FISIOPATOLOGIA
Degli scambi gassosi paziente ostruito, paziente ristretto

Policlinico Universitario Agostino Gemelli – IRCCS

Insufficienza respiratoria

Alterazione fisiopatologica in cui il <u>sistema toraco-polmonare</u> e/o i <u>centri nervosi</u> deputati al suo controllo non sono in grado di garantire:

- **Adeguata ossigenazione** (O_2) del sangue arterioso

e/o

- **Adeguata rimozione** **carbonica** (CO_2)

Meccanismo fisiopatologico

- Tipo 1 = **Alterazioni dell'ossigenazione**

ALTERAZIONI DEL RAPPORTO VENTILAZIONE/PERFUSIONE (V/Q), QUOTE DI SHUNT, CONDUCONO ALLA **RIDUZIONE** DI **p_aO_2**, MENTRE LA **p_aCO_2** E' **NORMALE** O DIMINUITA (IPERVENTILAZIONE COMPENSATORIA)

Gradiente alveolo–arterioso di pressione parziale di ossigeno aumentato

- Tipo 2 = **Alterazioni della ventilazione**

SUSSISTE IPOVENTILAZIONE ALVEOLARE. **p_aO_2 RIDOTTA** – **p_aCO_2 AUMENTATA**

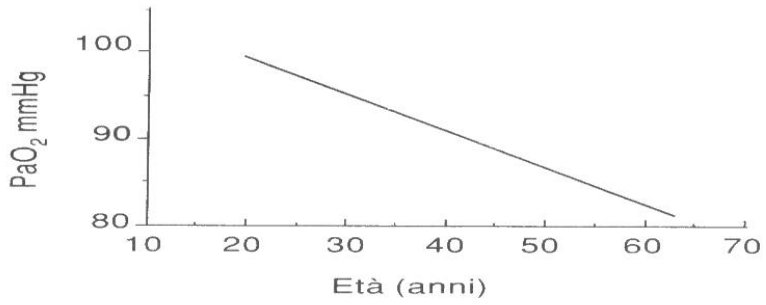
Gradiente alveolo–arterioso di pressione parziale di ossigeno invariato

- Tipo 3 = **Post – operatoria**
- Tipo 4 = **Secondaria a shock**

I criteri per definire un'insufficienza respiratoria si possono così schematizzare:

- **<u>IR di tipo 1 (ipossiemica)</u>**

P_aO_2 è 3 DS sotto il livello normale corretto per l'età:



P_aO_2 = 109 mmHg - 0,43 x età (anni)

P_aO_2 = 106,603 mmHg - 0,2447 x età (anni) ± 7,31

P_aO_2 standard, cioè il valore della P_aO_2 corretta per il grado di iperventilazione:

P_aO_2 standard = 1,66 x **P_aCO_2** + **P_aO_2** - 66,4 (quando **P_aCO_2** < 40 mmHg)

- **<u>IR di tipo2 (ipossiemica e ipercapnica)</u>**

P_aCO_2 è 2 DS sopra 40 mmHg (**> 45 mmHg**)

♂ tra 36,8 e 39,4 mmHg

♀ tra 35,5 e 38,1 mmHg

Crapo RO et al. Arterial blood gas reference values for sea level and an altitude of 1,400 meters. *Am J Respir Crit Care Med* 1999; 160: 1525-1531
Sorbini CA et al. Arterial oxygen tension in relation to age in healthy subjects. *Respiration* 1968; 25: 3-13

Insufficienza respiratoria

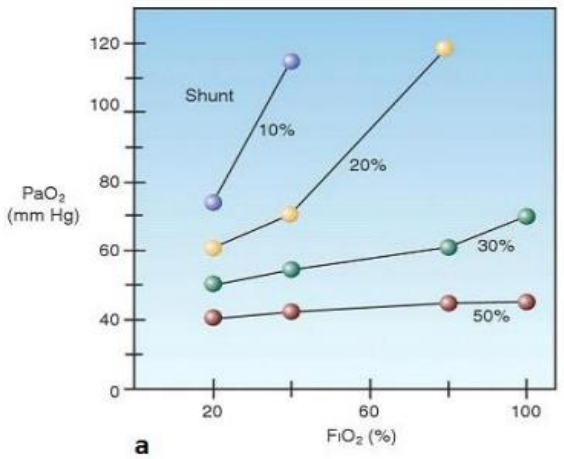
Tipo 1, *Insufficienza polmonare*

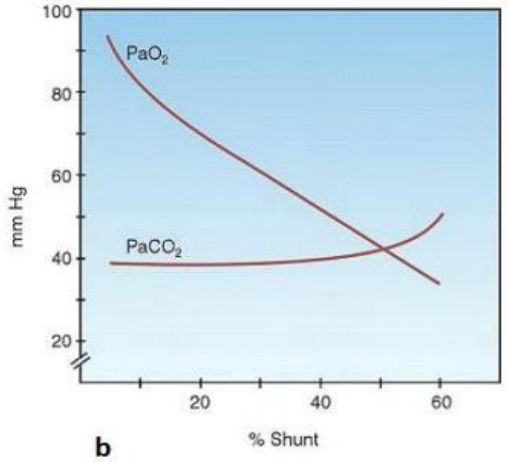
↑ *gradiente alveolo-arterioso O2* ↓ *PaO2, ↓ / = / ↑ PaCO2*

1. Alterazioni della diffusione alveolo-capillare (--)

a. ↑ spessore membrana
b. ↓ superficie di scambio
c. ↓ tempo di transito capillare (0.25 vs 0.8 sec)

O2-tp.





Reclutamento:
PEEP

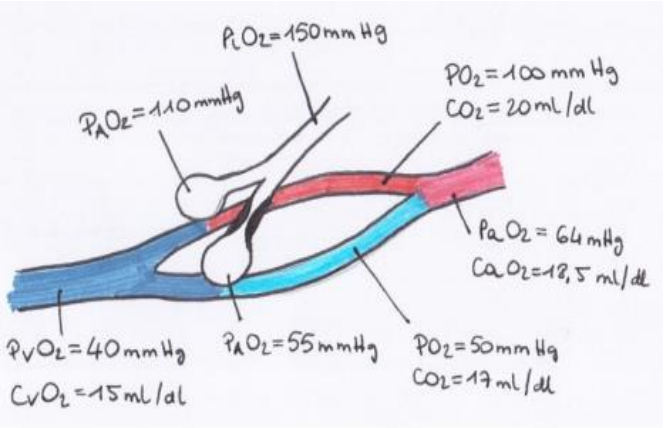
(++ P/F < 200)

Insufficienza respiratoria

Tipo 1, *Insufficienza polmonare*

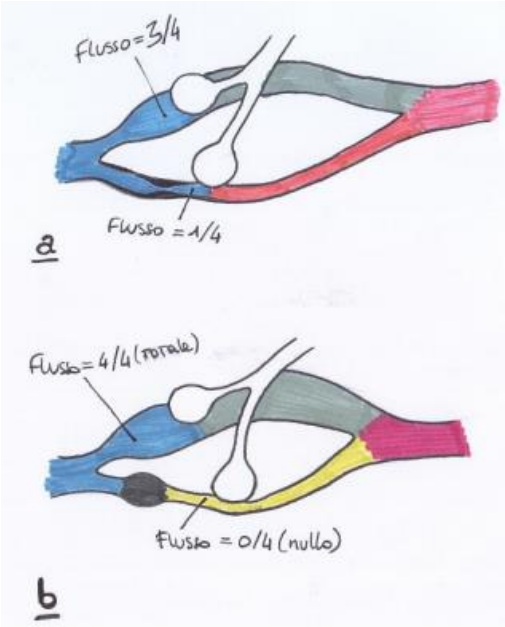
3. Mismatch ventilazione/perfusione (++)

In eccesso di perfusione (↓V/Q)



O2-tp.

In eccesso di ventilazione (↑ V/Q)



Insufficienza respiratoria

Tipo 2, *Insufficienza ventilatoria*

$$P_aCO_2 = P_ACO_2 = k \bullet \frac{VCO_2}{VA}$$

↑ *PaCO2, ± ↓ PaO2*

$$P_AO_2 = F_iO_2 \bullet (P_{atm} - P_{H2O}) - \frac{P_ACO_2}{R}$$

1. ↓ volume minuto

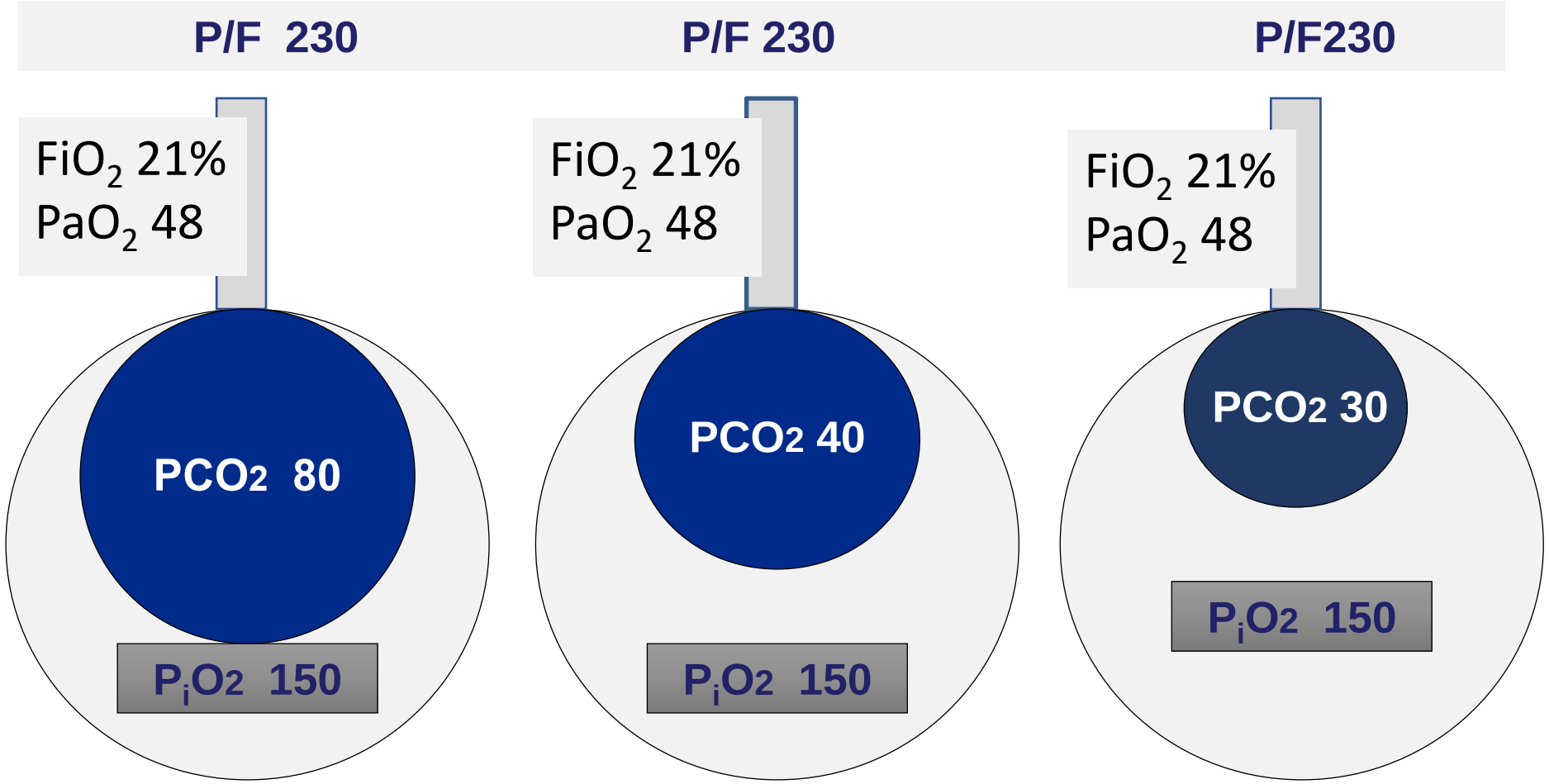
a. ↓ drive respiratorio
b. ↓ forza mm. respiratori / fatica (tipo 1 → + tipo 2)
c. ↑ carico di lavoro per il sistema toracopolmonare (elastico/resistivo)

2. ↑ spazio morto

a. anatomico (filtri/interfacce NIV!)
b. fisiologico (↑ V/Q) (--)
c. rapid shallow breathing

Ventilazione meccanica

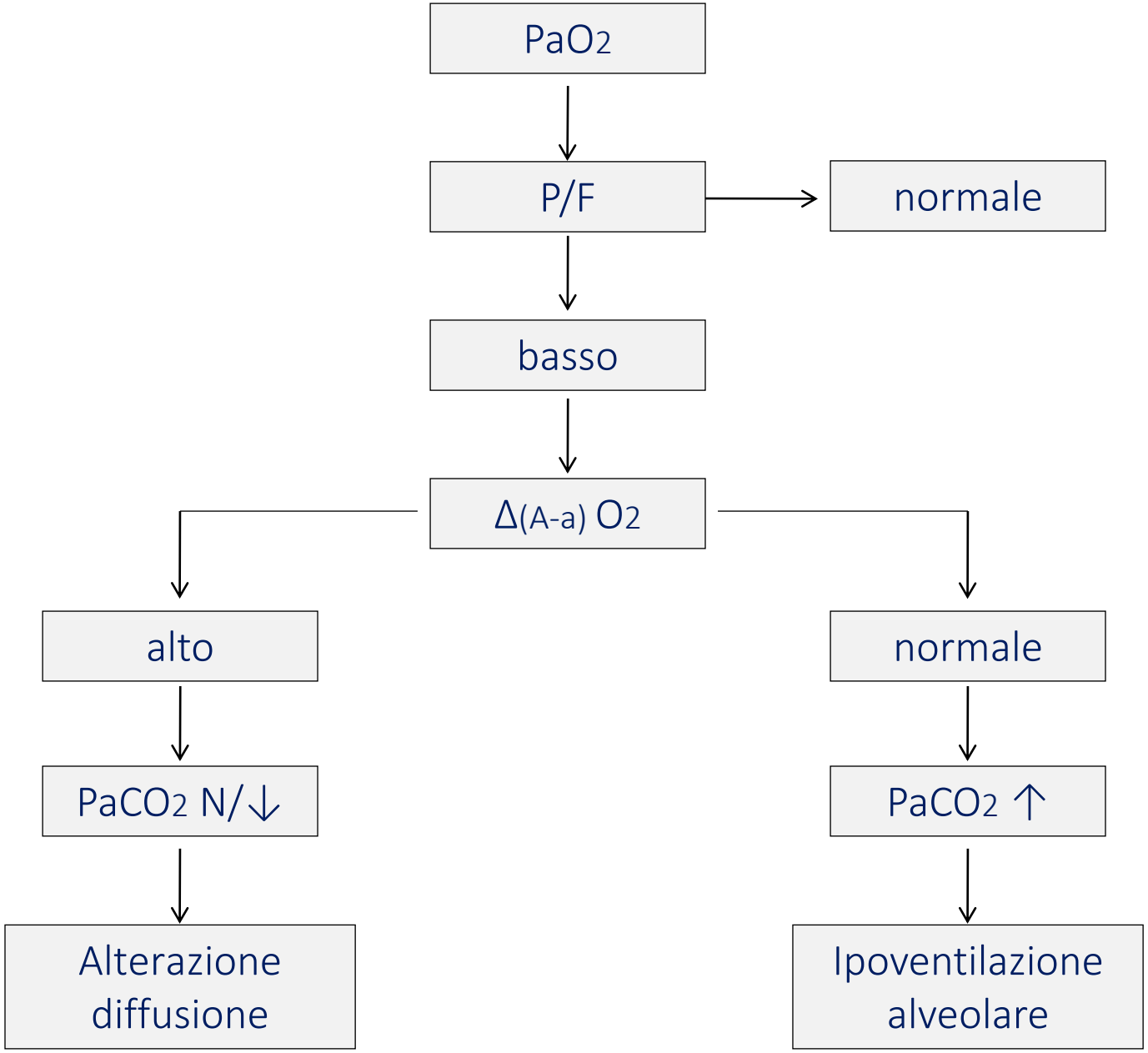
Δ (A-a)O2 vs P/F



Δ (A-a)O2=2

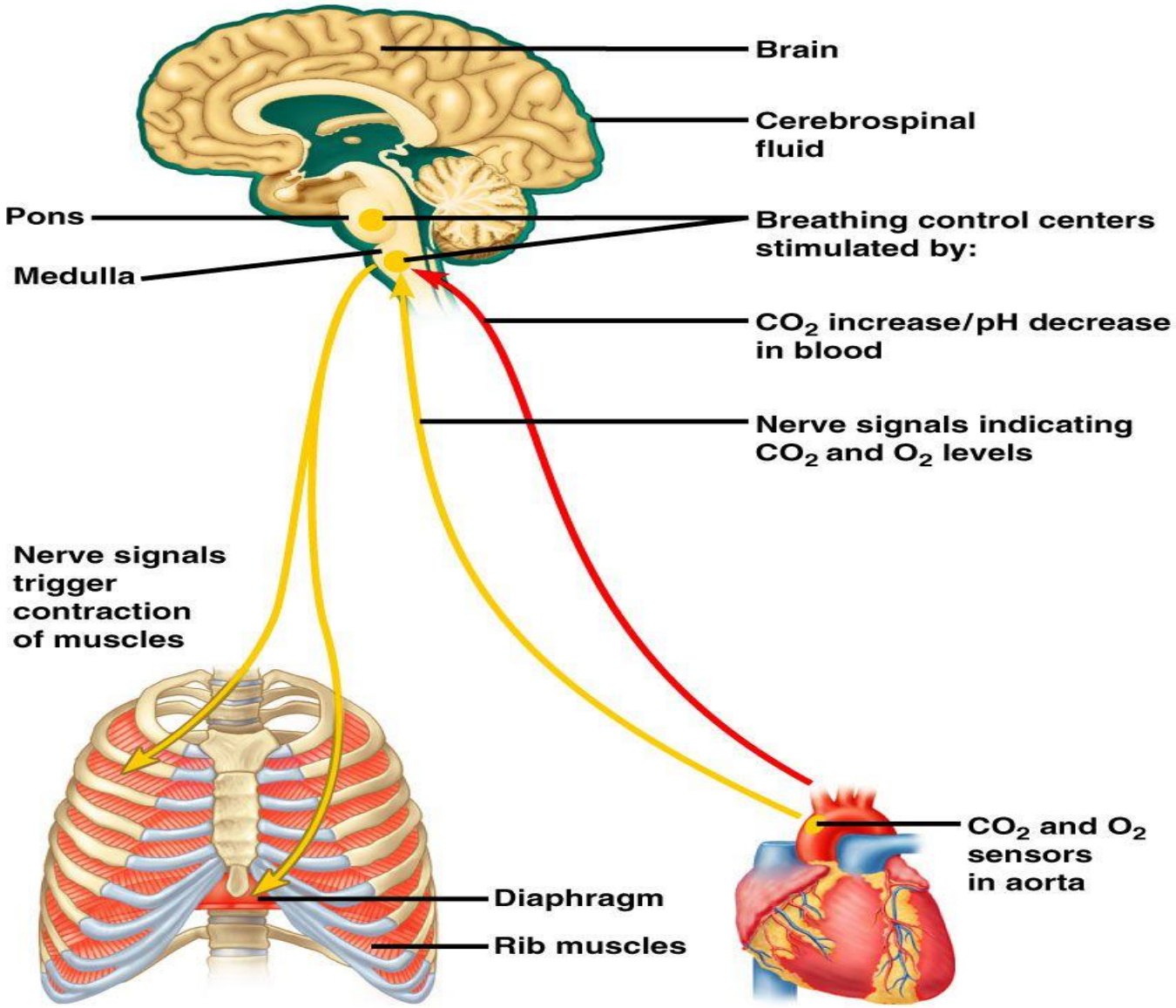
Δ (A-a)O2=52

Δ (A-a)O2=65


PaO2
P/F
normale
basso
Δ(A-a) O2
alto
normale
PaCO2 N/↓
PaCO2 ↑
Alterazione diffusione
Ipoventilazione alveolare

Tempo di insorgenza

- ACUTA
- CRONICA
- CRONICA RIACUTIZZATA



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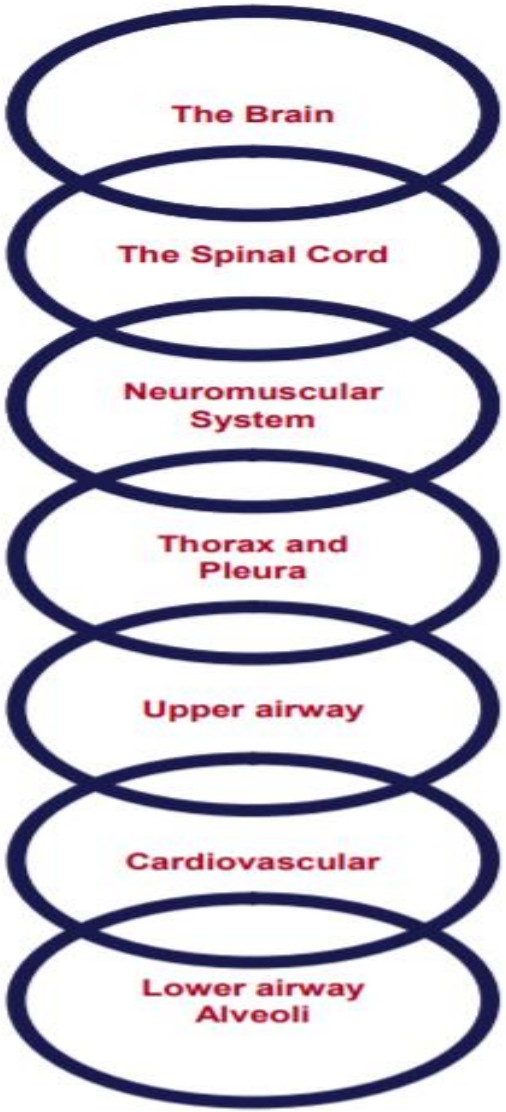

