به نام خدا

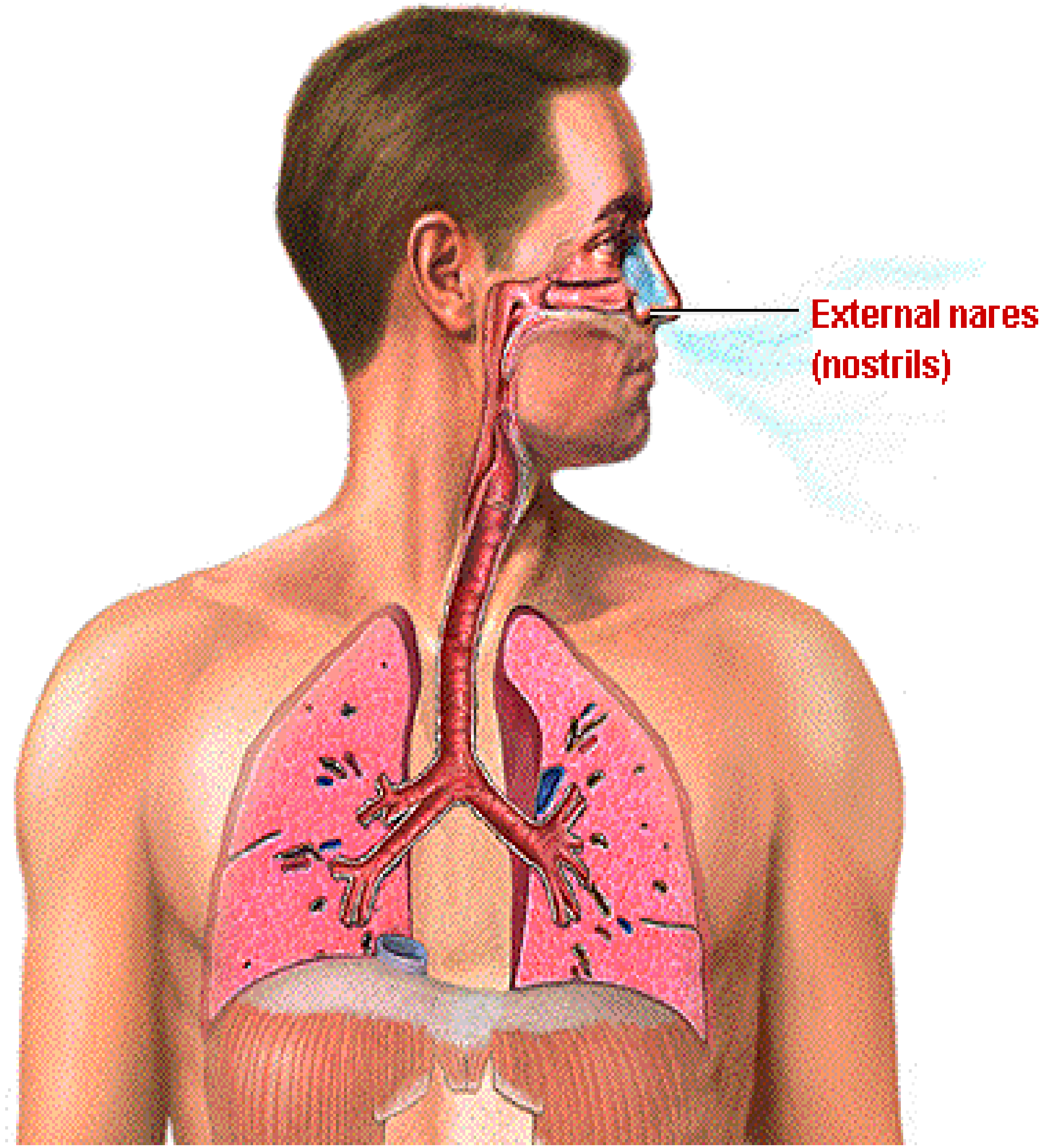
Respiratory Failure

Acute Respiratory Distress Syndrome

DR.SHAFIEPOUR
INTERNIST/PULMONOLOGIT

Respiratory Failure

Overview: Respiratory System Organs



RESPIRATORY FAILURE

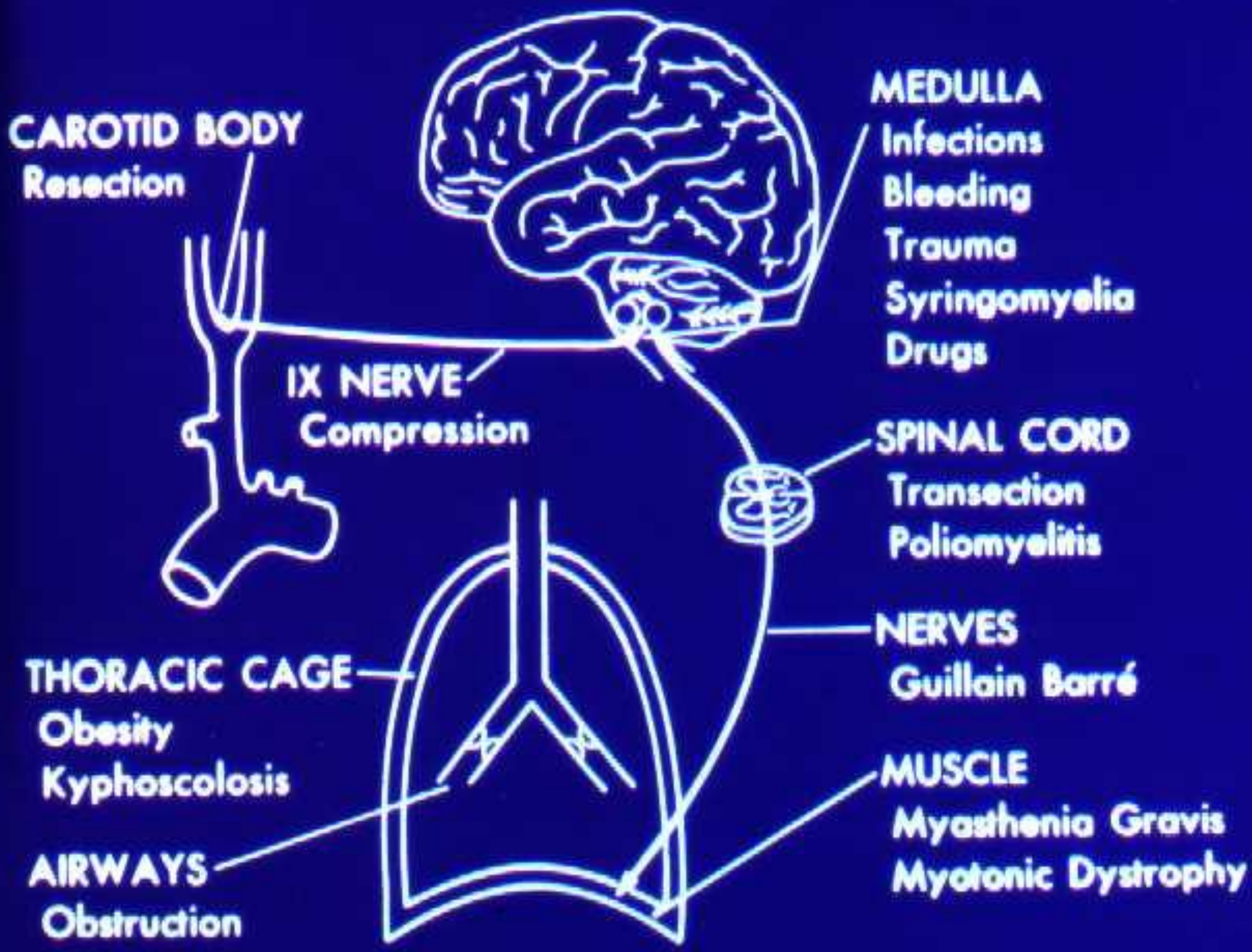
Definition

Respiration is gas exchange between the organism and its environment. Function of respiratory system is to transfer O_2 from atmosphere to blood and remove CO_2 from blood.

Respiratory system includes:

CNS (medulla) Peripheral nervous system
(phrenic nerve) Respiratory muscles
Chest wall Lung
Upper airway Bronchial tree
Alveoli Pulmonary vasculature

Potential causes of Respiratory Failure



Respiration

- external respiration (pulmonary ventilation and gas exchange in lung)
- transport of gas
- internal respiration

Respiratory failure

concept and classification

1. respiratory insufficiency

The condition in which the lungs can not take in sufficient oxygen or expel sufficient carbon dioxide to meet the needs of the cells of the body. Also called pulmonary insufficiency.

HYPOXEMIC RESPIRATORY FAILURE(TYPE 1)

PaO_2 <60mmHg with normal or low $PaCO_2$ $\rightarrow$ normal or high pH

Most common form of respiratory failure

Lung disease is severe to interfere with pulmonary O_2 exchange, but over all ventilation is maintained

Physiologic causes: V/Q mismatch and shunt

2. respiratory failure

Respiratory failure is a syndrome in which the respiratory system fails in one or both of its gas exchange functions: oxygenation and carbon dioxide elimination.

In practice, respiratory failure is defined as a PaO_2 value of less than 60 mm Hg while breathing air or a $PaCO_2$ of more than 50 mm Hg.

normal reference values ：

$PaO_2 < 60$mmHg（8kPa）

with or without $PaCO_2 > 50$mmHg（6.67kPa）

$RFI = PaO_2/FiO_2 \leq 300$

HYPOXEMIC RESPIRATORY FAILURE CAUSES OF ARTERIAL HYPOXEMIA

1. ↓FiO_2
2. Hypoventilation

   (↑ $PaCO_2$) Hypercapnic

3. V/Q mismatch Respiratory failure (eg.COPD)
4. Diffusion limitation ?
5. Intrapulmonary shunt
   - pneumonia
   - Atelectasis
   - CHF (high pressure pulmonary edema)
   - ARDS (low pressure pulmonary edema)

3． classification

（1） according to $PaCO_2$

- hypoxemic (Group Ⅰ) respiratory failure

  a PaO_2 of less than 60 mm Hg with a normal or low $PaCO_2$.

  Cause of: Edema, Vascular disease, Chest Wall.

- hypercapnic (Group Ⅱ) respiratory failure

  a PaO_2 low 60 mm Hg and $PaCO_2$ of more than 50 mm Hg.

  Cause of: Airway obstruction, Neuromuscular disease.

