Acute Respiratory Failure

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RESPIRATORY FAILURE

- Inability of the lung to meet the metabolic demands of the body.
- Either hypoxemia (inability to provide Oxygen to body tissues).
- Or hypercapnea (inability to wash out CO2).

ACUTE RESPIRATORY FAILURE

Definitions

Hypoxemia = is reduction in the oxygen content in the arterial blood system.
When arterial Oxygen partial pressure is less than 60 mmHg.

Tissue hypoxia is reduction in the oxygen delivered to the tissues.

Hypercapnea = when arterial CO2 partial pressure is greater than 50 mmHg.

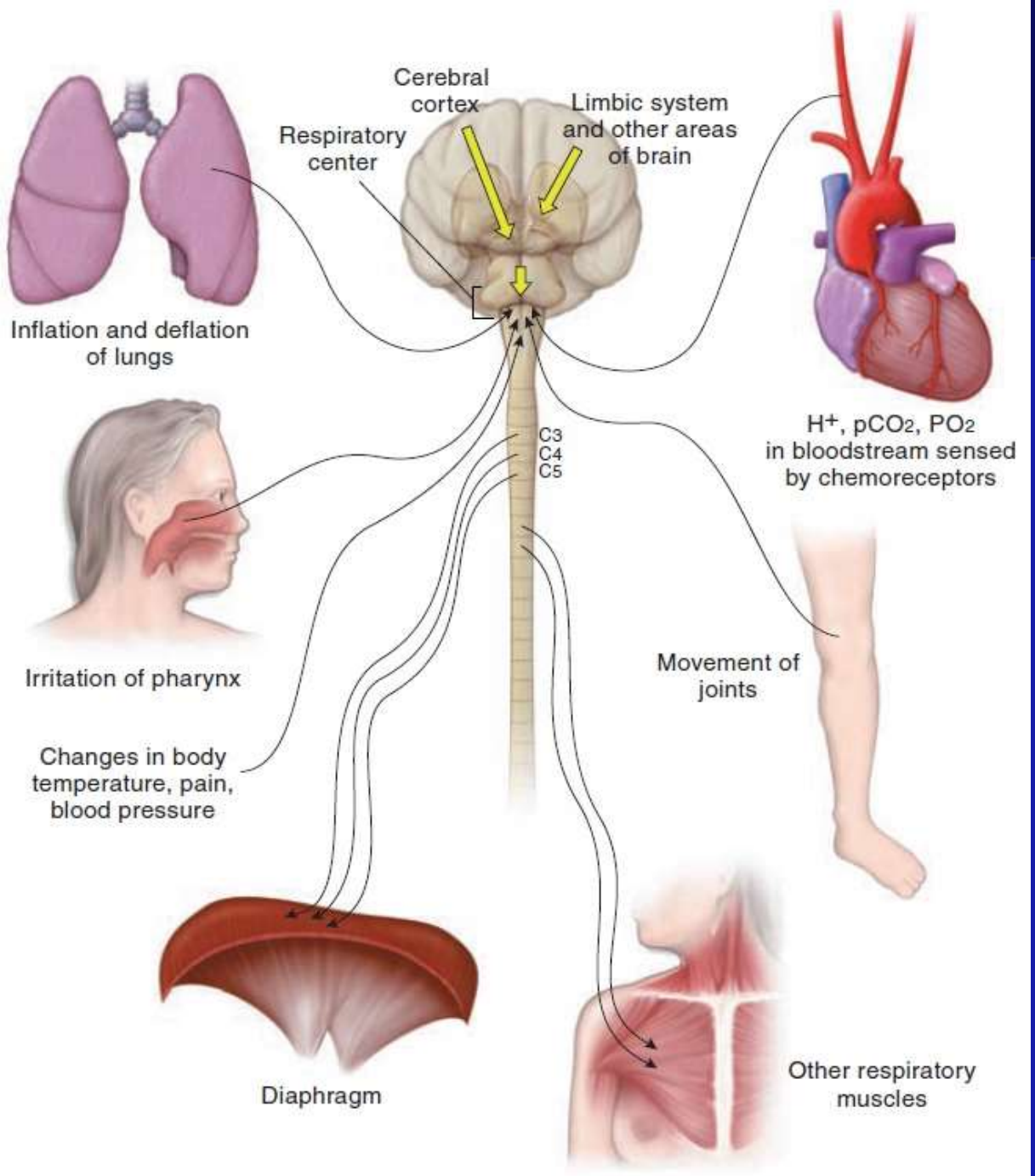


FIGURE 10.16. A Schematic Representation of the Regulation of Respiration

Respiratory system function depends on :

- CNS control.
- Neuromuscular function.
- Upper airway muscles and reflexes.
- Thorax and pleura.
- Alveolar function.

PH acidosis < 7.4 > alkalosis

PH	7.35 - 7.45
PaCo2	35 - 45
HCo3	22 - 28

Respiratory

Metabolic

R Respiratory

O Opposite

M Metabolic

E Equal

PH ↑ PCo2 ↓ Alkalosis

PH ↓ PCo2 ↑ Acidosis

PH ↑ HCo3 ↑ Alkalosis

PH ↓ HCo3 ↓ Acidosis

ARTERIAL BLOOD GAS INTERPRETATION

1° DISORDER	pH	P_aCO_2	$[HCO_3^-]$	COMPENSATION
AG/non-AG Metabolic Acidosis	↓	↓ (2°)	↓ (1°)	$P_aCO_{2,\,expect} = 1.5\,[HCO_3^-] + 8 \pm 2$ If $P_aCO_{2,\,actual} < P_aCO_{2,\,expect}$ also 1° respiratory alkalosis If $P_aCO_{2,\,actual} > P_aCO_{2,\,expect}$ also 1° respiratory acidosis
AG Acidosis "Delta/Delta"	For AG metabolic acidosis, calculate $\Delta AG / \Delta[HCO_3^-] = (AG - 12) / (24 - [HCO_3^-])$ if < 0.8, non-AG acidosis; if > 2, metabolic alkalosis			
Metabolic Alkalosis	↑	↑ (2°)	↑ (1°)	$P_aCO_2 = 0.7 \times [HCO_3^-] + 20 \pm 5$ If $P_aCO_{2,\,actual} < P_aCO_{2,\,expect}$ also 1° respiratory alkalosis If $P_aCO_{2,\,actual} > P_aCO_{2,\,expect}$ also 1° respiratory acidosis
Respiratory Acidosis	↓	↑ (1°)	↑ (2°)	For each ↑ 10 mmHg in P_aCO_2 Acute: ↑ $[HCO_3^-]$ 1 mmol/L and ↓ pH 0.08 Chronic: ↑ $[HCO_3^-]$ 4 mmol/L and ↓ pH 0.03
Respiratory Alkalosis	↑	↓ (1°)	↓ (2°)	For each ↓ 10 mmHg in P_aCO_2 Acute: ↓ $[HCO_3^-]$ 2 mmol/L and ↑ pH 0.08 Chronic: ↓ $[HCO_3^-]$ 5 mmol/L and ↑ pH 0.03
Primary disorder (1°), compensation (2°); arrows relative to "normal" baseline values: pH 7.35 - 7.45, P_aCO_2 35 - 45 mmHg and $[HCO_3^-]$ 22 - 26 mEq/L				

