La ventilazione meccanica non invasiva nel malato ostruito e nel malato con patologia restrittiva di parete

(sindrome obesità/cifoscoliosi)

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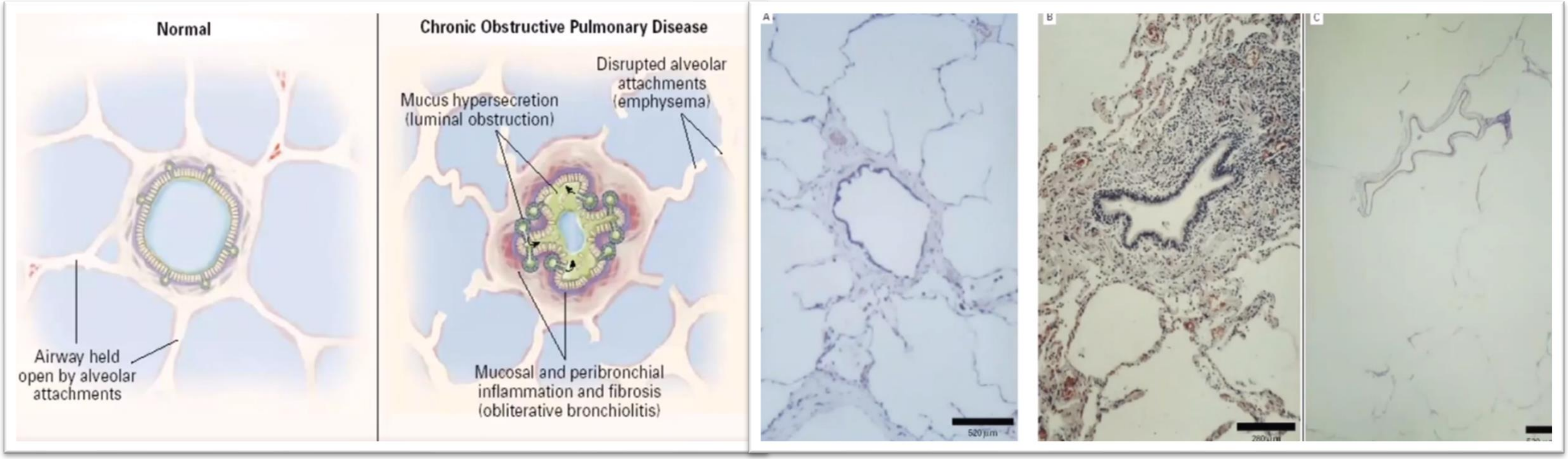
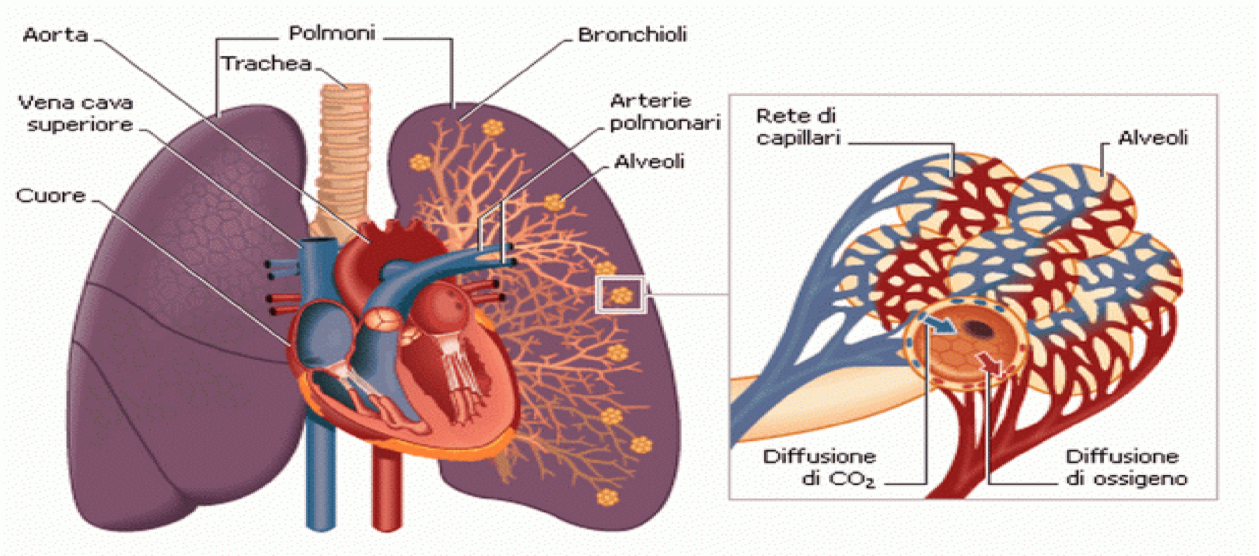
Roma, 30 novembre - 3 dicembre 2022
UNIVERSITÀ CATTOLICA DEL SACRO CUORE

Patologia ostruttiva



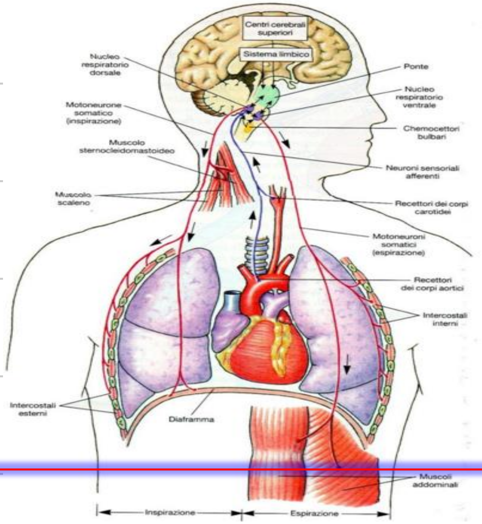
The partial pressure of carbon dioxide in arterial blood ($PaCO_2$) is **directly** proportional to the rate of carbon dioxide (CO_2) production (VCO_2) by oxidative metabolism and **indirectly** proportional to the rate of CO_2 elimination by the lung (alveolar ventilation; V_A).



$$PaCO_2 = (k) \times VCO_2/[V_E(1 - V_D/V_T)]$$

Respiratory pathway affecting carbon dioxide elimination

Central nervous system ↓	"Won't breathe"
Peripheral nervous system ↓	"Can't breathe"
Respiratory muscles ↓	
Chest wall and pleura ↓	
Upper airway ↓	
Lungs	**Abnormal gas exchange: "Can't breathe enough"**

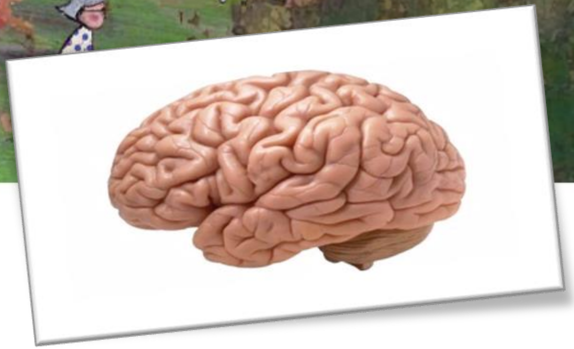


Oxygen-induced hypercapnia

Increased dead space – The largest component of acute hypercapnia (**48 %**) was due to an increase in dead space ventilation (ie, areas of high V/Q). This probably reflects worsening of V/Q matching due to a loss of hypoxic pulmonary vasoconstriction (HPV). HPV normally serves to improve the matching between blood flow and ventilation. This compensatory response improves V/Q matching and decreases physiologic dead space.

Haldane effect – An additional **30 %** rise in $PaCO_2$ was attributed to decreased hemoglobin affinity for CO_2. This occurs because oxyhemoglobin binds CO_2 less avidly than deoxyhemoglobin; thus, addition of oxygen to the blood displaces CO_2 from hemoglobin thereby increasing the amount of CO_2 dissolved in blood, which in turn determines $PaCO_2$.

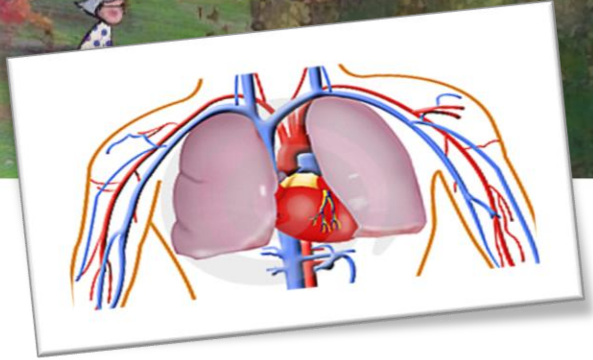
Decreased minute ventilation – Only about **22%** could be directly attributed to the small decrease in minute ventilation.



Cerebral effects

- ✓ An initial increase in respiratory drive followed by a depressed level of consciousness (also known as carbon dioxide [CO_2] narcosis) and reduced respiratory drive;

- ✓ An increase in cerebral blood flow and intracranial pressure.



Cardio-respiratory effects

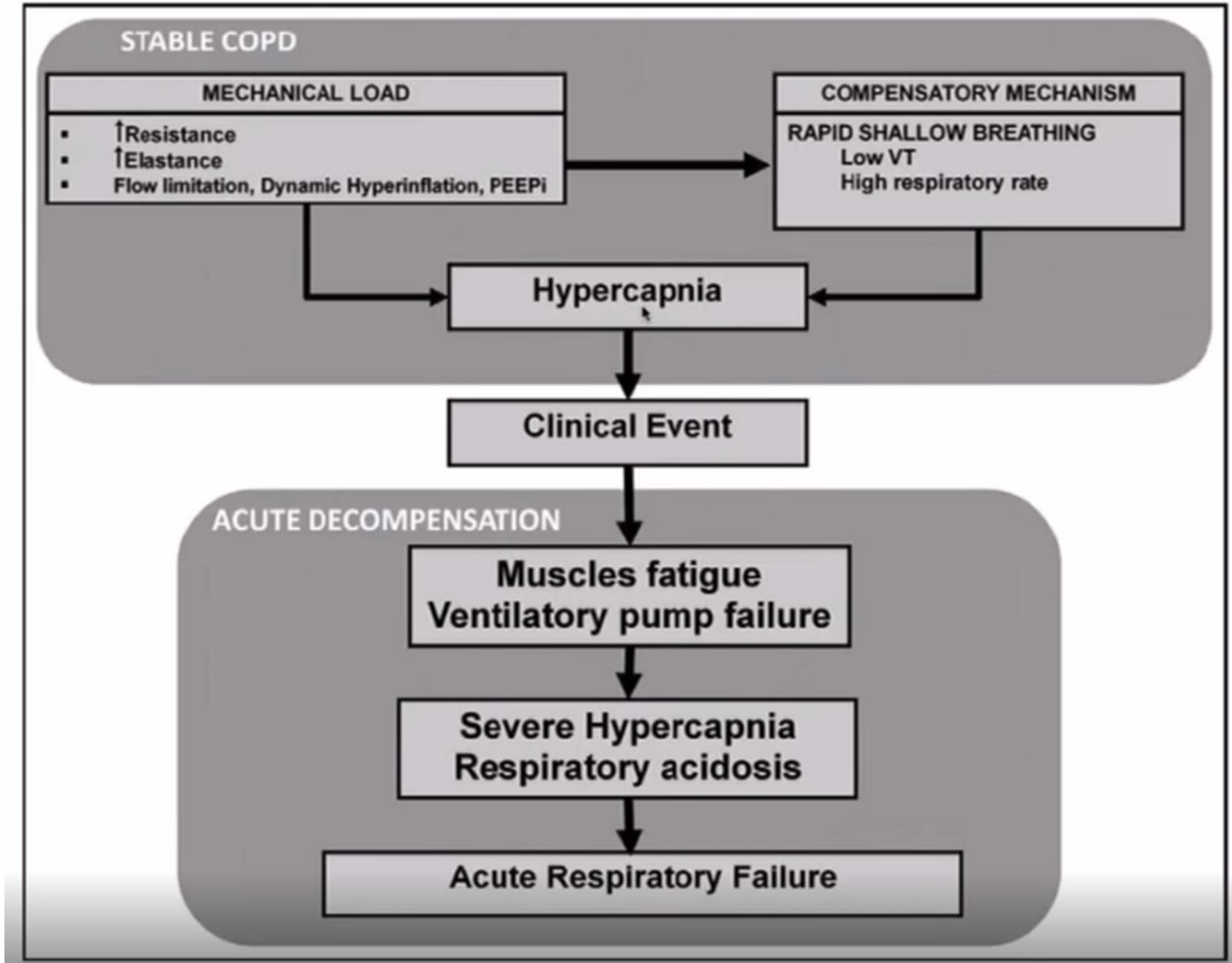
- ✓ Dyspnea, which is thought to be due to the initial compensatory increase in respiratory drive induced by elevated levels of arterial CO_2 and the associated acidemia (stimulation of peripheral and central chemoreceptors);

- ✓ Reduced myocardial and diaphragmatic contractility, which can progress to cardiovascular instability, arrhythmia, cardiac or respiratory arrest, and death.

Necessità di distinguere 2 diversi setting gestionali:

ACUTO

CRONICO


STABLE COPD
MECHANICAL LOAD
↑Resistance
↑Elastance
Flow limitation, Dynamic Hyperinflation, PEEPi
COMPENSATORY MECHANISM
RAPID SHALLOW BREATHING
Low VT
High respiratory rate
Hypercapnia
Clinical Event
ACUTE DECOMPENSATION
Muscles fatigue
Ventilatory pump failure
Severe Hypercapnia
Respiratory acidosis
Acute Respiratory Failure

Respirology 2019- 24, 308–317doi: 10.1111/resp.

INVITED REVIEW SERIES:
NON-INVASIVE VENTILATION
SERIES EDITORS: AMANDA PIPER AND CHUNG-MING CHU

Benefits of non-invasive ventilation in acute hypercapnic respiratory failure

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Table 1 Indications for NIV in acute hypercapnic respiratory failure

1	Acute exacerbation of COPD
2	Cardiogenic pulmonary oedema
3	Obesity and obesity hypoventilation syndrome
4	Weaning from invasive mechanical ventilation
5	Prevention of post-extubation failure in those patients previously intubated
6	Chest wall diseases and neuromuscular diseases
7	Palliative care and do-not-intubate patients
8	Miscellaneous (very old patients, community-acquired pneumonia and bridge to transplantation)

Eur Respir J 2017; 50: 1602426

TASK FORCE REPORT
ERS/ATS GUIDELINES

CrossMark

Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure

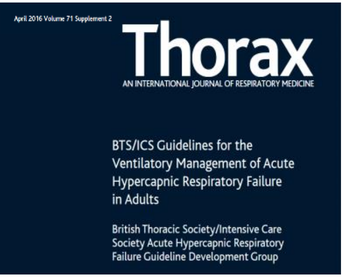
Bram Rochwerg[1], Laurent Brochard[2,3], Mark W. Elliott[4], Dean Hess[5], Nicholas S. Hill[6], Stefano Nava[7] and Paolo Navalesi[8] (members of the steering committee); Massimo Antonelli[9], Jan Brozek[1], Giorgio Conti[9], Miquel Ferrer[10], Kalpalatha Guntupalli[11], Samir Jaber[12], Sean Keenan[13,14], Jordi Mancebo[15], Sangeeta Mehta[16] and Suhail Raoof[17,18] (members of the task force)

PICO: *(population–intervention–comparison–outcome) format*
GRADE: *(Grading of Recommendations, Assessment, Development and Evaluation) methodology*

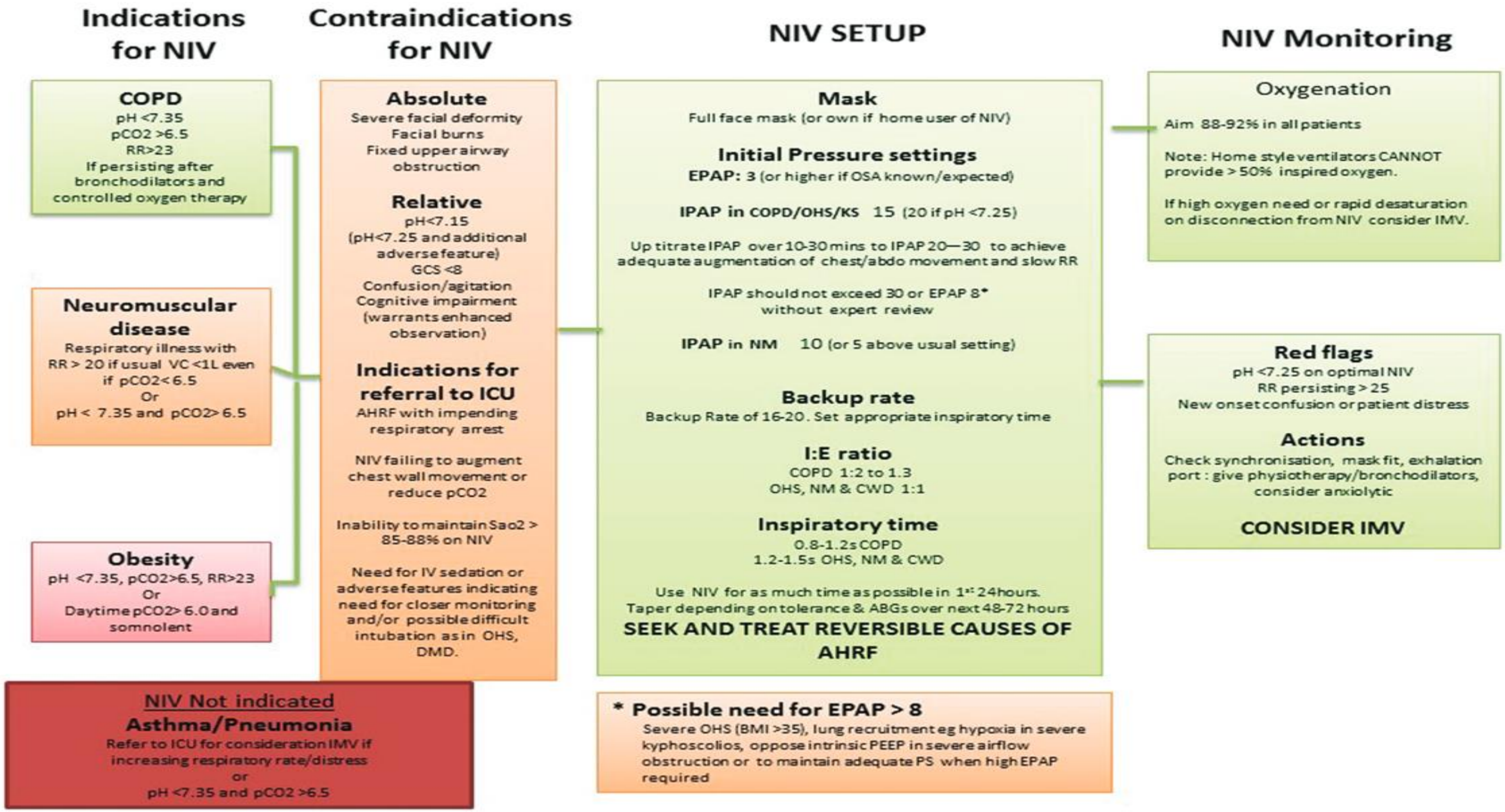
TABLE 2 Recommendations for actionable PICO questions

Clinical indication[#]	Certainty of evidence[¶]	Recommendation
Prevention of hypercapnia in COPD exacerbation	⊕⊕	Conditional recommendation against
Hypercapnia with COPD exacerbation	⊕⊕⊕⊕	Strong recommendation for
Cardiogenic pulmonary oedema	⊕⊕⊕	Strong recommendation for
Acute asthma exacerbation		No recommendation made
Immunocompromised	⊕⊕⊕	Conditional recommendation for
***De novo* respiratory failure**		No recommendation made
Post-operative patients	⊕⊕⊕	Conditional recommendation for
Palliative care	⊕⊕⊕	Conditional recommendation for
Trauma	⊕⊕⊕	Conditional recommendation for
Pandemic viral illness		No recommendation made
Post-extubation in high-risk patients (prophylaxis)	⊕⊕	Conditional recommendation for
Post-extubation respiratory failure	⊕⊕	Conditional recommendation against
Weaning in hypercapnic patients	⊕⊕⊕	Conditional recommendation for

#: all in the setting of acute respiratory failure; ¶: certainty of effect estimates: ⊕⊕⊕⊕, high; ⊕⊕⊕, moderate; ⊕⊕, low; ⊕, very low.



April 2016 Volume 71 Supplement



AMERICAN THORACIC SOCIETY DOCUMENTS

Long-Term Noninvasive Ventilation in Chronic Stable Hypercapnic Chronic Obstructive Pulmonary Disease

An Official American Thoracic Society Clinical Practice Guideline

Madalina Macrea, Simon Oczkowski, Bram Rochwerg, Richard D. Branson, Bartolome Celli, John M. Coleman III, Dean R. Hess, Shandra Lee Knight, Jill A. Ohar, Jeremy E. Orr, Amanda J. Piper, Naresh M. Punjabi, Shilpa Rahangdale, Peter J. Wijkstra, Susie Yim-Yeh, M. Bradley Drummond, and Robert L. Owens; on behalf of the American Thoracic Society Assembly on Sleep and Respiratory Neurobiology

This official clinical practice guideline of the American Thoracic Society was approved May 2020

Summary of Recommendations:

1. We suggest the use of nocturnal noninvasive ventilation (NIV) in addition to usual care for patients with chronic stable hypercapnic COPD (conditional recommendation, moderate certainty).

2. We suggest that patients with chronic stable hypercapnic COPD undergo screening for obstructive sleep apnea before initiation of long-term NIV (conditional recommendation, very low certainty).

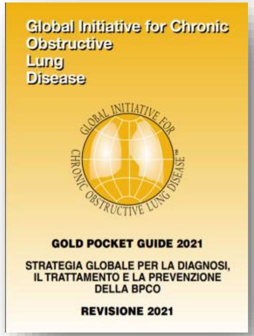
3. We suggest not initiating long-term NIV during an admission for acute on-chronic hypercapnic respiratory failure, favoring instead reassessment for NIV at 2–4 weeks after resolution (conditional recommendation, low certainty).

4. We suggest not using an in-laboratory overnight polysomnogram (PSG) to titrate NIV in patients with chronic stable hypercapnic COPD who are initiating NIV (conditional recommendation, very low certainty).

5. We suggest NIV with targeted normalization of PaCO2 in patients with hypercapnic COPD on long-term NIV (conditional recommendation, low certainty).

KEY POINTS FOR THE MANAGEMENT OF EXACERBATIONS

- Short-acting inhaled beta$_2$-agonists, with or without short-acting anticholinergics, are recommended as the initial bronchodilators to treat an acute exacerbation **(Evidence C)**.
- Systemic corticosteroids can improve lung function (FEV_1), oxygenation and shorten recovery time and hospitalization duration. Duration of therapy should not be more than 5-7 days **(Evidence A)**.
- Antibiotics, when indicated, can shorten recovery time, reduce the risk of early relapse, treatment failure, and hospitalization duration. Duration of therapy should be 5-7 days **(Evidence B)**.
- Methylxanthines are not recommended due to increased side effect profiles **(Evidence B)**.
- Non-invasive mechanical ventilation should be the first mode of ventilation used in COPD patients with acute respiratory failure who have no absolute contraindication because it improves gas exchange, reduces work of breathing and the need for intubation, decreases hospitalization duration and improves survival **(Evidence A)**.



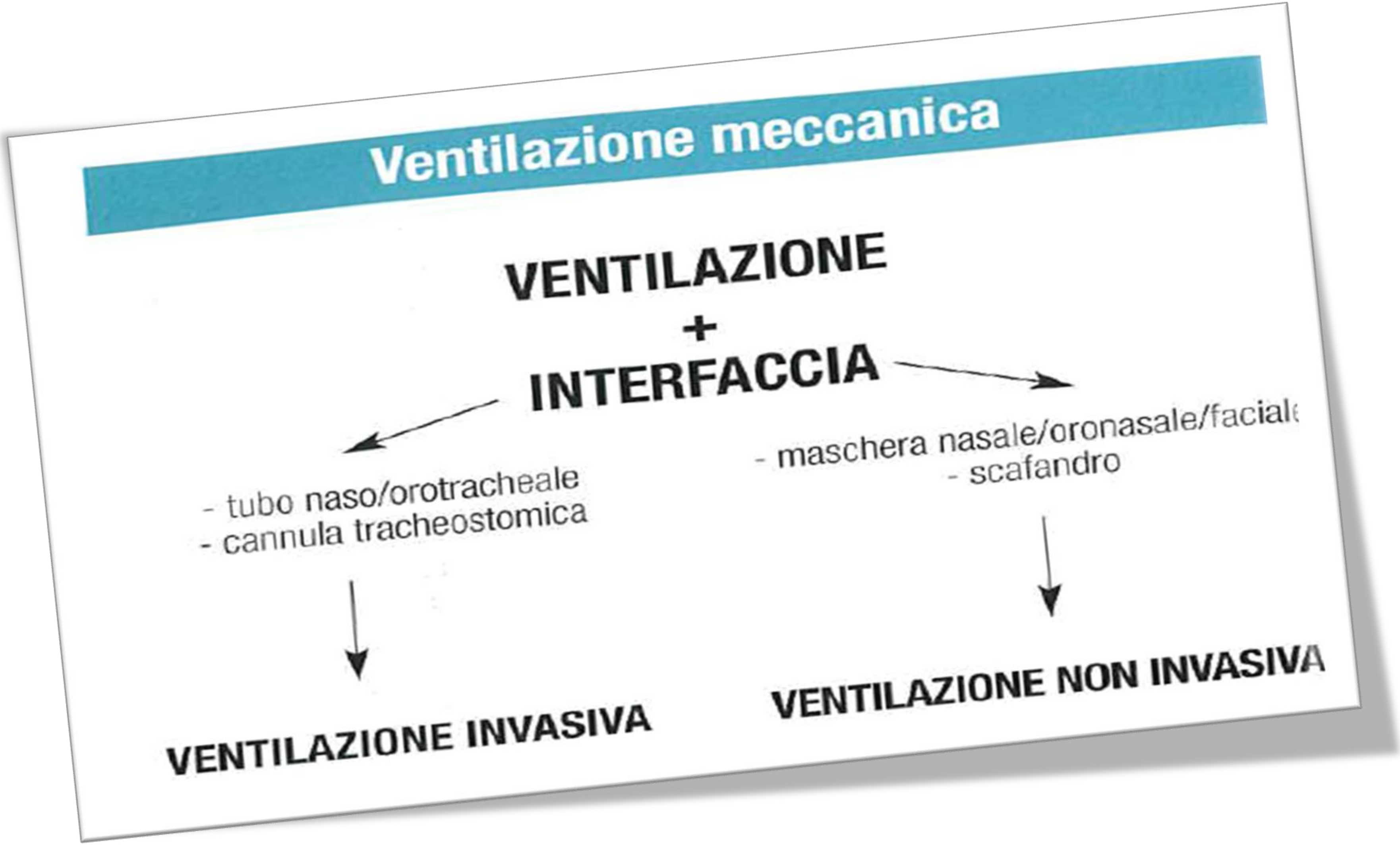
OXYGEN THERAPY AND VENTILATORY SUPPORT IN STABLE COPD

OXYGEN THERAPY

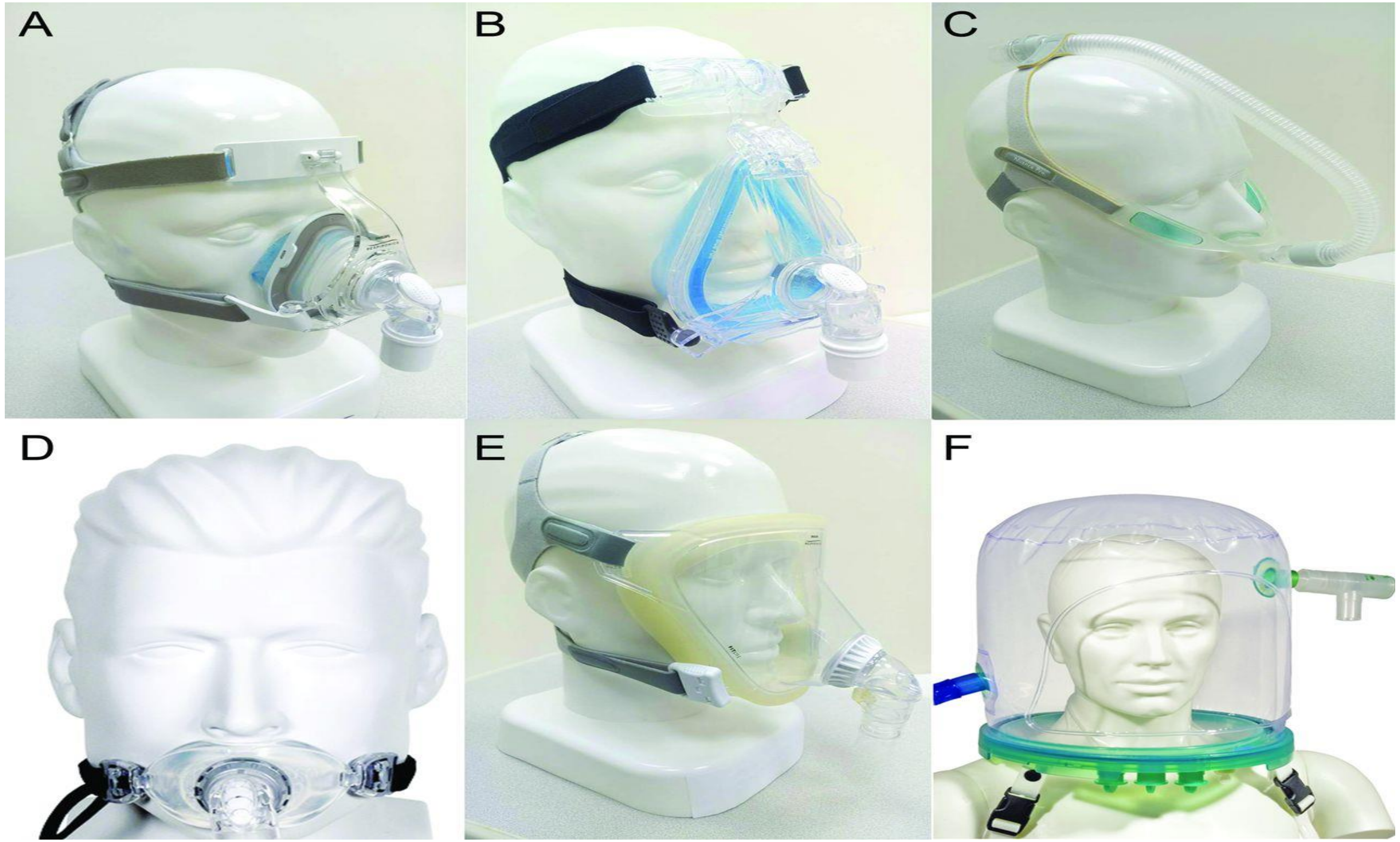
- The long-term administration of oxygen increases survival in patients with severe chronic resting arterial hypoxemia **(Evidence A)**.
- In patients with stable COPD and moderate resting or exercise-induced arterial desaturation, prescription of long-term oxygen does not lengthen time to death or first hospitalization or provide sustained benefit in health status, lung function and 6-minute walk distance **(Evidence A)**.
- Resting oxygenation at sea level does not exclude the development of severe hypoxemia when traveling by air **(Evidence C)**.