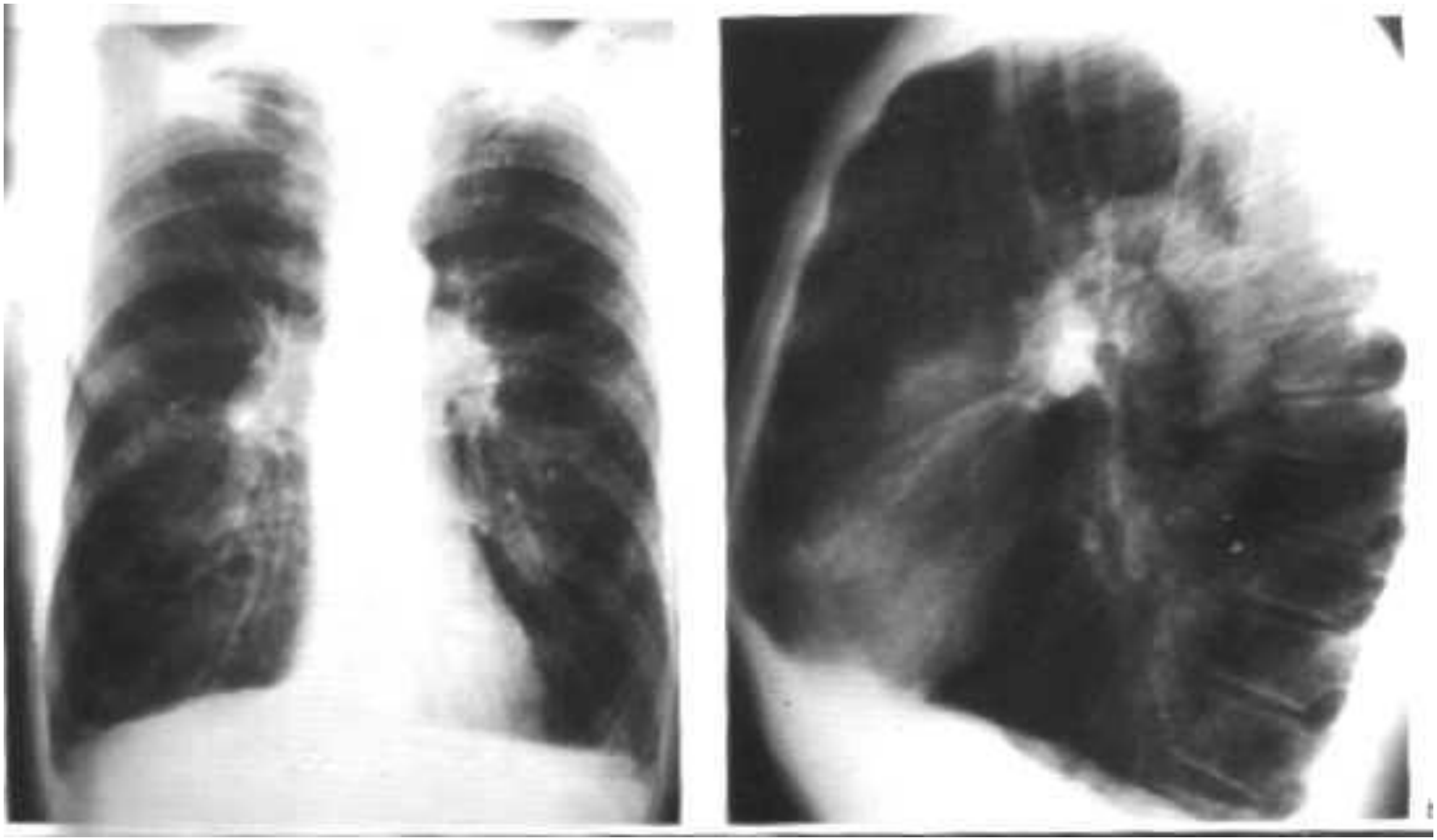
Causes of Hypoxemic Respiratory failure

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

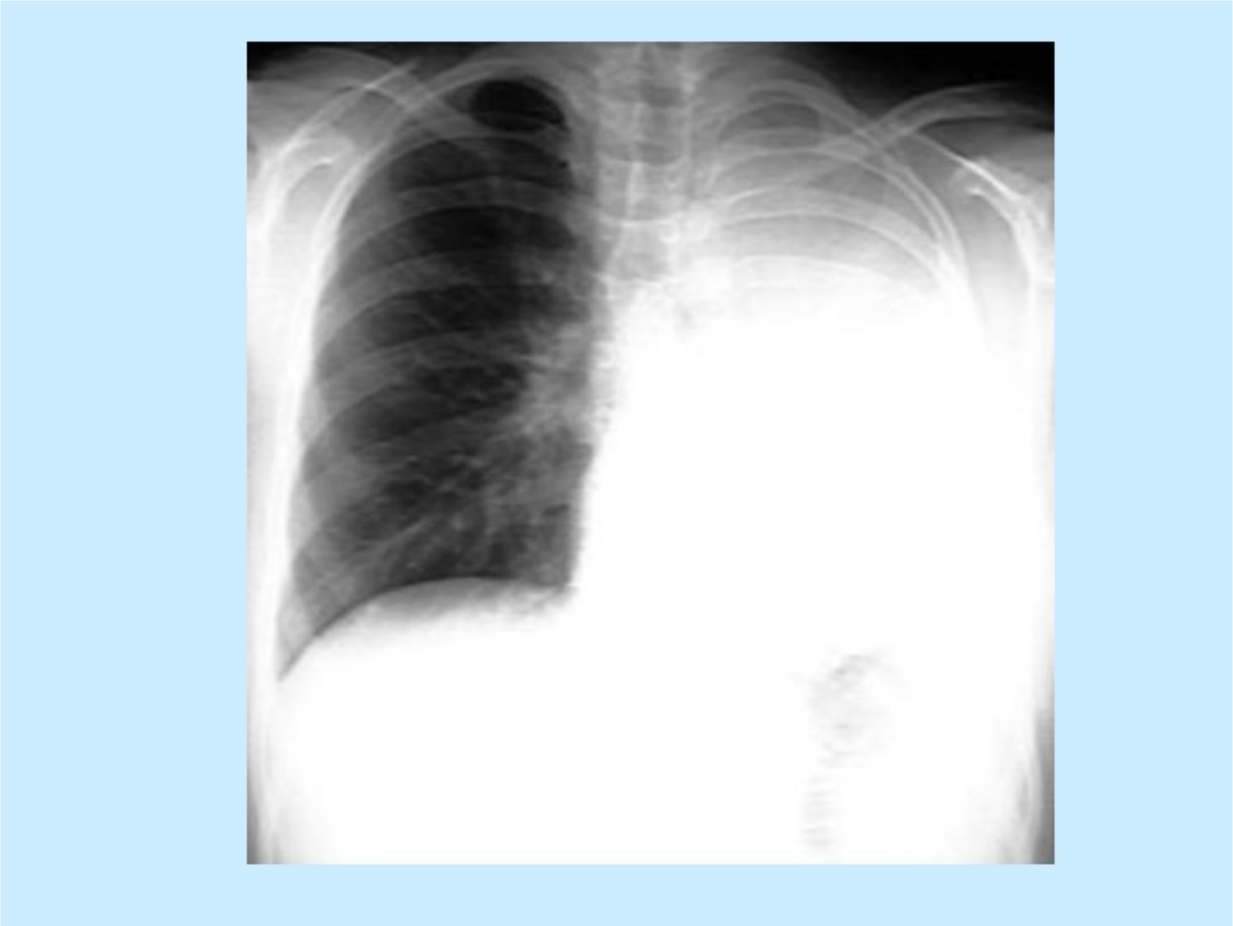


Causes of Hypoxemic Respiratory failure (cont'd.)

Focal infiltrates on CXR

- Atelectasis
- Pneumonia

An example of intrapulmonary shunt

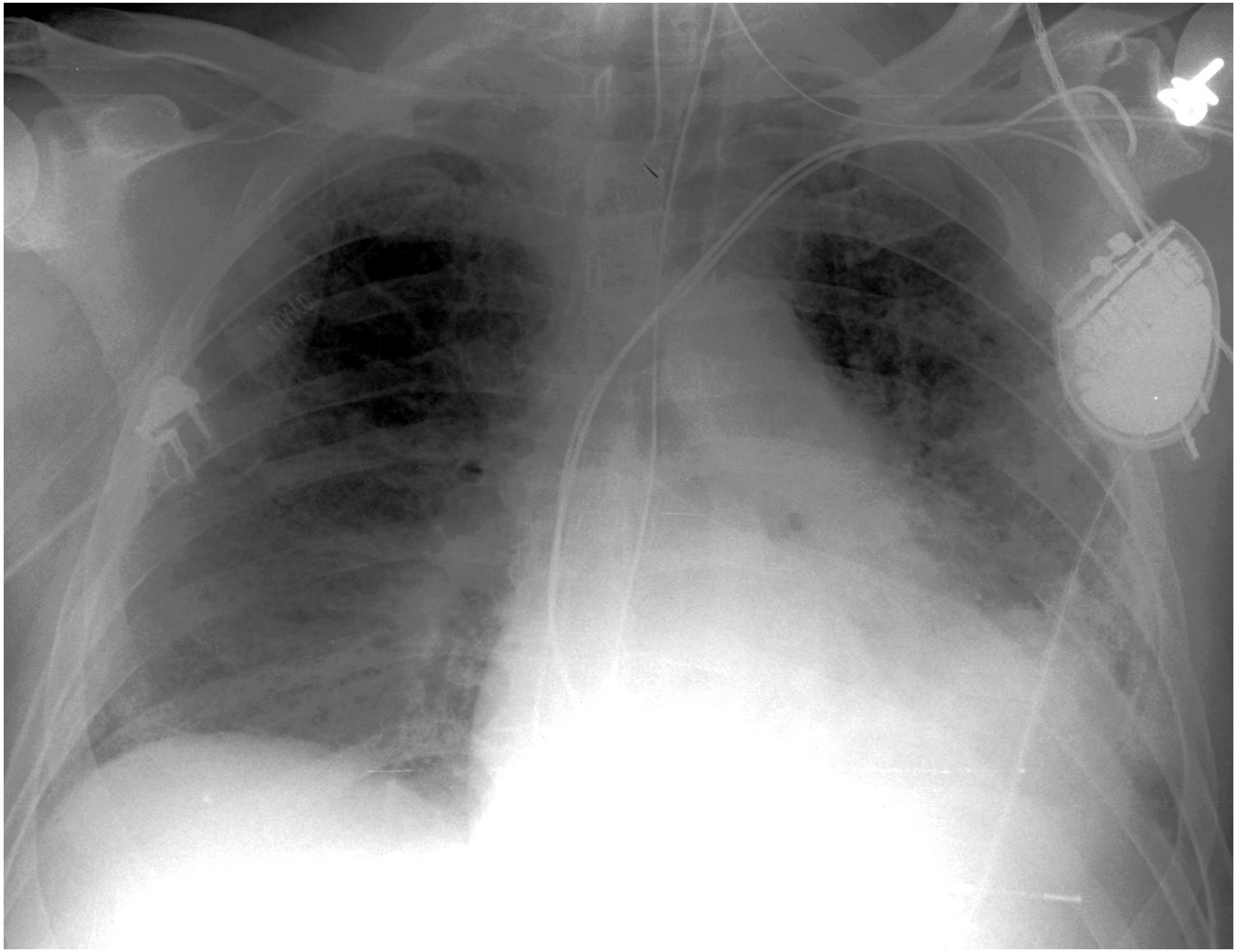


Causes of Hypoxemic Respiratory Failure (cont'd.)

Diffuse infiltrates on CXR

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

Diffuse pulmonary infiltrates



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

（2） according to pathogenic mechanism

- ventilatory disorders
- gas exchange disorders

（3） according to primary site

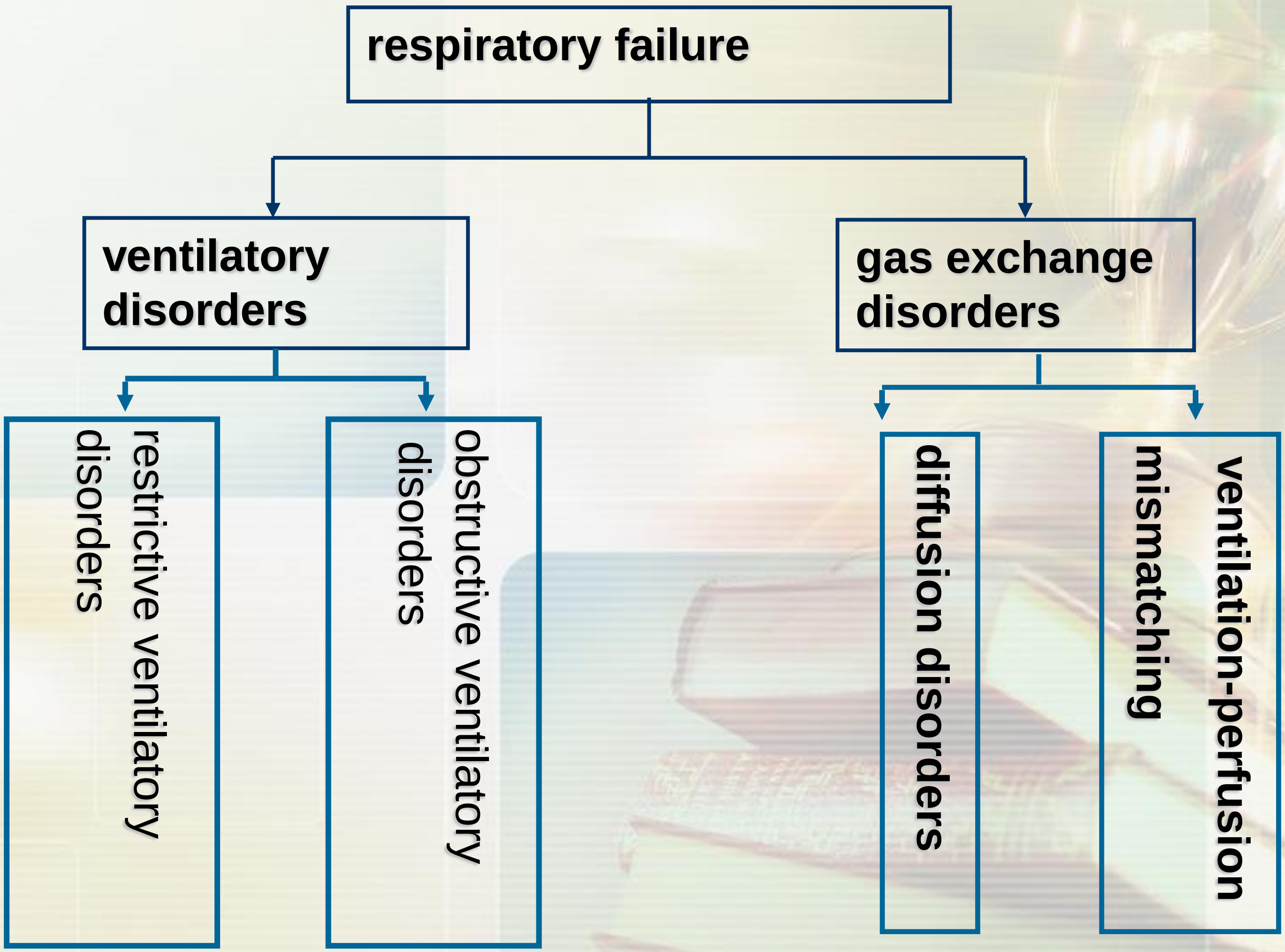
- central respiratory failure
- peripheral respiratory failure