RESPIRATORY FAILURE

Mechanisms of respiratory failure:

- the incapacity of the thoracic-pulmonary system to achieve a normal gas exchange at the pulmonary level (pulmonary respiratory failure);
- the incapacity of the cardio-vascular system to maintain an optimal tissue perfusion (e.g. referring to the shock states);
- the incapacity of tissues to use the oxygen brought by the arterial blood at the cellular level (e.g. septic shock, cyanide poisoning);

Central nervous system

- Brain and spinal cord control breathing initiation and fine tuning

Disorders that affect breathing:

- Drug overdose
- Stroke
- Trauma
- Tumors

Neuromuscular Junction

Disease of the diaphragm and respiratory muscles

- Myasthenia Gravis.
- Polio.
- Guillian Barre syndrome.
- Amyotrophic lateral sclerosis.

Upper airways

- Disorder of the muscles of the reflexes can cause problems
- Obstructive sleep apnea
- Infections (epiglottitis)
- Foreign body obstruction
- Laryngospasm
- paralysis

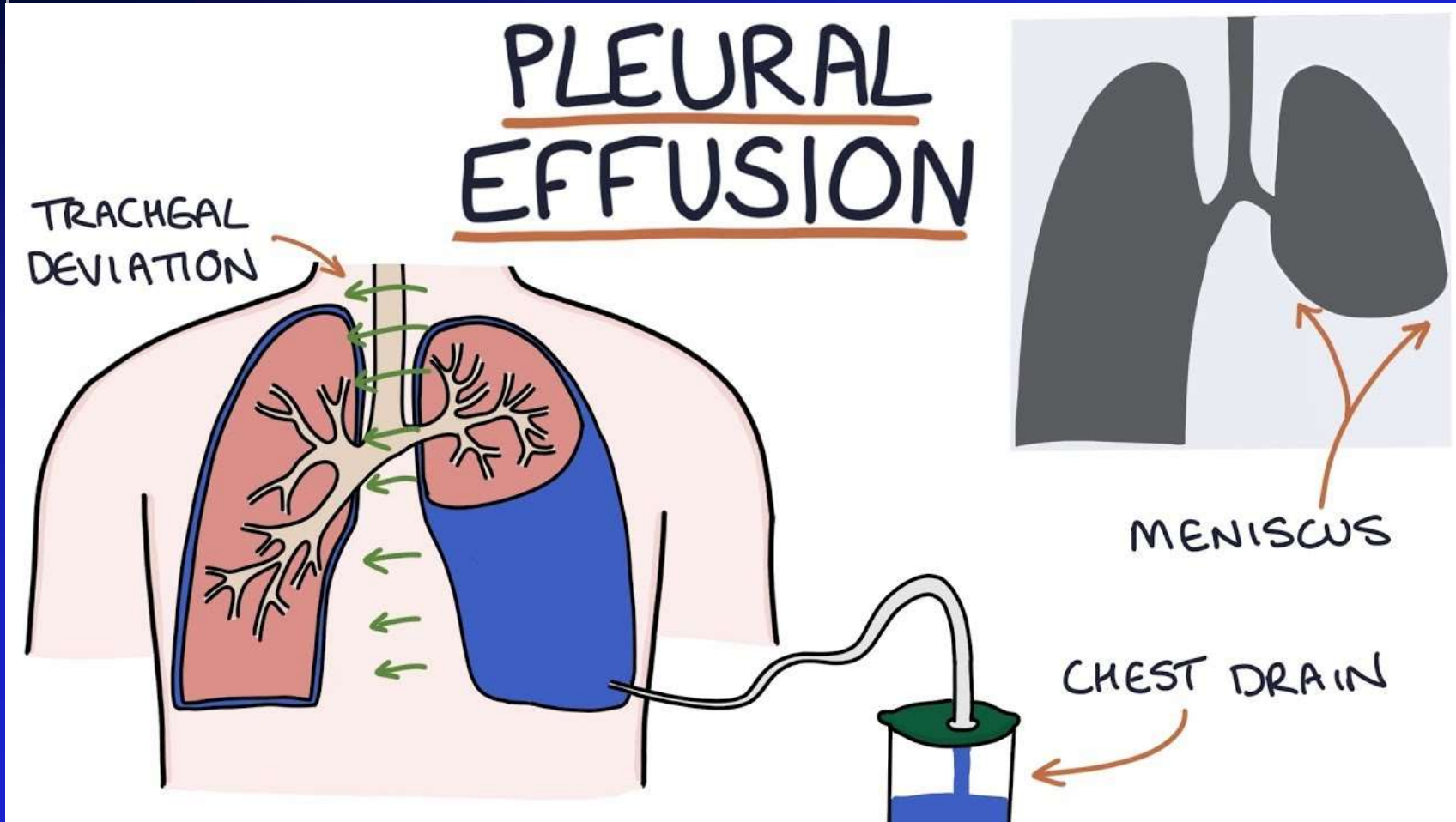
Thorax and pleural

- Mechanical problems such as kyphosis and scoliosis
- Functional problems such as pleural effusion and pneumothorax

Pneumothorax

Abnormal collection of air in pleural space

"Collapsed Lung"


PLEURAL EFFUSION
TRACHEAL DEVIATION
MENISCUS
CHEST DRAIN

Alveolar and parenchymal problems

- Pulmonary edema (primary and secondary to heart failure)
- Lung fibrosis
- COPD
- ARDS

Classification

- Acute vs. Chronic.
- Type I (hypoxemic) and Type II (Hypercapnic).

Classification

Acute: occurs within hours.

- Must be treated immediately (emergency).
- Acute ↓ pH
- If not treated = high mortality.

Chronic: develops over days and months

- pH is usually preserved. (Compensatory ↑ in HCO_3).
- Corpulmonale; Polycythemia

Classification of RF

- Type 1
- Hypoxemic RF **
- PaO2 < 60 mmHg with normal or ↓ PaCO2
- Associated with acute diseases of the lung
- Pulmonary edema (Cardiogenic, noncardiogenic (ARDS), pneumonia, pulmonary hemorrhage, and collapse

- Type 2
- Hypercapnic RF
- PaCO2 > 50 mmHg
- **Hypoxemia is common**
- Drug overdose, neuromuscular disease, chest wall deformity, COPD, and Bronchial asthma

Pathophysiologic causes of Acute RF

- Hypoventilation
- V/P mismatch
- Shunt
- Diffusion abnormality

1 - Hypoventilation

- Occurs when ventilation ↓ 4-6 l/min
- Causes
  - Depression of CNS from drugs
  - Neuromuscular disease of respiratory ms
- ↑PaCO2 and ↓PaO2
- Alveolar –arterial PO2 gradient is normal
- COPD

2 -V/Q mismatch

- Most common cause of hypoxemia
- Caused by ventilation of non-perfused alveoli.