VENTILATORY SUPPORT

- NPPV may improve hospitalization-free survival in selected patients after recent hospitalization, particularly in those with pronounced daytime persistent hypercapnia ($PaCO_2 \geq 52$ mmHg) **(Evidence B)**.

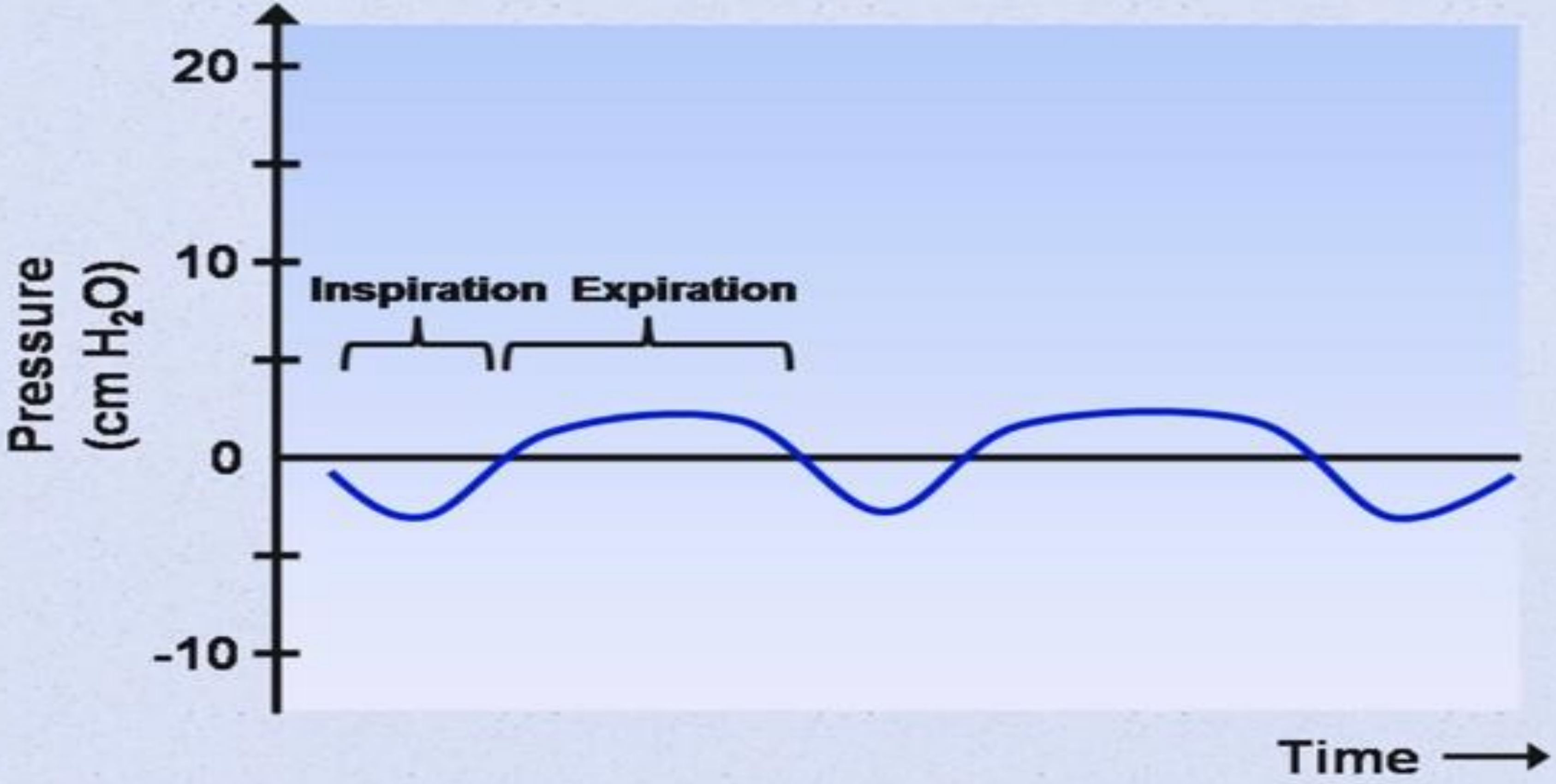

Ventilazione meccanica
VENTILAZIONE
+
INTERFACCIA
- tubo naso/orotracheale
- cannula tracheostomica
VENTILAZIONE INVASIVA
- maschera nasale/oronasale/faciale
- scafandro
VENTILAZIONE NON INVASIVA

Examples of different interfaces that can be used during non-invasive ventilation.

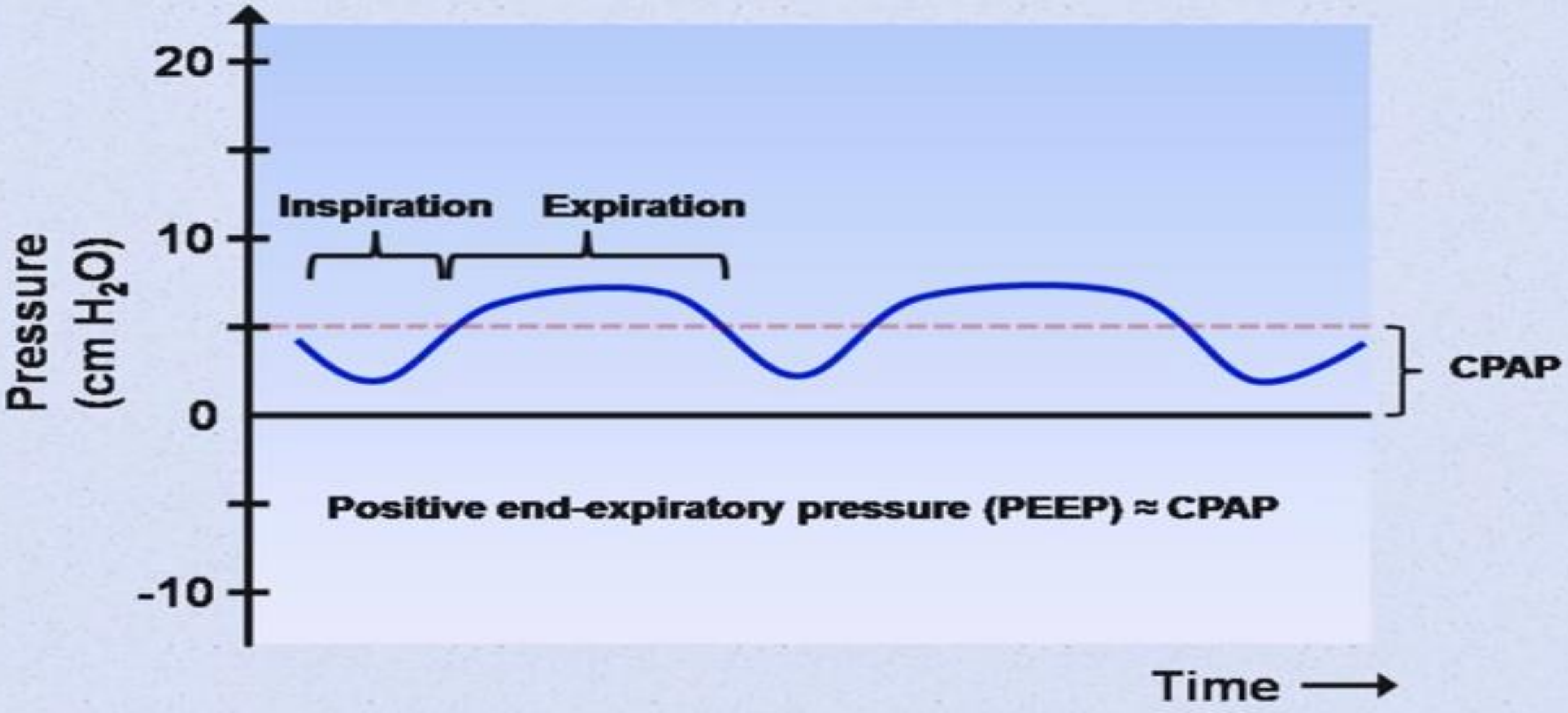


Ahmed S BaHammam et al. Respir Care 2018;63:227-237

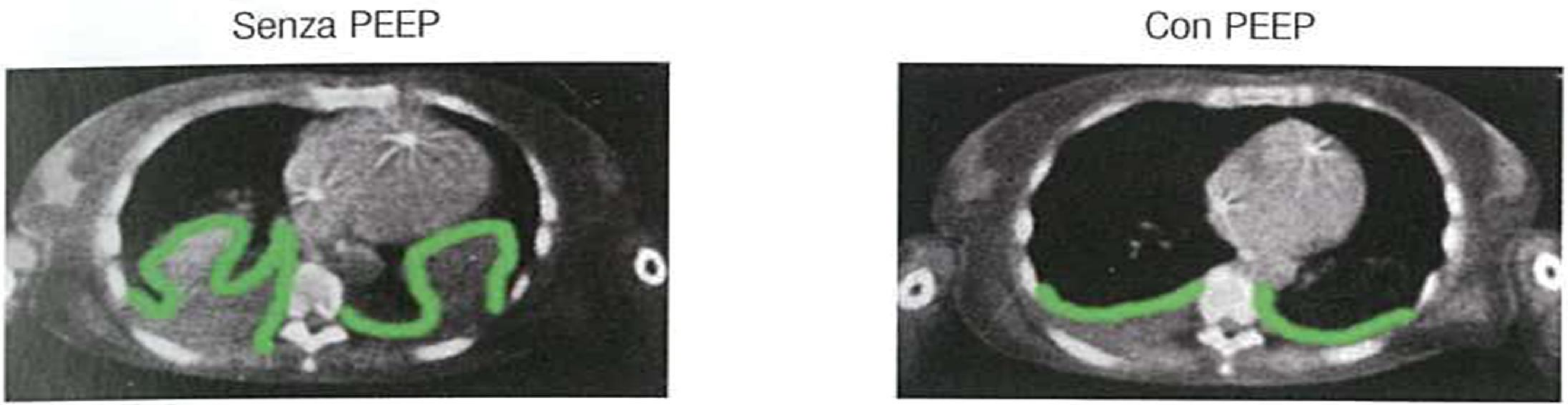
Intraalveolar Pressure During Unassisted Breathing



Intraalveolar Pressure During CPAP

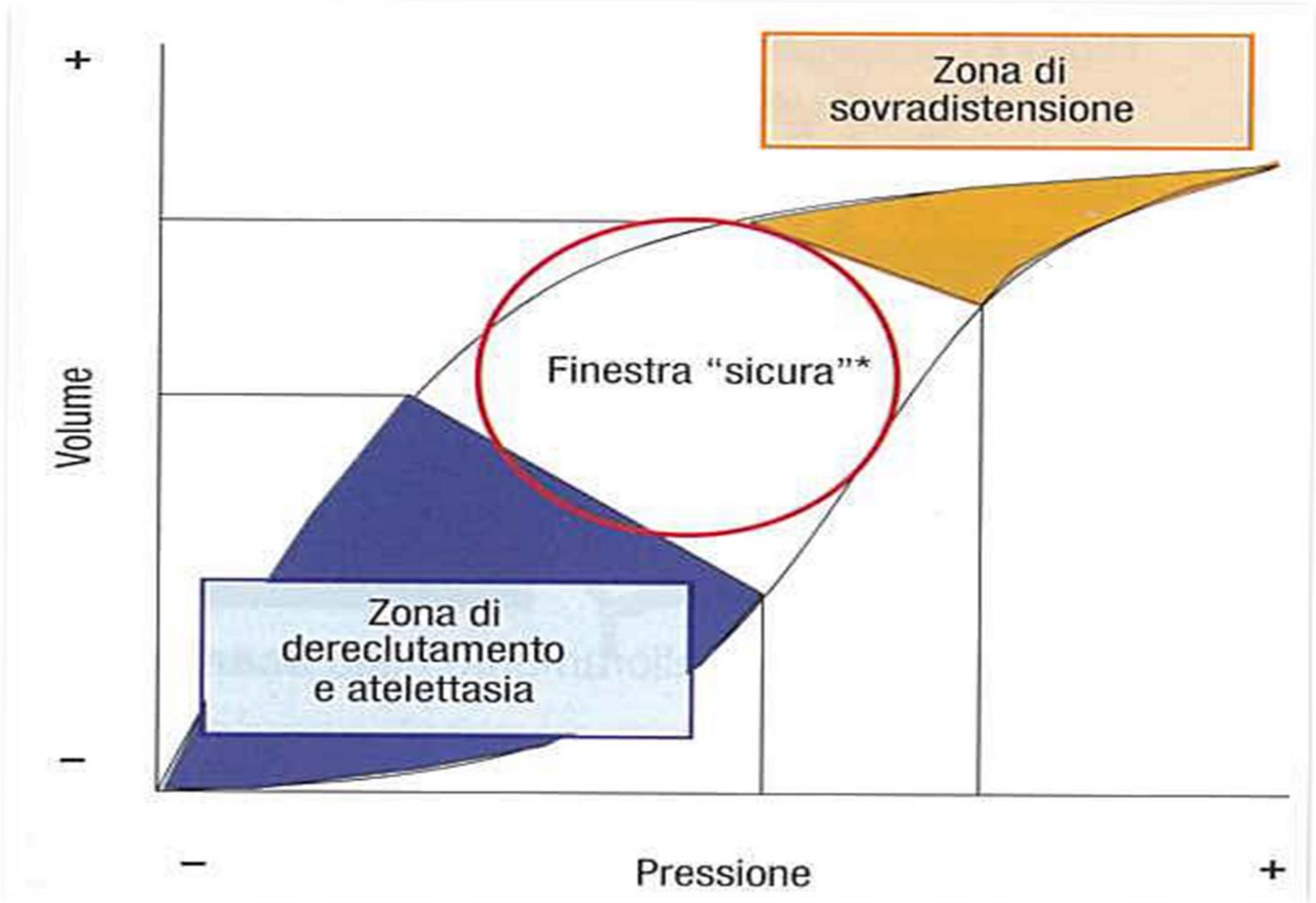


Efficacia della PEEP

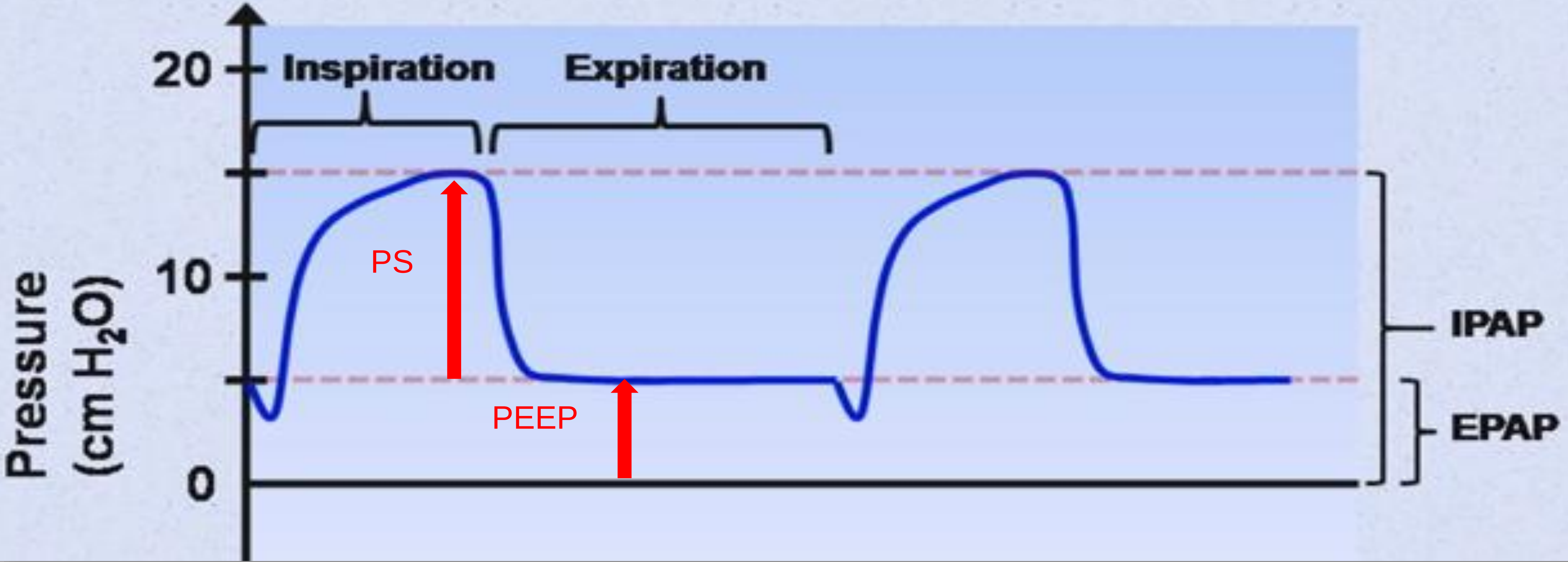


Il risultato del reclutamento è il miglioramento dello **scambio gassoso**.

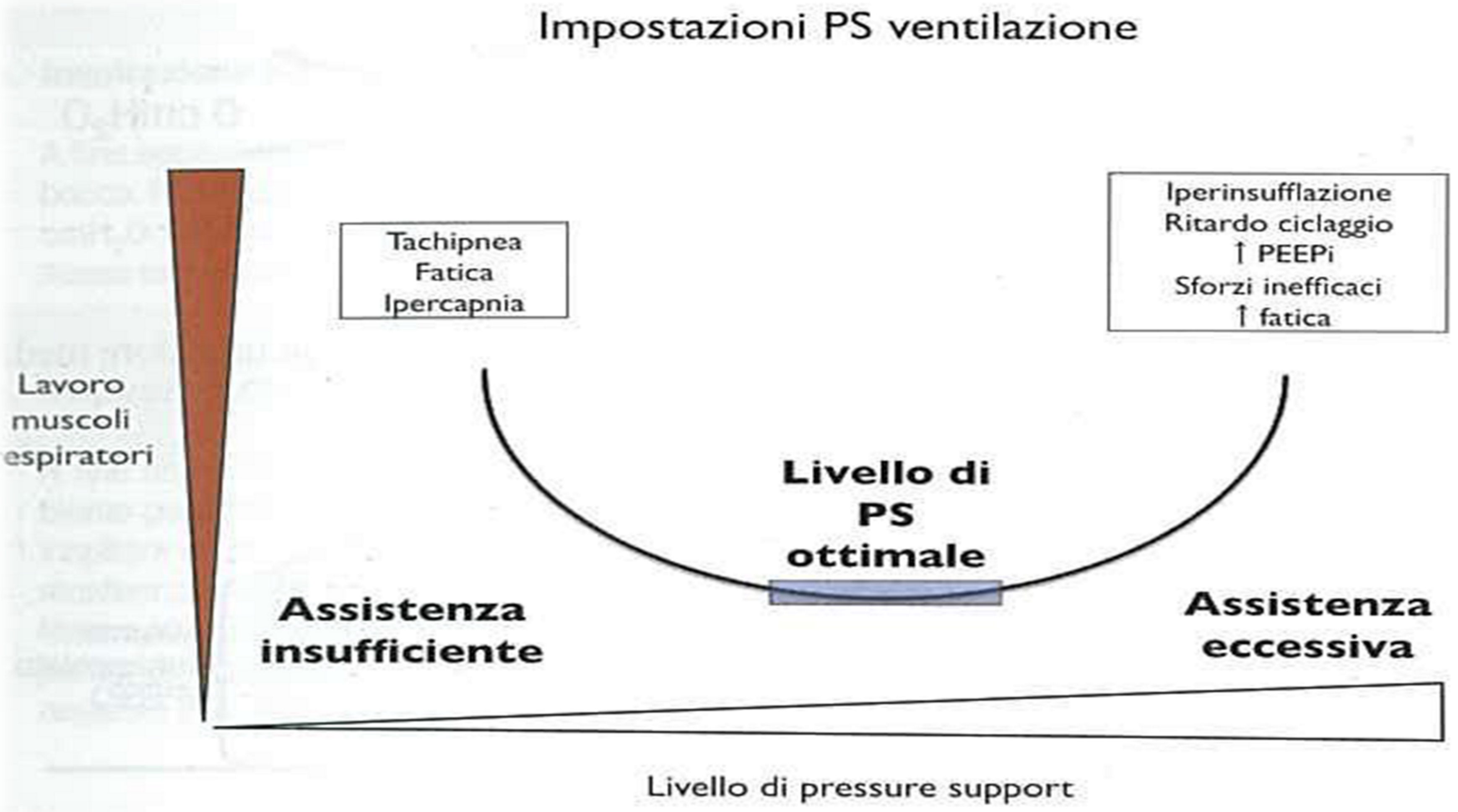
Perché è importante impostare un corretto valore di PEEP?



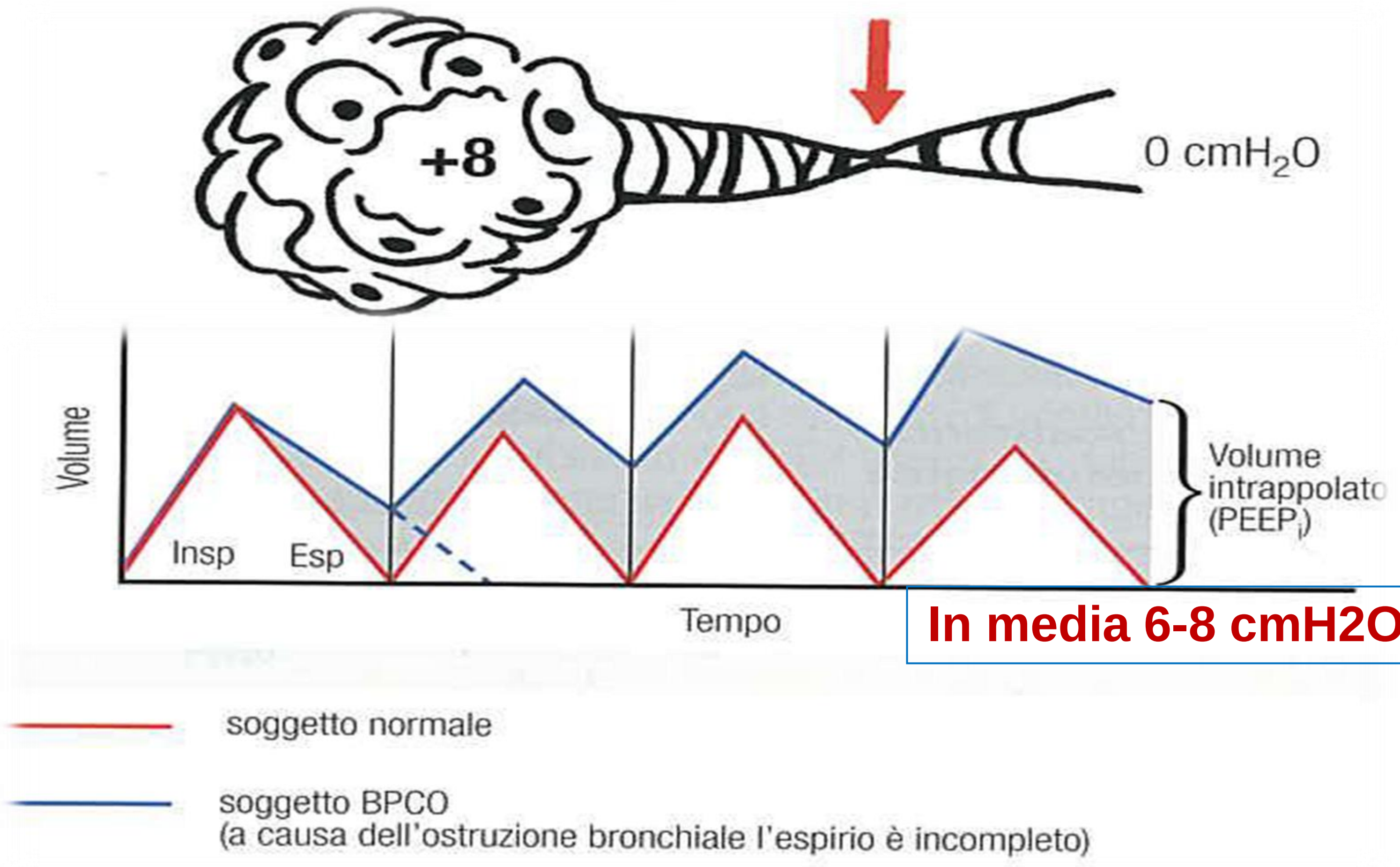
Intraalveolar Pressure During BPAP



Perché è importante impostare un corretto valore di PS?