STATE OF THE ART

Respiratory Drive in Critically Ill Patients

Pathophysiology and Clinical Implications

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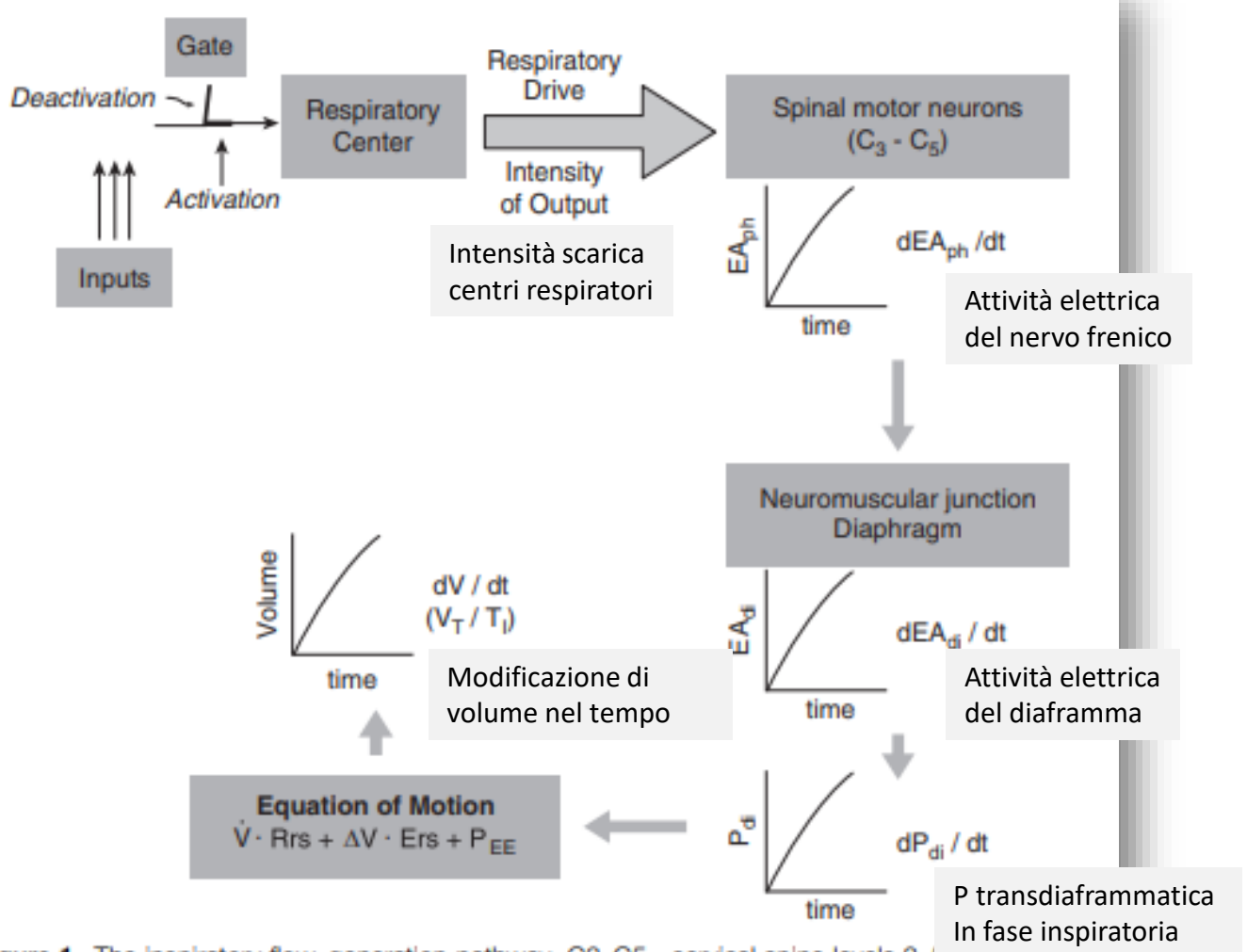
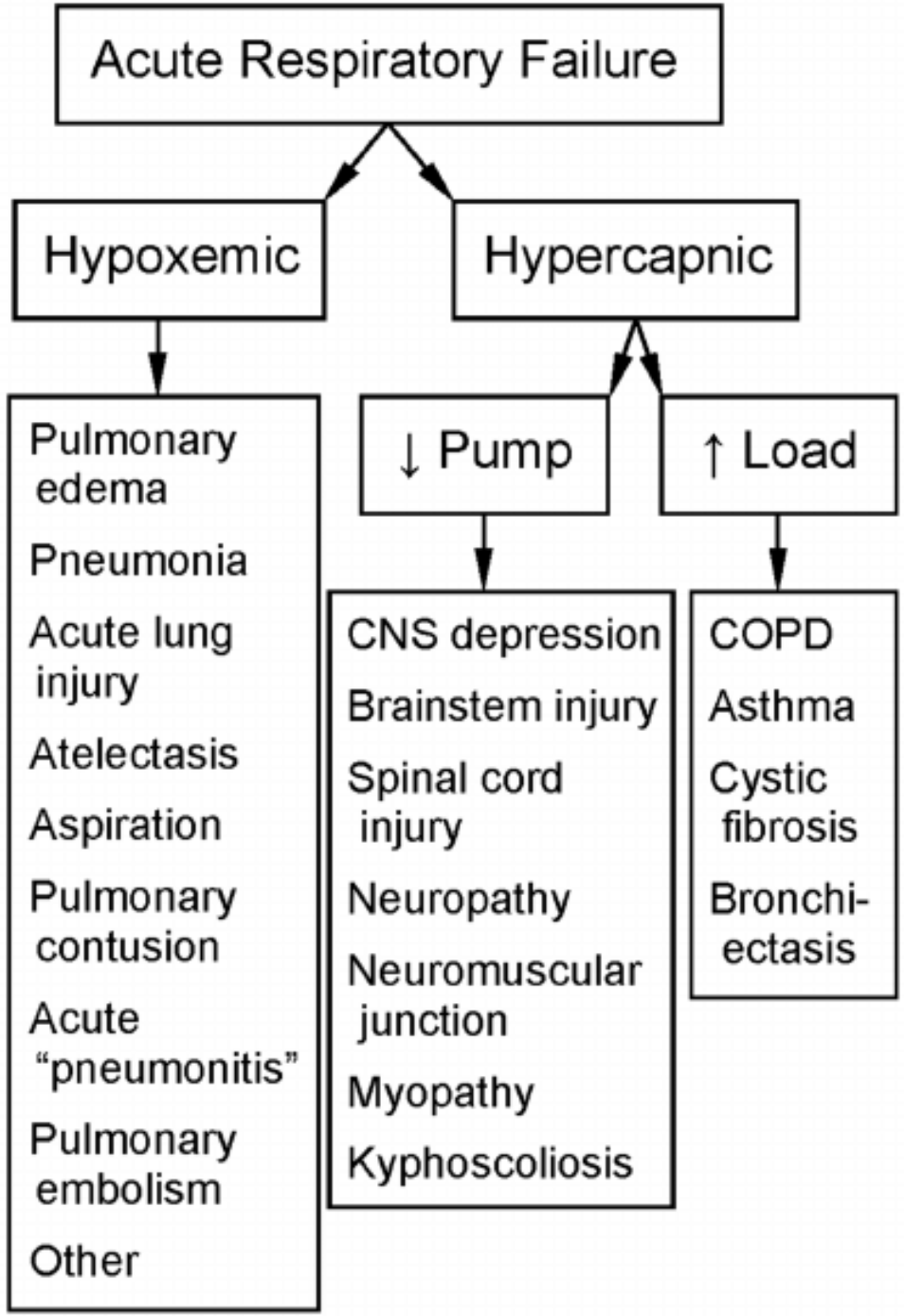


Figure 1. The inspiratory flow–generation pathway. C3–C5 = cervical spine levels 3–5, dEAdi/dt = change over time of electrical activity of the diaphragm during the inspiratory phase; dEAph/dt = change over time of electrical activity of the phrenic nerve during the inspiratory phase; dPdi/dt = change over time of transdiaphragmatic pressure during the inspiratory phase; dV/dt = change in volume over time; EAdi = electrical activity of the diaphragm; EAph = electrical activity of the phrenic nerve; Ers = respiratory system elastance; Gate = effects of afferent signals (inputs) vary, depending on the phase of the inspiratory cycle when they arrive; Pdi = transdiaphragmatic pressure; P_{EE} = elastic recoil pressure at end expiration (zero at FRC); Rrs = respiratory system resistance; V_T/T_I = V_T/inspiratory time ratio or mean inspiratory flow; ΔV = volume above end-expiratory lung volume.

- Riduzione FiO_2 inspirata
- **Ipoventilazione**
- Alterazione della diffusione
- Alterazione V/Q
- Shunt


Acute Respiratory Failure
Hypoxemic
Hypercapnic
Pulmonary edema
Pneumonia
Acute lung injury
Atelectasis
Aspiration
Pulmonary contusion
Acute "pneumonitis"
Pulmonary embolism
Other
↓ Pump
↑ Load
CNS depression
Brainstem injury
Spinal cord injury
Neuropathy
Neuromuscular junction
Myopathy
Kyphoscoliosis
COPD
Asthma
Cystic fibrosis
Bronchi-ectasis

La pompa ventilatoria
I controllori della ventilazione

Corteccia parziale controllo volontario

↓

Centri respiratori

- **Bulbo encefalico generatori primari del respiro**
  - gruppo ventilatorio dorsale, INSPIRATORIO
  - gruppo ventilatorio ventrale, ESPIRATORIO
- **Ponte (modulano attività Bulbo)**

↓

Motoneuroni primari

↓

Motoneuroni secondari

↓

Muscoli inspiratori ed espiratori

Sensori neurochimici CENTRALI: pavimento IV ventricolo: incremento scarica per ↑pCO2

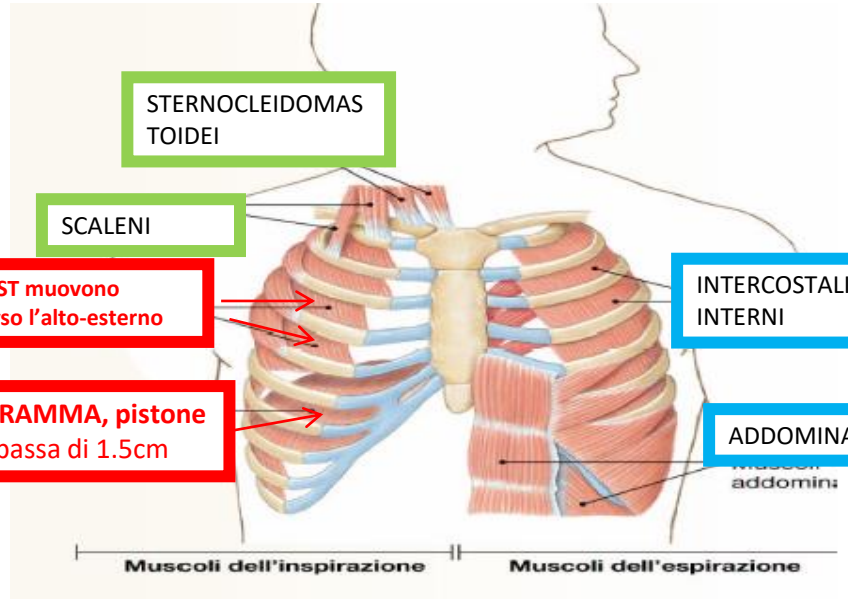
Sensori neuromeccanici (X) a livello:
- Vie aeree sup
- Trachea
- Bronchi
- Parete toracica (tendini, mmm, articolazioni)

Sensori neurochimici (IX) PERIFERICI Glomo carotideo: incremento scarica se paO2<60mmHg

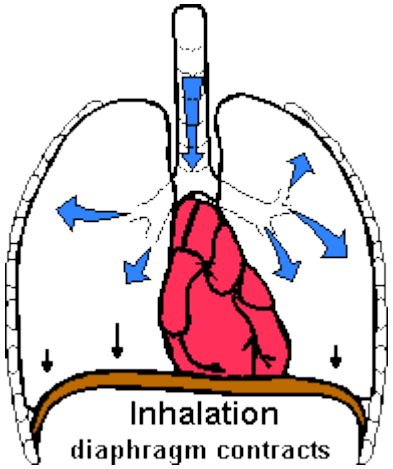
La pompa ventilatoria

Utilizzati in inspirazione forzata

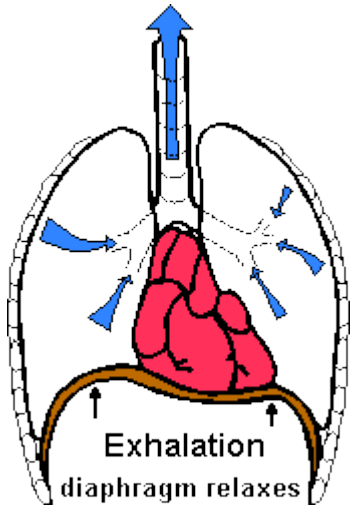
Inspirazione tranquilla



Utilizzati in espirazione forzata



Espirazione: PASSIVA



paziente

$$P_{musc} = (Flusso \cdot R) + (Volume \cdot E) + P_0$$

paziente

Il Sistema respiratoria puà essere schematizzato come composto da due elementi posti in serie

- elemento resistive (vie aeree)
- elemento elastico (gabbia toracica e polmone)

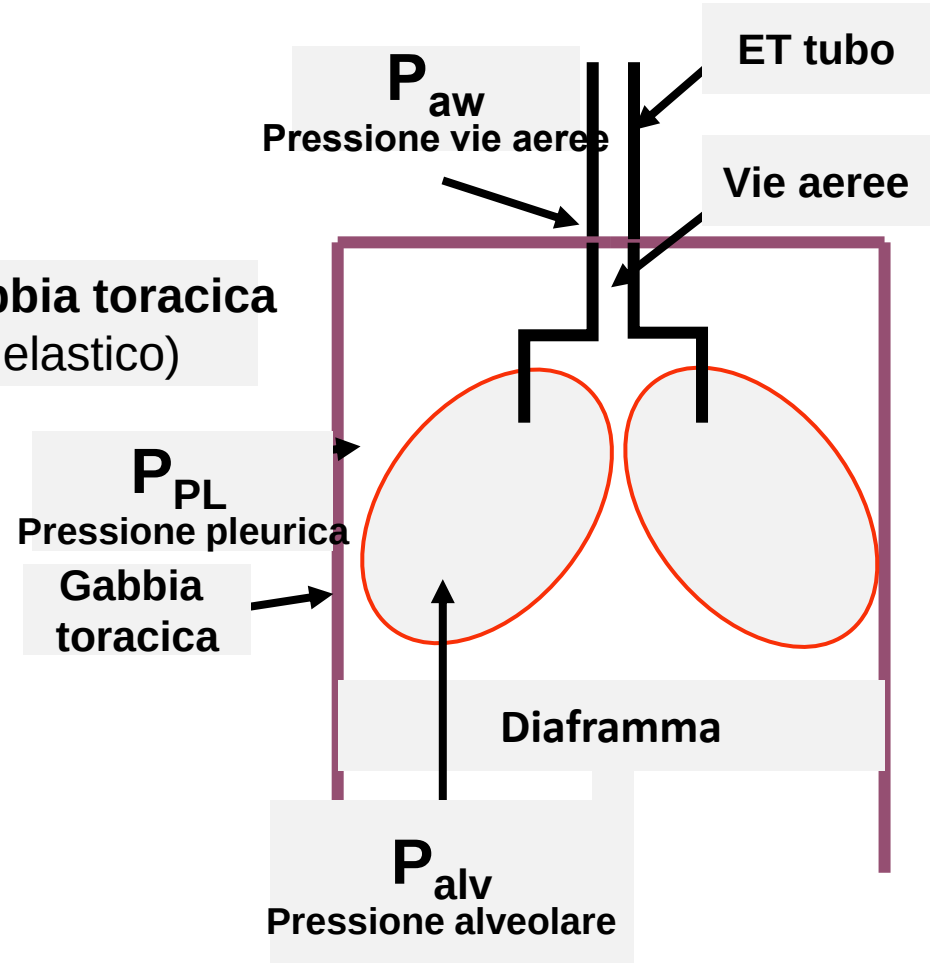
$$P_{aw} = \text{Flusso} \times \text{Resistenze} + \frac{\text{Volume}}{\text{Compliance}}$$

Vie Aeree
(elemento resistivo)

Polmoni + gabbia toracica
(elemento elastico)

il contributo dell'elemento elastico (polmoni + gabbia toracica) dipende dal grado di inflazione polmonare e da compliance di polmone e gabbia toracica

$$\text{Flu} \quad \frac{\text{Volume}}{\text{compliance}}$$



Ipoventilazione

- Determina sempre un aumento della $PaCO_2$
- Equazione della ventilazione alveolare:

$$PaCO_2 = VCO_2 \times K / VA$$

$VCO_2 = CO_2$ espirata

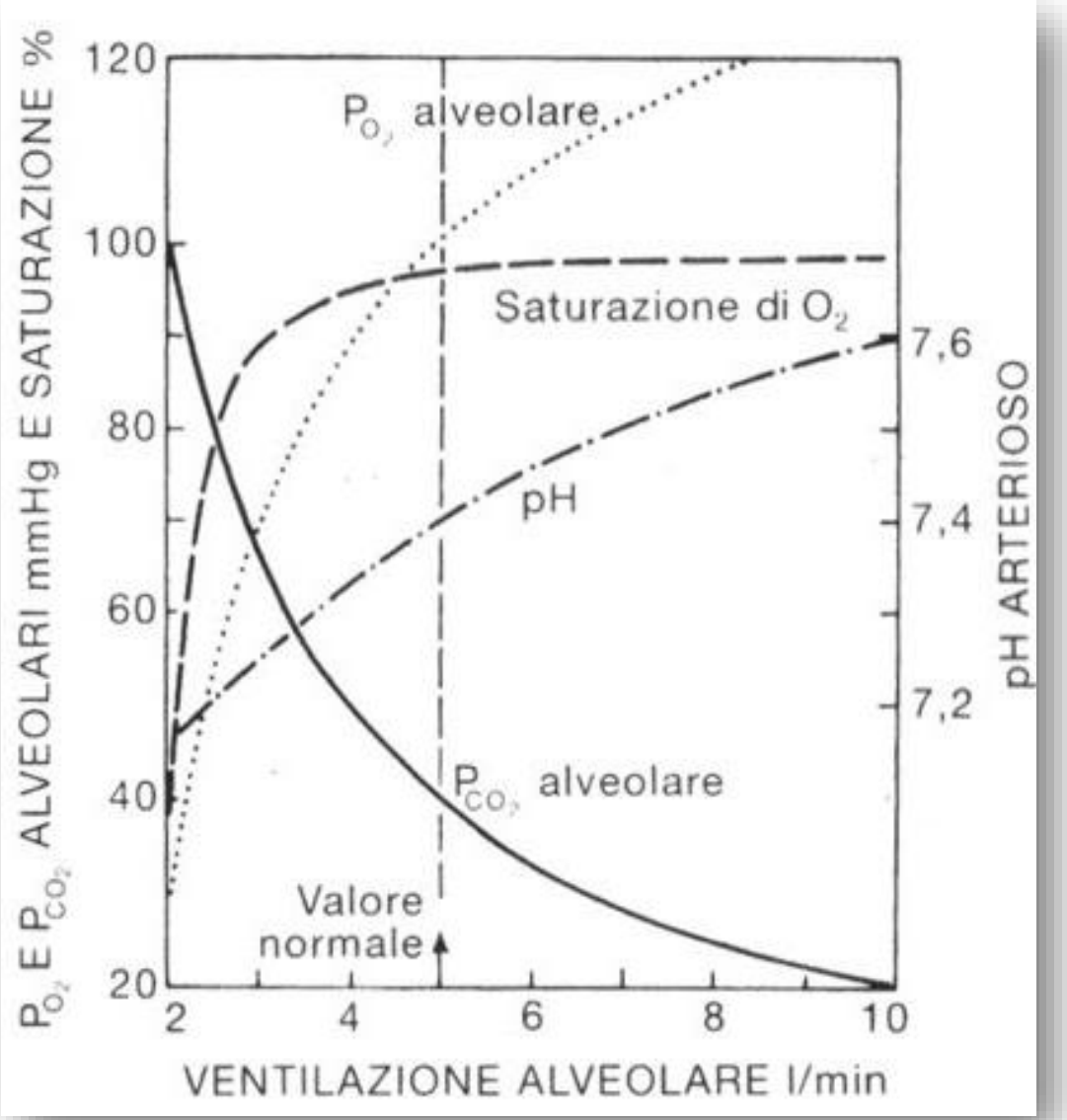
K = costante

VA = ventilazione alveolare

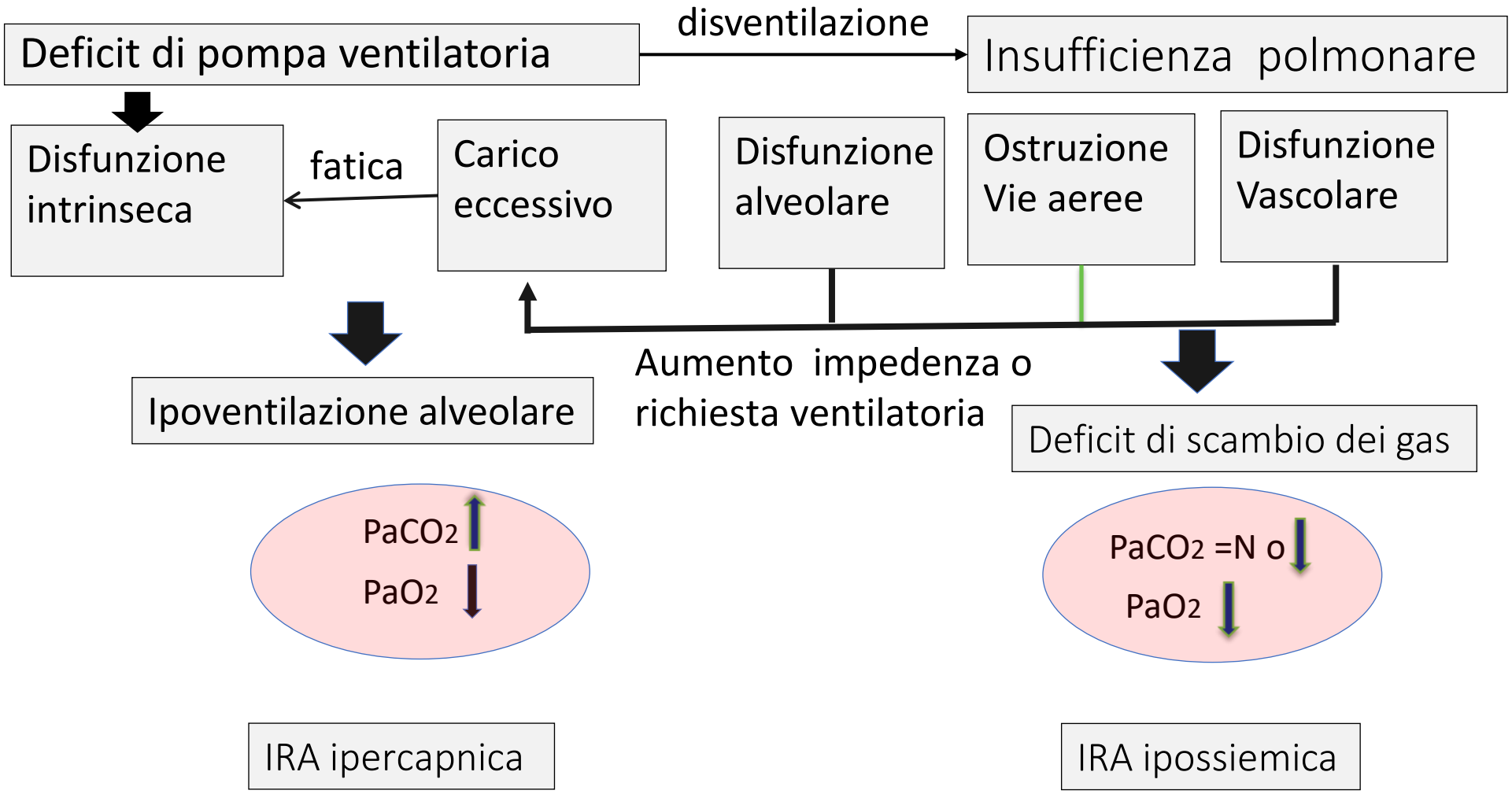
VA=(VT-VD) x FR

- **Se si dimezza la ventilazione alveolare la $PaCO_2$ raddoppia**

- Origine Polmonare
- Origine Extra – Polmonare



Insufficienza respiratoria: fisiopatologia

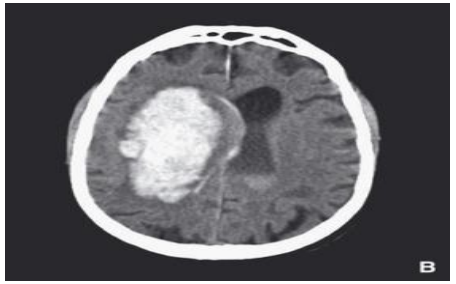


L'insufficienza di pompa ventilatoria e l'insufficienza polmonare raramente sono isolate (spesso i pazienti presentano problemi misti)

CAUSE EXTRA – POLMONARI

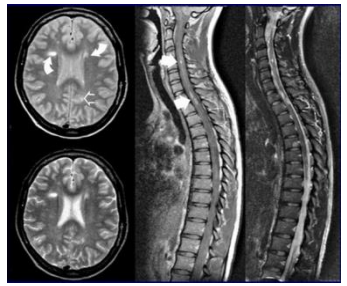
- **ALTERAZIONI SNC**

Farmaci (ipnotici, oppiacei) – Traumi cranici – Infezioni SNC



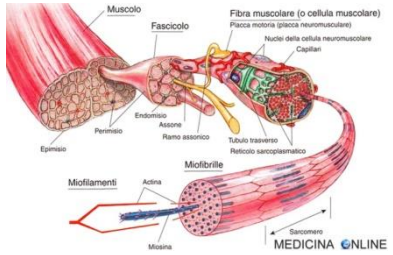
- **ALTERAZIONI VIE NERVOSE DI CONDUZIONE/SNP**