（4） according to duration

- acute respiratory failure
- chronic respiratory failure

etiology and pathogenesis

【classification of respiration failure mechanism】

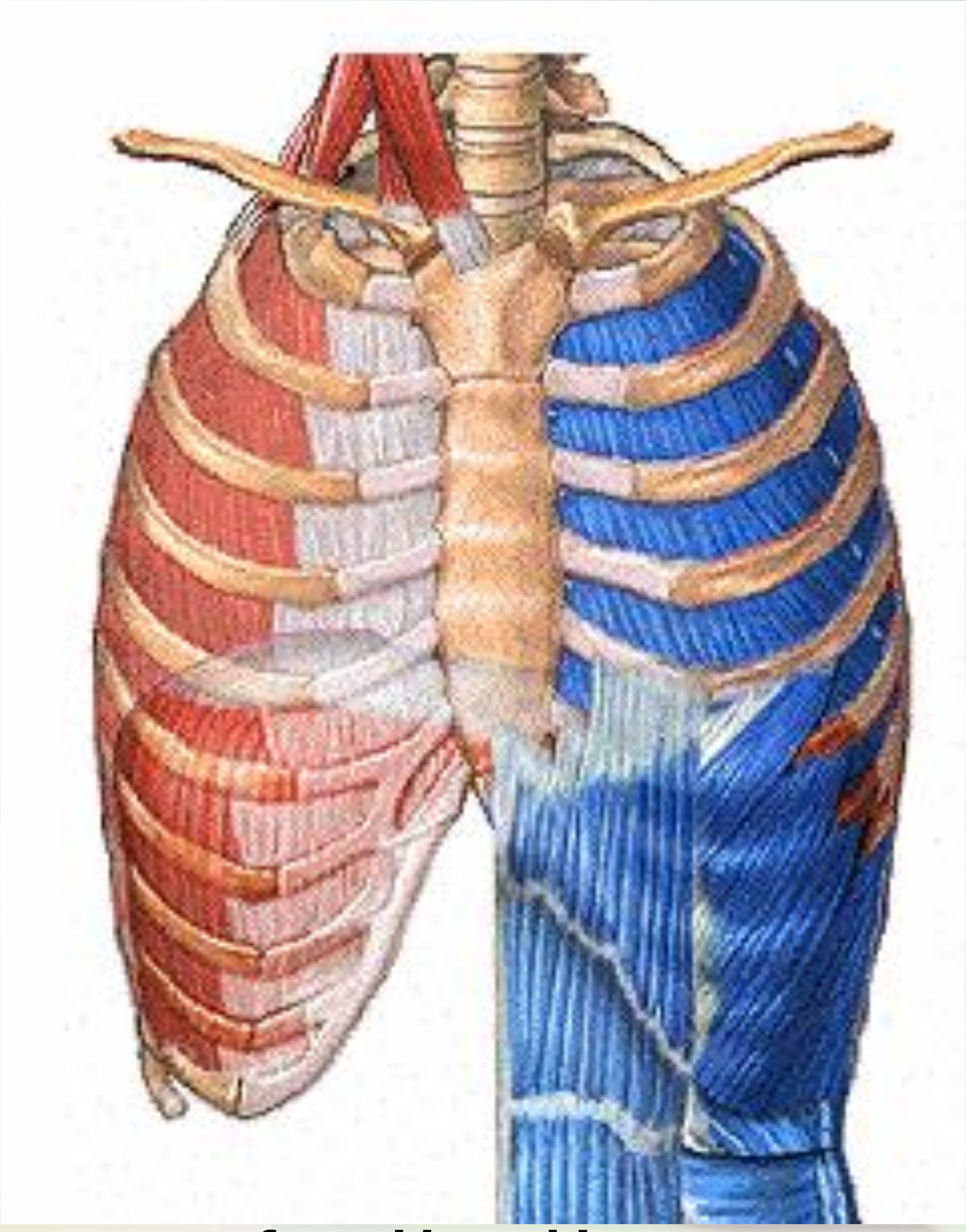


I. ventilatory disorders

1. restrictive ventilatory disorders

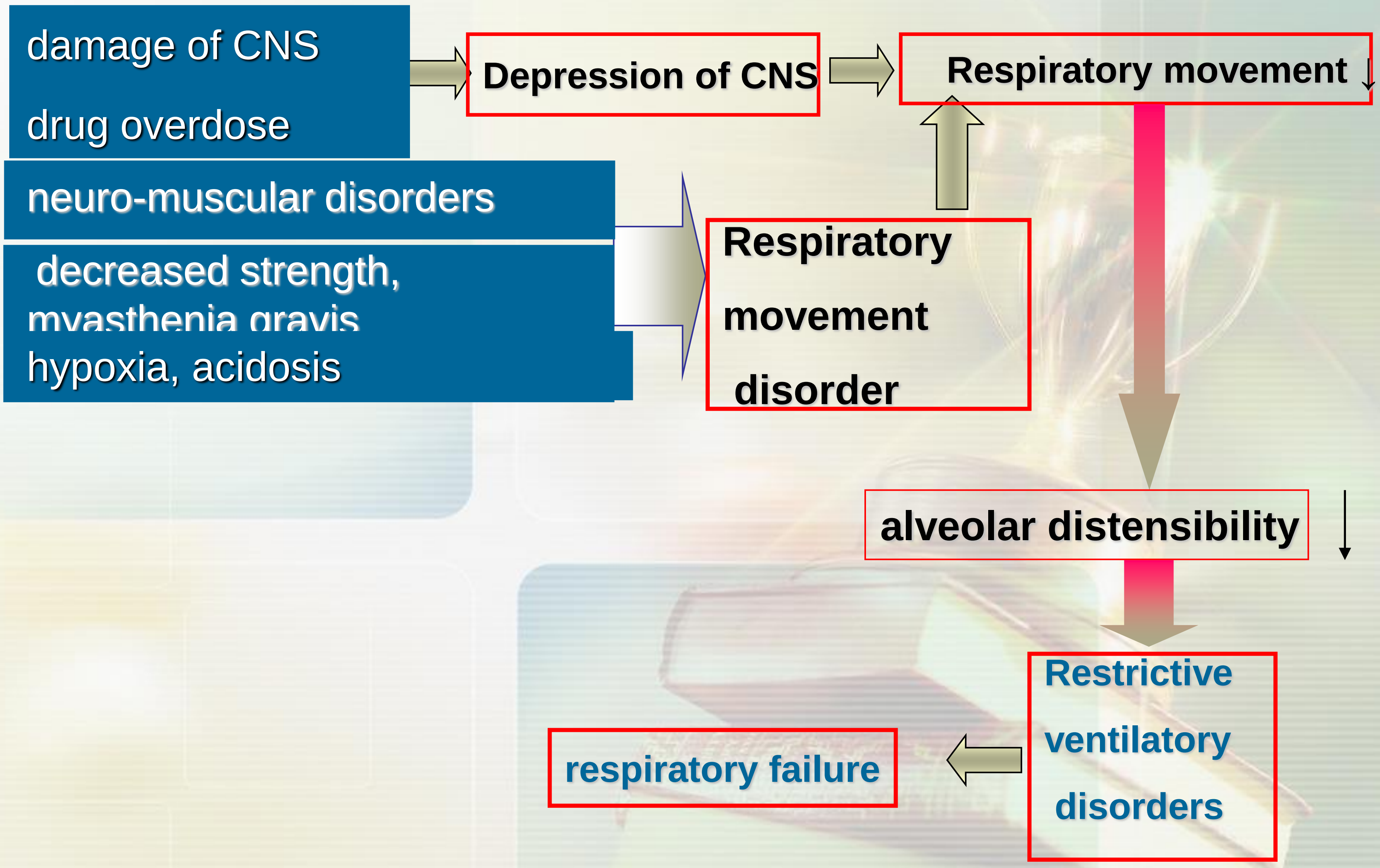
Restrictive hypoventilation is caused by the diseases that affect the distensibility of the alveolar.