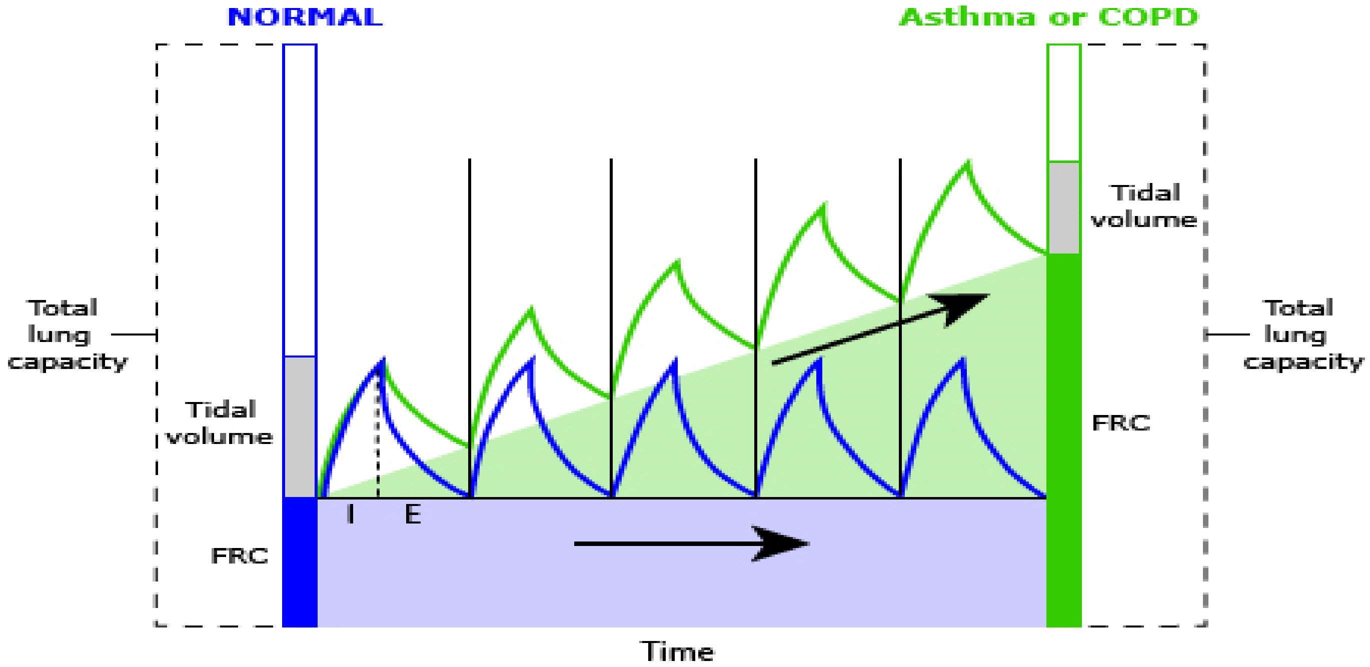


PEEP INTRINSECA

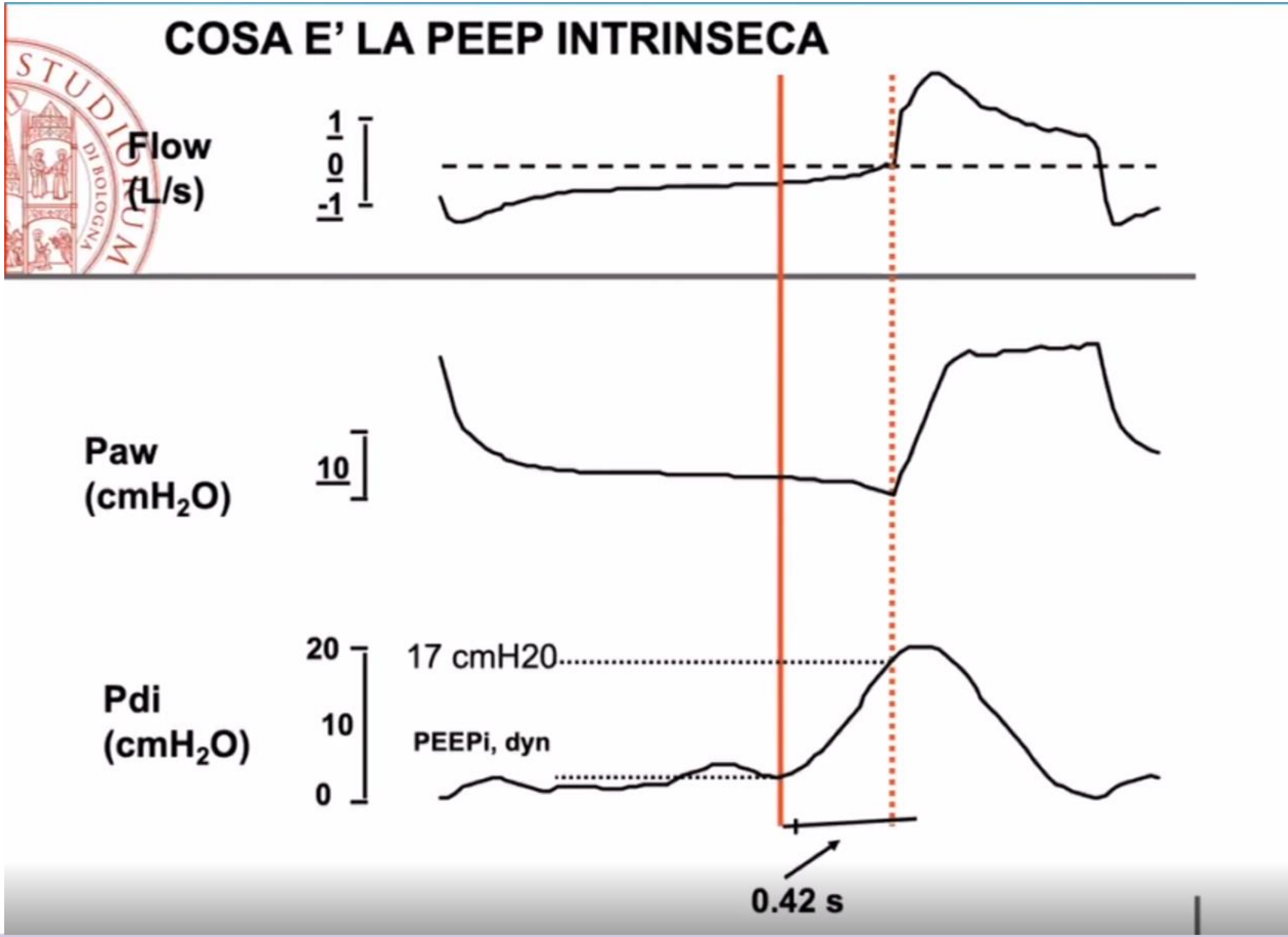


In media 6-8 cmH2O

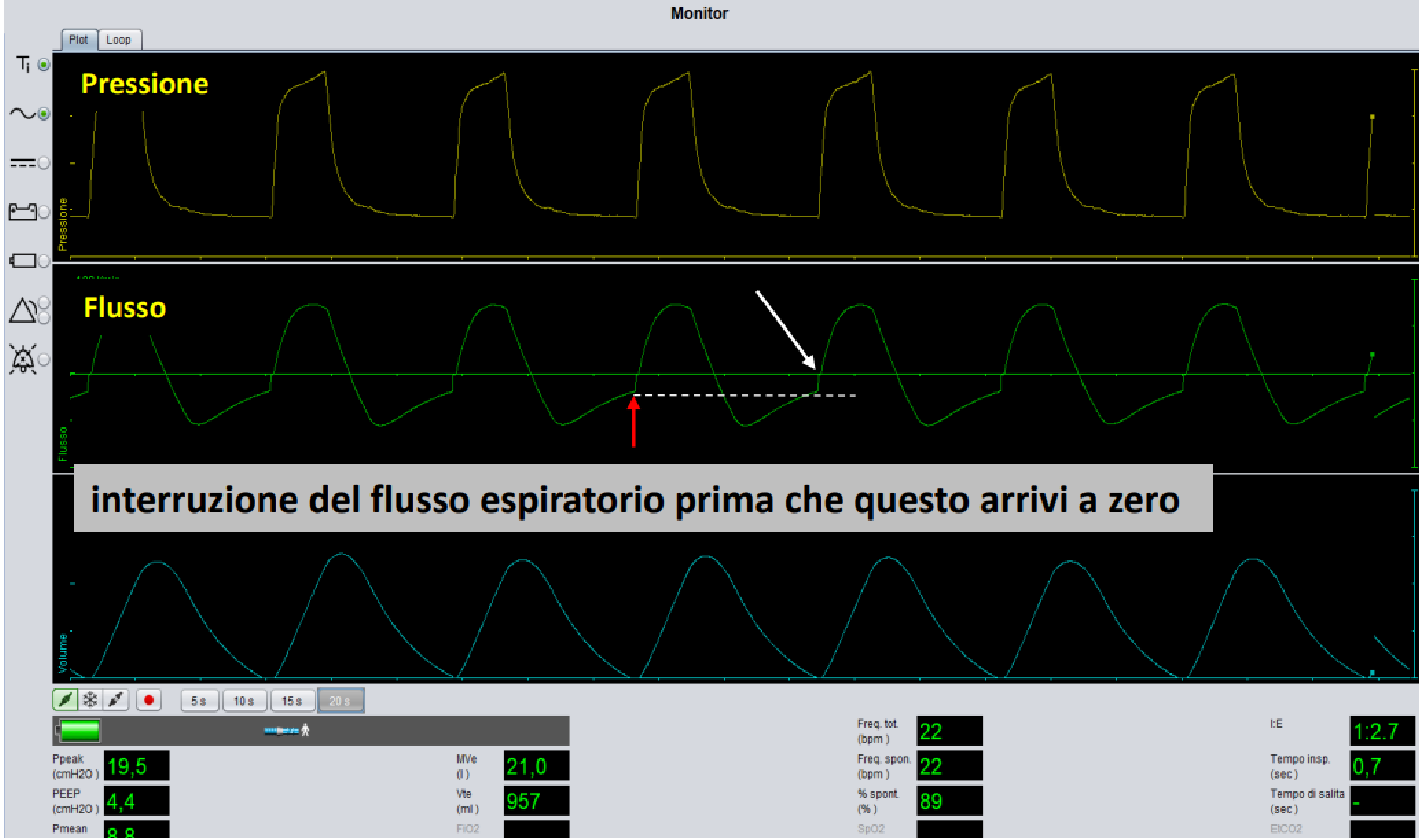
Dynamic hyperinflation during controlled ventilation in obstructive lung disease

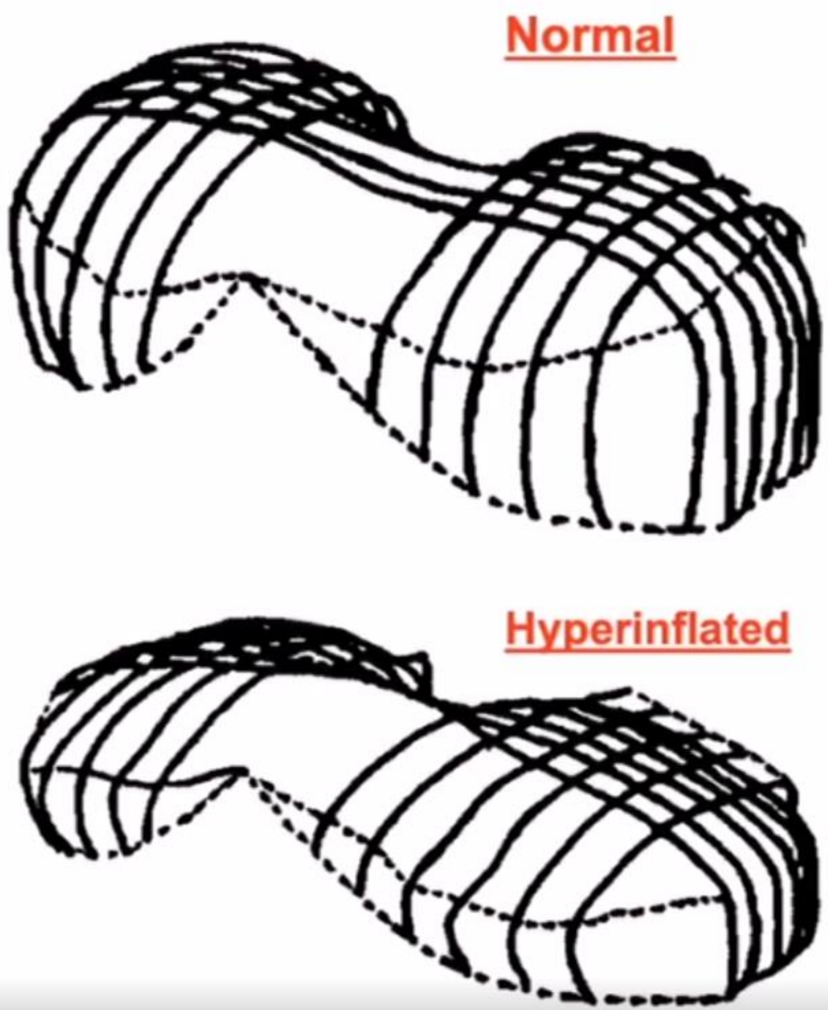


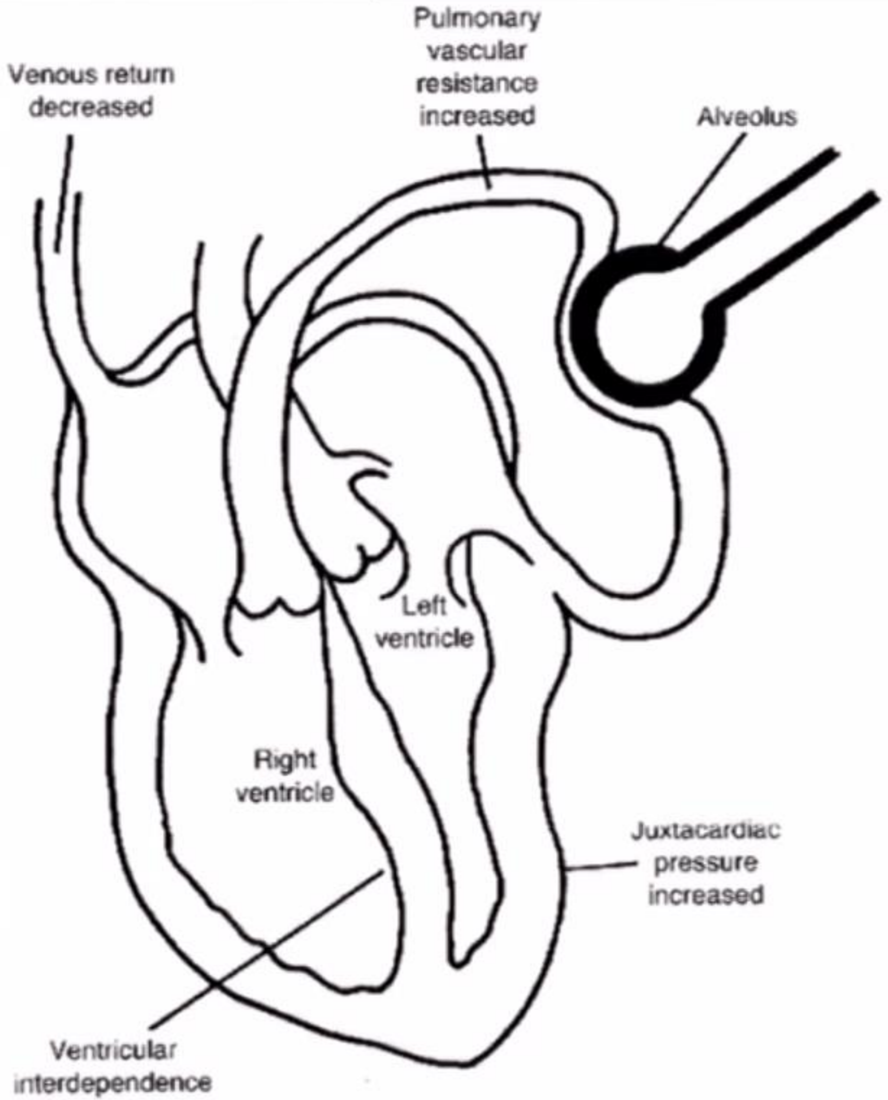
Dynamic hyperinflation is associated with increased intrathoracic pressure and potentially decreased venous return to the heart. Dynamic hyperventilation is treated by decreasing minute ventilation (ie, reducing tidal volume and/or respiratory rate) and sometimes by shortening inspiratory time to enable adequate time for exhalation.



PRESSIONE DI CONTRAZIONE DIAFRAMMATICA
=
SFORZO DEL PAZIENTE


Monitor
Plot
Loop
Pressione
Flusso
interruzione del flusso espiratorio prima che questo arrivi a zero
Volume
5 s
10 s
15 s
20 s
Ppeak (cmH2O) 19,5
PEEP (cmH2O) 4,4
Pmean 8,8
MVe (l) 21,0
Vte (ml) 957
FiO2
Freq. tot. (bpm) 22
Freq. spon. (bpm) 22
% spont. (%) 89
SpO2
I:E 1:2.7
Tempo insp. (sec) 0,7
Tempo di salita (sec) -
EtCO2


Normal
Hyperinflated


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

OBIETTIVI DELLA NIV NELLA OSTRUZIONE BRONCHIALE SEVERA:

1- OSSIGENAZIONE ADEGUATA

2- RIDUZIONE DELL'IPERINFLAZIONE POLMONARE

(broncodilatazione aggressiva, setting del ventilatore)

Come prolungare il Tempo espiratorio (Te)?

- ✓ Riduzione della FR
- ✓ Riduzione del Tempo inspiratorio (rapporto I:E)
- ✓ Abolizione delle pause tele-inspiratorie
- ✓ Sedazione

MODALITA' DI SEDAZIONE CON DEXMEDETOMIDINA (DEXDOR)

(agonista recettori α2-adrenergici centrali con effetto simpaticolitico ed inibente il *locus coeruleus*)

INDICAZIONI

"Per la sedazione di pazienti adulti in Unità di Terapia Intensiva che necessitano di un livello di sedazione non più profondo del risveglio in risposta alla stimolazione verbale.
Per la sedazione di pazienti adulti non intubati prima e/o durante procedure diagnostiche o chirurgiche che richiedono sedazione, cioè sedazione procedurale/cosciente" (ad esempio NIV).

PREPARAZIONE

Abbiamo a disposizione **fiale di Dexdor da 200 mcg (2 ml)**. Modalità di diluizione:

- **1 fiala in totali 50 ml** di sol. fisiol. o glucosata 5% o Ringer in pompa-siringa **oppure**
- **5 fiale in totali 250 ml** di sol. fisiol. o glucosata 5% o Ringer in pompa volumetrica

(la soluzione contiene 4 mcg/ml di dexmedetomidina).

DOSAGGIO

Bolo iniziale (se ritenuto necessario):

Peso corporeo	Bolo in 10 minuti *(0,5-1 mcg/kg)*
50 kg	37-75 ml/h per 10 min
70 kg	54-108 ml/h per 10 min
90 kg	67-135 ml/h per 10 min
110 kg	82-165 ml/h per 10 min

A seguire infusione continua mediamente di 0,6-0,7 mcg/kg/h (range dosi 0,2-1,4).
I valori nella tabella indicano le velocità di infusione in ml/h in base al peso e range dosi

Range dosi

Peso corporeo

so (kg)	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3	1,4
50	2,5	3,8	5,0	6,3	7,5	8,8	10,0	11,3	12,5	13,8	15,0	16,3	17,5
55	2,8	4,1	5,5	6,9	8,3	9,6	11,0	12,4	13,8	15,1	16,5	17,9	19,3
60	3,0	4,5	6,0	7,5	9,0	10,5	12,0	13,5	15,0	16,5	18,0	19,5	21,0
65	3,3	4,9	6,5	8,1	9,8	11,4	13,0	14,6	16,3	17,9	19,5	21,1	22,8
70	3,5	5,3	7,0	8,8	10,5	12,3	14,0	15,8	17,5	19,3	21,0	22,8	24,5
75	3,8	5,6	7,5	9,4	11,3	13,1	15,0	16,9	18,8	20,6	22,5	24,4	26,3
80	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20,0	22,0	24,0	26,0	28,0
85	4,3	6,4	8,5	10,6	12,8	14,9	17,0	19,1	21,3	23,4	25,5	27,6	29,8
90	4,5	6,8	9,0	11,3	13,5	15,8	18,0	20,3	22,5	24,8	27,0	29,3	31,5
95	4,8	7,1	9,5	11,9	14,3	16,6	19,0	21,4	23,8	26,1	28,5	30,9	33,3
100	5,0	7,5	10,0	12,5	15,0	17,5	20,0	22,5	25,0	27,5	30,0	32,5	35,0
105	5,3	7,9	10,5	13,1	15,8	18,4	21,0	23,6	26,3	28,9	31,5	34,1	36,8
110	5,5	8,3	11,0	13,8	16,5	19,3	22,0	24,8	27,5	30,3	33,0	35,8	38,5
115	5,8	8,6	11,5	14,4	17,3	20,1	23,0	25,9	28,8	31,6	34,5	37,4	40,3
120	6,0	9,0	12,0	15,0	18,0	21,0	24,0	27,0	30,0	33,0	36,0	39,0	42,0

N.B. Cautela e dose ridotta in presenza di insufficienza epatica. Nessuna modificazione nell'insufficienza renale. Negli anziani (> 65 anni) considerare dosi ridotte.

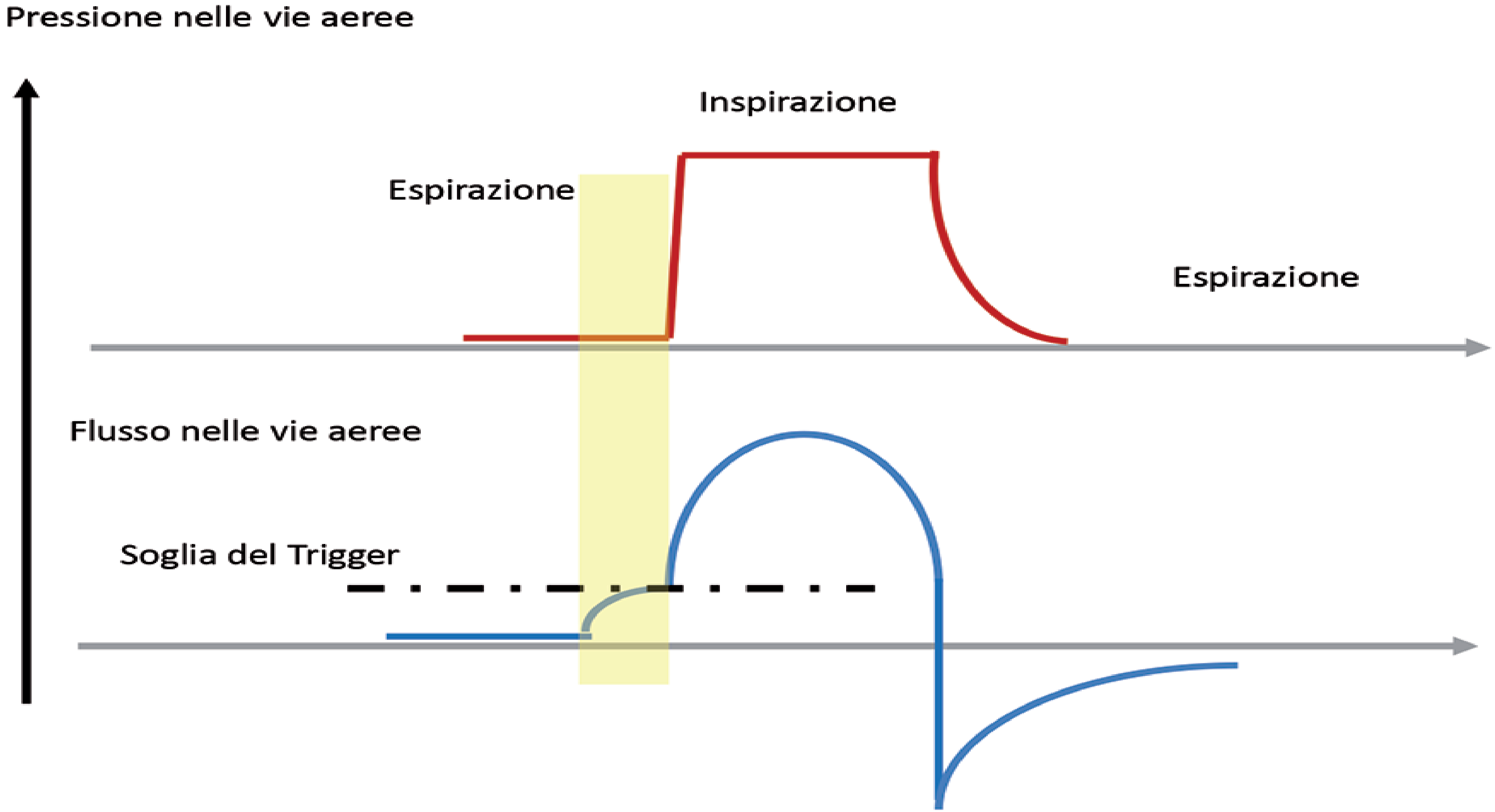
Effetti collaterali

Ipotensione arteriosa e bradicardia (azione simpaticolitica); a dosi elevate può invece dare ipertensione (per vasocostrizione) e tachicardia (attenzione alla possibilità di cardiopatia ischemica). Ipertermia. Depressione respiratoria.

Variabili che controllano il funzionamento del ventilatore

- ✓ *Trigger*
- ✓ *Variabile di controllo*
- ✓ *Cycling*

Trigger inspiratorio a flusso



Variabile di controllo

Identifica quale aspetto dell'atto inspiratorio è la variabile controllata primariamente dal ventilatore.