Or

- Perfusion to non-ventilated alveoli
- Admin. of 100% O2 eliminate hypoxemia

3 -Shunt

- The deoxygenated blood bypasses the ventilated alveoli and mixes with oxygenated blood → hypoxemia
- Persistent of hypoxemia despite 100% O2 inhalation
- Hypercapnia occur when shunt is excessive > 60%

Causes of Shunt

- Intra-cardiac
  - Right to left shunt
    - Fallot's tetralogy
    - Eisenmenger's syndrome
- Pulmonary
  - A/V malformation
  - Pneumonia
  - Pulmonary edema
  - Atelectasis/collapse
  - Pulmonary Hge
  - Pulmonary contusion

4 - Diffusion abnormality

- Less common
- Due to
  - abnormality of the alveolar membrane
  - ↓ the number of the alveoli
- Causes
  - ARDS
  - Fibrotic lung disease

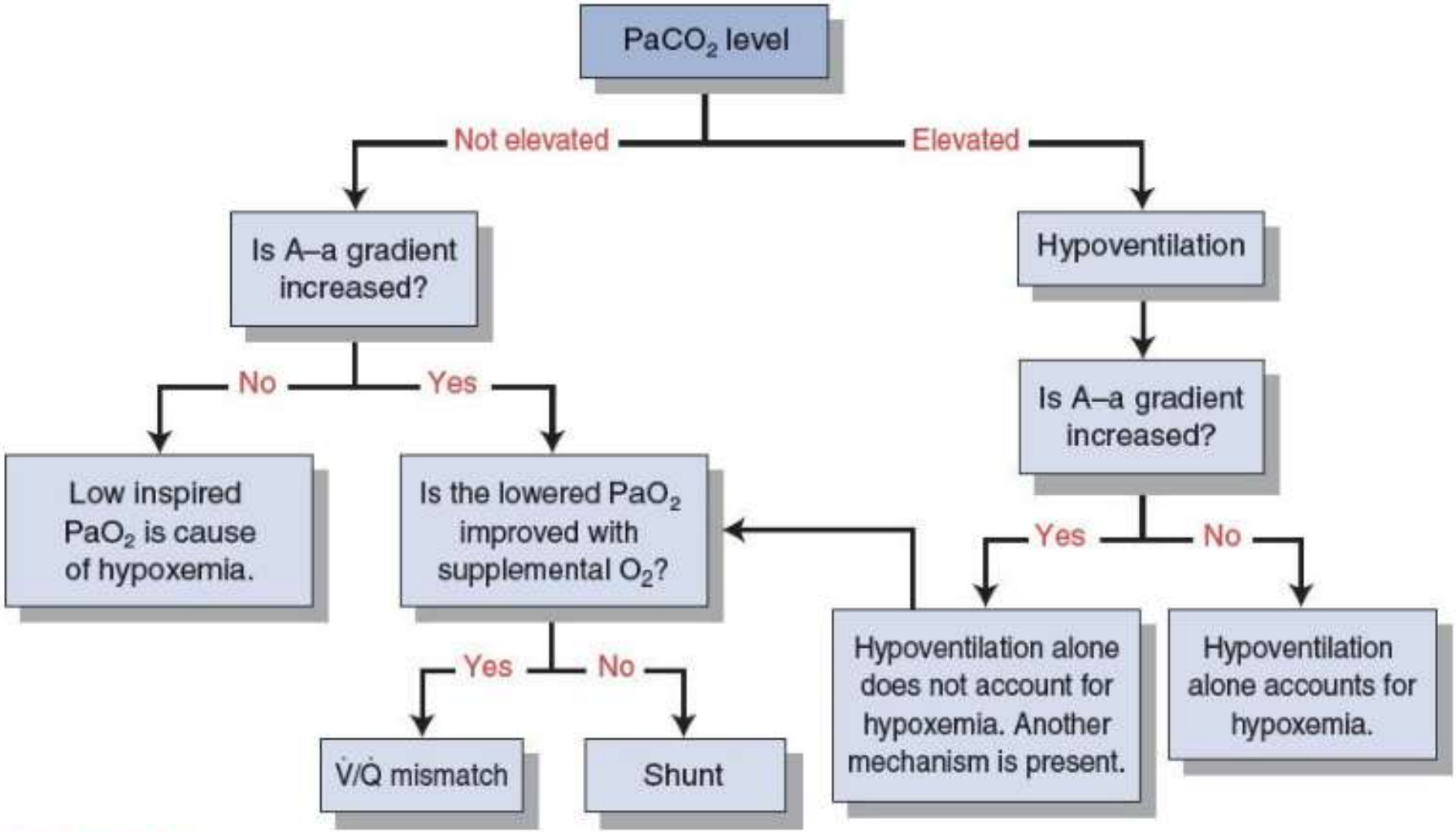


FIGURE 2.12 **Evaluation of a patient with hypoxemia.**

Causes of Hypoxemic Respiratory failure

- Caused by a disorder of heart, lung or blood.
- Etiology easier to assess by CXR abnormality:

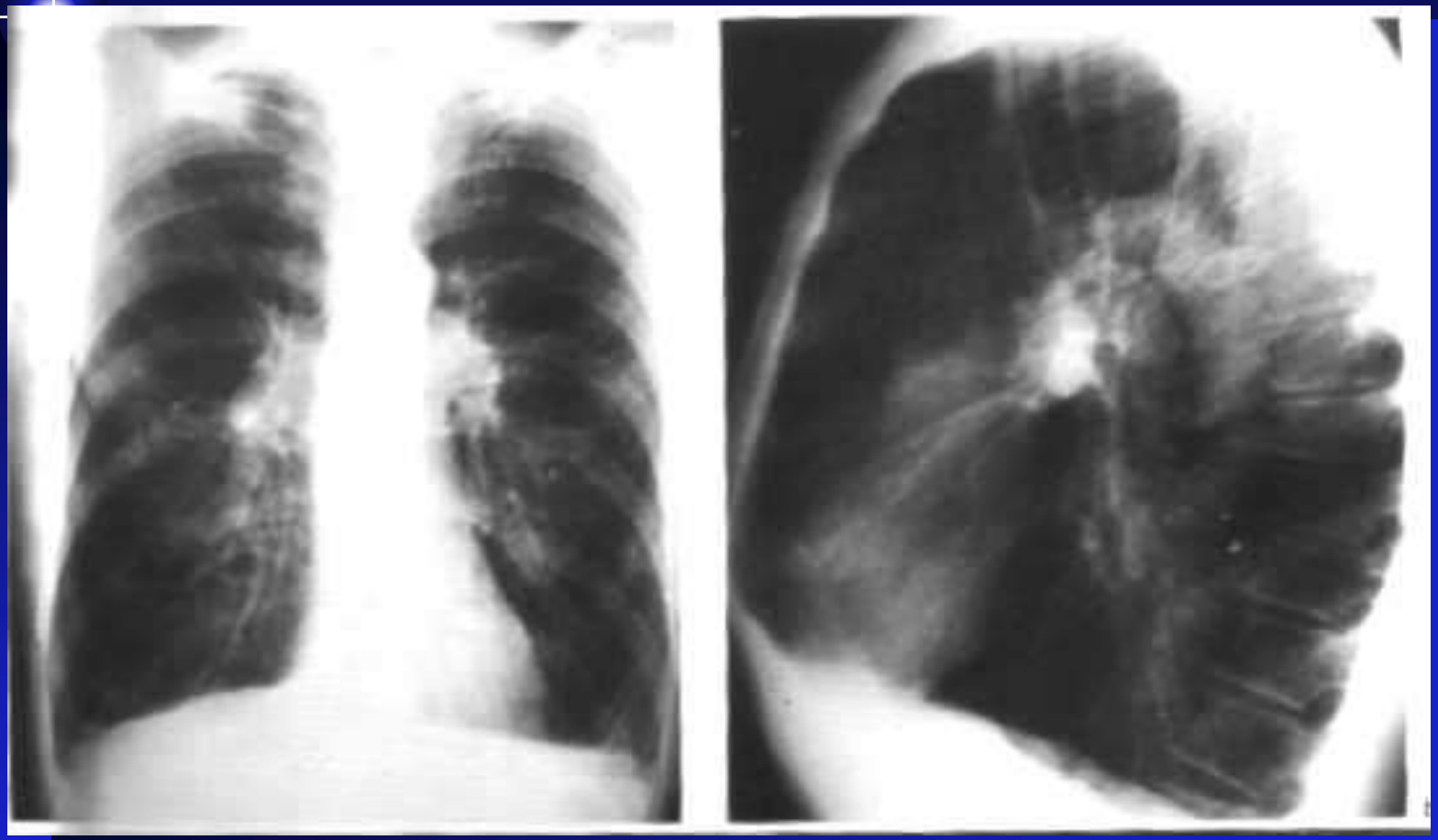
  - Normal Chest x-ray

    Cardiac shunt (right to left)