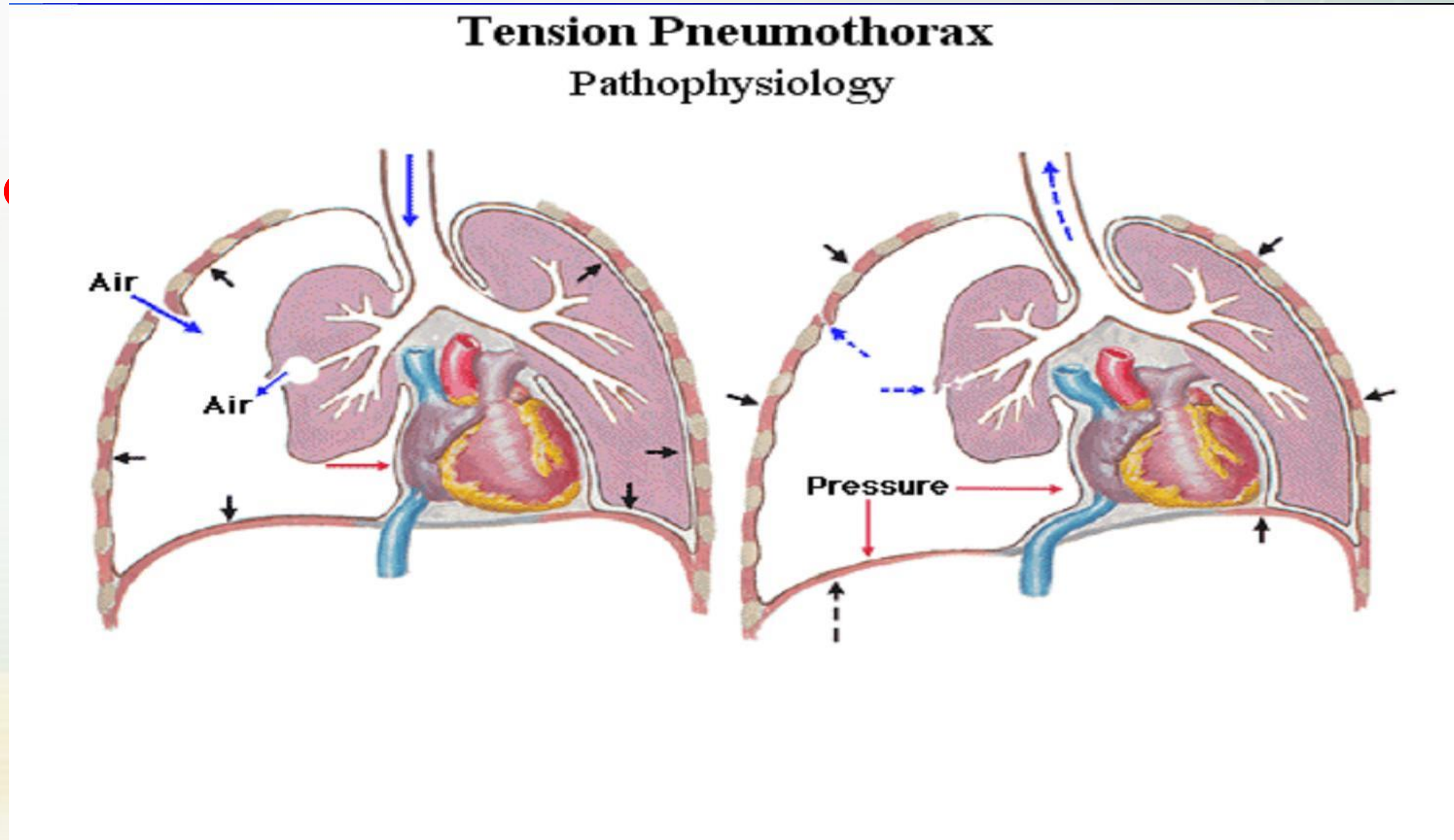
Respiratory movement



forced breathing

▲ Disorders of the respiratory muscles





ion

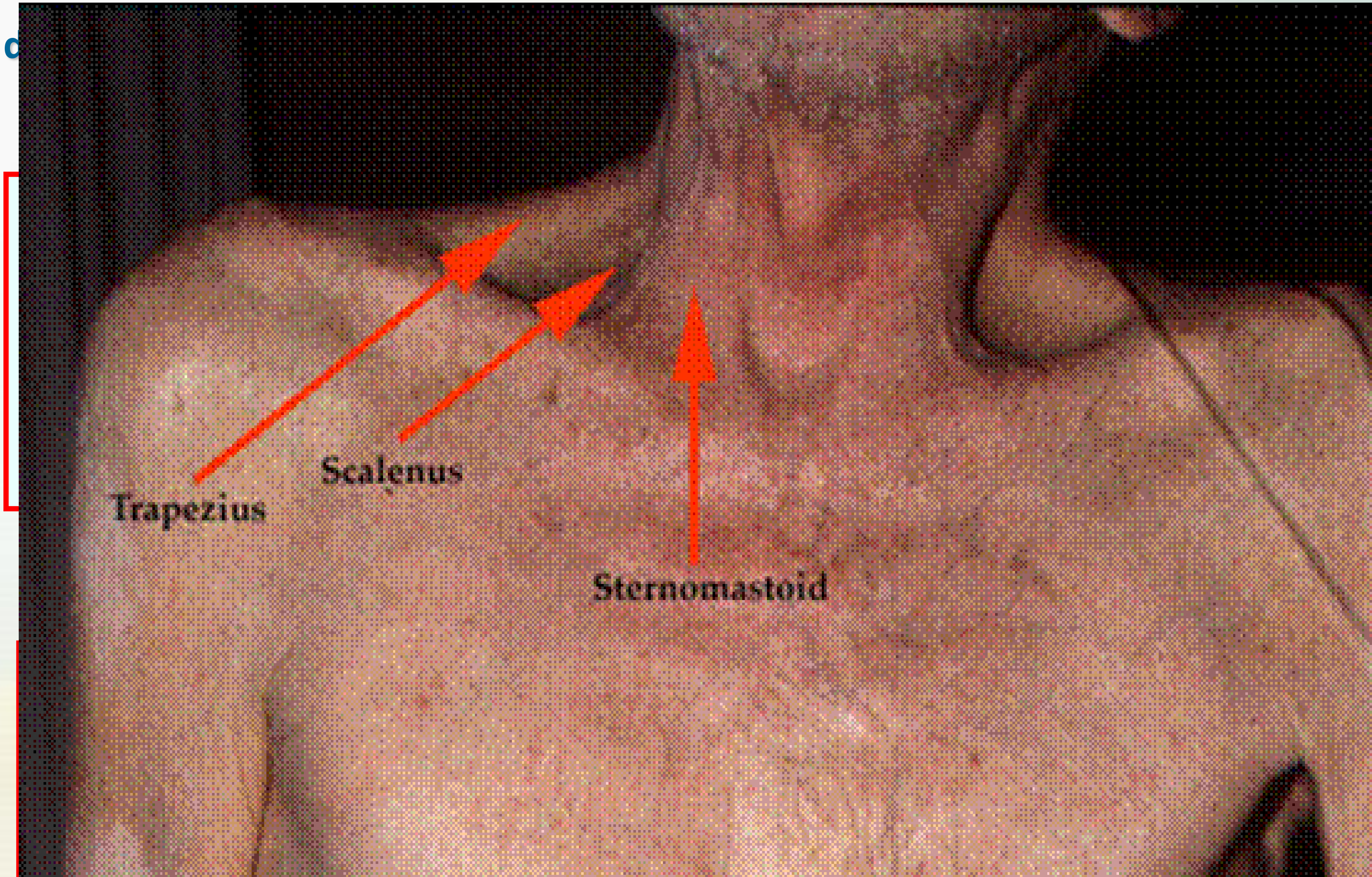
2. obstructive ventilatory disorders

- obstructive ventilatory disorders are caused by the diseases which share the common characterestic of causing enough narrowing within the tracheobronchial tree to increase resistance to the flow of air.

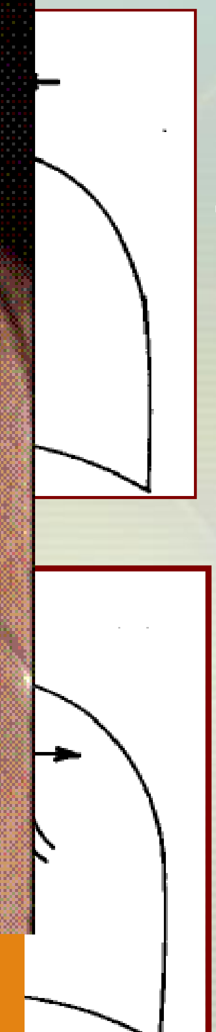
- **etiology**

  asthma, emphysema, chronic bronchitis, and bronchiectasis.

1） central airway obstruction



three depression sign



2） peripheral airway obstruction

smaller airways less than 2 mm in diameter.

Determinants of airway closure are the intrinsic caliber of peripheral airways.

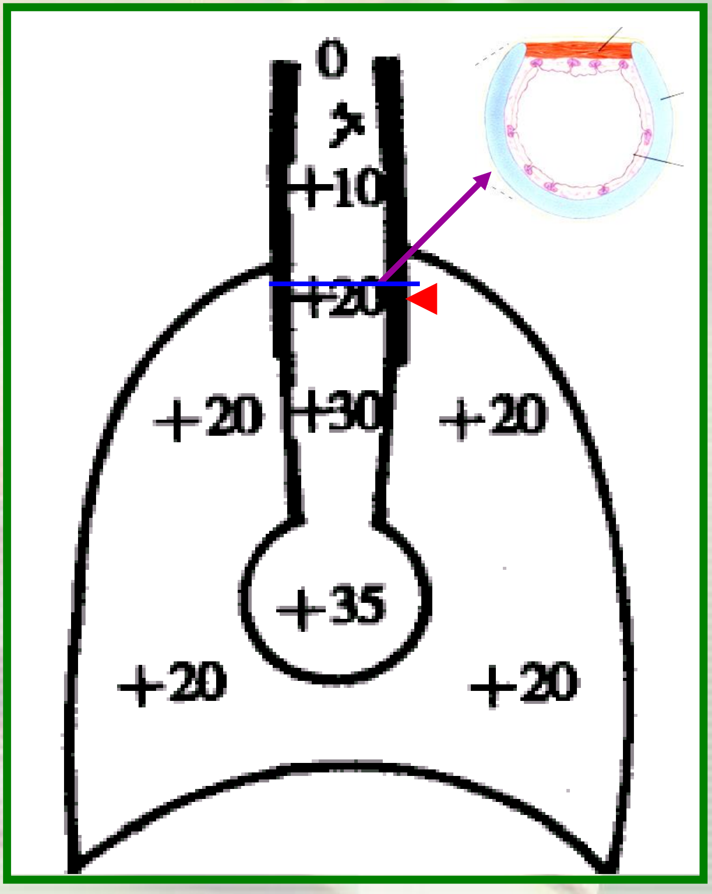
Smooth muscle tone, thickness of the wall,

mechanical properties of the surface film,

and secretions in the lumen ,bingding

effect of attachments of the surrounding

lung parenchyma.

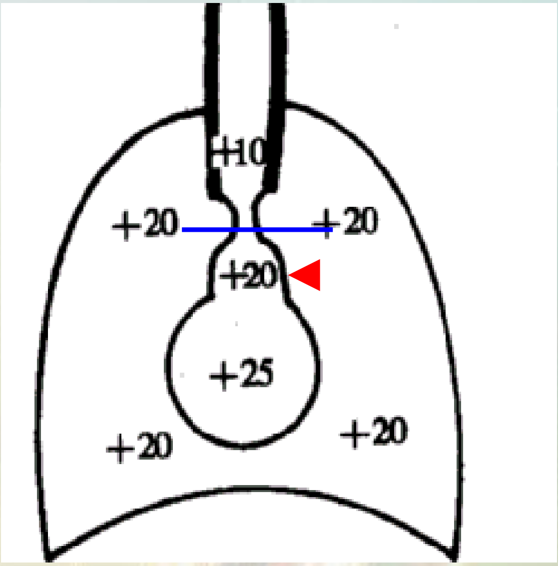


equal pressure point (EPP)

In forced expiration, the point where intrapleural pressure and alveolar pressure are equal.

Peripheral airway obstruction may be caused by: specific chemical mediators (such as histamine, leukotrienes, prostaglandins), other substances released during inflammatory and allergic responses.

EPP moves distally as expiration progresses because as air leaves the alveolar unit, the pressure in the alveolar decreases hence the pressure in the airway decreases as well.



forced expiration

3. The alteration of blood gas

1）Low PaO_2： $PaO_2 < 60mmHg$

2）$PaCO_2$ change：

A. hypoventilation：high $PaCO_2$.

R=40/50 mmHg=0.8；

B. part hypoventilation: Low PaO_2 and normal or low $PaCO_2$.

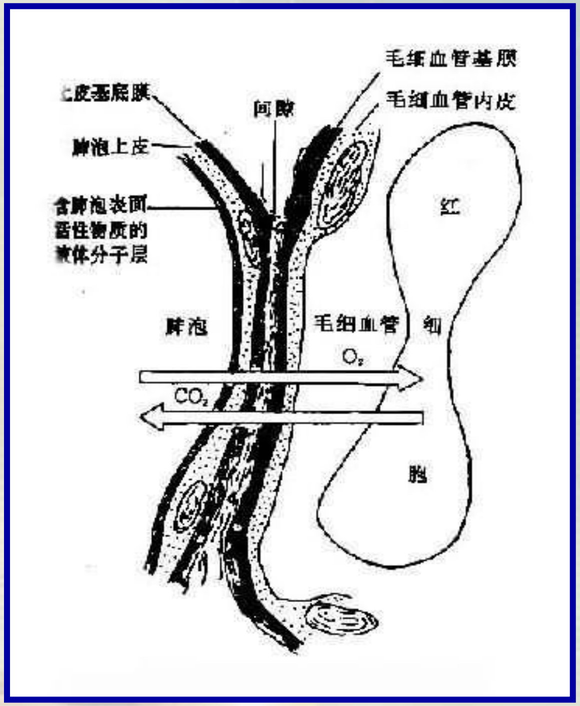
Ⅱ. gas-exchanging dysfunction

1. diffusion disorders

The diffusion impairment is characterized by a disruption in the exchange of O_2 or CO_2 or both across the alveolar-capillary membrane.

Causes:

reduction and/or thicken of alveolar-capillary membrane or reduction of the diffuse time.



1） etiology of diffusion disorders

- reduction of diffusion membrane area

  Abnormalities of diffusion may not cause arterial hypoxia in persons at rest unless they are extremely severe.

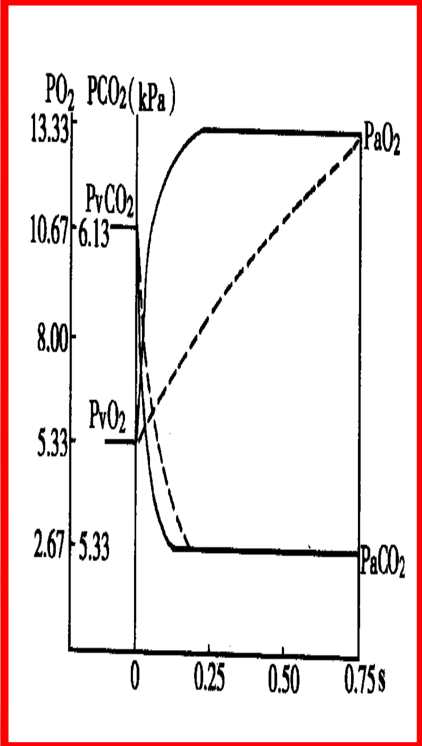
  (total: 80 mm^2; at rest: 30~40 mm^2)

  Causes: emphysema, pneumonia, lobectomy

- increase of diffusion membrane thickness

  edema, fibrosis, capillary vessel dilatation

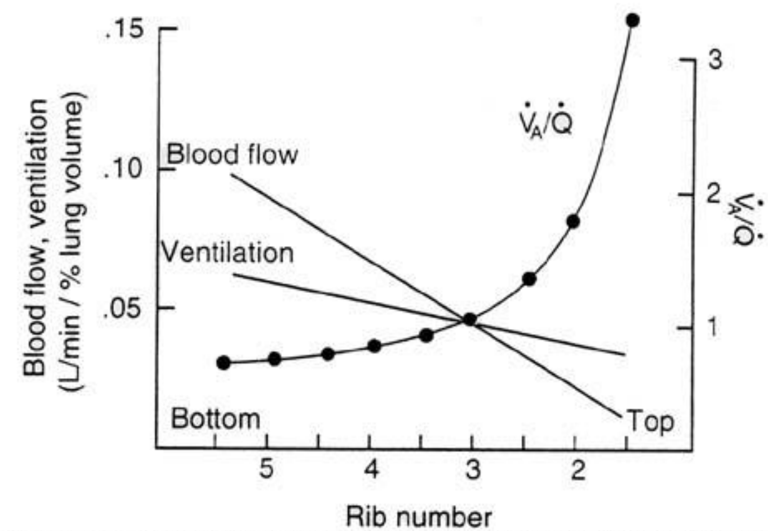
- decreased time of blood contacts with alveolar



2. ventilation/perfusion imbalance

The dysfunction of gas exchange can arise secondary to ventilation /perfusion mismatching.