Opzioni:

- A controllo di pressione
- A controllo di flusso (o di volume)

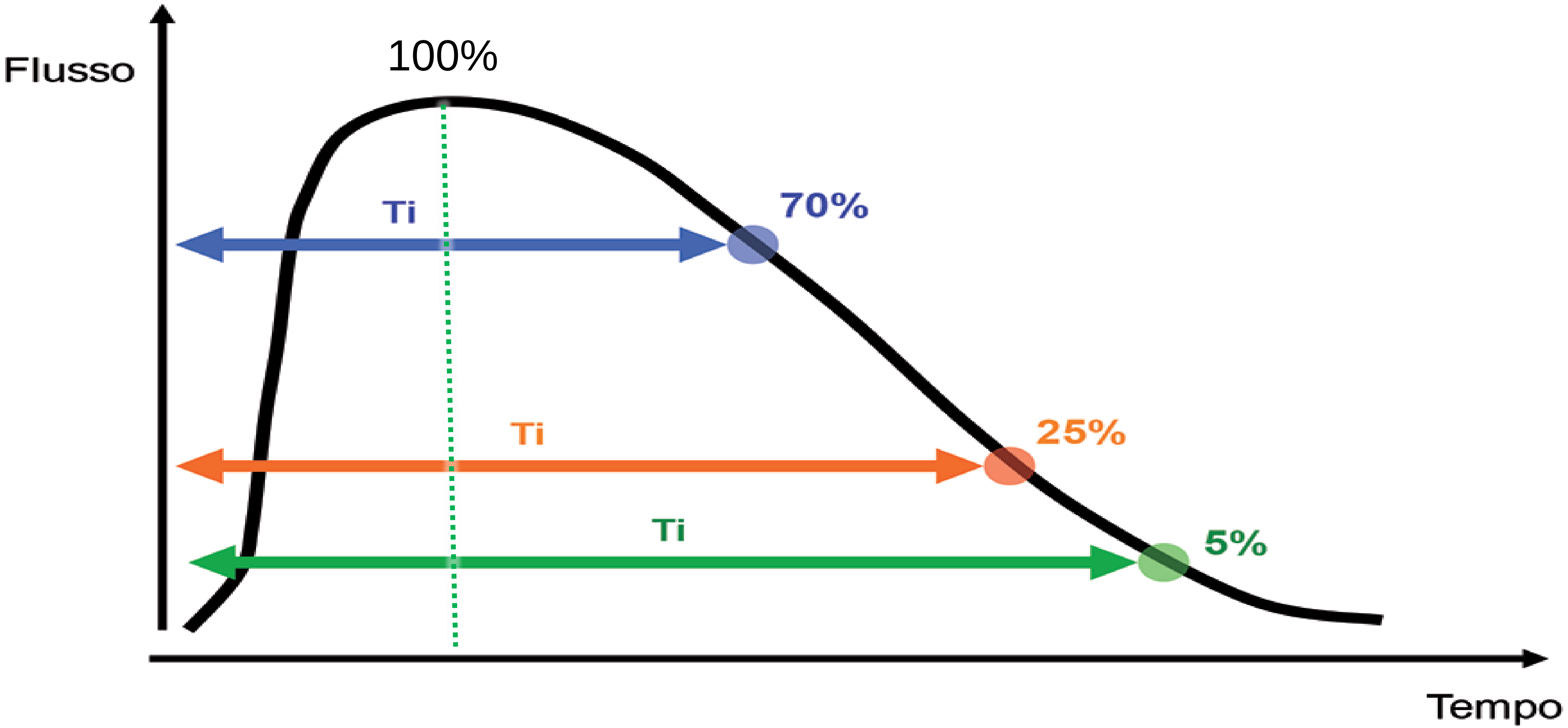
Variabile di Cycling

O Trigger espiratorio definisce la variabile che viene regolata per avviare il ciclaggio cioè il passaggio dall'inspirazione all'espirazione.

Definisce cosa dice al ventilatore di interrompere l'atto inspiratorio

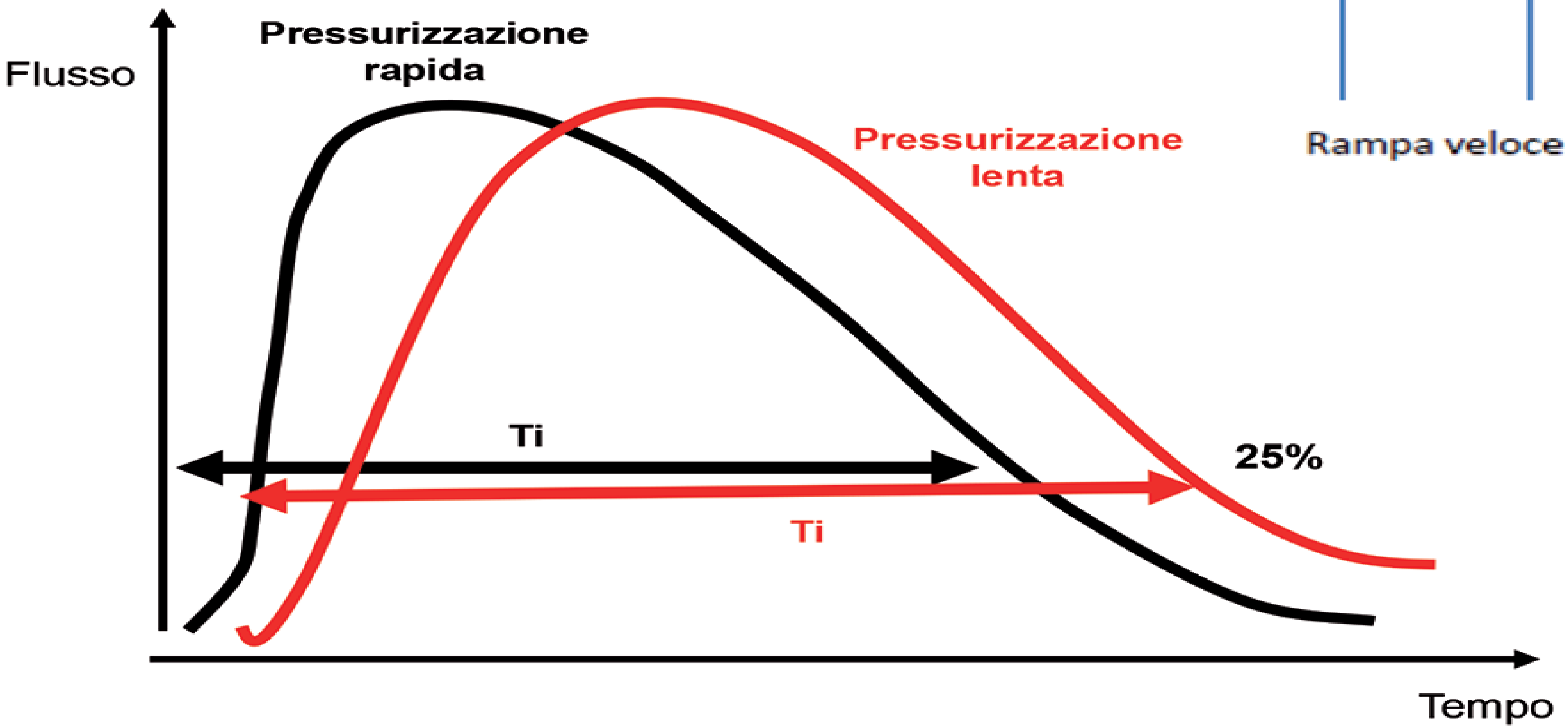
Opzioni :

- ✓ Volume
- ✓ Flusso
- ✓ Tempo



Aumentare la percentuale di picco di flusso inspiratorio al quale la macchina deve ciclare (50-70%) significa ridurre il tempo inspiratorio anticipando il ciclaggio, viceversa ridurre la percentuale di picco di flusso inspiratorio al quale la macchina deve ciclare (20-10%) significa aumentare il tempo inspiratorio posticipando il ciclaggio.

Rampa/ Salita/ T di pressurizzazione



Tempo in cui viene erogato il supporto pressorio inspiratorio. Graficamente rappresentato dalla pendenza della curva di pressione: a parità di trigger espiratorio anch'essa influisce sul tempo inspiratorio. Una rampa *ripida riduce il tempo inspiratorio,* al contrario una pressurizzazione lenta ritarda il ciclaggio

VENTILAZIONE MODALITA' PSV

- TRIGGER INSPIRATORIO: sensibile (sopra il limite di autotrigger)
- PEEP : 4-5 cmH2O o 80% di PEEP intrinseca
- IPAP: tale da mantenere Vt 6-8 ml/kg e ridurre il lavoro respiratorio;
- TRIGGER ESPIRATORIO: 30-50% (fino al 70%)
- RAMPA: alta

- *VOLUME: 6-8 ml/kg (peso ideale)*
- *FREQUENZA RESPIRATORIA: 12-13 atti/min*

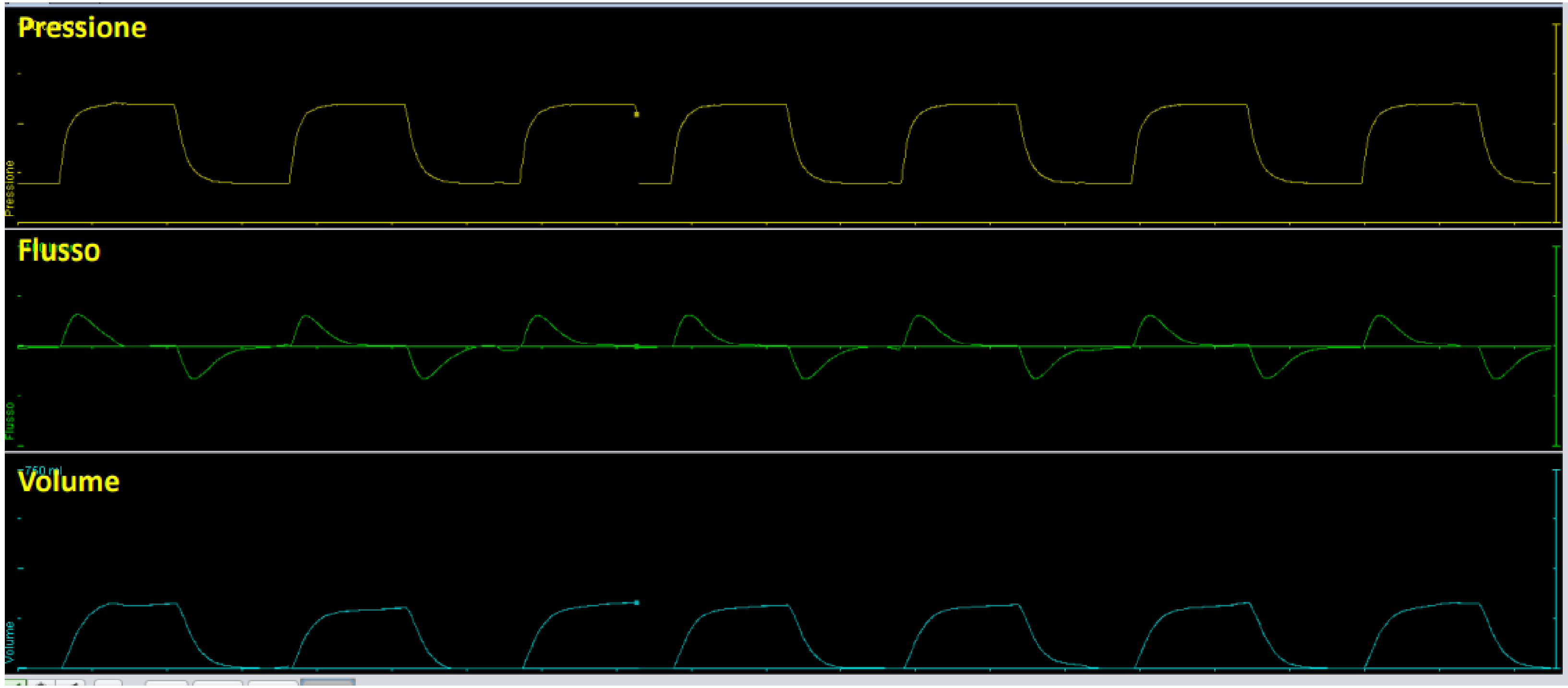
VENTILAZIONE MODALITA' APCV (Assisted Pressure Controlled Ventilation)

- TRIGGER INSPIRATORIO: sensibile (sopra il limite di autotrigger)
- PEEP : 4-5 cmH2O o 80% di PEEP intrinseca
- IPAP: tale da mantenere Vt 6-8 ml/kg e ridurre il lavoro respiratorio;
- I:E: rapporto inspirazione/espirazione (tempo) >1:2-1:2,5
- RAMPA: alta

- *VOLUME: 6-8 ml/kg(peso ideale)*
- *FREQUENZA RESPIRATORIA: 12-13 atti/min*

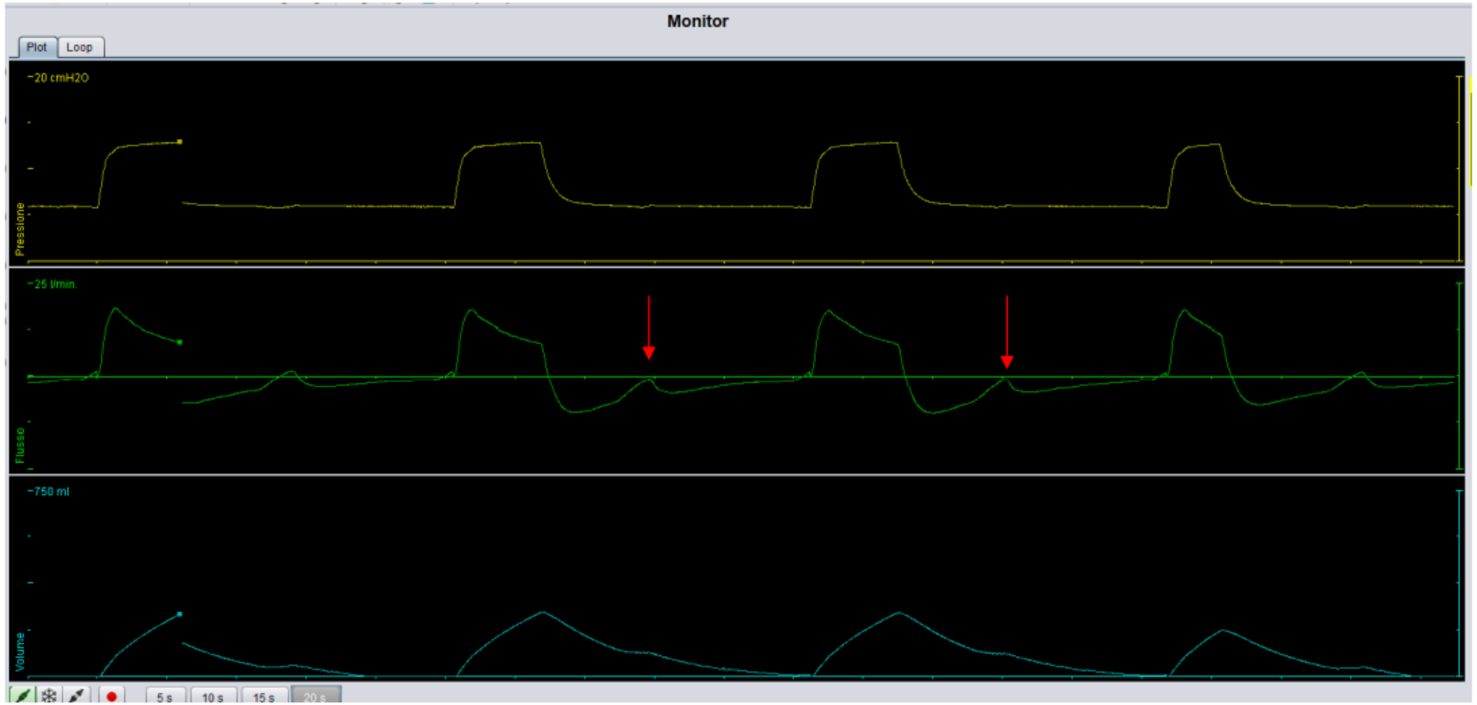
Protocol for initiation of noninvasive positive pressure ventilation

1. Appropriately monitored location, oximetry, respiratory impedance, vital signs as clinically indicated
2. Patient in bed or chair at >30-degree angle
3. Select and fit interface
4. Select ventilator
5. Apply headgear; avoid excessive strap tension (one or two fingers under strap)
6. Connect interface to ventilator tubing and turn on ventilator
7. Start with low pressure in spontaneously triggered mode with backup rate; pressure limited: 8 to 12 cmH_2O inspiratory pressure; 3 to 5 cmH_2O expiratory pressure
8. Gradually increase inspiratory pressure (10 to 20 cmH_2O) as tolerated to achieve alleviation of dyspnea, decreased respiratory rate, increased tidal volume (if being monitored), and good patient–ventilator synchrony
9. Provide O_2 supplementation as needed to keep O_2 saturation >90 percent
10. Check for air leaks, readjust straps as needed
11. Add humidifier as indicated
12. Consider mild sedation (eg, intravenously administered lorazepam 0.5 mg) in agitated patients
13. Encouragement, reassurance, and frequent checks and adjustments as needed
14. Monitor occasional blood gases (within 1 to 2 hours) and then as needed


Pressione
Flusso
Volume

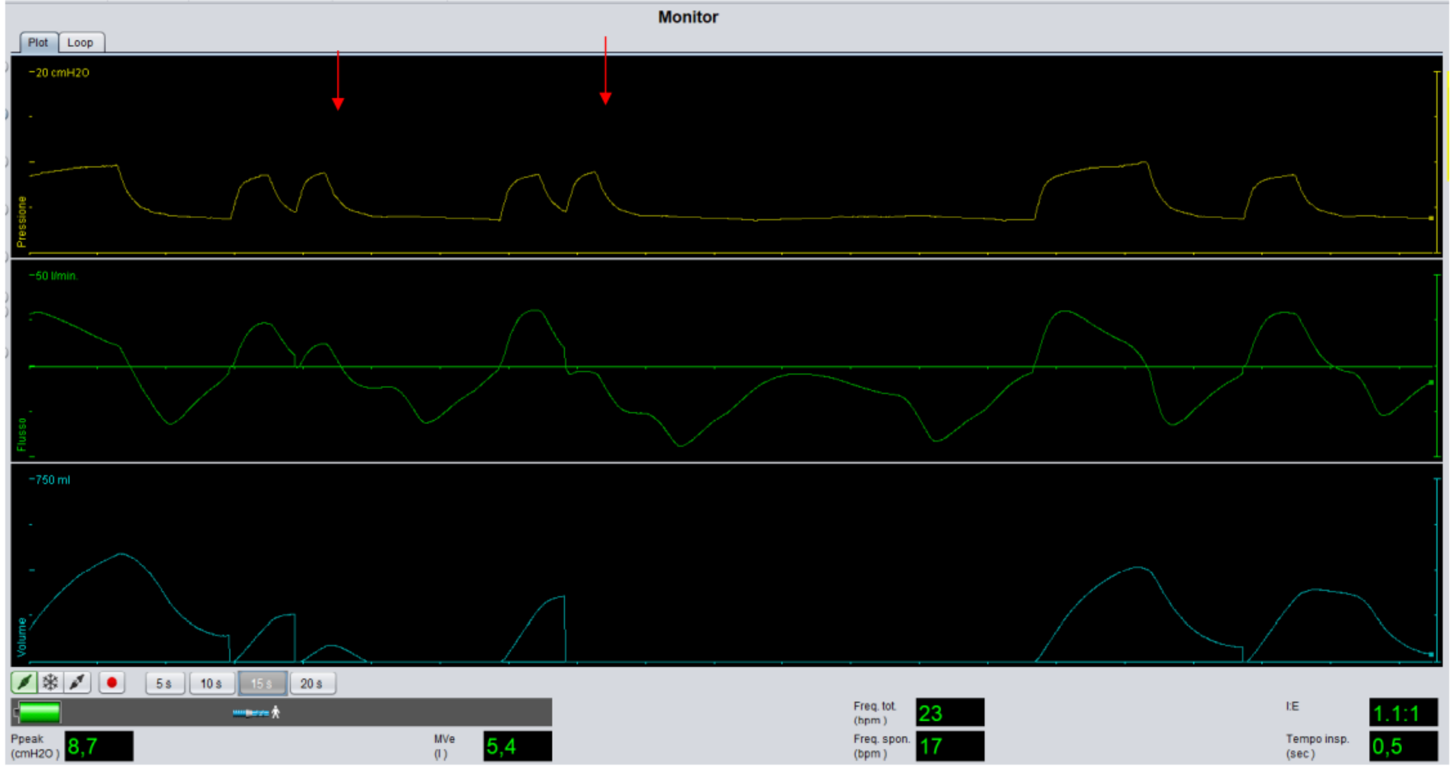
Sforzo inefficace

lo sforzo inspiratorio del paziente non è seguito dall'atto ventilatorio meccanico.
Riduzione del flusso espiratorio cui non segue l'inspirazione assistita.



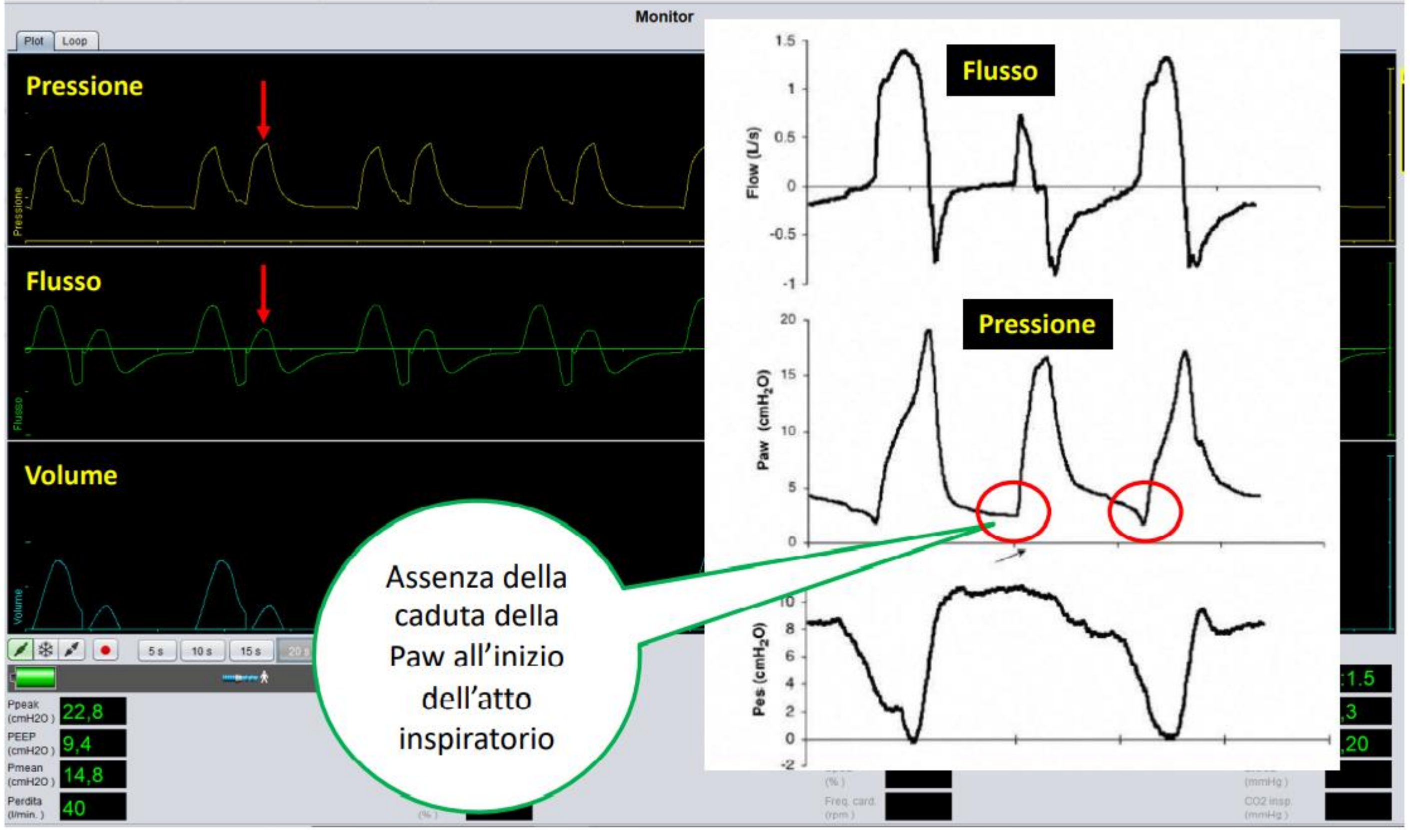
Doppio Trigger

Due inspirazioni separate da un tempo espiratorio molto breve in seguito ad un singolo sforzo inspiratorio del paziente.



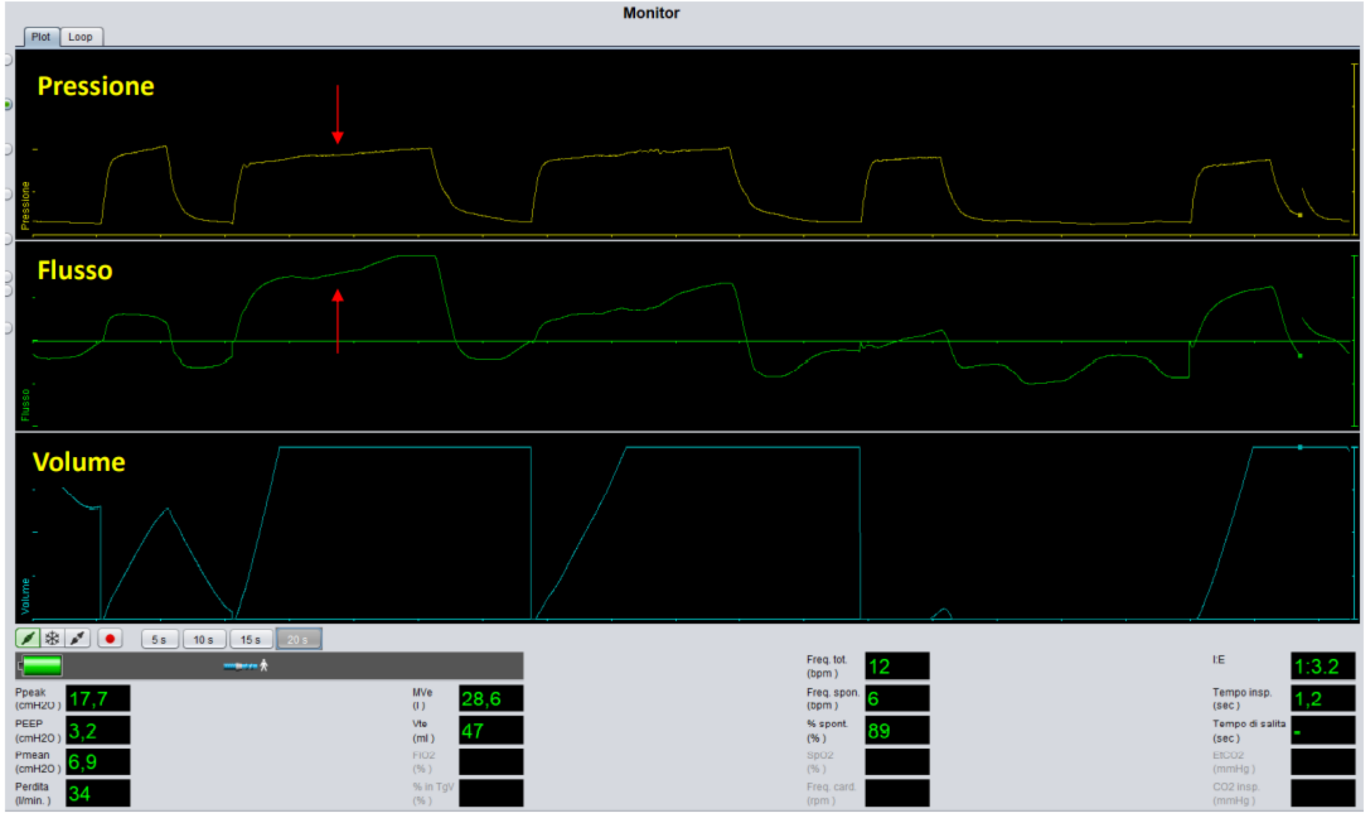
Auto-trigger

Atto inspiratorio erogato dal ventilatore in assenza di sforzo inspiratorio da parte del pz.