Lesioni midollari – Infezioni (poliomielite, botulismo) – Neuriti periferiche (Sdr. di Guillain-Barré) – Malattie degenerative (SLA, SM)



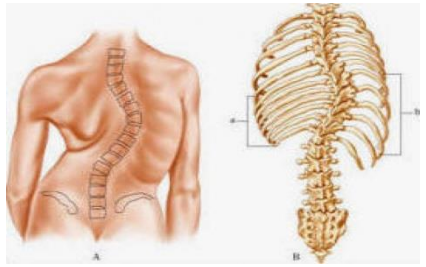
- **MALATTIE MUSCOLI RESPIRATORI**

Miopatie (distrofie, connettiviti) – Paralisi diaframmatica (iatrogeno)



- **ALTERAZIONI GABBIA TORACICA**

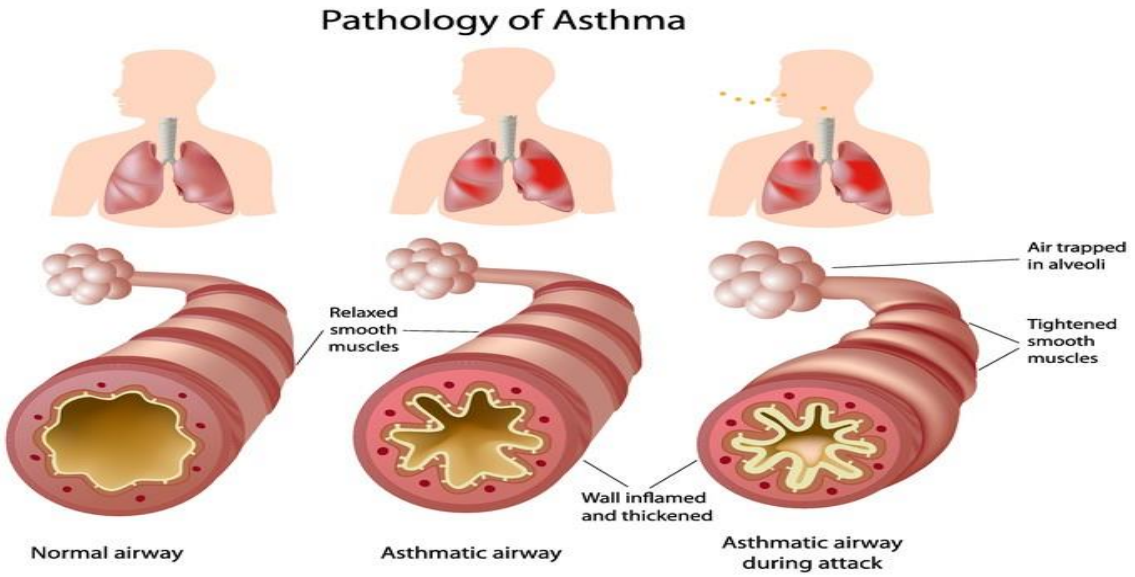
Cifoscoliosi – Torace carenato – Toracoplastica – Fratture costali multiple – Alterazioni diaframmatiche (ernie) – Obesità estrema – Peritonite/occlusione intestinale



CAUSE POLMONARI

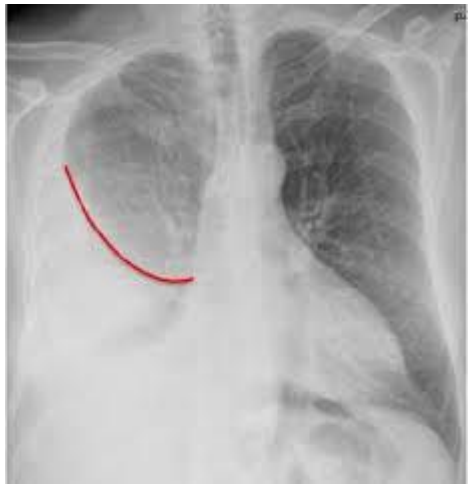
- **PATOLOGIE OSTRUTTIVE**

Asma, Bronchite Cronica, enfisema



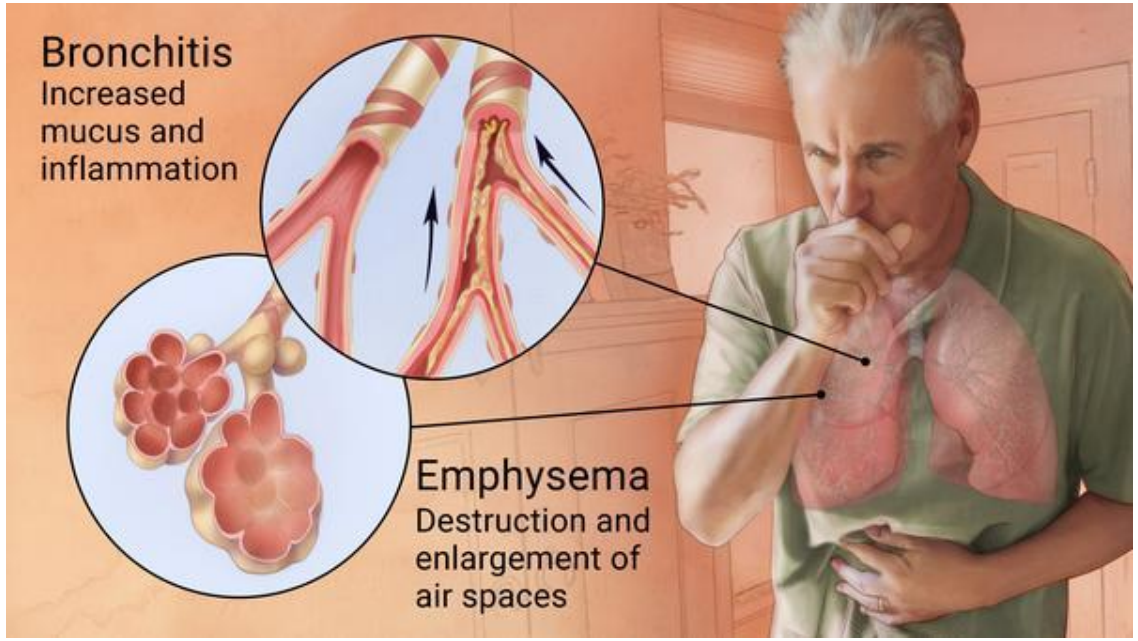
- **PATOLOGIE RESTRITTIVE**

Interstiziopatie, Fibrosi polmonare, Sarcoidosi, Pneumoconiosi



BPCO ?

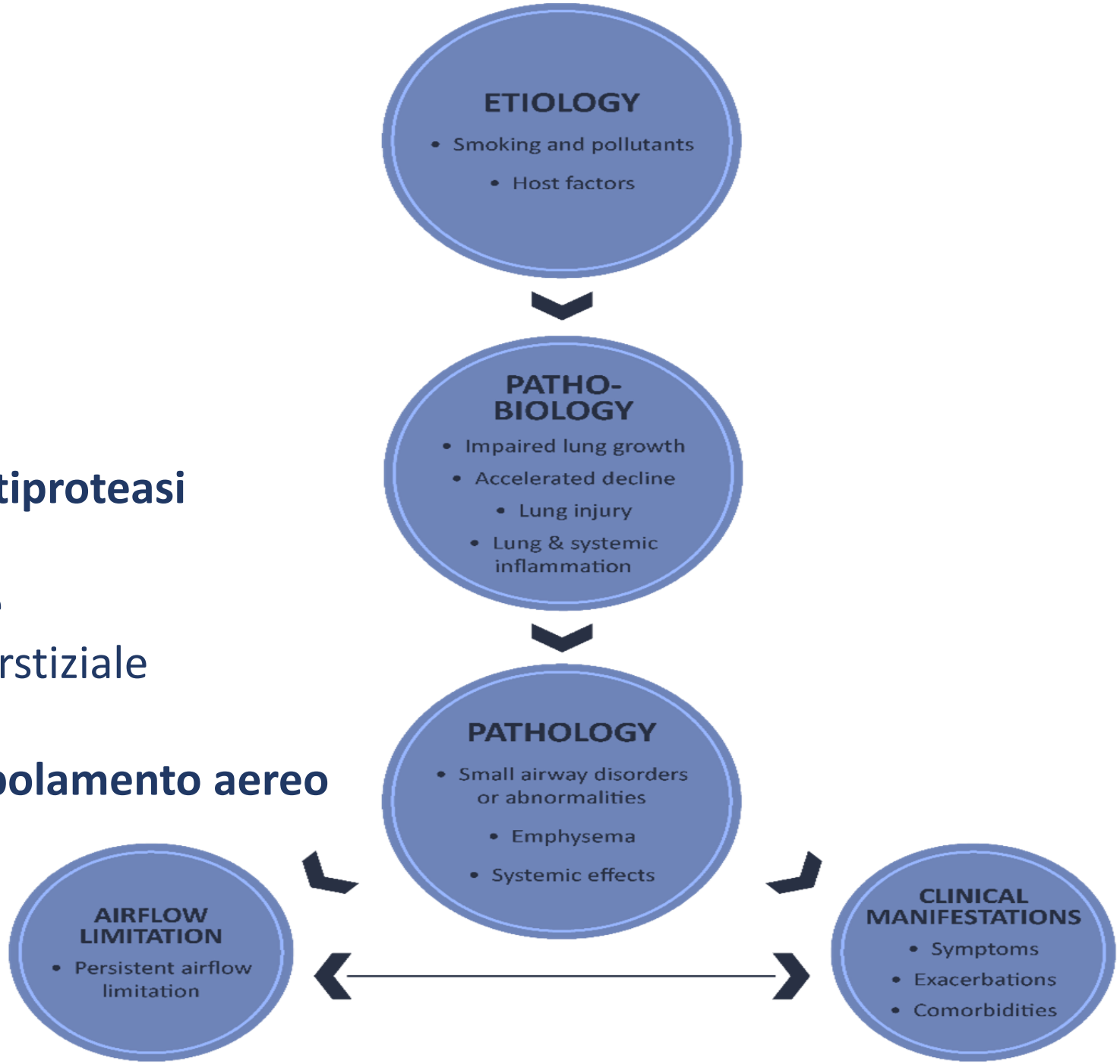
- La BPCO è una condizione patologica **comune , prevenibile e trattabile caratterizzata da sintomi respiratori persistenti e limitazione al flusso dovuta ad alterazioni di vie aeree e/o alveoli**
- **Storia di fumo o esposizione ad altri inquinanti**
- I sintomi respiratori più comuni sono **include dispnea, tosse e/o aumento dell'espettorazione**.
- La storia clinica della BPCO puo presentari fasi di peggioramento acuto dei sintomi (riacutizzazioni)



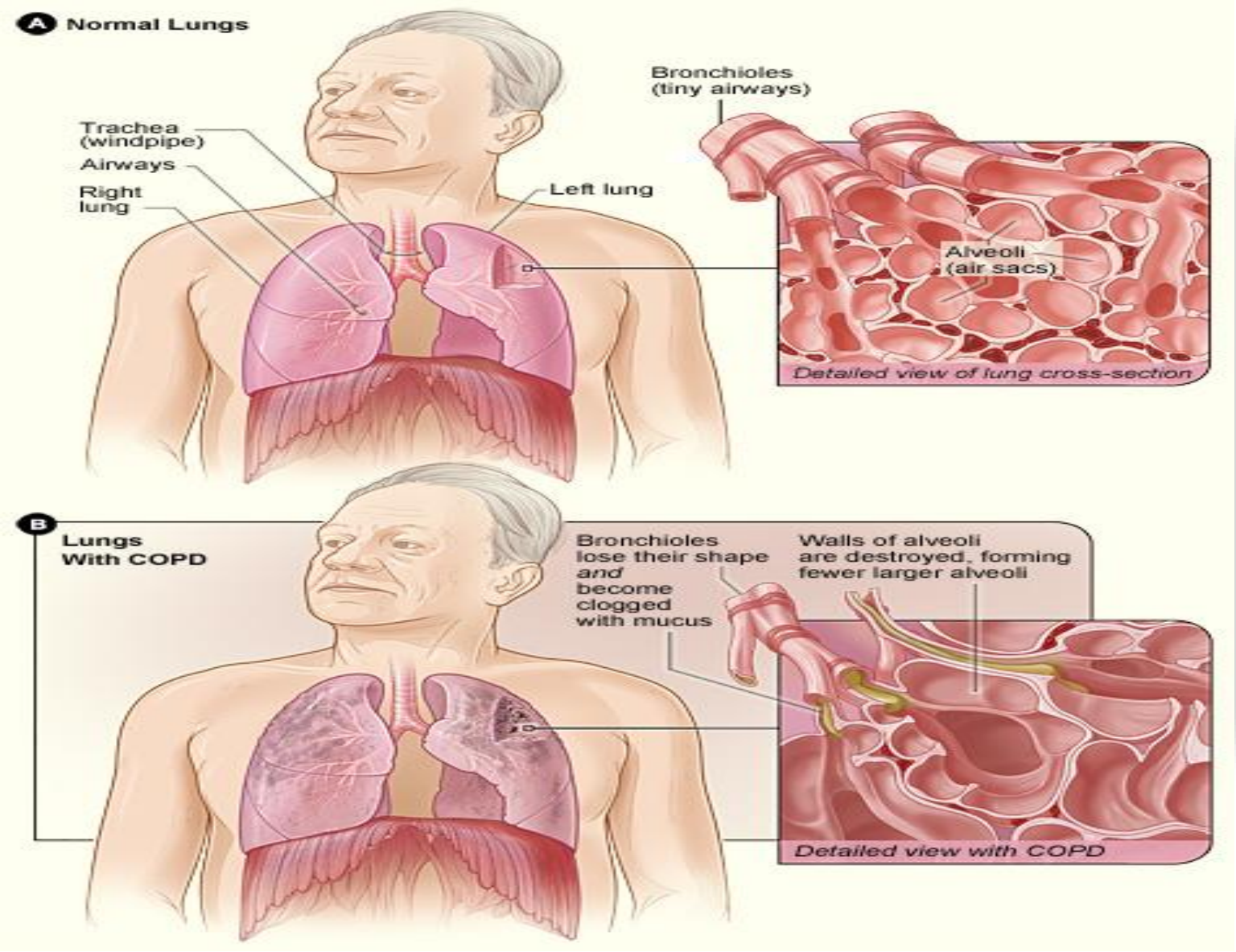
Sebbene la BPCO sia una patologia polmonare produce anche importanti conseguenze sistemiche

- Patologia
  - **Infiammazione cronica**
  - **Modificazioni strutturali**

- Patogenesi
  - **Stress ossidativo**
  - **Squilibrio attività proteasi-antiproteasi**
  - Cellulle infiammatoria
  - **Mediatori dell'infiammazione**
  - Fibrosi peribronchiolare e interstiziale
- Patofisiologia
  - **Limitazione di flusso e intrappolamento aereo**
  - Alterazioni emogasanalitiche
  - **Ipersecrezione di muco**
  - **Ipertensione polmonare**



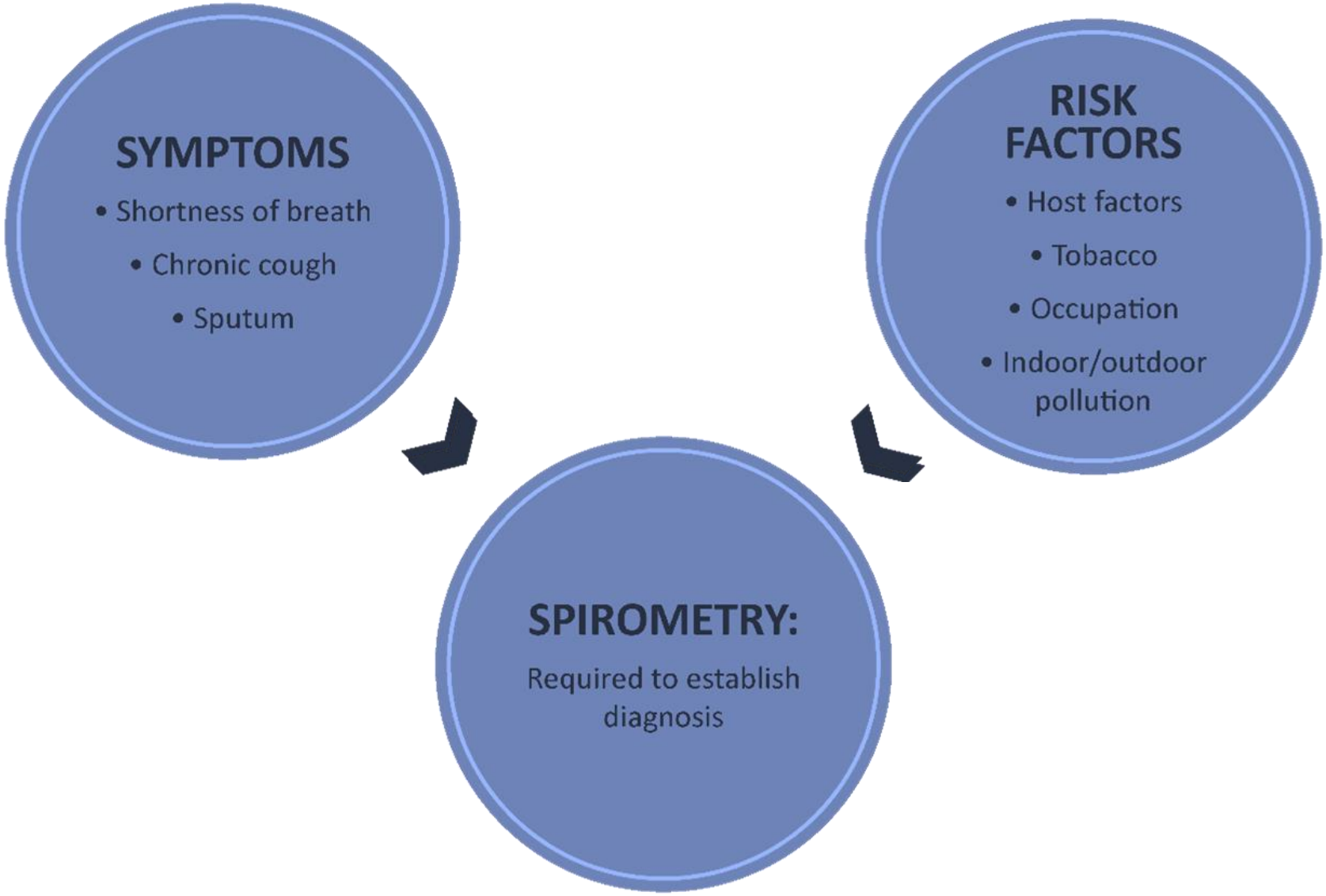
BPCO alterazioni funzionali



Ostruzione delle vie aeree di piccolo calibro

Distruzione del parenchima(enfisema)

BPCO diagnosi



BPCO Diagnosi

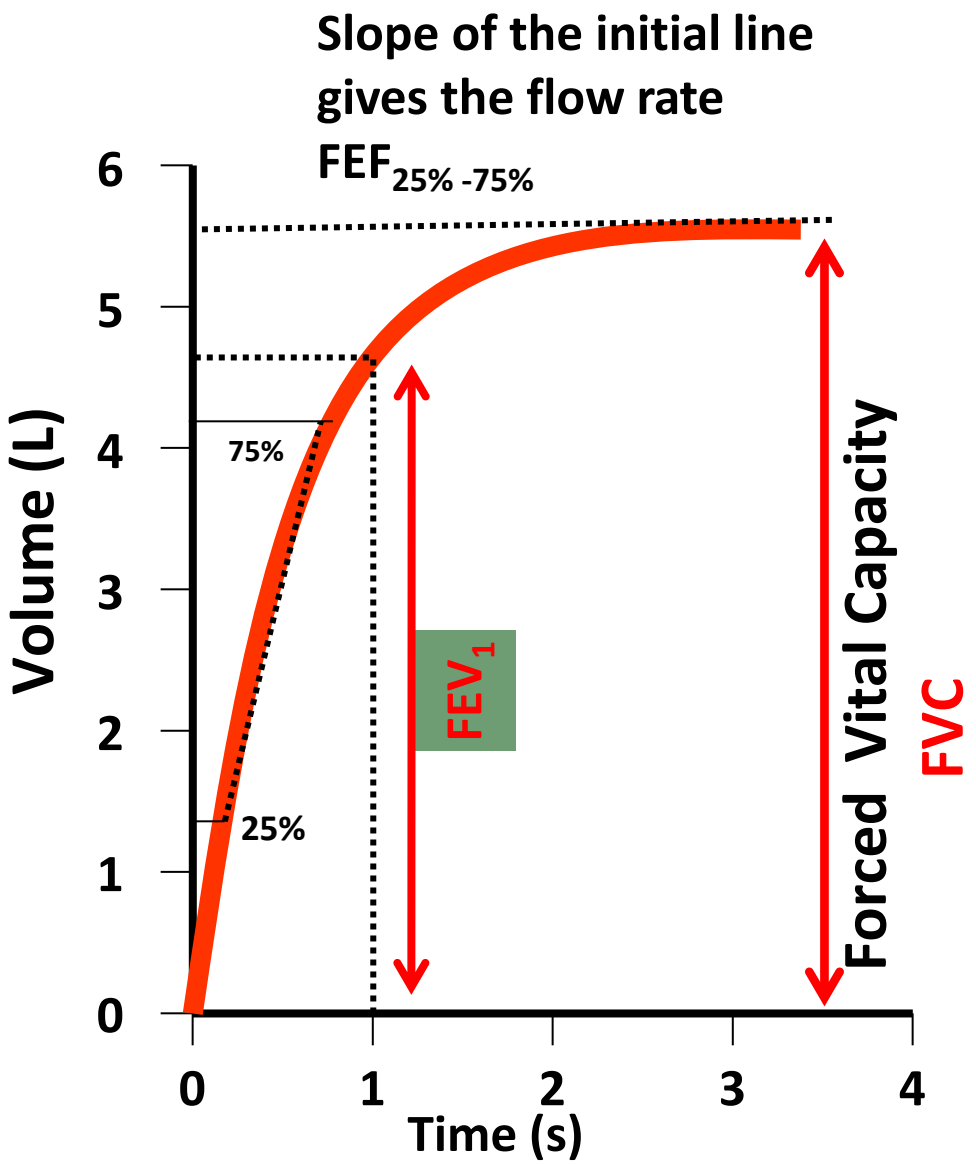
- Prove di funzionalità respiratoria
  - FVC: ↓ Capacità vitale forzata
  - FEV1: ↓ volume espiratorio forzato in 1 secondo
  - FEV1/FVC = <70%
- Emogasanalisi
  - ↑ PaCO2
  - ↓ PaO2
- Laboratorio
  - ↑ Hct

Spirometry- Vol/Time

Normally,
FEV_1/FVC ratio= 0.8 or FEV_1 = 80% FVC

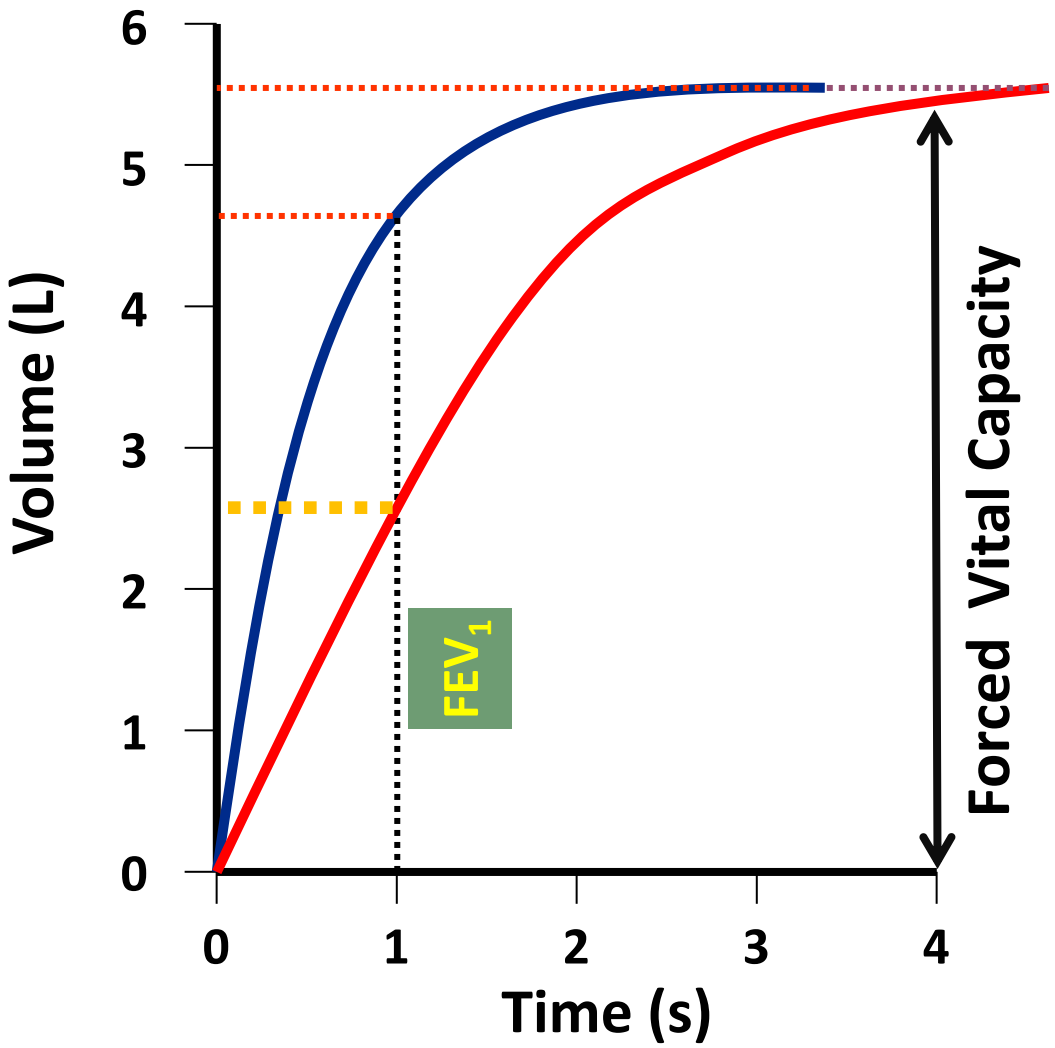
At the end of normal expiration (FRC), ask subject to inhale fully until they are at TLC, and exhale as hard and fast as possible – at RV.