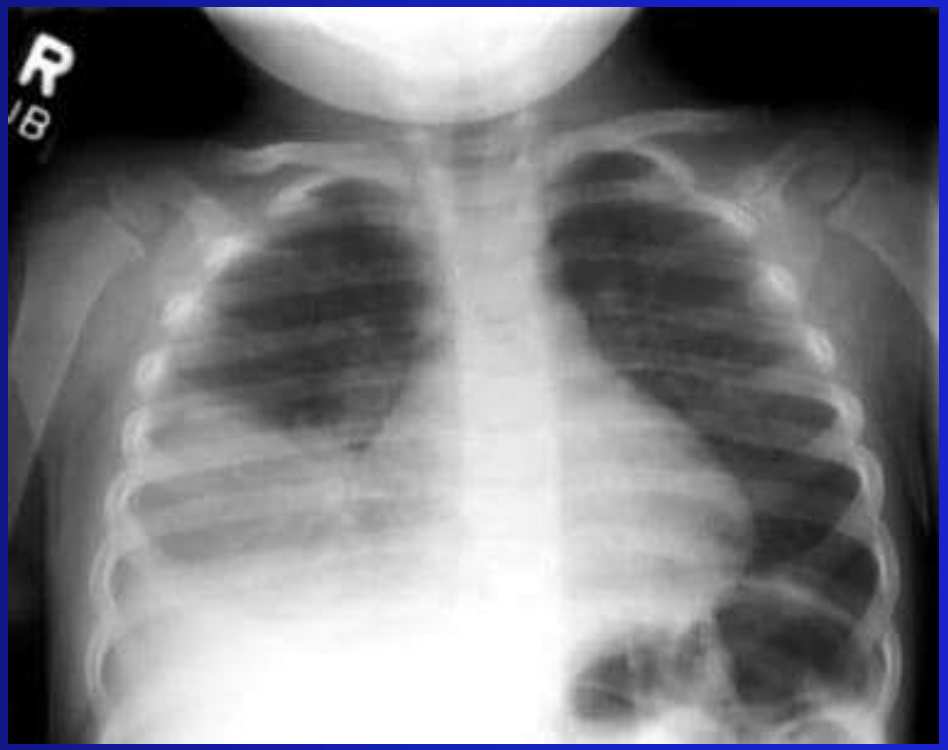
    Asthma, COPD

    Pulmonary embolism

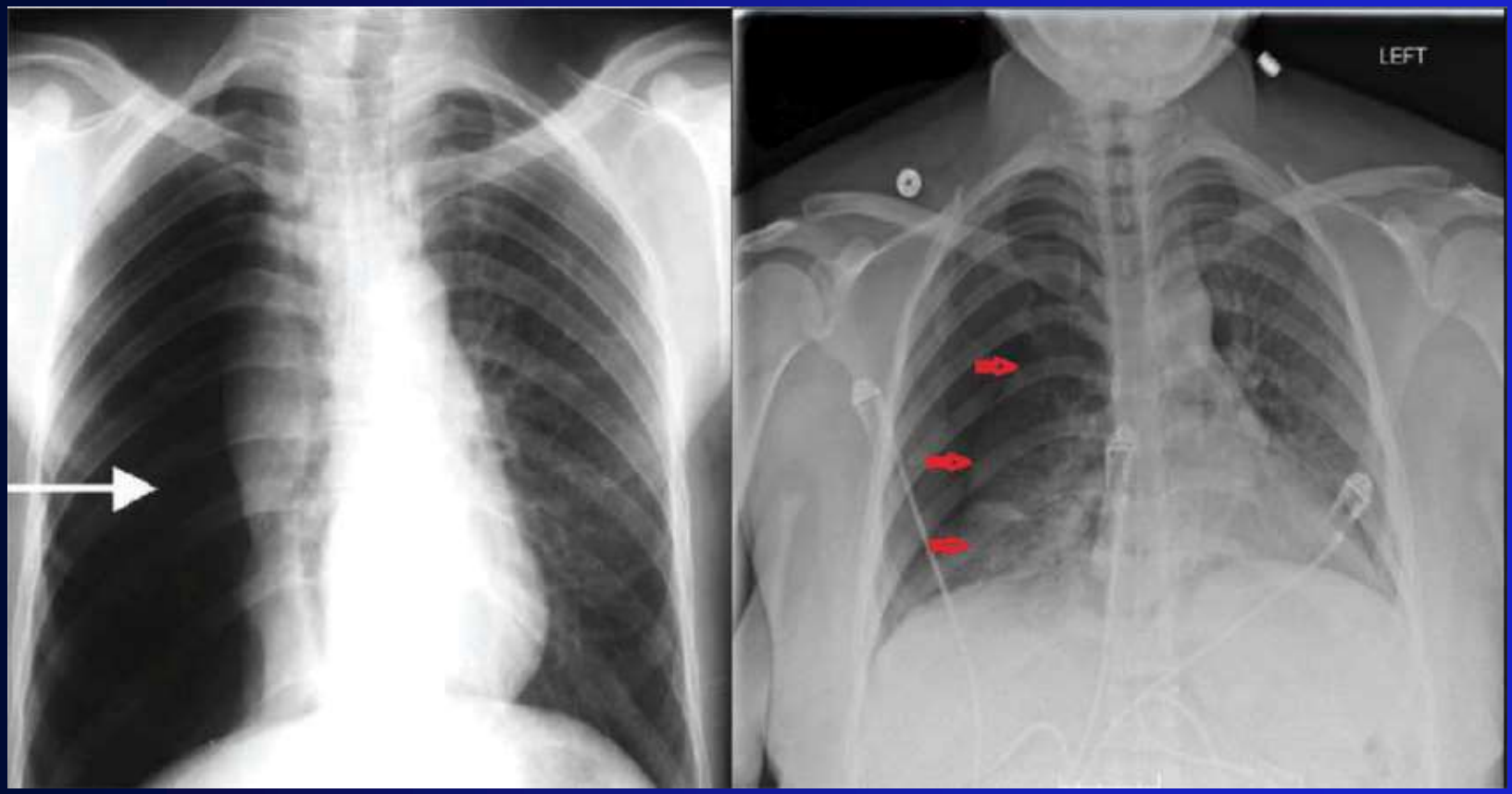
Hyperinflated Lungs : COPD



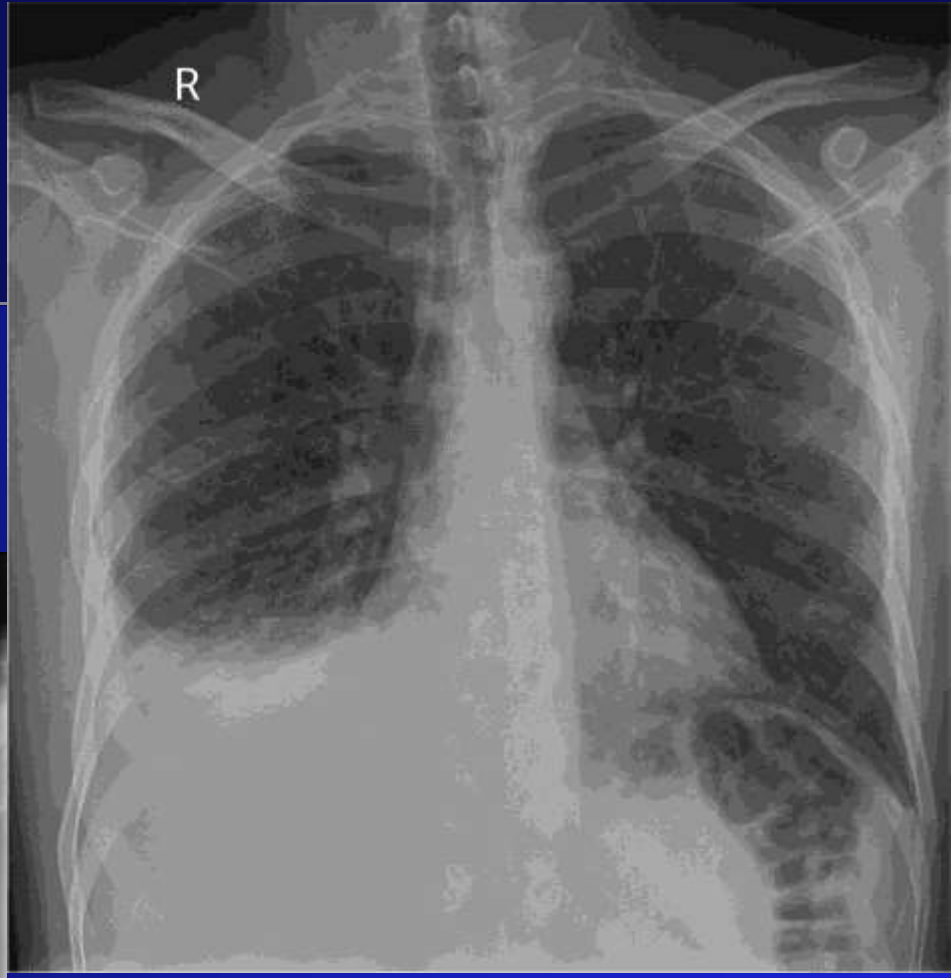
ARDS



Pneumonia



Pneumothorax



Pleural effusion

Causes of Hypoxemic Respiratory Failure (cont'd.)

Focal infiltrates on CXR

Atelectasis

Pneumonia

Diffuse infiltrates on CXR

- Cardiogenic Pulmonary Edema
- Non cardiogenic pulmonary edema (ARDS)
- Interstitial pneumonitis or fibrosis
- Infections

Hypercapnic Respiratory Failure (Type II)

- $PaCO_2$ >50 mmHg
- Hypoxemia is always present
- pH depends on level of HCO_3
- HCO_3 depends on duration of hypercapnia
- Renal response occurs over days to weeks

Acute Hypercapnic Respiratory Failure (Type II)

- Acute
- Arterial pH is low
- Causes
  - sedative drug over dose
  - acute muscle weakness such as myasthenia gravis
  - severe lung disease:
    alveolar ventilation can not be maintained (i.e. Asthma or pneumonia)
- Acute on chronic:
- This occurs in patients with chronic CO_2 retention who worsen and have rising CO_2 and low pH.
- Mechanism: respiratory muscle fatigue

Causes of Hypercapnic Respiratory failure

- Respiratory centre (medulla) dysfunction
- Drug over dose, CVA, tumor, hypothyroidism,central hypoventilation
- Neuromuscular disease
  Guillain-Barre, Myasthenia Gravis, polio, spinal injuries
- Chest wall/Pleural diseases
  kyphoscoliosis, pneumothorax, massive pleural effusion
- Upper airways obstruction
  tumor, foreign body, laryngeal edema
- Peripheral airway disorder
  asthma, COPD

Diagnosis

1- focused history

Might complain of cough, dyspnea, chest discomfort.

If acute and severe patient is tachypneac and can't talk clearly.

History should be taken carefully from patient's family and companions.

History of allergy and acute events are important.

Diagnosis

2- Physical examination:

- Cyanosis.
- Tachypnea.
- Paradoxical breathing.
- Silent Chest.
- Confusion, somnolence and coma.
- Convulsions.
- sub-costal retractions.
- Wheezes and crackles.
- Drooling.