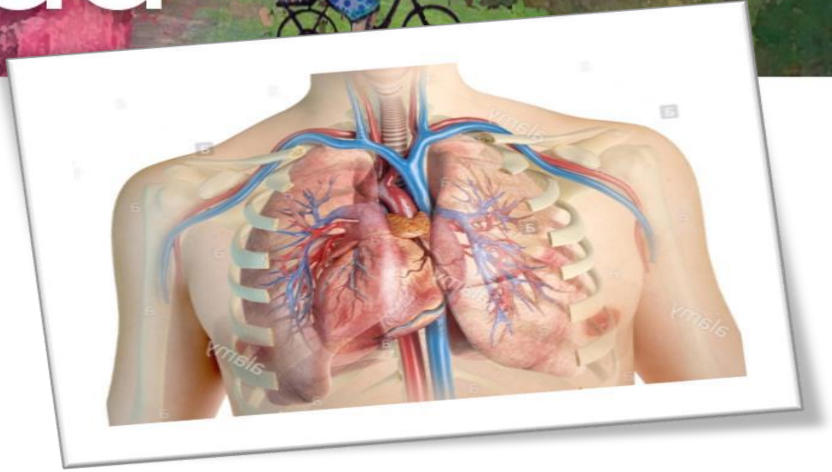


Hang-up

Inspirazione prolungata oltre quanto necessario



Patologia restrittiva



Restrictive respiratory diseases are a heterogeneous group of disorders characterized by:

- ✓reduction in all lung volumes (restriction)
- ✓decreased compliance on pulmonary function testing
- ✓preservation of expiratory flow.

Classification:

- **Intrinsic disorders:** such as interstitial lung diseases that cause diffuse inflammation or scarring of the lung tissue

- **Extrinsic disorders:** such as abnormalities of the chest wall , pleura, or abdomen that mechanically compress the lungs or limit their expansion

- **Neuromuscular diseases:** affecting chest wall nerves and muscles to decrease the ability of the respiratory muscles to inflate and deflate the lungs, resulting in chronically-reduced lung volumes and restrictive physiology

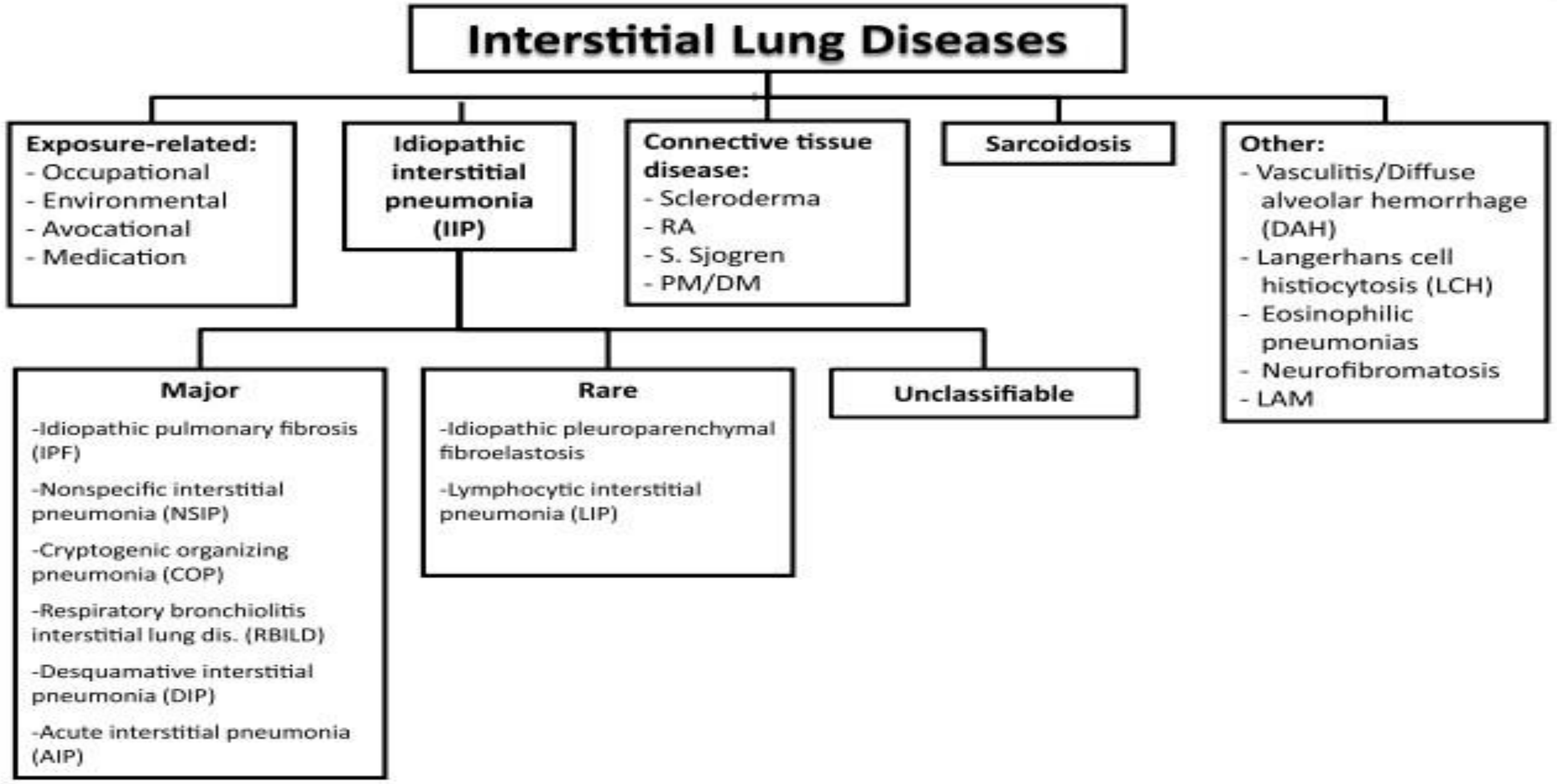
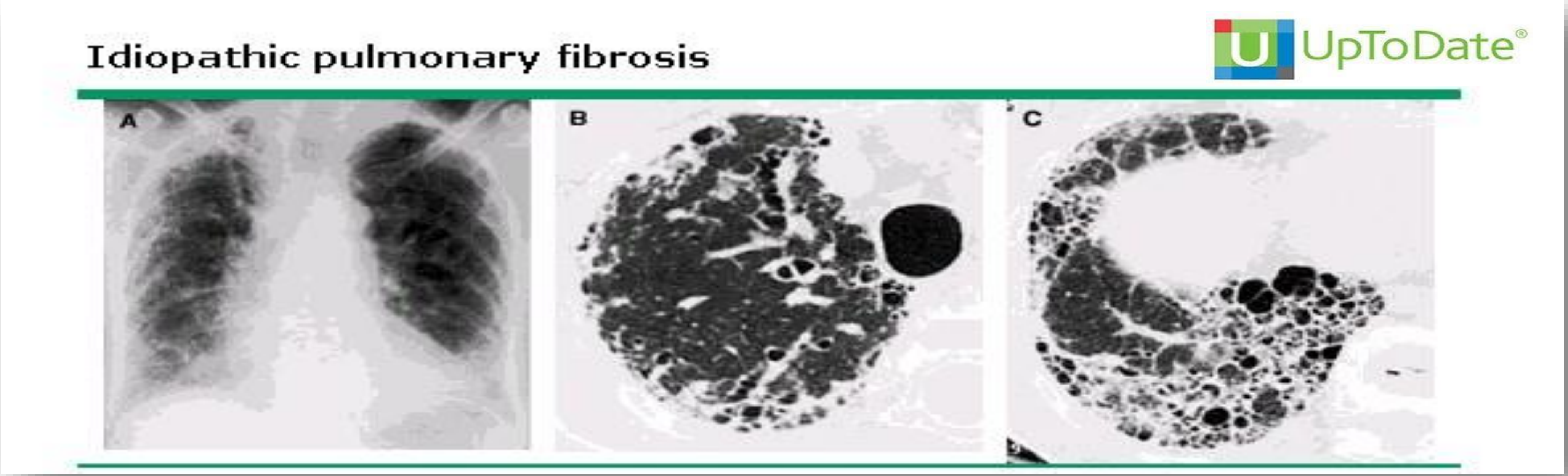


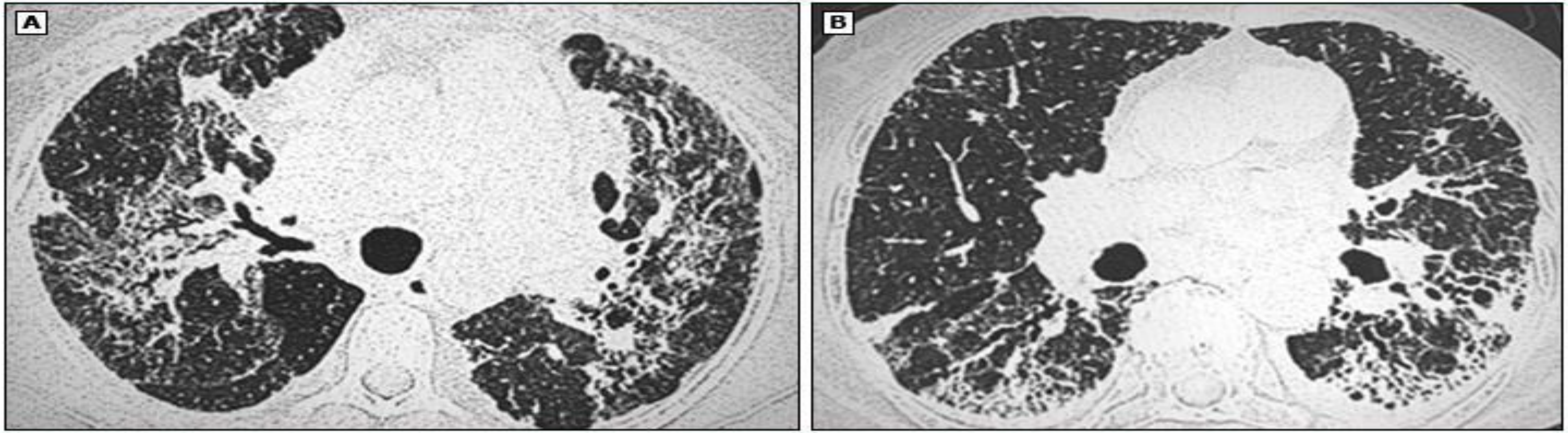
Fig. 1 Classification of Interstitial Lung Diseases. Footnotes: RA = Rheumatoid Arthritis; PM/DM = polymyositis/dermatomyositis; LAM = lymphangioleiomyomatosis

Idiopathic interstitial pneumonias

IPF is the most common type of idiopathic interstitial pneumonia (IIP). Clinical features of IPF include non-productive cough, dyspnea on exertion, a restrictive pattern on pulmonary function tests (PFTs), with impaired gas transfer, and bibasilar reticular opacities, traction bronchiectasis, and often subpleural honeycomb cysts on high resolution computed tomography (HRCT)



High resolution computed tomography of chronic hypersensitivity pneumonitis



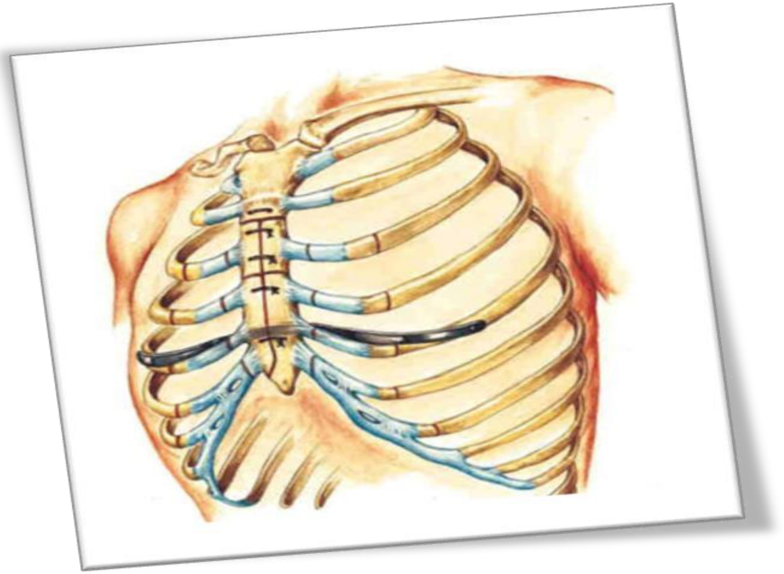
High resolution computed tomography (HRCT) from a patient with chronic hypersensitivity pneumonitis. Image A from the upper lung zone shows a bronchocentric pattern of reticular opacities and traction bronchiectasis. Vaguely centrilobular ground-glass opacities are also present. Image B from a lower lung zone shows a peripheral, predominantly reticular pattern with traction bronchiectasis and honeycombing.

Chest HRCT showing honeycomb change

HRCT showing increased reticular opacities and patchy, subpleural areas of honeycomb change in a patient with idiopathic pulmonary fibrosis. Honeycomb change refers to clusters of cystic airspaces approximately 3 to 10 mm in diameter, usually in a subpleural location. Areas of honeycomb change are indicated by the ovals.

HRCT: high resolution computed tomography.

Extrinsic restrictive disorders :
Several conditions extrinsic to the lung parenchyma result in chronically-reduced lung volumes due to mechanical compression or other limitations on lung expansion.

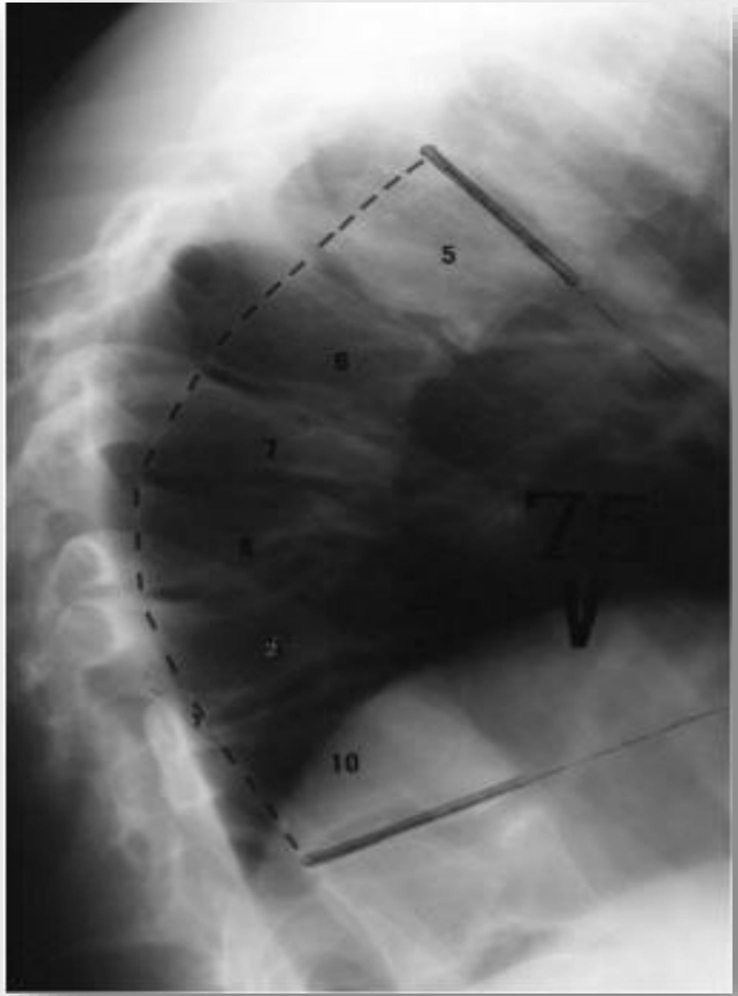


Increased chest wall impedance :

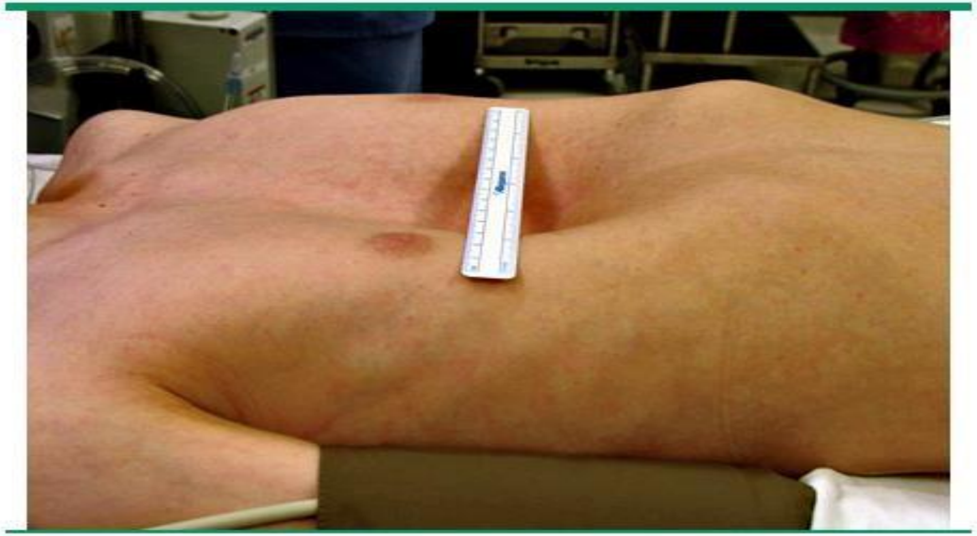
- ✓Space-occupying pathological conditions
- ✓Ankylosing spondylitis, kyphosis, scoliosis
- ✓Congenital abnormalities of the chest wall
- ✓Traumatic and iatrogenic abnormalities of the chest wall

Increased intra-abdominal pressure :

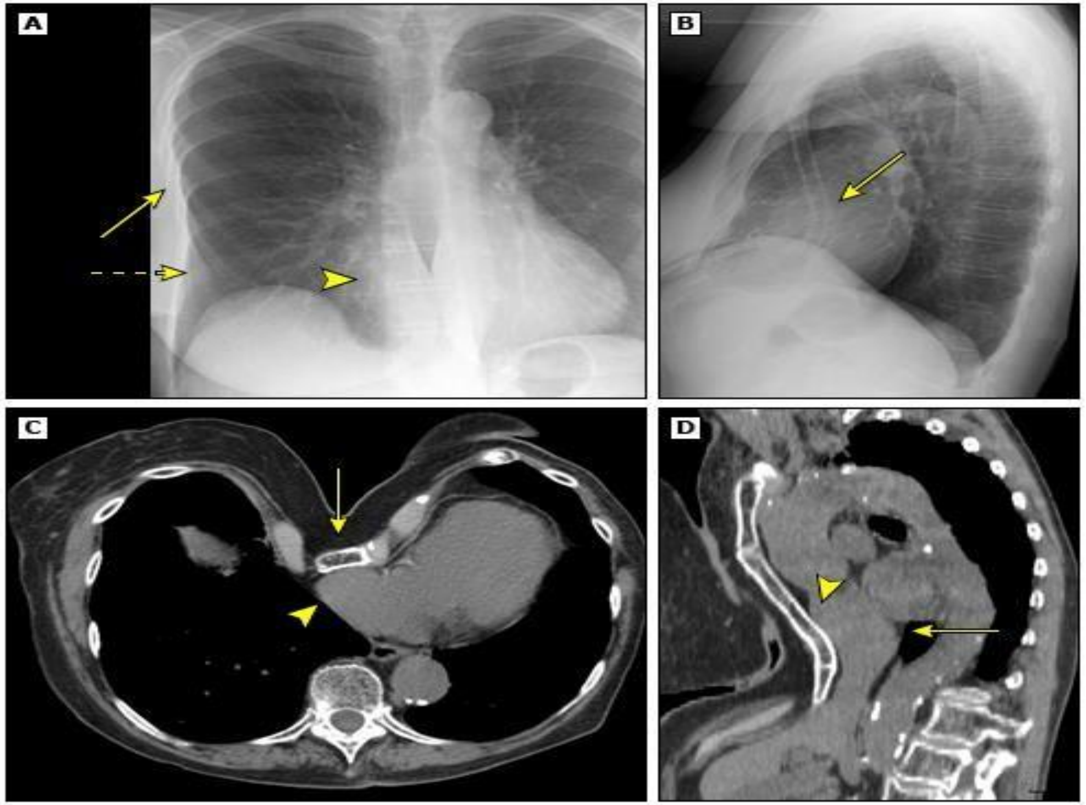
- ✓Obesity
- ✓Ascites

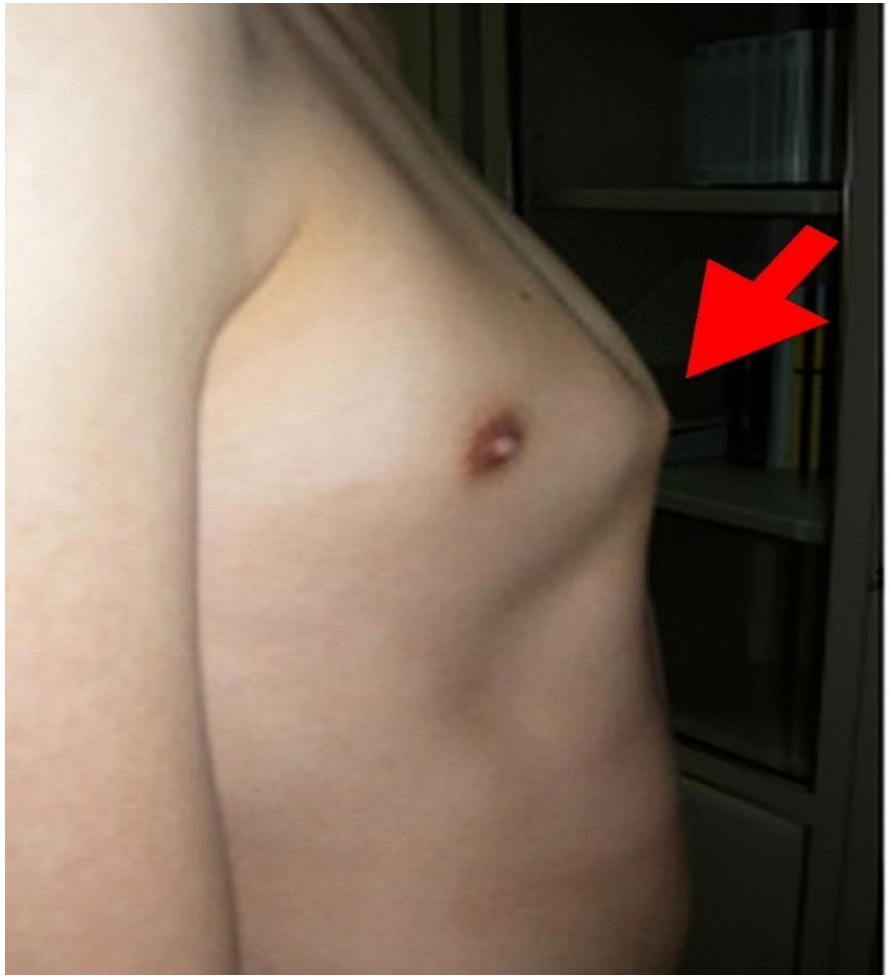

5
6
7
10

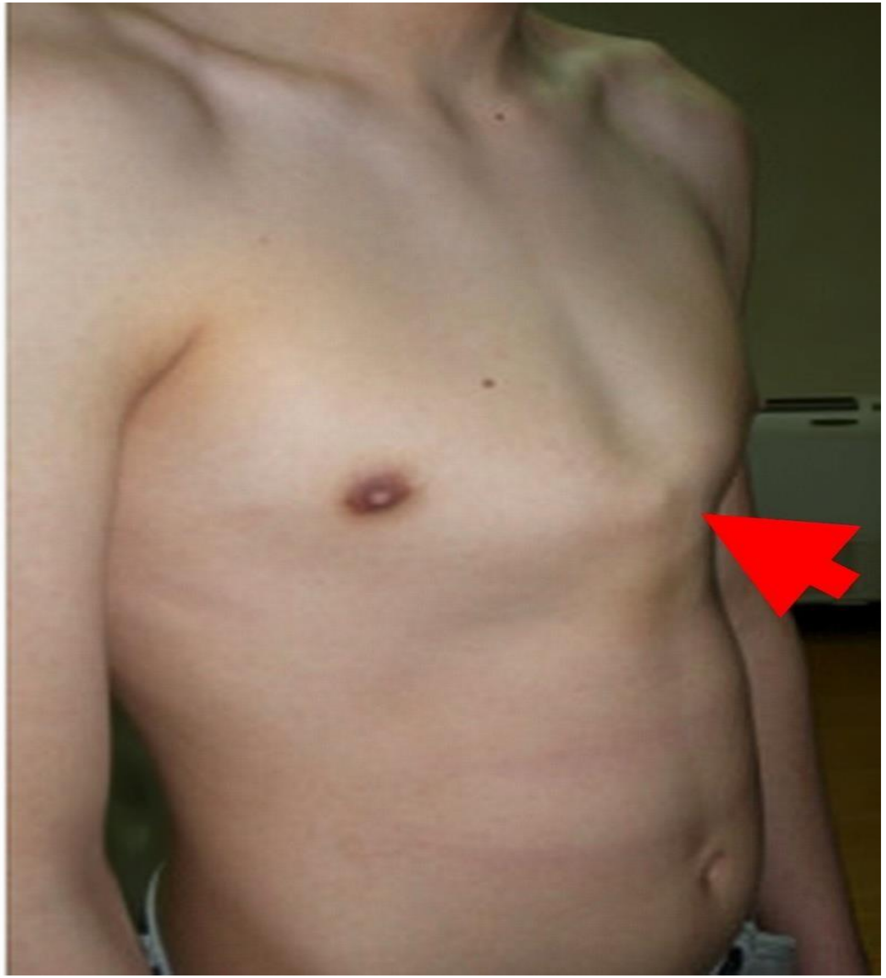
Pectus excavatum



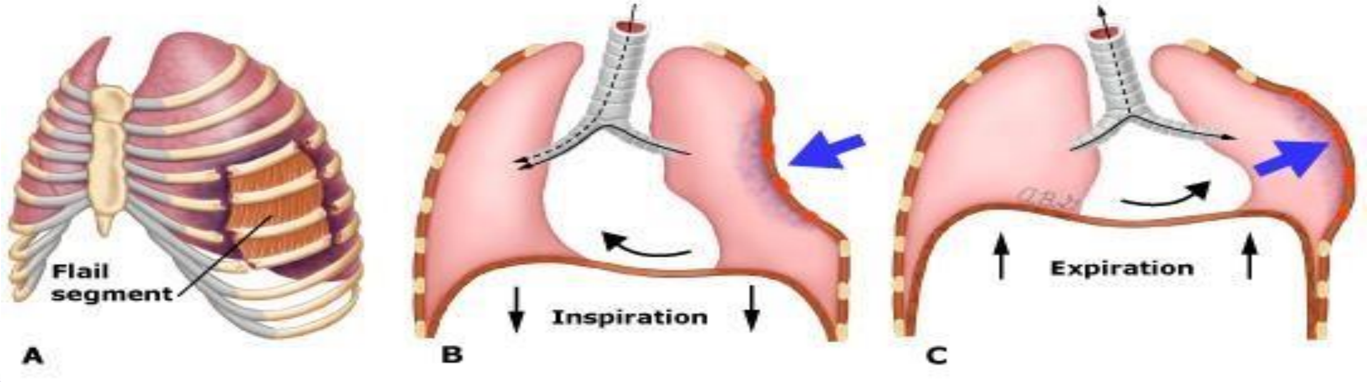
Pectus excavtum in an adolescent patient demonstrating severe invagination of the lower sternum. The patient had significant exercise intolerance.







