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# Respiratory system IV

Lung diseases
VLA 1. 12. 2020

## Opakování

- Pod pojmem dýchání rozumíme výměnu dýchacích plynů mezi vnitřním a zevním prostředím.
- Někdy se používá pojem buněčné dýchání pro procesy spojené s tvorbou energie za spotřeby kyslíku v mitochondriích buněk.

## Anatomie dýchacího systému

- Horní cesty dýchací
- Dolní cesty dýchací
- Plíce

## Hlavní funkce dýchacího systému

- Ventilace
- Difúze
- Perfúze

- Činnost respiračního systému úzce souvisí s činností oběhového systému, proto se někdy mohou poruchy oběhového systému manifestovat jako poruchy respirace.

## Funkce horních cest dýchacích

- Zvlhčit a ohřát vzduch
- Odstranit větší nečistoty

- Relativní vlhkost vzduchu
- Ztráty vody dýchacím systémem cca 0,5l/den

## Funkce dolních cest dýchacích

- Křižovatka mezi dýchacími cestami a trávicím traktem.
- Ochrana dýchacích cest před průnikem potravy – epiglotis, hlasivky – laryngeální spasmus

## Funkce plic

- Vlastní výměník, ve kterém dochází k výměně plynů mezi alveolárním vzduchem a krví.

## Ventilace

- Alveolární ventilace $V_A$ je rozdíl mezi celkovou plicní ventilací a ventilací mrtvého prostoru. $V_A=V_T-V_D$
- Ventilace je součin dechové frekvence a dechového objemu $V_A= f*(TV-DV)$
- Přírůstu dechové frekvence a poklesu dechového objemu zůstává sice $V_T$ zachována ale $V_A$ klesá, protože relativně roste ventilace mrtvého prostoru.

- Tlakový gradient
- Nádech
- Výdech
- Aktivní a pasivní děje
- Negativní tlak v pleurální dutině
- Elasticita plic
- Odpor dýchacích cest

## Perfúze

- Výměna plynů mezi krví a alveolárním vzduchem probíhá jen tehdy pokud dochází ke kontaktu krve a vzduchu na dostatečně velké ploše alveolokapilární membrány po dostatečně dlouhou dobu.
- Regulace vlivem hypoxie.
- Respirační perfúzní poměr
- Filtrace krve – trombembolie, metastázy; rezervoár krve.

## Difúze

- Na rychlosti difúze, respektive difúzním toku se podílí vlastnosti membrány, koncentrační gradient a velikost plochy.
- Vůči různým plynům se difúzní membrána chová různě.
- Oxid uhličitý difunduje snáze než kyslík 20x – při chorobných stavech bývá postižen přestup kyslíku více než přestup $CO_2$.

## Hlavní typy poruch funkce dýchacího systému

- Poruchy pleurální dutiny
- Obstrukce dýchacích cest
- Restrikční plicní choroby
- Cirkulační plicní poruchy
- Intersticiální plicní nemoci
- Respirační selhání

## Odlišení dvou hlavních klinických kategorií

- Obstrukční plicní choroby
- Restrikční plicní choroby

## Pleurální dutina

- Pleuritida
- Exudát, transudát
- Pneumothorax (zevní x vnitřní, otevřený, uzavřený, ventilový)
- Atelektáza x kolaps plicní tkáně

## Obstrukce dýchacích cest

- Obstrukce dolních dýchacích cest. Ovlivněn hlavně výdech, primárně snížení ventilace

## Asthma bronchiale

- Extrinsic asthma
- Intrinsic asthma

- Otok, sekrece, spasmus
- Chronický zánět

- Chronic obstructive pulmonary disease
  - Chronická obstruktivní bronchitida
  - Emfyzém

## Emfyzém

- Destrukce interalveolárních sept vedoucí ke hyperinflaci plicní tkáně a kolapsu malých dýchacích cest.
- Kouření cigaret, defekt alfa1-antitripsinu (1% případů).

## Chronická bronchitida

- Kouření a chronické infekce.
- Hypersekrece hlenu a hypertrofie hlenovýchžláz s fibrózou stěny bronchu.

## Klinický obraz COPD - zjednodušeno

- Pink puffer - emfyzematik s hyperventilací
- Blue bloater - bronchitik s hypoxií

Intersticiální plicní choroby

- Pneumokoniózy
- Sarkoidosa
- Některé léky, ionizující záření
- Autoimunitní choroby

## Poruchy krevního oběhu

- Plicní embolie
  - Tromembolie
  - Jiné typy embolií
- Plicní hypertenze
  - Prekapilární *(pravolevý zkrat, embolie)*
  - Kapilární *(hypoxie)*
  - Postkapilární *(levostranné srdeční selhání)*
- Cor pulmonále

## ARDS

- Acute respiratory distress syndrome
- Popsán teprve v roce 1967
- Vyústění spousty etiopatogeneticky rozličných, velmi těžkých stavů
- Poškození alveolokapilární membrány, deaktivace surfaktantu.

## Respirační selhání

- Hypoxemie
- Hypoxemie s hyperkapnií

- Hypoventilace
- Ventilačně perfúzní nepoměr
- Poruchy difúze

# Pathophysiology of pulmonary hypertension



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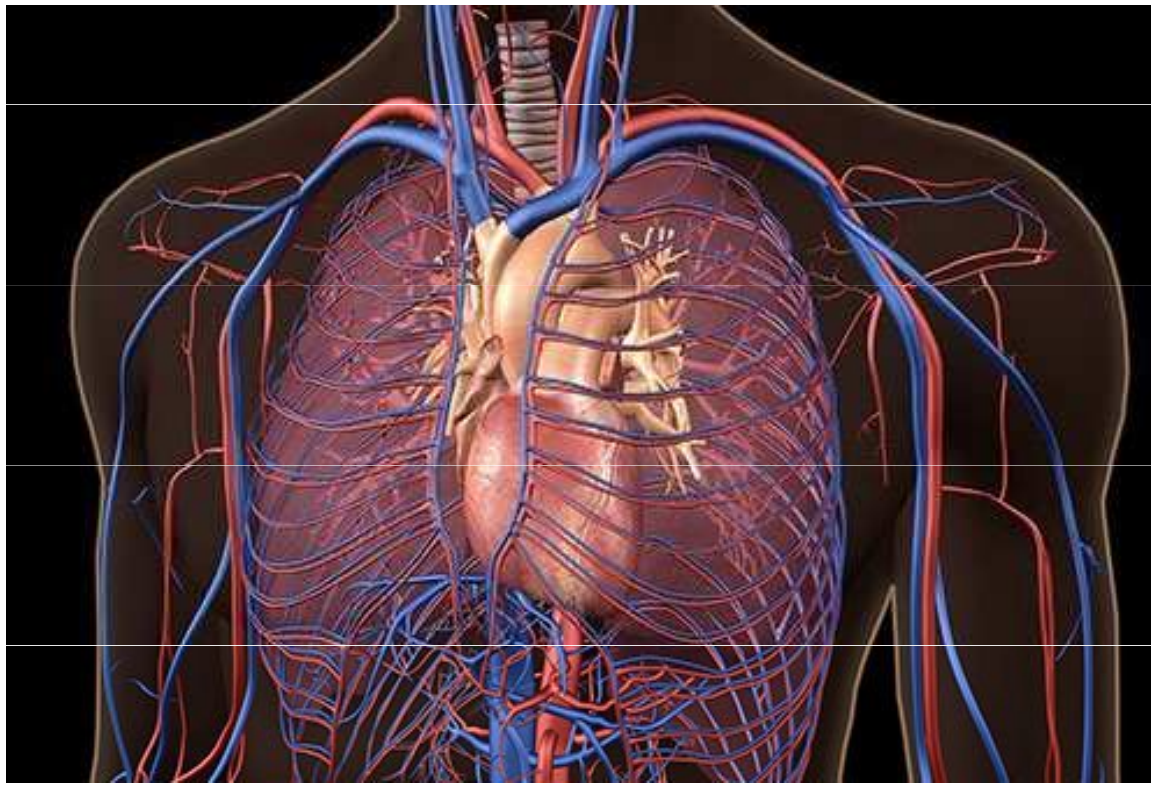
# Background normal anatomy and physiology





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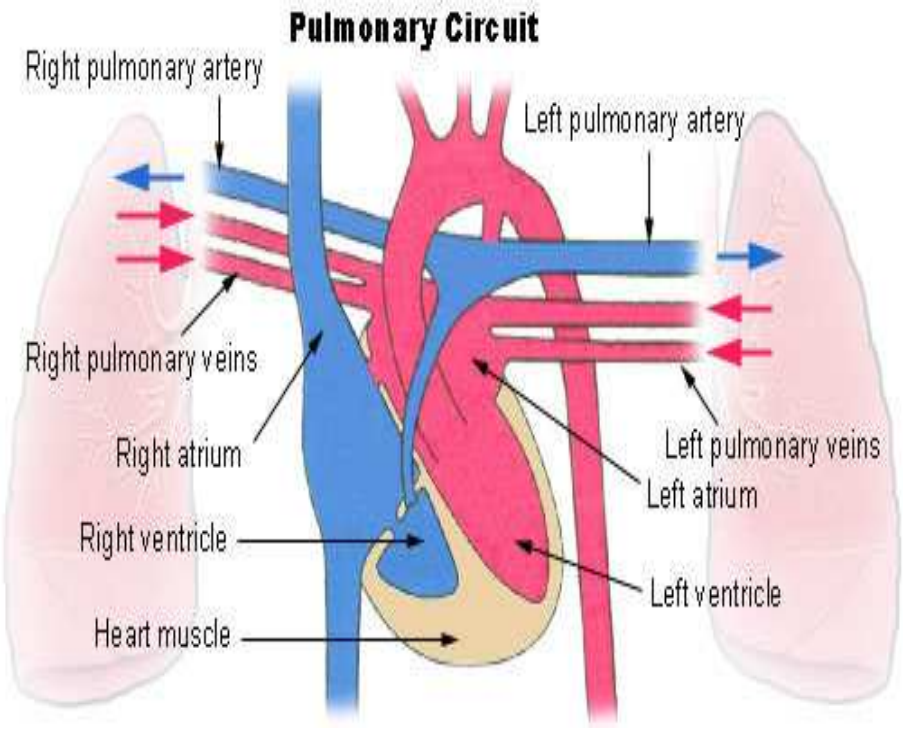
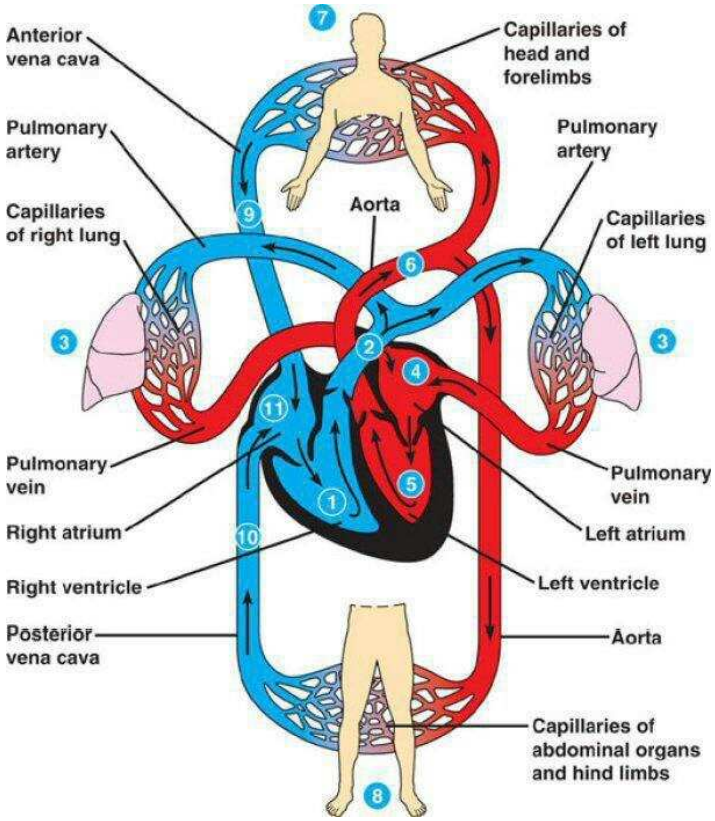
# Anatomy review - schematic



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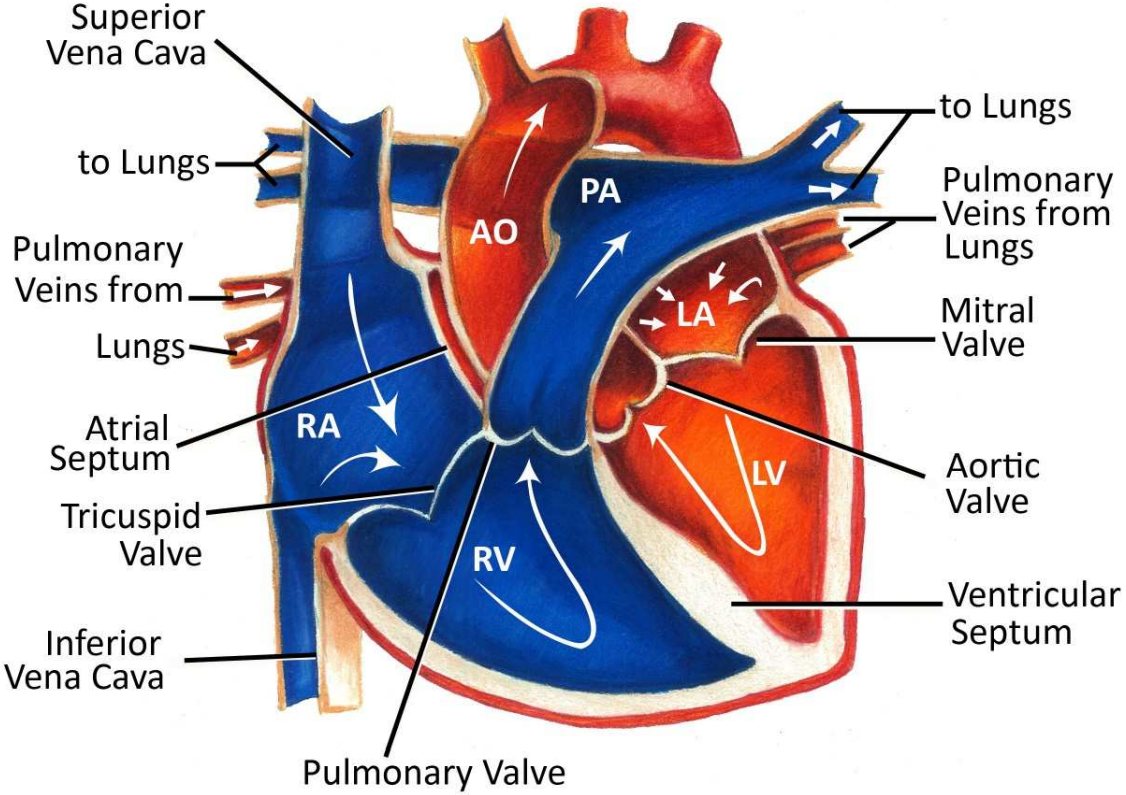
# Anatomy review - Realistic