	$\dot{V}_A$	$\dot{Q}$	$\dot{V}_A/\dot{Q}$
Top	1.2L/min	0.4L/min	3.0
Middle	1.8L/min	2.0L/min	0.9
Bottom	2.1L/min	3.4L/min	0.6

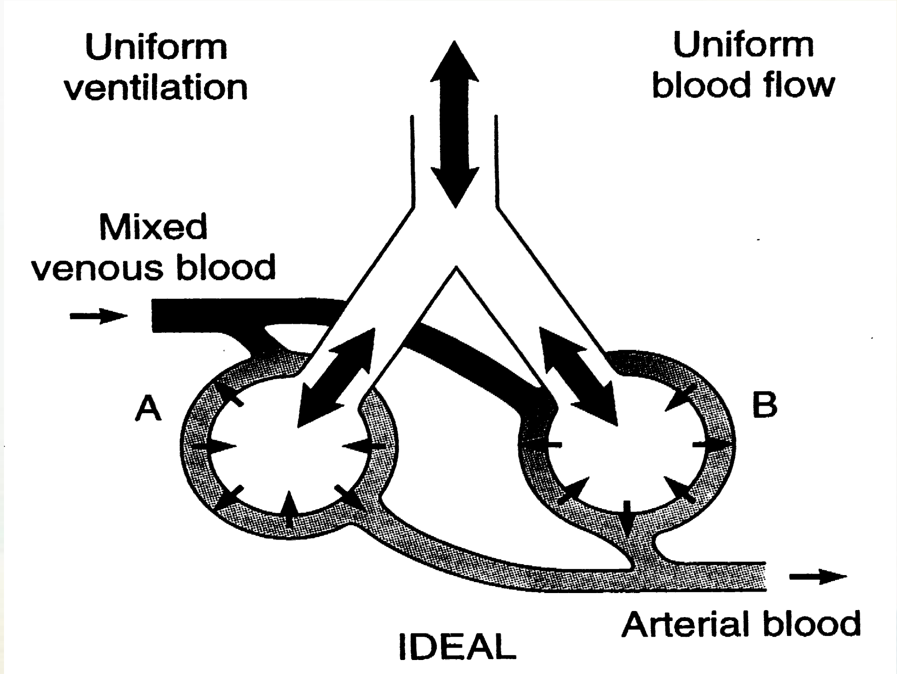


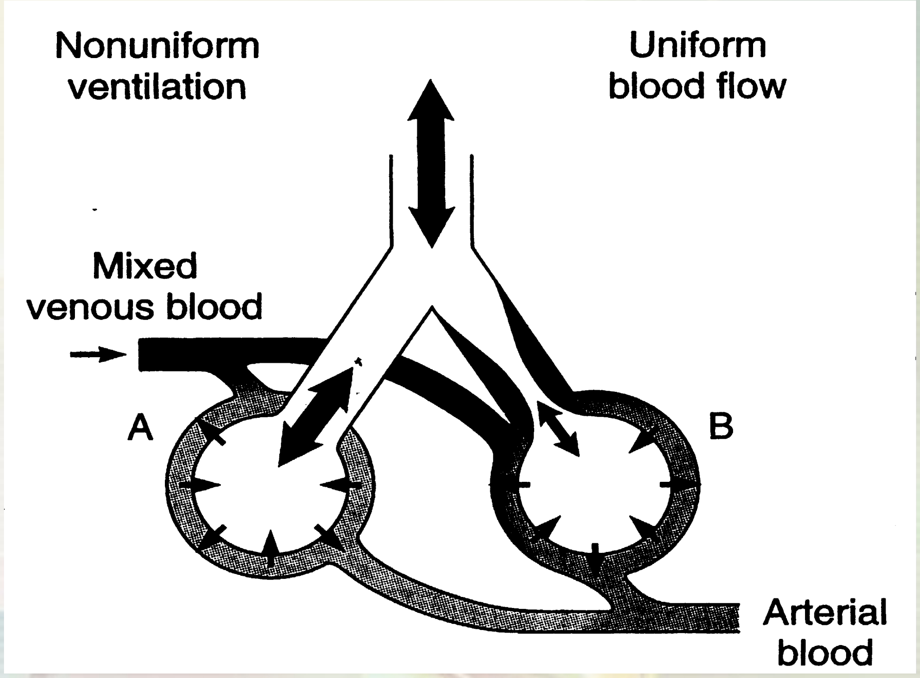
Regional variation of ventilation and perfusion and their relationship to one another (VA/Q) from the apex to the base of the upright lung. Ventilation and perfusion are greater at the base andt he VA/Q is lower at the base
From West JB. Ventilation/Blood flow and Gas Exchange. Oxford: Blackwell, 1077, p. 30

1) type and cause of ventilation-perfusion-mismatching

(1) decreased ratio of $\dot{V}_A/\dot{Q}$

underventilated in relation to their perfusion





asthma, chronic bronchitis, obstructive emphysema, fibrosis, edema

$\dot{V}_A/\dot{Q}$↓ ← part alveolar ventilatory ↓

functional shunt↑>30% → respiratory failure

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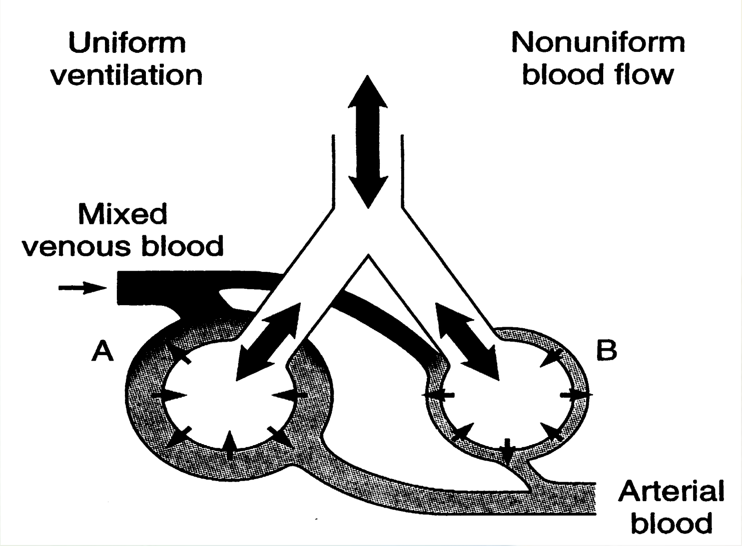
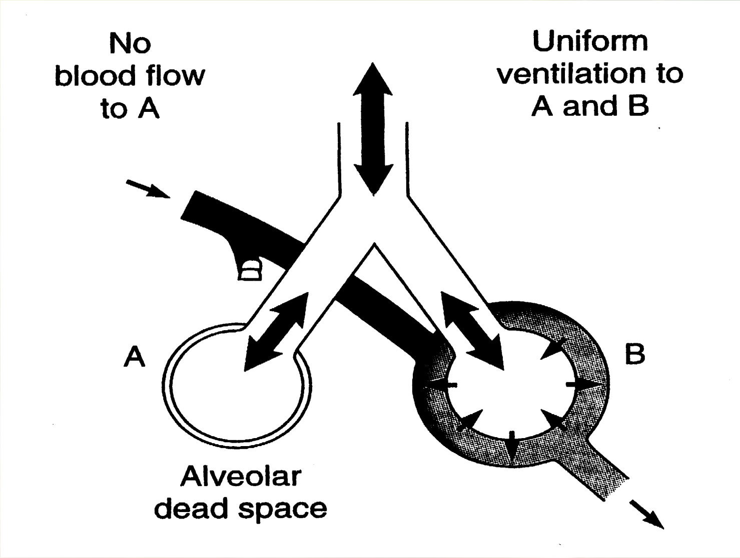
(2) increased ratio of V_A/Q

poor perfusion in relation to their ventilation with air





pulmonary artery embolization, DIC in lung, vessels contract, pulmonary arteritis,

dead space like ventilation ↑ ← V_A/Q↑ ← poor perfusion↓

↓

respiratory failure

3）increased of anatomical shunt

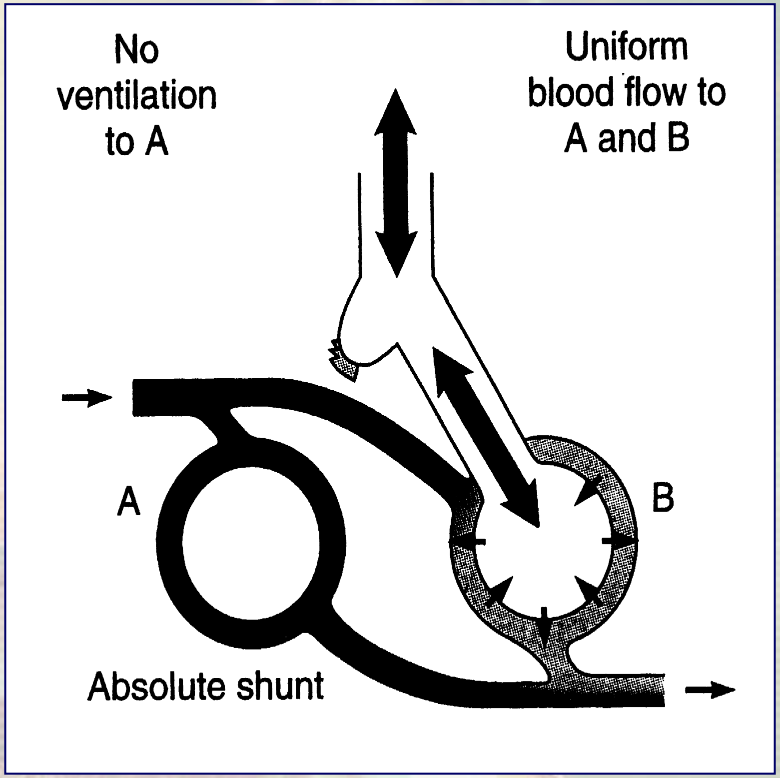
Right-to-left shunts or anatomic shunt

▲ increased of anatomical shunt

bronchiectasis → anatomic shunt ↑ → Pulmonary A-V shunt open↑ → true shunt↑

▲ increased of anatomical-like shunt

pulmonary consolidation,At electasis → anatomical-like shunt → Respiratory failure



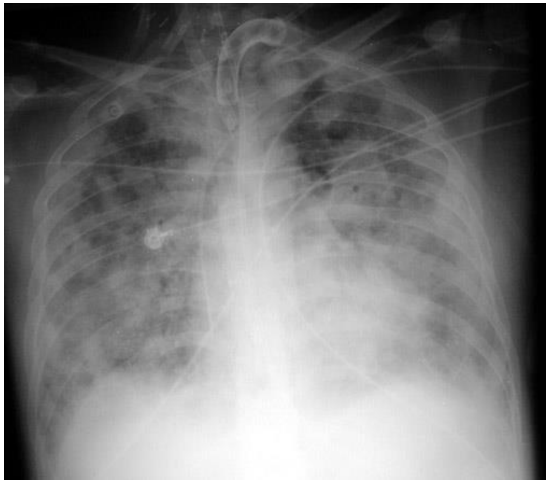
Objectives

- Review the causes and differentials for ARDS
- Briefly discuss the pathophysiology
- Discuss the clinical manifestations of ARDS
- Understand evidence based treatment options

Statistics

- Epidemiology
  - Annual incidence: 60/100,000
  - 20% ICU patients meet criteria for ARDS
- Morbidity / Mortality
  - 26-44%, most (80%) deaths attributed to non-pulmonary organ failure or sepsis
- Risk Factors
  - Advanced age, pre-existing organ dysfunction or chronic medical illness
  - Patient with ARDS from direct lung injury has higher incidence of death than those from non-pulmonary injury

. Acute respiratory distress syndrome（ARDS）



Definition

1) Acute onset
2) Bilateral infiltrates
3) No clinical evidence of left heart failure (or PCWP <=18)

PaO2:FiO2 ≤ 300
Or
SaO2:FiO2 ≤ 315

PaO2:FiO2 ≤ 200
Or
SaO2:FiO2 ≤ 235

Acute Lung Injury

Acute Respiratory Distress Syndrome

Table 3. The Berlin Definition of Acute Respiratory Distress Syndrome

	Acute Respiratory Distress Syndrome
Timing	Within 1 week of a known clinical insult or new or worsening respiratory symptoms
Chest imaging[a]	Bilateral opacities—not fully explained by effusions, lobar/lung collapse, or nodules
Origin of edema	Respiratory failure not fully explained by cardiac failure or fluid overload Need objective assessment (eg, echocardiography) to exclude hydrostatic edema if no risk factor present
Oxygenation[b]	
Mild	200 mm Hg < PaO_2/FIO_2 ≤ 300 mm Hg with PEEP or CPAP ≥5 cm H_2O[c]
Moderate	100 mm Hg < PaO_2/FIO_2 ≤ 200 mm Hg with PEEP ≥5 cm H_2O
Severe	PaO_2/FIO_2 ≤ 100 mm Hg with PEEP ≥5 cm H_2O

Abbreviations: CPAP, continuous positive airway pressure; FIO_2, fraction of inspired oxygen; PaO_2, partial pressure of arterial oxygen; PEEP, positive end-expiratory pressure.