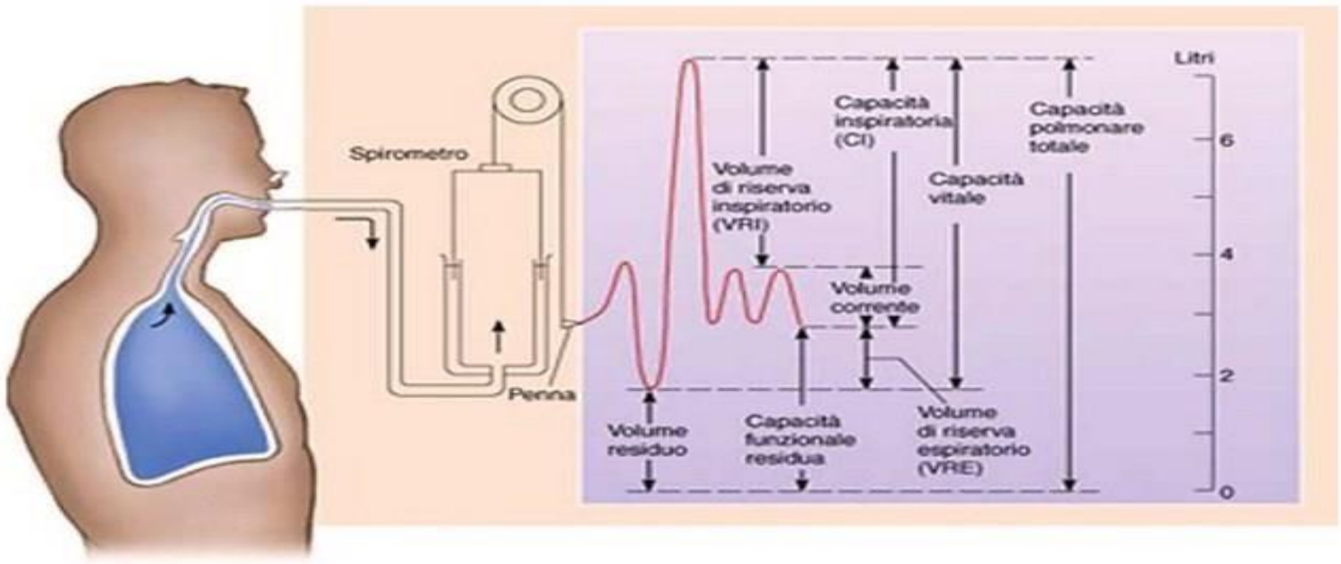
Poland Synd*rome*



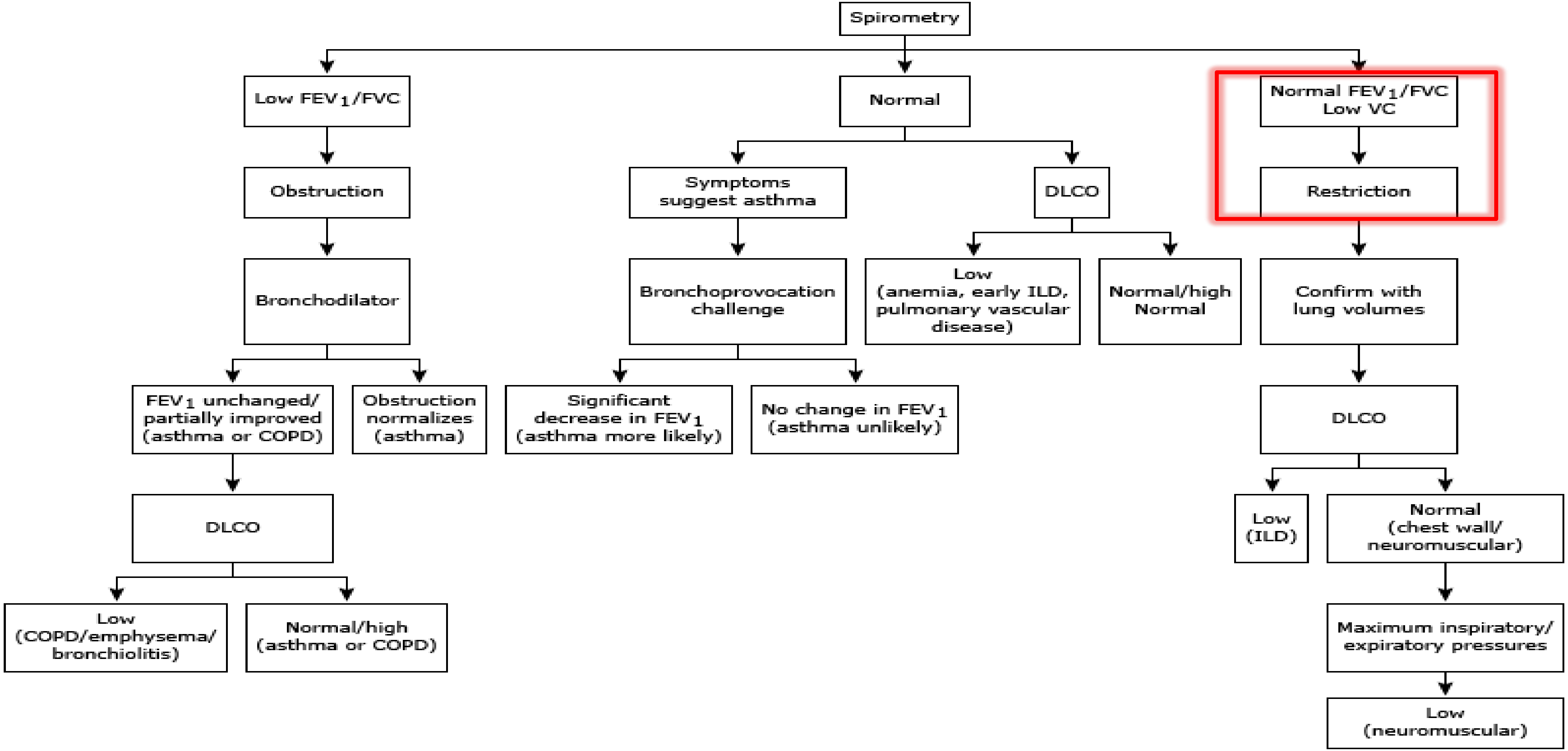
Fibrodysplasia ossificans is a heritable disorder caused by a genetic variant in the gene ACVR1/ALK2 encoding Activin A receptor type I/Activin-like kinase 2, a bone morphogenetic protein (BMP) type I receptor. It is characterized by congenital malformations of the great toes and progressive heterotopic ossification, which can affect the chest wall and lead to respiratory insufficiency

Spirometry :

The hallmark of restrictive physiology on spirometry is the presence of matched reductions in the total exhaled volume (known as the forced vital capacity [FVC]) and the volume exhaled in the first second (known as the forced expiratory volume in one second [FEV_1]), with absence of airflow obstruction

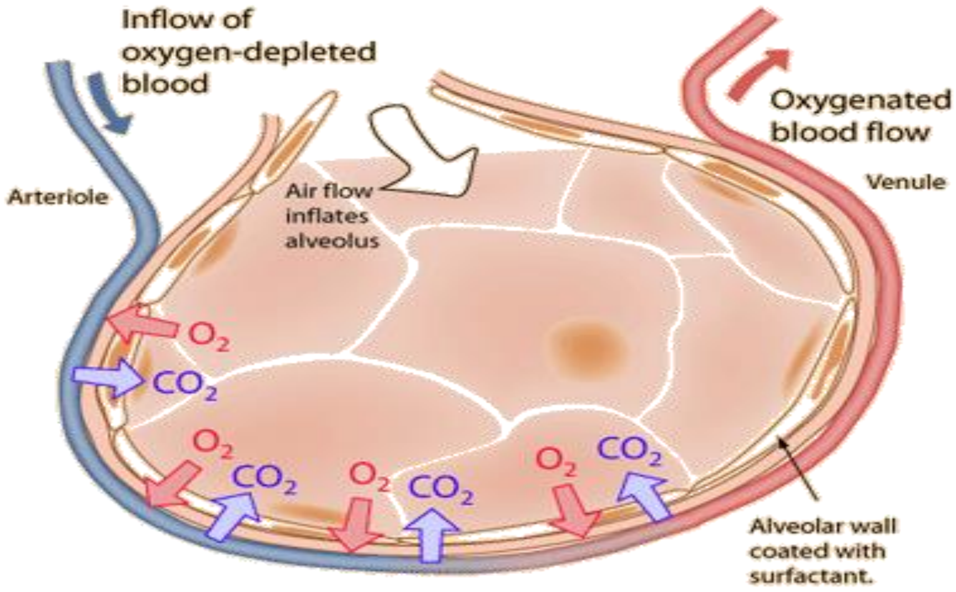


Algorithm for pulmonary function test interpretation

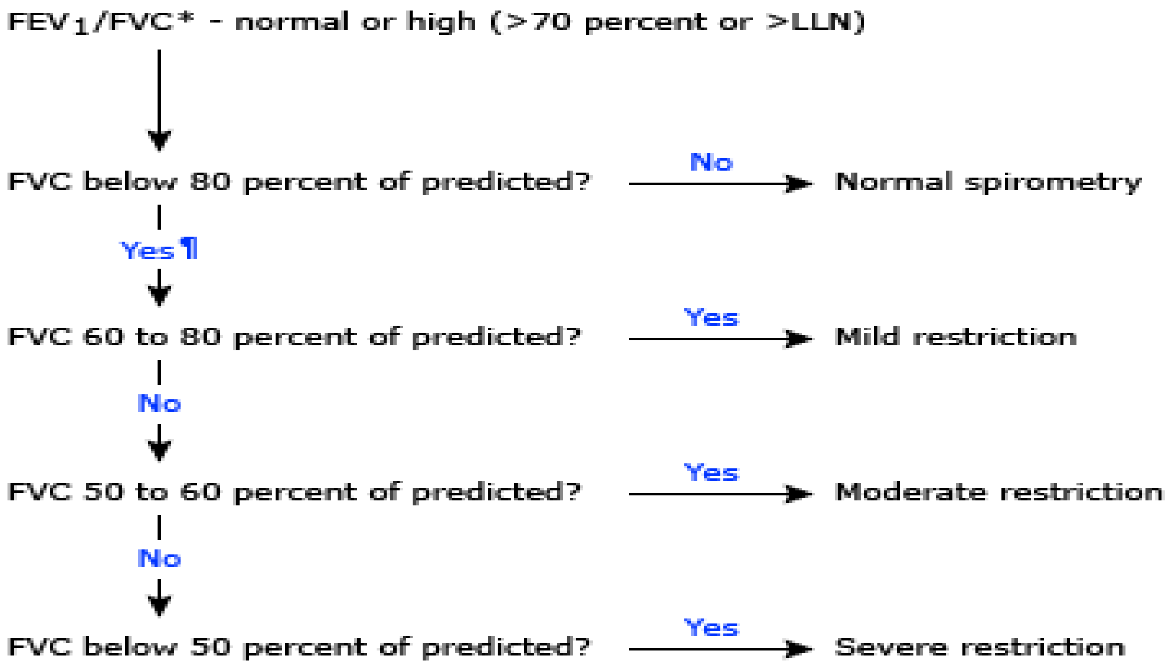


COPD: chronic obstructive pulmonary disease; DLCO: diffusing capacity for carbon monoxide; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; VC: vital capacity; ILD: interstitial lung disease.

Assessment of gas transfer – DLCO measurements aid in diagnosis of the underlying process. The DLCO helps to distinguish between ILD in which DLCO is usually reduced versus other causes of restriction in which DLCO is usually normal. Specifically, impaired DLCO suggests a process involving the pulmonary parenchyma (ie, ILD) or pulmonary vasculature (eg, PH), whereas a normal DLCO is typically seen in conditions that cause increased chest wall impedance or respiratory muscle weakness.

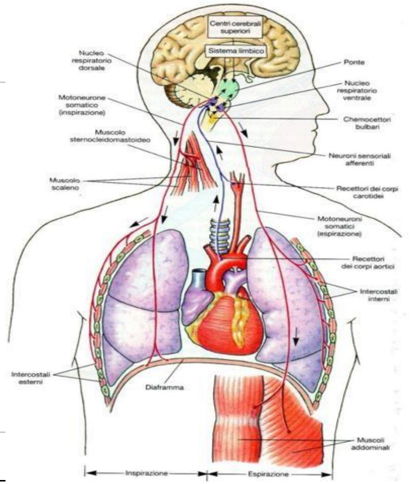


Interpretation of office spirometry: Restrictive pattern



Spirometry interpretation flow chart for the detection of a restrictive ventilatory defect.

Respiratory pathway affecting carbon dioxide elimination	
Central nervous system ↓	"Won't breathe"
Peripheral nervous system ↓	"Can't breathe"
Respiratory muscles ↓	
Chest wall and pleura ↓	
Upper airway ↓	
Lungs	Abnormal gas exchange: "Can't breathe enough"



$$PaCO_2 = (k) \times VCO_2/[V_E(1 - V_D/V_T)]$$

Acute Setting

SOCIETÀ ITALIANA DI GERONTOLOGIA E GERIATRIA

67° CONGRESSO NAZIONALE SIGG

LA LONGEVITÀ DECLINATA AL FEMMINILE

Respirology

Respirology (2019) 24, 308–317doi: 10.1111/resp.13469

INVITED REVIEW SERIES:
NON-INVASIVE VENTILATION
SERIES EDITORS: AMANDA PIPER AND CHUNG-MING CHU

Benefits of non-invasive ventilation in acute hypercapnic respiratory failure

VITTORIA COMELLINI,[1] ANGELA MARIA GRAZIA PACILLI[2] AND STEFANO NAVA[1,2]

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Table 1 Indications for NIV in acute hypercapnic respiratory failure

1	Acute exacerbation of COPD
2	Cardiogenic pulmonary oedema
3	Obesity and obesity hypoventilation syndrome
4	Weaning from invasive mechanical ventilation
5	Prevention of post-extubation failure in those patients previously intubated
6	Chest wall diseases and neuromuscular diseases
7	Palliative care and do-not-intubate patients
8	Miscellaneous (very old patients, community-acquired pneumonia and bridge to transplantation)

Faverio *et al. BMC Pulmonary Medicine* (2018) 18:70
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BMC Pulmonary Medicine

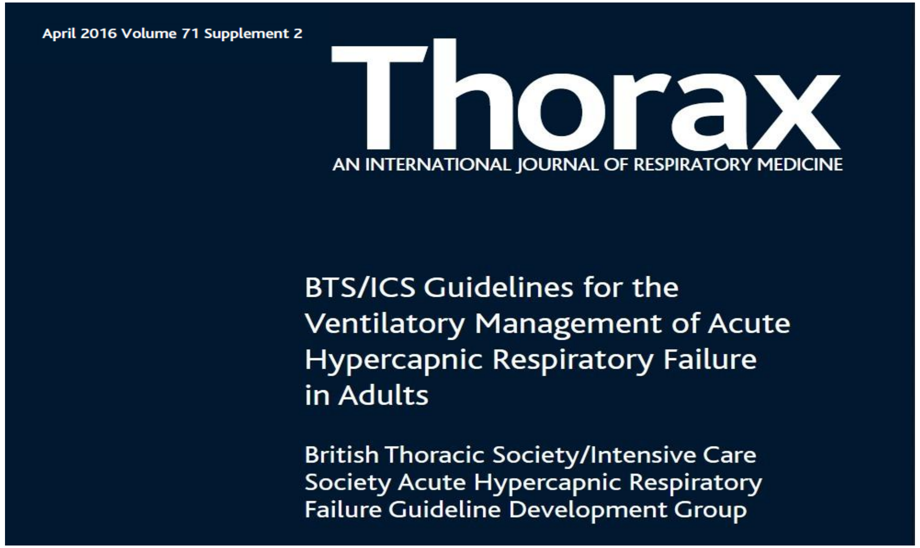
REVIEW Open Access

Management of acute respiratory failure in interstitial lung diseases: overview and clinical insights

Paola Faverio[1*], Federica De Giacomi[1], Luca Sardella[1], Giuseppe Fiorentino[2], Mauro Carone[3], Francesco Salerno[3], Jousel Ora[4], Paola Rogliani[4], Giulia Pellegrino[5], Giuseppe Francesco Sferrazza Papa[5], Francesco Bini[6], Bruno Dino Bodini[7], Grazia Messinesi[1], Alberto Pesci[1] and Antonio Esquinas[8]

Problem	Tip for solution
High pressures required to obtain ideal tidal volume in fibrotic lung with risk of pneumothorax	- Tolerate low tidal volumes with higher respiratory rate to obtain acceptable minute ventilation - Low to moderate PEEP levels to avoid overdistension of "healthy" lung units
High respiratory rate that hampers patient-ventilator adaptation	- Titrate drugs to control respiratory rate, e.g. opiates (morphine or fentanyl)[§]
Intense breathlessness reported by patients especially in the acute phase	- Titrate drugs to control respiratory rate, e.g. opiates (morphine or fentanyl)[§] - Rapid inspiratory curve - Increase FIO2

Restrictive lung diseases (NMD and CWD)



April 2016 Volume 71 Supplement 2

Thorax

AN INTERNATIONAL JOURNAL OF RESPIRATORY MEDICINE

BTS/ICS Guidelines for the Ventilatory Management of Acute Hypercapnic Respiratory Failure in Adults

British Thoracic Society/Intensive Care Society Acute Hypercapnic Respiratory Failure Guideline Development Group

Recommendations:

49.Controlled oxygen therapy should be used in patients with NMD or CWD and AHRF (Grade D).

50.NIV should almost always be trialled in the acutely unwell patients with NMD or CWD with hypercapnia. Do not wait for acidosis to develop (Grade D).

51.In patients with NMD or CWD, NIV should be considered in acute illness when vital capacity (VC) is known to be <1 L and RR >20, even if normo-capnic (Grade D).

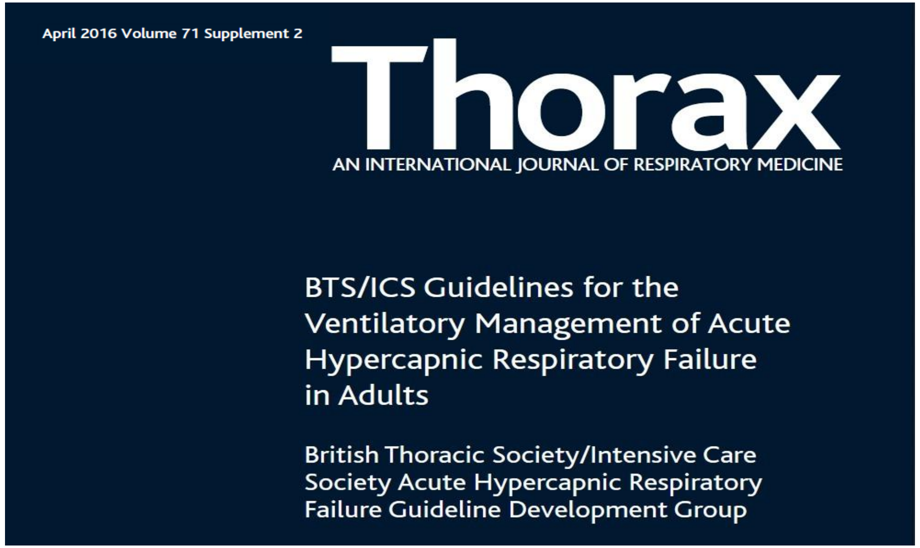
52.In patients with NMD or CWD, consider controlled ventilation as triggering may be ineffective (Grade D).

53.In NMD or CWD, unless escalation to IMV is not desired by the patient, or is deemed to be inappropriate, intubation should not be delayed if NIV is failing (Grade D)

Good practice points:

- Patients with NMD usually require low levels of PS (IPAP 8-12 cmH2O)
- Patients with chest wall deformity usually require higher levels of PS (IPAP > 20 cmH2O)
- PEEP in the range of 5–10 is commonly required to increase residual volume and reduce oxygen dependency in both patient groups.

Obesity hypoventilation syndrome



Recommendations:

56.Controlled oxygen therapy should be used in patients with OHS and AHRF (Grade D).

57.In patients with OHS, NIV should be started in AHRF using the same criteria as in AECOPD (Grade B).

58.NIV is indicated in some hospitalised obese hypercapnic patients with daytime somnolence, sleep disordered breathing and/or right heart failure in the absence of acidosis (Grade D).

Good practice points:

- High inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP) settings are commonly required in patients with OHS (eg, IPAP>30, EPAP>8).
- Volume control (or volume assured) providing NIV may be more effective when high inflation pressures are required.

Indications for NIV

COPD
pH <7.35
pCO2 >6.5
RR>23
If persisting after bronchodilators and controlled oxygen therapy

Neuromuscular disease
Respiratory illness with RR > 20 if usual VC <1L even if pCO2< 6.5
Or
pH < 7.35 and pCO2> 6.5

Obesity
pH <7.35, pCO2>6.5, RR>23
Or
Daytime pCO2> 6.0 and somnolent

NIV Not indicated
Asthma/Pneumonia
Refer to ICU for consideration IMV if increasing respiratory rate/distress
or
pH <7.35 and pCO2 >6.5

Contraindications for NIV

Absolute
Severe facial deformity
Facial burns
Fixed upper airway obstruction

Relative
pH<7.15
(pH<7.25 and additional adverse feature)
GCS <8
Confusion/agitation
Cognitive impairment (warrants enhanced observation)

Indications for referral to ICU
AHRF with impending respiratory arrest

NIV failing to augment chest wall movement or reduce pCO2

Inability to maintain Sao2 > 85-88% on NIV

Need for IV sedation or adverse features indicating need for closer monitoring and/or possible difficult intubation as in OHS, DMD.

NIV SETUP

Mask
Full face mask (or own if home user of NIV)

Initial Pressure settings
EPAP: 3 (or higher if OSA known/expected)

IPAP in COPD/OHS/KS 15 (20 if pH <7.25)

Up titrate IPAP over 10-30 mins to IPAP 20—30 to achieve adequate augmentation of chest/abdo movement and slow RR

IPAP should not exceed 30 or EPAP 8*
without expert review

IPAP in NM 10 (or 5 above usual setting)

Backup rate
Backup Rate of 16-20. Set appropriate inspiratory time

I:E ratio
COPD 1:2 to 1.3
OHS, NM & CWD 1:1

Inspiratory time
0.8-1.2s COPD
1.2-1.5s OHS, NM & CWD

Use NIV for as much time as possible in 1st 24hours.
Taper depending on tolerance & ABGs over next 48-72 hours

SEEK AND TREAT REVERSIBLE CAUSES OF AHRF

*** Possible need for EPAP > 8**
Severe OHS (BMI >35), lung recruitment eg hypoxia in severe kyphoscolios, oppose intrinsic PEEP in severe airflow obstruction or to maintain adequate PS when high EPAP required

NIV Monitoring

Oxygenation
Aim 88-92% in all patients

Note: Home style ventilators CANNOT provide > 50% inspired oxygen.

If high oxygen need or rapid desaturation on disconnection from NIV consider IMV.

Red flags
pH <7.25 on optimal NIV
RR persisting > 25
New onset confusion or patient distress

Actions
Check synchronisation, mask fit, exhalation port : give physiotherapy/bronchodilators, consider anxiolytic

CONSIDER IMV

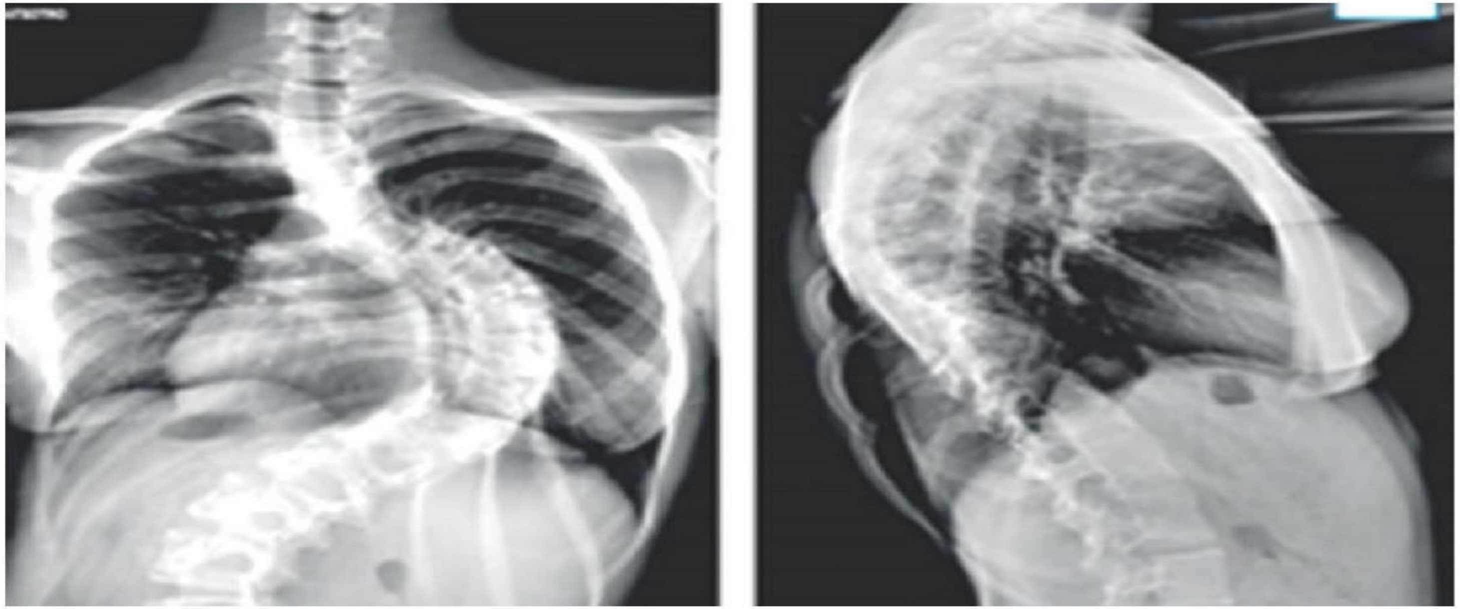
Chronic Setting

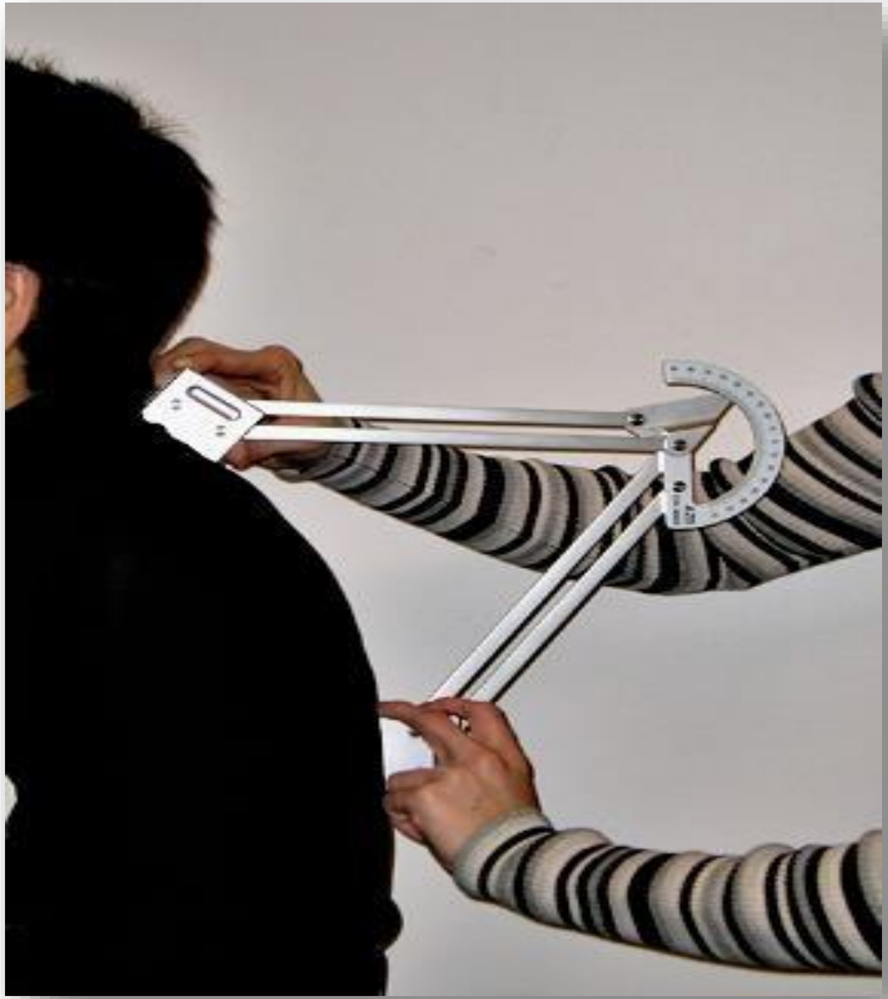
Hyperkyphosis

Hyperkyphosis is excessive curvature of the thoracic spine, commonly known as the "dowager's hump." Although it is also referred to as kyphosis, the term kyphosis is meant to describe the sagittal convexity, or forward curvature, of the normal thoracic spine which can range from normal to abnormal. Kyphosis tends to progress with age.