**Normal Heart**



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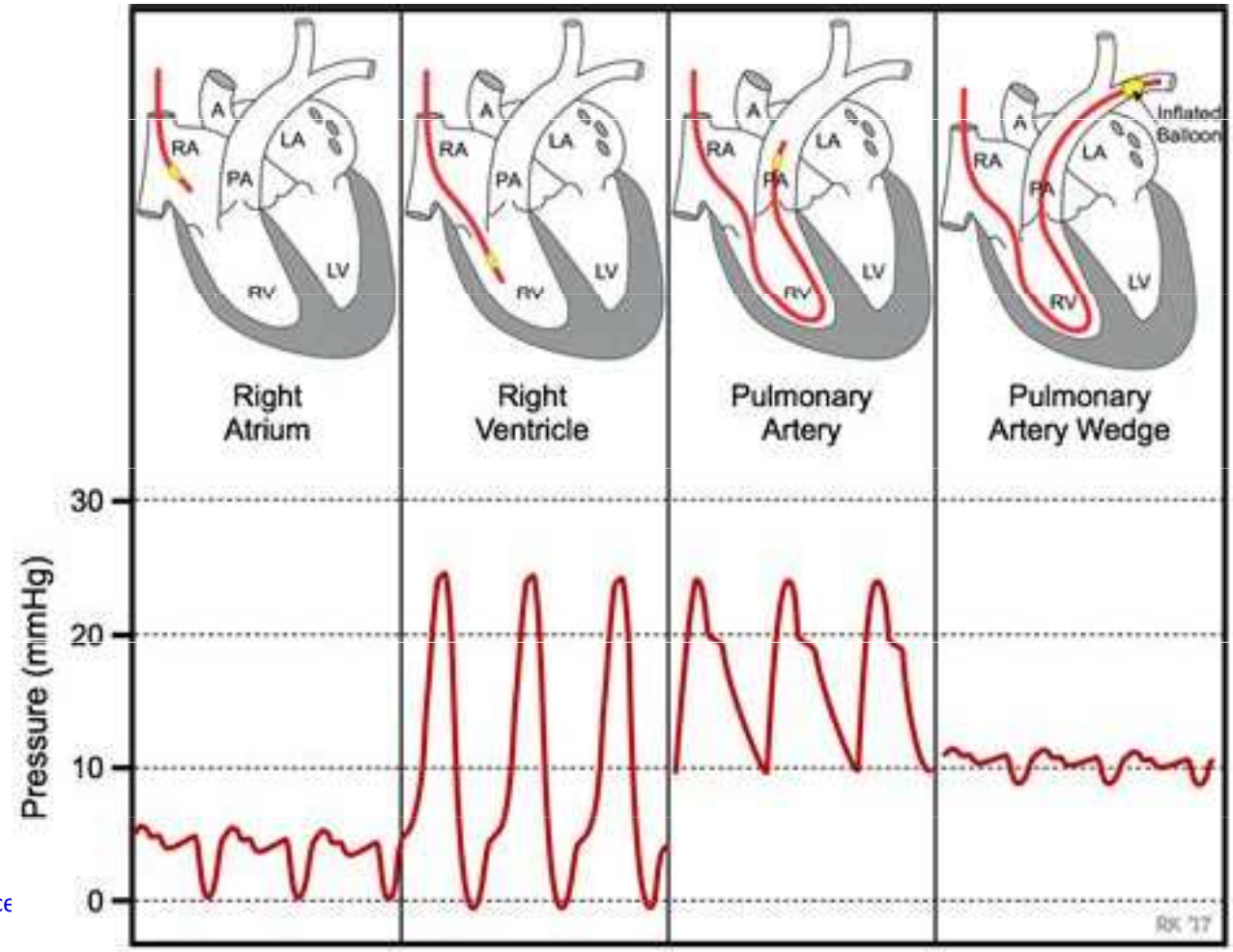
# Swan Ganz catheter placement



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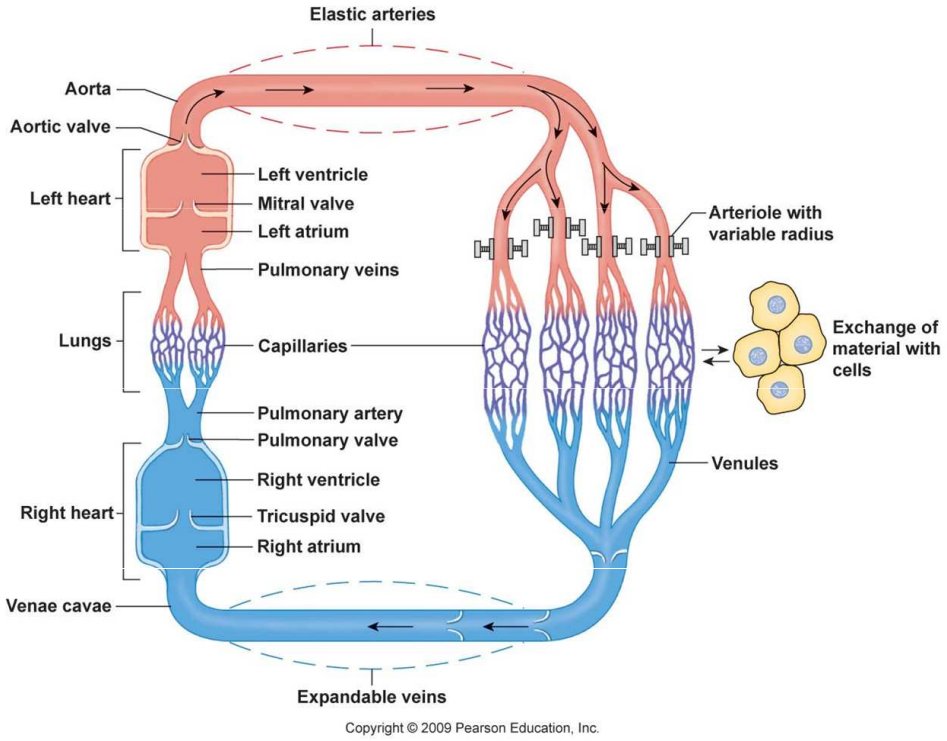
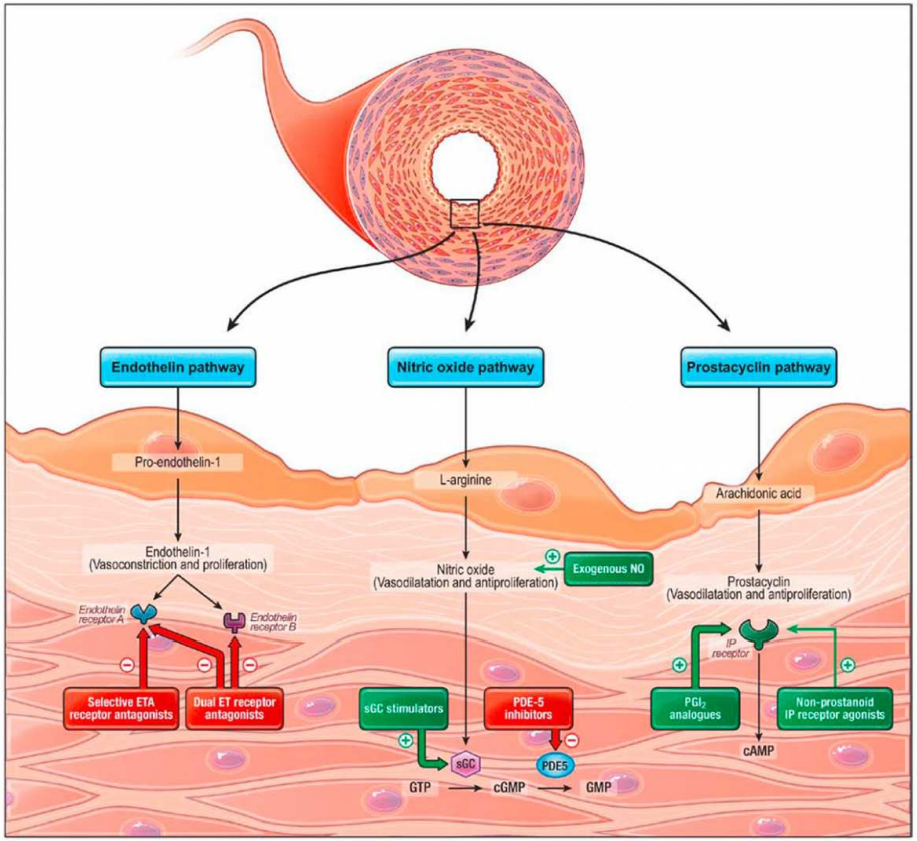
# Why is pulmonary artery pressure normally low?



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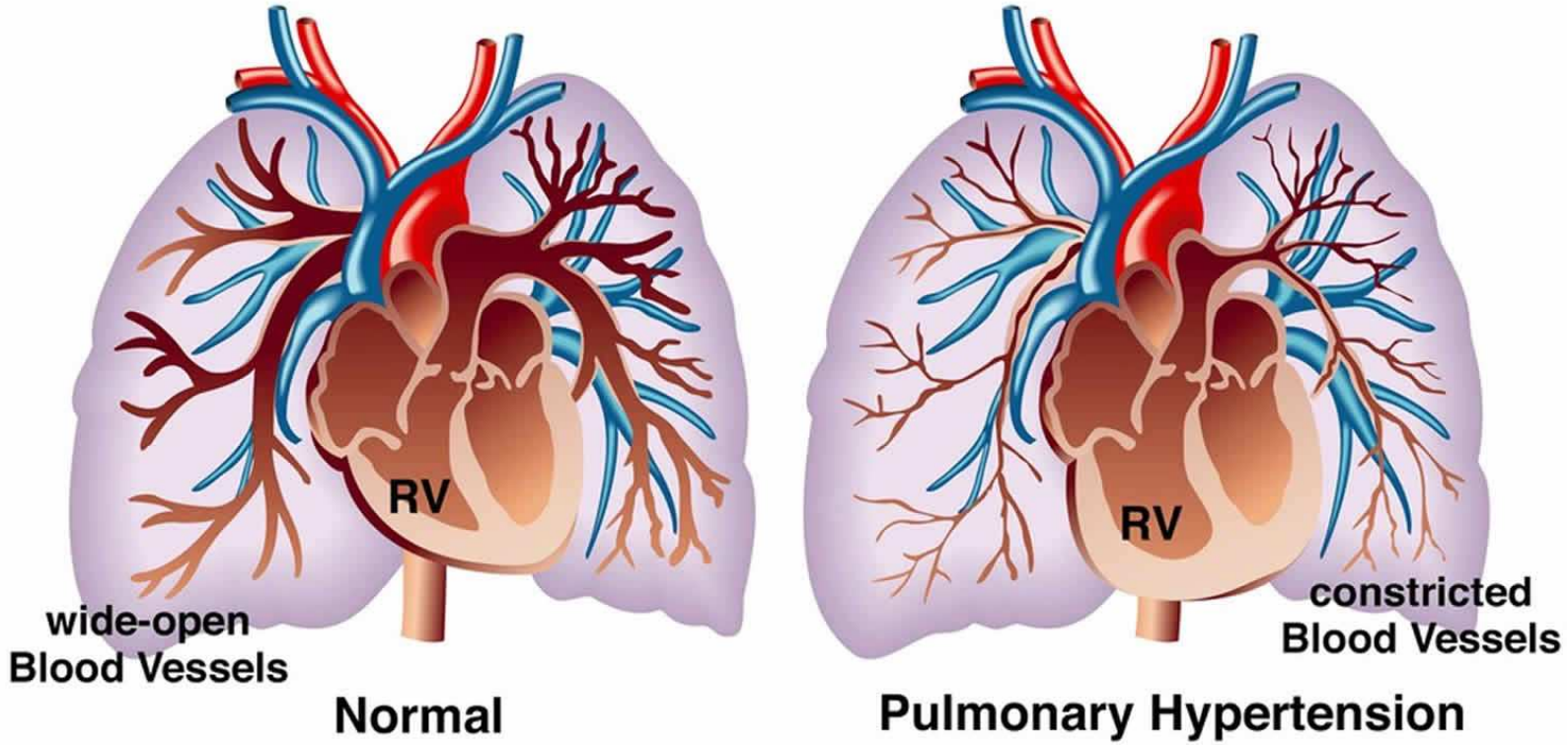
# Abnormal anatomy and physiology