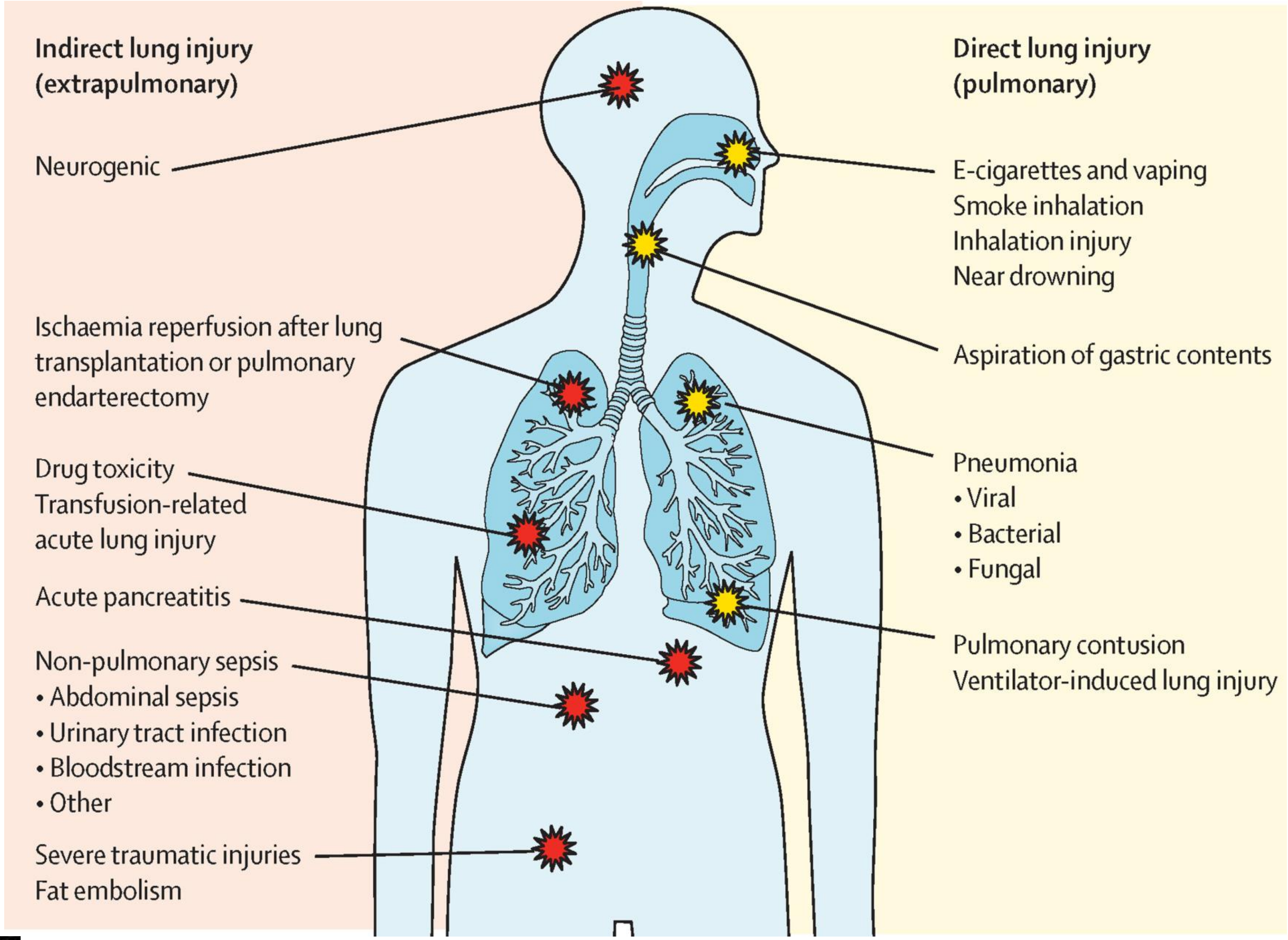
[a] Chest radiograph or computed tomography scan.

[b] If altitude is higher than 1000 m, the correction factor should be calculated as follows: [PaO_2/FIO_2 × (barometric pressure/760)].

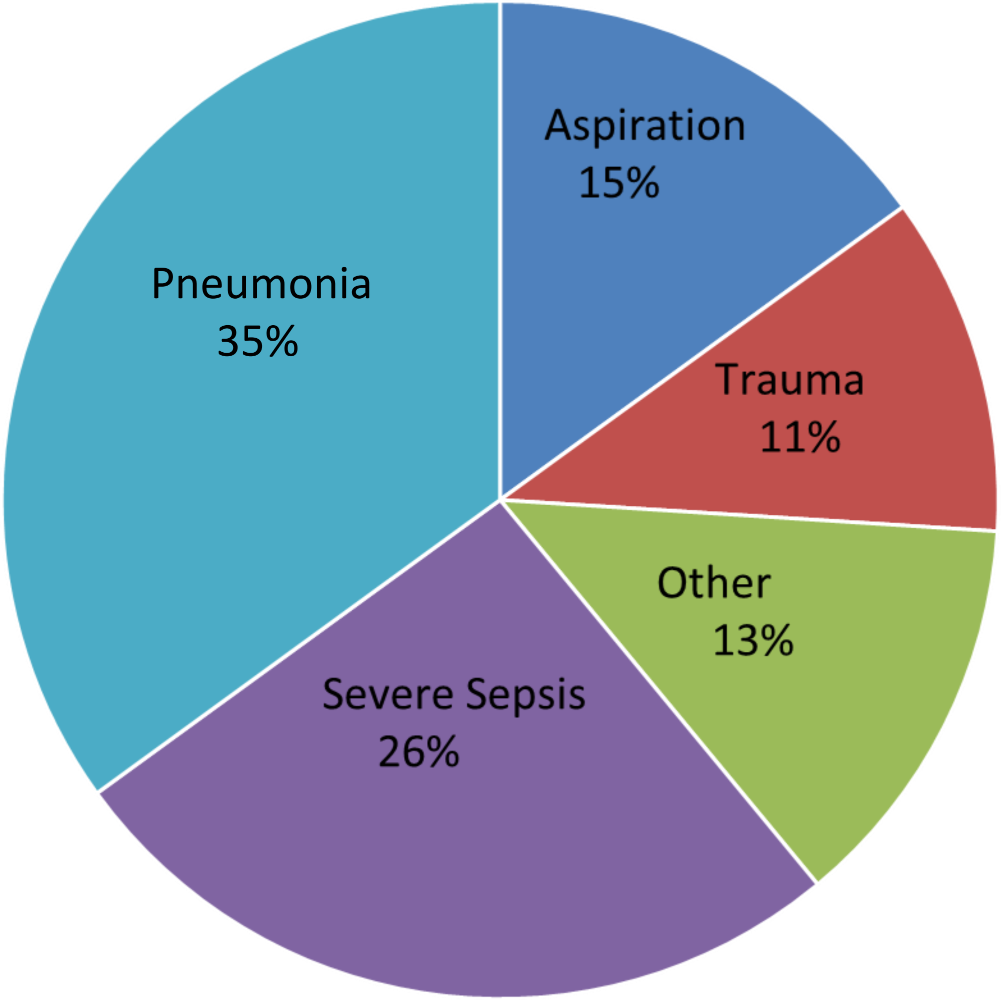
[c] This may be delivered noninvasively in the mild acute respiratory distress syndrome group.

TABLE 322-1 CLINICAL DISORDERS COMMONLY ASSOCIATED WITH ARDS

Direct Lung Injury	Indirect Lung Injury
Pneumonia	Sepsis
Aspiration of gastric contents	Severe trauma
Pulmonary contusion	Multiple bone fractures
Near-drowning	Flail chest
Toxic inhalation injury	Head trauma
	Burns
	Multiple transfusions
	Drug overdose
	Pancreatitis
	Postcardiopulmonary bypass

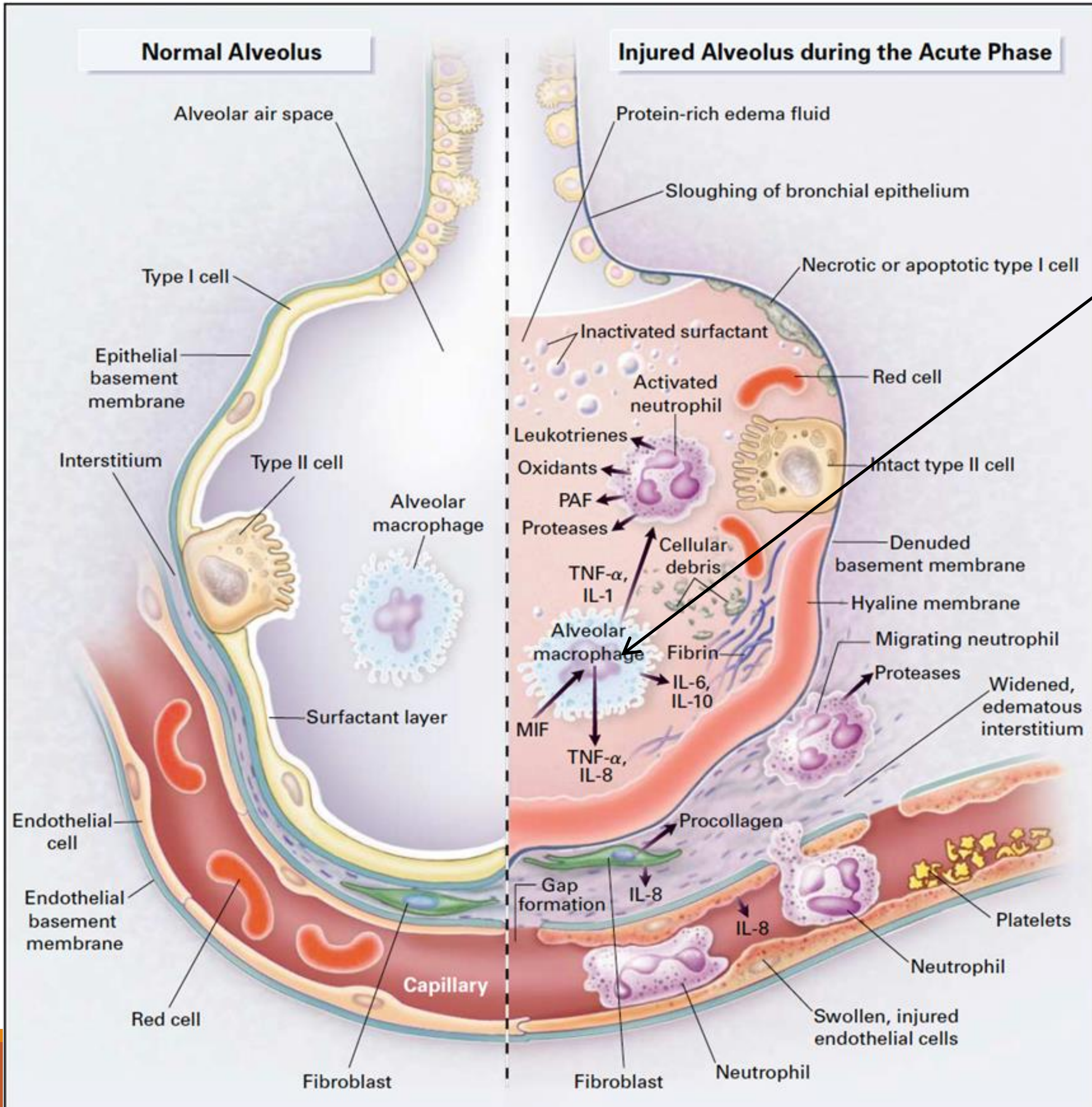


The Lancet 2022 4001145-1156DOI: (10.1016/S0140-6736(22)01485-4)


Aspiration
15%
Trauma
11%
Other
13%
Severe Sepsis
26%
Pneumonia
35%

D.DX

- Left ventricular failure/volume overload
- Mitral stenosis
- Pulmonary veno-occlusive disease
- Lymphangitic spread of malignancy
- Interstitial and/or airway disease
  - Hypersensitivity pneumonia
  - Acute eosinophilic pneumonia
  - Acute interstitial pneumonitis



