

FISIOPATOLOGIA
DELL'INSUFFICIENZA
RESPIRATORIA ACUTA.

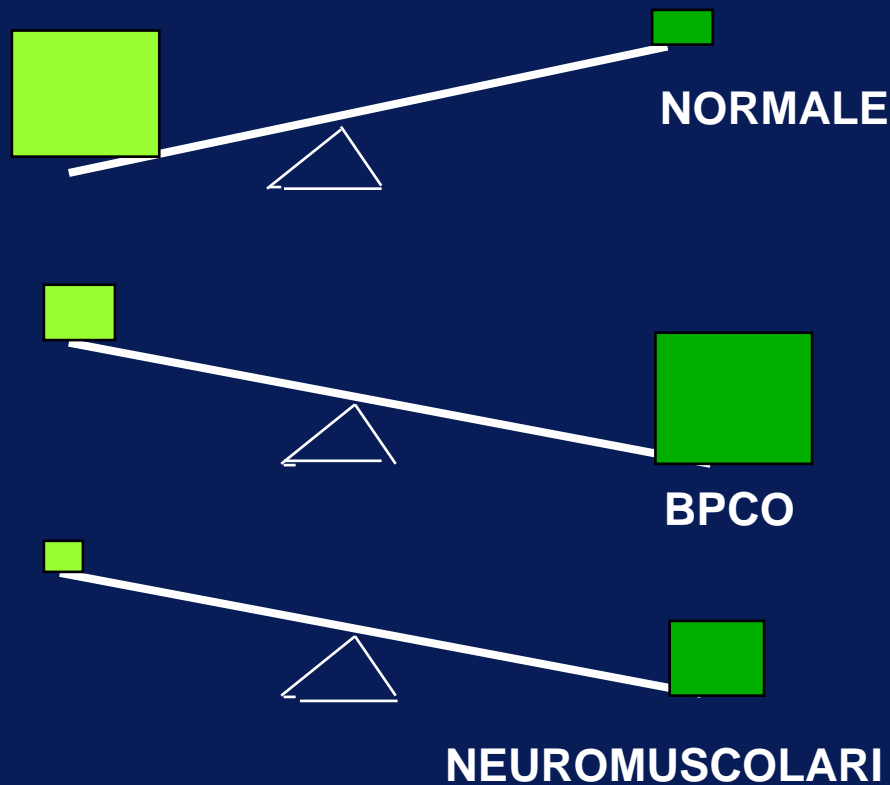
WWW.FISIOKINESITERAPIA.BIZ

IRA: fisiopatologia

ENDURANCE
DEI MUSCOLI RESPIRATORI

CARICO RESPIRATORIO

PTI norm.
PTI >>
PTI >>>



MIP norm.

>> RAW
> PEEPi dyn
MIP ridotta

MEP ridotta
MIP ridotta

FATICA MUSCOLARE

Condizione in cui vi e' una perdita della capacita' di sviluppare forza e/o velocita' in risposta ad un carico e che e' reversibile con il riposo.

(NHBLI-Workshop.

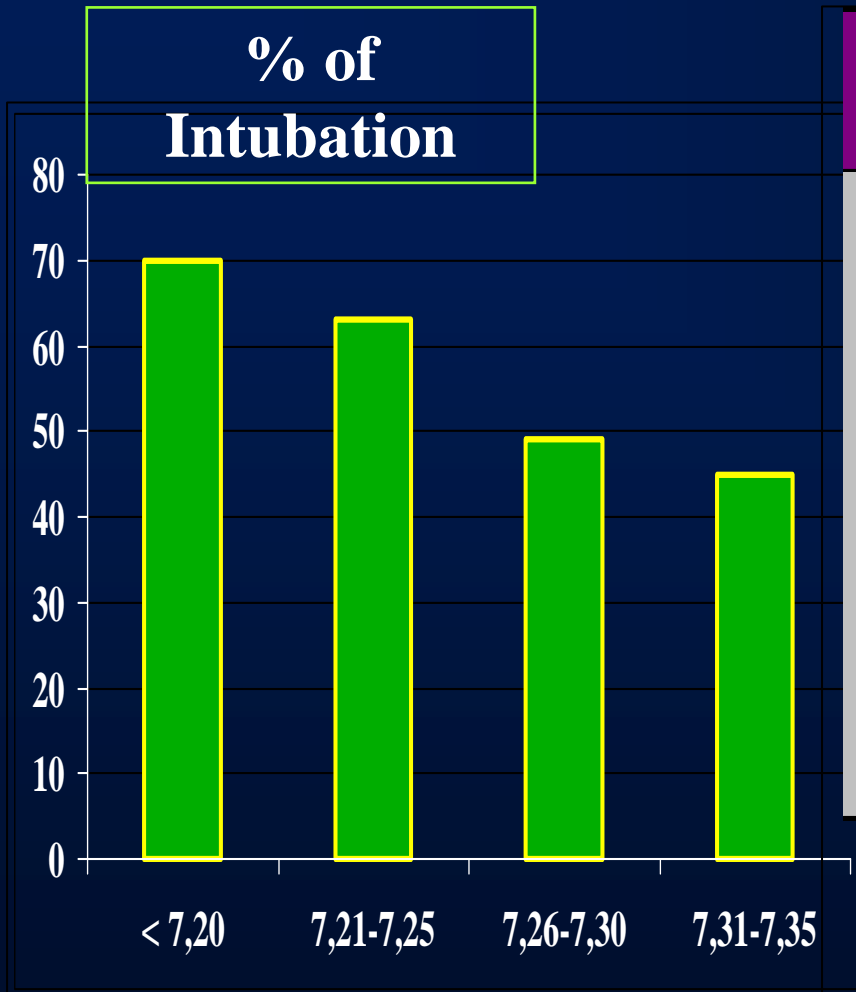
Am.Rev.Respir.Dis.1990;142:474-480)

Acute exacerbations in COPD

Predictors for NIV (n=39)

Parameters	<u>Failure</u>	<u>Success</u>
Weight, <i>kg</i>	53 (12)	67 (16)
NPI	46 (22)	24 (8) @
Apache II, <i>score</i>	20 (7)	12 (3)
pH	7.34 (0.03)	7.36 (0.03)
PaCO₂, <i>kPa</i>	7.8 (1.3)	6.2 (1.0)
MIP, <i>cmH₂O</i>	40 (22)	50 (19)
FEV₁, <i>% pred.</i>	26 (11)	41 (18) @

RESPONSE TO THERAPY in COPD RELAPSE



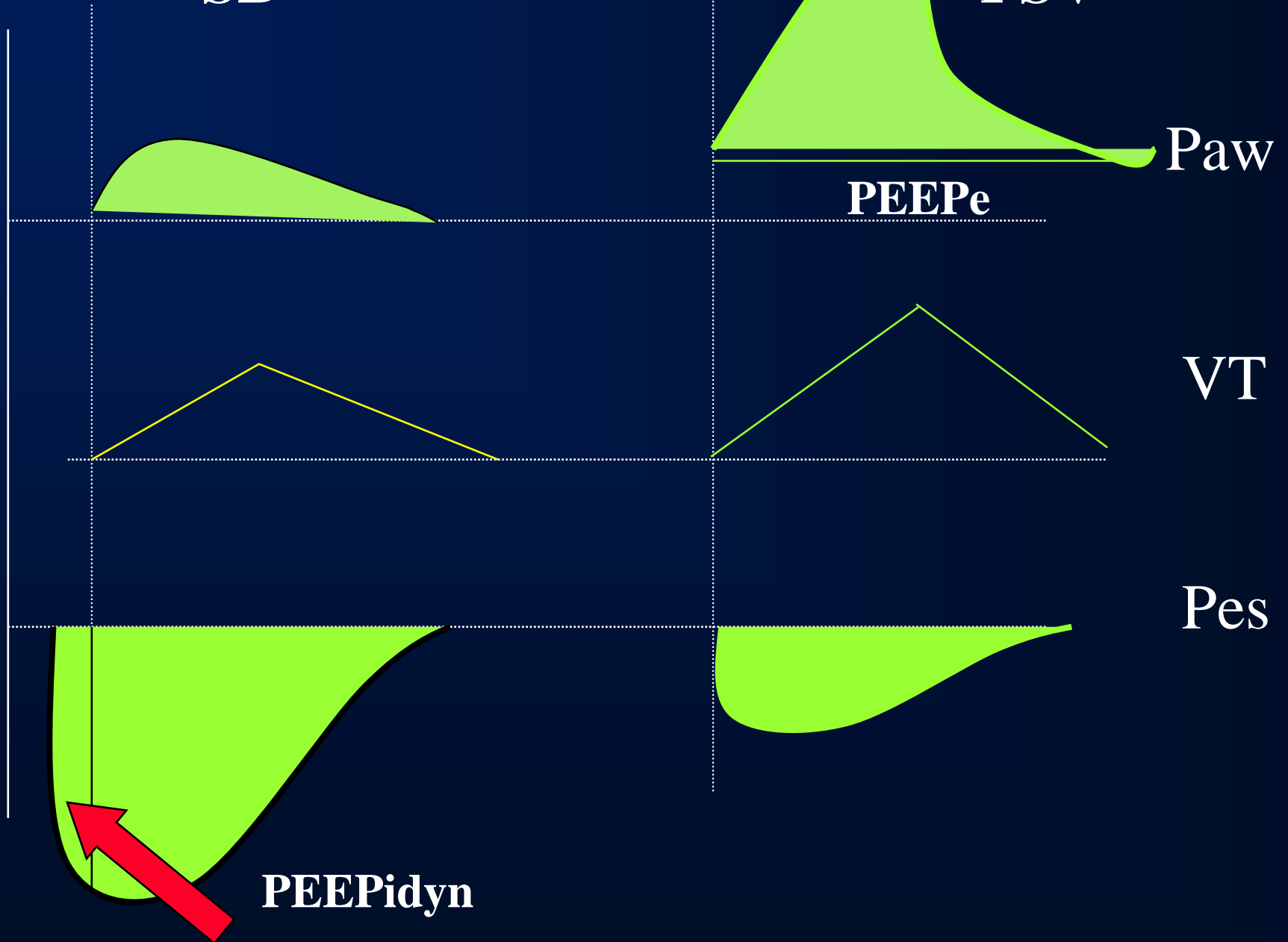
	<7.20	7.21-7.25	7.26-7.30	7.31-7.35
Time to nor.h	69±60	36±29	31±24	30±18
Death, %	50	20	8	0
Time EI	2±2	5±4	8±10	13±18
Death %	21	6	9	5



NMV has a role ?

SB

PSV



Paw

PEEP_e

VT

Pes

PEEP_{idyn}

Psyche

brain

spinal cord

peripheral nerve

neuromuscular
junction



Muscle cell membrane

transverse tubular system

calcium release

actin myosin cross bridge
formation

FORCE

FATICA MUSCOLARE

Fatica centrale: diminuzione del drive centrale (volontario o meno)

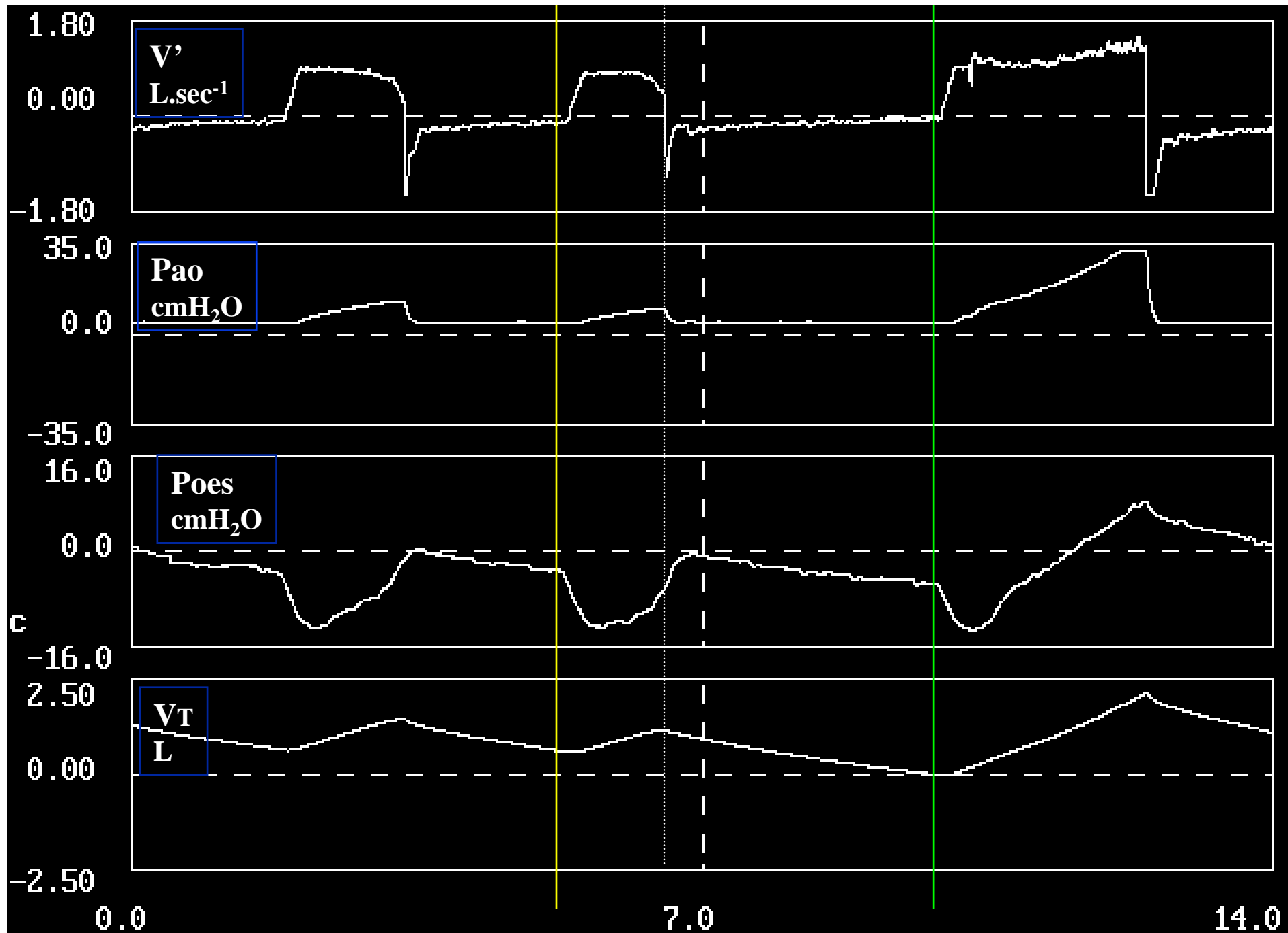
Fatica di trasmissione: nervo o giunzione neuromuscolare

Fatica contrattile: difetto di risposta per un accumulo di sostanze tossiche

MUSCOLI e COPD

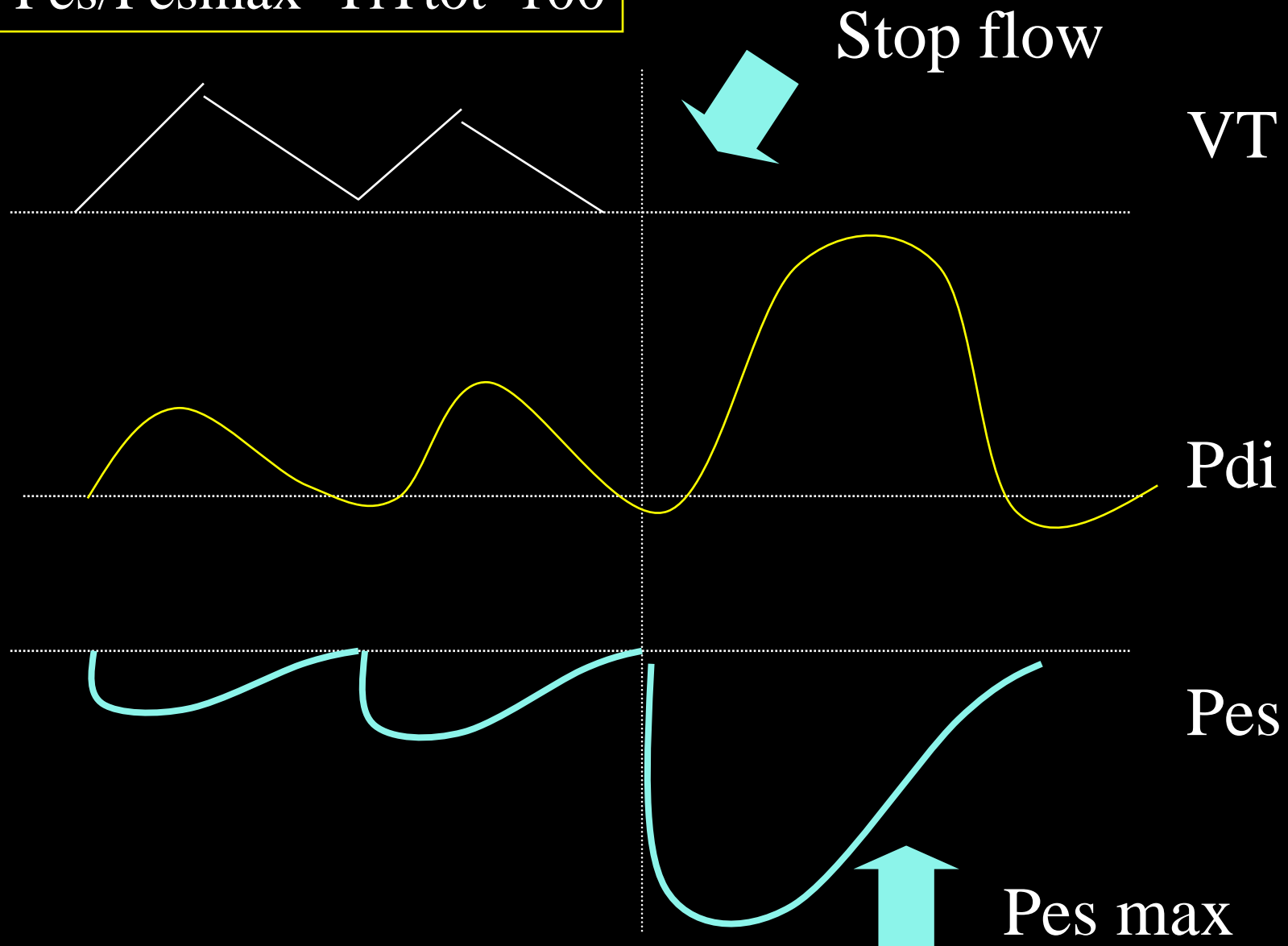
PRESENTANO ALTERAZIONI STRUTTURALI

- **DISUSO E IPOSSIEMIA**
- **LA FORZA CONTRATTILE**
- **LA SOGLIA DI FATICA**
- **L'ENDURANCE SONO RIDOTTE**
- **IL METABOLISMO OSSIDATIVO E RIDOTTO**
- **LA MASSA MAGRA E RIDOTTA**
- **> CATABOLISMO = ridotta tolleranza allo sforzo**