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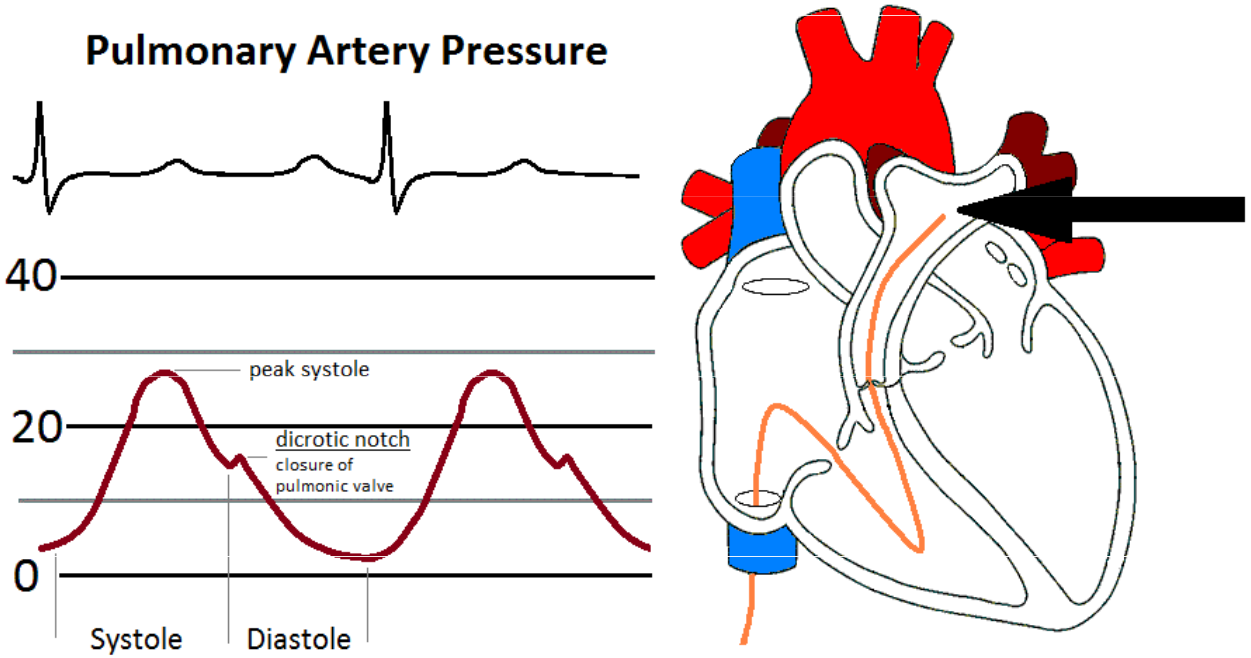
# Abnormal PA pressures in real patients range from 30 to 100 mmHg



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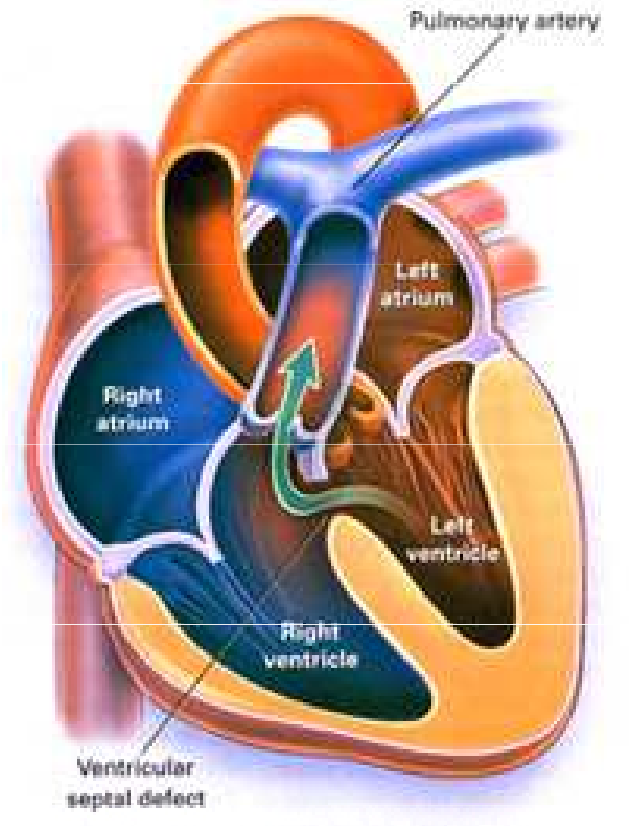
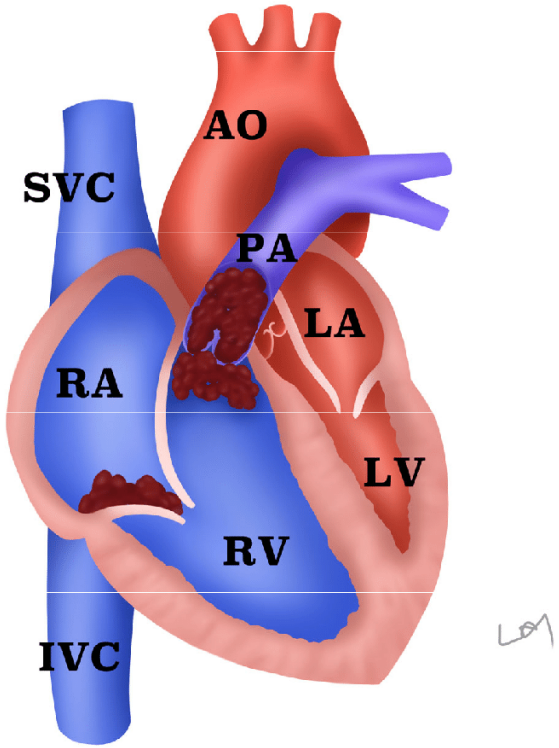
# Ventricular septal defect and pulmonary embolism



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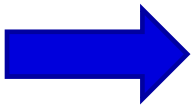
# Blood flow vs. Velocity of blood flow

- **Ohm´s law:**
- BF=BP/R, BP=blood pressure, BF=blood flow, R= resistance of blood vessels
- BF=BP/R

- Velocity of blood flow (v):
- $\Pi \times r^2 . v =$ (constant !!!!!)
- Blood vessels „like“ their natural (physiological) diameter and they have tendency to do it by



remodelling of blood flow

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# Blood flow energy

- Because flowing blood has mass and velocity it has **kinetic energy** (KE). This KE is proportionate to the mean velocity squared ($V^2$; from KE = ½ $mV^2$). Furthermore, as the blood flows inside a vessel, pressure is exerted laterally against the walls of the vessel; this pressure represents the **potential or pressure energy** (PE). The total energy (E) of the blood flowing within the vessel, therefore, is the sum of the kinetic and potential energies (assuming no gravitational effects) as shown below.
- E = KE + PE *(where KE $\propto V^2$)* *Therefore*, E $\propto V^2$ + PE

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# Blood as hemodynamic priority

- **Blood flow is driven by the difference in total energy between two points.** Although pressure is normally considered as the driving force for blood flow, in reality it is the total energy that drives flow between two points (e.g., longitudinally along a blood vessel or across a heart valve). Throughout most of the cardiovascular system, KE is relatively low, so for practical purposes, it is stated that the pressure energy (PE) difference drives flow. When KE is high, however, adding KE to the PE significantly increases the total energy, E. To illustrate this, consider the flow across the aortic valve during cardiac ejection. Late during ejection, the intraventricular pressure (PE) falls slightly below the aortic pressure (PE), nevertheless, flow continues to be ejected into the aorta. The reason for this is that the KE of the blood as it moves across the valve at a very high velocity ensures that the total energy (E) in the blood crossing the valve is higher than the total energy of the blood more distal in the aorta.

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# Energy of blood flow and Bernoulli's Principle

- **Kinetic energy and pressure energy can be interconverted so that total energy remains unchanged.** This is the basis of **Bernoulli's Principle**. This principle can be illustrated by a blood vessel that is suddenly narrowed then returned to its normal diameter. In the narrowed region (stenosis), the velocity increases as the diameter decreases. Quantitatively, $v \propto 1/D^2$ because flow (BF) is the product of mean velocity (v) and vessel cross-sectional area (S) ($BF = v \cdot D$), and S is directly related to diameter (D) (or radius, r) squared (from $S = \pi \cdot r^2$). If the diameter is reduced by one-half in the region of the stenosis, the velocity increases 4-fold. Because $KE \propto v^2$, the KE increases 16-fold. Assuming that the total energy is conserved within the stenosis (E actually decreases because of resistance), then the 16-fold increase in KE must result in a proportionate decrease in PE. Once past the narrowed segment, KE will revert back to its pre-stenosis value because the post-stenosis diameter is the same as the pre-stenosis diameter and flow is conserved. Because of the resistance of the stenosis, and the likelihood of turbulence, the post-stenosis PE and E will both fall.
- To summarize this concept, *blood flowing at higher velocities has a higher ratio of kinetic energy to potential (pressure) energy*.

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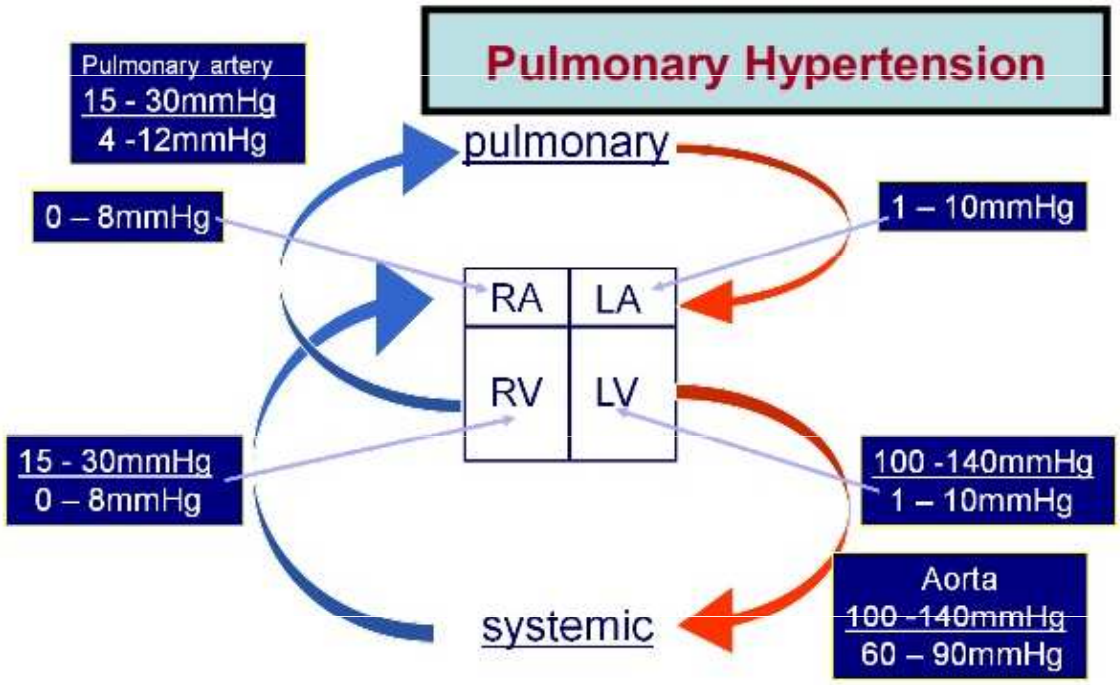
# Many causes of PAH*, Part 1




**Pulmonary hypertension is defined as increased mean pulmonary artery pressure (PAP) to ≥ 25 mmHg at rest as assessed during right heart catheterization. (ULN: 14 ± 3)**



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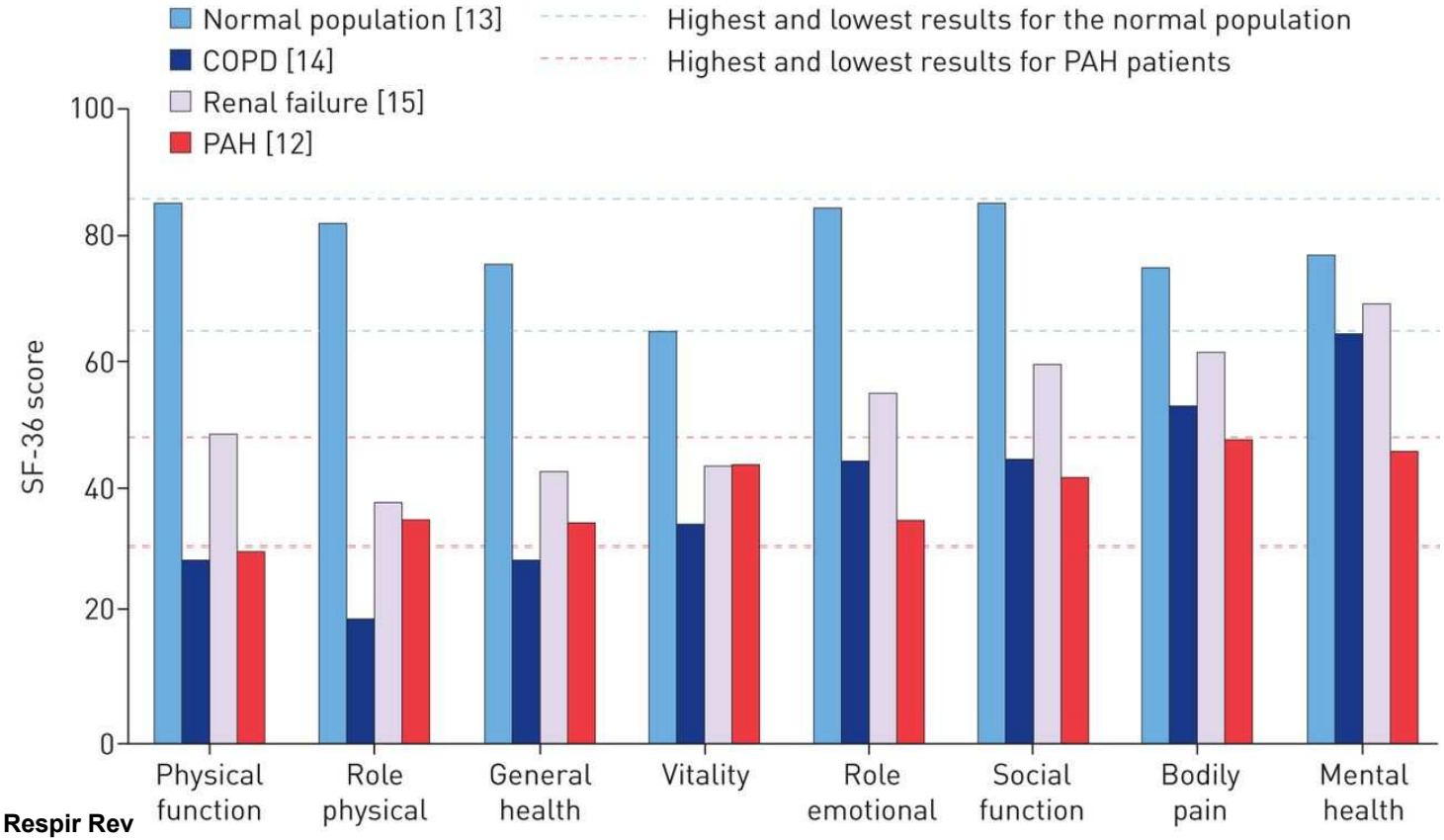
# Effect of pulmonary arterial hypertension (PAH) on SF-36-measured health-related quality of life (HRQoL) measures versus the normal population and other disease conditions [12–15].