ACUTE RESPIRATORY FAILURE

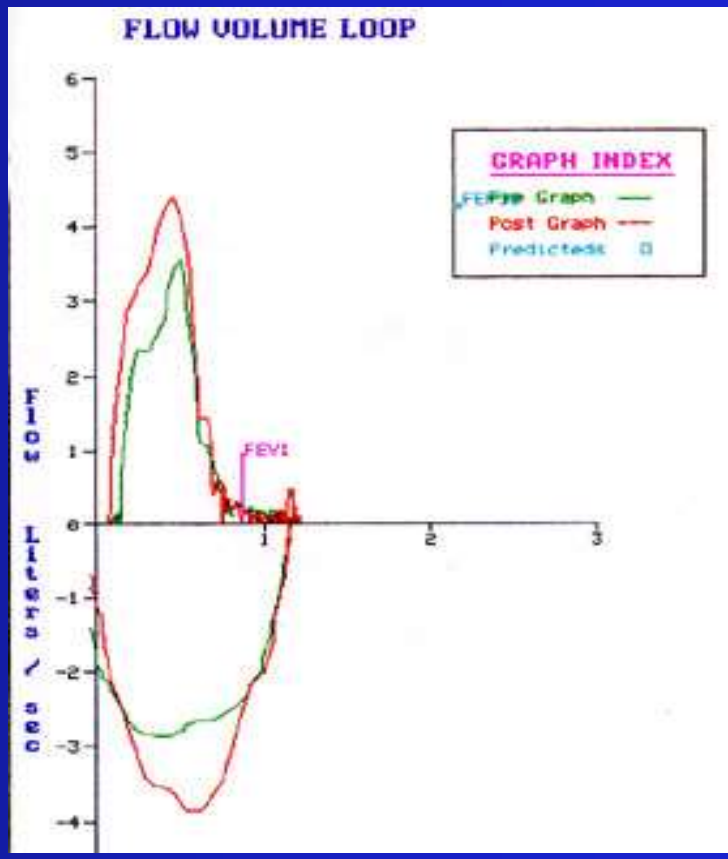
- **Wheezing – Suggest A/W obstruction :**
  Bronchospasm
  upper or lower airway pathology
  Secretion
  Pulmonary edema
- ***Stridor suggests upper airway obstruction***
- ***Elevated jugular venous pressure suggests right ventricular dysfunction due to accompanying pulmonary hypertension***

Clinical & Laboratory Manifestations

- Circulatory changes
  - tachycardia, hypertension, hypotension
- Polycythemia
  - chronic hypoxemia - erythropoietin synthesis
- Pulmonary hypertension
- Cor-pulmonale or right ventricular failure

Laboratory assessment

- ABG analysis
  -classify RF and help with cause
- Lung function
- Vitalogram
- Chest Radiograph
- ECG
- Echocardiography
- CBC and blood cultures.



Management of Respiratory Failure Principles

- Hypoxemia may cause death in RF
- Primary objective is to reverse and prevent hypoxemia
- Secondary objective is to control $PaCO_2$ and respiratory acidosis
- Treatment of underlying disease
- Patient's CNS and CVS must be monitored and treated

ACUTE RESPIRATORY FAILURE

- ***Management***

- **ABC's**
- **Ensure airway is adequate**
- **Oxygen therapy and assisted ventilation if needed**
- **Support circulation**

Oxygen Therapy

- Supplemental O_2 therapy essential
- titration based on SaO_2, PaO_2 levels and $PaCO_2$
- Goal is to prevent tissue hypoxia
- Increase arterial PaO_2 > 60 mmHg(SaO_2 > 90%) or venous SaO_2 > 60%
- O_2 dose either flow rate (L/min) or FiO_2 (%)

Risks of Oxygen Therapy

- **O_2 toxicity**:
  - very high levels(>1000 mmHg) CNS toxicity and seizures
  - lower levels (FiO_2 > 60%) and longer exposure: - capillary damage, leak and pulmonary fibrosis
  - PaO_2 >150 can cause retrolental fibroplasia, Retinopathy of prematurity in pediatrics.
  - FiO_2 35 to 40% can be safely tolerated indefinitely.
- **CO_2 narcosis:**
  - $PaCO_2$ may increase severely to cause respiratory acidosis, somnolence and coma
  - $PaCO_2$ increase secondary to combination of
    a) abolition of hypoxic drive to breathe
    b) increase in dead space

Management of ARF

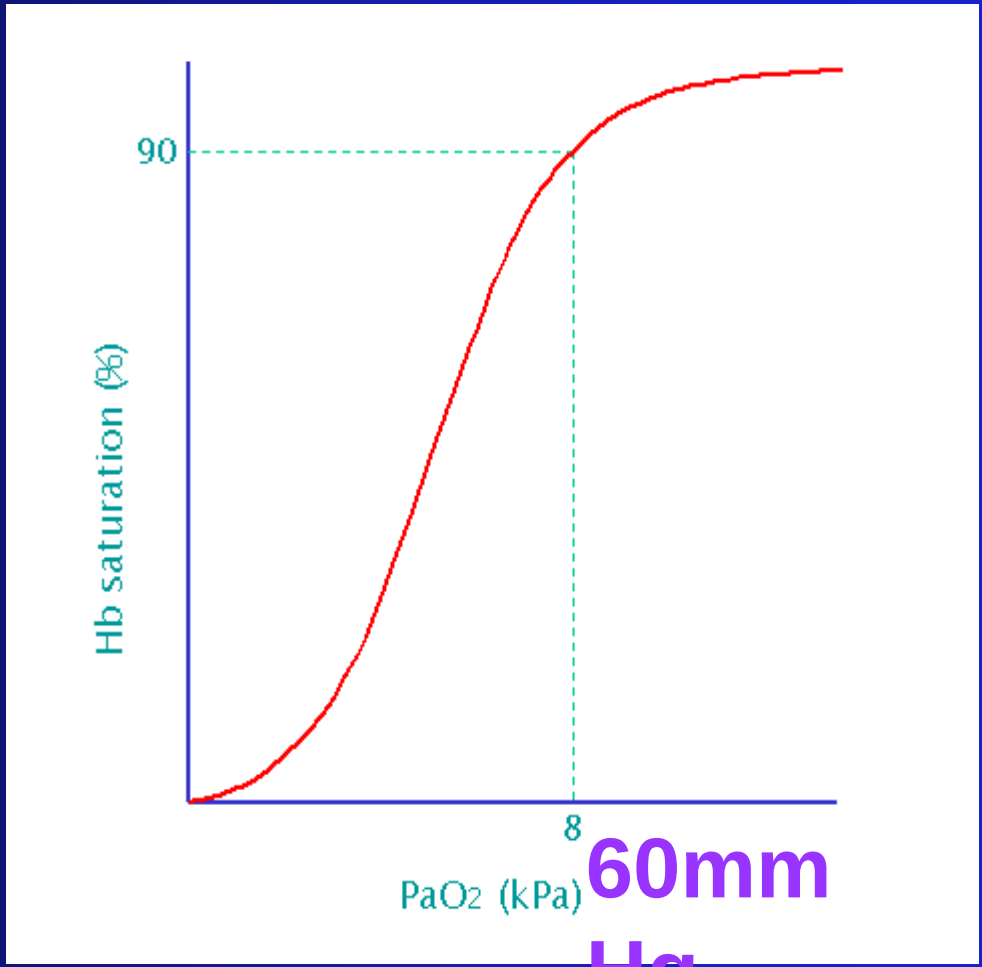
- Correction of hypoxemia
  - O2 administration via nasal prongs, face mask, intubation and Mechanical ventilation
  - Goal: Adequate O2 delivery to tissues
  - PaO2 = > 60 mmHg
  - Arterial O2 saturation >90%