PATTERN RESPIRATORIO

$$TTI = \frac{P_{es}}{P_{esmax}} * T_i T_{tot} * 100$$

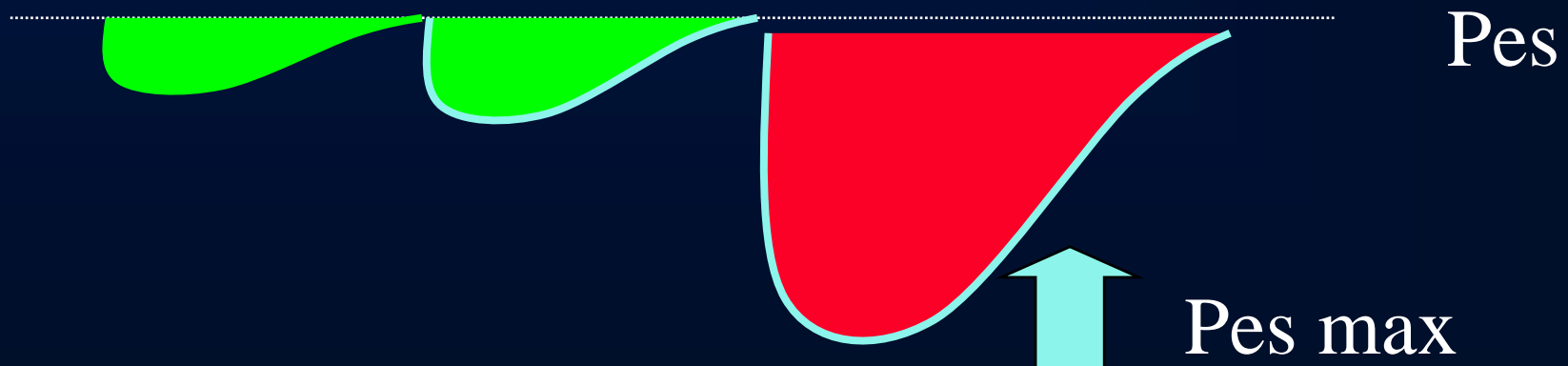


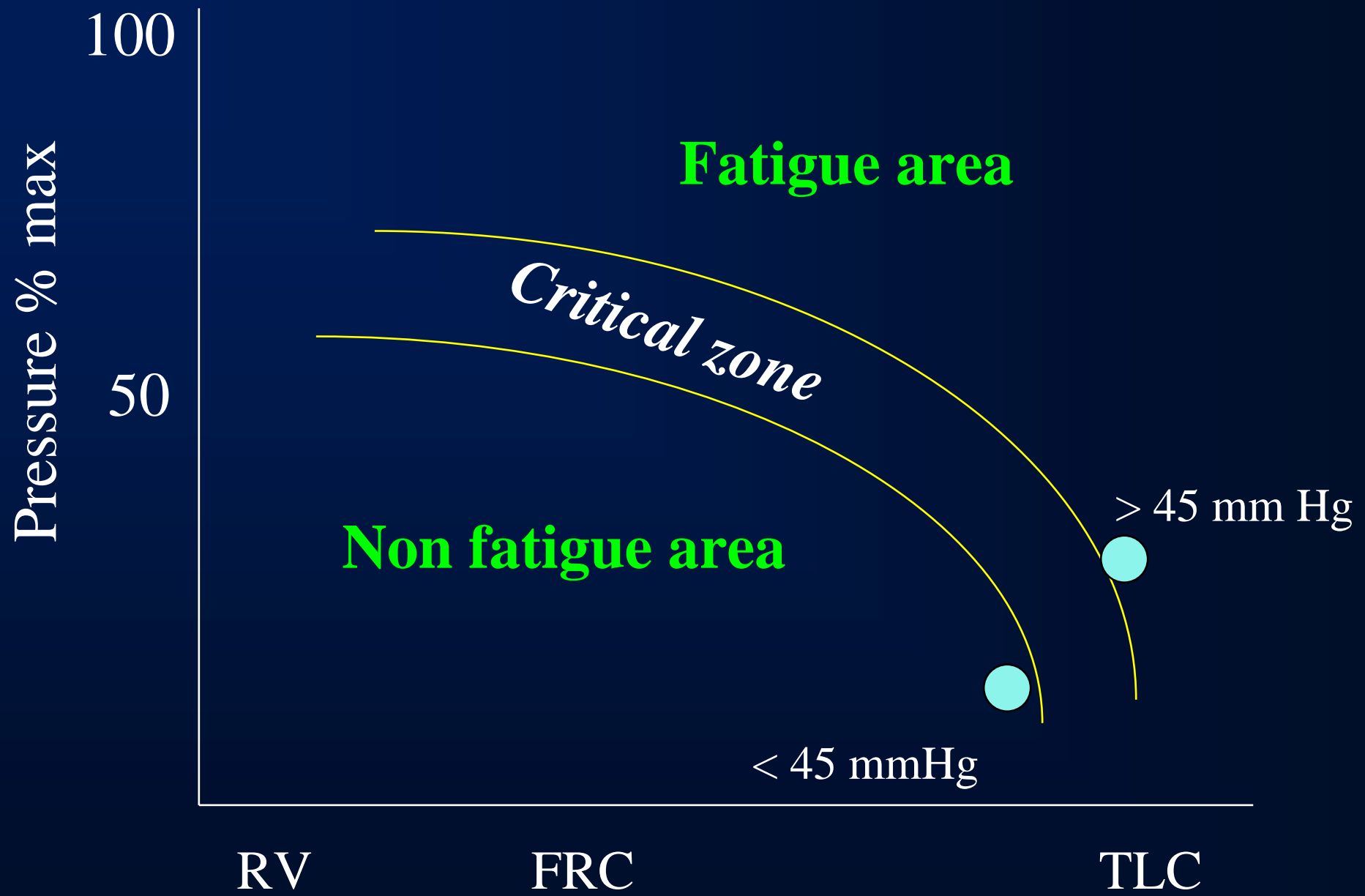
$$TTI = \text{Pes} / \text{Pesmax} * \text{TiTtot} * 100$$

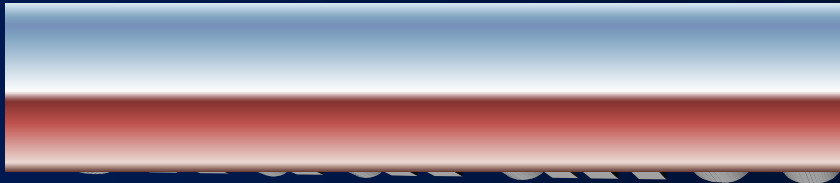
PES = 10 cmH2O; Pes max 40 cmH2O

PES = 10 cmH2O; Pes max 25 cmH2O

Pes = 20 cmh20; Pes max 35 cmH2O







% MVV

100

75

50

0

5

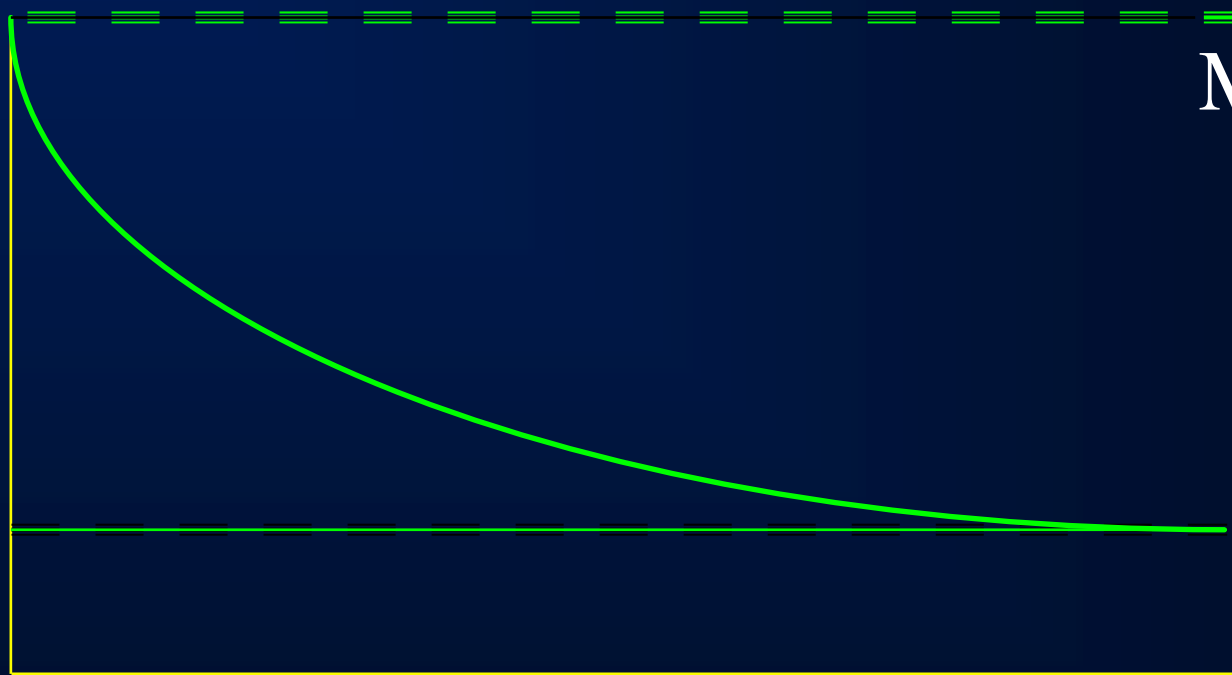
10

15

Endurance time (min)

MVV

MSV



Pimax
(cmH2O)

-125

-75

-25

% della CPT

0

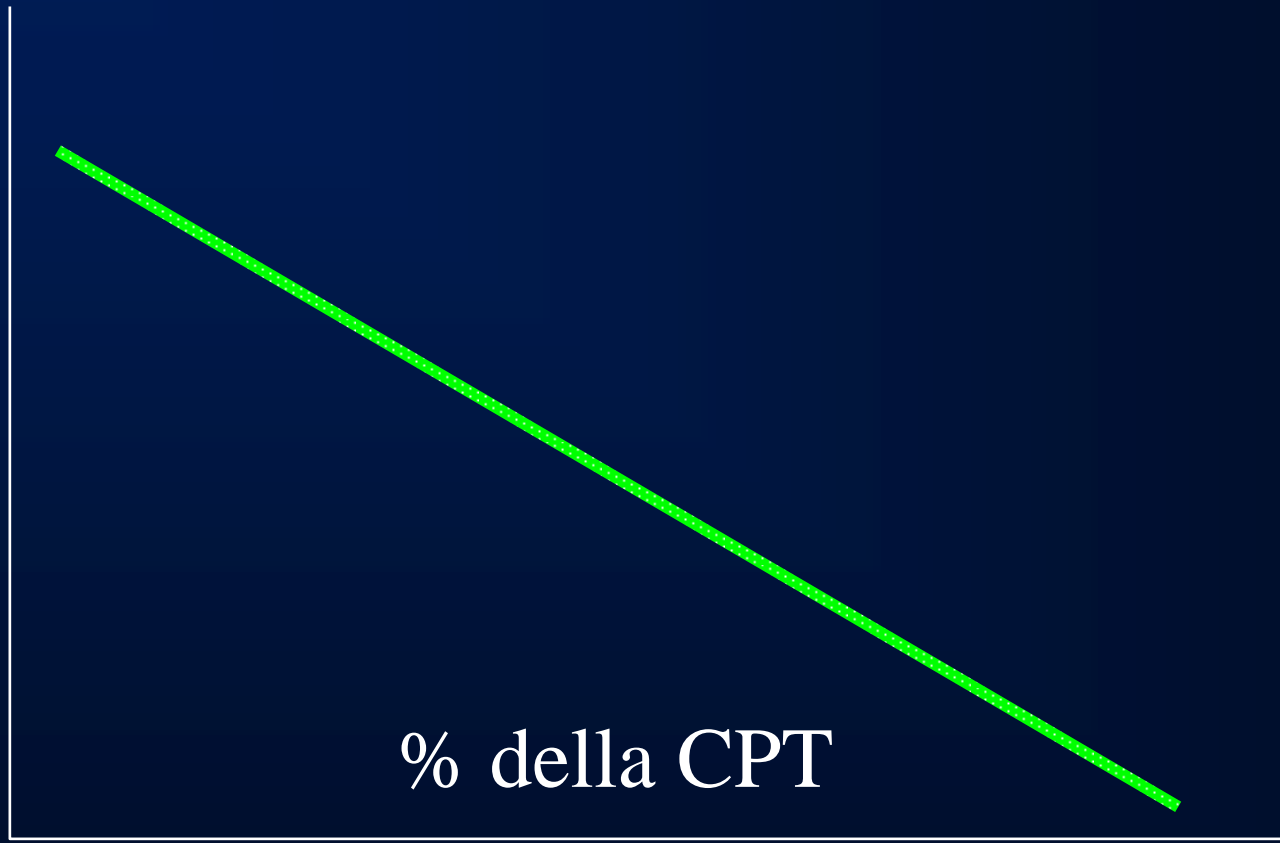
50

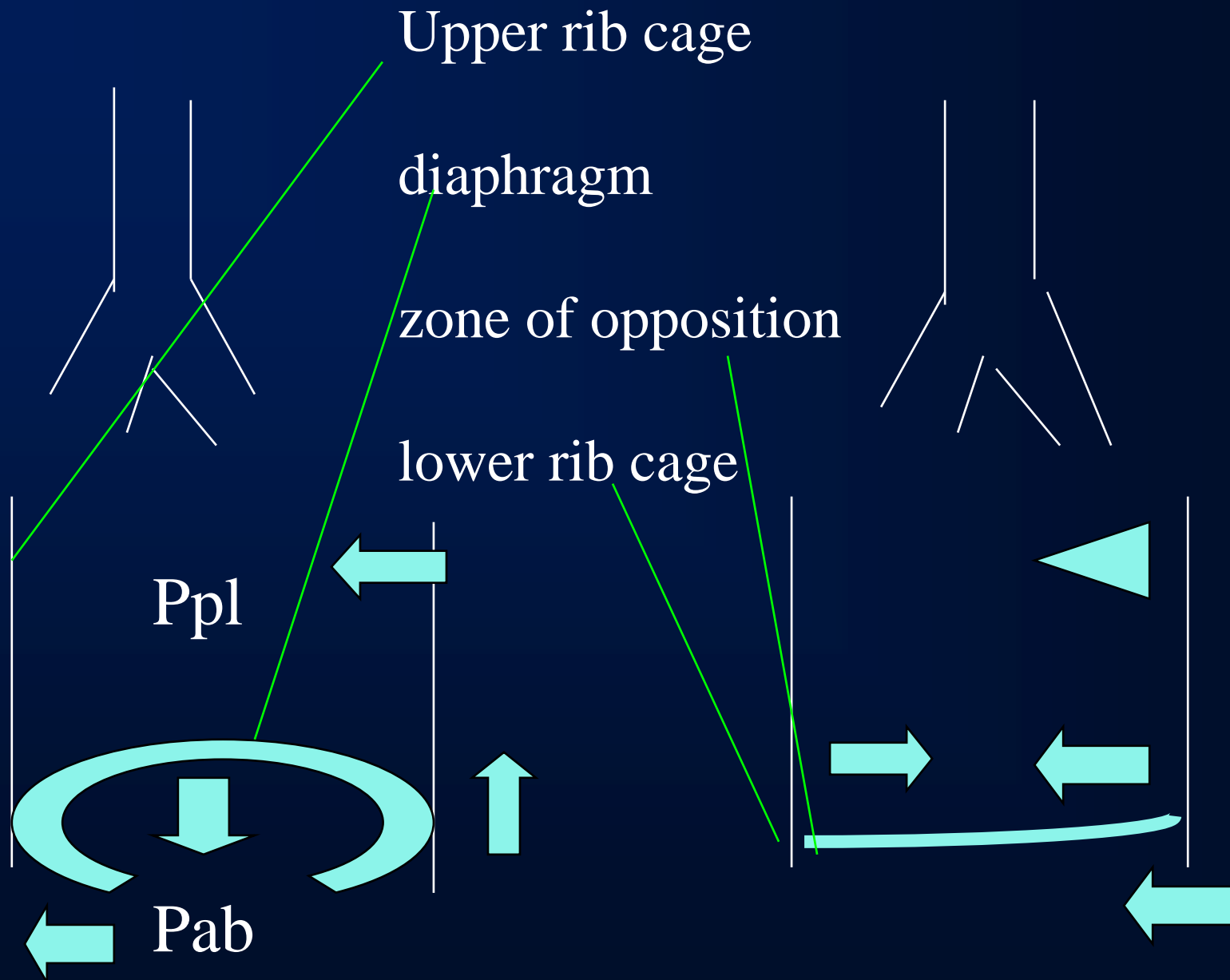
75

100

125

150

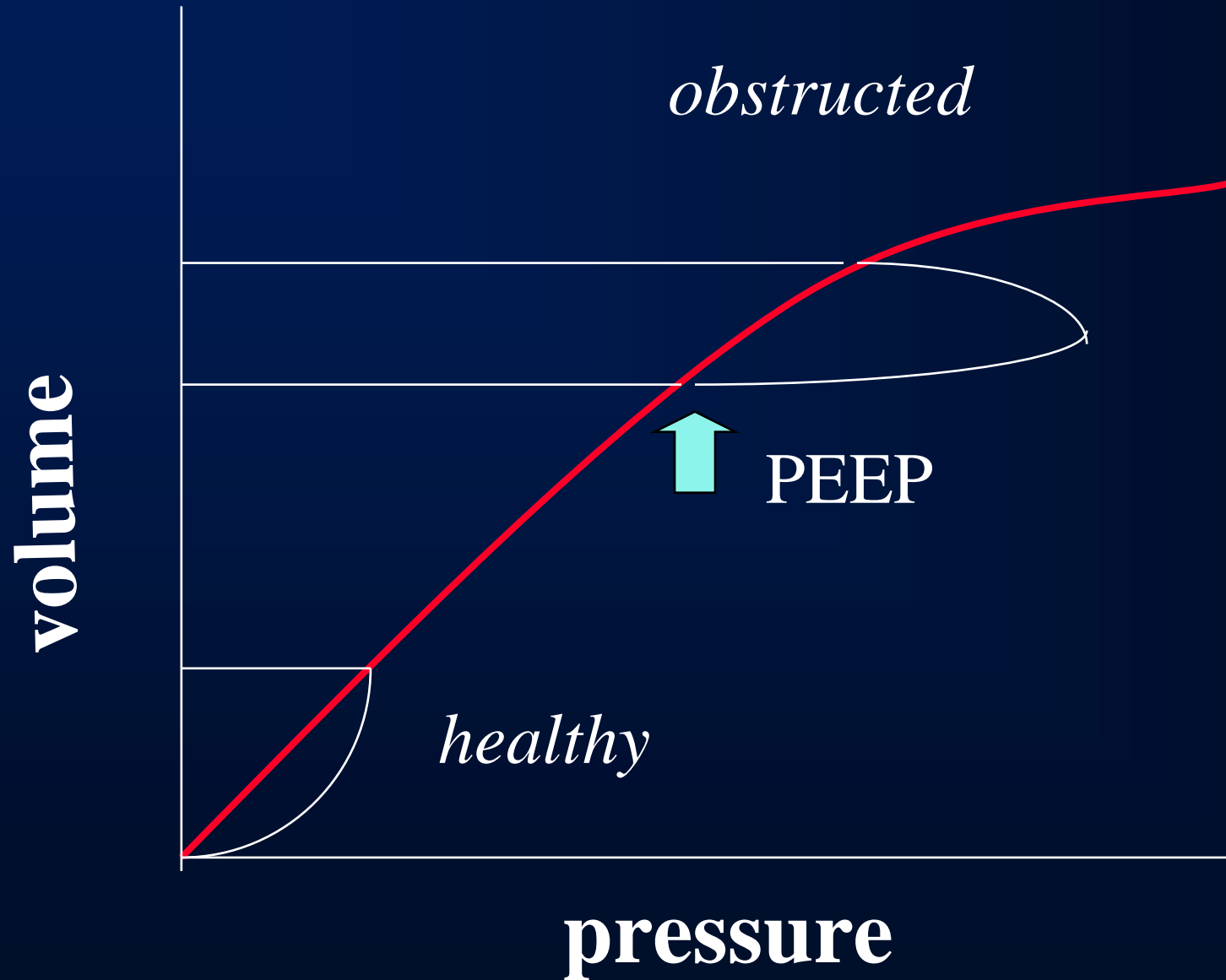




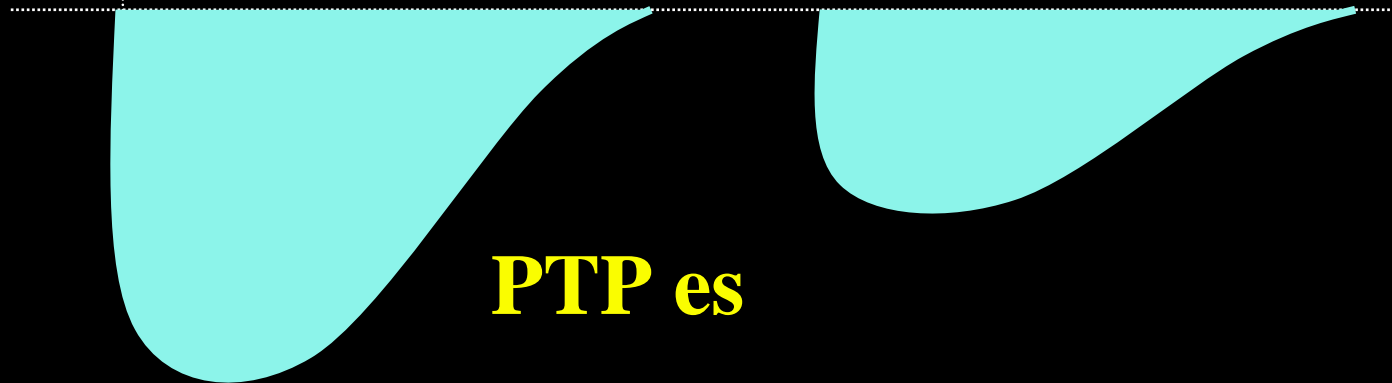
EFFETTI DELLA IPERINFLAZIONE SUL DIAFRAMMA

- **LUNGHEZZA (meccanismo di adattamento)**
- **GEOMETRIA (legge di Laplace)**
- **GRANDEZZA DELLA COMPONENTE OPPOSIZIONALE E INSERZIONALE DELL'AZIONE DIAFRAMMATICA**
- **EFFETTI DELLE DIFFERENTI PARTI DEL DIAFRAMMA (arrangiamento meccanico)**

