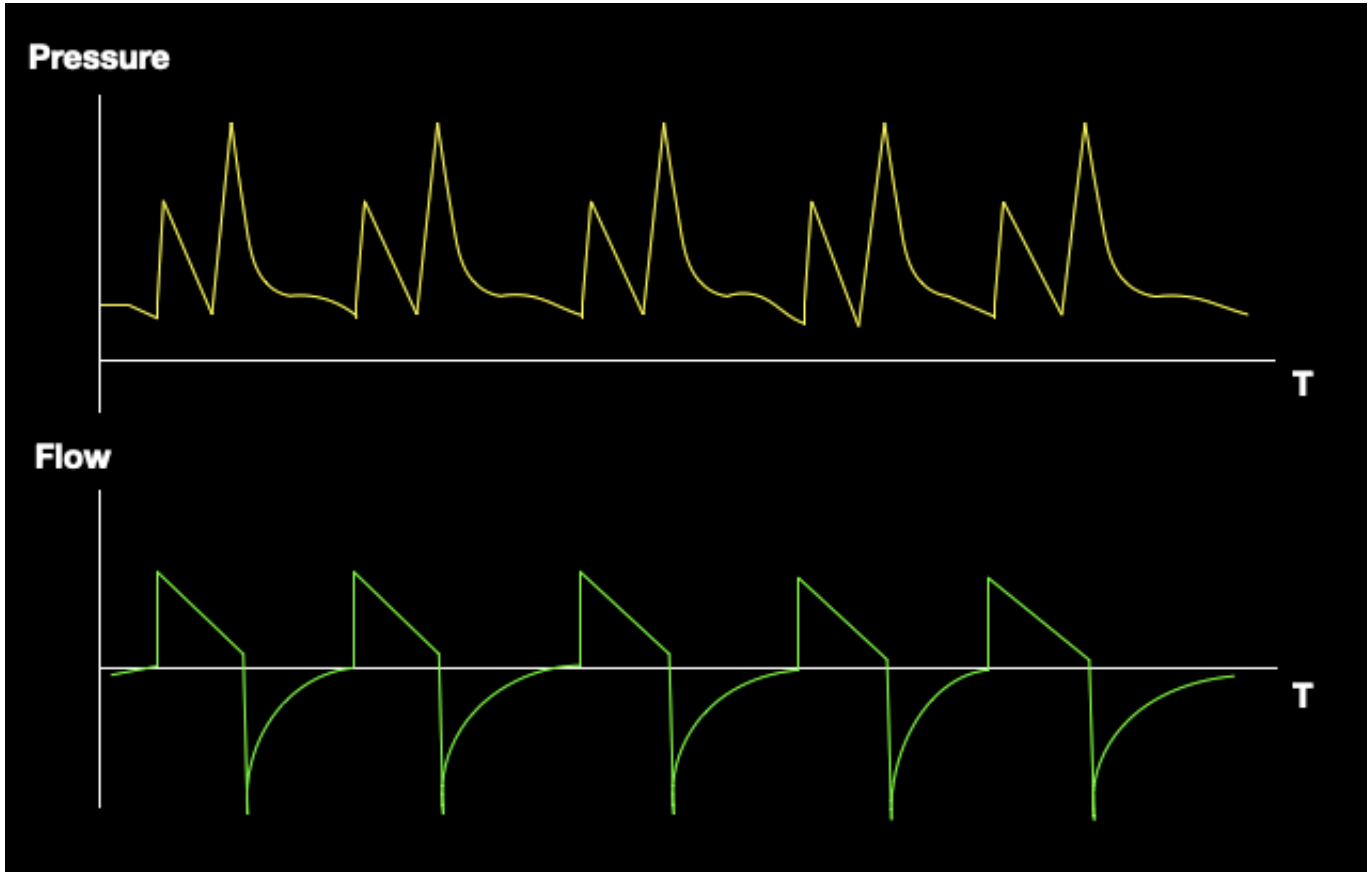


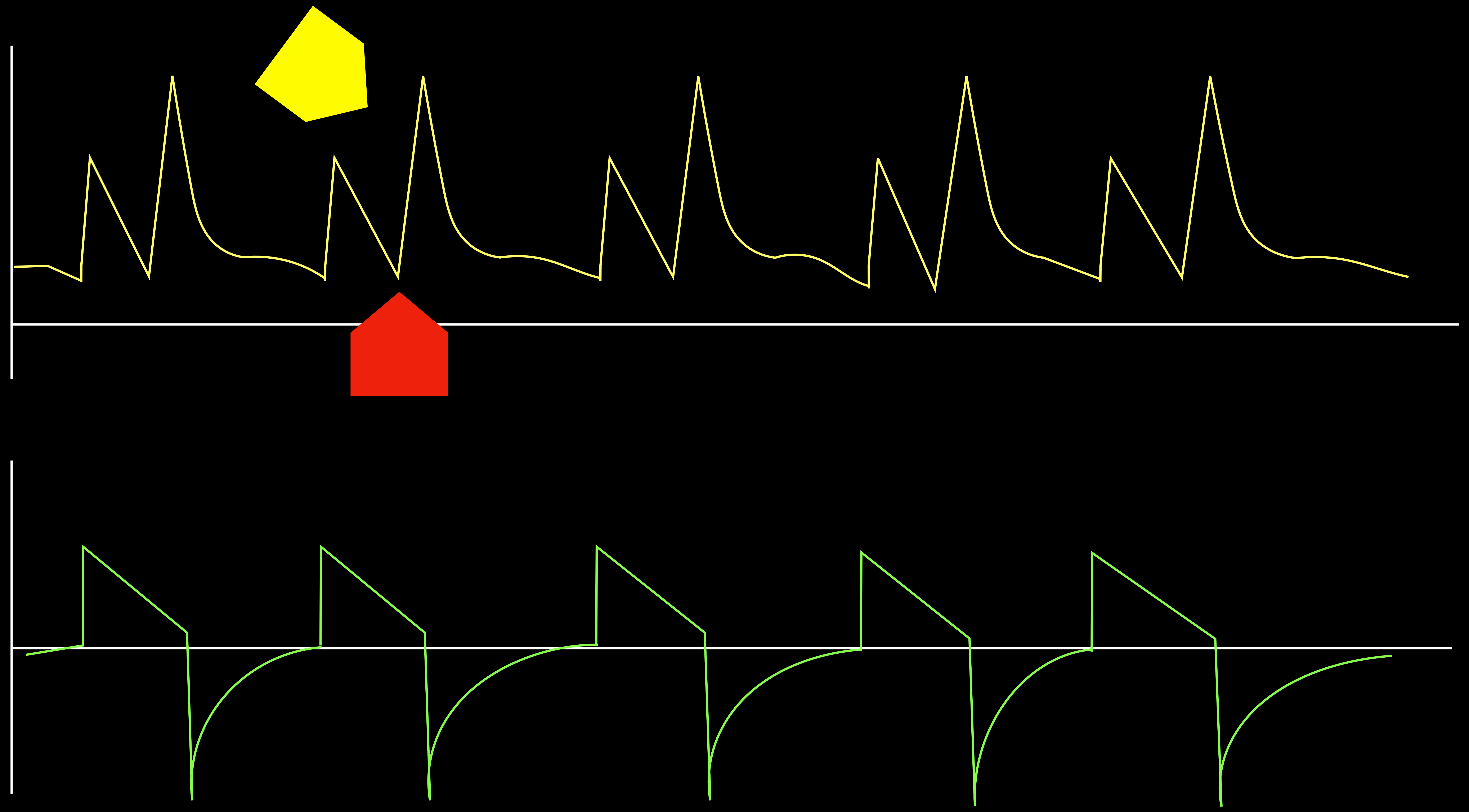
Flow starvation



Flow asynchrony

Case 6 A 25-year-old man presented with acute asthmatic attack. He was intubated and on MV. MV was setting with VCV: Vt 400 mL, RR 20/min, PIF 40 LPM, PEEP 5 cmH_2O, FiO_2 0.3. His MV waveform as showed.





Flow starvation —> double triggering

What is the most likely diagnosis?