Marion Delcroix, and Luke Howard Eur Respir Rev 2015;24:621-629



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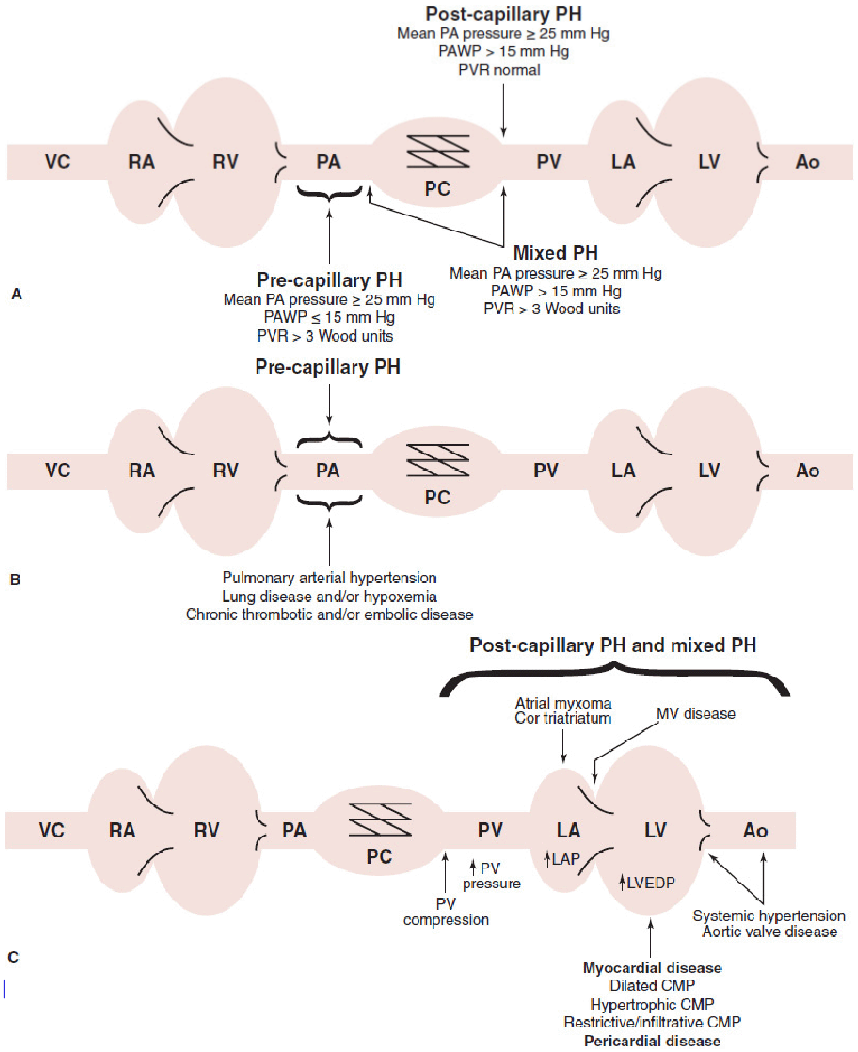
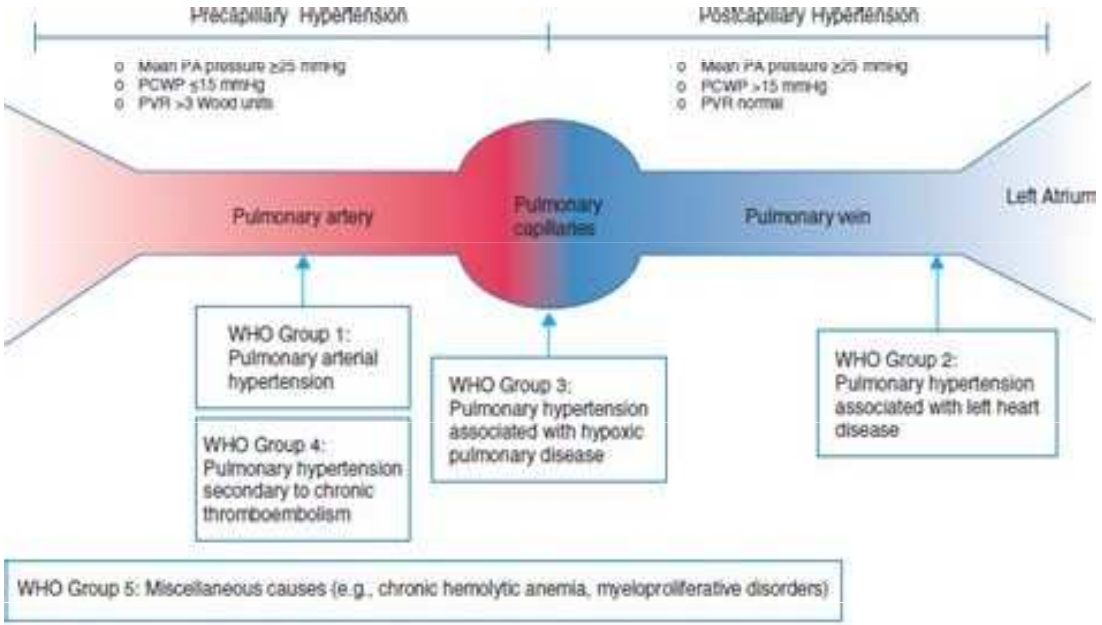
# Precapillary vs. postcapillary PAH




Source: Navin Kumar, Anica Law: Teaching Rounds: A Visual Aid to Teaching Internal Medicine Pearls on the Wards
www.accessmedicine.com

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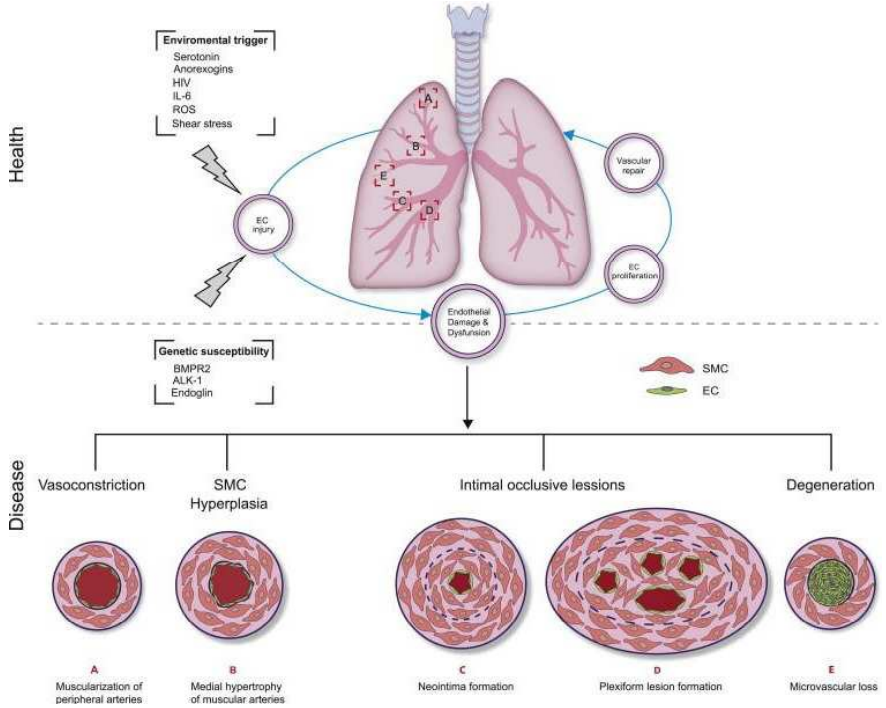
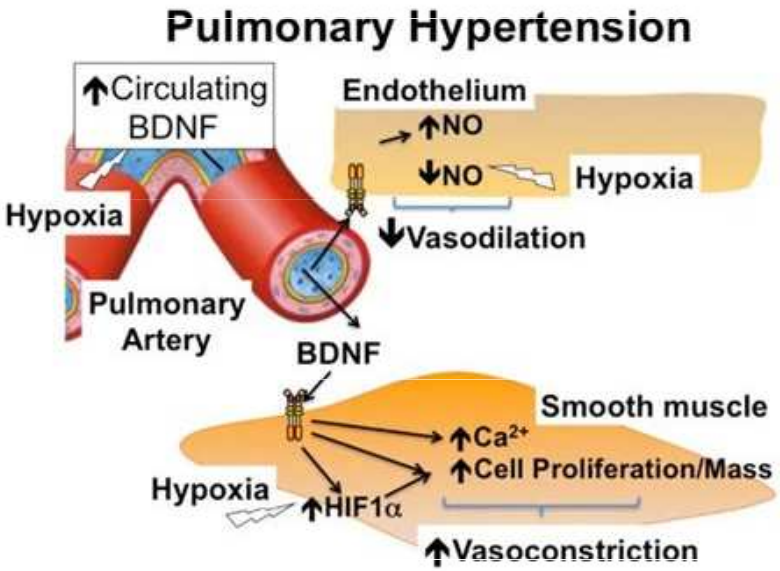
# Pathophysiology of pulmonary hypertension




Continuing Cardiology Education, Volume: 4, Issue: 1, Pages: 2-12, First published: 27 July 2018, DOI: (10.1002/cce2.71)

# Pulmonary vascular disease

is an important risk factor for disease progression and exacerbation risk.
Relative pulmonary artery enlargement on computed tomography scan, defined by a pulmonary artery to aortic (PA:A) ratio >1, has been evaluated as a marker of pulmonary vascular disease.
In healthy patients a PA:A ratio >0.9 is considered to be abnormal.
The PA:A ratio has been compared with invasive hemodynamic parameters, primarily mean pulmonary artery pressure in various disease conditions and is more strongly correlated with mean pulmonary artery pressure in obstructive as compared with interstitial lung disease.
In patients without known cardiac or pulmonary disease, the PA:A ratio is predictive of mortality, while in COPD, an elevated PA:A ratio is correlated with increased exacerbation risk, outperforming other well established predictors of these events.

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# Classification of pulmonary hypertension


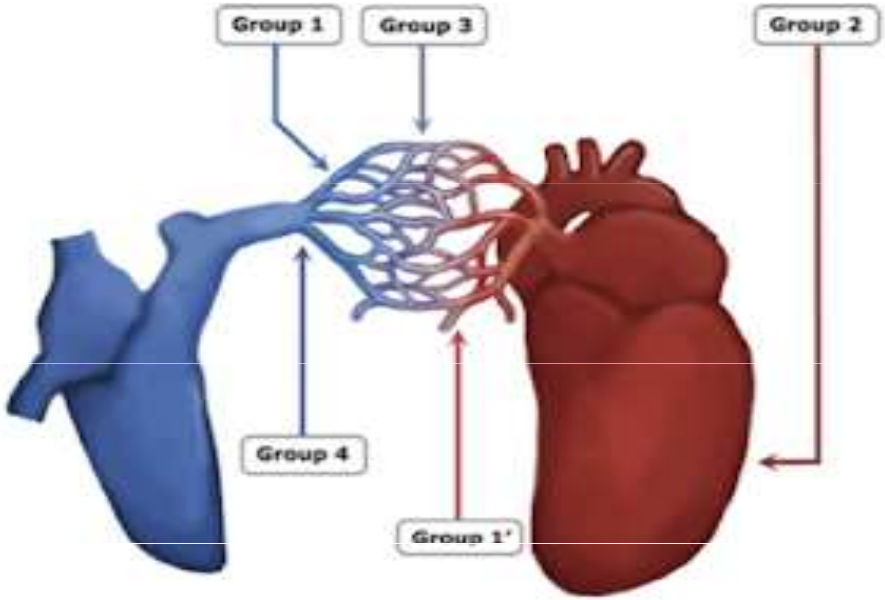


Fig. 1. Anatomic and pathophysiological considerations for patients with PH.