Resistive and PEEPi WOB



SB



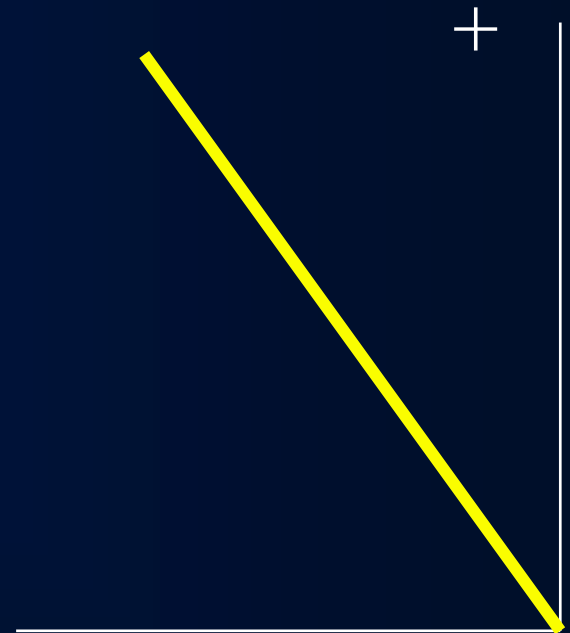
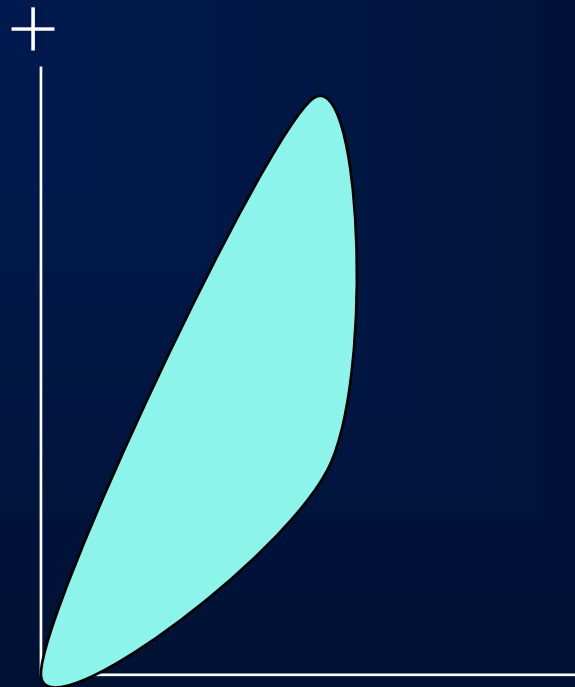
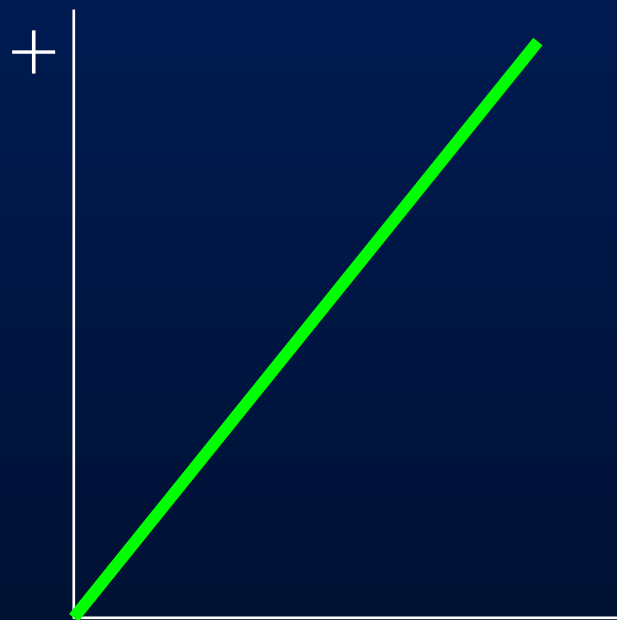
PTP es

SINCRONA

ASINCRONA

PARADOSSO

torace



Addome

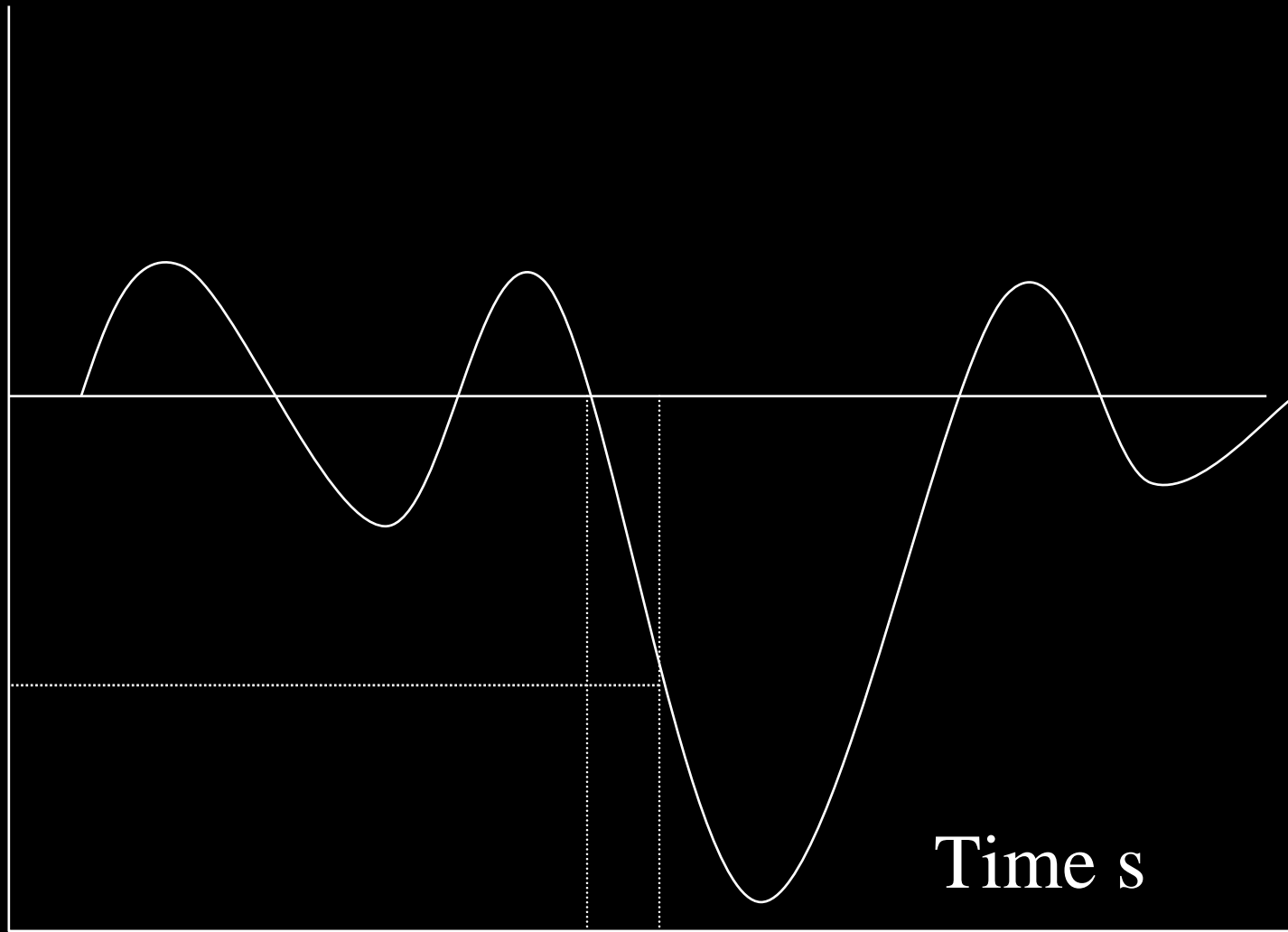
Medical disorders for which assessment of RM is needed before surgical approach

1. COPD
2. obesity
3. Kyphoscoliosis
4. Neuromuscular
5. Poor nutritional status
6. Steroids therapy
7. Endocrine diseases

Pressure

P0.1

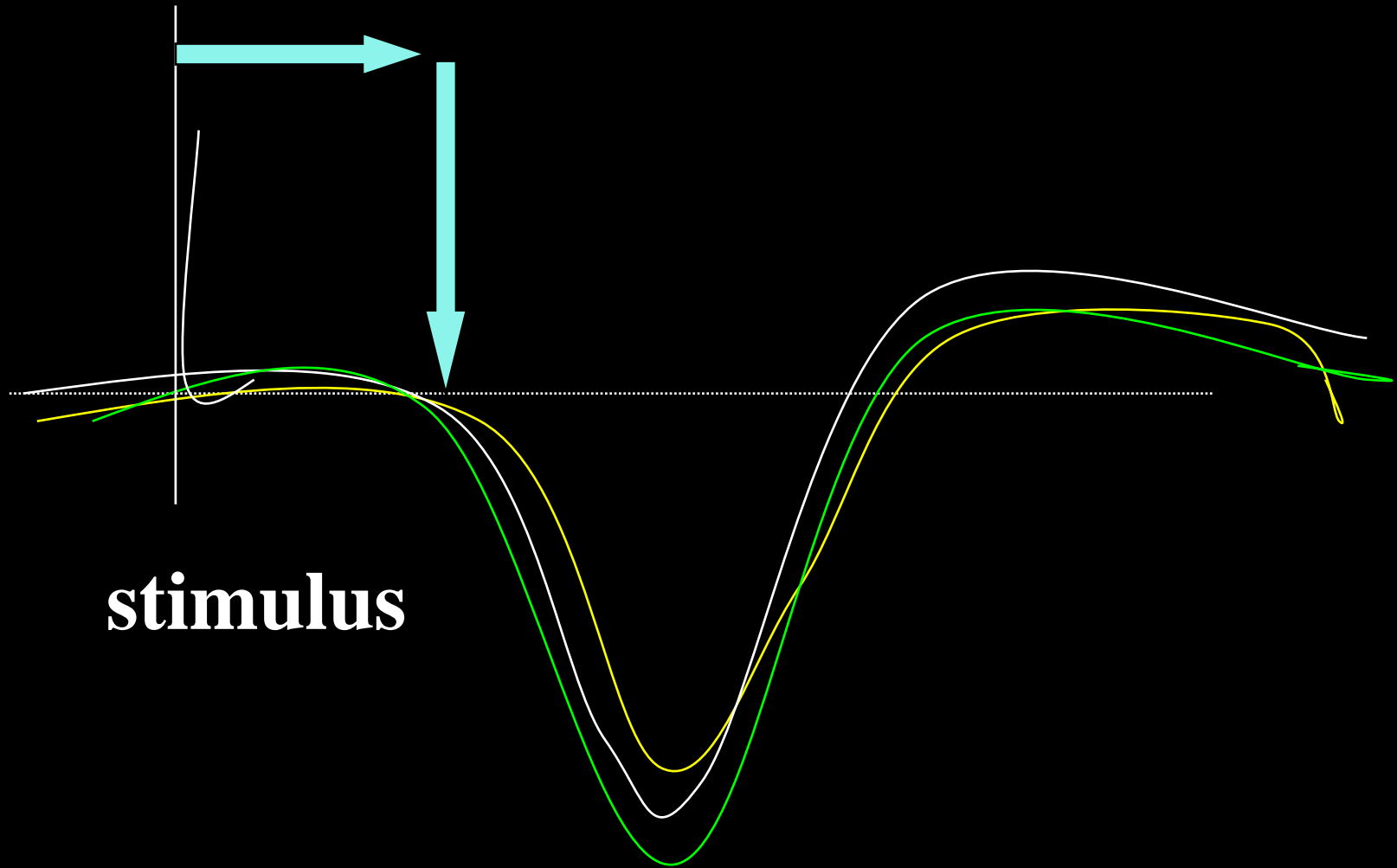
0



Time s

0,1

Phrenic nerve latency



stimulus

MECCANISMI PATOGENICI CHE PORTANO AD IPOSSIEMIA E IPERCAPNIA ARTERIOSA

DIFETTO
FUNZIONALE

IPOVENTILAZIONE

ALTERATA
DIFFUSIONE

ALTERATO
RAPPORTO V / Q

SHUNTS DX-SX

INSUFFICIENZA RESPIRATORIA IPOSSIEMICA

INTRAPOLMONARI

- o Ipoventilazione alveolare
- o Alterato rapporto V/Q
- o Shunt intrapolmonari
- o Ridotta diffusione all' O₂
- o Ridotta pressione inspiratoria parziale di O₂ (altitudine)

MECCANISMI

- o Alveolari: polmoniti; atelettasie; enfisema polmonare; EPA
- o Interstiziali: pneumopatie; pneumoconiosi; sarcoidosi; ARDS
- o Vascolari: embolia polmonare; ipertensione polmonare primitiva

CAUSE

EXTRAPOLMONARI

- o Ridotta frazione inspiratoria di O₂
- o Portata cardiaca
- o Concentrazione di Hb
- o Il valore di P₅₀ della curva di dissociazione dell' Hb
- o pH
- o consumo di O₂

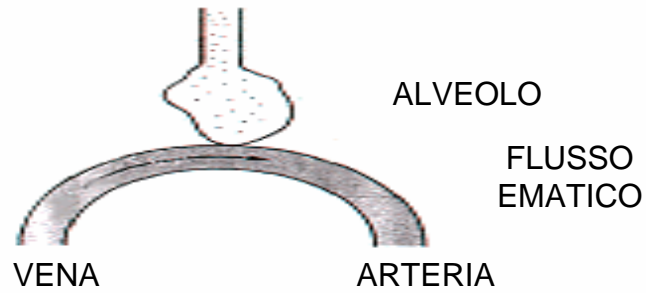
MECCANISMI

- o Shock, insufficienza epatica, sindrome uremica
- o Sepsi, peritoniti
- o post-trauma
- o post-chirurgici
- o emorragie

CAUSE

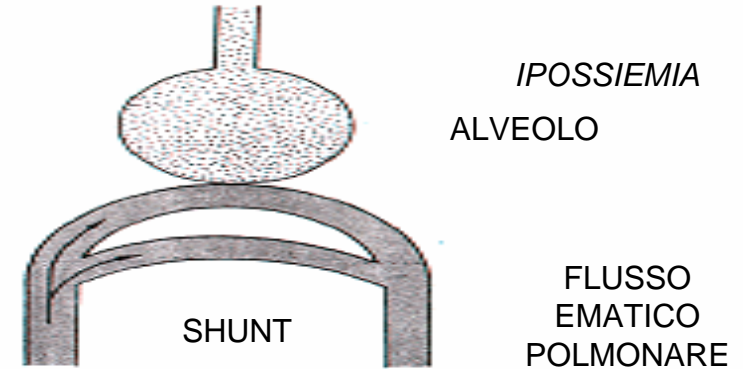
A) IPOVENTILAZIONE ALVEOLARE

IPOSSIEMIA
IPERCAPNIA



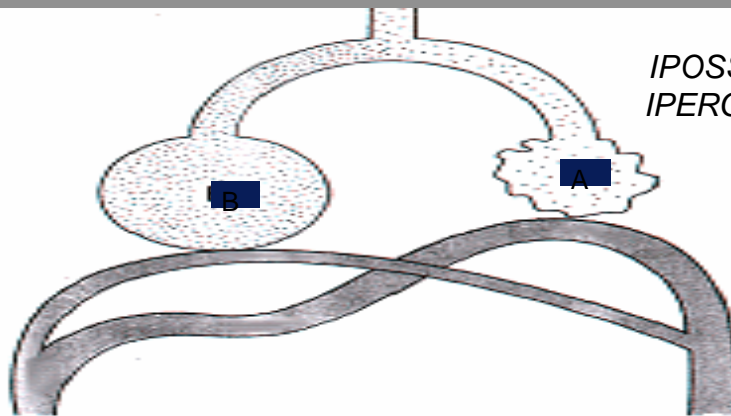
B) SHUNT DX-SX

IPOSSIEMIA
ALVEOLO



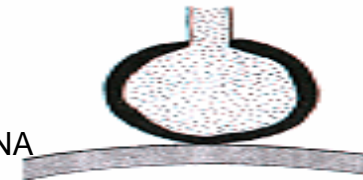
C) ALTERATO RAPPORTO V / Q

IPOSSIEMIA
IPERCAPNIA



D) ALTERATA DIFFUSIONE

VENA



MEMBRANA
ISPESSITA
ARTERIA

V ELEVATO

Q RIDOTTO

V RIDOTTA

Q ELEVATO

meccanismi patogenici dell' ipossiemia

CAUSE DI INSUFFICIENZA RESPIRATORIA IPERCAPNICA

RIDUZIONE DRIVE INSPIRATORIO

- o Ipoventilazione alveolare centrale
- o Chemosensitivit geneticamente depressa
- o Ipotiroidismo
- o Diuretici e ventilazione meccanica -> alcalosi metabolica
- o Errato uso ipnotici, sedativi, narcotici

AUMENTATO CARICO INSPIRATORIO

- o ↑ Resistenze delle vie aeree
- o ↓ Compliance gabbia toracica
- o ↓ Compliance del polmone
- o ↑ Iperinflazione dinamica toracica (PEEPi)

DISFUNZIONE DEI MUSCOLI INSPIRATORI

- o Iperinflazione statica e/o dinamica del torace
- o Affaticamento muscolare

COMBINAZIONE DELLE CAUSE SOPRAELENCCATE

- o BPCO
- o ObesitÓ
- o ARDS
- o Malattie neuromuscolari
- o Trauma toracico
- o Disturbi della gabbia toracica



CAUSE NON POLMONARI DI INSUFFICIENZA RESPIRATORIA

	RIDOTTO DRIVE VENTILATORIO	OSTRUZIONE VIE AEREE SUPERIORI	↓ COMPLIANCE GABBIA TORACICA	FATICA MUSCOLI RESPIRATORI
ENCEFALITE	++	+		
DISORDINI SISTEMA NERVOSO AUTONOMO	++	+		
APNEA DEL SONNO DI ORIGINE CENTRALE	++			
ABUSO SEDATIVI	++	+		
POLIOMELITE	++	+	+	
QUADRIPLEGIA				++
PATOLOGIA DEL MOTONEURONE		+		++
MIASTENIA		+		++
DISTROFIA MUSCOLARE		+		++
MIOPATIE CONGENITE				++
OBESITA'		++	+	++
MALNUTRIZIONE				+
TRAUMA TORACICO			++	++
CIFOSI			++	+
SCOLIOSI			++	

CAUSE DI IPOSSIEMIA

Apnea	CNS pathology, respiratory drive depression, muscular weakness
Inability to Oxygenate	ARDS, pneumonia, apnea
Inability to Ventilate	CNS depression, respiratory drive depression, muscular weakness
Inability to Protect Airway	Coma, GI bleed, overdose convulsion, trauma
Anatomical Airway Obstruction	Tumor, edema, head and neck trauma
Unstable Cardiovascular Status	Recent cardiac arrest, multiple system disease
Chest Wall Integrity	Trauma, pleural fistula pneumothorax
Cardiac Arrest	To be determined
Excessive Secretion	Aspiration, bronchorhea