The volume of the exhaled gas is the FVC.
The curve is steeper at the beginning that near the end, slope of the curve at any given point of the graph is equal to the flow at that point. Flow = $\Delta V/\Delta t$.



Vol-Time Spirometry in Obstructive Lung Disease

In **COPD curve shifted downwards and to the right**, TLC & FVC may be normal, but the **patient needs longer time for expiration** due to airway obstruction, hence the **decrease in FEV1**, and **the ratio of FEV1/FVC**



Obstructive Lung Disease
Total Volume (TLC and FVC) may be normal
but FEV_1 is reduced

And FEV_1/FVC ratio <0.8 (<50% here)

BPCO riacutizzazioni

- **BPCO riacutizzazioni** : peggioramento acuto dei sintomi respiratori che determina una terapia addizionale

:

- Lieve (trattata con SABDs)
- Moderata (SABDs + antibiotici e/o corticosteroidi orali)
- **Grave (accesso al DEA e/ospedalizzazione può associarsi a ARF)**

Trigger (Polmonite batterica o virale, irritant ambientali)

STATE OF THE ART

Chronic Obstructive Pulmonary Disease and Cardiac Diseases
An Urgent Need for Integrated Care

Sara Roversi[1], Leonardo M. Fabbri[1], Don D. Sin[2], Nathaniel M. Hawkins[3], and Alvar Agustí[4]

[1]Department of Metabolic Medicine, University of Modena and Reggio Emilia and Sant'Agostino Estense Hospital, Modena, Italy; [2]Division of Respirology and [3]Division of Cardiology, Department of Medicine, Centre for Heart Lung Innovation, University of British Columbia, Vancouver, British Columbia, Canada; and [4]Thorax Institute, Hospital Clinic in Barcelona, University of Barcelona, Barcelona, Spain

Excerbations of respiratory symptoms in pts with COPD may not be exacerbations of COPD

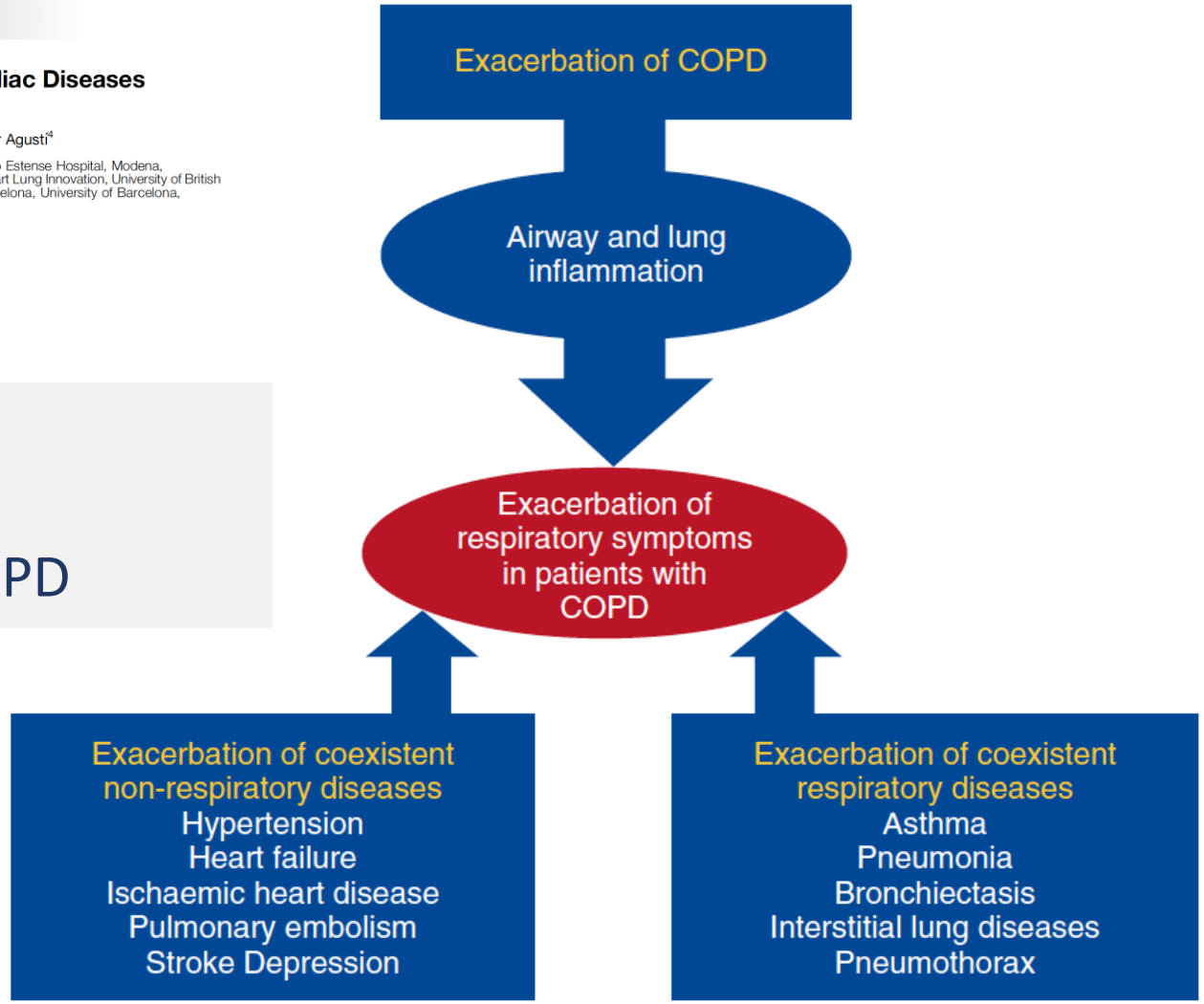


Figure 4. Exacerbation of respiratory symptoms in patients with chronic obstructive pulmonary disease (COPD). Acute episodes may be caused by respiratory infections and/or pollutants that cause acute inflammation of the airways (thus properly defined as exacerbations of COPD). However, exacerbation of respiratory symptoms in patients with COPD may be caused by other nonpulmonary disorders, including acute heart failure, ischemic heart disease, or atrial fibrillation. Thus, these acute events do not represent the "typical" exacerbation of COPD but should rather be described as exacerbations of respiratory symptoms in patients with COPD. In such cases, other causative mechanisms, particularly coexisting cardiac diseases, should be investigated and treated. Reproduced by permission from Reference 226.

Comorbidities and Risk of Mortality in Patients with Chronic Obstructive Pulmonary Disease

Miguel Divo[1], Claudia Cote[2†], Juan P. de Torres[3], Ciro Casanova[4], Jose M. Marin[5], Victor Pinto-Plata[1], Javier Zulueta[3], Carlos Cabrera[6], Jorge Zagaceta[3], Gary Hunninghake[1], and Bartolome Celli[1]; for the BODE Collaborative Group

- 1,664 COPD pts in 5 centers for a median of 51 months.
- Systematically, 79 comorbidities were recorded.
- Mortality risk was calculated using Cox proportional hazard, and it was developed a graphic representation of the prevalence and strength of association to mortality in the form of a "**comorbidome**."
- **15 comorbidities had a significantly higher prevalence in nonsurvivors compared with survivors**
- **Using multivariate analysis, only 12 of them increased the risk of death** over the study time and were selected to construct the **COTE index**

The «comorbidome»

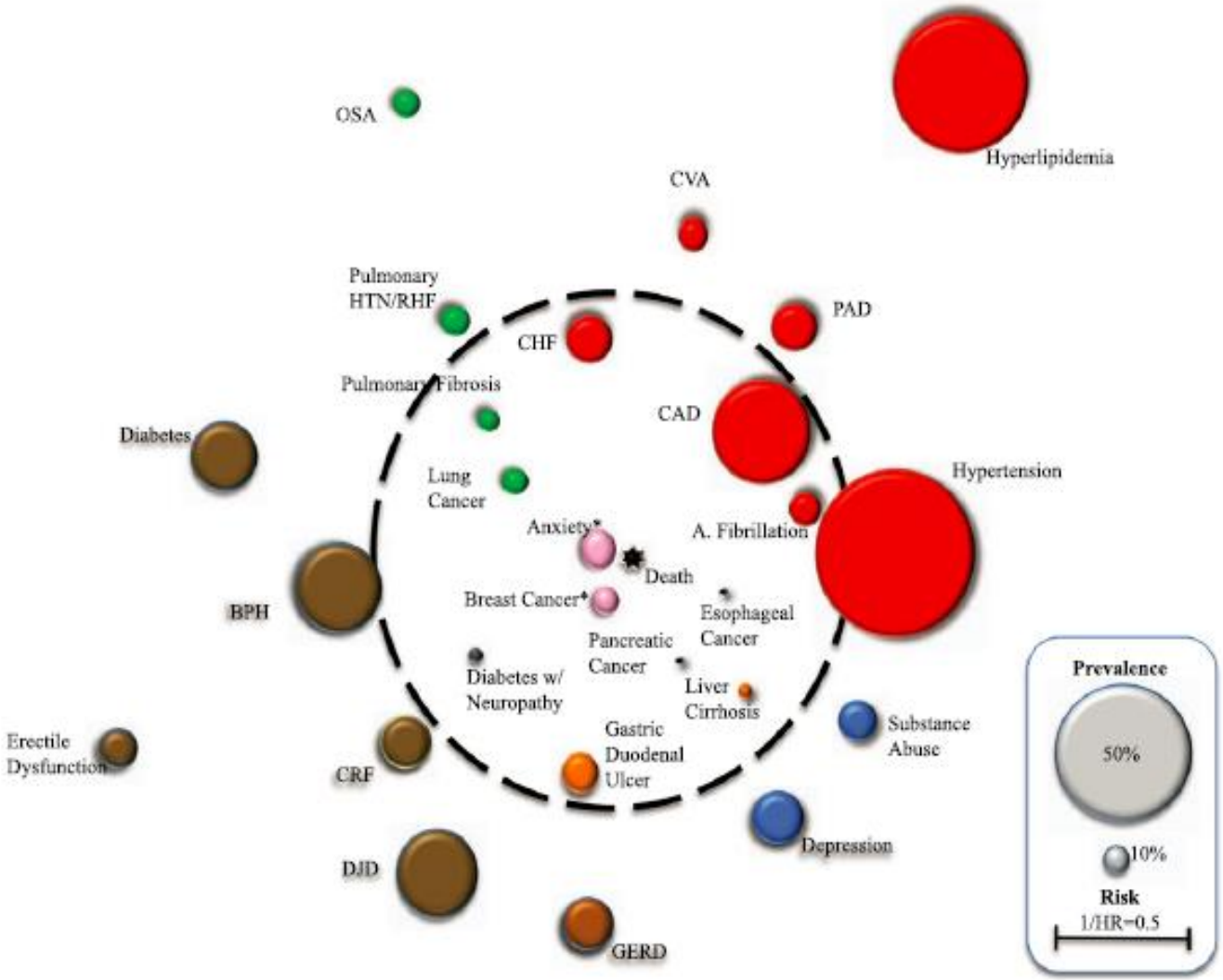
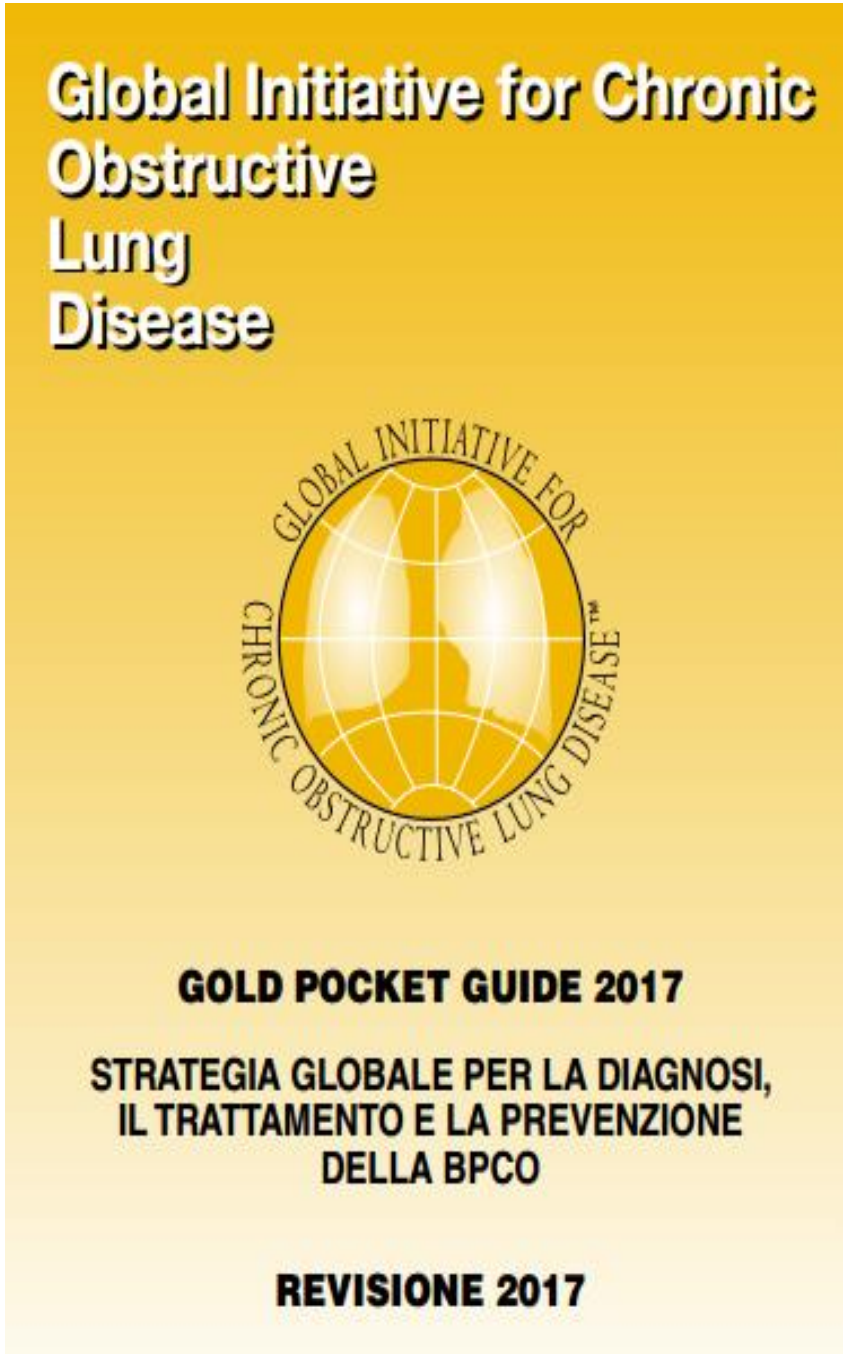


Figure 2. The "comorbidome" is a graphic expression of comorbidities with more than 10% prevalence in the entire cohort, and those comorbidities with the strongest association with mortality (hazard ratio [HR], >1; 95% confidence interval, >1; $P \leq 0.05$). The area of the circle relates to the prevalence of the disease. The proximity to the center (mortality) expresses the strength of the association between the disease and risk of death. This was scaled from the inverse of the HR (1/HR). All bubbles associated with a statistically significant increase in mortality are fully inside the *dotted orbit* (1/HR <1). Bubble colors represent organ systems or disease clusters (cardiovascular = *red*, female-specific comorbidities = *pink*, pulmonary = *green*, psychiatric = *blue*, others = *brown* and *orange*). A. fibrillation = atrial fibrillation/flutter; BPH = benign prostatic hypertrophy; CAD = coronary artery disease; CHF = congestive heart failure; CRF = chronic renal failure; CVA = cerebrovascular accident; DJD = degenerative joint disease; GERD = gastroesophageal reflux disease; OSA = obstructive sleep apnea; PAD = peripheral artery disease; pulmonary HTN+RHF =

M. Divo, et al ,"*Am Journal of Respir and Crit Care Med*, 2012



- **COPD often coexist with other diseases (comorbidities)** that may have a significant impact on disease course.
- In general, the presence of **comorbidities should not alter COPD treatment** and **comorbidities should be treated per usual standard regardless the presence of COPD**.
- **Cardiovascular disease are common and important comorbidities in COPD**.
- There is no evidence that chronic heart failure should be treated differentely in the presence of COPD. Treatment with β1-blockers improves survival in heart failure and is recommended. However, β1-blockers are not prescribed in COPD despite available evidence showing that their use is safe. Selective β1-blockers should be used.

Inspirazione

Paw = Pel + Pres + PEEP totale = E x VT + R x V’ + PEEP totale

Espirazione passiva

$$\Delta V / C = -V' \bullet R$$

RITORNO ELASTICO
SPINGE

RESISTENZA VIE AEREE
FRENA

Costante di tempo del sistema respiratorio

Come rapidamente il sistema respiratorio risponde quando la pressione si modifica

R x C (τ)

R ($cmH_2O/L/s$) x C (L/cmH_2O) = secondi

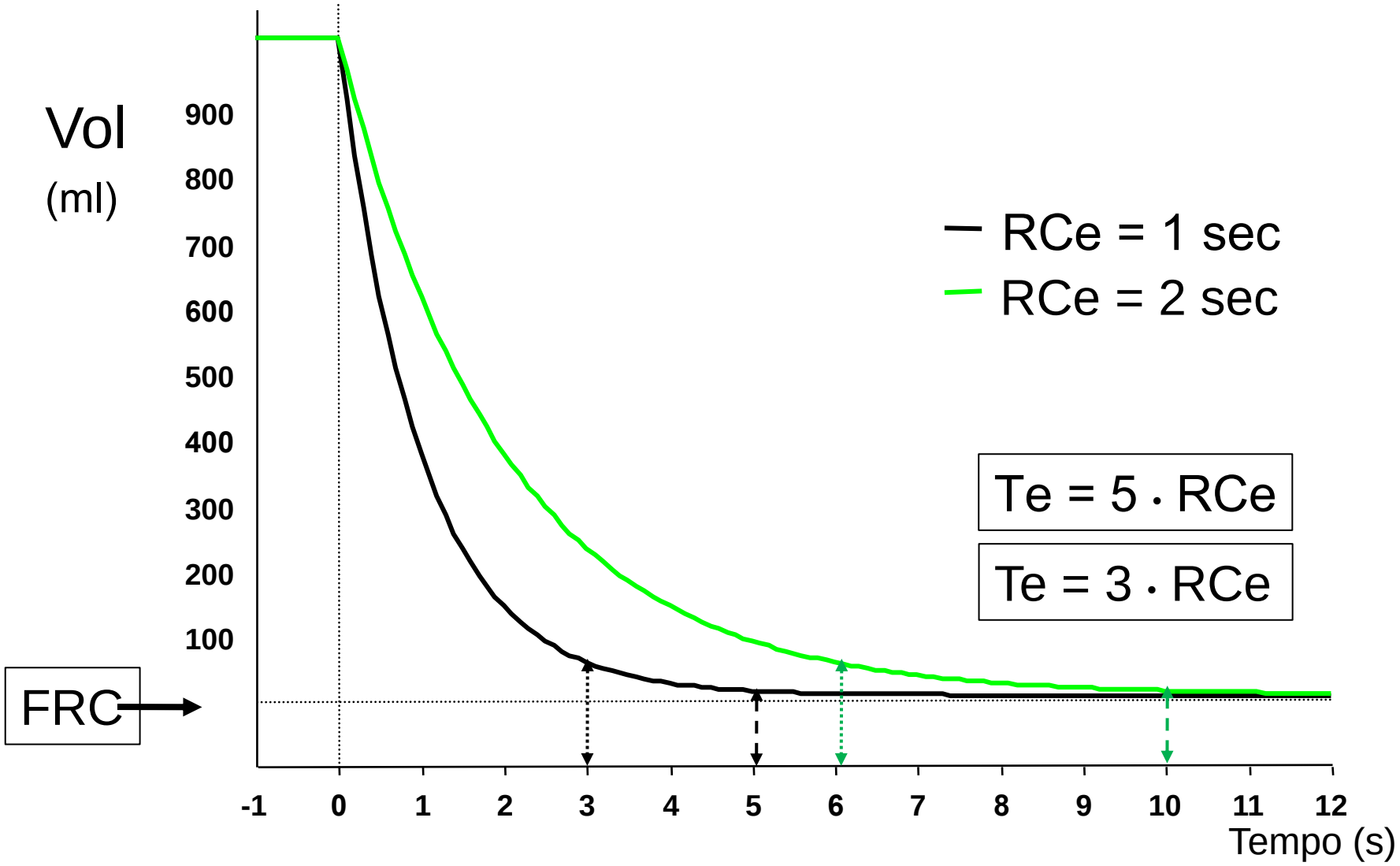
Il volume si modifica in accordo con una equazione esponenziale:

$V = (P \times C) \times e^{-t/RC}$; Flusso $= (P/R) \times e^{-t/RC}$

Quando t = RC, l'espressione esponensiale è uguale 1/2.718 (36.8% del volume iniziale).