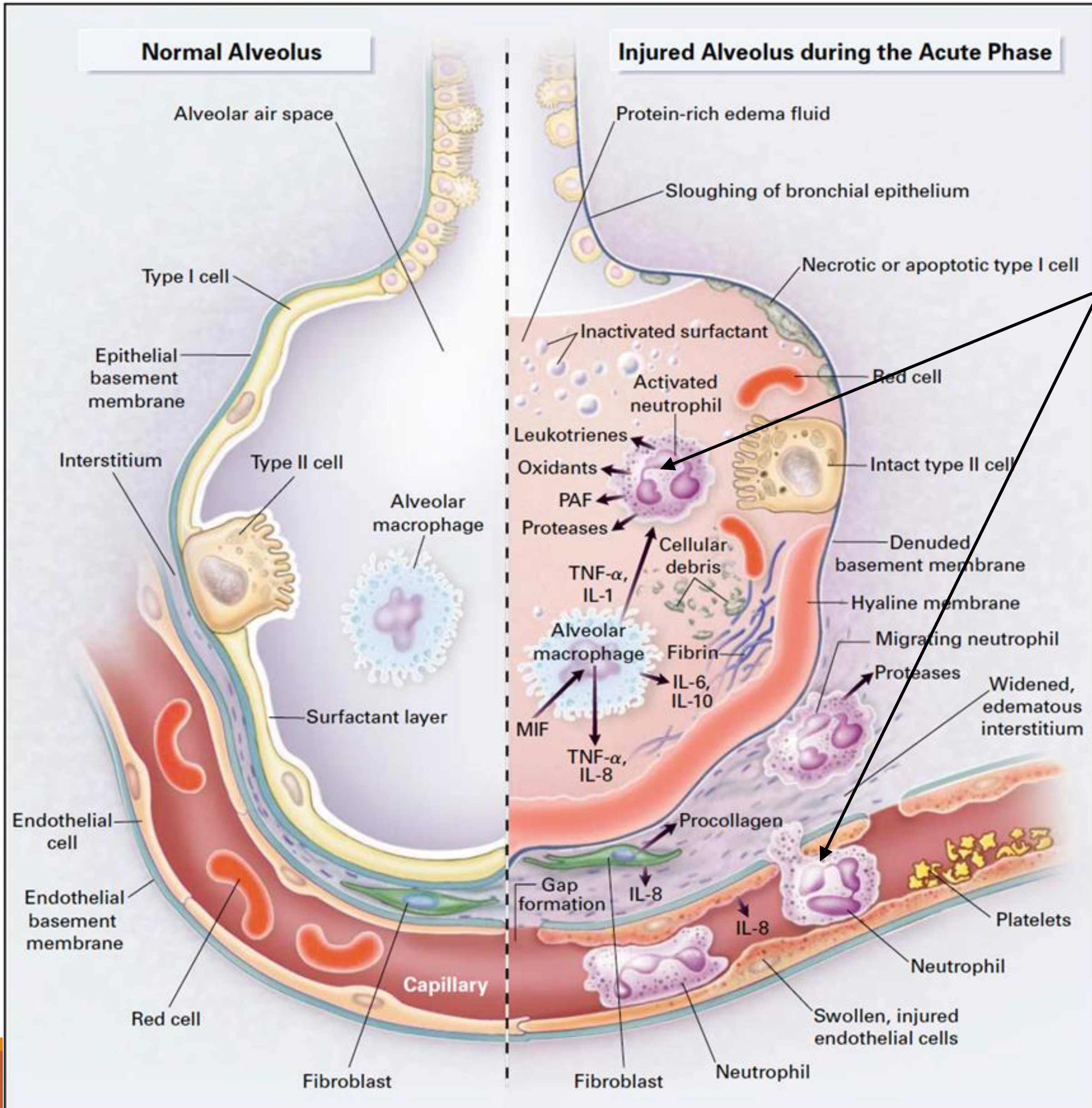
Pathophysiology

1. Direct or indirect injury to the alveolus causes alveolar macrophages to release pro-inflammatory cytokines

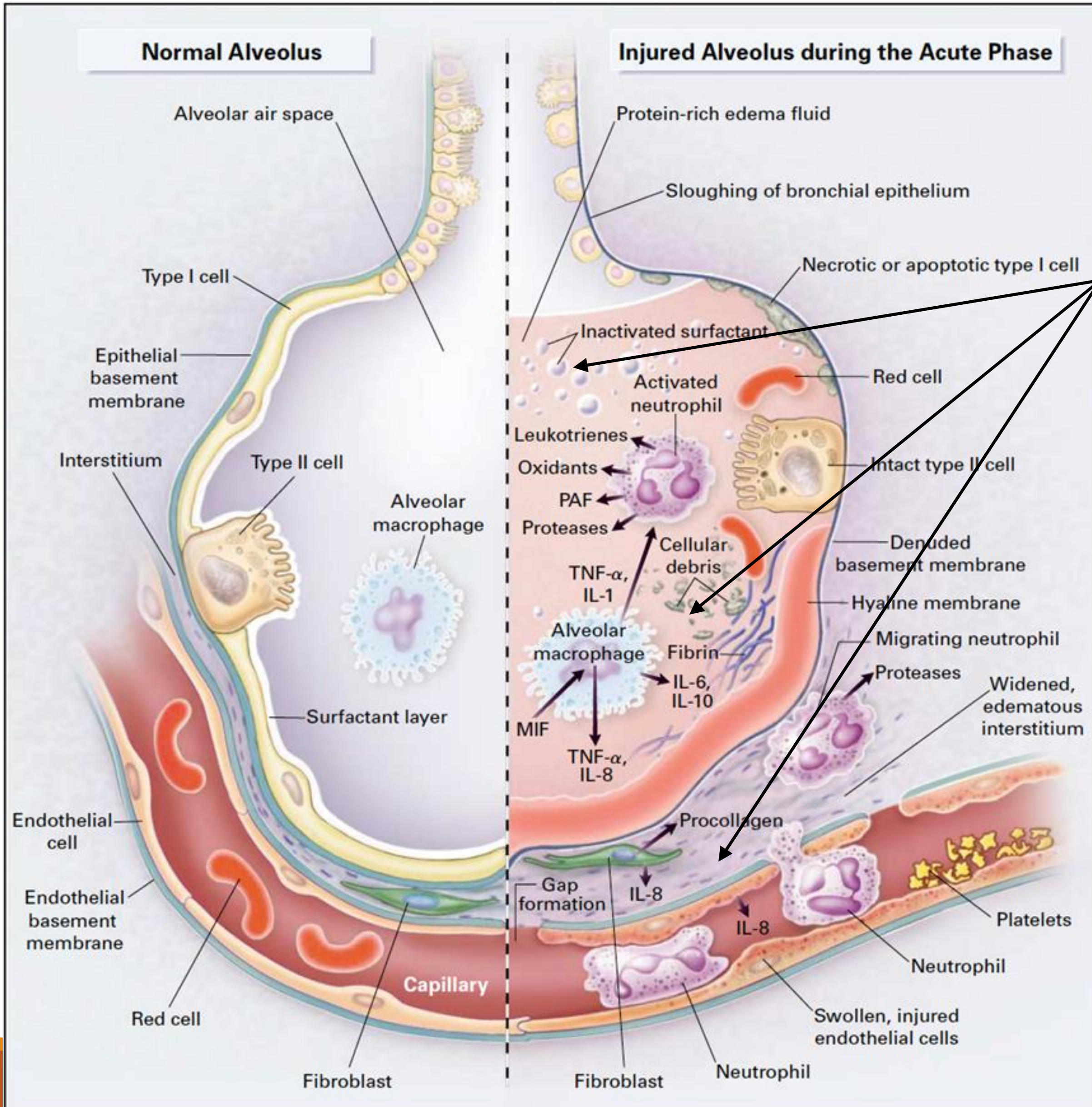
Ware et al. NEJM 2000; 342:1334

Pathophysiology

2. Cytokines attract neutrophils into the alveolus and interstitum, where they damage the alveolar-capillary membrane (ACM).



Ware et al. NEJM 2000; 342:1334



Pathophysiology

3. ACM integrity is lost, interstitial and alveolus fills with proteinaceous fluid, surfactant car no longer support alveolus

Ware et al. NEJM 2000; 342:1334

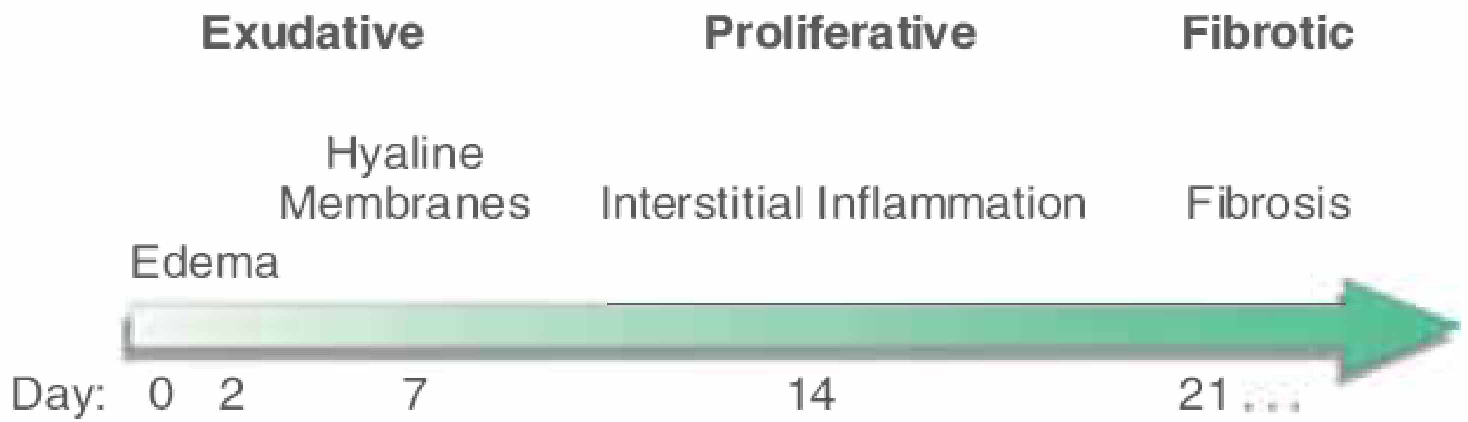


FIGURE 322-1 **Diagram illustrating the time course for the development and resolution of ARDS.** The exudative phase is notable for early alveolar edema and neutrophil-rich leukocytic infiltration of the lungs, with subsequent formation of hyaline membranes from diffuse alveolar damage. Within 7 days, a proliferative phase ensues with prominent interstitial inflammation and early fibrotic changes. Approximately 3 weeks after the initial pulmonary injury, most patients recover. However, some patients enter the fibrotic phase, with substantial fibrosis and bullae formation.

Pathophysiology

Consequences of lung injury include:

- Impaired gas exchange
- Decreased compliance
- Increased pulmonary arterial pressure

ASSESSMENT OF PATIENT

Careful history

Physical Examination

ABG analysis -classify RF and help with cause

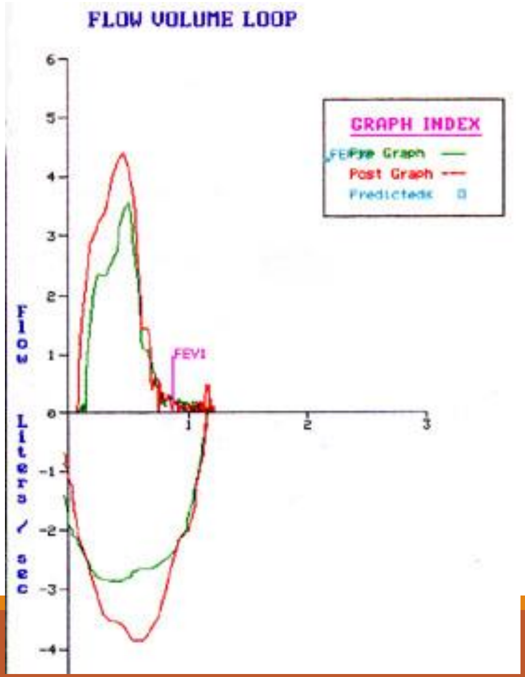
1) $PaCO_2 = \frac{VCO_2}{VA} \times 0.863$

2) $P(A\text{-}a)0_2 = PIO_2 - \frac{PaCO_2}{R}) - PaO_2$

Lung function
RVP vs NVP

Chest Radiograph

EKG



Impaired Gas Exchange

V/Q mismatch

- Related to filling of alveoli
- Shunting causes hypoxemia

Increased dead space

- Related to capillary dead space and V/Q mismatch
- Impairs carbon dioxide elimination
- Results in high minute ventilation

Decreased Compliance

Hallmark of ARDS

Consequence of the stiffness of poorly or nonaerated lung

Fluid filled lung becomes stiff/boggy

Requires increased pressure to deliver Vt

Increased Pulmonary Arterial Pressure

Occurs in up to 25% of ARDS patients

Results from hypoxic vasoconstriction

Positive airway pressure causing vascular compression

Can result in right ventricular failure

Not a practice we routinely measure

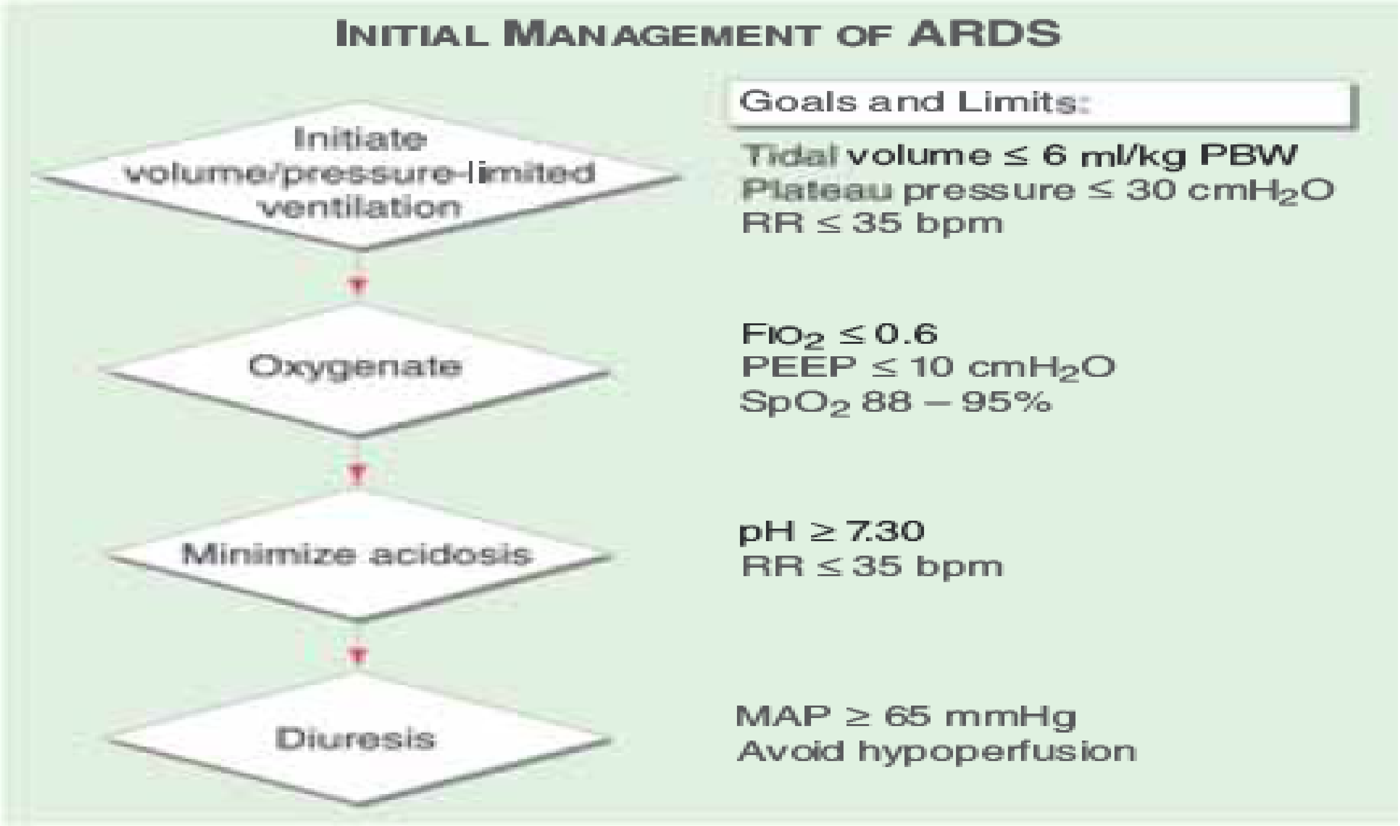


FIGURE 322-5 Algorithm for the initial management of ARDS. Clinical trials have provided evidence-based therapeutic goals for a stepwise approach to the early mechanical ventilation, oxygenation, and correction of acidosis and diuresis of critically ill patients with ARDS. FIO_2, inspired O_2 percentage; MAP, mean arterial pressure; PBW, predicted body weight; PEEP, positive end expiratory pressure; RR, respiratory rate; SpO_2, arterial oxyhemoglobin saturation measured by pulse oximetry.