Continuing Cardiology Education, Volume: 4, Issue: 1, Pages: 2-12, First published: 27 July 2018, DOI: (10.1002/cce2.71)

# Group 1 PAH

1.1 Idiopathic PAH
1.2 Heritable PAH
1.2.1 BMPR2
1.2.2 ALK-1, ENG, SMAD9, CAV1, KCNK3
1.2.3 Unknown
1.3 Drug and toxin induced
1.4 Associated with:
1.4.1 Connective tissue disease
1.4.2 HIV infection
1.4.3 Portal hypertension
1.4.4 Congenital heart diseases
1.4.5 Schistosomiasis
1
0
Pulmonary veno-occlusive disease and/or pulmonary capillary hemangiomatosis
1
00
Persistent pulmonary hypertension of the newborn (PPHN)

IPAH
Familial – BMPR2, ALK
1,Unknown Associated
with PAH

- Connective Tissue Disease (Scleroderma, SLE, MCTD, RA)
- Congenital Heart Disease
- Portal hypertension (5-7% of patients)
- HIV (0.5% of patients)
- Drugs/toxins (aminorex-, dexfenfluramine-, or fenfluramine-containing products, cocaine, methamphetamine)
- Other:

hereditary hemorrhagic telangiectasia, hemoglobinopathies, myeloproliferative disorders, splenectomy

Associated with venous/capillary involvement

- Pulmonary veno-occlusive disease (evidence of pulmonary vascular congestion)

– Pulmonary capillary
hemangiomatosis Persistent PH
of newborn.



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# Group 2-3

- Group 2: Pulmonary hypertension due to left heart disease
  - 2.1 Left ventricular systoli c dysfunction
  - 2.2 Left ventricular diasto lic dysfunction
  - 2.3 Valvular disease
  - 2.4 Congenital/acquired left heart inflow/outflow tract obstruction and congenital cardiomyopathies

- Group 3: Pulmonary hypertension associated with lung disease and/or hypoxemia
  - 3.1 Chronic obstructive pulmonary disease
  - 3.2 Interstitial lung disease
  - 3.3 Other pulmonary diseases with mixed restrictive and obstruc-
  - tive pattern
  - 3.4 Sleep-disordered breathing
  - 3.5 Alveolar hypoventilation disorders
  - 3.6 Chronic exposure to high altitude
  - 3.7 Developmental lung diseases



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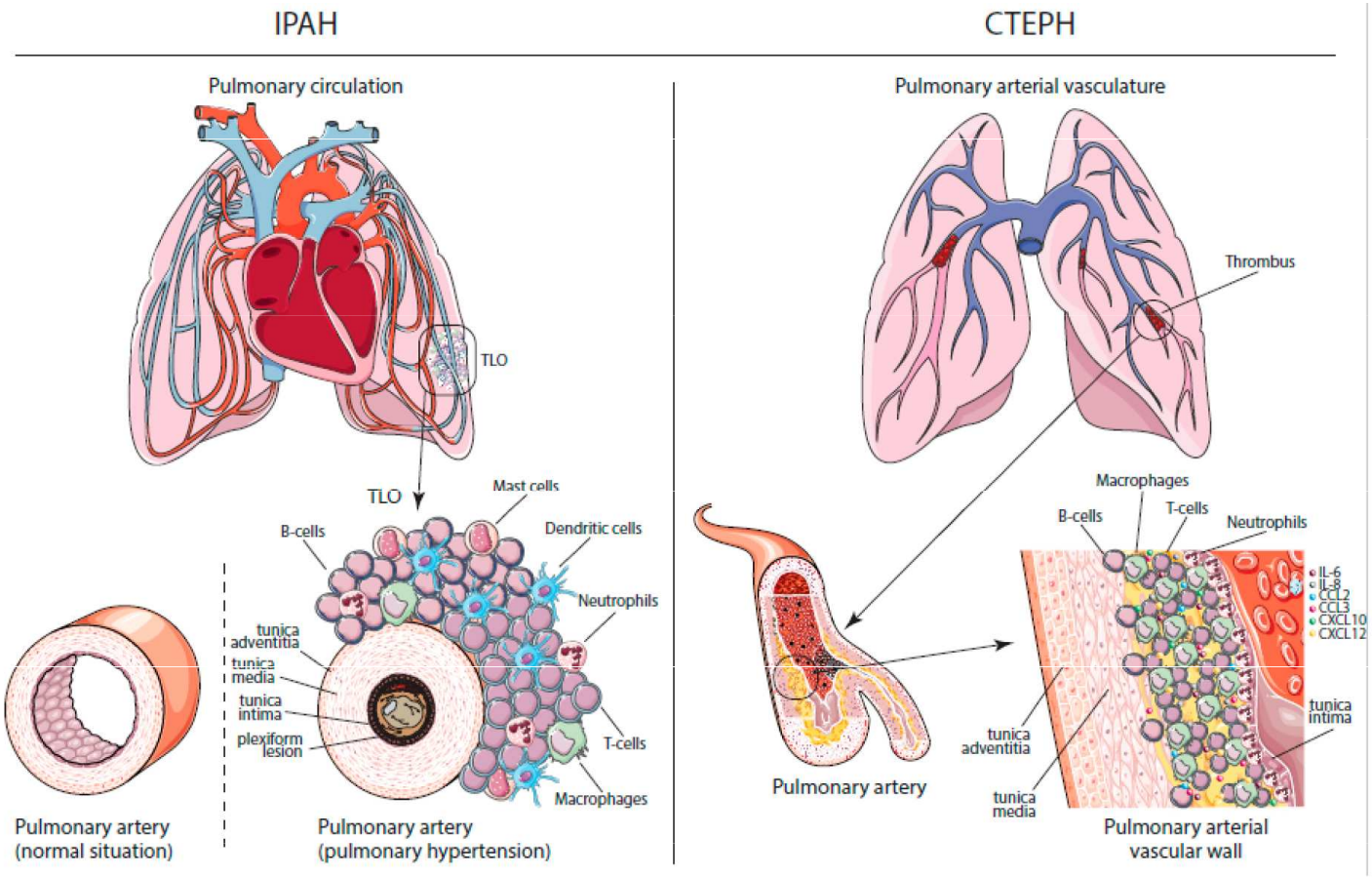
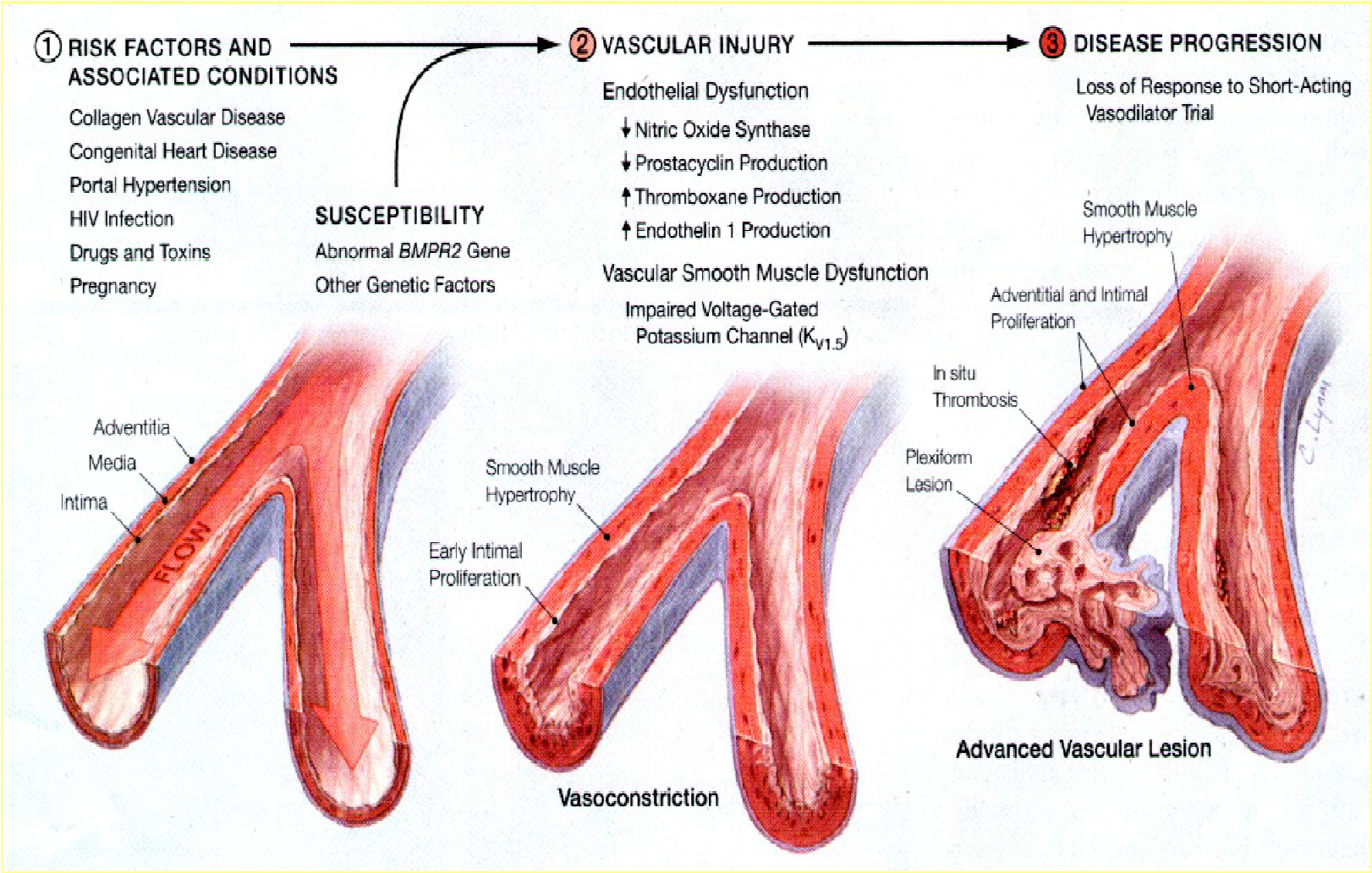
# Differences




Continuing Cardiology Education, Volume: 4, Issue: 1, Pages: 2-12, First published: 27 July 2018, DOI: (10.1002/cce2.71)

# Group 4-5

- Group 4: Pulmonary hypertension due to chronic thrombotic and/or embolic disease
  - Thromboembolic obstruction of proximal pulmonary arteries
  - Thromboembolic obstruction of distal pulmonary arteries
- Group 5: Miscellaneous
  - 5.1 Hematologic disorders: chronic hemolytic anemia, myeloproliferative disorders, splenectomy
  - 5.2 Systemic disorders: sarcoidosis, pulmonary histiocytosis,lymphangioleiomyomatosis
  - 5.3 Metabolic disorders: glycogen storage disease, Gaucher disease, thyroid disorders
  - 5.4 Others: tumoral obstruction, fibrosing mediastinitis, chronic renal failure, segmental PH


1 RISK FACTORS AND ASSOCIATED CONDITIONS
Collagen Vascular Disease
Congenital Heart Disease
Portal Hypertension
HIV Infection
Drugs and Toxins
Pregnancy
SUSCEPTIBILITY
Abnormal BMPR2 Gene
Other Genetic Factors
2 VASCULAR INJURY
Endothelial Dysfunction
↓ Nitric Oxide Synthase
↓ Prostacyclin Production
↑ Thromboxane Production
↑ Endothelin 1 Production
Vascular Smooth Muscle Dysfunction
Impaired Voltage-Gated Potassium Channel ($K_{V1.5}$)
3 DISEASE PROGRESSION
Loss of Response to Short-Acting Vasodilator Trial
Adventitia
Media
Intima
FLOW
Smooth Muscle Hypertrophy
Early Intimal Proliferation
Vasoconstriction
Smooth Muscle Hypertrophy
Adventitial and Intimal Proliferation
In situ Thrombosis
Plexiform Lesion
Advanced Vascular Lesion



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# Group 1 - Pathophysiology

- Exact mechanism – unknown.
- Multifactorial.

1) Excessive vasoconstriction -abnormal function or expression of potassium channels in the smooth muscle cells .

2) Endothelial dysfunction leads to chronically impaired production of vasodilator

NO, prostacyclin, thromboxane A2 and endothelin-1

3) Reduced plasma levels of other vasodilator and antiproliferative substances such as vasoactive intestinal peptide
4) In the adventitia there is increased production of extracellular matrix including collagen, elastin, fibronectin. Inflammatory cells and platelets (through the serotonin pathway)
5) Prothrombotic abnormalities have been demonstrated in PAH patients, and thrombi are present in both the small distal pulmonary arteries and the proximal elastic pulmonary arteries

1. Tunica media hypertrophy
2. Tunica intima proliferation
3. Fibrotic changes of tunica intima

concentric eccentric

4. Tunica adventitial thickening with moderate perivascular infiltrates
5. Complex lesions

Plexiform Dilated

6. Thrombotic lesions.

# Group 2 - Pathophysiology

- Due to lt. heart diseases:
- Pulmonary venous hypertension-most common cause
- Usually due to left-sided heart disease (valvular, coronary or myocardial), ◊obstruction to blood flow downstream from the pulmonary veins.
- Reversibility is variable

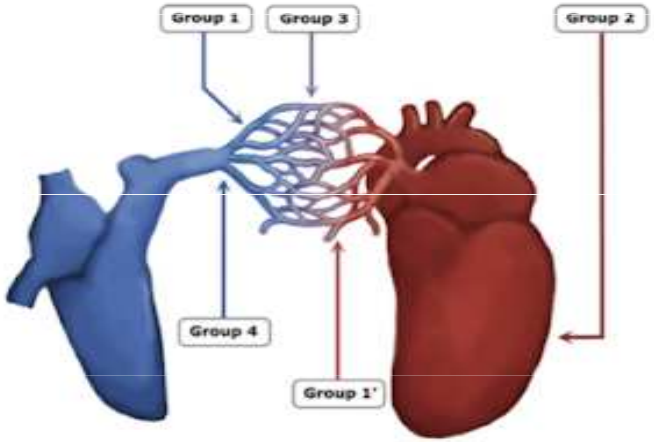


Fig. 1. Anatomic and pathophysiological considerations for patients with PH.