Quando t = 3 τ, il volume iniziale diminuisce fiino al 95% del valore iniziale

Costante di Tempo Espiratoria (RCe)



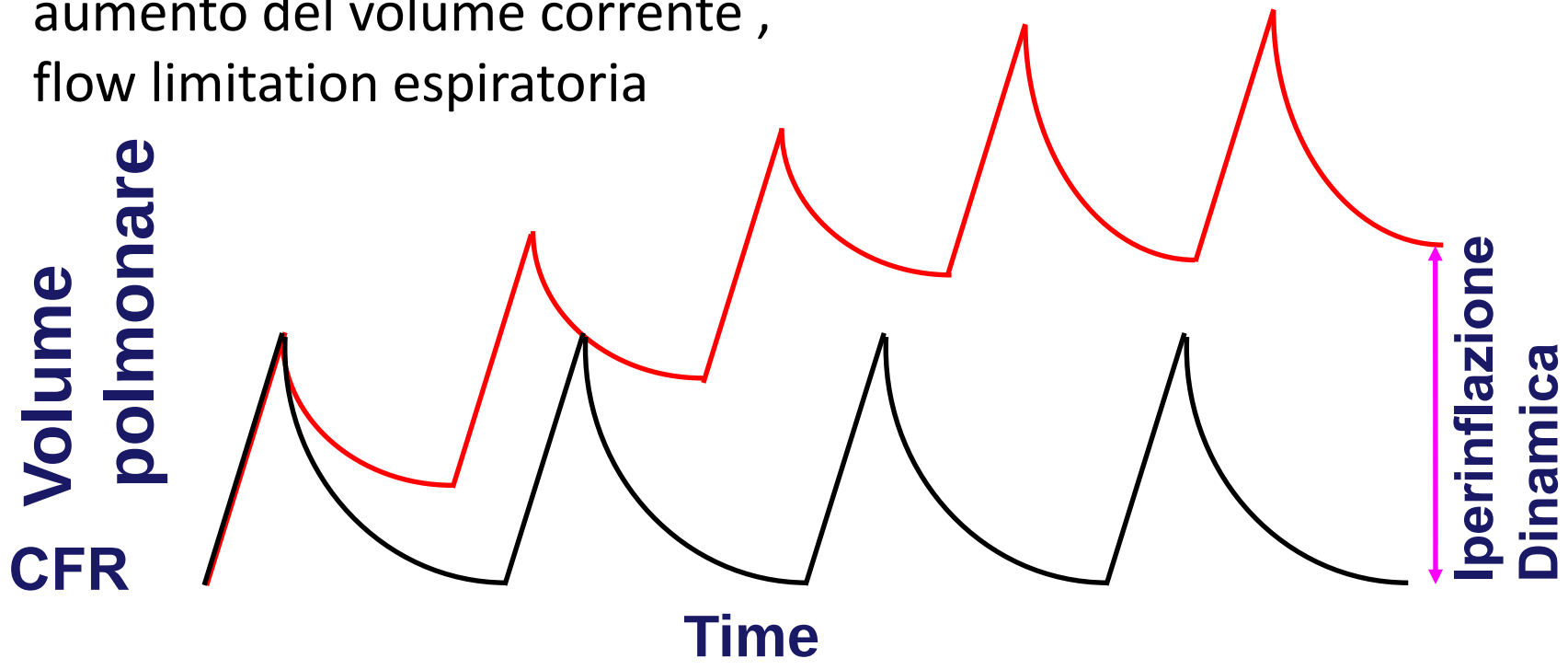
$RCe = Re \bullet C$ $[s] = [cmH_2O \bullet l/s] \bullet [ml/cmH_2O] / 1000$

Iperinflazione dinamica

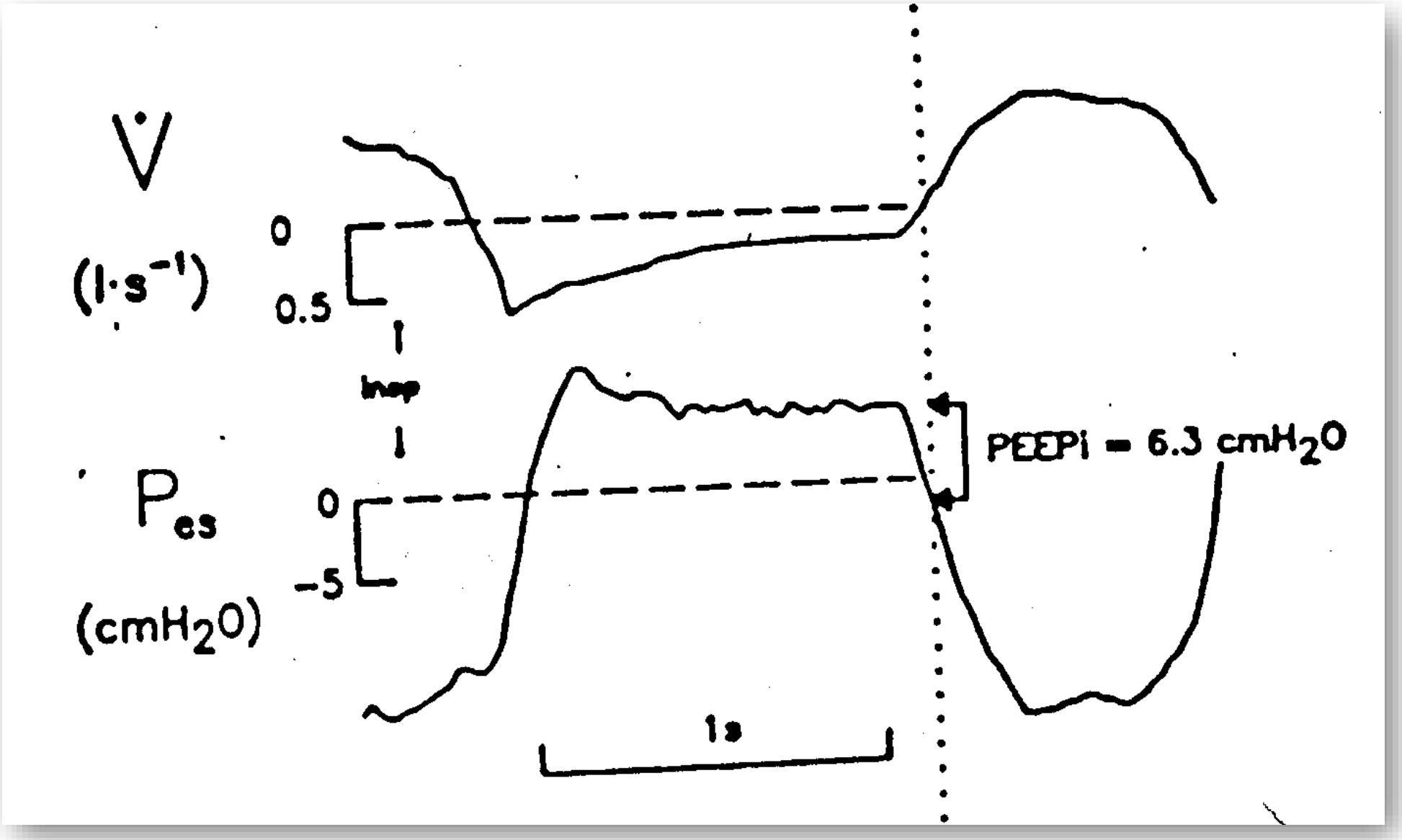
Durata espirazione insufficiente per permettere al polmone di svuotarsi fino al volume di rilasciamento del sistema respiratorio

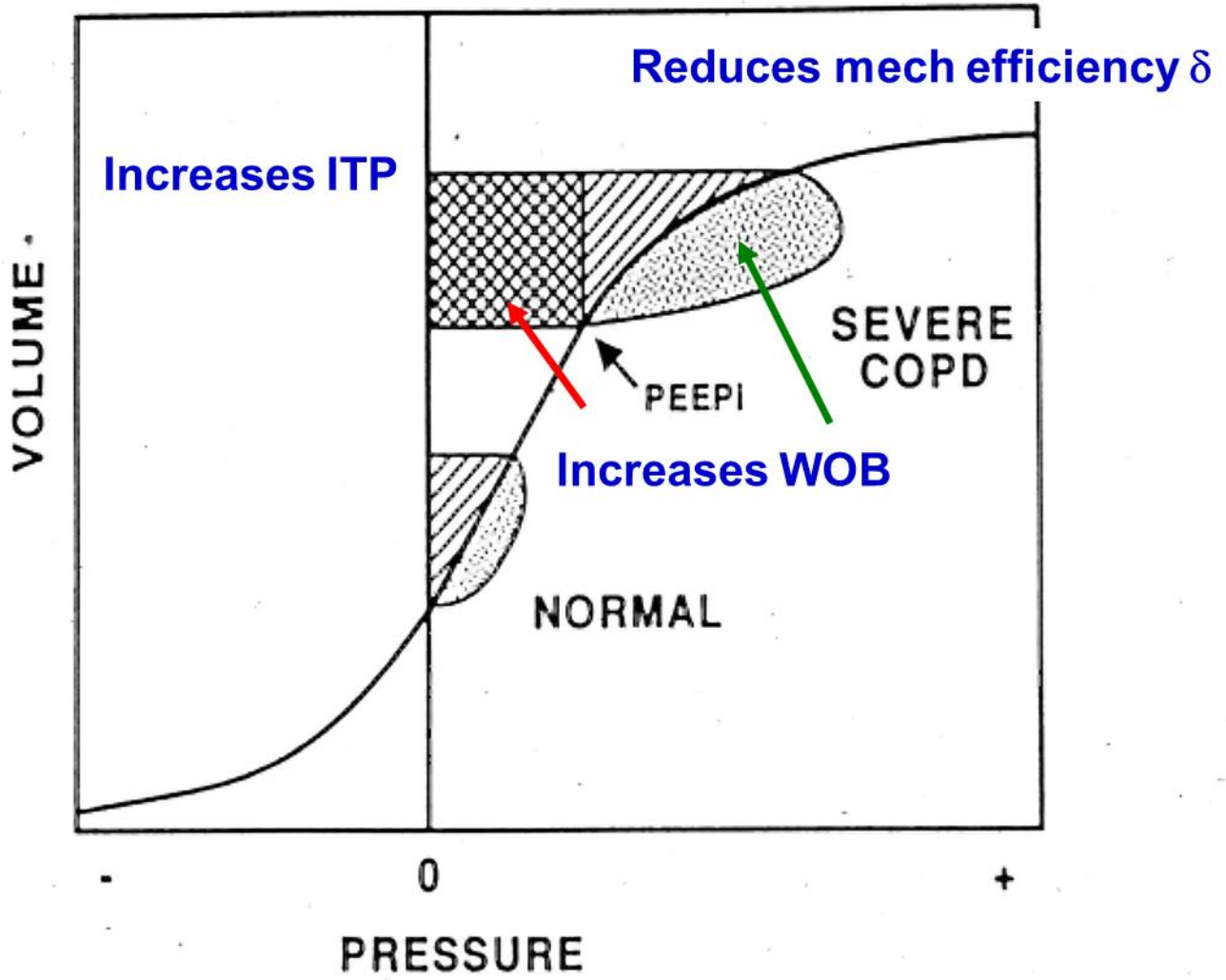
Cause:

- ostruzione vie aeree,
- aumento frequenza respiratoria,
- aumento del volume corrente ,
- flow limitation espiratoria



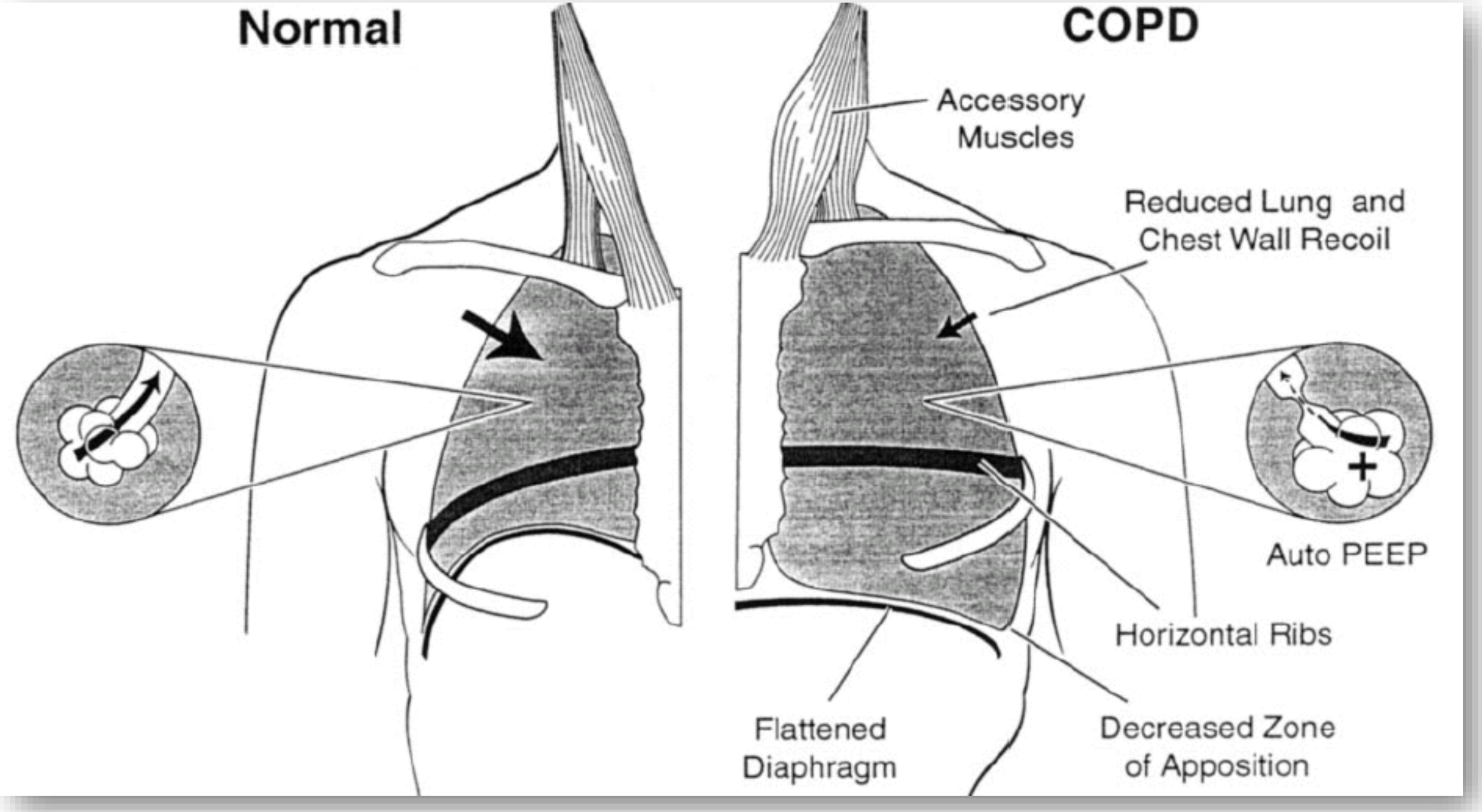
AutoPEEP: lavoro respiratorio aggiuntivo

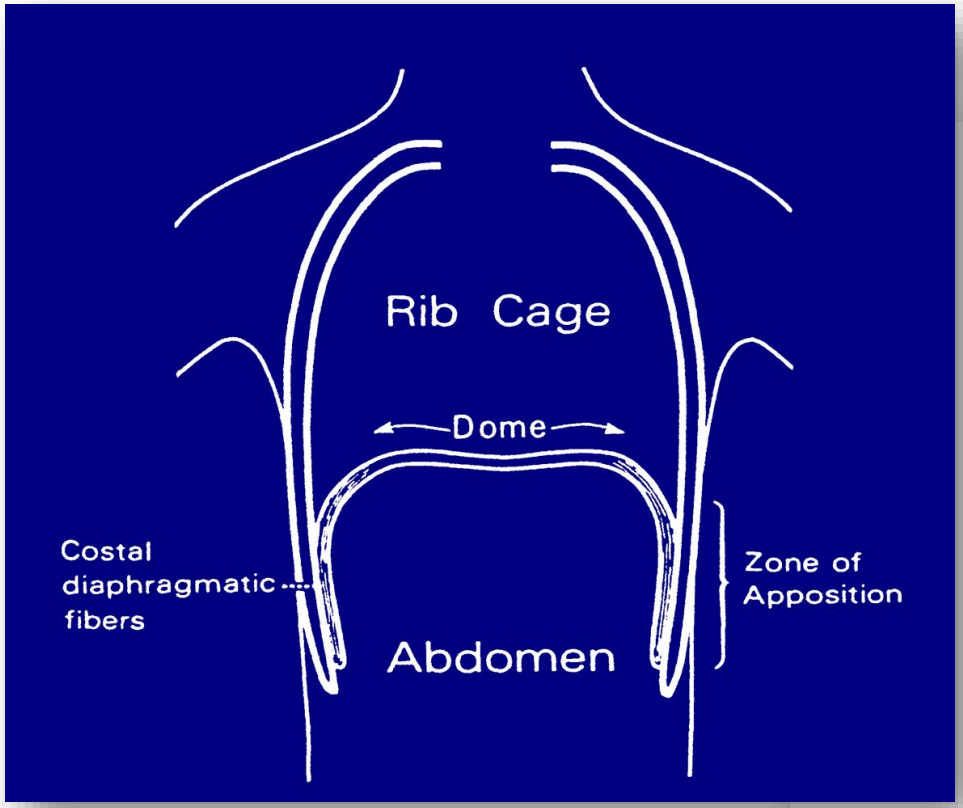


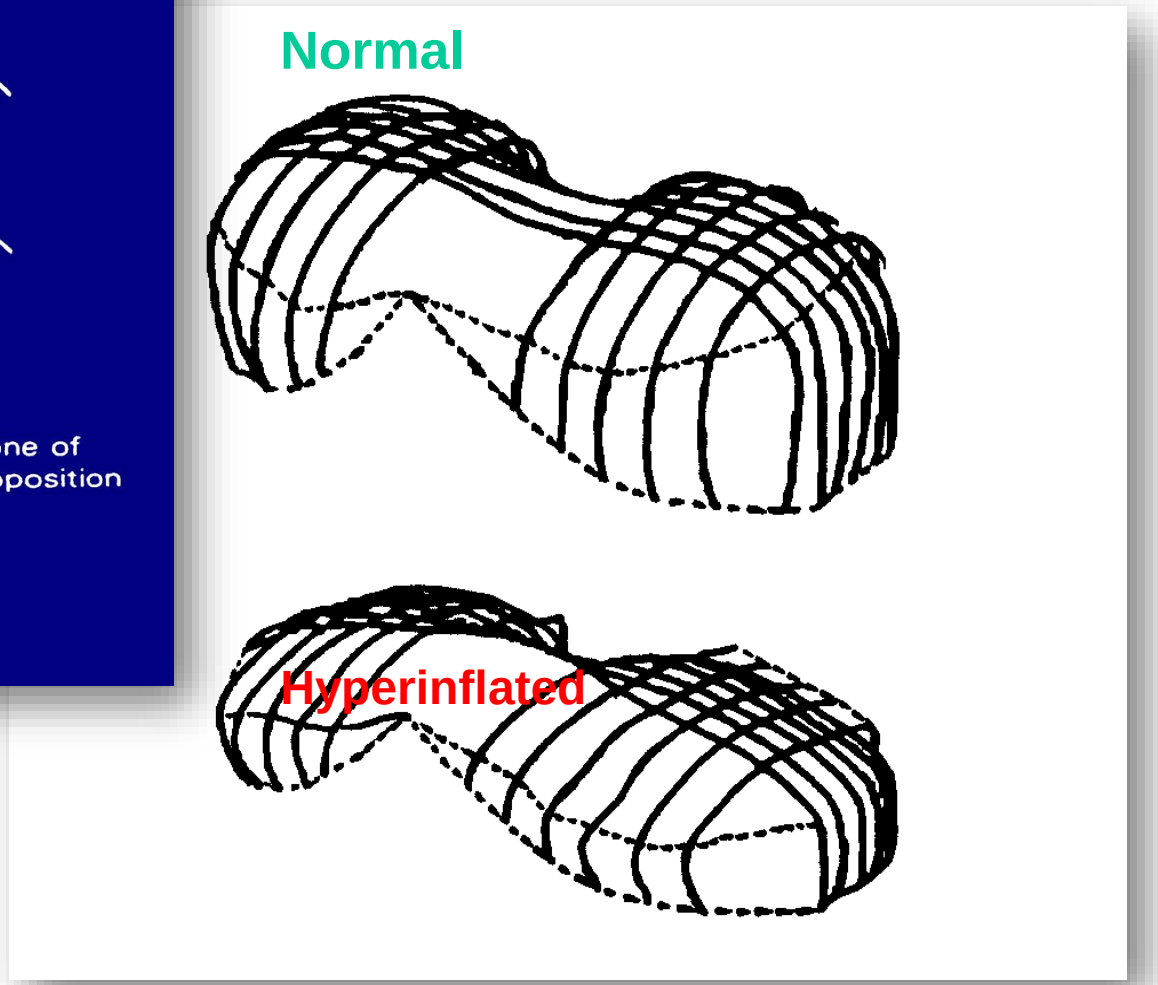


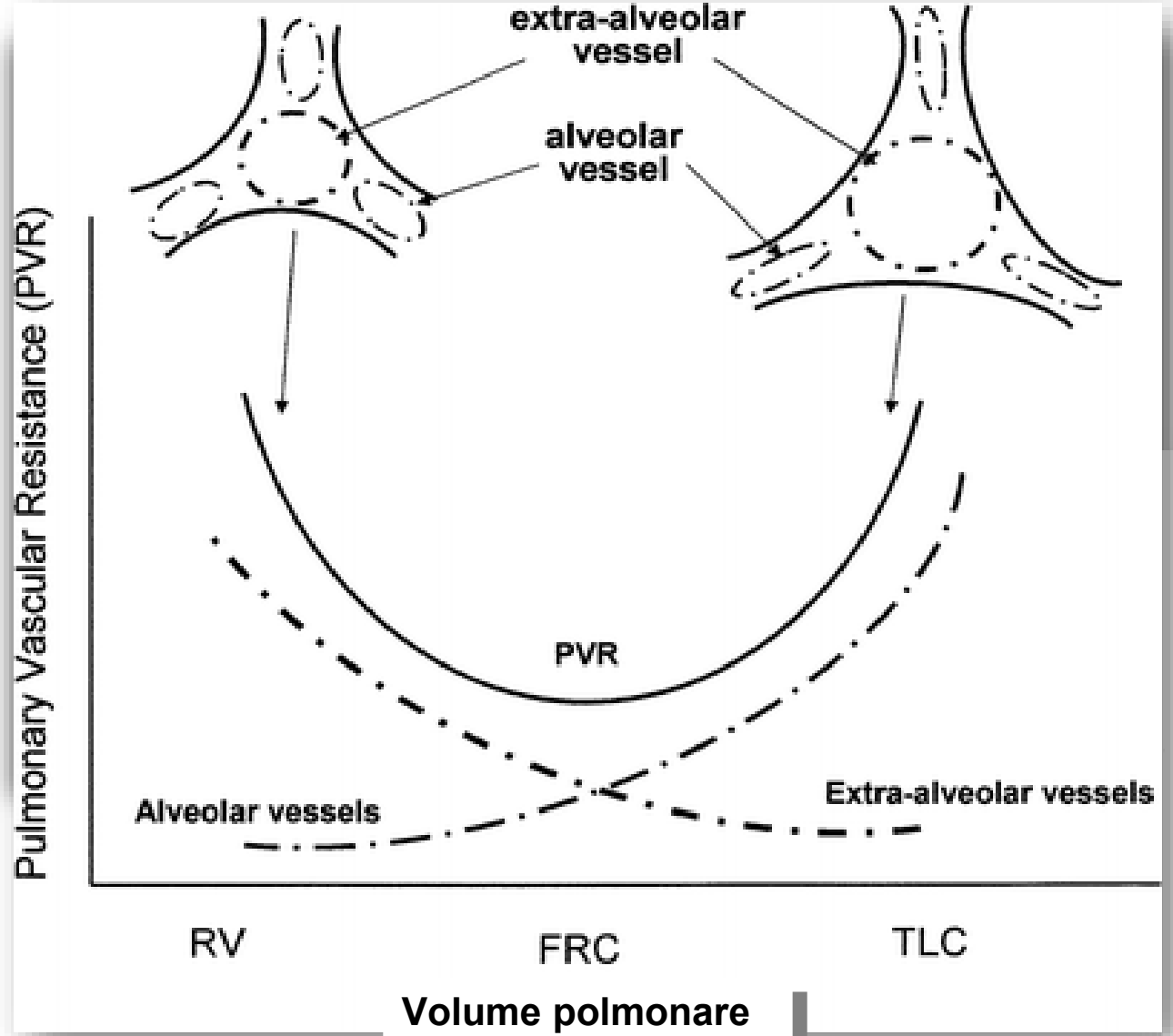
Gottfried SB. In: VentilatoryFailure.
Marini JJ, Roussos C, eds.
Springer Verlag. Berlin 1991;392-418