TABLE 322-3 EVIDENCE-BASED RECOMMENDATIONS FOR ARDS THERAPIES	
Treatment	**Recommendation**[a]
Mechanical ventilation	
Low tidal volume	A
Minimized left atrial filling pressures	B
High-PEEP or "open lung"	C
Prone position	C
Recruitment maneuvers	C
High-frequency ventilation	D
ECMO	C
Early neuromuscular blockade	A
Glucocorticoid treatment	D
Surfactant replacement, inhaled NO, inhaled epoprostenol, and other anti-inflammatory therapy (e.g., ketoconazole, PGE1, NSAIDs)	D

[a]Key: A, recommended therapy based on strong clinical evidence from randomized clinical trials; B, recommended therapy based on supportive but limited clinical data; C, recommended only as alternative therapy on the basis of indeterminate evidence; D, not recommended on the basis of clinical evidence against efficacy of therapy.

Abbreviations: ARDS, acute respiratory distress syndrome; ECMO, extracorporeal membrane oxygenation; NO, nitric oxide; NSAIDs, nonsteroidal anti-inflammatory drugs; PEEP, positive end-expiratory pressure; PGE1, prostaglandin E_1.

Evidence based management of ARDS

Treat the underlying cause

Low tidal volume ventilation

Use PEEP

Monitor Airway pressures

Conservative fluid management

Reduce potential complications

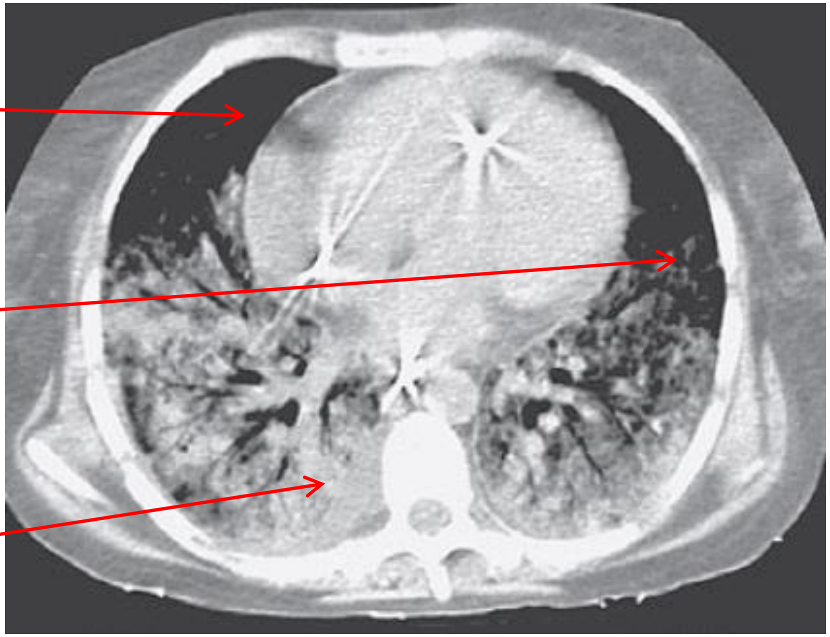
Low Tidal Volume Ventilation

- When compared to larger tidal volumes, Vt of 6ml/kg of ideal body weight:
  - Decreased mortality
  - Increased number of ventilator free days
  - Decreased extrapulmonary organ failure
- Mortality is decreased in the low tidal volume group despite these patients having:
  - Worse oxygenation
  - Increased pCO_2 (permissive hypercapnia)
  - Lower pH

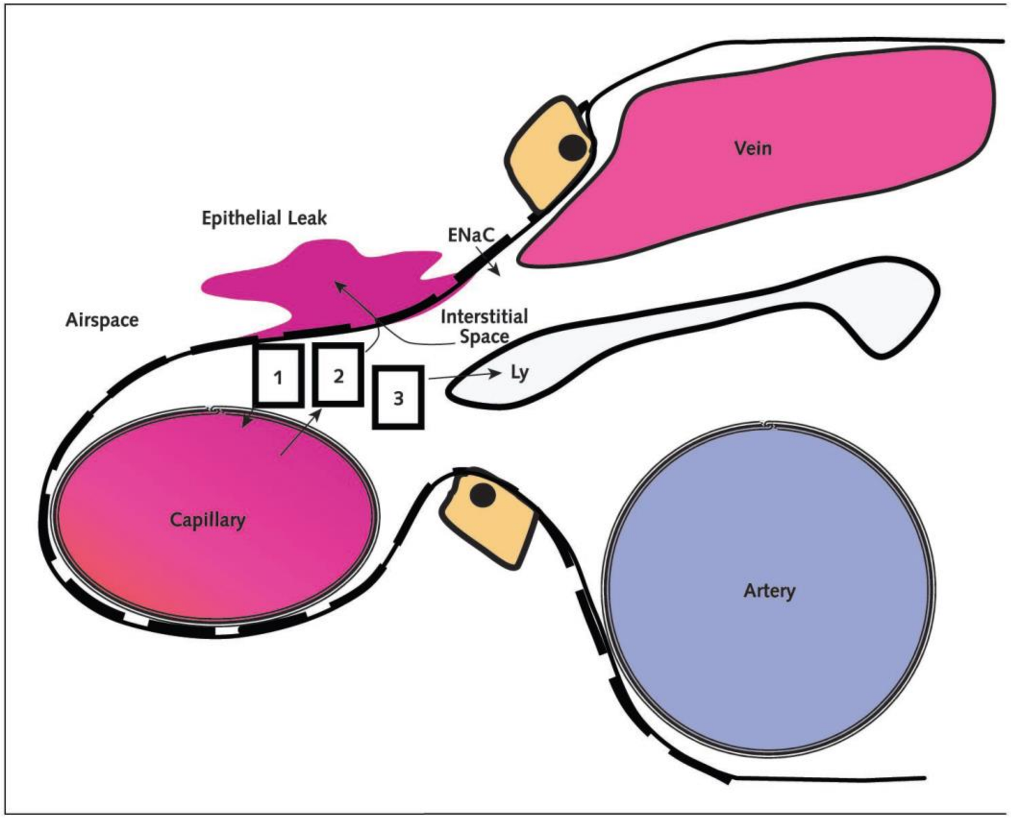
Low Tidal Volume Ventilation

ARDS affects the lung in a heterogeneous fashion

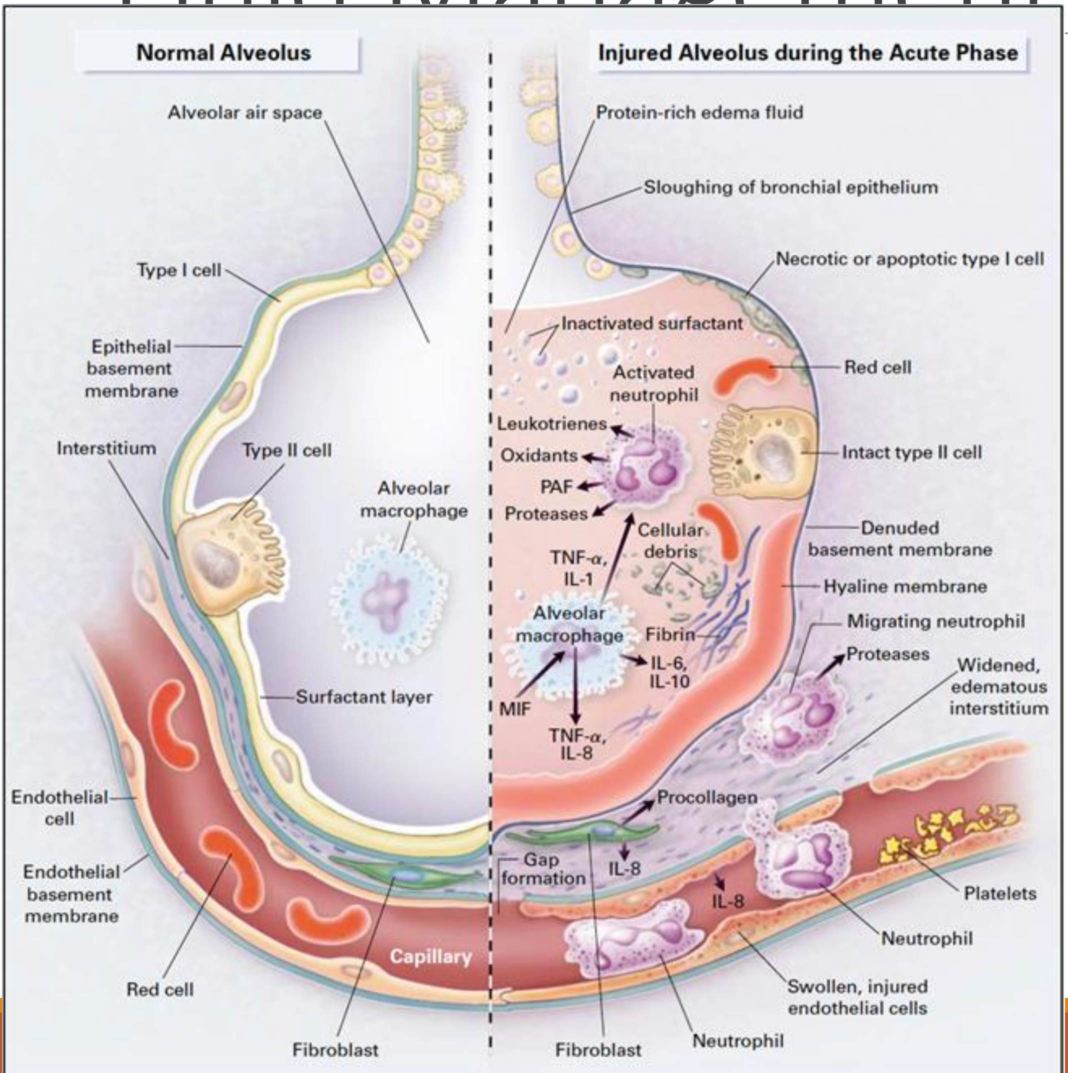
- Normal alveoli
- Injured alveoli can potentially participate in gas exchange, susceptible to damage from opening and closing
- Damaged alveoli filled with fluid, do not participate in gas exchange



Fluid Management



Fluid Management



- Increased lung water is the underlying cause of many of the clinical abnormalities in ARDS (decreased compliance, poor gas exchange, atelectasis)
- After resolution of shock, effort should be made to attempt diuresis
- CVP used as guide, goal <4
- Shortens time on vent and ICU length of stay (13 days vs 11 days)

ARDSnet. *NEJM* 2006; 354: 2564

Supportive Therapies

Treat underlying infection

DVT prophylaxis / stress ulcer prevention

HOB 30˚

Hand washing

Use full barriers with chlorhexadine

Sedation / analgesia

Feeding protocol

Avoid contrast nephropathy

Pressure ulcer prevention, turning Q2h

Avoid steroid use

Conclusion

Recovery dependent on health prior to onset

Within 6 months, will have reached max recovery

At 1 year post-extubation, >1/3 have normal spirometry

- Significant burden of emotional and depressive symptoms with increased depression and PTSD in ARDS survivors
  - Survivor clinic catches symptoms early by screening patients

New treatment modalities, lung protective ventilation

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
- 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

Thanks for attention