Management of ARF

- Correction of hypercapnia
- Control the underlying cause
- Controlled O2 supply
- 1 -3 lit/min, titrate according O2 saturation
- O2 supply to keep the O2 saturation >90% but <93 to avoid inducing hypercapnia
- COPD-chronic bronchitis, emphysema

Management of ARF

- Oxyhemoglobin dissociations curve



Management of Severe ARF

Management of ARF

- ICU admition
- Airway management
  - Endotracheal intubation:
    - Indications
      - Severe Hypoxemia
      - Altered mental status
    - Importance
      - precise O2 delivery to the lungs
      - remove secretion
      - ensures adequate ventilation

Management of ARF

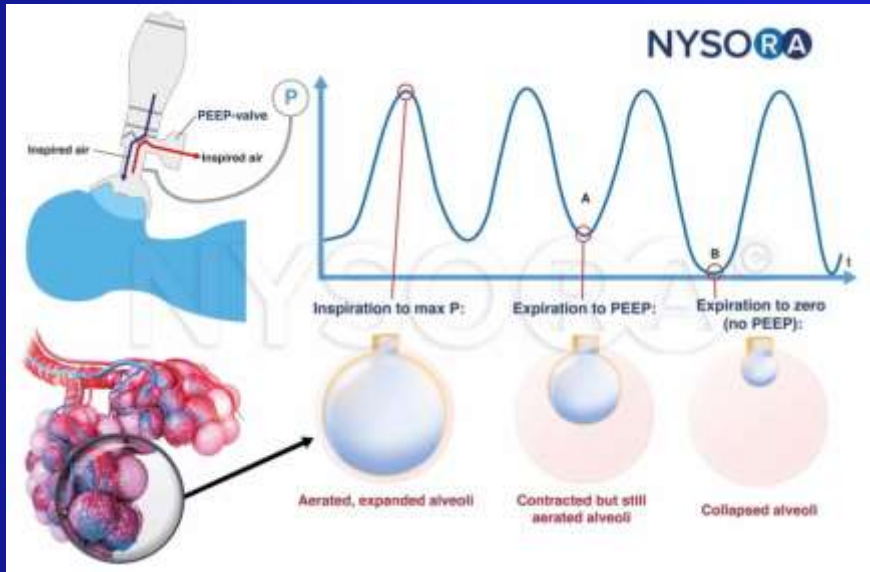
- Mechanical ventilation
- Indications
  - Persistence hypoxemia despite O2supply
  - Decreased level of consciousness
  - Hypercapnia with severe acidosis (pH< 7.2)

Management of ARF

- Mechanical ventilation
  - Increase PaO2
  - Lower PaCO2
  - Rest respiratory ms (respiratory ms fatigue)
  - Ventilator
    - Assists or controls the patient breathing
  - The lowest FIO2 that produces SaO2 >90% and PO2 >60 mmHg should be given to avoid O2 toxicity

Management of ARF

- PEEP (positive End-Expiratory pressure
- Used with mechanical ventilation
  - Increase intrathoracic pressure
  - Keeps the alveoli open
  - Decrease shunting
  - Improve gas exchange
- Hypoxemic RF (type 1)
  - ARDS
  - Pneumonias

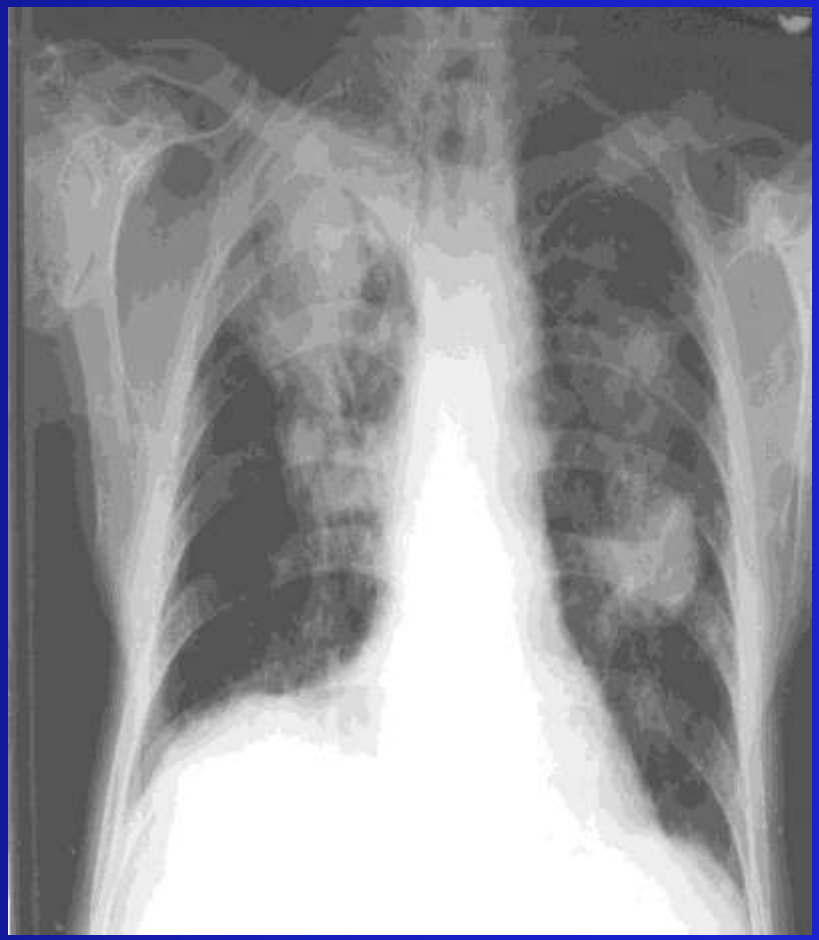


Management of ARF

- Noninvasive Ventilatory support (IPPV)
- Mild to moderate RF
- Patient should have
  - Intact airway,
  - Alert, normal airway protective reflexes
- Nasal or full face mask
  - Improve oxygenation,
  - Reduce work of breathing
  - Increase cardiac output
- AECOPD, asthma, CHF

Management of ARF

- Treatment of the underlying causes
- After correction of hypoxemia, hemodynamic stability
- Antibiotics
  - Pneumonia
  - Infection
- Bronchodilators (COPD, BA)
  - Salbutamol
    - reduce bronchospasm
    - airway resistance