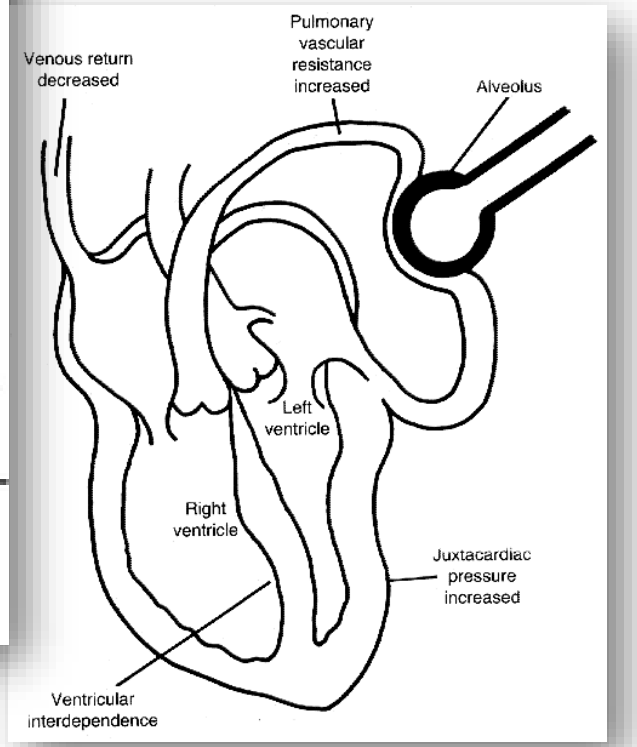
Riacutizzazione BPCO

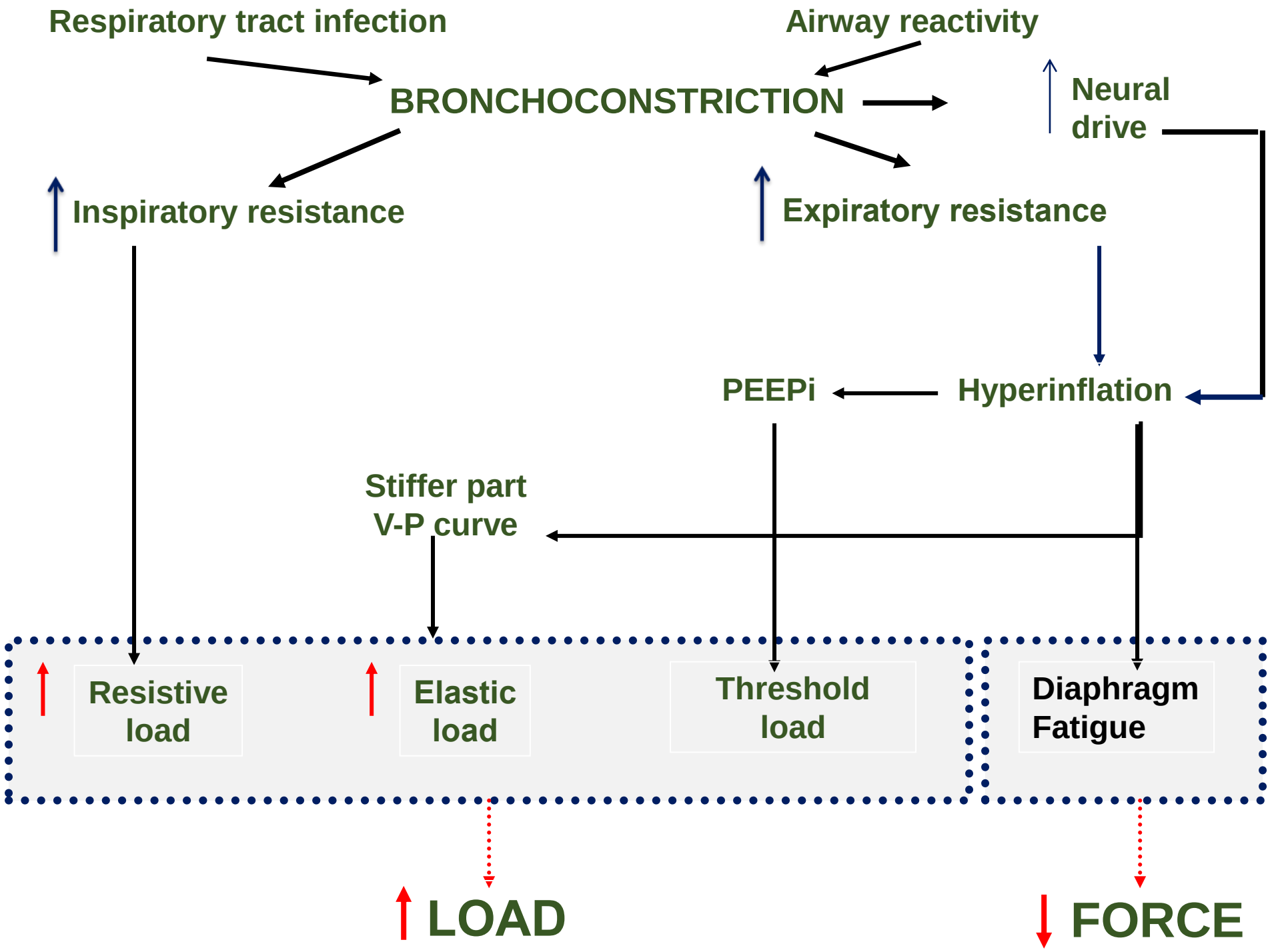



Rib Cage
Dome
Costal
diaphragmatic
fibers
Zone of
Apposition
Abdomen


Normal
Hyperinflated


extra-alveolar vessel
alveolar vessel
Pulmonary Vascular Resistance (PVR)
PVR
Alveolar vessels
Extra-alveolar vessels
RV
FRC
TLC
Volume polmonare


Venous return decreased
Pulmonary vascular resistance increased
Alveolus
Left ventricle
Right ventricle
Juxtacardiac pressure increased
Ventricular interdependence


Respiratory tract infection
Airway reactivity
BRONCHOCONSTRICTION
Neural drive
Inspiratory resistance
Expiratory resistance
PEEPi
Hyperinflation
Stiffer part V-P curve
Resistive load
Elastic load
Threshold load
Diaphragm Fatigue
LOAD
FORCE

Restrictive lung diseases are characterized by reduced lung volume

The many disorders that cause reduction or restriction of lung volumes may be divided into 2 groups

1. **Intrinsic lung diseases**
   - alteration in lung parenchyma
2. **Extrinsic disorders** (or extraparenchymal diseases)
   - disease of the pleura or chest wall
   - disease of neuromuscular apparatus

- Riduzione FiO_2 inspirata
- Ipoventilazione
- **Alterazione della diffusione**
- Alterazione V/Q
- Shunt

DLCO (Capacità di diffusione per il monossido di carbonio)

Misura la capacità dei polmoni di trasferire O_2 al sangue

Patologia restrittiva

- Ridotti volume polmonari con **riduzione DLCO**

  -malattie polmonari interstiziali

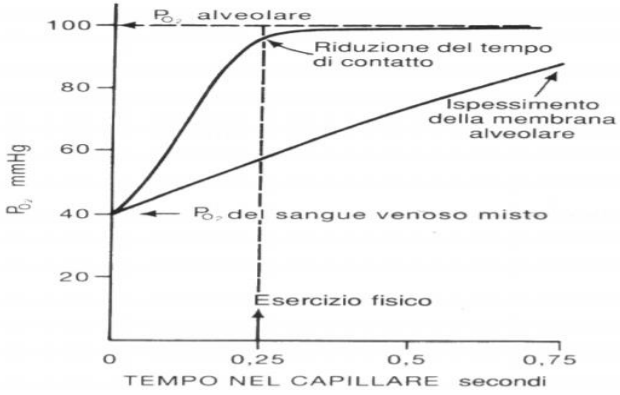
- Ridotti volume polmonari con **normale DLCO**

  - cause extrapolmonari :

    Obesità, versamento pleurico, malattie neuromusculari, scoliosi

ALTERAZIONE DELLA CAPACITA' DI DIFFUSIONE DEI GAS ATTRAVERSO LA MEMBRANA ALVEOLO – CAPILLARE

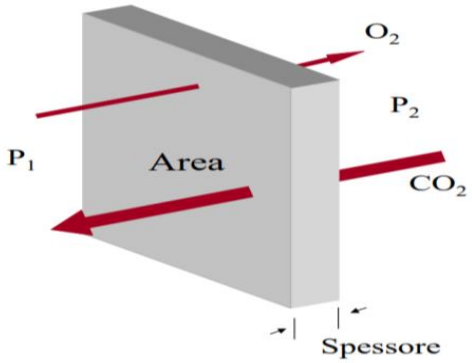
- Ispessimento della parete alveolare
- Ispessimento della membrana capillare
- Aumento del tratto di diffusione tra entrambe le membrane



ASBESTOSI – SARCOIDOSI – FIBROSI POLMONARE IDIOPATICA – SCLERODERMIA – ARTRITE REUMATOIDE

VASCULITI

EDEMA POLMONARE CARDIOGENO



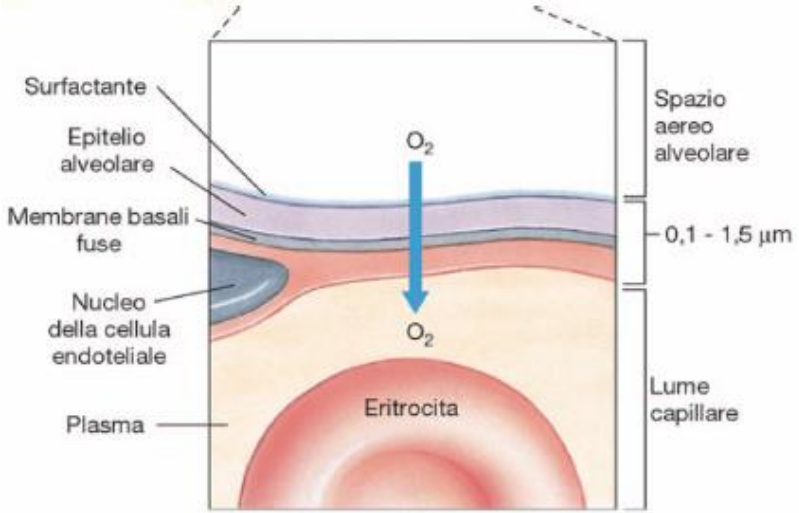
Legge di Fick

$$\dot{V}gas = \frac{A \times D \times (P_1 - P_2)}{S}$$

$$D \propto \frac{\text{solubilità}}{\sqrt{PM}}$$

Gli alveoli e la diffusione

- Membrana semipermeabile
- 130m^2 superficie alveolare (1/2 campo tennis)

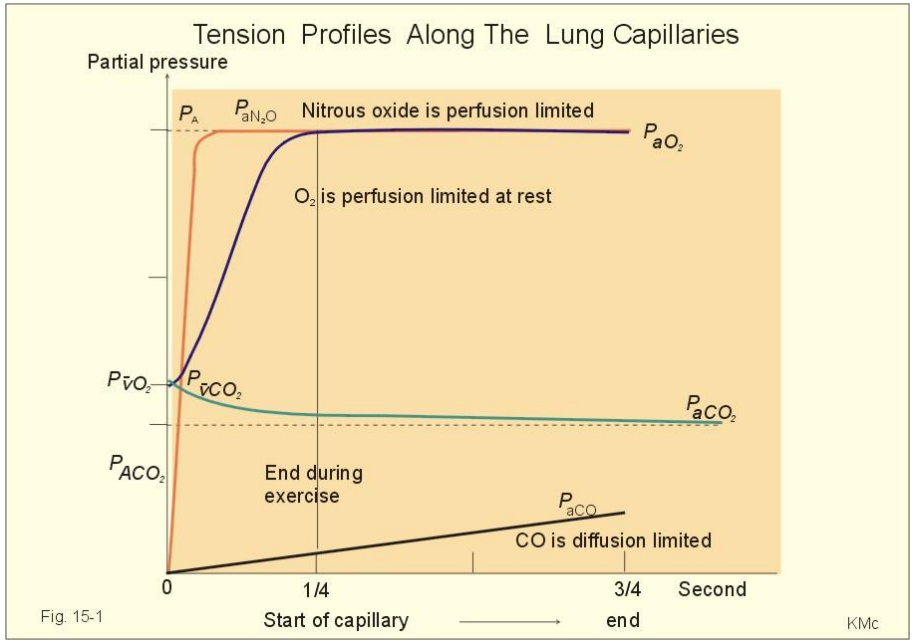


- Barriera alveolo capillare 0.5um
- Contenuto sangue capillare 200ml
- Legge di Fick

V= Coeff xArea/Spess x (P1-P2)

α/√PM

Coeff. solubilità

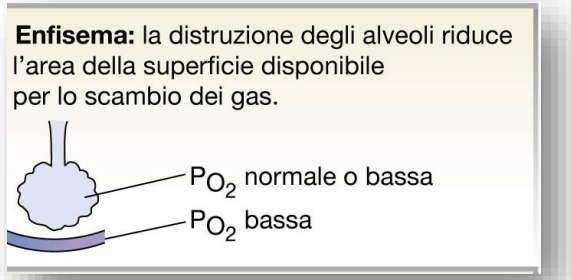


Le alterazioni della membrana alveolare modificano lo scambio di gas fra alveoli e capillari polmonari

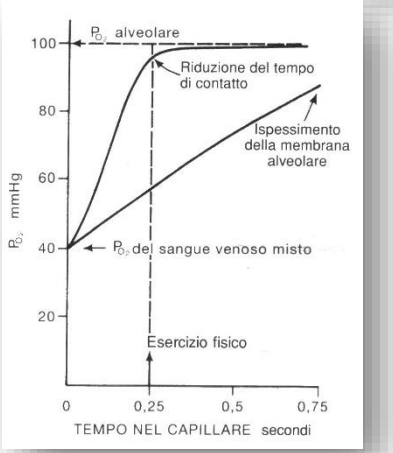
Lo scambio di ossigeno dagli alveoli al sangue richiede il passaggio attraverso la barriera formata da cellule alveolari e endotelio capillare.

Diffusione può essere alterata per:

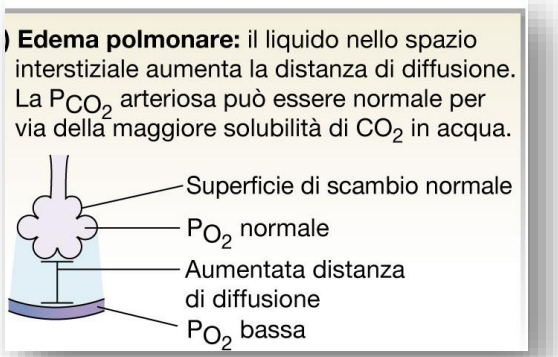
- ✓ **Diminuzione dell'area disponibile per lo scambio gassoso**



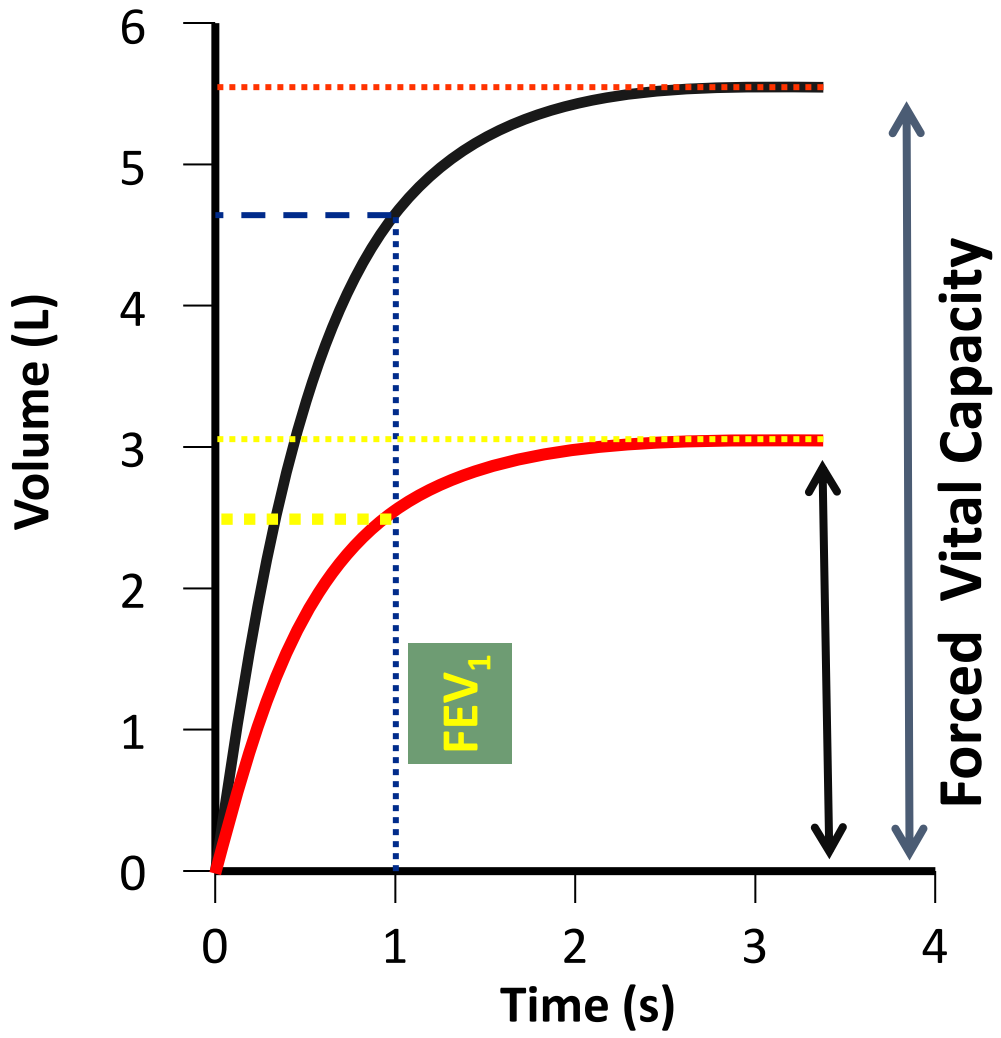
- ✓ **Aumento spessore membrana alveolare**