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# Group 3 - Pathophysiology

PH due to lung diseases and/or hypoxia:

Multiple

1) hypoxic vasoconstriction,
2) mechanical stress of hyperinflated lungs,
3) loss of capillaries – emphysema, fibrosis
4)inflammation, and toxic effects of cigarette smoke.
5)endothelium-derived vasoconstrictor–vasodilator imbalance.

Hypoxia induced pulmonary vasoconstriction and anatomical destruction of the vascular bed due to high pulmonary resistance and ultimately RV failure.



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# Group 4-5 - Pathophysiology

- CTEPH: non-resolution of acute embolic masses which later undergo fibrosis leading to mechanical obstruction of pulmonary arteries is the most important process.
- PH with unclear and/or multifactorial mechanisms.

# Reasons to suspect PH

- Unexplained dyspnea despite multiple diagnostic tests
- Typical symptoms (look for Raynaud's)
- Comorbid conditons:
  - CREST, liver disease, HIV, sickle cell, OSA
  - Family history of PAH
  - History of stimulant/anorexigen use



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# Symptoms of PH

| | |
|---|---|
| Dyspnea | 60% |
| Fatigue | 19% |
| Near syncope/syncope | 13% |
| Chest pain | 7% |
| Palpitations | 5% |
| LE edema | 3% |
| Hoarseness of voice (Ortners syndrome) | 2% |



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# Pathophysiology of ARDS

# 2016 ARDS epidemiology

**ARDS stats**

- 170,000 cases/year
- 10 percent of ICU patients diagnosed with ARDS
- 78 percent within 48 hours of admission
- 23 percent of ventilated patients develop ARDS
  - Most develop ARDS within 24 hours of ventilation
- Ventilator stats
  - 8 day LOS
  - 35 percent received >8 ml/kg PBW tidal volumes
  - 82 percent received <12 PEEP
- Cost: $115,000 per hospital stay

## Severe ARDS survivors

- Ventilator LOS 11 days
- ICU LOS 14 days
- Hospital LOS 26 days

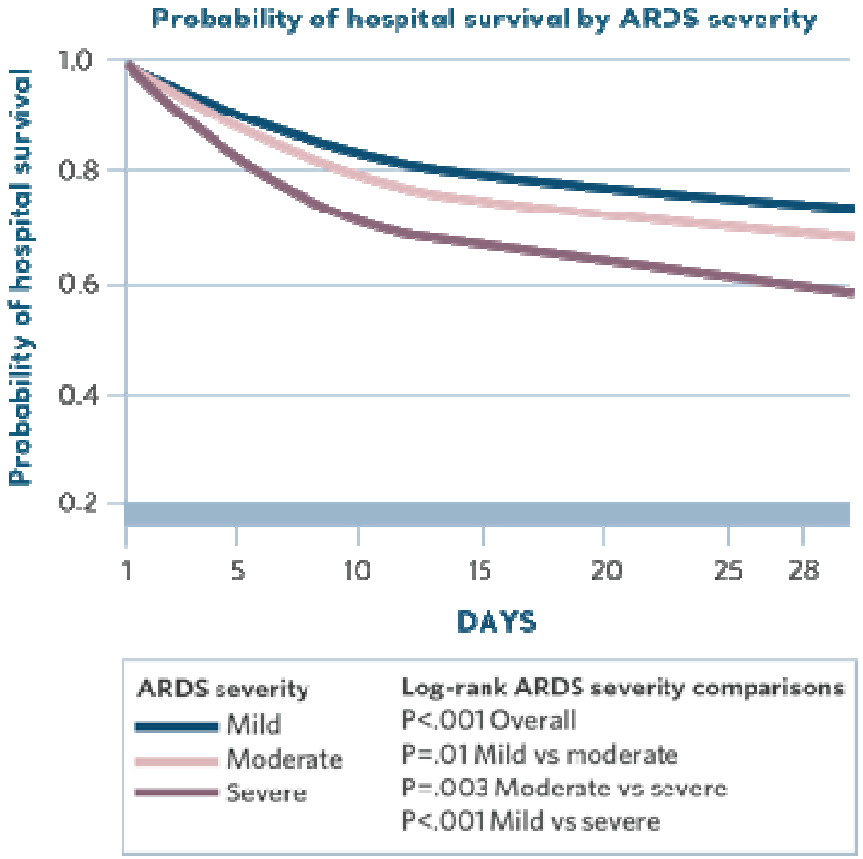
Bellaini, et al (2017). Epidemiology, patterns of care, and mortality for patients with acute respiratory distress syndrome in intensive care units of 50 countries. *Journal of American Medical Association*, 315 (8),: 788-800.

# 2016 ARDS epidemiology *continued*

**Identification and diagnosis of ARDS is lacking**

- 40 percent of all cases *never diagnosed* with ARDS
- Only 34 percent of ARDS cases being identified when criteria is met

**Opportunity to improve outcomes with *early identification and intervention***




Bellaini, et al (2017). Epidemiology, patterns of care, and mortality for patients with acute respiratory distress syndrome in intensive care units of 50 countries. *Journal of American Medical Association*, 315 (8),: 788-800.

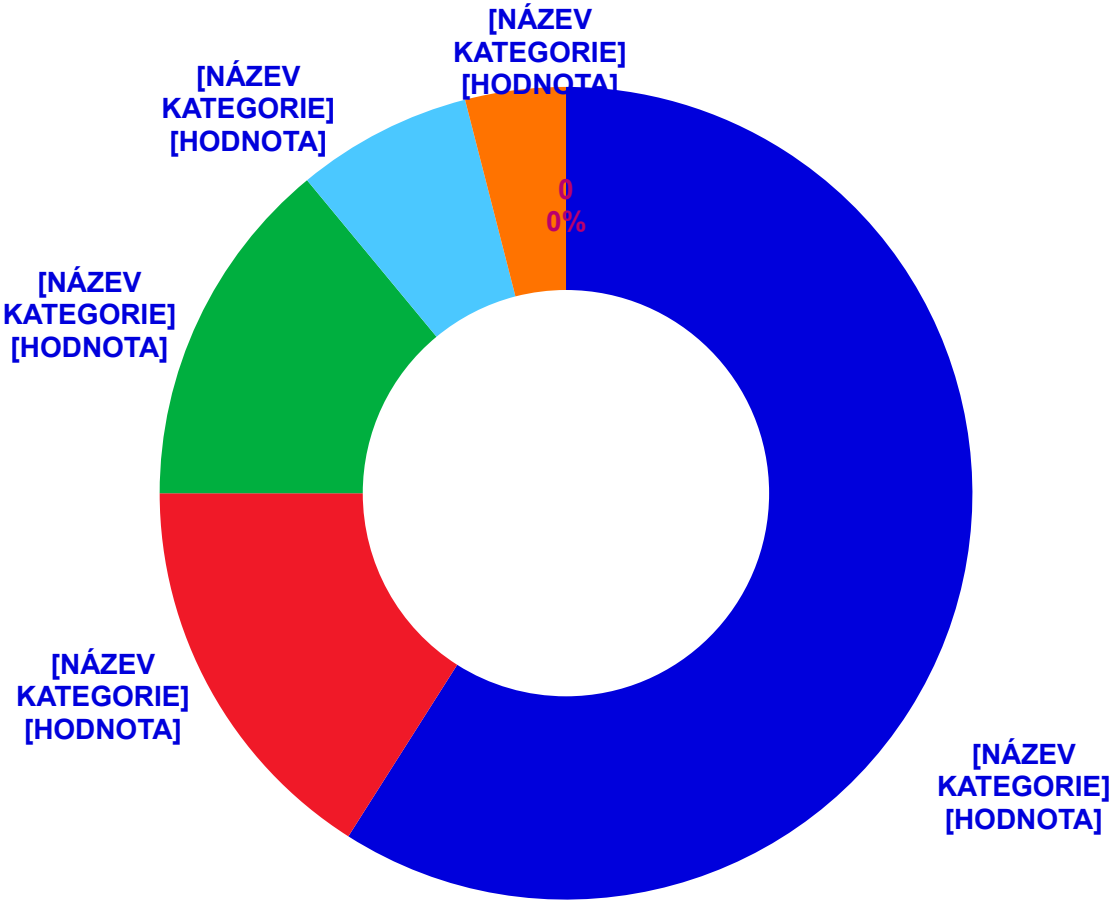
# Causes of ARDS

**Direct injury**

- Pulmonary contusion
- Pneumonia
- Aspiration of gastric contents
- Inhalation of toxins
- Pulmonary infection (flu/H1N1)
- Oxygen toxicity

**Indirect injury**

- Sepsis syndrome
- Multiple transfusions
- Trauma
- Pancreatitis
- Cardiopulmonary bypass
- DIC

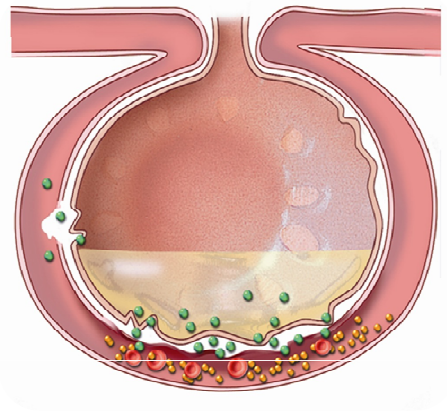


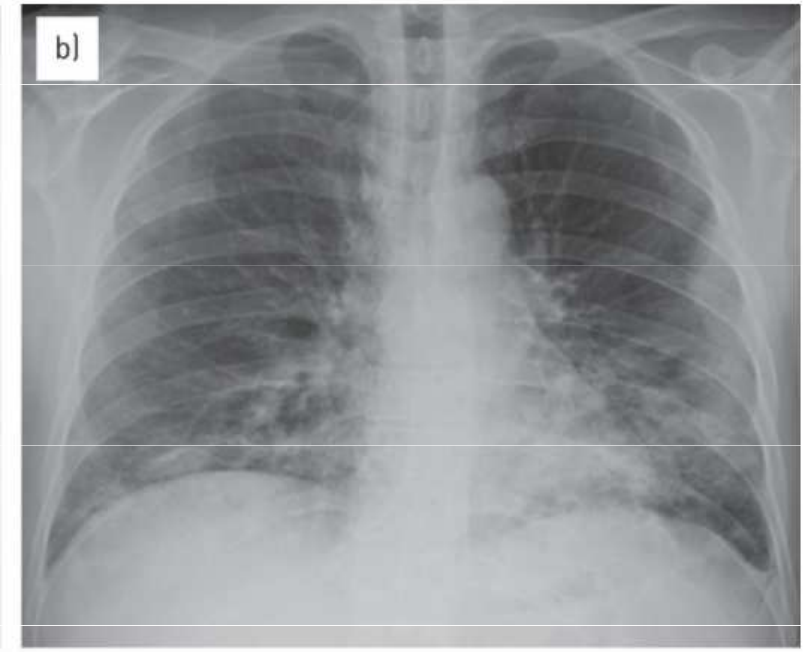


- Bellaini, et al (2017). Epidemiology, patterns of care, and mortality for patients with acute respiratory distress syndrome in intensive care units of 50 countries. *Journal of American Medical Association*, 315 (8),: 788-800.
- 2000 ARDSnet study- patient population diagnoses.*The New England Journal of Medicine*, (342) 18.

# Phases of ARDS

- Phase no. 1 – Injury or Exudative
  *1-7 days post-injury, 50 percent of cases within 24 hours of event*
- Pathophysiology
- Reduced blood flow to lungs
- Inflammatory mediator release
- Increased capillary permeability
- Intrapulmonary shunting begins
- Symptoms
- Refractory hypoxemia
- Increased respiratory rate
- Decreased tidal volume
- Respiratory alkalosis
- CXR infiltrates







- Levy, B., Shapiro, S., and Choi., A. Acute Respiratory Distress Syndrome. *Critical Care Medicine* Chapter 268, retrieved from http://media.axon.es/pdf/83592.pdf
- Zompatori, M., Ciccarese, F., and Fasano, L. Overview of current lung imaging in acute respiratory distress syndrome. *European Respiratory Review*, 2014; 23: 519-530.