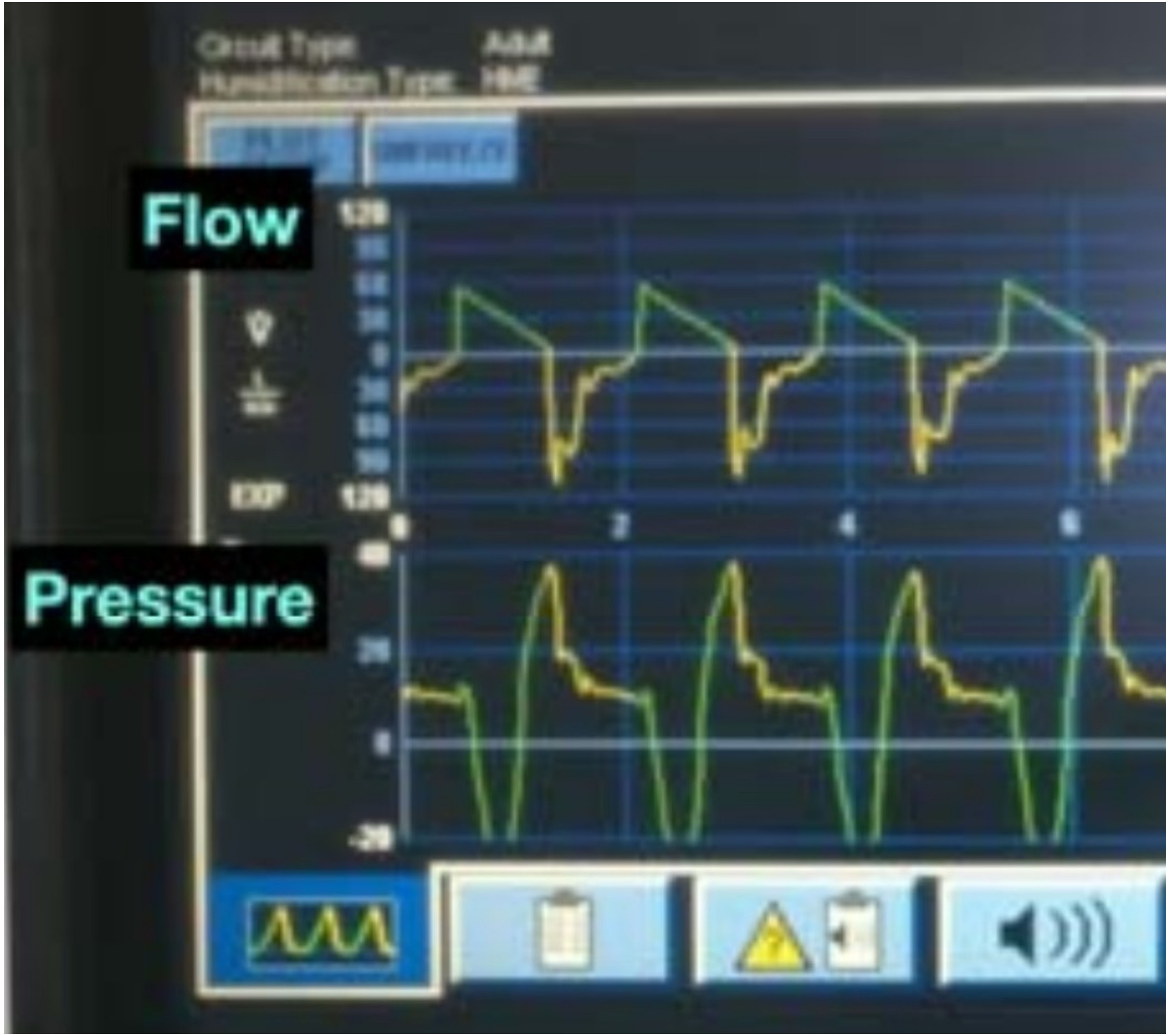
A. Delayed termination

B. Auto triggering

C. Double triggering

D. Flow starvation

E. Early termination



Circuit Type: Adult
Flow
EXP
Pressure
120
0
120
0
2
4
6
40
20
0
-20