- ✓ **Aumento della distanza di diffusione**

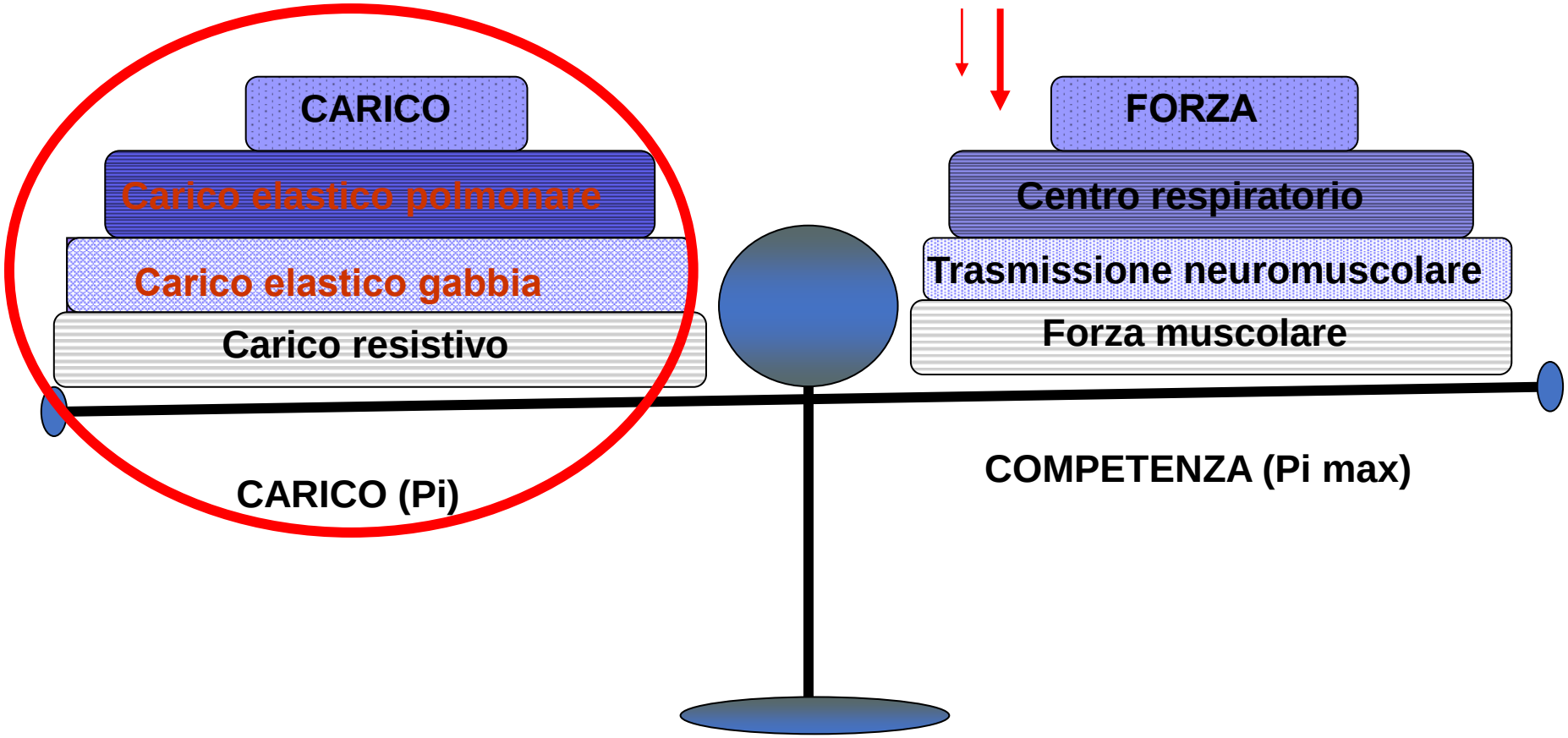


Vol-Time Spirometry in Restrictive Lung Disease

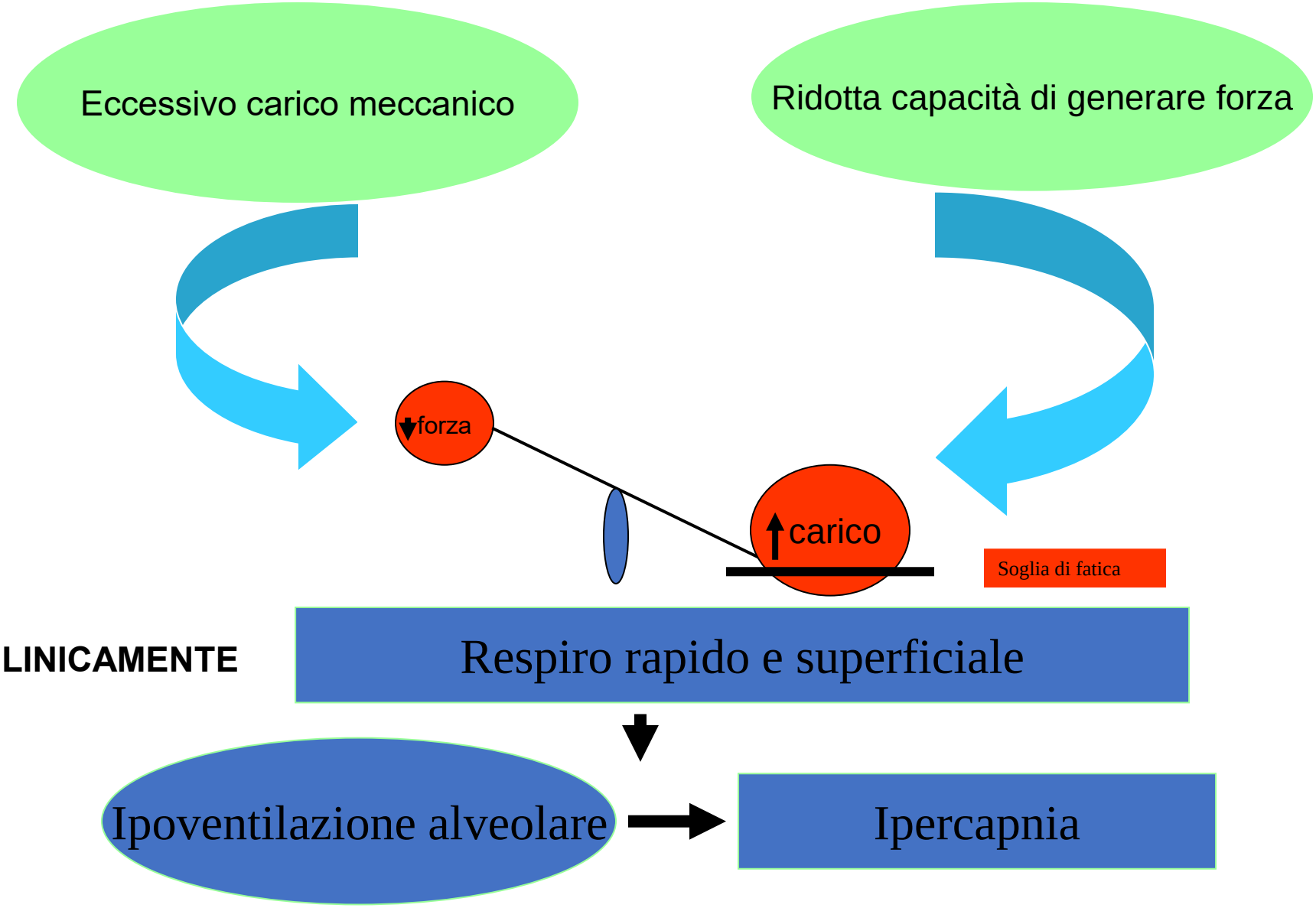


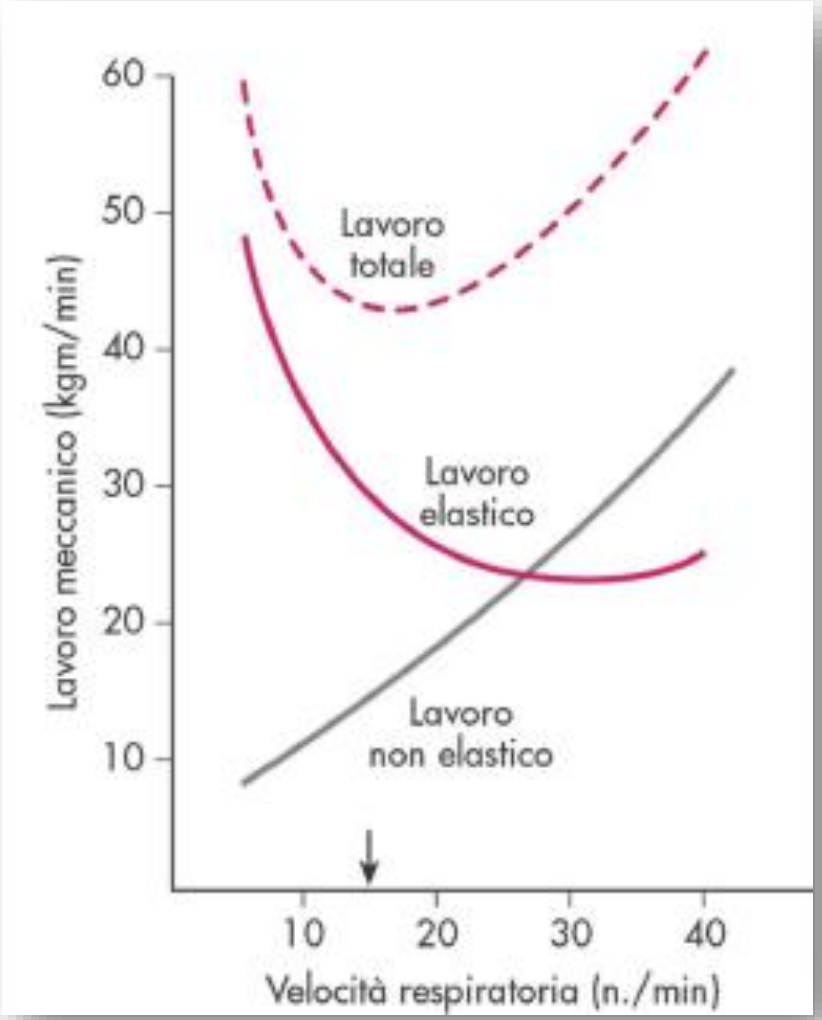
Restrictive Lung Disease:
Total Volume reduced and
FVC reduced, FEV_1 reduced
But FEV_1/FVC ratio =
NORMAL!

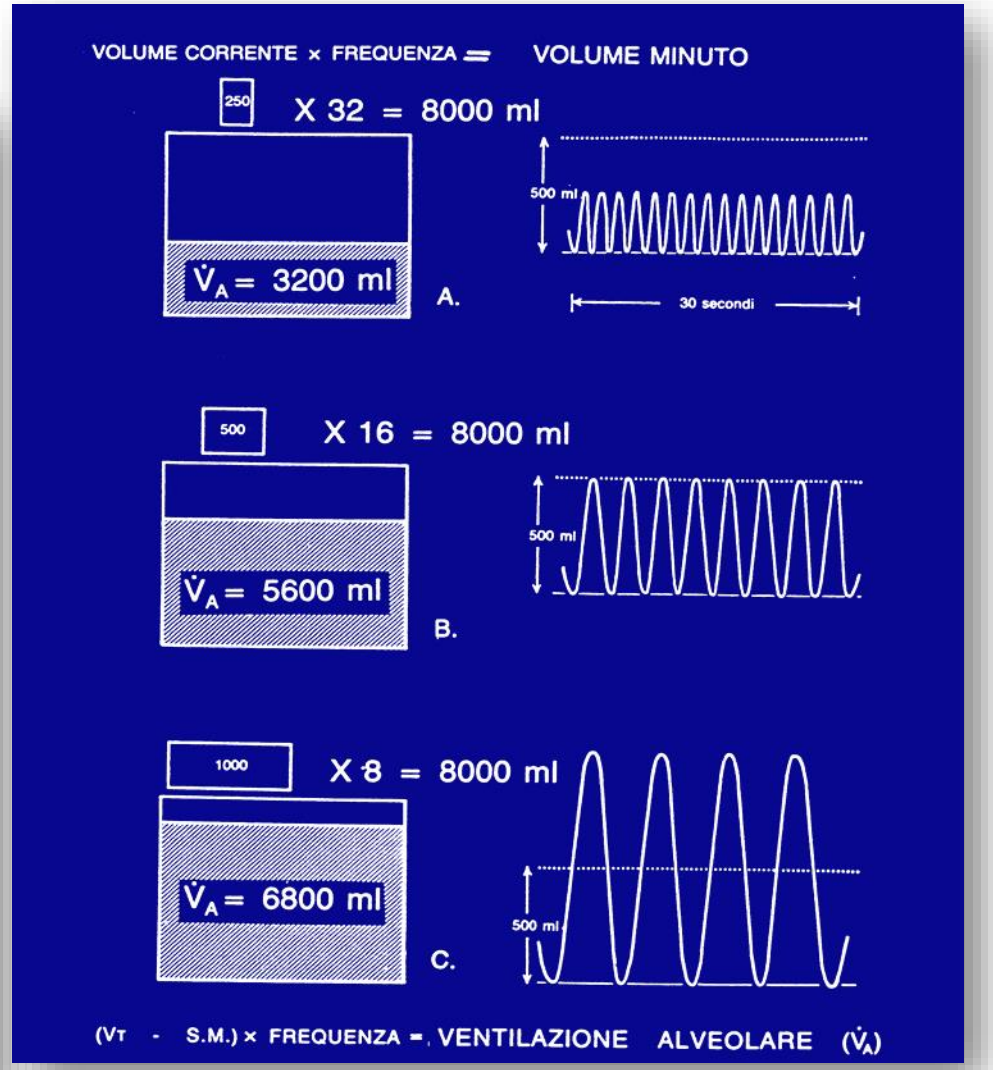
Relazione carico-forza (Chest-wall)

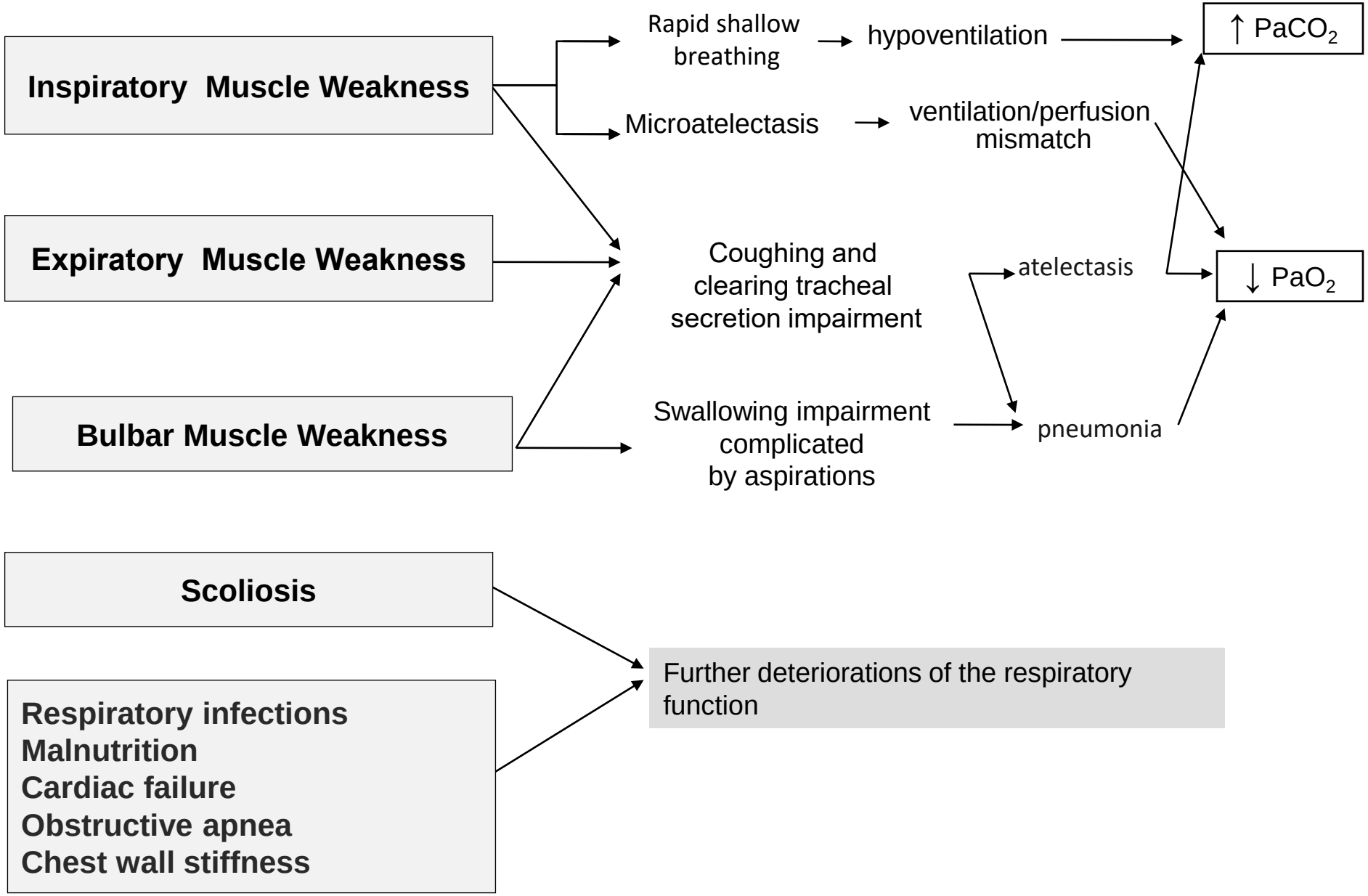


Risposta a sbilanciamento del rapporto carico-forza




Lavoro meccanico (kgm/min)
60
50
40
30
20
10
Lavoro totale
Lavoro elastico
Lavoro non elastico
10
20
30
40
Velocità respiratoria (n./min)


VOLUME CORRENTE × FREQUENZA = VOLUME MINUTO
250
X 32 = 8000 ml
V̇A = 3200 ml
A.
500 ml
30 secondi
500
X 16 = 8000 ml
V̇A = 5600 ml
B.
500 ml
1000
X 8 = 8000 ml
V̇A = 6800 ml
C.
500 ml
(VT - S.M.) × FREQUENZA = VENTILAZIONE ALVEOLARE (V̇A)



Racca F, Del Sorbo L, Mongini T, Vianello A, Ranieri VM. *Minerva Anestesiologica 2010 ;76:51-62*

Malattie neuromuscolari con compromissione respiratoria

Malattie del motoneurone

- ✓ Sclerosi laterale amiotrofica (SLA)
- ✓ Poliomielite e S. Post polio
- ✓ Atrofia muscolare spinale (SMA)
- ✓ Atrofia muscolare spino bulbare (syndrome di Kennedy)

Malattie della giunzione neuromuscolare

- ✓ Myasthenia gravis (MG), Lambert-Eaton
- ✓ Sindromi miasteniche congenite

Neuropatie periferiche

- ✓ Sindrome di Guillain–Barrè (GBS),
- ✓ Polineuroptia demielinizzante infiammatoria cronica (CIDP)
- ✓ Polineuropatia del paziente critico (CIP

Miopatie ereditarie

Distrofie muscolari progressive

- ✓ S. Duchenne , Becker
- ✓ Distrofia facio scapolo omerale
- ✓ Distrofia miotonica

Miopatie congenite

- ✓ Miopatie miotubulari
- ✓ Miopatia a corpi nemalinici miopatie miofibrillari

Distrofie muscolari congenite

- ✓ Di Ulrich, Da deficit di merosina (DMC 1A),
- ✓ Di Emery-Dreyfuss
- ✓ **Miopatie metaboliche**
- ✓ Miopatie mitocondriali
- ✓ Glicogenosi

Miopatie acquisite

- ✓ Miopatie infiammatorie (polimiosite)
- ✓ Miopatia del paziente critico
- ✓ Miopatie tossiche

PROBABILITA' DI SVILUPPARE INSUFFICIENZA REPIRATORIA

Inevitabile

- Distrofia muscolare di Duchenne
- Atrofia muscolare spinale (SMA) tipo 1
- Malattie del motoneurone SLA

Frequente:

- distrofia muscolare dei cingoli MD 2C,2D,2F,2I
- Miopatia nemalinica
- Int SMA
- Deficit di maltase acida
- miopatia miotubulare legata la cromosoma X
- Distrofia muscolare congenital di Ulrich
- Miastenia congenita
- Distrofia miotonica congenita

Occasionale

- Malattia muscolare di Emery Dreifuss, Becker
- miopatia di Bethlem

Bassa

- Miopatia mitocondriale
- Distrofia muscolare dei cingoli MD 1, 2A,B,G,H,
- Distrofia muscolare oculofaringea

ORIGINAL ARTICLE

Patterns and predictors of sleep disordered breathing in primary myopathies

R Ragette, U Mellies, C Schwake, T Voit, H Teschler

Thorax 2002;57:724–728

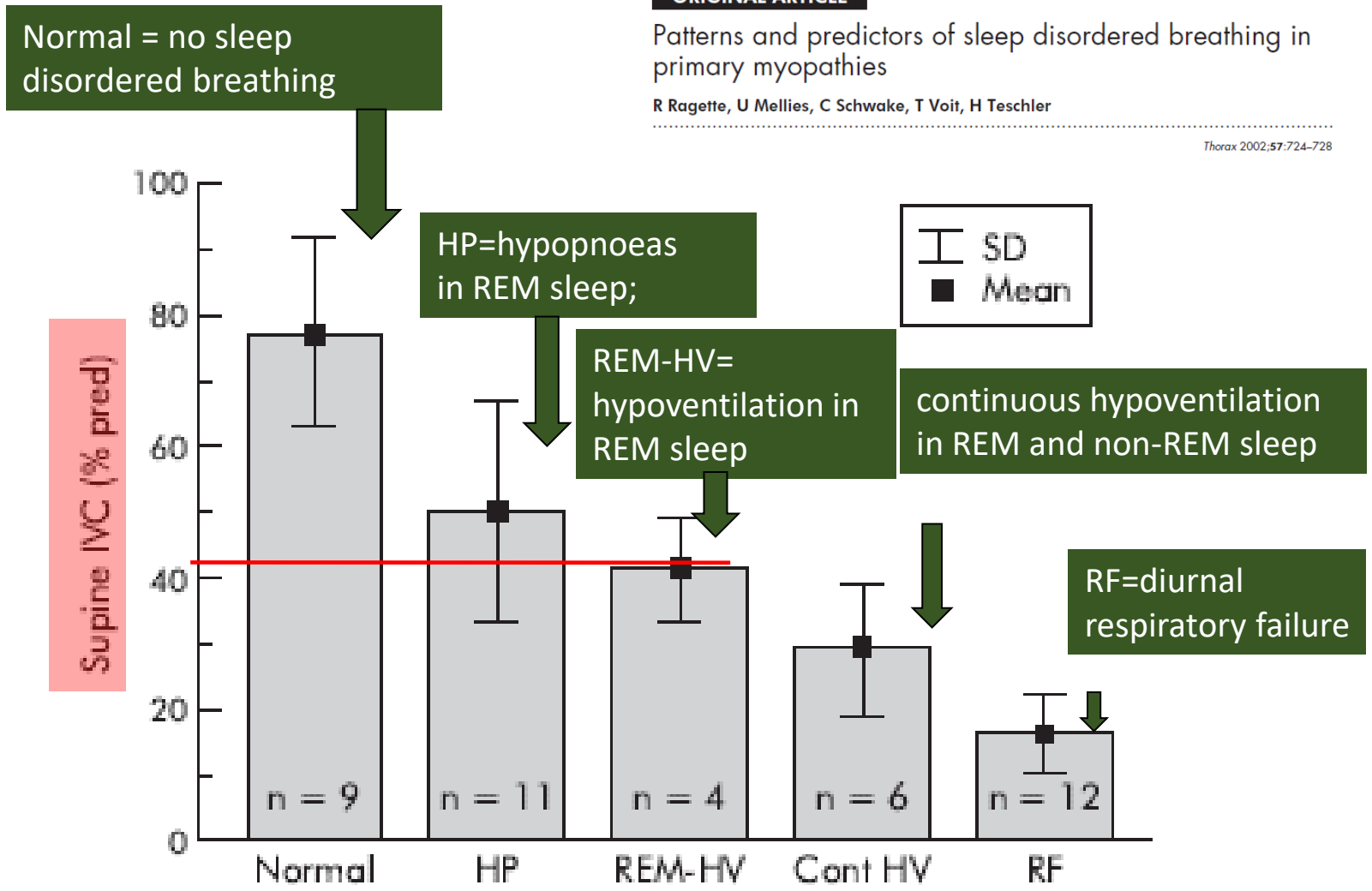


Figure 2 Relationships between IVC and respiratory abnormality (R=0.88, $p<0.0001$). Normal–no sleep disordered breathing; HP–hypopnoeas in REM sleep; REM-HV–hypoventilation in REM sleep; REM/non-REM-HV–continuous hypoventilation in REM and non-REM sleep; RF–diurnal respiratory failure.

ORIGINAL ARTICLE

Patterns and predictors of sleep disordered breathing in primary myopathies

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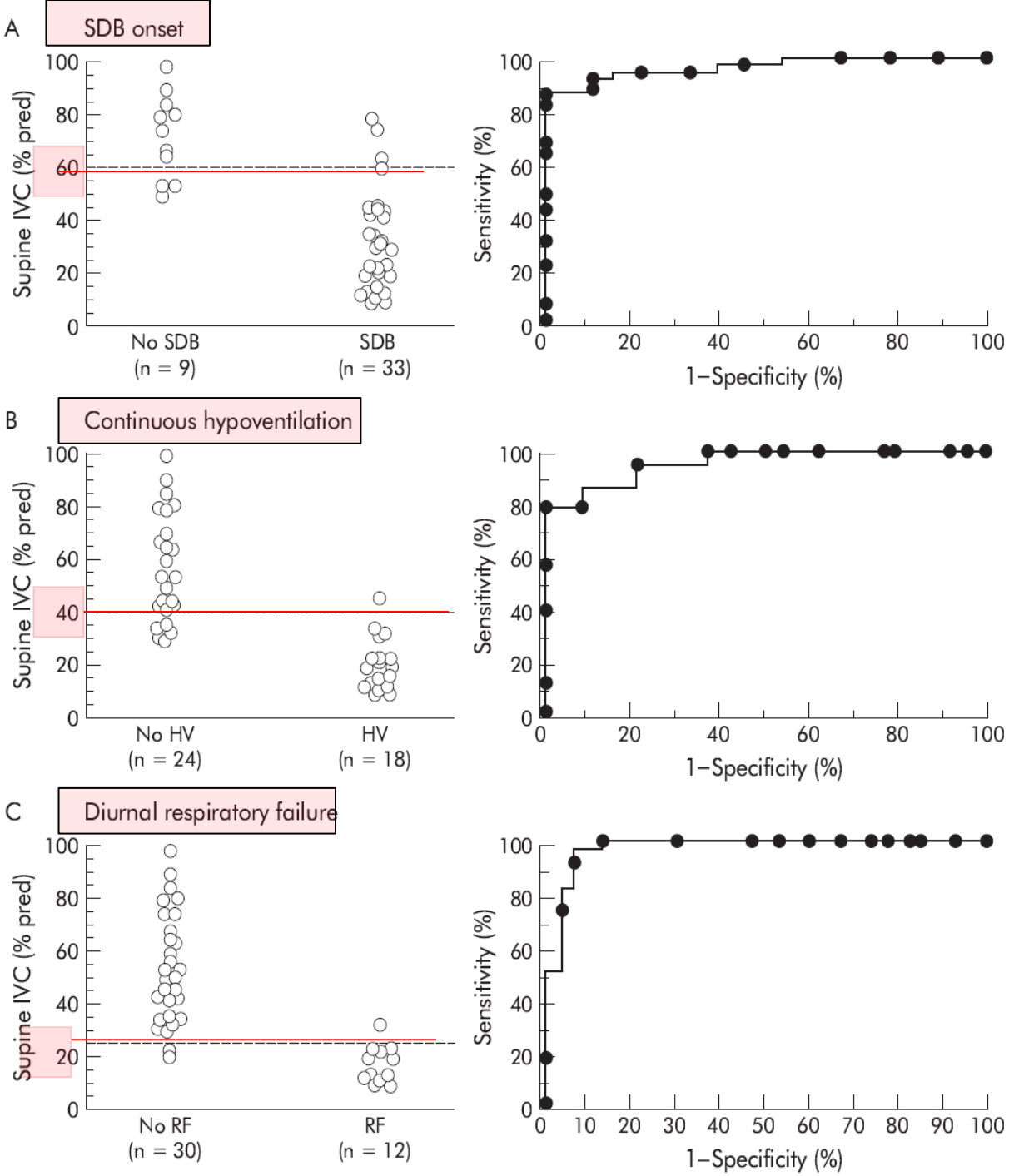
Thorax 2002;57:724–728

Table 1 Predictors of sleep disordered breathing (SDB) and diurnal respiratory failure

Predictors	Sensitivity (%)	Specificity (%)	AUC (%)
IVC (%)			
<60: SDB onset	91	89	97
<40: continuous HV	94	79	98
<25: dRF	92	93	96
Pimax (kPa)			
<4.5: SDB onset	82	89	85
<4.0: continuous HV	95	65	80
<3.5: dRF	92	55	81

IVC=inspiratory vital capacity; Pimax=maximal inspiratory pressure; HV=hypercapnic hypoventilation; dRF=diurnal respiratory failure; AUC=area under the curve.