RESPIRATORY FAILURE

PUMP FAILURE

LUNG FAILURE

**ALVEOLAR
HYPOVENTILATION**

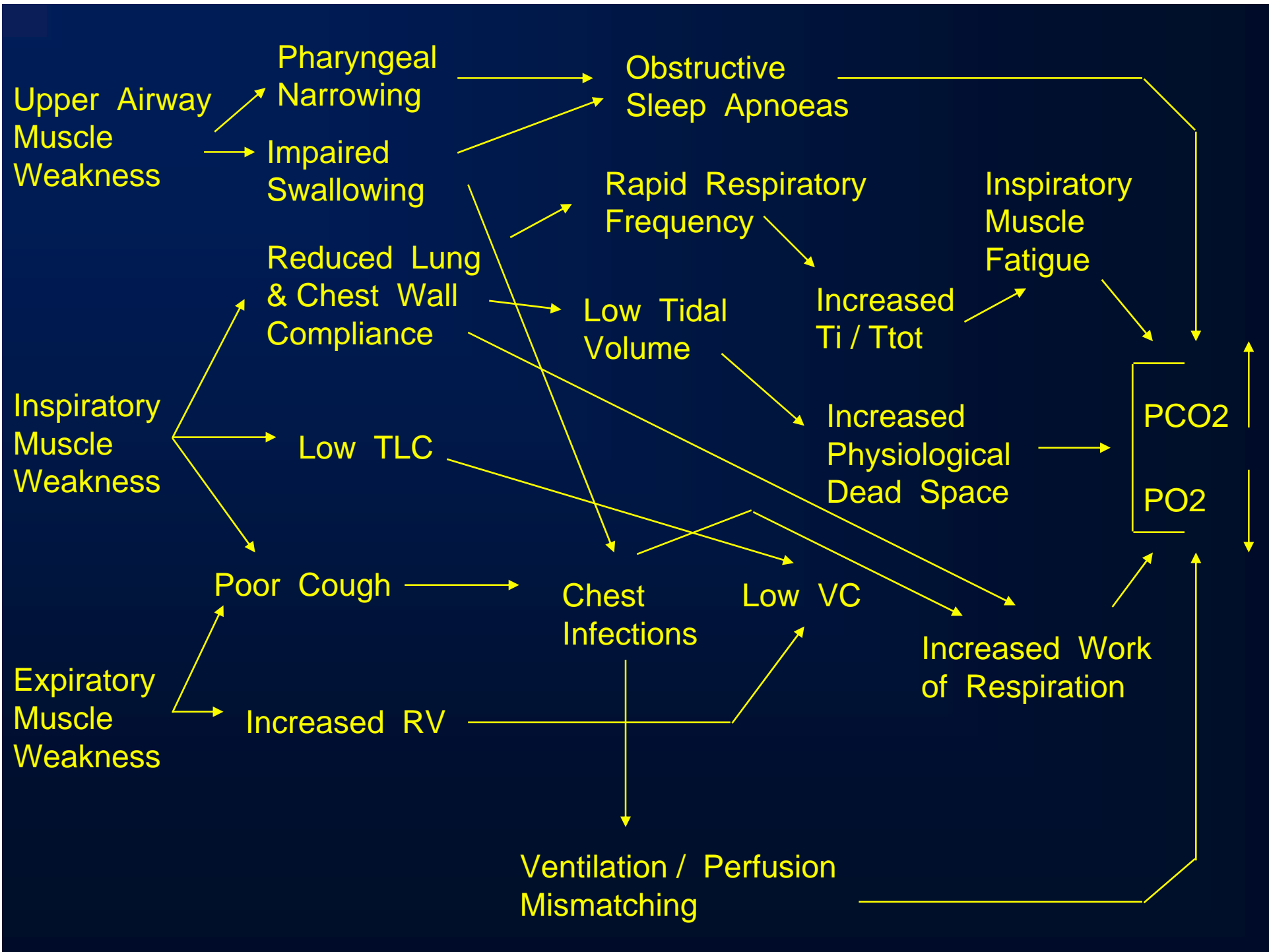
**IMPAIRED GAS
EXCHANGE**

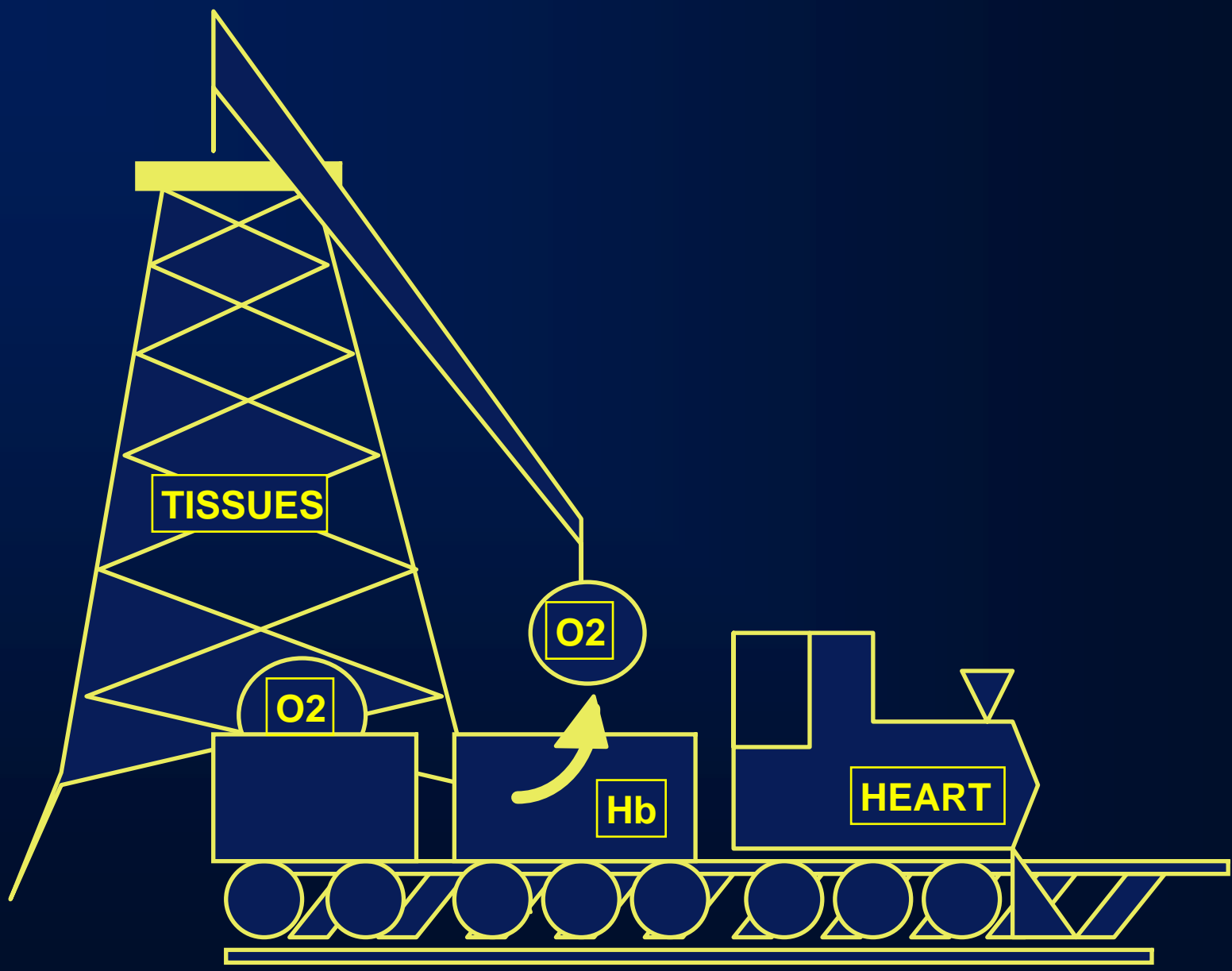
PCO₂ ↑

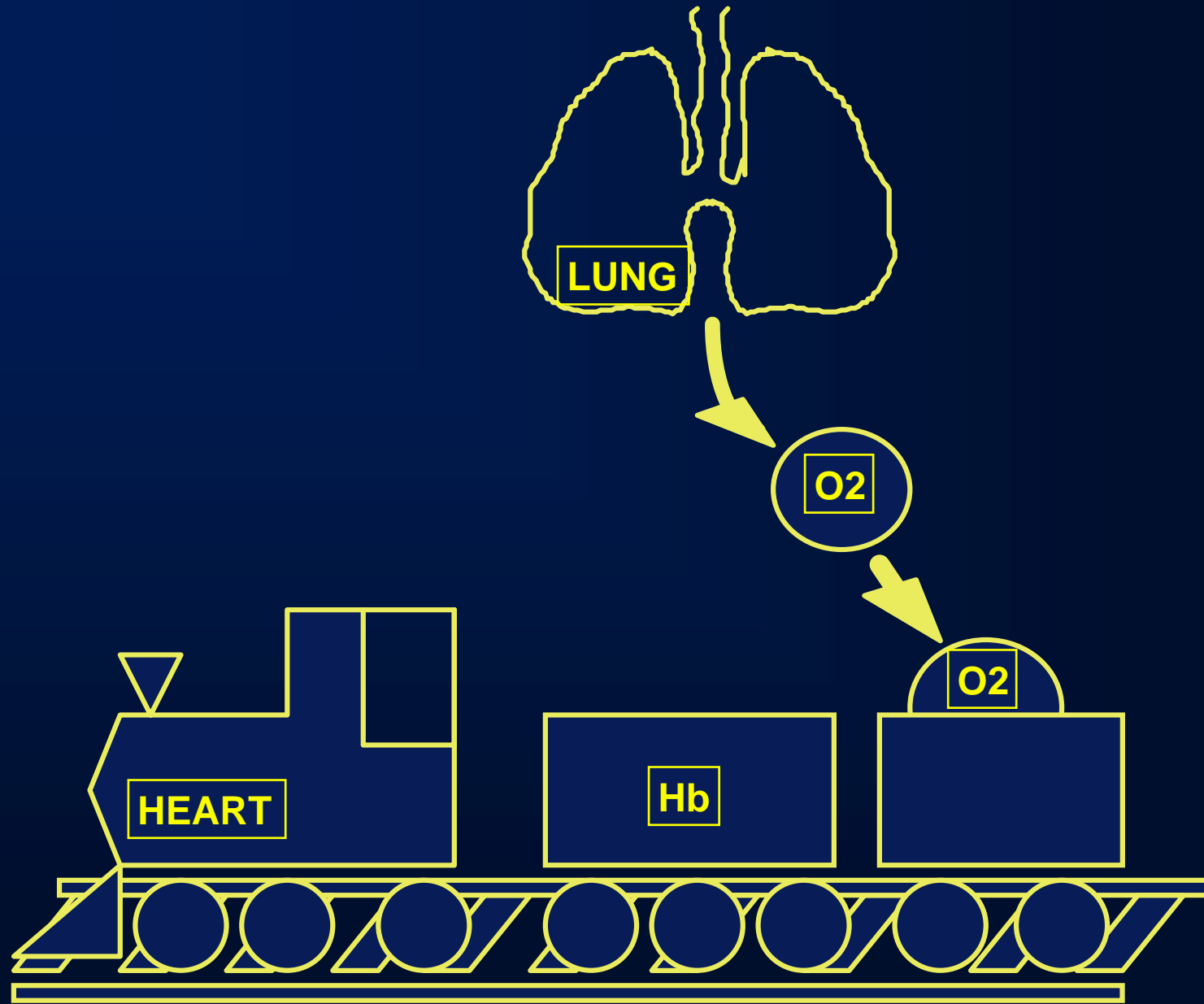
PO₂ ↓

PCO₂ Normal

PO₂ ↓



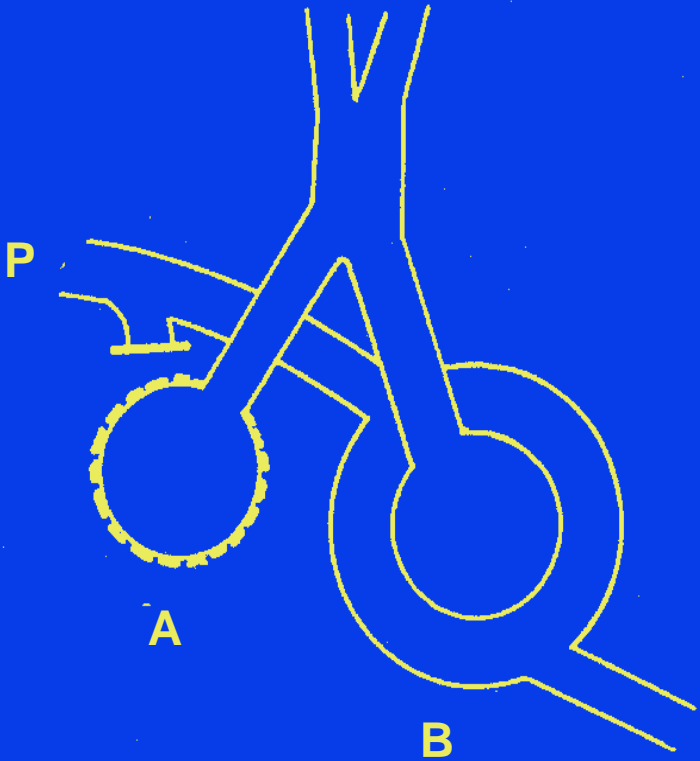




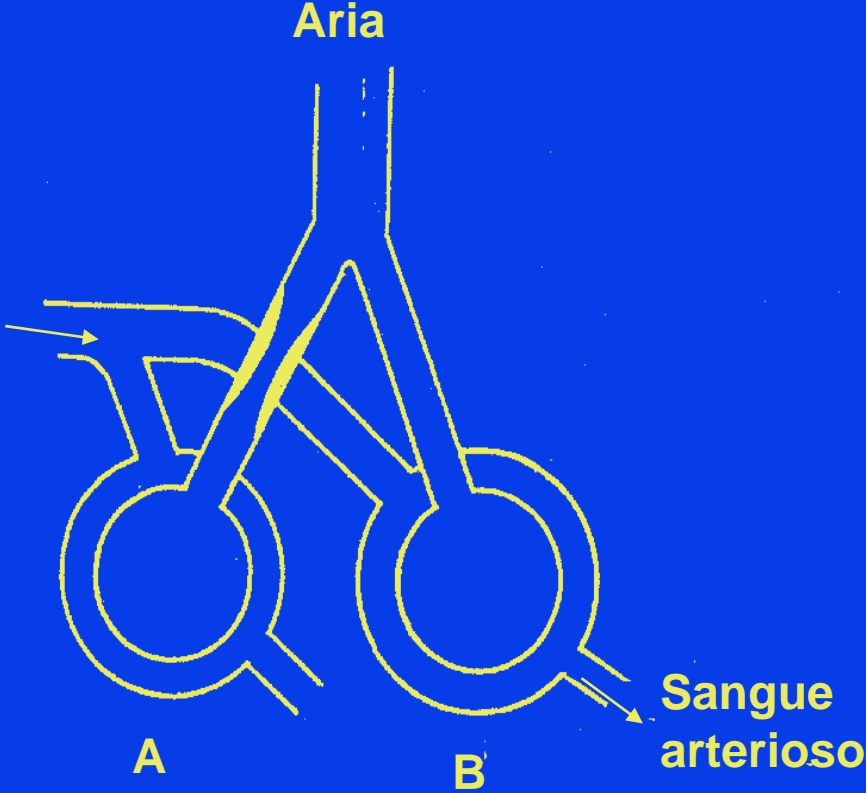
INSUFFICIENZA RESPIRATORIA



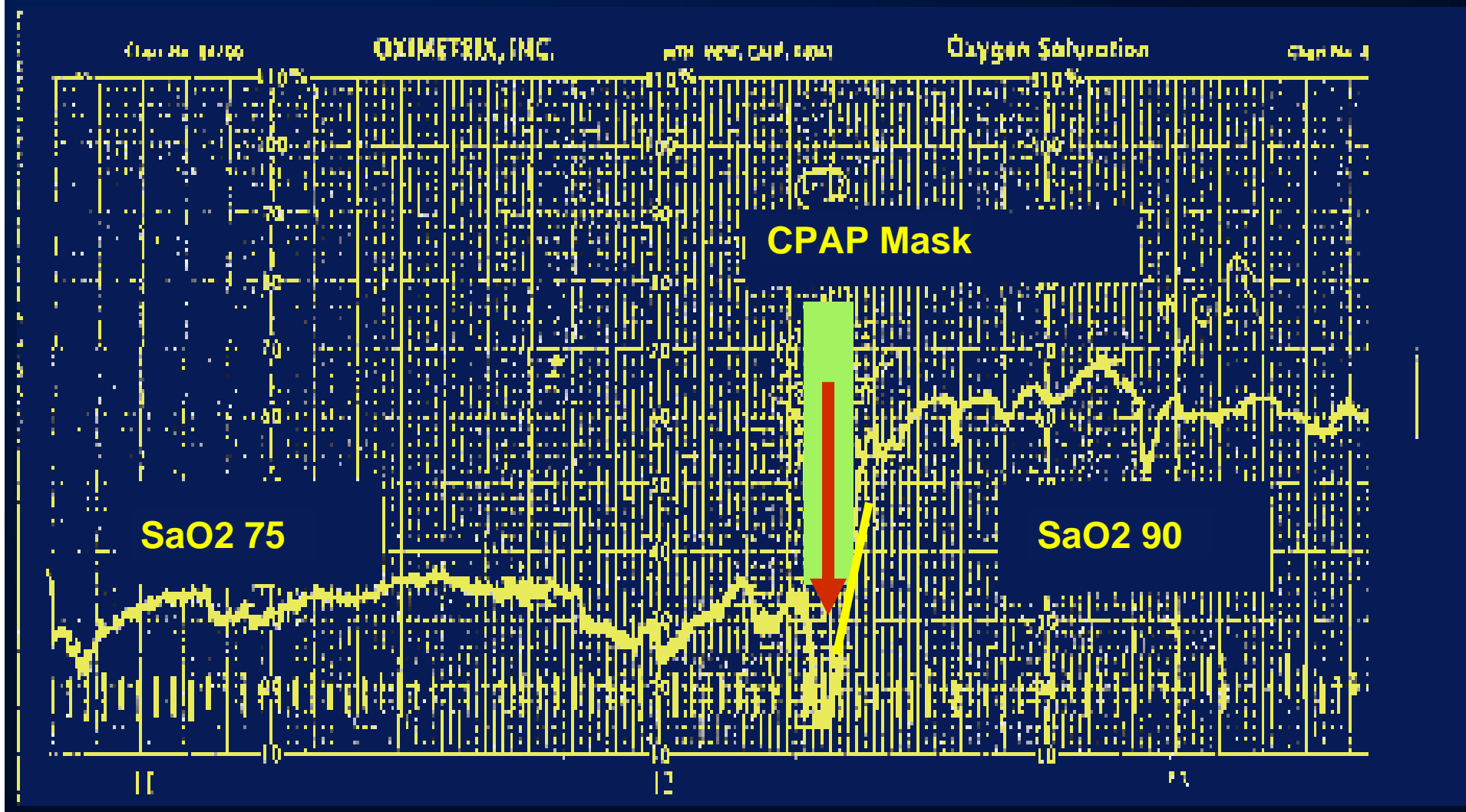
RAPPORTO VENTILAZIONE / PERFUSIONE

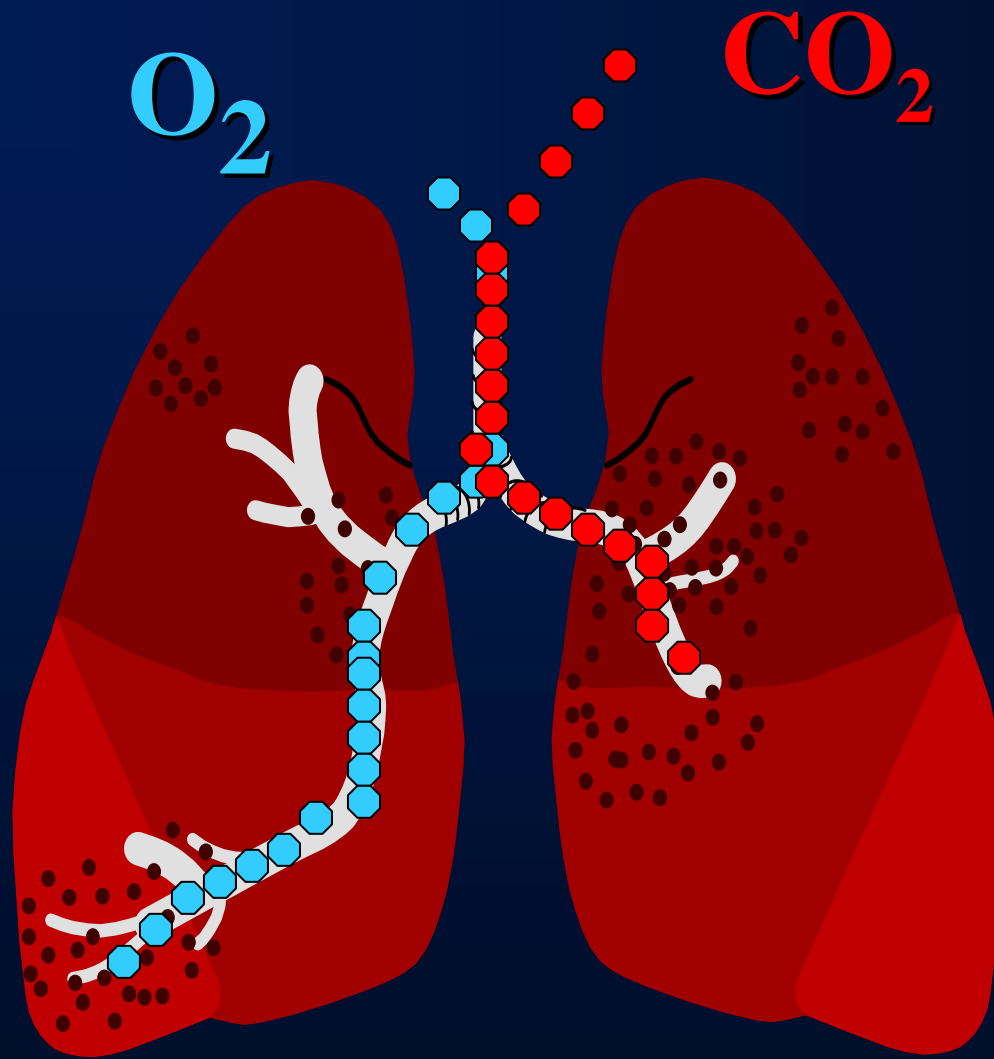


Sangue venoso misto



INSUFFICENZA VENTRICOLARE SX



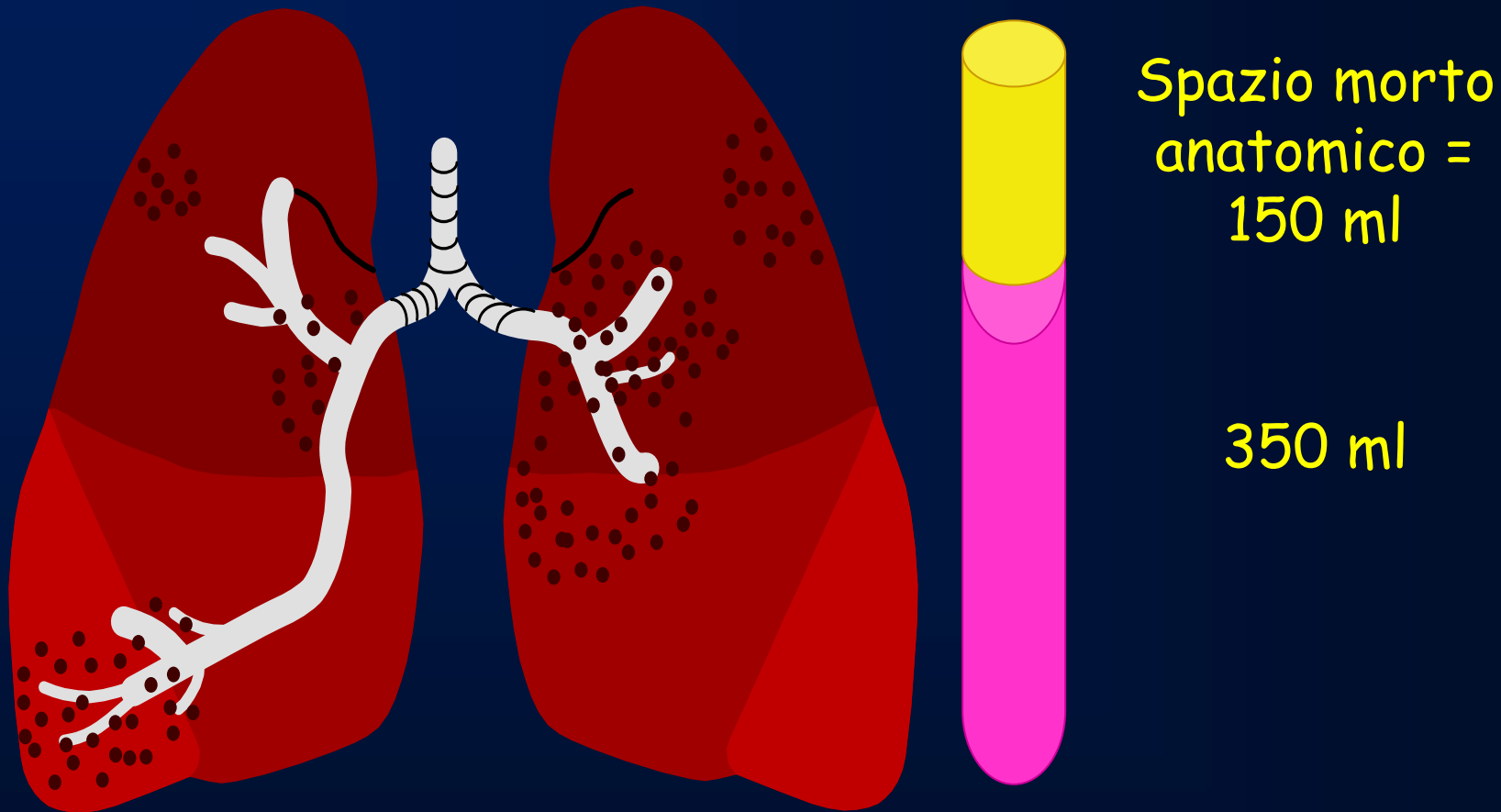


IPOSSIEMIA= $pO_2 < 60$ mmHg o $SatO_2 < 90\%$

Possibili cause:

- Ipoventilazione alveolare
- Alterazione della diffusione
- Alterazione del rapporto ventilazione/perfusione
- Shunt destro/sinistro

IPOVENTILAZIONE ALVEOLARE



1 Aumento $PaCO_2$ \Rightarrow $PaCO_2 = \frac{V_{CO_2}}{V_A}$

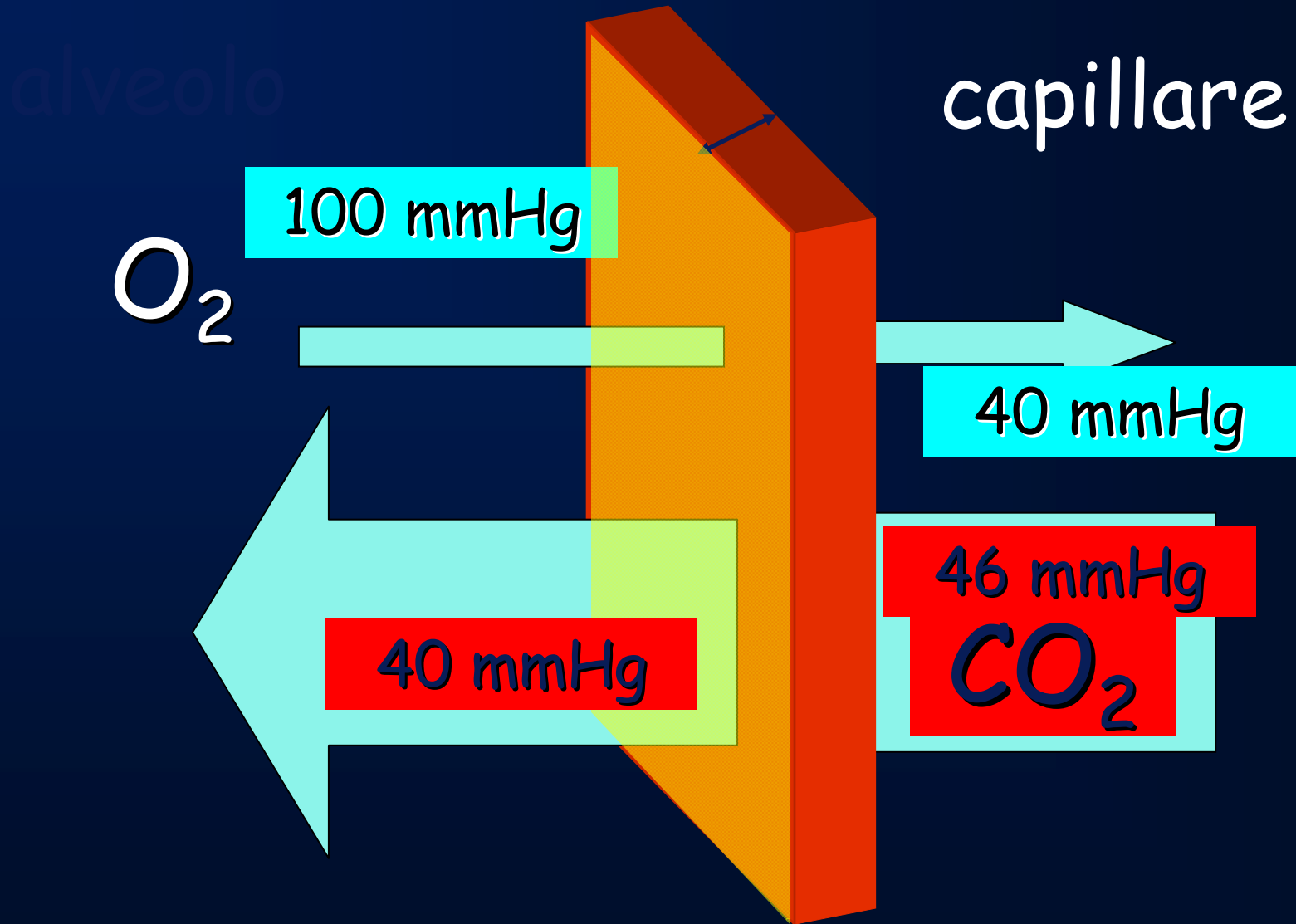
2 Somministrazione di O_2 \Rightarrow PaO_2 aumenta ■

IPOSSIEMIA= $pO_2 < 60$ mmHg o $SatO_2 < 90\%$

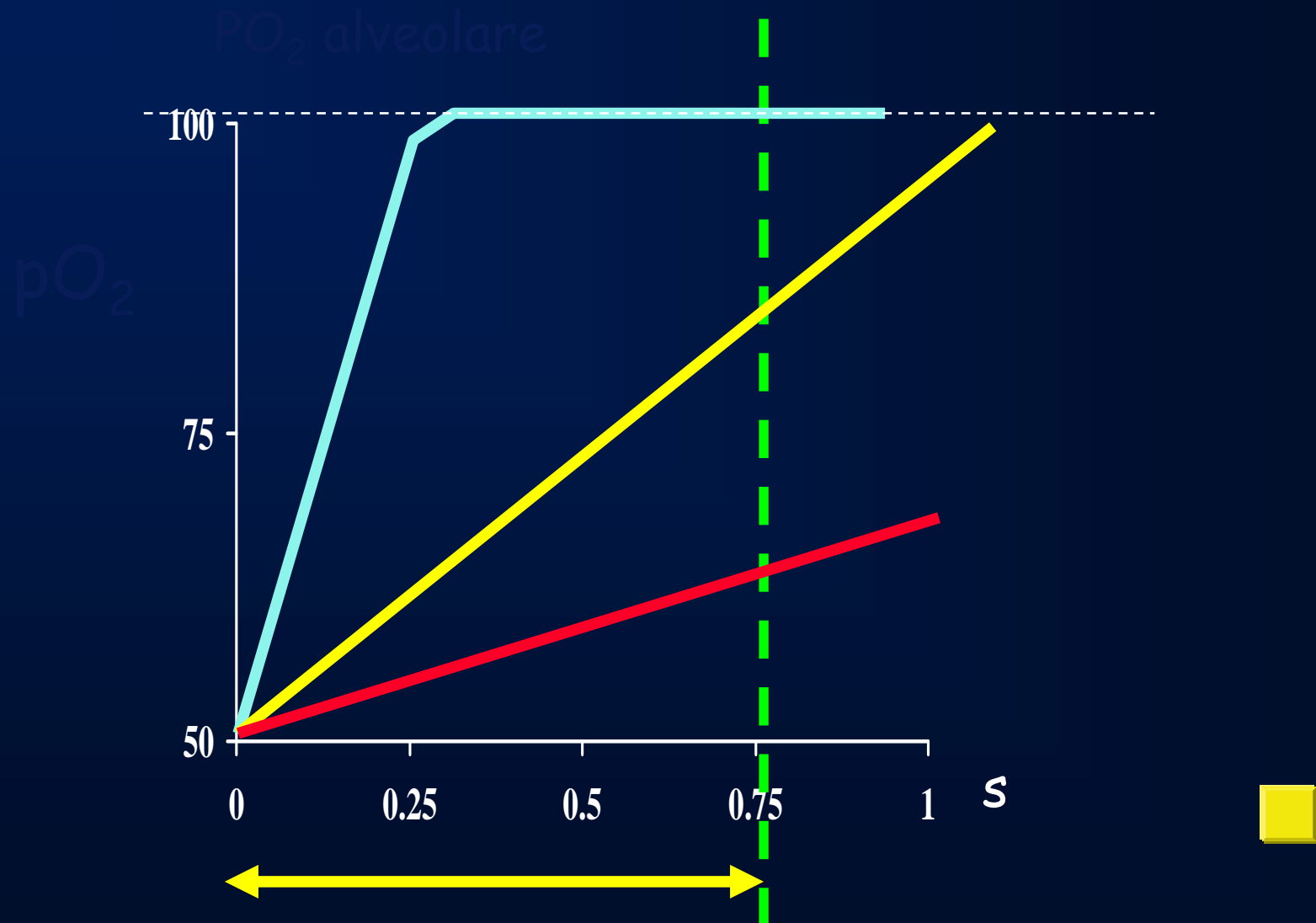
Possibili cause:

- Ipoventilazione alveolare
- Alterazione della diffusione
- Alterazione del rapporto ventilazione/perfusione
- Shunt destro/sinistro