ETIOLOGY

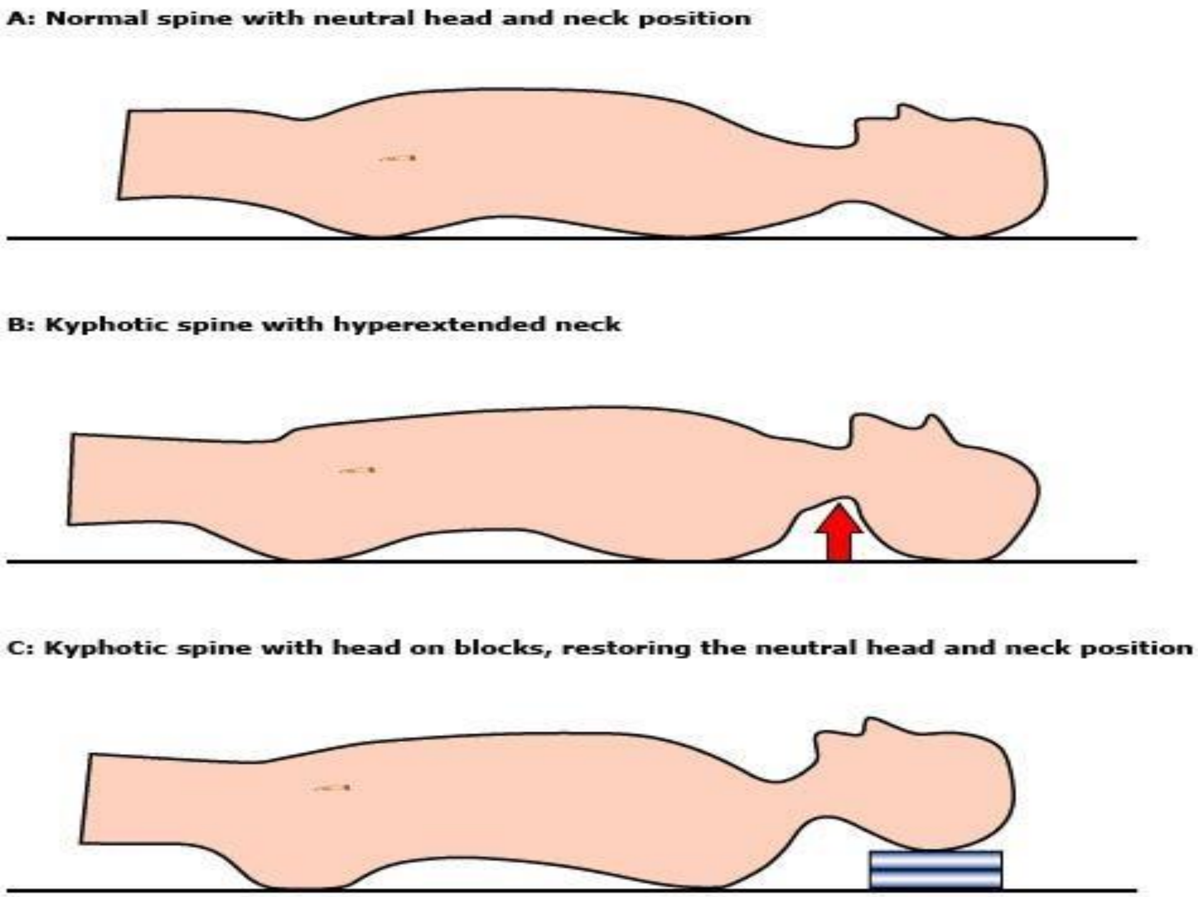
- *Vertebral fractures*
- *Low bone density*
- *Short vertebral height*
- *Degenerative disc disease*
- *Postural changes*
- *Muscle weakness*
- *Intervertebral ligaments*
- *Genetic/metabolic conditions*

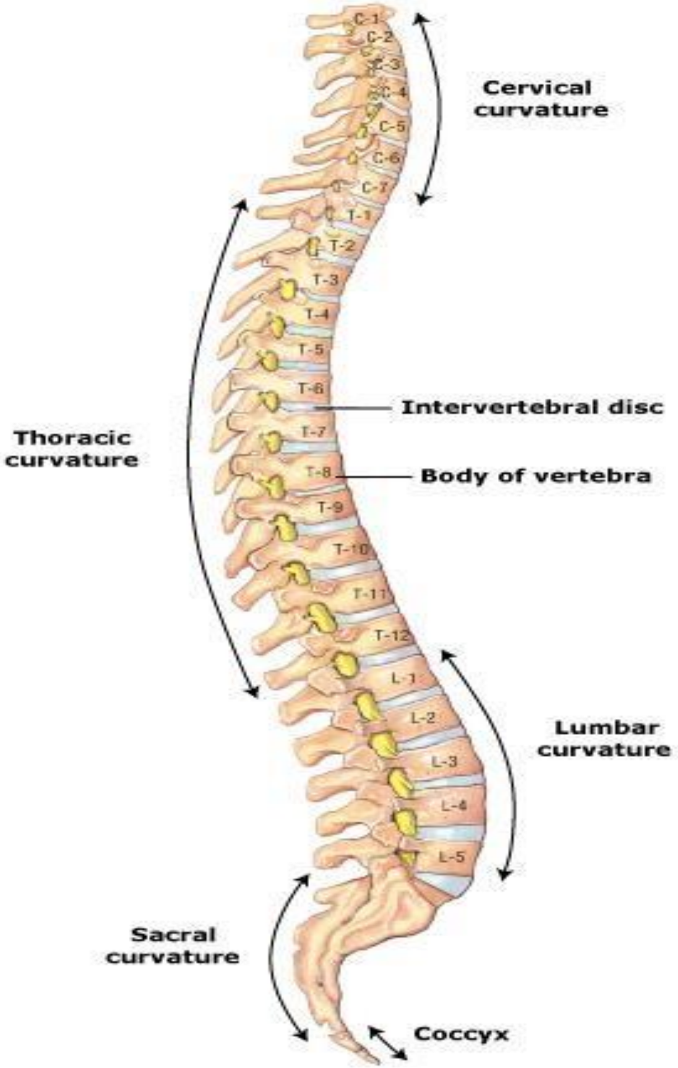


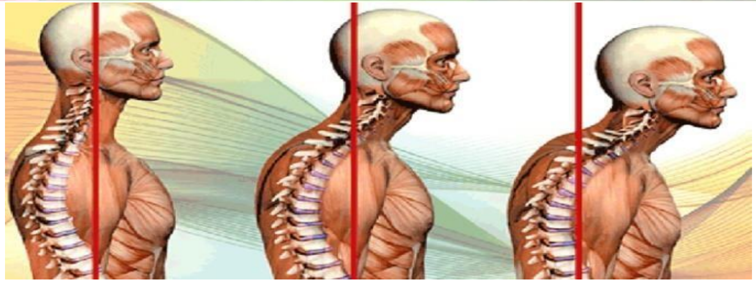


Debrunner kyphometer

Distance from the occiput-to-wall

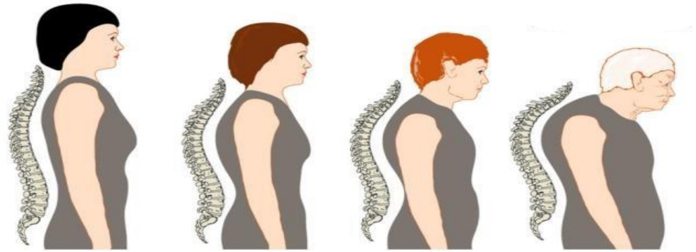






Effect of aging :

- ✓ Chest wall compliance decreases with age;
- ✓ Increasing work of breathing and risk of respiratory muscle fatigue;
- ✓ Patients tend to breathe with lower tidal volumes and increased respiratory rate;
- ✓ Dead space fraction may be increased;
- ✓ Alveolar hypoventilation may ensue with resultant hypercapnia;
- ✓ Hypoxemia without hypercapnia is seen in moderate to severe disease;
- ✓ Ventilation-perfusion (V/Q) mismatch has been reported with a scoliosis angle greater than 65 degrees;
- ✓ Pulmonary hypertension develops as a result of persistent hypoxemia;
- ✓ Nocturnal hypoventilation and arterial oxygen desaturation are described, particularly during rapid eye movement (REM) sleep.



Mateusz Pajdziński, Paulina Młynarczyk, Joanna Miłkowska-Dymanowska, Adam J. Białas, Moin Aldin Muhammad Afzal, Wojciech J. Piotrowski, Paweł Górski

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Adv. Respir. Med. 2017; 85: 352–357

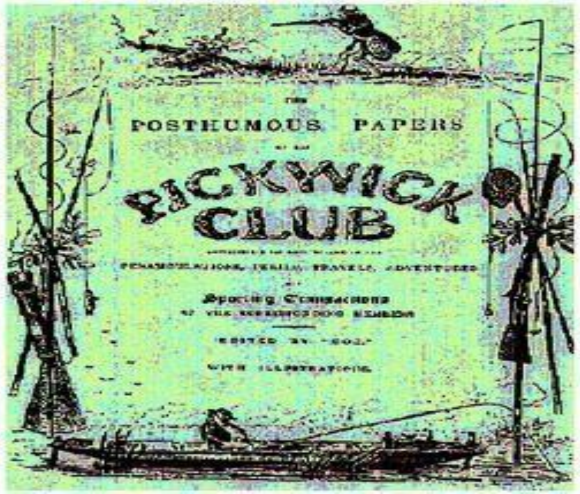
Kyphoscoliosis — what can we do for respiration besides NIV?

- ✓ NIV is now regarded as an option of treating CRF in patients with KS;
- ✓ The survival rate of patients using home mechanical ventilation was three times higher than that of patients using long-term oxygen therapy alone (LTOT);
- ✓ If the patient has obstructive disorders, continuous positive airways pressure (CPAP) is recommended;
- ✓ After three months of NIV in KS patients the length and quality of REM sleep improved, while oxygenation increased and transcutaneous carbon dioxide tension decreased;

Obesity hypoventilation syndrome

"Pickwickian syndrome"

Obesity is associated with restrictive physiology on pulmonary function testing due to increased weight of the chest wall and increased abdominal adipose tissue restricting diaphragmatic motion.
The severity of obesity is most commonly determined by the body mass index (BMI); a BMI greater than 30 kg/m^2 is commonly used as a definition of obesity.



Obesity Hypoventilation Syndrome (OHS) is defined as the presence of awake alveolar hypoventilation in an obese individual which cannot be attributed to other conditions associated with alveolar hypoventilation

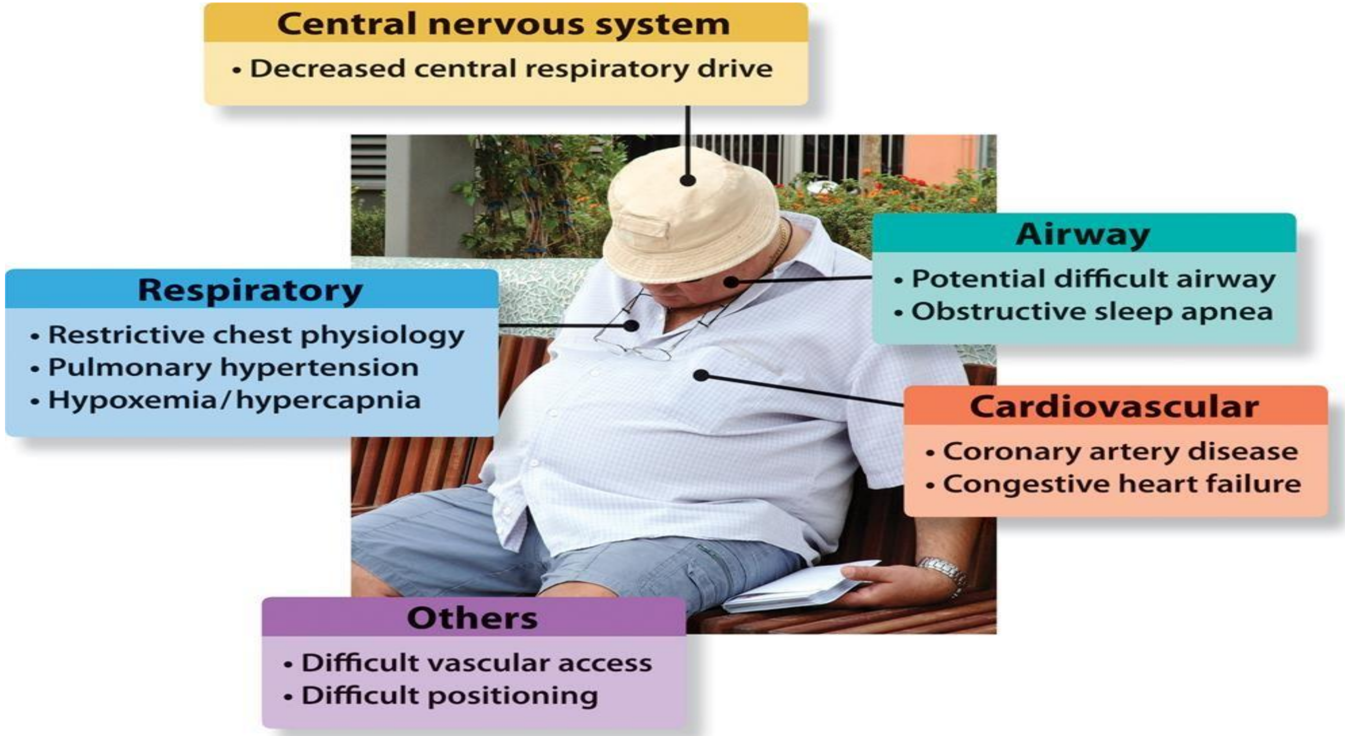
OHS is a <u>diagnosis of exclusion</u> that can be made when the following criteria are met:

- ✓ **Obesity (body mass index [BMI] >30 kg/m[2])**
- ✓ **Awake alveolar hypoventilation as indicated by a partial arterial pressure of carbon dioxide (CO2) >45 mmHg**
- ✓ **Alternative causes hypercapnia and hypoventilation have been excluded**

- ✓ Elevated serum bicarbonate (>27 mEq/L)
- ✓ Hypoxemia (PaO_2 <70 mmHg)
- ✓ Polycythemia

Medical impairments associated with obesity hypoventilation syndrome

Central nervous system
▪ Cognitive deficit
▪ Decrease neuronal drive
Upper airway
▪ Obstructive sleep apnea
▪ Increased intubation risk
Respiratory
▪ Restrictive lung function
▪ Pulmonary hypertension
▪ Hypercapnia/hypoxemia
Metabolic
▪ Central obesity
▪ Metabolic syndrome
▪ Chronic inflammation
▪ IGF-1 deficit
Cardiovascular
▪ Endothelial dysfunction
▪ Coronary artery disease
▪ Chronic heart failure
General
▪ Peripheral edema
▪ Increased morbi-mortality
▪ Decreased physical activity



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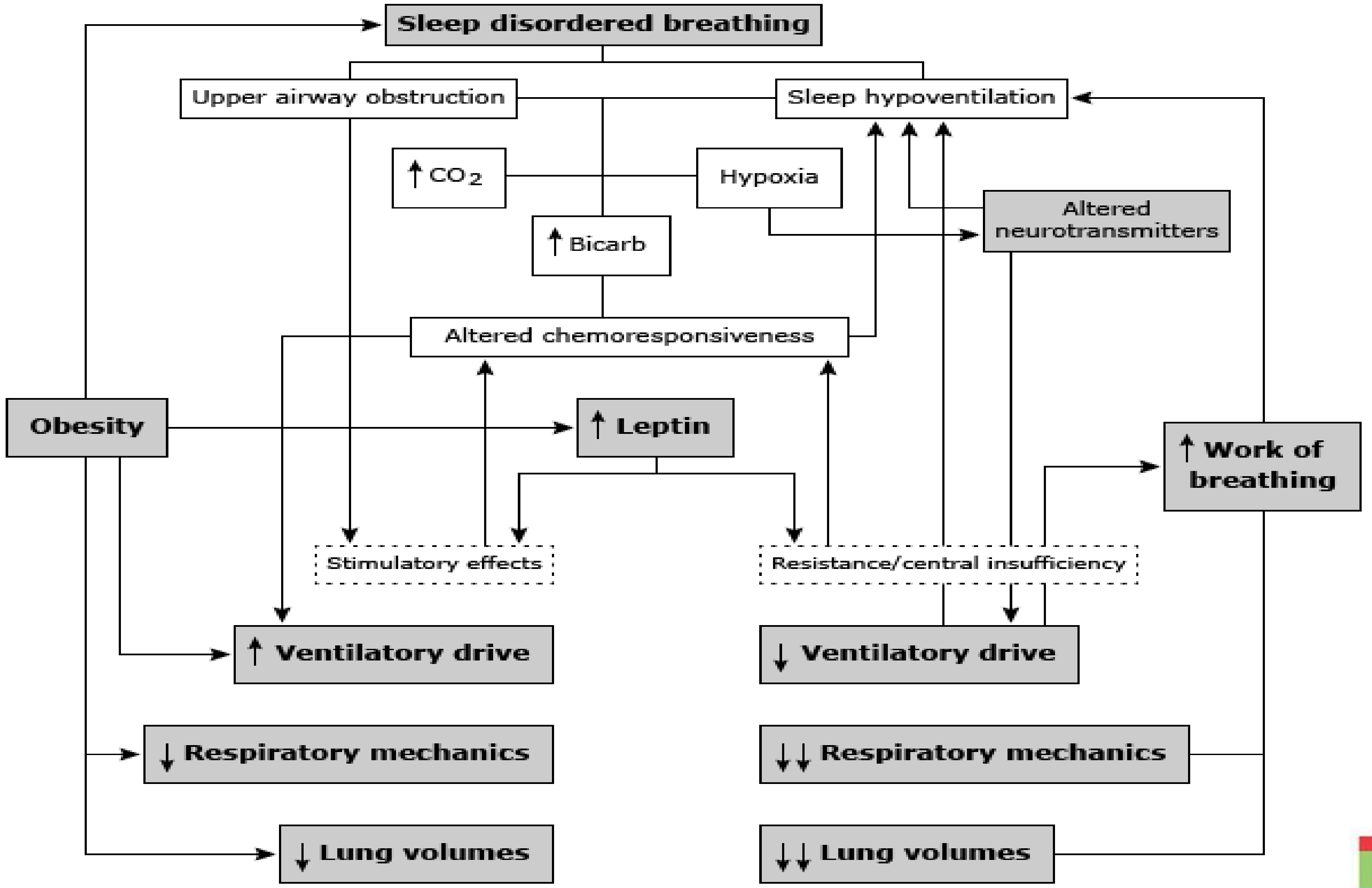
Mechanisms of sleep disordered breathing in obesity hypoventilation



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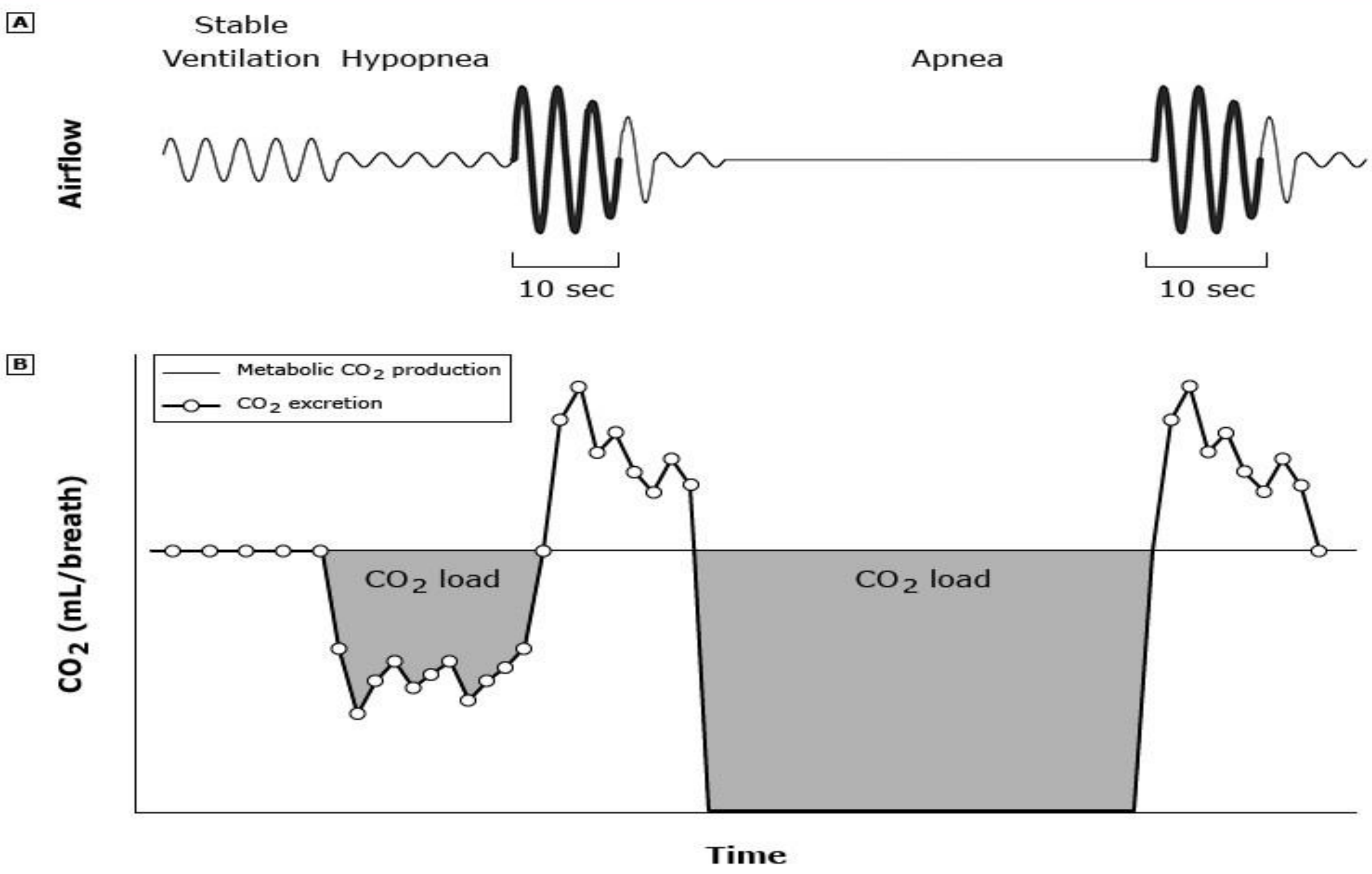
Role of obstructive events and carbon dioxide accumulation in obesity hypoventilation syndrome



AMERICAN THORACIC SOCIETY DOCUMENTS

Evaluation and Management of Obesity Hypoventilation Syndrome

An Official American Thoracic Society Clinical Practice Guideline

Babak Mokhlesi, Juan Fernando Masa, Jan L. Brozek, Indira Gurubhagavatula, Patrick B. Murphy, Amanda J. Piper, Aiman Tulaimat, Majid Afshar, Jay S. Balachandran, Raed A. Dweik, Ronald R. Grunstein, Nicholas Hart, Roop Kaw, Geraldo Lorenzi-Filho, Sushmita Pamidi, Bhakti K. Patel, Susheel P. Patil, Jean Louis Pépin, Israa Soghier, Maximiliano Tamae Kakazu, and Mihaela Teodorescu; on behalf of the American Thoracic Society Assembly on Sleep and Respiratory Neurobiology

This official Clinical Practice Guideline of the American Thoracic Society was approved May 2019

Question 2: Should adults with OHS be treated with PAP—either CPAP or NIV—or not be treated with PAP?	
Recommendation 2: For stable ambulatory patients diagnosed with OHS, we suggest treatment with PAP during sleep (*conditional recommendation, very low level of certainty in the evidence*).	Note: Patients with symptomatic OHS who have significant comorbidities and those with chronic respiratory failure after an episode of acute-on-chronic hypercapnic respiratory failure may particularly benefit from using PAP.
Question 3: Should adults with OHS be treated with CPAP or with NIV?	
Recommendation 3: For stable ambulatory patients diagnosed with OHS and concomitant severe OSA (apnea–hypopnea index ⩾ 30 events/h), we suggest initiating first-line treatment with CPAP therapy rather than NIV (*conditional recommendation, very low level of certainty in the evidence*).	More than 70% of patients with OHS also have severe OSA; therefore, this recommendation applies to the majority of patients with OHS who have concomitant severe OSA. However, panel members lacked certainty on the clinical benefits of initiating treatment with CPAP, rather than NIV, in patients with OHS who have sleep hypoventilation without severe OSA.
Question 4: Should hospitalized adults suspected of having OHS, in whom the diagnosis has not yet been made, be discharged from the hospital with or without PAP treatment until the diagnosis of OHS is either confirmed or ruled out?	
Recommendation 4: We suggest that hospitalized patients with respiratory failure suspected of having OHS be started on NIV therapy before being discharged from the hospital, until they undergo outpatient workup and titration of PAP therapy in the sleep laboratory, ideally within the first 3 mo after hospital discharge (*conditional recommendation, very low level of certainty in the evidence*).	Note: Discharging patients from the hospital with NIV should not be a substitute for arranging the outpatient sleep study and PAP titration in the sleep laboratory, as soon as it is feasible.
Question 5: Should a weight-loss intervention or no such intervention be used for adults with OHS?	
Recommendation 5: For patients with OHS, we suggest using weight-loss interventions that produce sustained weight loss of 25–30% of actual body weight. This level of weight loss is most likely required to achieve resolution of hypoventilation (*conditional recommendation, very low level of certainty in the evidence*).	Note: Many patients may not be able to achieve this degree of sustained weight loss despite participating in multifaceted comprehensive weight-loss lifestyle intervention program; those who have no contraindications may benefit from being evaluated for bariatric surgery.