Management of ARF

- Treatment of the underlying causes
- Anticholinergics (COPD,BA)
  - Ibratropium bromide
    - inhibit vagal tone
    - relax smooth ms
- Theophylline (COPD, BA)
  - improve diaphragmatic contraction
  - relax smooth ms
- Diuretics (pulmonary edema)
  - Furosemide

Management of ARF

- Treatment of the underlying causes
- Methyl prednisone (COPD, BA, acute esinophilic pn)
  - Reverse bronchospasm, inflammation
- Fluids and electrolytes
  - Maintain fluid balance and avoid fluid overload
- IV nutritional support
  - To restore strength, loss of ms mass
  - Fat, carbohydrate, protein

Management of ARF

- Treatment of the underlying causes
- Physiotherapy
  - Chest percussion to loosen secretion
  - Suction of airways
  - Help to drain secretion
  - Maintain alveolar inflation
  - Prevent atelectasis, help lung expansion

Management of ARF

- Weaning from mechanical ventilation
  - Stable underlying respiratory status
  - Adequate oxygenation
  - Intact respiratory drive
  - Stable cardiovascular status
  - Patient is a wake, has good nutrition, able to cough and breath deeply

THE WEANING PATH

Ready, weaning!

If:

- Reversal of cause for respiratory failure
- GCS ≥ 8
- Spontaneous breathing
- PaO_2/FiO_2 > 200
- Hemodinamic stability

Ready, breathing!

If:

- Reversal of cause for respiratory failure
- GCS ≥ 8
- Spontaneous breathing
- PaO_2/FiO_2 > 200
- Hemodinamic stability

- Able to cough
- O_2 saturation > 90% on FiO_2 ≤ 0.4
- RR < 35 bpm
- PEEP ≤ 8 cmH_2O
- RSBI < 105

Rapid shallow breathing index (RSBI) = TV/RR

Ready, extubation!

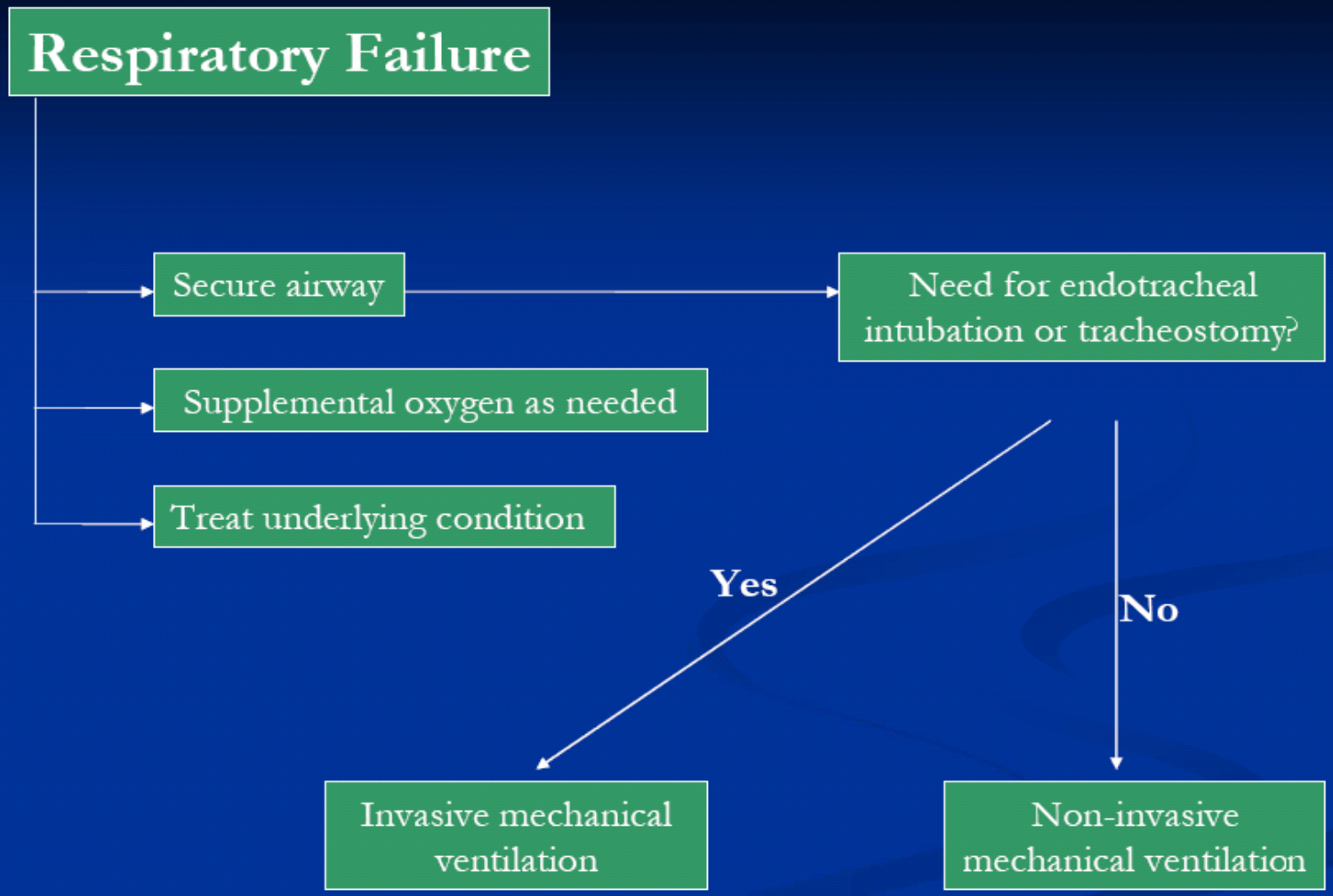
If:

- Reversal of cause for respiratory failure
- GCS ≥ 8
- Spontaneous breathing
- PaO_2/FiO_2 > 200
- Hemodinamic stability

- Able to cough
- O_2 saturation > 90% on FiO_2 ≤ 0.4
- RR < 35 bpm
- PEEP ≤ 8 cmH_2O
- RSBI < 105

- Successful 30 minutes SBT

ACUTE RESPIRATORY FAILURE



Complications of ARF

- Pulmonary
  - Pulmonary embolism
  - barotrauma
  - pulmonary fibrosis (ARDS)
  - Nosocomial pneumonia
- Cardiovascular
  - Hypotension, ↓COP
  - Arrhythmia
  - MI, pericarditis
- GIT
  - Stress ulcer, ileus, diarrhea, hemorrhage
- Infections
  - Nosocomial infection
  - Pneumonia, UTI, catheter related sepsis
- Renal
  - ARF (hypoperfusion, nephrotoxic drugs)
  - Poor prognosis
- Nutritional
  - Malnutrition, diarrhea hypoglycemia, electrolyte disturbances

Prognosis of ARF

- Mortality rate for ARDS → 40%
- 35% among those with mild ARDS, 40% for those with moderate disease, and 46% for patients with severe ARDS.
  - Younger patient <60 has better survival rate
  - 75% of patient survive ARDS have impairment of pulmonary function one or more years after recovery

Thank you