DIFFUSIONE ALVEOLO-CAPILLARE

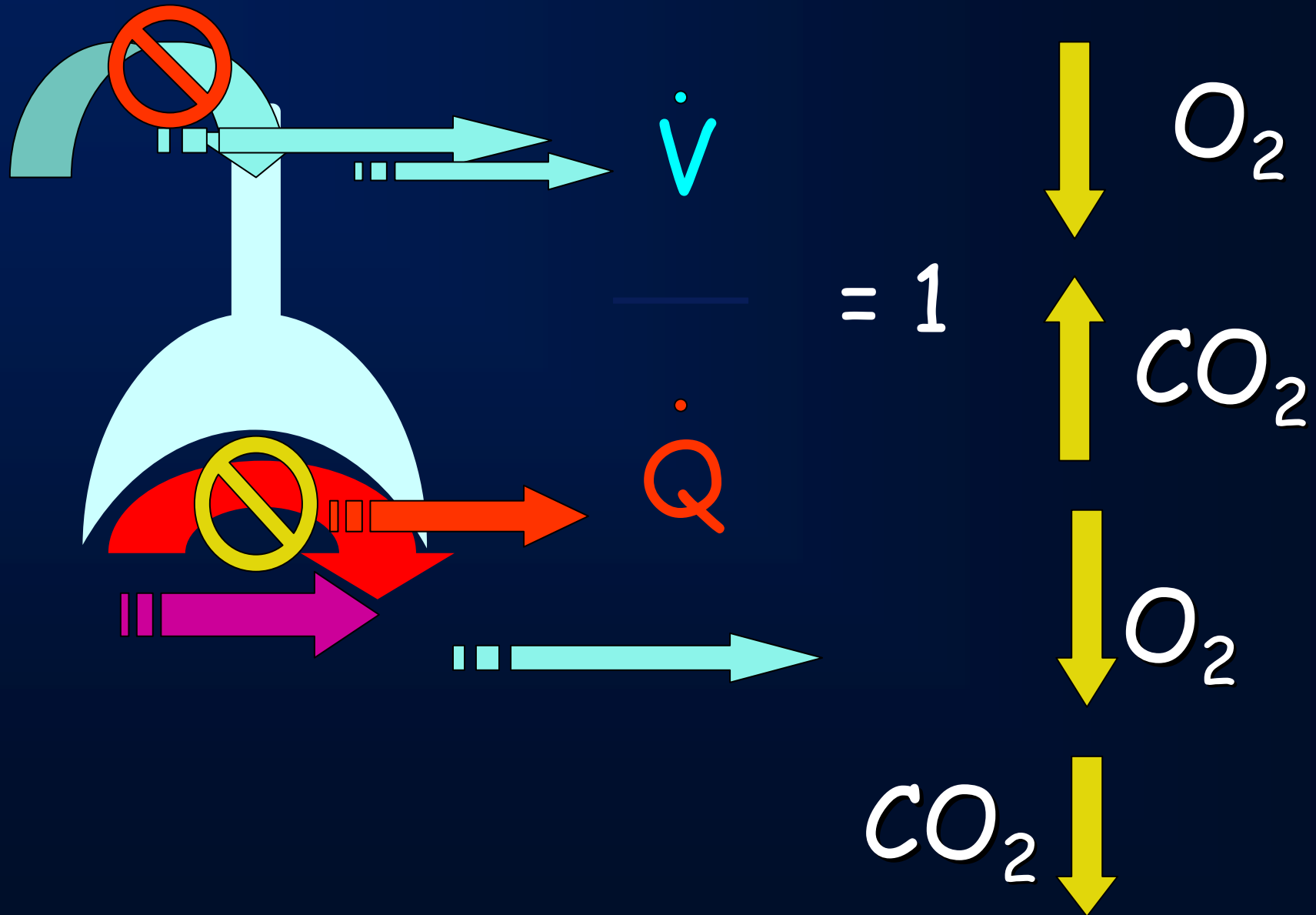


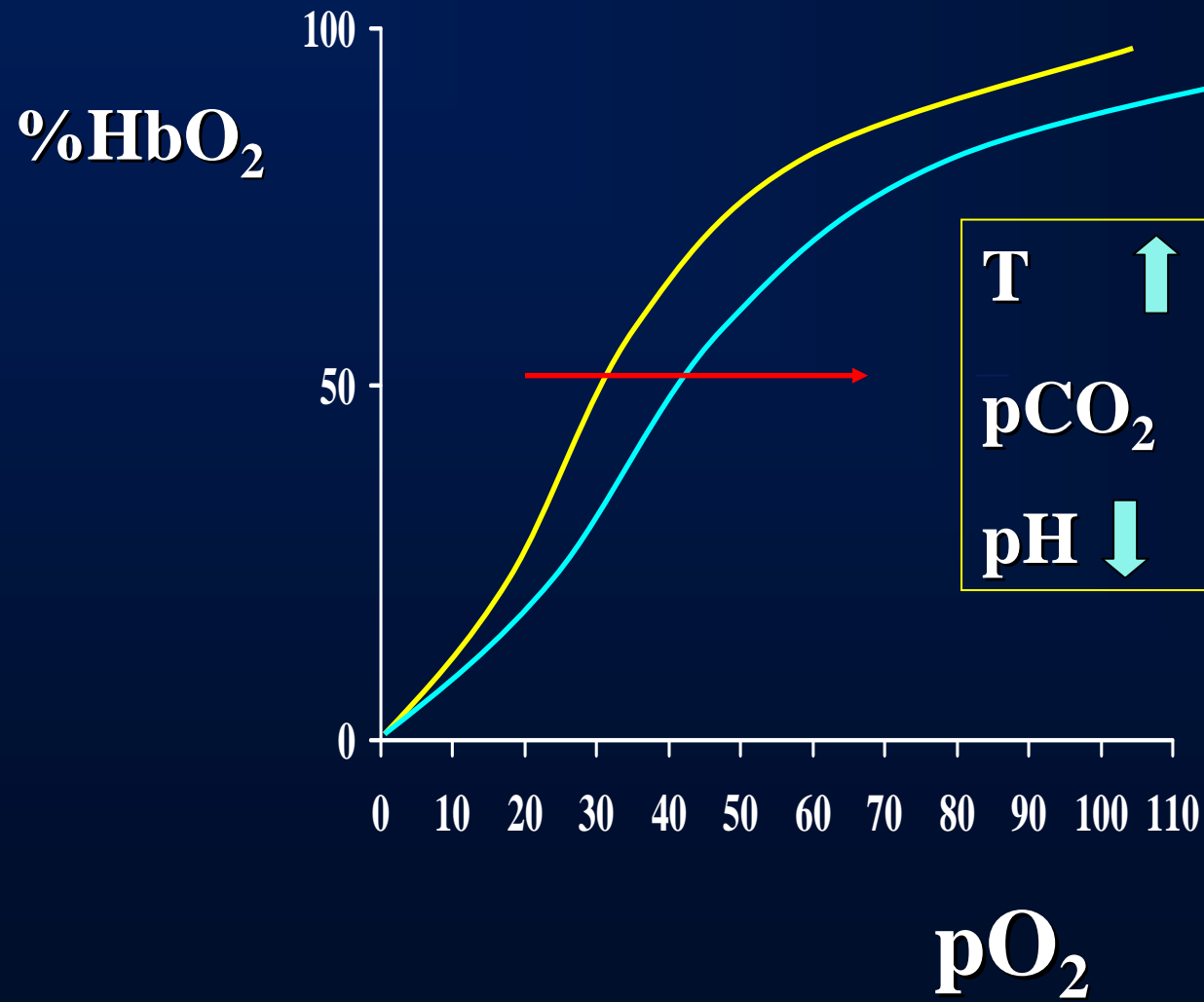
ALTERAZIONE DELLA DIFFUSIONE



Tempo di permanenza di un eritrocita nel capillare alveolare = 0.75 s

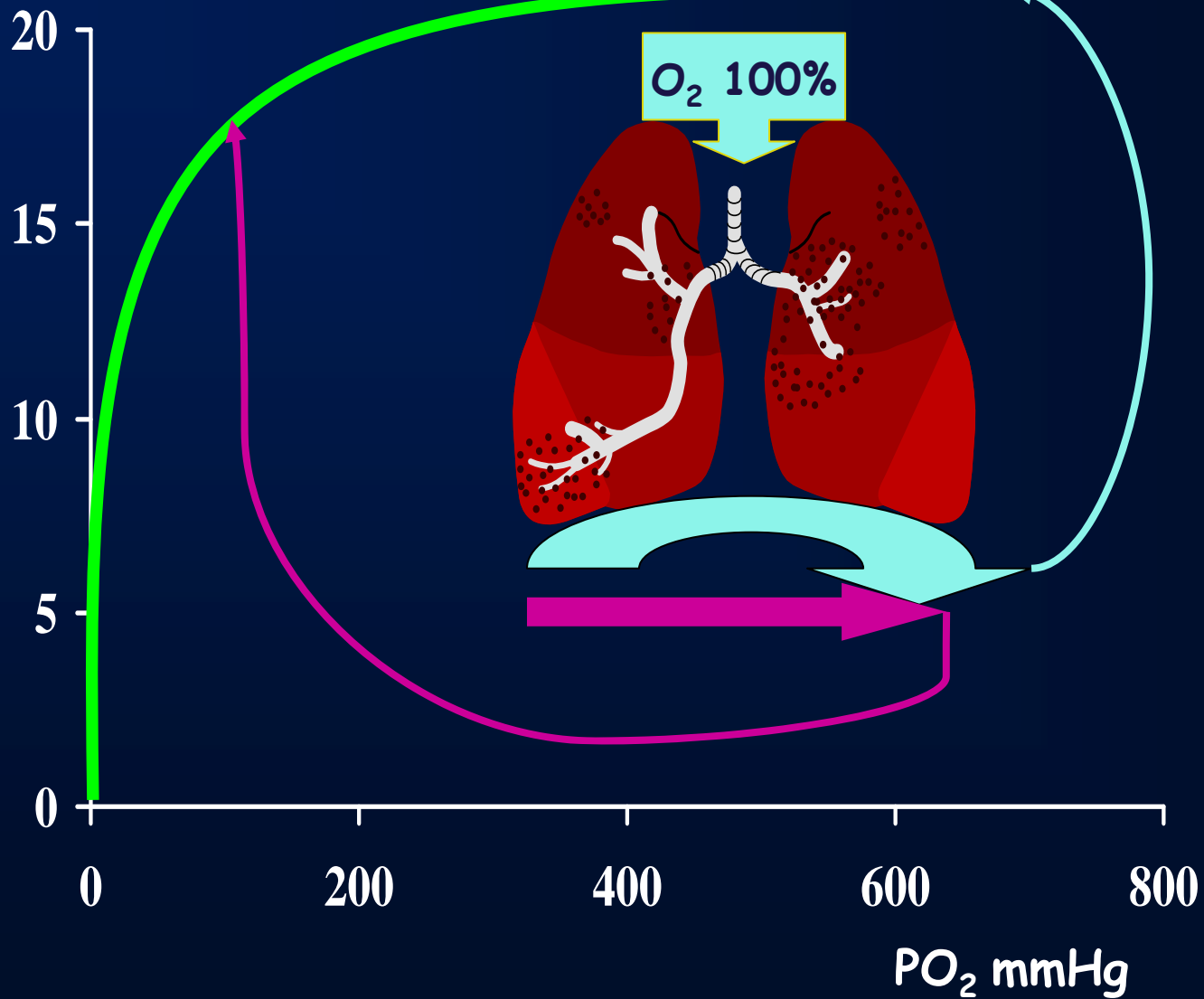
RAPPORTO VENTILAZIONE/PERFUSIONE





SHUNT

O_2
ml/100 ml

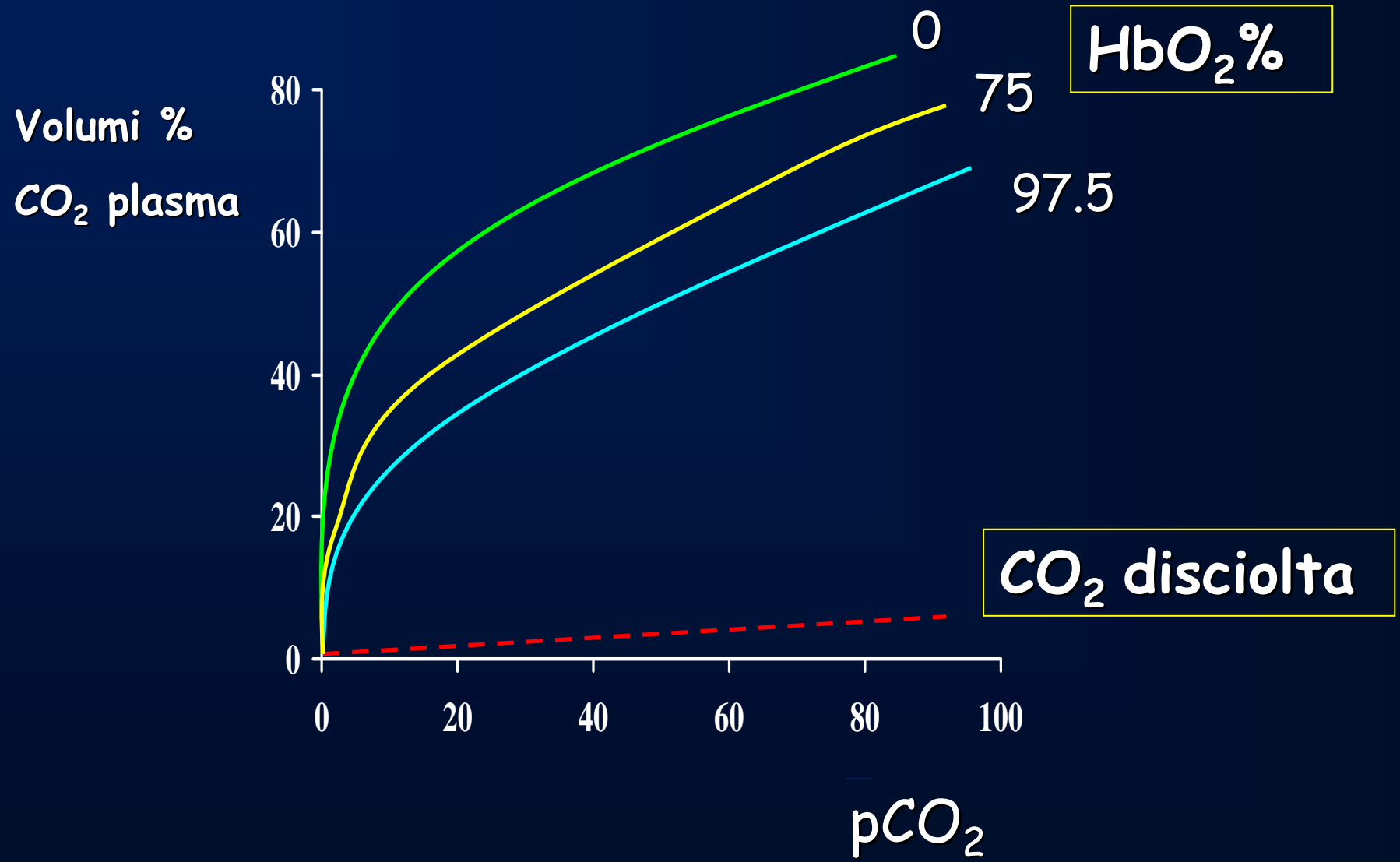


PCO_2 arteriosa = 35-45 mmHg

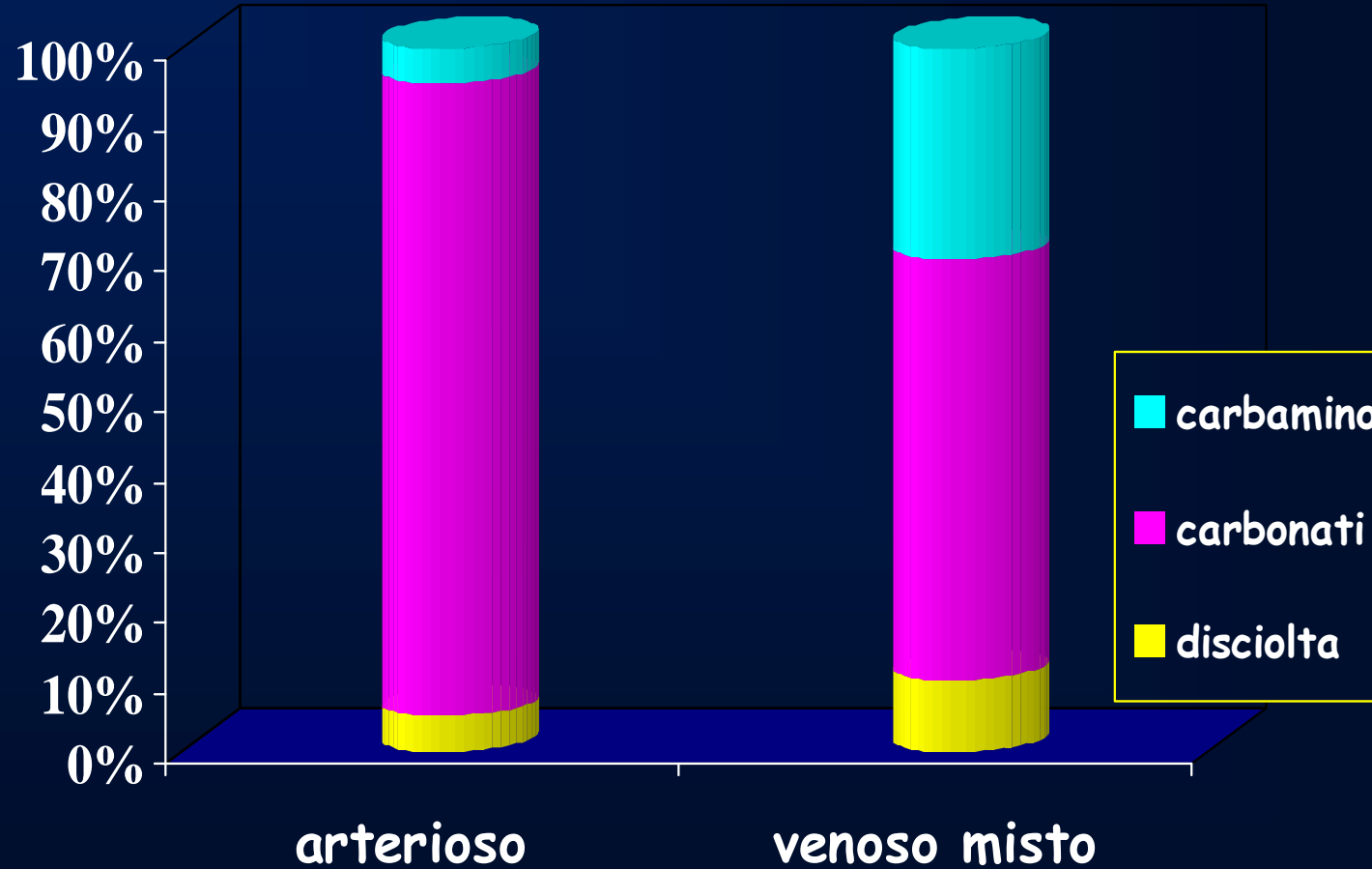


Ventilazione $\Rightarrow PaCO_2 = \frac{VCO_2}{V_A}$

- Ipoventilazione
- Alterazione ventilazione/perfusione



CO₂ nel sangue



Equilibrio acido-base



$$\text{pH arterioso} = \text{pK} + \log \frac{(\text{HCO}_3^-)}{\text{PCO}_2} = 7.4$$

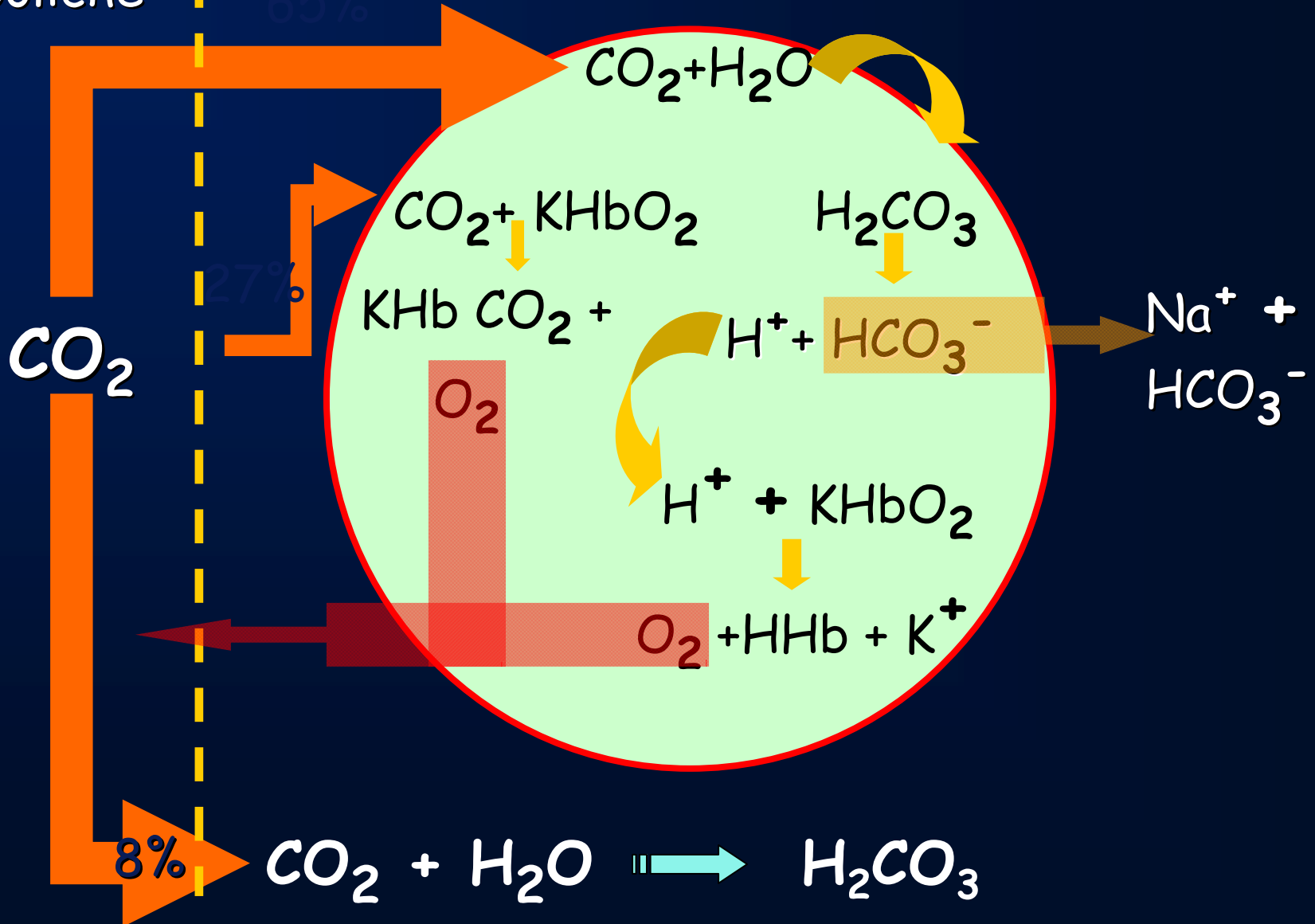
Acidosis = pH ↓ (<7.35)

Alcalosis = pH ↑ (>7.45)

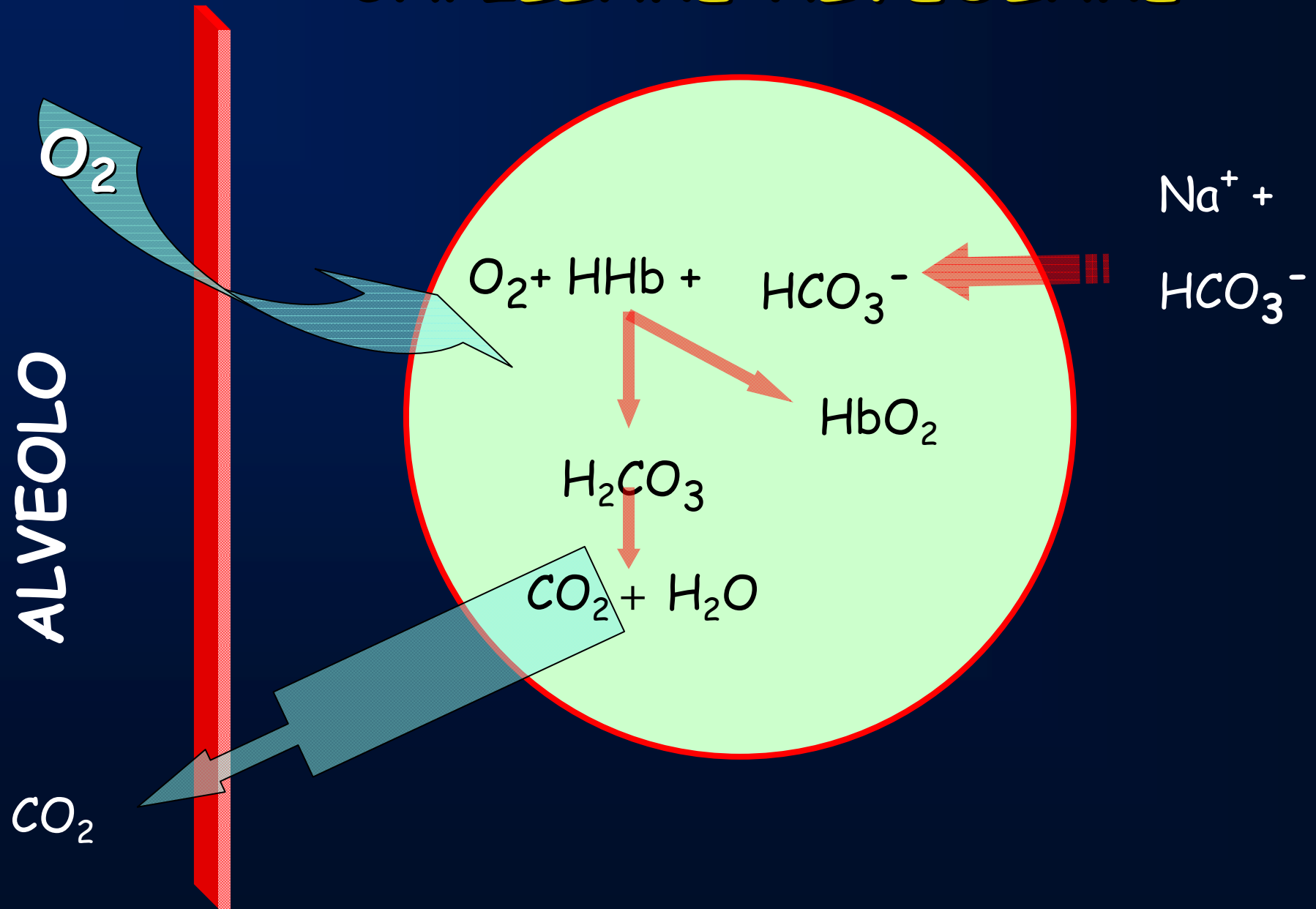
PERIFERIA

Reazioni cataboliche

TESSUTI



CAPILLARE ALVEOLARE



pH 7.30

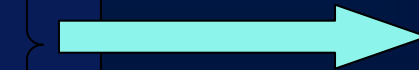
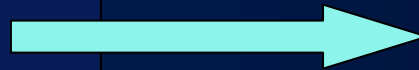
PaCO₂ 75