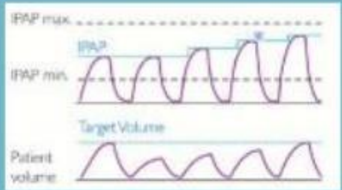
Definition of abbreviations: CPAP = continuous positive airway pressure; NIV = noninvasive ventilation; OHS = obesity hypoventilation syndrome; OSA = obstructive sleep apnea; PAP = positive airway pressure; Sp_{O_2} = oxygen saturation by pulse oximetry.

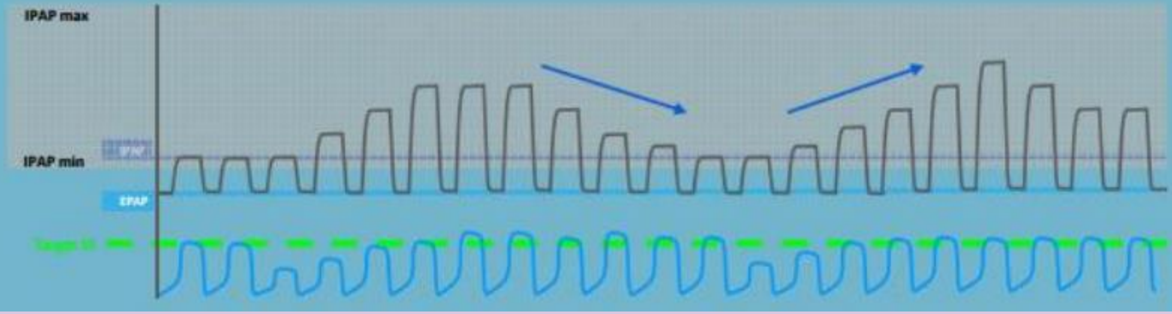
Average Volume Assured Pressure Support

- Modalità ibrida che fornisce il volume corrente costante ad ogni respiro offrendo allo stesso tempo il comfort e i vantaggi della ventilazione a pressione di supporto *
- Progettata per applicare il supporto minimo di pressione necessaria per raggiungere il volume corrente impostato
  - Aiuta a mantenere il comfort ottimale del paziente, sostenendo la cura e la ventilazione del paziente, semplificando il processo di titolazione.

AVAPS

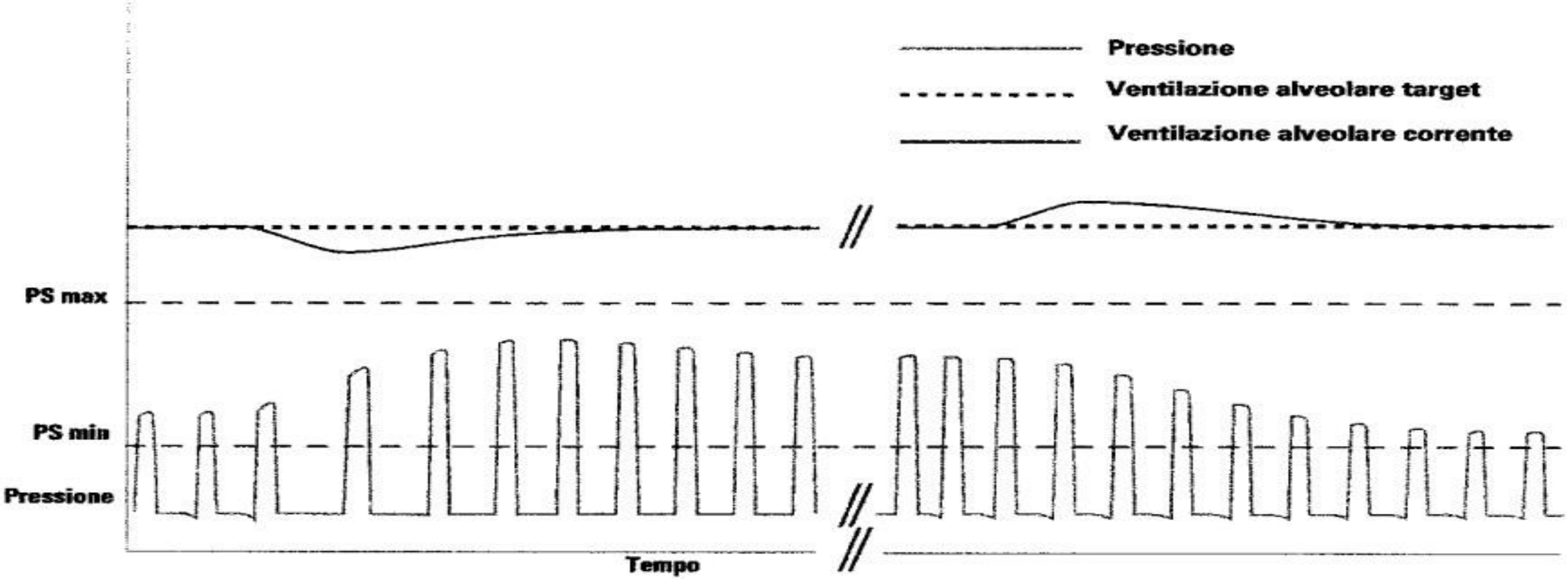
L'algoritmo AVAPS adatta automaticamente la pressione di supporto al paziente per garantire un volume medio assicurato di ventilazione, controbilanciando il carico di lavoro ventilatorio dovuto alla posizione del corpo, agli stadi del sonno e a tutta la meccanica respiratoria

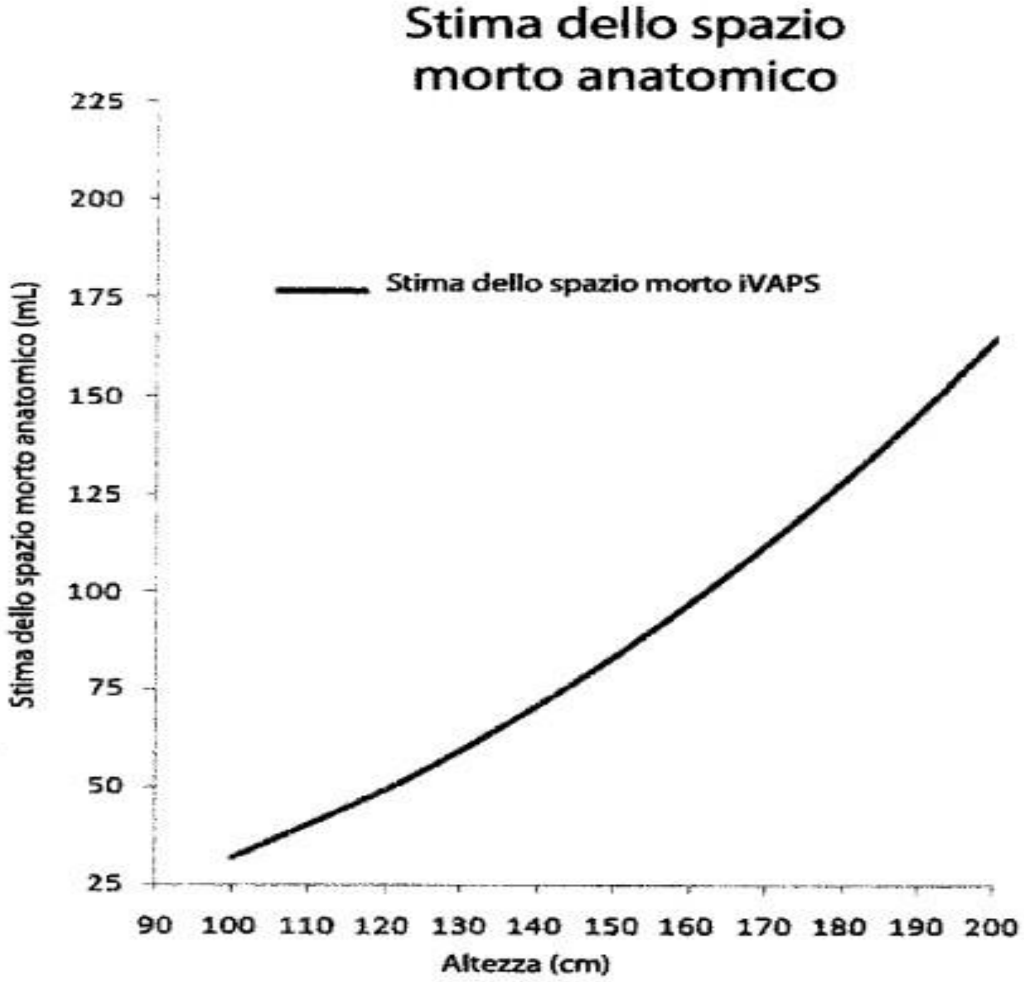


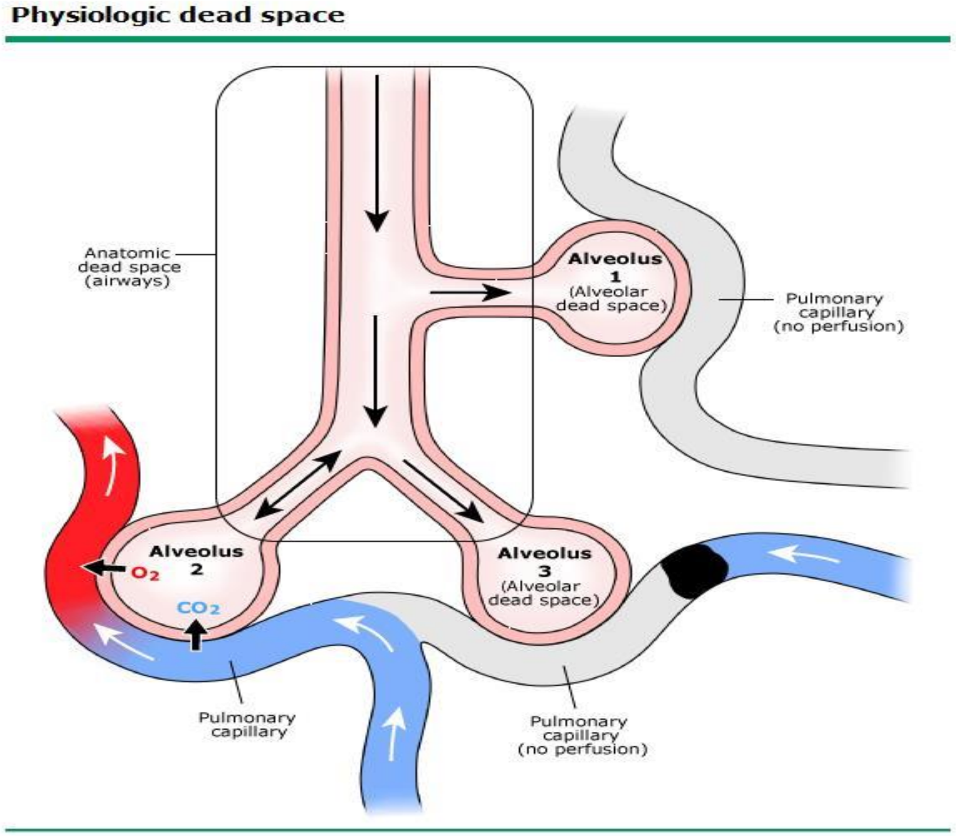


AVAPS

(Pressione di supporto a Volume assicurato/garantito)

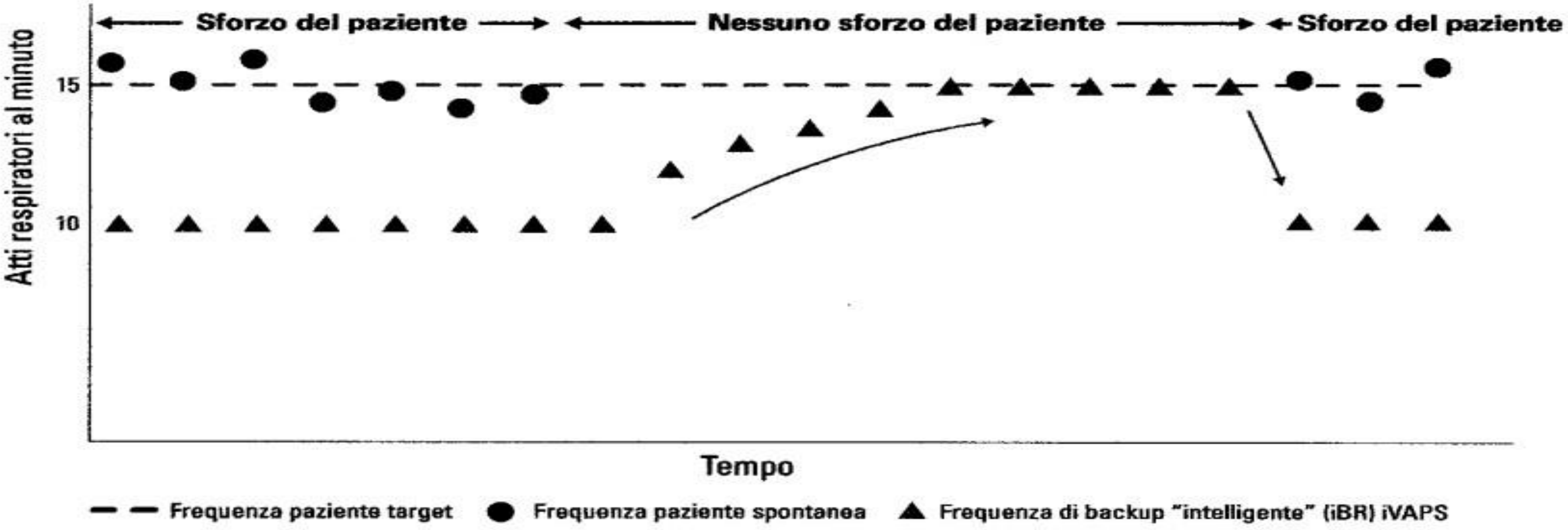






Adattato da Hart MC et al. Journal Applied Physiology.18(3), p519-522. 1963

La funzione iBR riporta il paziente ai livelli definiti quando è necessaria la respirazione di backup



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Original Article

Sleep in ventilatory failure in restrictive thoracic disorders. Effects of treatment with non invasive ventilation

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Table 2
Diagnoses of patients with restrictive disorders.

Diagnoses	N	%
Chest wall disorders	17	28
Congenital myopathy	9	15
Amyotrophic lateral sclerosis	8	13
Obesity-hypoventilation syndrome	6	10
Myotonic muscular dystrophy	6	10
Duchenne muscular dystrophy	4	7
Diaphragmatic paralysis	4	7
Sequelae of tuberculosis	3	5
Sequelae of polyomyelitis	2	3
Ondine's Curse	1	2

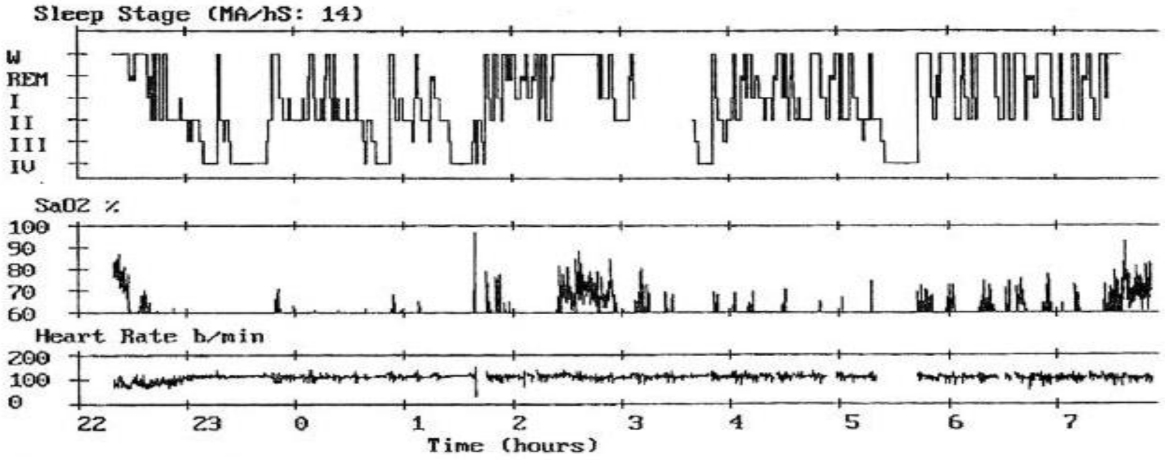


Fig. 1. Summary of full night polysomnography (10 h recording) in a patient with a severe restrictive respiratory disorder and ventilatory failure. Upper tracing: hypnogram; in parentheses: movement arousals per hour of sleep. W: wakefulness; REM: rapid-eye movement sleep; I–IV: non-REM sleep stages 1–4. Middle tracing: transcutaneous oxygen saturation (SpO_2). Lower tracing: pulse rate. Note severe alteration of sleep architecture and very low SpO_2 during most of the sleep study.

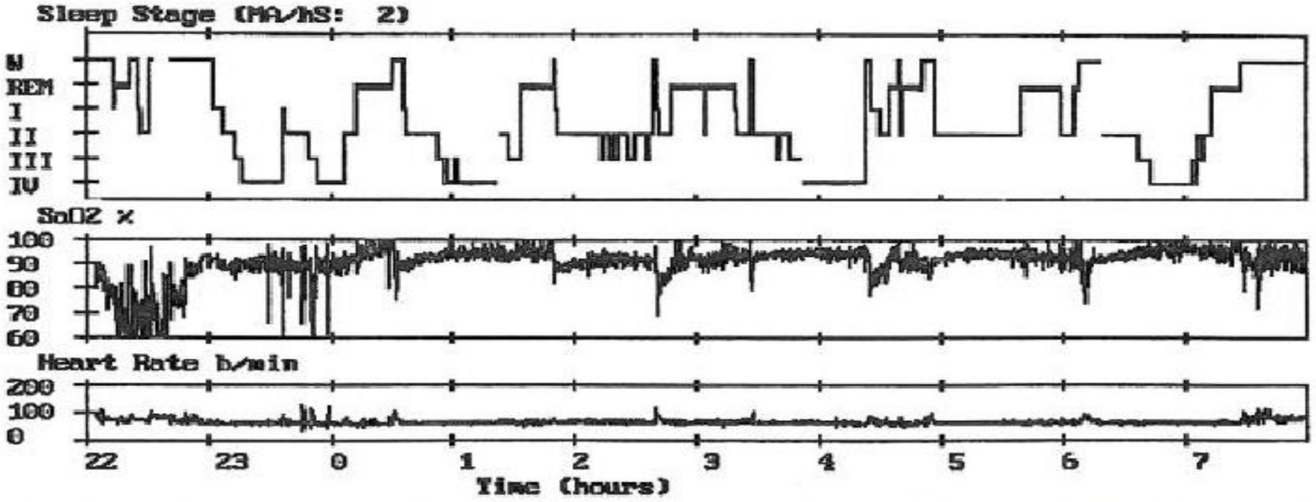


Fig. 2. Summary of full night polysomnography performed in the same patient as in Fig. 1, four days after non invasive ventilation was initiated.

Protocol for initiation of noninvasive positive pressure ventilation in patients with neuromuscular and chest wall disease in the chronic setting

UpToDate®

Choose location*

↓

Ensure patient is comfortable in a chair or bed (>30º angle)

↓

Select and fit mask¶

↓

Apply headgear, avoiding excessive strap tension (one or two fingers should fit under the straps)

↓

Connect interface to ventilator tubing and turn on the ventilatorΔ

↓

Begin titration

Pressure-cycled settings (in spontaneously-triggered [S/T] mode)

- IPAP: 8 to 10 cm H_2O
- EPAP: 4 to 5 cm H_2O
- Backup rate: 2 bpm below resting respiratory rate

↓

Gradually increase IPAP by 1 to 2 cm H_2O increments, as tolerated (usual maximum 20 cm H_2O, may exceed if chest wall stiffness), to achieve alleviation of dyspnea, decreased respiratory rate, increased tidal volume (not all devices monitor this), and good patient-ventilator synchrony

↓

- Provide encouragement, reassurance, frequent checks, and adjustments, as needed
- Check for air leaks, adjust straps if needed
- Add a chin strap or switch to oronasal (full face) mask if oral air leak is noted
- Monitor vital signs and oximetry during the trial
- Obtain ABG as needed

Volume-cycled settings (in synchronized mandatory ventilation mode)

- Vt: 6 to 10 mL/kg IBW
- PEEP: 4 to 5 cm H_2O
- Backup rate: 2 bpm below resting respiratory rate

↓

Gradually increase Vt by 25 to 50 mL increments, as tolerated, to achieve alleviation of dyspnea, decreased respiratory rate, target tidal volume (usually 6 to 8 mL/kg IBW, but may need more to compensate for leaks), and good patient-ventilator synchrony

↓

- Provide encouragement, reassurance, frequent checks, and adjustments, as needed
- Check for air leaks, adjust straps if needed
- Add a chin strap or switch to oronasal (full face) mask if oral air leak is noted
- Monitor vital signs and oximetry during the trial
- Obtain ABG as needed

Average- or intelligent-volume assured pressure support settings◊

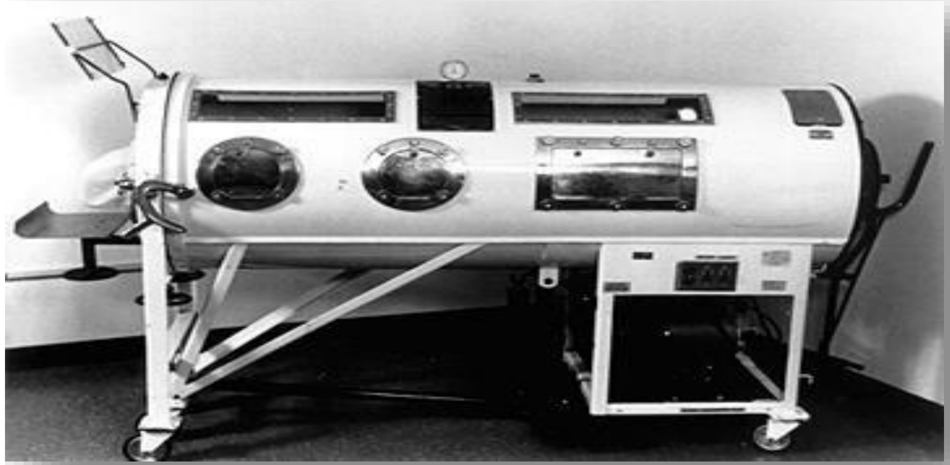
- $IPAP_{min}$: IPAP is gradually increased and set at a target level that results in a tidal volume of 8 mL/kg IBW§
- $IPAP_{max}$: $IPAP_{min}$ + 5 cm H_2O¥
- EPAP: 4 to 5 cm H_2O‡
- Backup rate: 2 to 3 breaths below resting respiratory rate
- Inspiratory time: 33 to 50% (for restrictive lung diseases, shorter for obstructive)
- Rise time: 300 to 600 ms†

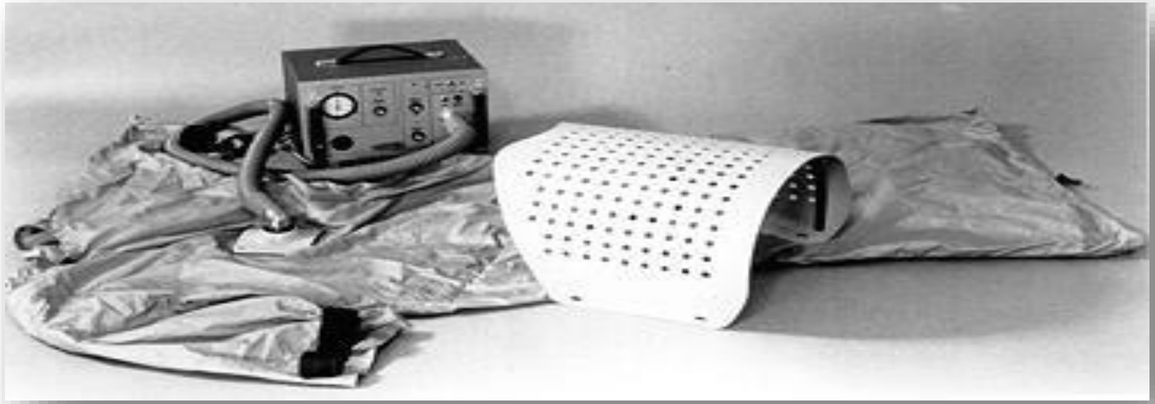
↓

The rise time, inspiratory time, and IPAP and EPAP can be adjusted for patient comfort and to alleviate dyspnea and improve oxygen saturations

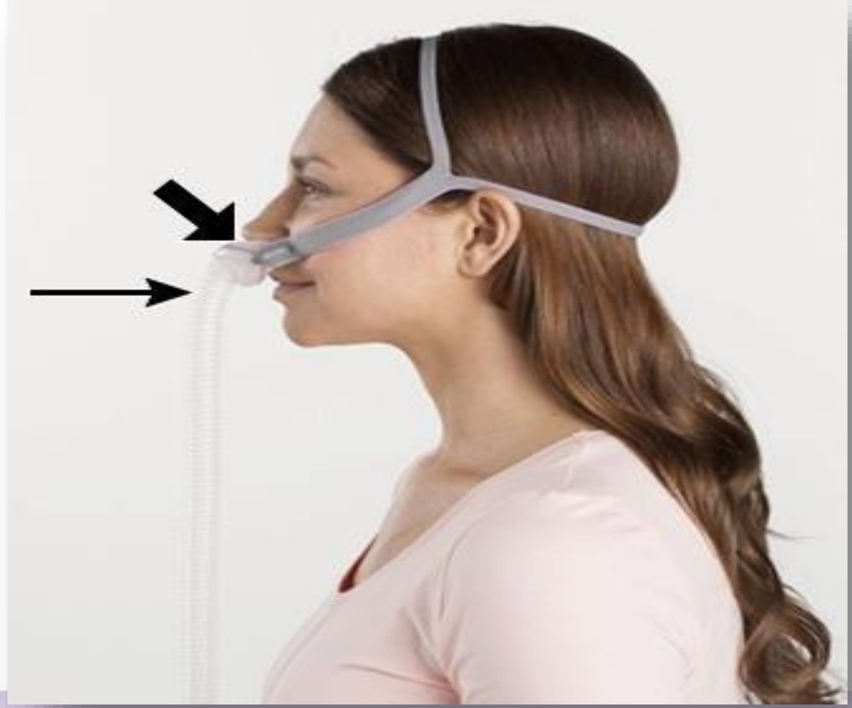
↓

- Provide encouragement, reassurance, frequent checks, and adjustments, as needed
- Check for air leaks, adjust straps if needed
- Add a chin strap or switch to oronasal (full face) mask if oral air leak is noted
- Monitor vital signs and oximetry during the trial
- Obtain ABG as needed






Swift LT




Making quality of care easy

Notes:

Despite many previously published studies on non-invasive ventilation (NIV), it is still difficult to draw any conclusions about an optimal ventilation strategy in thoracic restrictive diseases.

- ✓ Restrictive patients are a non-homogenous population where the use of EPAP is different:
  - ➢ EPAP settings of less than 5 cm H2O are typically used in neuromuscular and scoliosis patients to mitigate end-expiratory alveolar collapse and to influence atelectasis.
  - ➢ In patients with the obesity hypoventilation syndrome, the most common use of EPAP of around 10 cm H2O overcomes upper airway obstruction.

- ✓ IPAPs have to be increased in order to achieve an adequate Vt, commonly targeted at around 6-8 ml/kg ideal body weight (IBW). The assessment of IBW in the neuromuscular or kyphoscoliosis patient is different from highly obese patient. Decreasing EPAP is an alternative to increasing IPAP if measurements of gas exchange during NIV indicate that ventilation is inadequate.

Grazie per l'attenzione