# Phases of ARDS

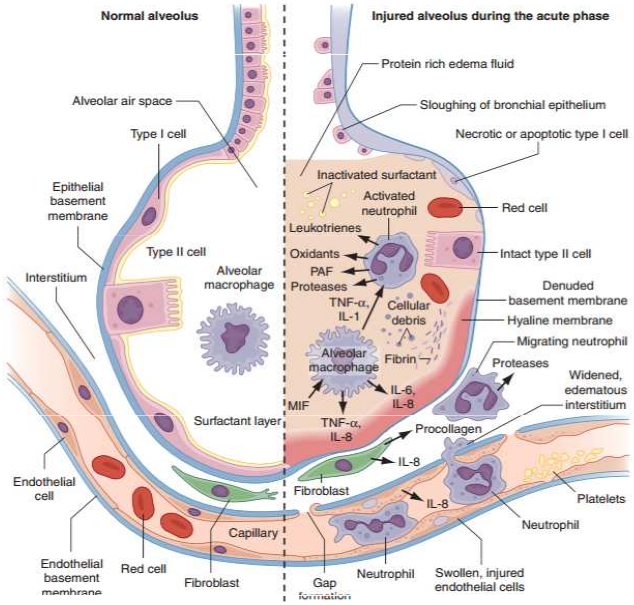
Phase no. 2 – Reparative or Proliferative *1-2 weeks after initial injury*

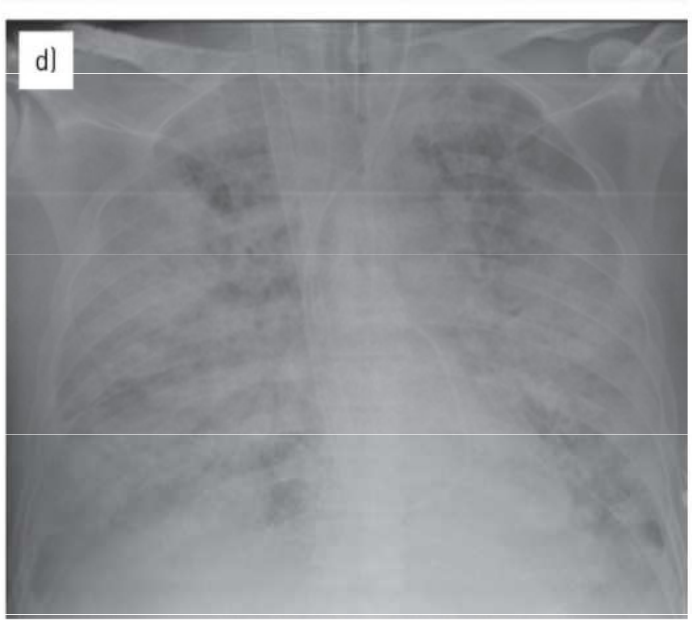
**Pathophysiology**

- Increased capillary permeability
- Protein and fluid leakage
- Pulmonary edema
- Alveolar collapse

**Symptoms**

- Decreased lung compliance
- Worsened hypoxia
- CXR “white out”





Levy, B., Shapiro, S., and Choi., A. Acute Respiratory Distress Syndrome. *Critical Care Medicine* Chapter 268, retrieved from http://media.axon.es/pdf/83592.pdf

Zompatori, M., Ciccarese, F., and Fasano, L. Overview of current lung imaging in acute respiratory distress syndrome. *European Respiratory Review* 2014; 23: 519-530.

# Phases of ARDS

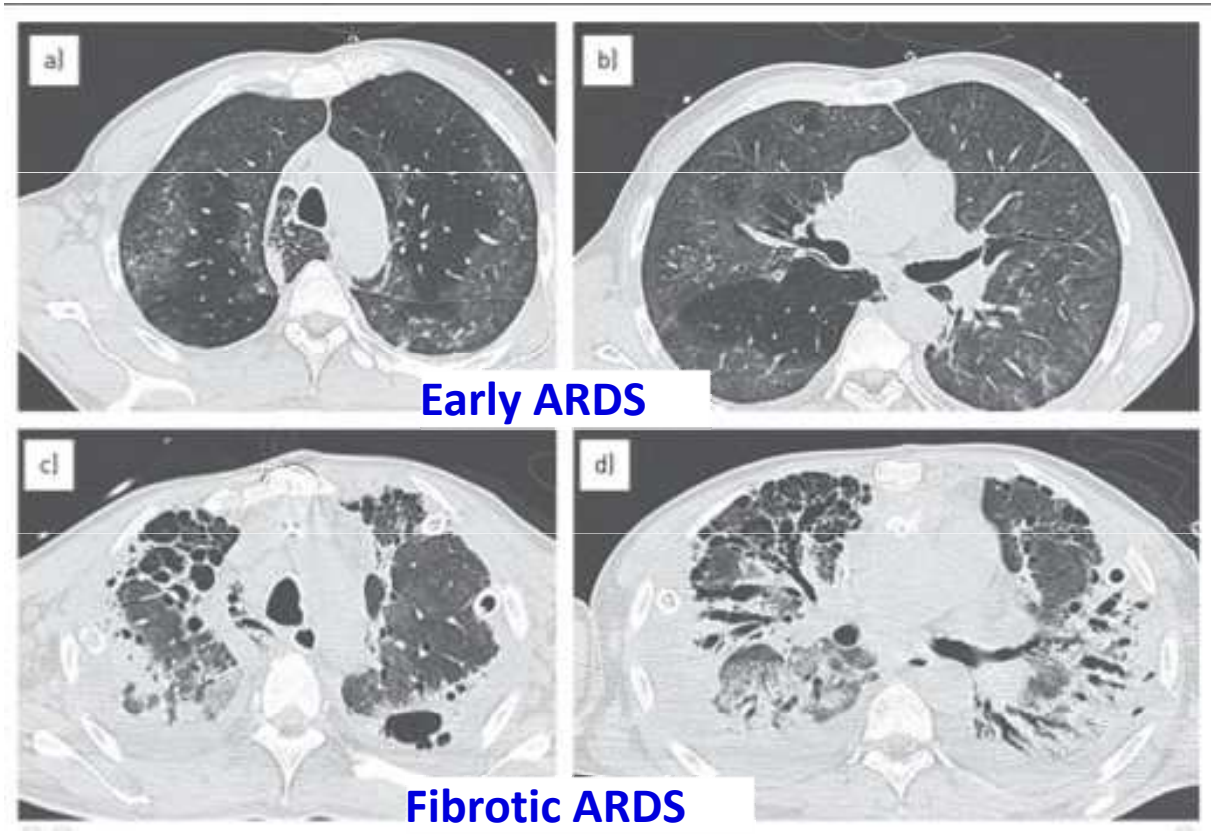
Phase no. 3 – Fibrotic or Chronic
*2-3 weeks after injury*

**Pathophysiology**

- Fibrous tissue throughout lung
- Diffuse scarring

**Symptoms**

- Severe acidosis on ABG
- Overwhelming hypoxemia
- Multi-organ dysfunction (MODS)
- Hypotension
- Low urine output




Zompatori, M., Ciccarese, F., and Fasano, L. Overview of current lung imaging in acute respiratory distress syndrome. *European Respiratory Review*, 2014; 23: 519-530.

# Calculating $PaO_2$ / $FiO_2$ ratio

It is important to consider *how much oxygen* a patient requires to achieve their $PaO_2$ on an ABG. The P/F ratio is a very useful tool to monitor your patient's oxygenation status.

**$PaO_2$ / $FiO_2$= P/F Ratio**

Healthy adult $PaO_2$ = 80-100 mmHg

Room air = 21 percent oxygen

100/.21 = P/F ratio 476 for a healthy adult

$$\frac{PaO_2}{FiO_2} = \text{P/F ratio}$$

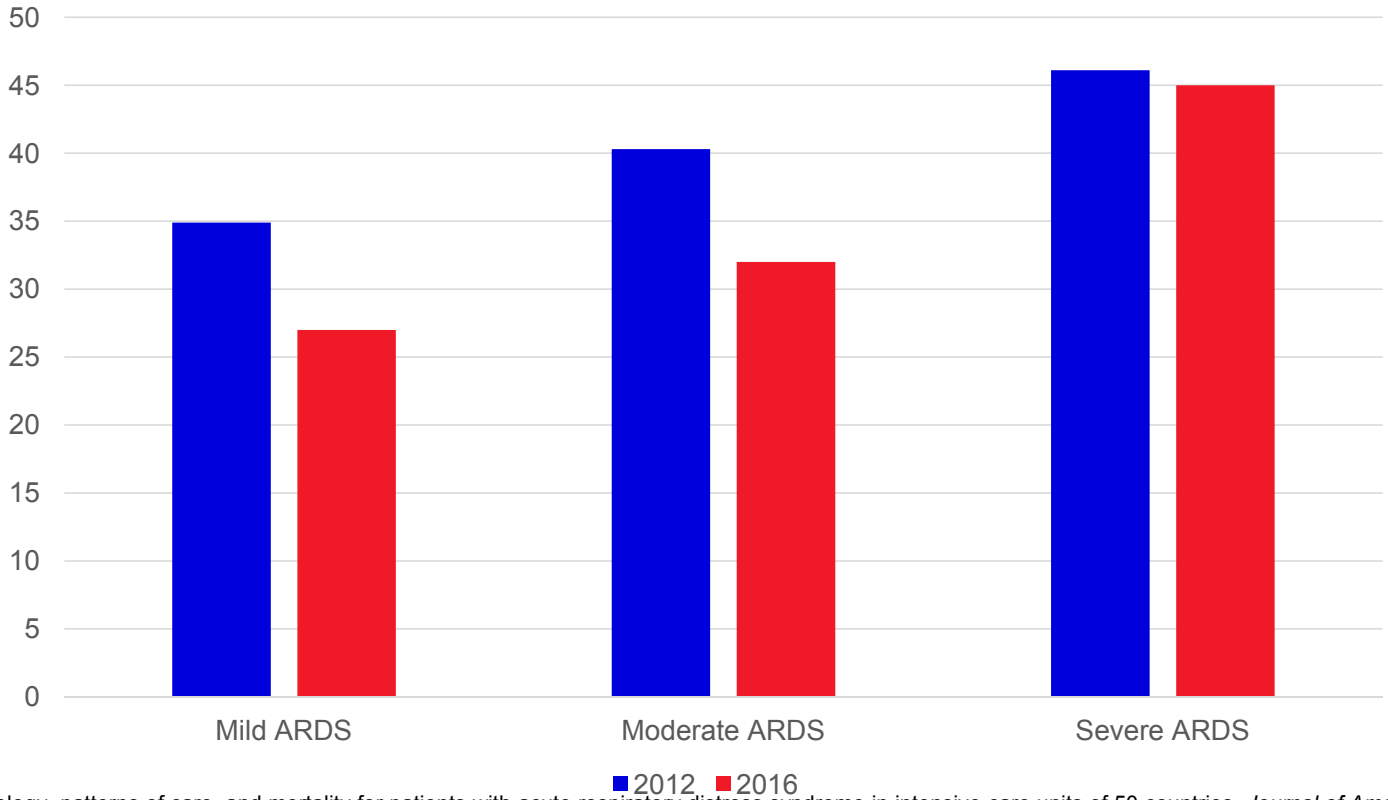
European Society of Intensive Care. Medicine, *Journal of American Medical Association* June 2012: 307 (23).

# 2012 Berlin ARDS definition

| 2012 BERLIN ARDS DEFINITION | | | |
|---|---|---|---|
| | **Mild** | **Moderate** | **Severe** |
| **Timing** | Acute onset within 1 week of known clinical consult or new/worsening symptoms | | |
| **Hypoxemia** | $PaO_2$ / $FiO_2$ <300->200 with PEEP ≥ 5 | $PaO_2$ / $FiO_2$ <200->100 with PEEP ≥ 5 | $PaO_2$ / $FiO_2$ ≤100 with PEEP ≥ 5 |
| **Origin of Edema** | Respiratory failure not fully explained by cardiac failure or fluid overload objective assessment if no risk factors present | | |
| **Radiologic Abnormalities** | Bilateral chest opacities | Bilateral chest opacities | Opacities involving at least 3 quadrants |


1. Munro, C.L. and Savel, R. H. *A, Journal of Critical Care*, Sept. 2012. http://ajccjournals.org/content/21/5/305.
2. European Society of Intensive Care. Medicine, *Journal of American Medical Association*, June 2012: 307 (23).

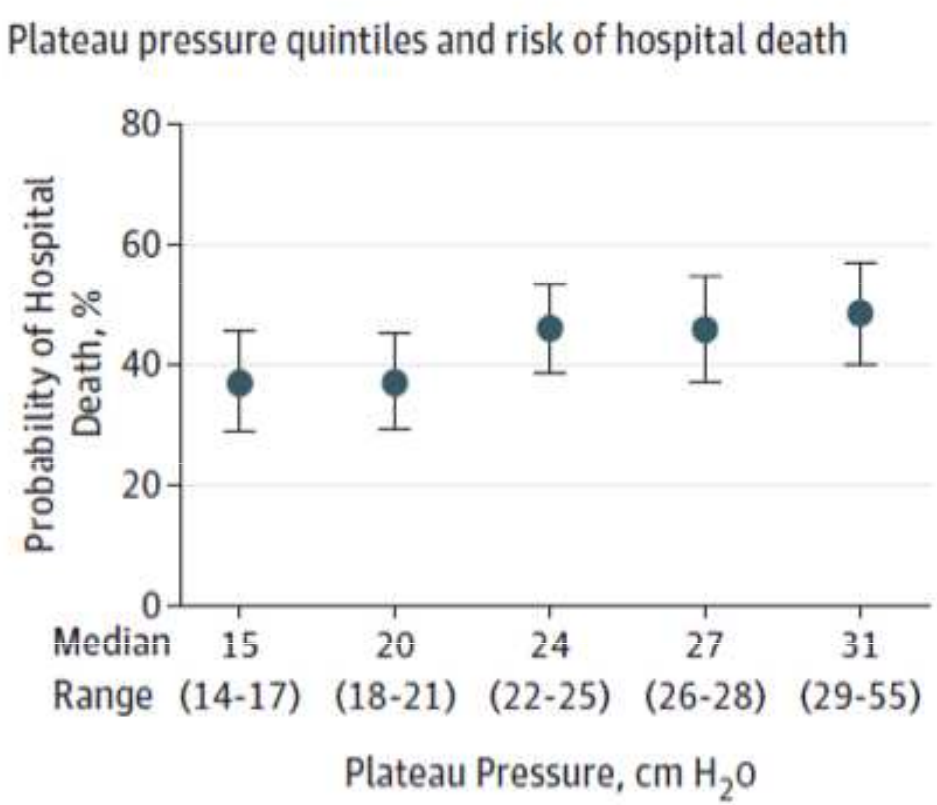
# ARDS mortality rates 2012 to 2016




Bellaini, et al (2017). Epidemiology, patterns of care, and mortality for patients with acute respiratory distress syndrome in intensive care units of 50 countries. *Journal of American Medical Association*, 315 (8): 788-800.