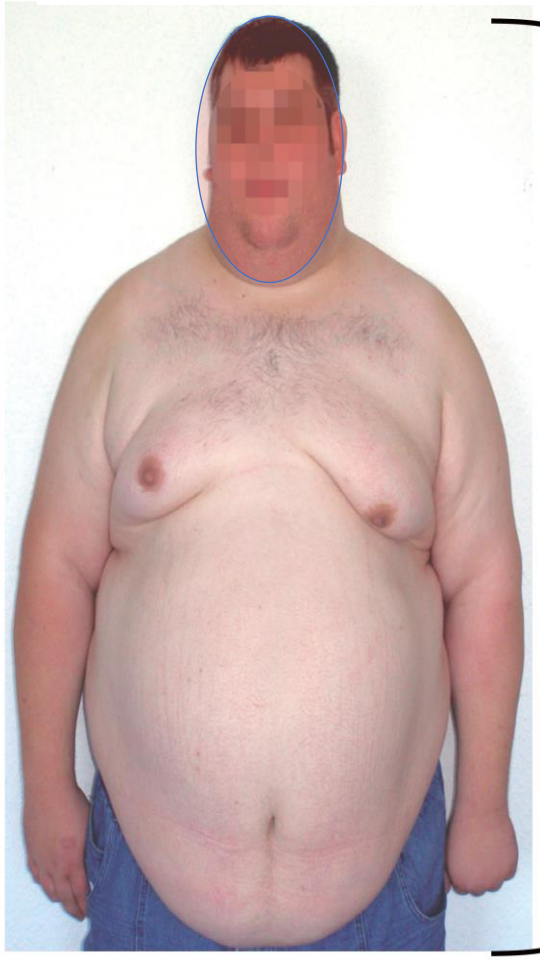


VC <60% predicted is associated with **REM related hypopnoeas**

VC< 40 % predicted and MIP < 30 cm H_2O are strongly correlated with the **nocturnal hypoventilation in both REM and NREM sleep**

VC < 25% correlated with diurnal RF

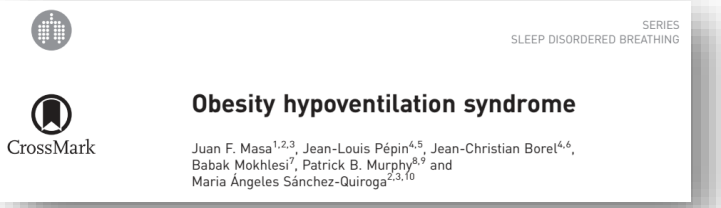
Obesity hypoventilation syndrome (OHS)



- Altered upper airway mechanics; ↑ upper-airway resistance, OSA
- Impaired respiratory mechanics; ↓FRC, ↓ ERV, ↓ compliance, ↑ resistance, ↑ mechanical load
- Gas exchange deterioration; V/Q mismatch, ↑VD/VT
- Respiratory muscles weakness
- Neurohumoral influences leptin resistance

- ↑ Sleep $PaCO_2$, ↓ sleep PaO_2, ↑ serum bicarbonate
- ↑ Work of breathing
- Blunted ventilatory drive; ↓ CO_2 response

- Chronic daytime hypercapnia



Pathophysiology of OHS is related to three major mechanisms:

1) obesity-related changes in the respiratory system;
2) alterations in respiratory drive;
3) breathing abnormalities during sleep

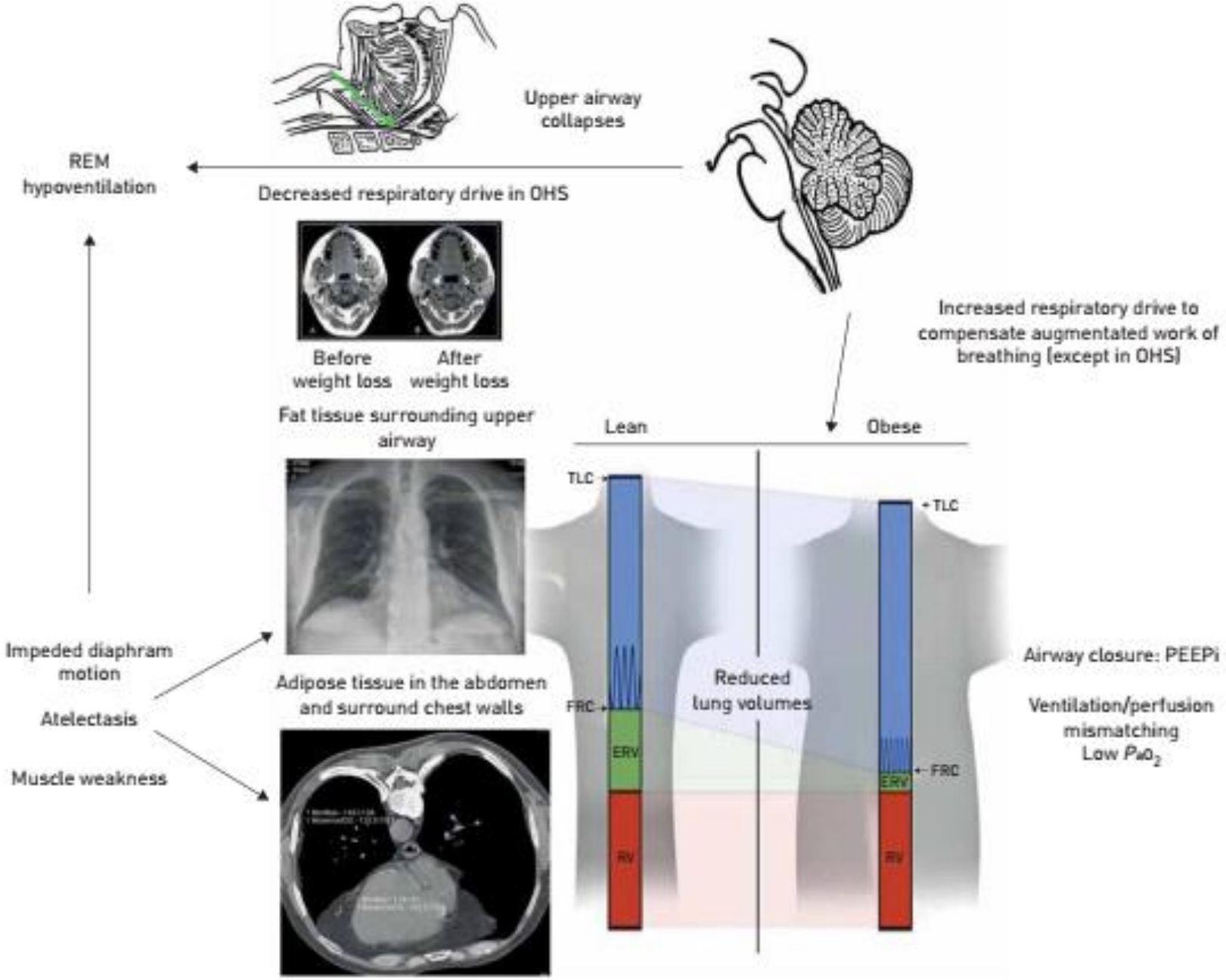
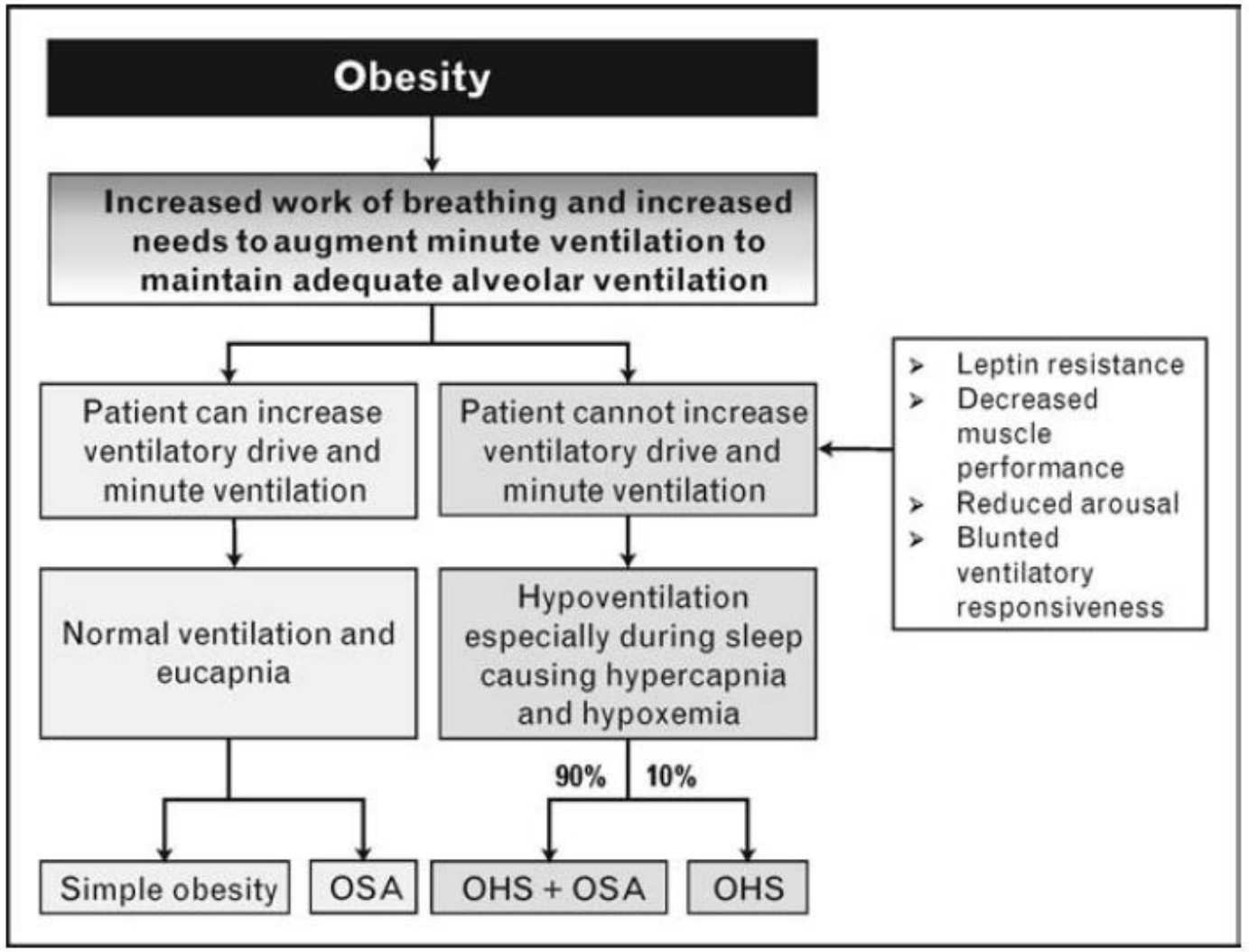


FIGURE 2 Pathophysiology of obesity hypoventilation syndrome (OHS). The implicated mechanisms leading to daytime hypercapnia are, potentially, the obesity-related changes in the respiratory system, central hypoventilation, obstructive sleep apnoeas and hypoventilation during sleep, mainly during rapid eye movement (REM). PEEPi: intrinsic positive end-expiratory pressure; P_aO_2: arterial oxygen tension; FRC: functional residual capacity; ERV: expiratory reserve volume; RV: residual volume; TLC: total lung capacity.

Acute ventilatory failure complicating obesity hypoventilation: update on a 'critical care syndrome'

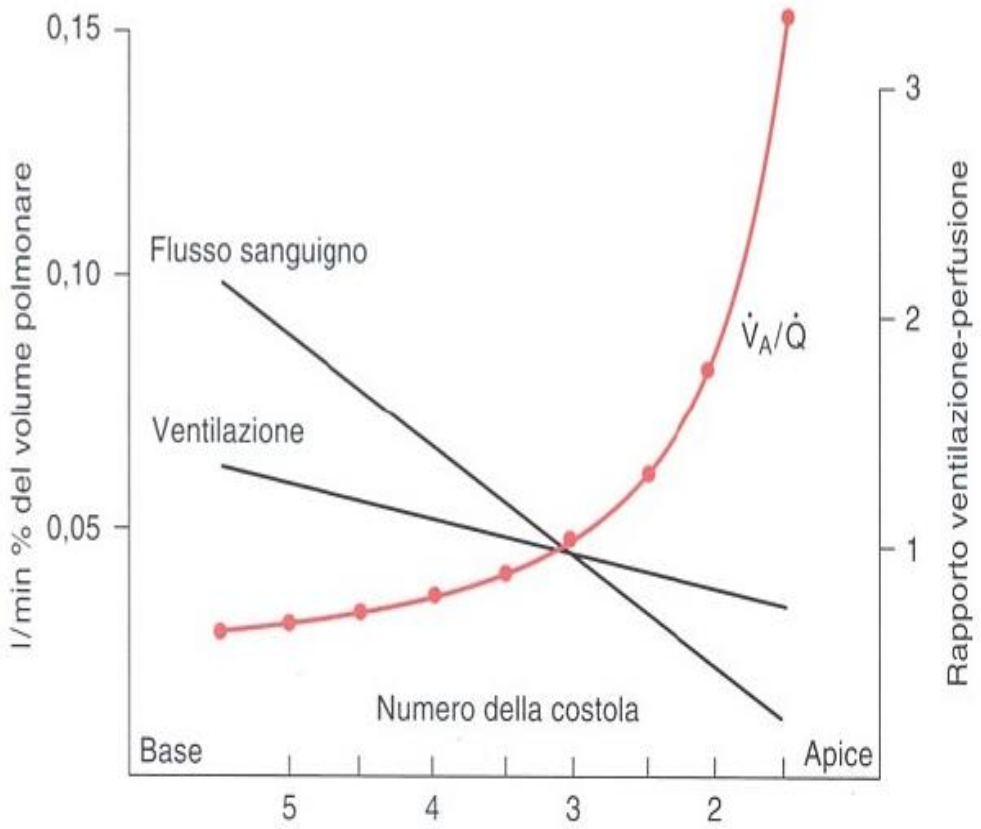
Ahmed BaHammam

Current Opinion in Pulmonary Medicine 2010, 16:543–551

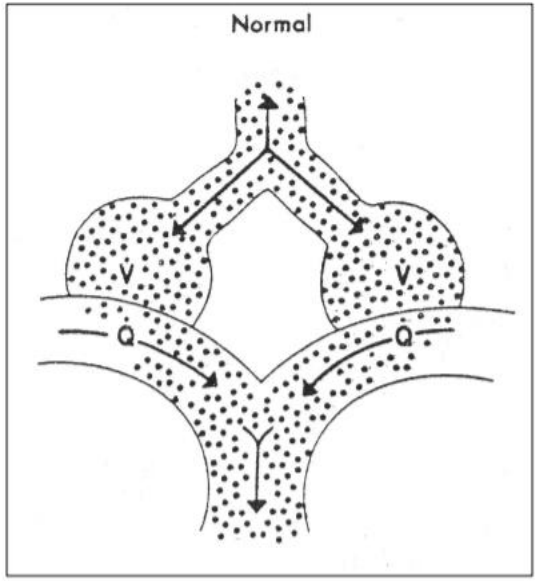


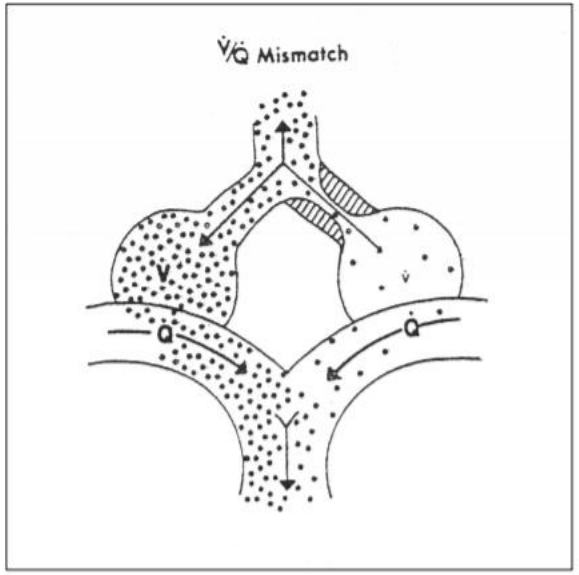
- Riduzione FiO_2 inspirata
- Ipoventilazione
- Alterazione della diffusione
- **Alterazione V/Q**
- Shunt

Rapporto tra Ventilazione alveolare (V) e Perfusione capillare (Q)

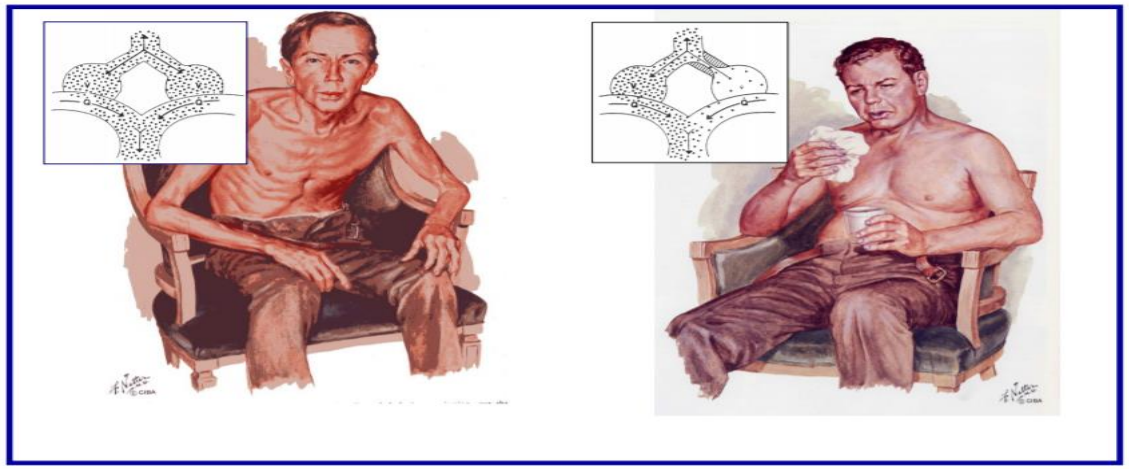


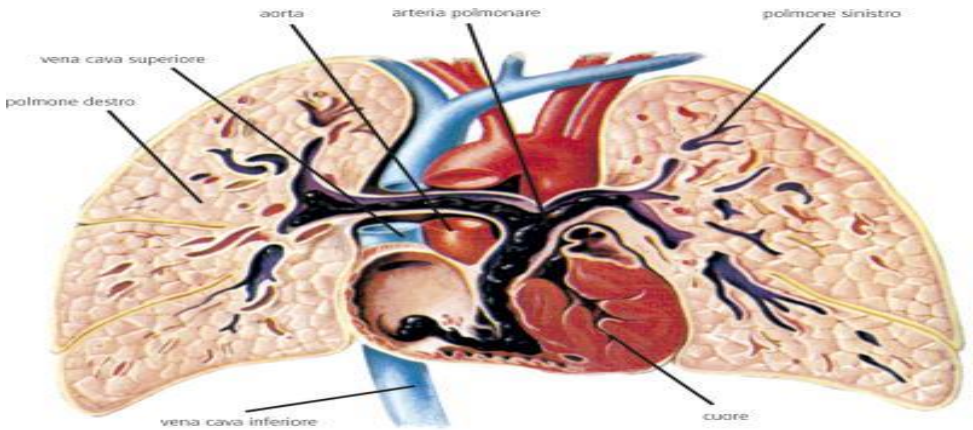
$$V/Q = 0.8$$





- BPCO
- EMBOLIA POLMONARE
- ASMA
- EDEMA POLMONARE

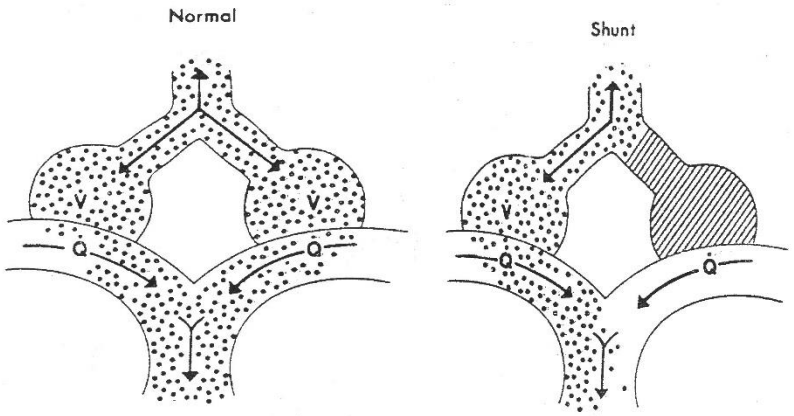


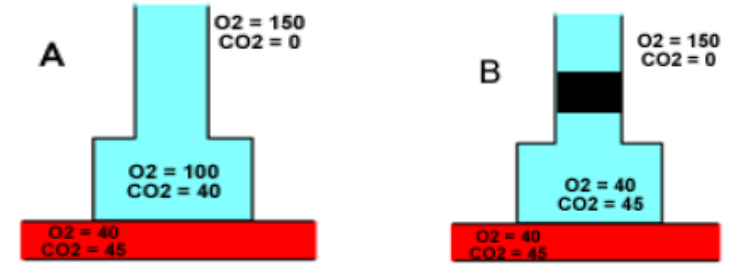


- ❑ Riduzione FiO_2 inspirata
- ❑ Ipoventilazione
- ❑ Alterazione della diffusione
- ❑ Alterazione V/Q
- ❑ **Shunt**

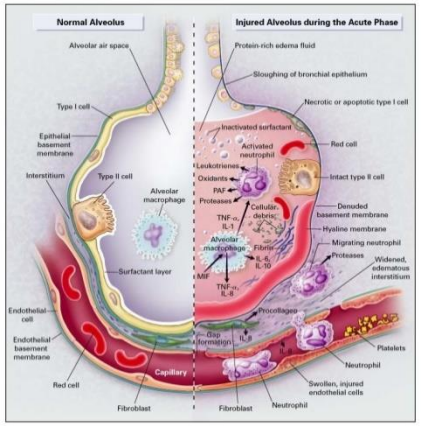
QUOTA DI SANGUE CHE RAGGIUNGE IL CIRCOLO ARTERIOSO DOPO AVER ATTRAVERSATO AREE NON VENTILATE

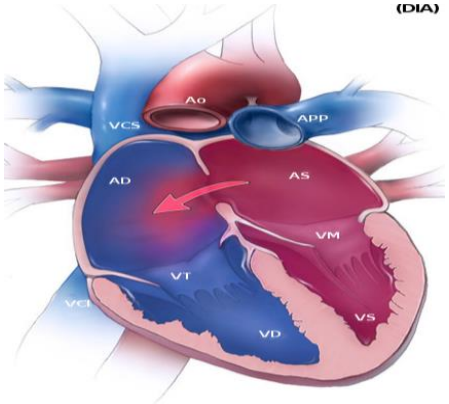
$$\frac{V}{Q} = 0$$





rapporto Va/Q normale rapporto Va/Q diminuito





SHUNT INTRAPOLMONARE

CONSOLIDAMENTO POLMONARE – ARDS

SHUNT ANATOMICO

FISTOLE ARTERO – VENOSE

SHUNT INTRCARDIACO (FOP – DIA – DIV – DOTTO DI BOTALLO)