PaO₂ 60

HCO₃⁻ 33

BE 5

O₂ sat 91%



acidosi

ipercapnia

ipossiemia

Sistemi
tampone alti



**ACIDOSI
RESPIRATORIA**

pH 7.30



acidosi

PaCO₂ 30



ipocapnia

PaO₂ 68



normossiemia

HCO₃⁻ 18



Sistemi

BE -4



tampone bassi

O₂ sat 94%

**ACIDOSI
METABOLICA**



pH 7.50

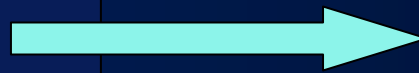
PaCO₂ 24

PaO₂ 68

HCO₃⁻ 18

BE -4

O₂ sat 94%



alcalosi

ipocapnia

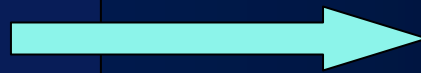
normossiem

Sistemi
tampone bassi



**ALCALOSI
RESPIRATORIA**

pH 7.50



alcalosi

PaCO₂ 55



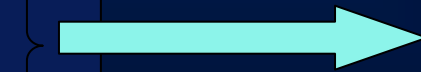
ipercapnia

PaO₂ 68



normossiem

HCO₃⁻ 42



Sistemi

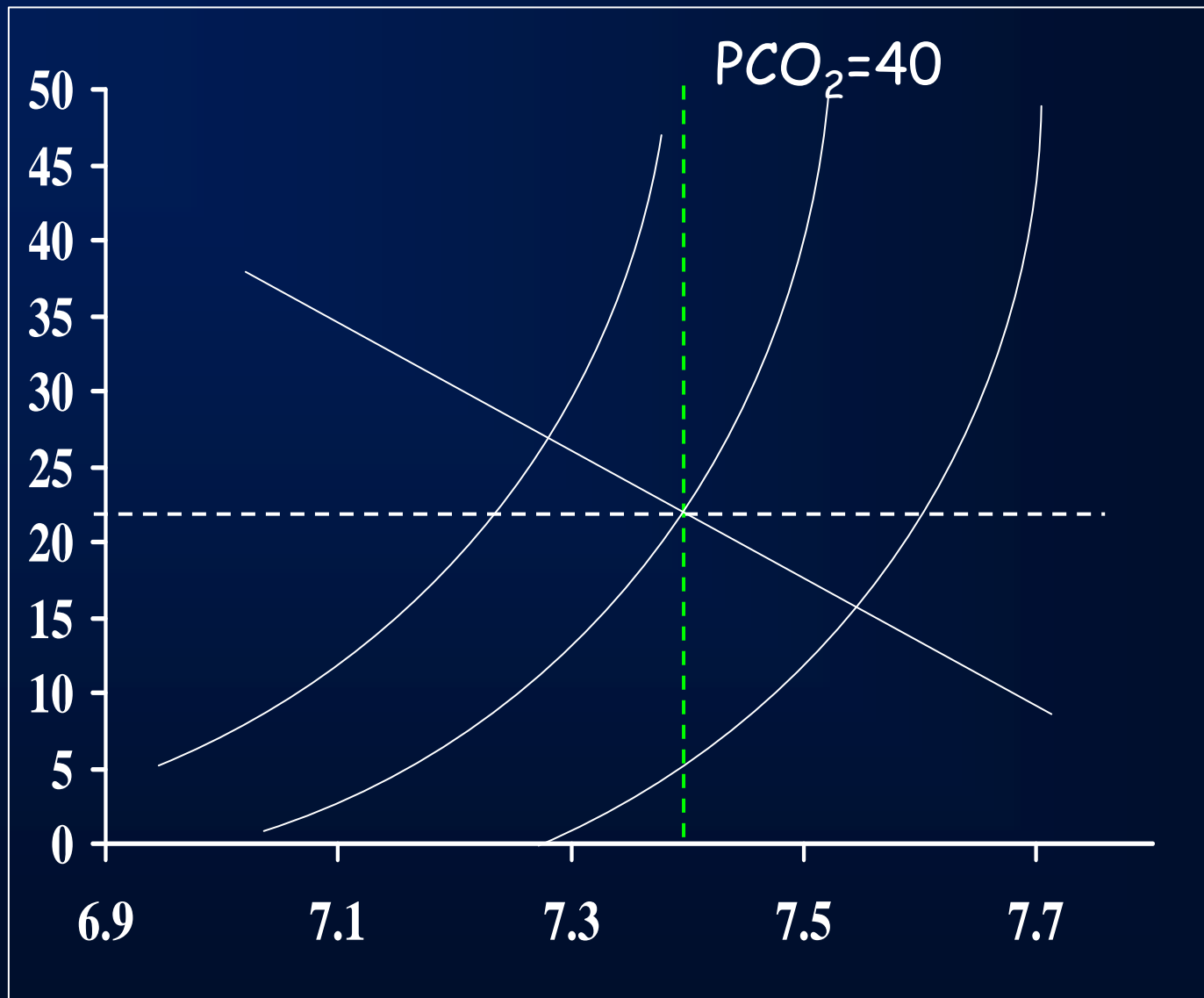
BE 14

tampone alti

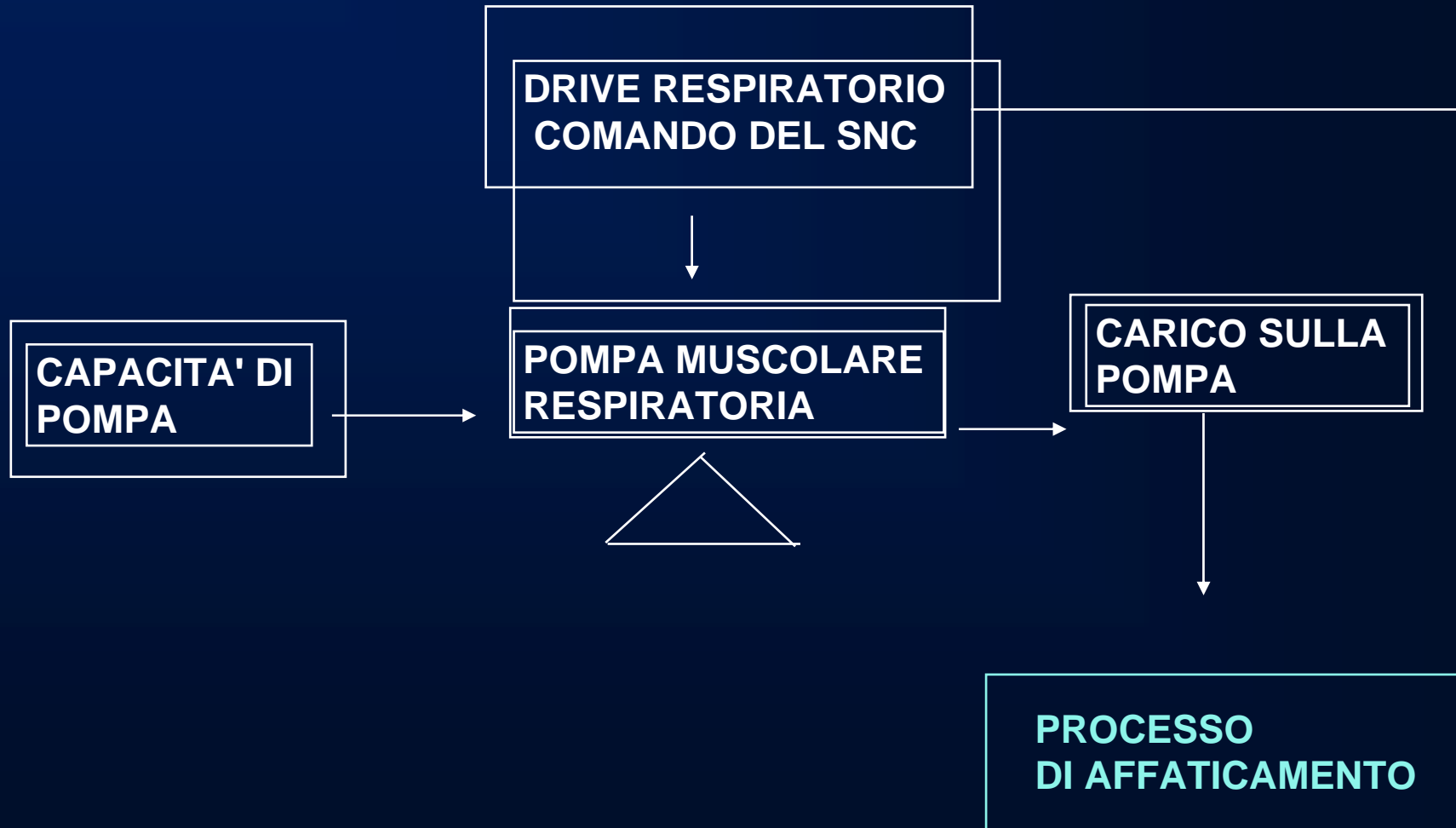
O₂ sat 94%



**ALCALOSI
METABOLICA**



POMPA RESPIRATORIA



SCOLIOSI

DEFORMITA' DELLA CASSATORACICA

**ALTERATA FUNZIONE E STRUTTURA
SISTEMA RESPIRATORIO**



COMPLIANCE

SVANTAGGI MECCANICA

MALDISTRIBU.

VASI POLMO.

MUSCOLI INSPIR.

VENT/PERF.

**RIDOTTA RISPOSTA
CO2**

FATICA MM

**AUMENTO RICHIESTA
ventilatoria Vd/Vt A-a D02**

ETA'

**iperter
polmo**

IPOSSIEMIA IPERCAPNIA

INSUFFICIENZA RESPIRATORIA

FARMACI

FATT.METABOLICI SNC

BPCO MALAT. RESTRIT.

DRIVE CENTRALE

ECESSIVO CARICO
MUSCOLI RESPIRATORI

INSUFFICIENZA RESPIRATORIA

ENDURANCE INADEGUATA DEI
MUSCOLI RESPIRATORI

MALNUTRIZIONE

MAL.NEUROMUSCOLARI

FATT.METAB.

IPERINFLAZIONE

COPD

> RESISTANCES

< RECOIL

< FLOW , HYPERINFLATION , V/Q ABNORM.
EXACERBATION

viral bacterial
irritants

fluid imbalance
cardiac dysfunction

exudate, inflammation
muscle constriction

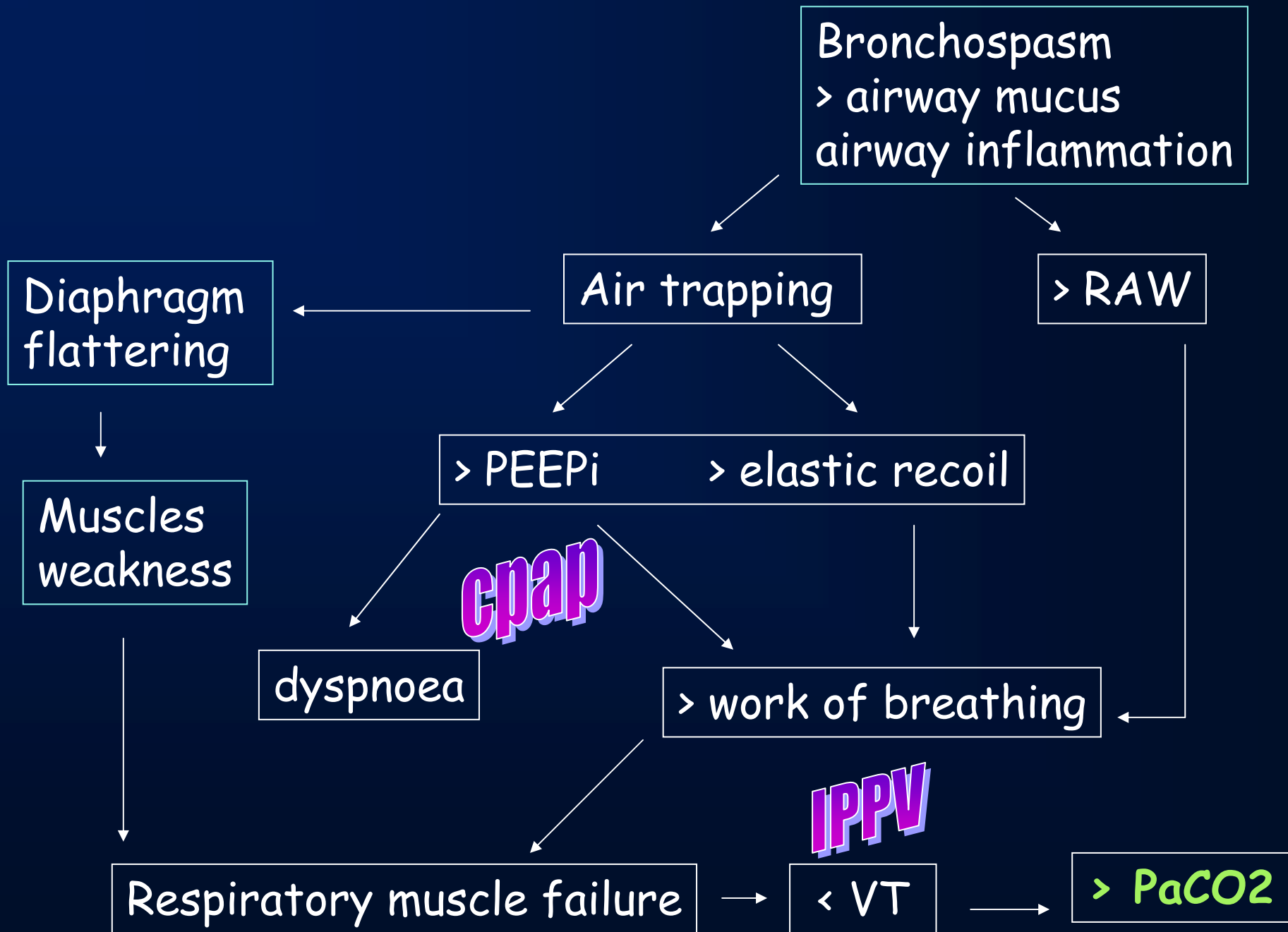
lung oedema
recoil uncoupling

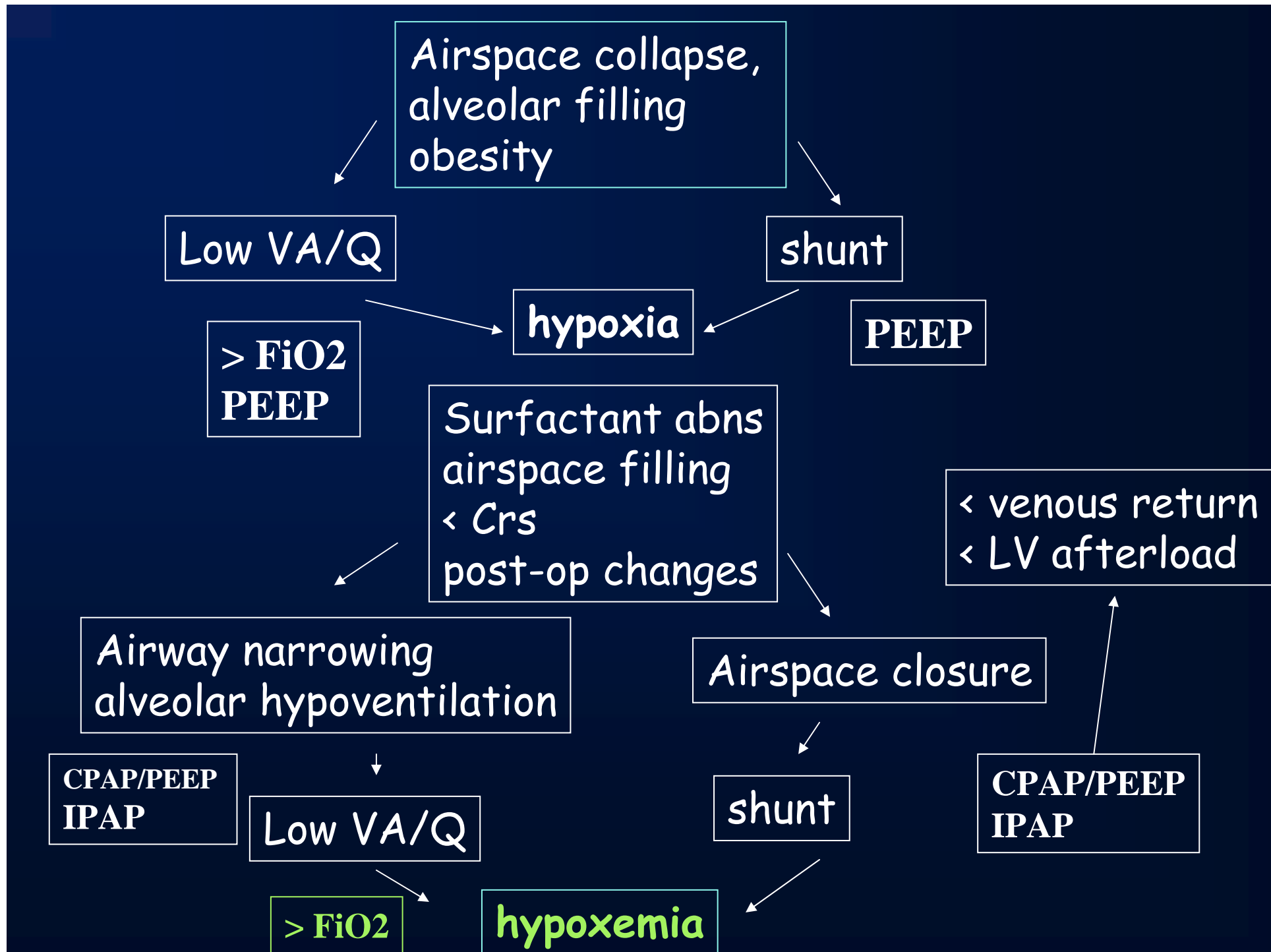
< AIRWAY DIAMETER

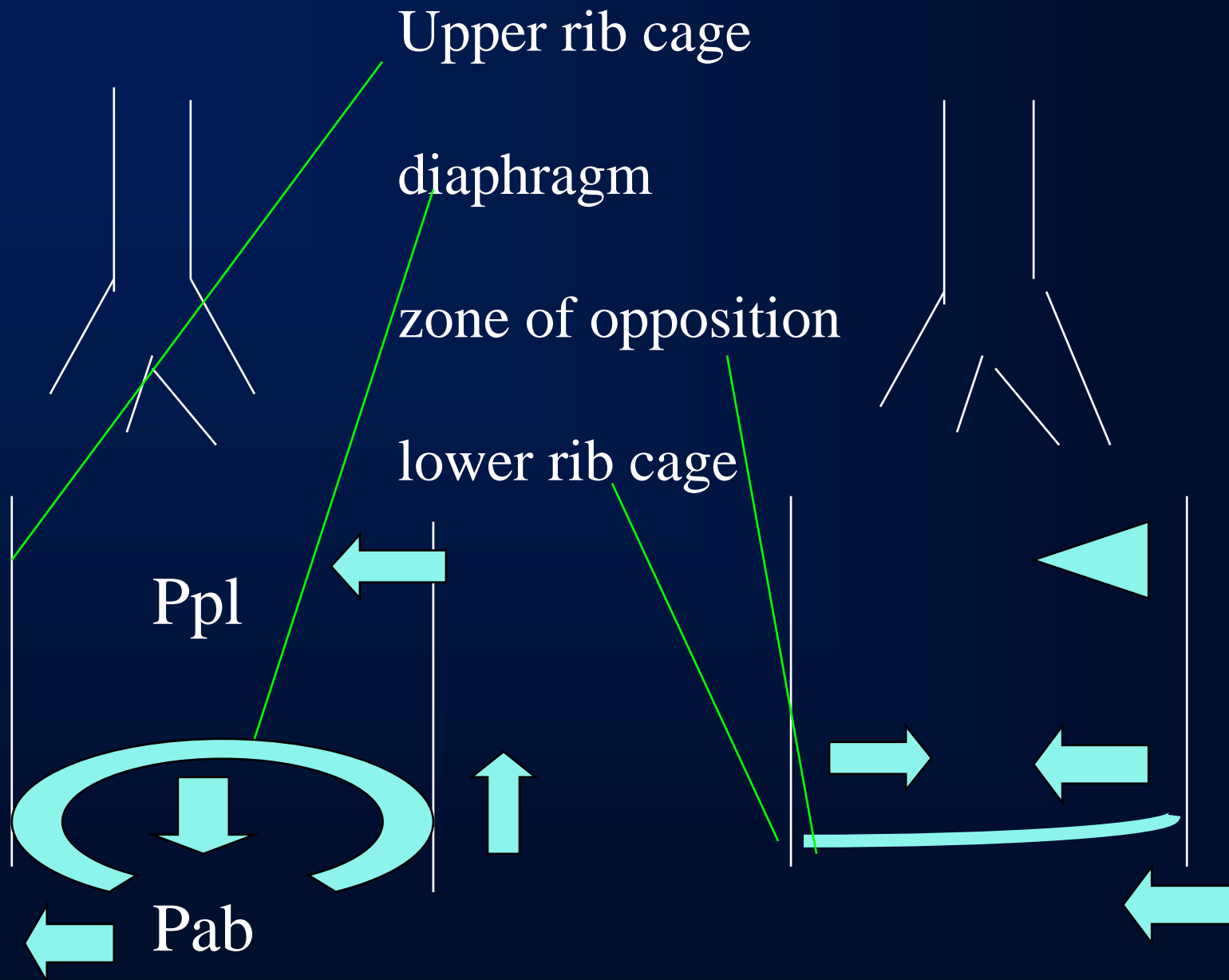
> resistances, muscle impair.

Hyperinflation, V/Q abnorm

VENTILATORY FAILURE







EFFETTI DELLA IPERINFLAZIONE SUL DIAFRAMMA

- **LUNGHEZZA (meccanismo di adattamento)**
- **GEOMETRIA (legge di Laplace)**
- **GRANDEZZA DELLA COMPONENTE OPPOSIZIONALE E INSERZIONALE DELL'AZIONE DIAFRAMMATICA**
- **EFFETTI DELLE DIFFERENTI PARTI DEL DIAFRAMMA (arrangiamento meccanico)**

Pimax
(cmH2O)

-125

-75

-25

% della CPT

0

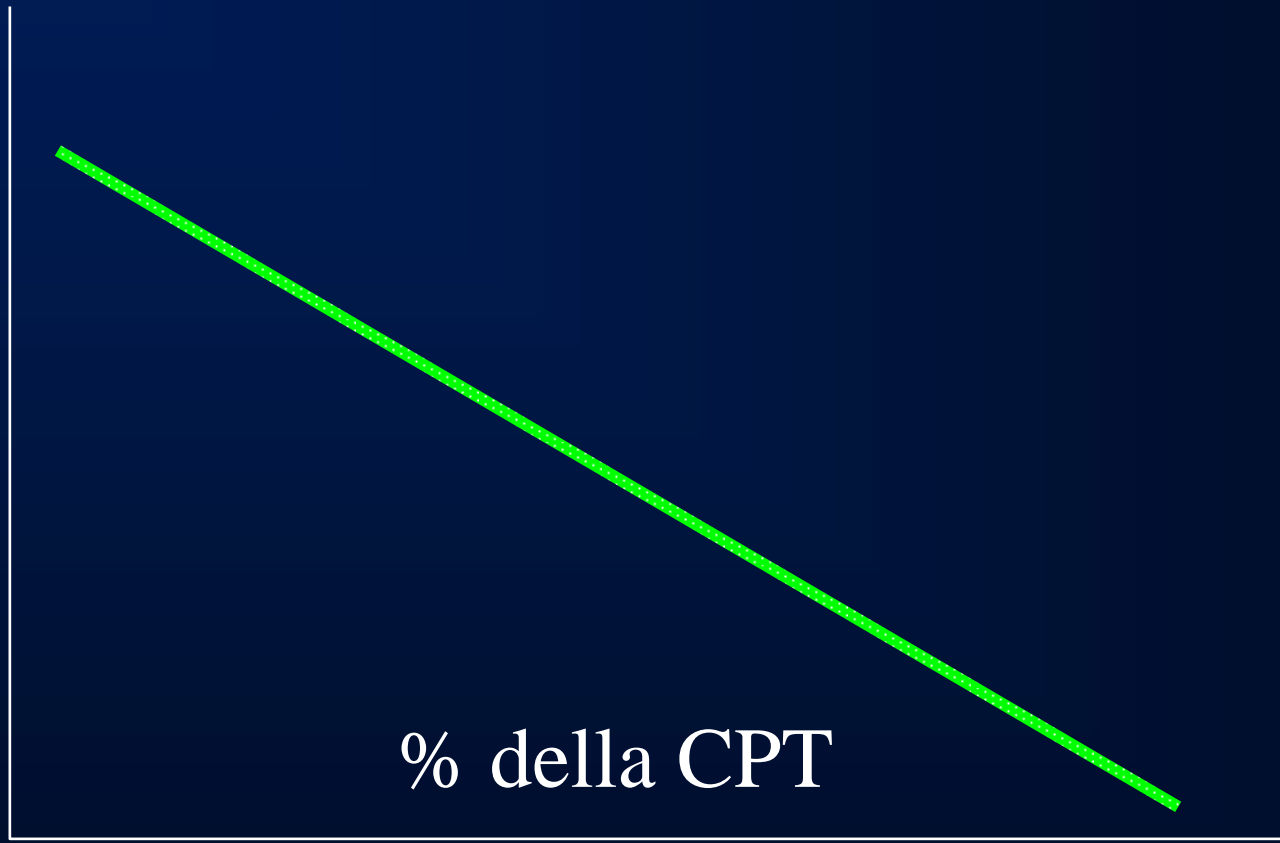
50

75

100

125

150



INSUFFICIENZA RESPIRATORIA

```
graph TD; A[INSUFFICIENZA RESPIRATORIA] --> B[INSUFFICIENZA DI POMPA TORACICA]; A --> C[INSUFFICIENZA DI PARENCHIMA]; B --> D[IPOVENTILAZIONE ALVEOLARE]; C --> E[ALTERATI SCAMBI GASSOSI]; D --> F["↑ PaCO2<br/>↓ PaO2"]; E --> G["= PaCO2<br/>↓ PaO2"];
```

INSUFFICIENZA DI
POMPA TORACICA

IPOVENTILAZIONE
ALVEOLARE

↑ PaCO₂
↓ PaO₂

INSUFFICIENZA DI
PARENCHIMA

ALTERATI SCAMBI
GASSOSI

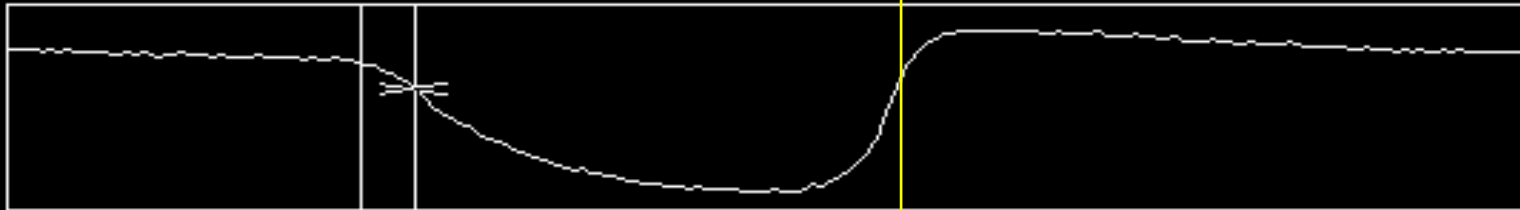
= PaCO₂
↓ PaO₂

SPONTANEOUS BREATHING

FLOW
(L/m)



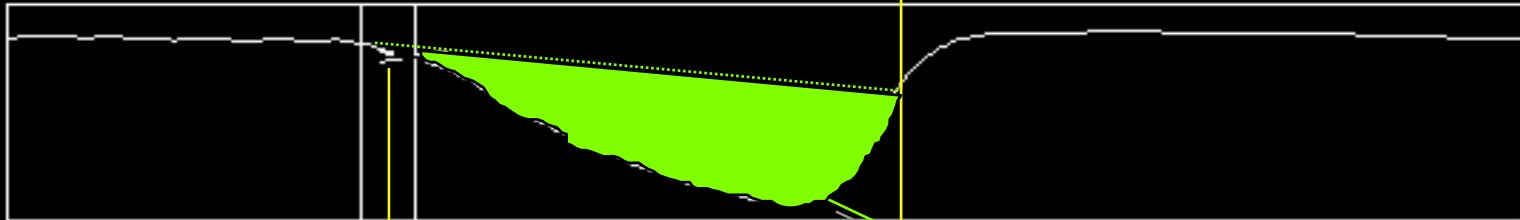
PAO
(cmH2O)



VT
(ml)



PES
(cmH2O)



.4

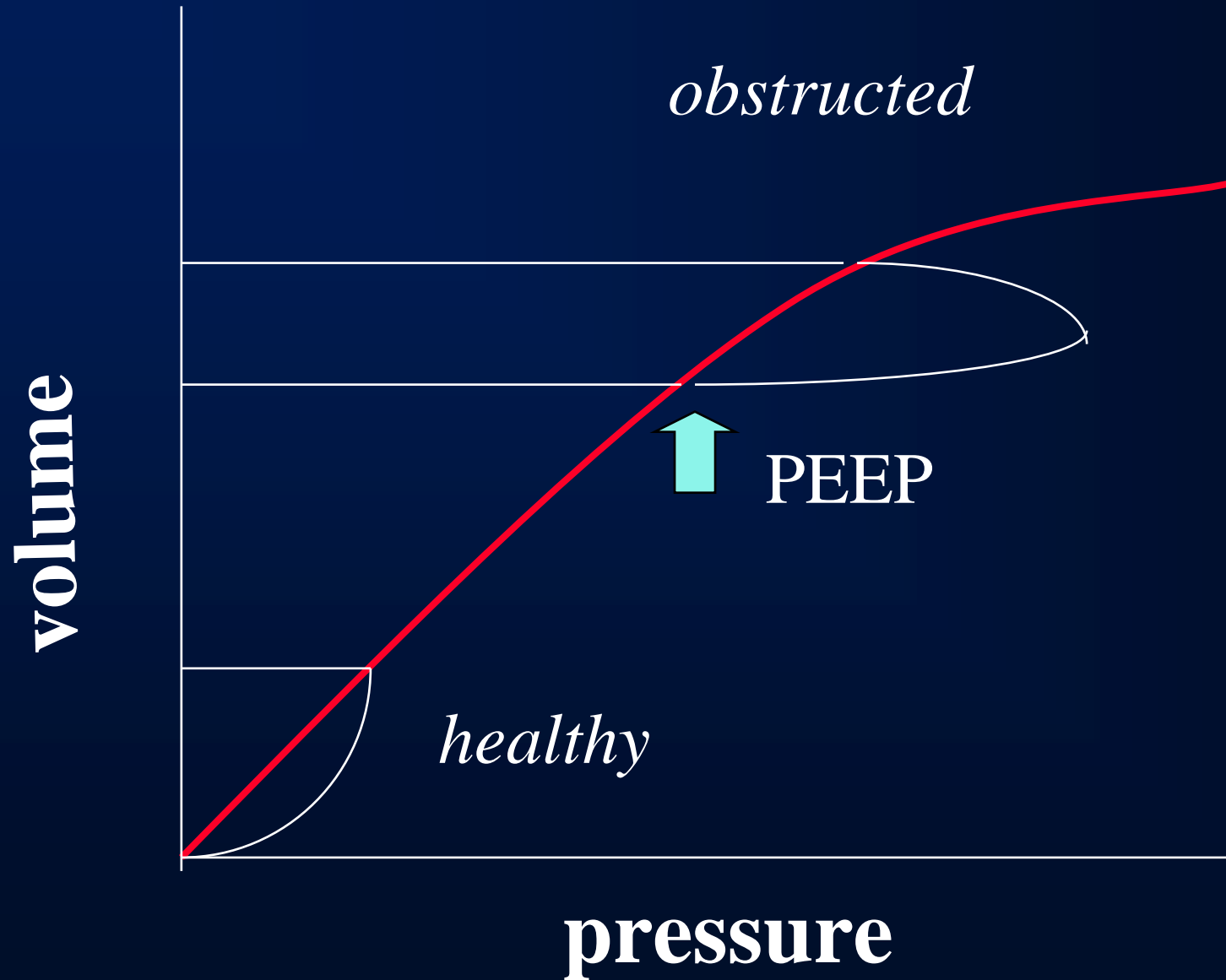
27.4

Time (s)

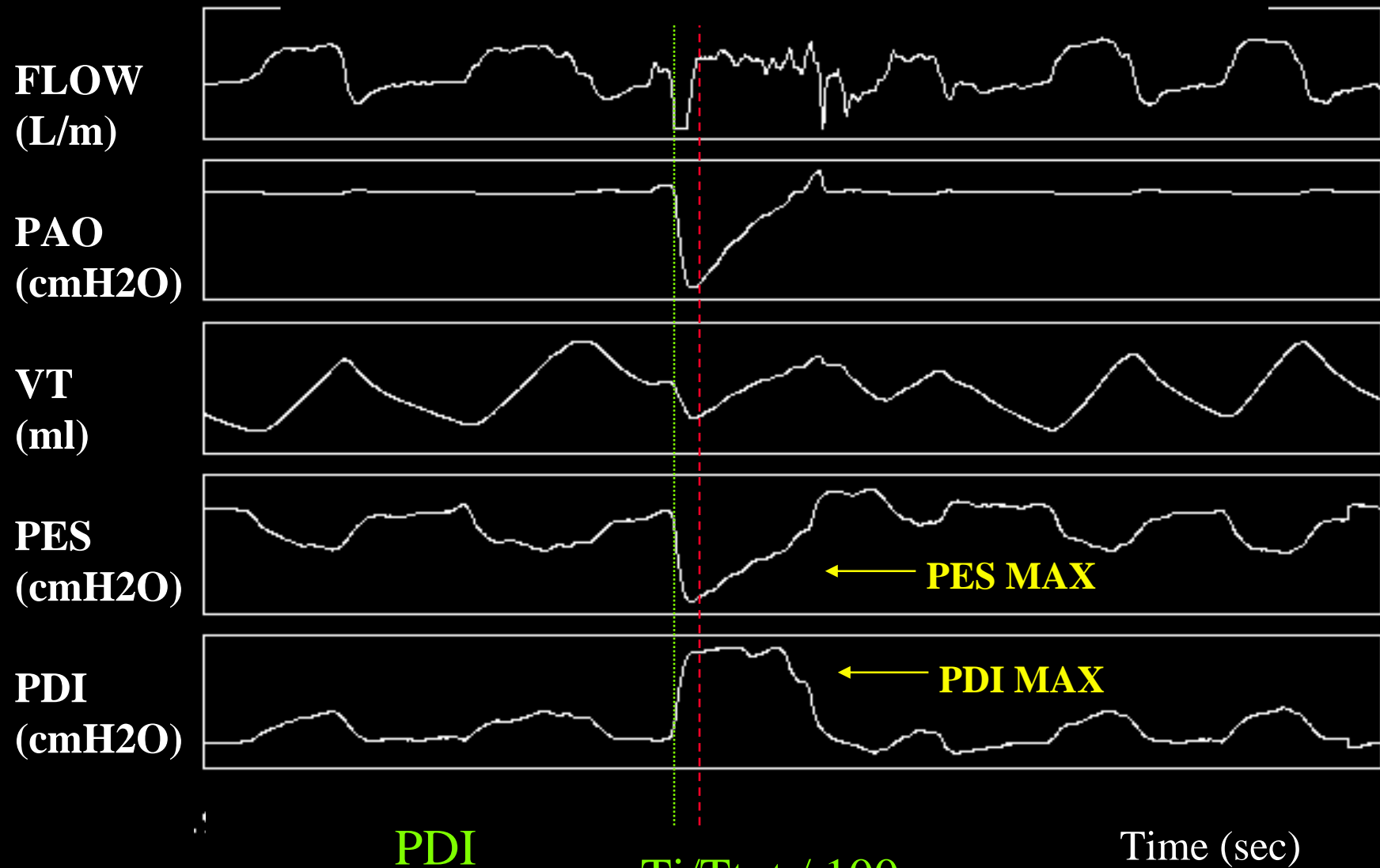
Peepi dyn

PTP es

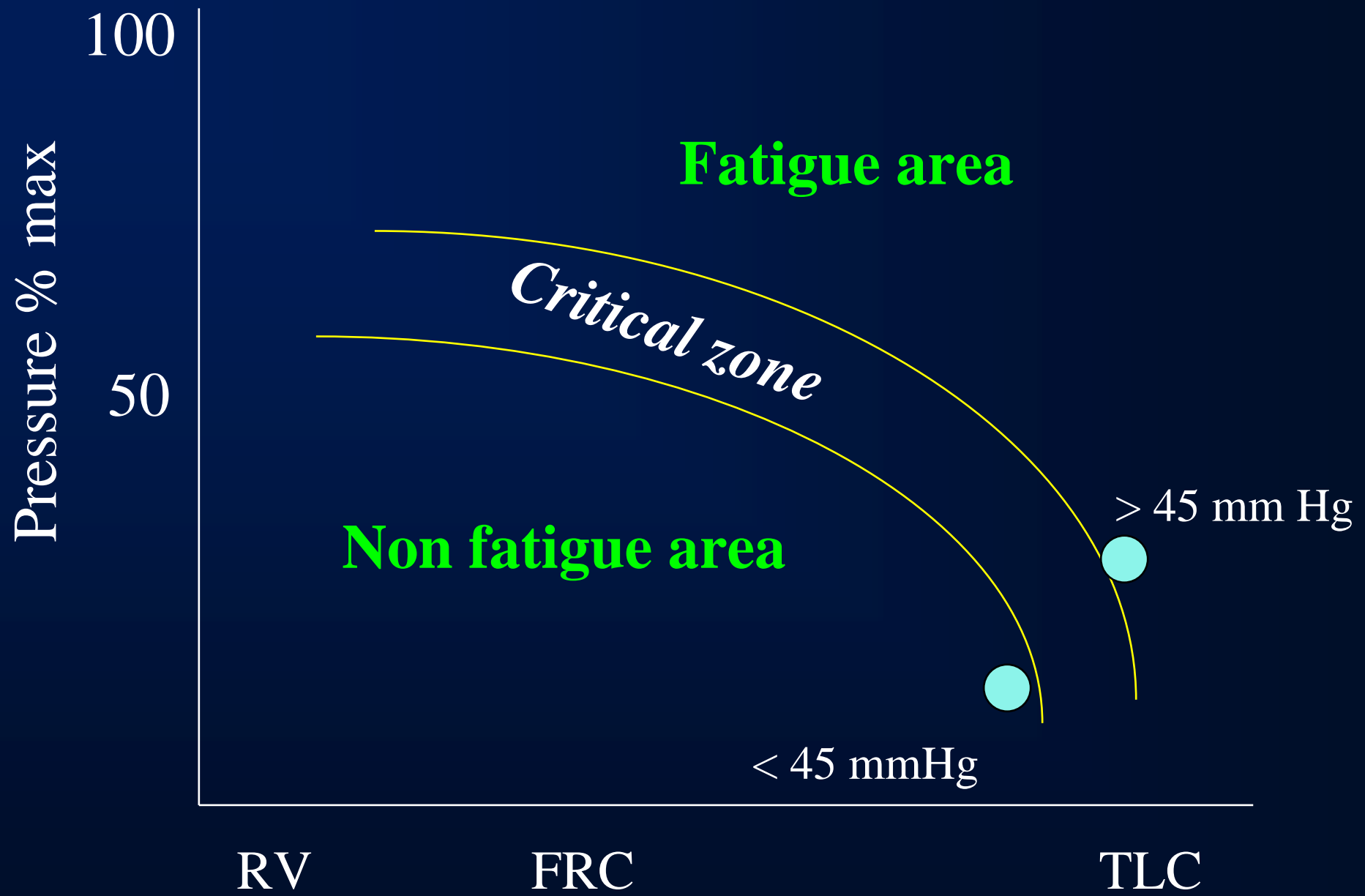
Resistive and PEEPi WOB



Respiratory Muscle Strength



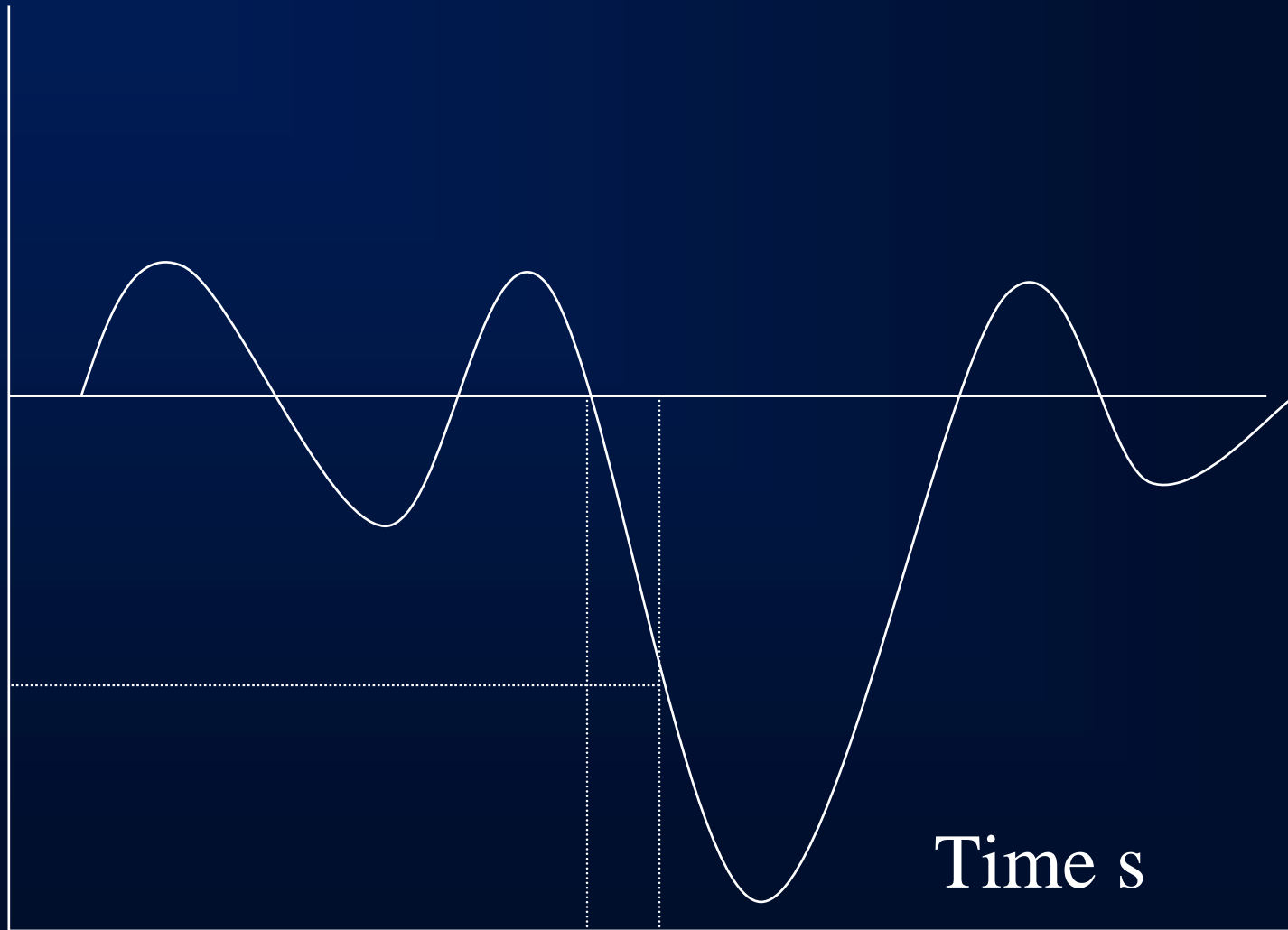
$$TTi = \frac{PDI}{PDI \text{ max}} \times Ti/Ttot / 100$$



Pressure

P0.1

0



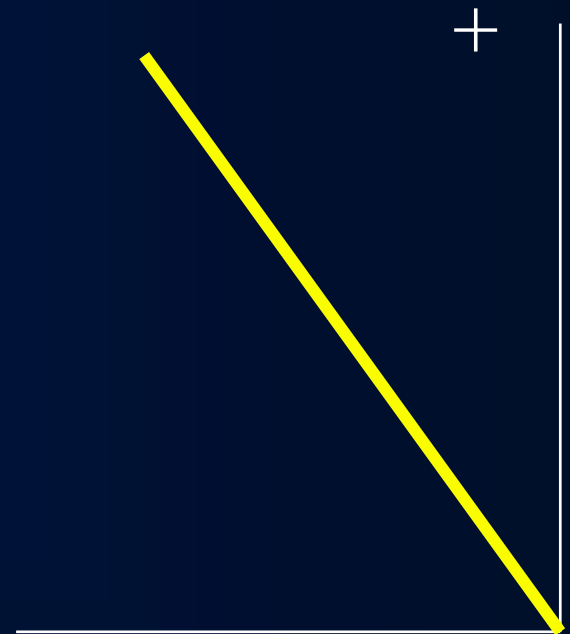
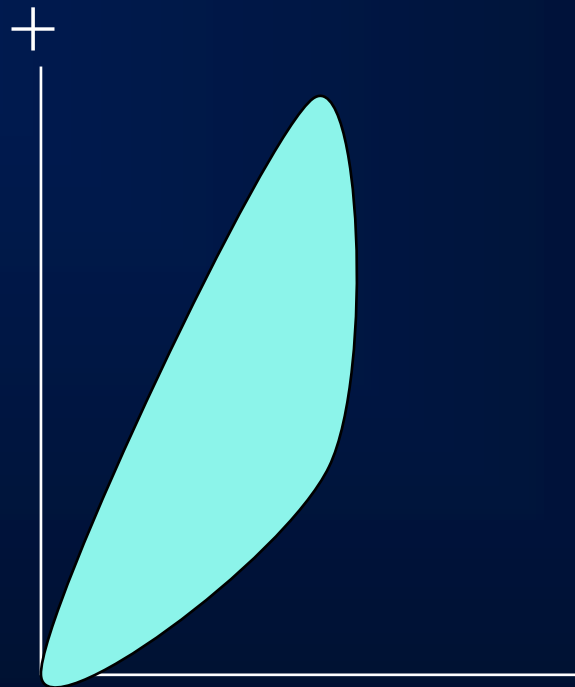
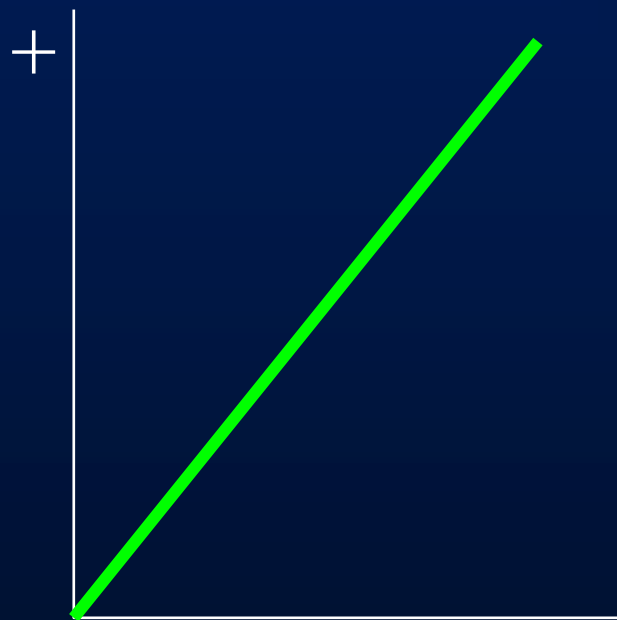
0,1

SINCRONA

ASINCRONA


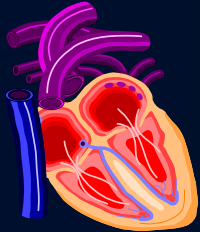
PARADOSSO

torace



Addome

Primary discharge diagnosis and ICD-9-M codes

Diagnosis	%	
COPD	32,7	 69,8%
Respiratory failure	11,9	
Pneumonia	13,1	
Upper respiratory tract infections	6,0	
Lung malignancy	1,8	
Other respiratory	1,8	
Heart failure	12,0	 20,4%
Ischemic heart disease and acute myocardial infarction	4,7	
Arrhythmias	1,3	
Other cardiovascular	2,5	

Predictive factors for ARF

previous lung function,
previous ADL, age,
hypercapnia, muscles,
nutrition, comorbidity.