# ARDS predictors of mortality

- Severity of hypoxemia
- Infection/sepsis
- Multi-organ dysfunction
- Positive fluid balance
- Age
- Patients with higher plateau pressures have higher risks of death (>20 cm $H_20$)




Bellaini, et al (2017). Epidemiology, patterns of care, and mortality for patients with acute respiratory distress syndrome in intensive care units of 50 countries. *Journal of American Medical Association*, 315 (8): 788-800.

# P/F ratio calculation

Let's do a quick analysis of an ICU patient diagnosed with pneumonia and recently intubated:

**ABG**

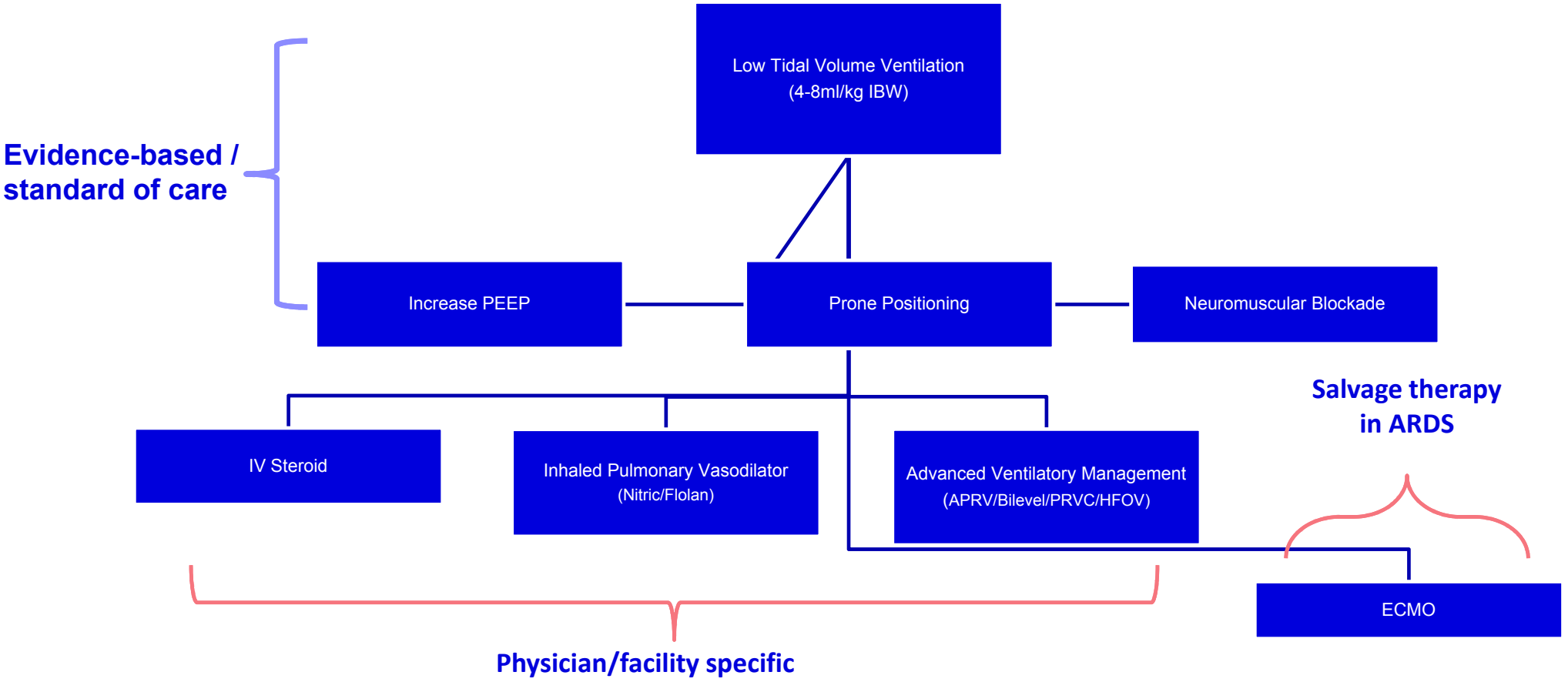
pH **7.12** $PaO_2$ **80** $HCO_3$ **19** $CO_2$ **60** $FiO_2$ **80%**

What is their P/F ratio and their stage in ARDS?

$$\frac{PaO_2}{FiO_2} \quad \frac{80}{.6}$$

P/F ratio
133
Moderate
ARDS

# Treatment modalities for ARDS



# Why does prone positioning work?

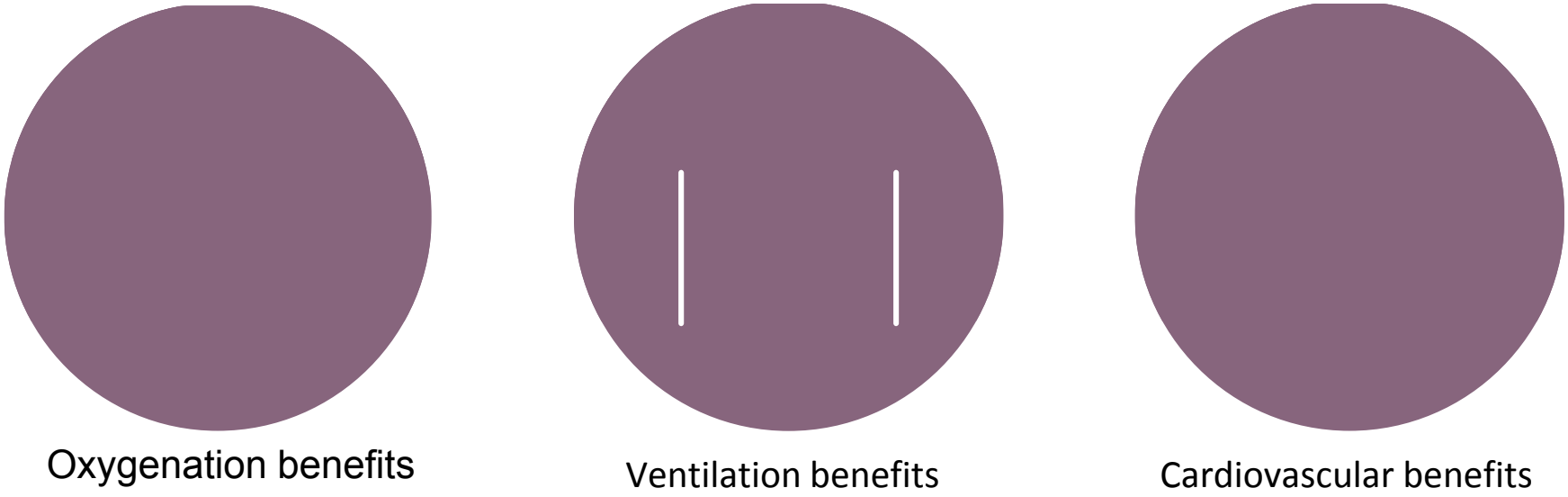
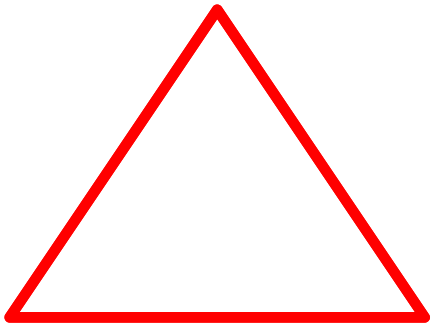


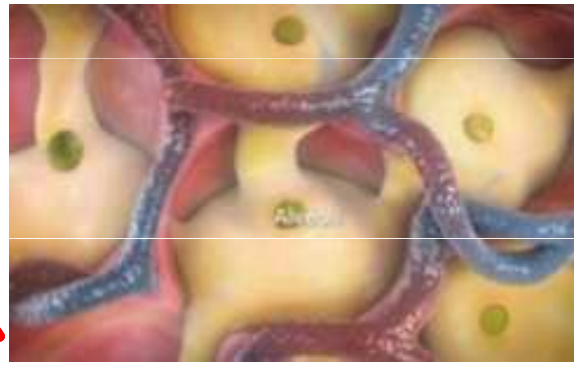

**Figure 1.** Pelosi, et al. Prone position in acute respiratory distress syndrome. *European Respiratory Journal*, 2002; 20(4): 1017-1028

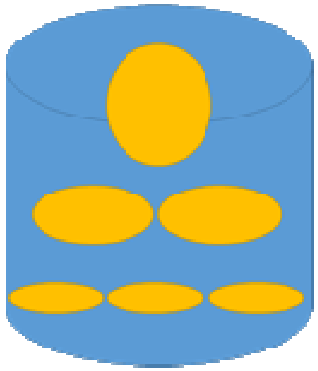

What do you do when you
are out of breath?

## Oxygenation benefits

- **Shape of the lungs**
  Dependent fluid accumulation
- **Alveolar recruitment**
  Mobilization of secretions
- **Downward shape of esophagus**
  Secretions!





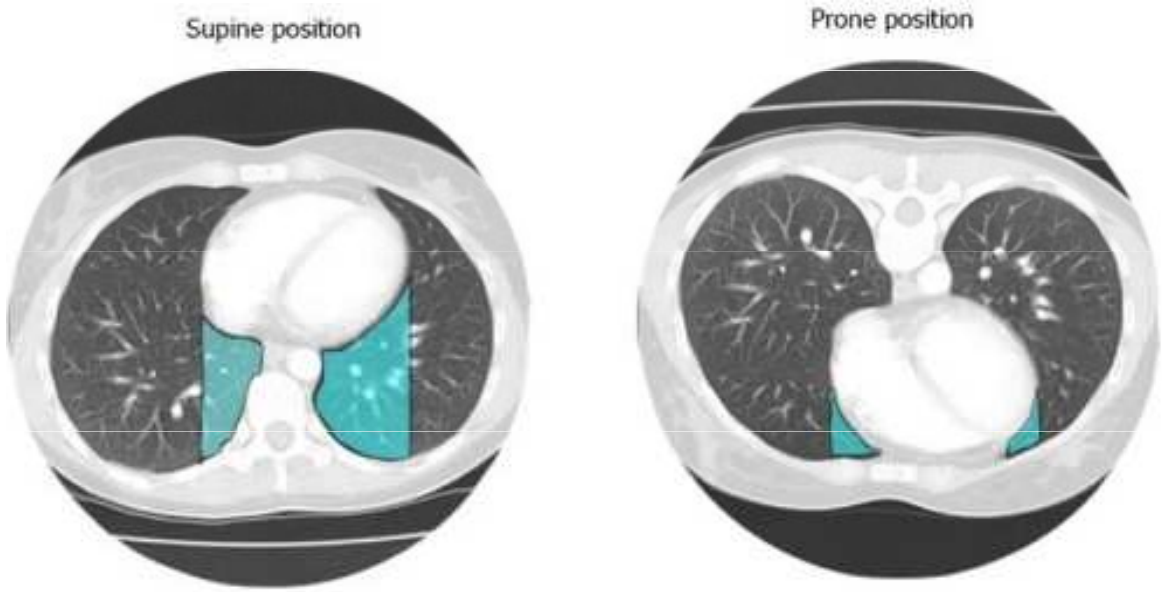


**~ 75 percent** of patients will have an increase in oxygenation in the prone position.

Mackenzie, CF. Anatomy, Physiology, and pathology of the prone position and postural drainage. *Critical Care Medicine,* 2001;29(5): 1084-1085.

# Cardiovascular benefits

- **Relief of pressure of heart on lungs**
  - Improved tidal volume
  - Reduced pressure on right ventricle
    - Supine compression of the lungs from the heart is ~20 percent
    - Prone compression of the lungs is ~3.5 percent
- **Perfusion preferentially directed to dorsal lung regions**
- **Removal of abdominal pressure reduces pressure on vena cava to improve venous return**



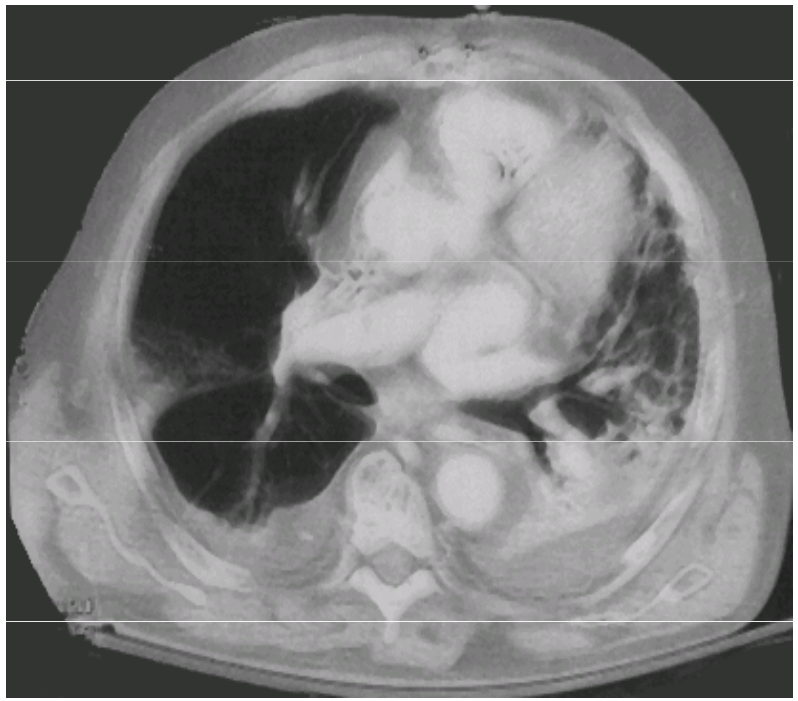


- Murray, T. A. and Patterson, L.A. Prone positioning of trauma patients with acute respiratory distress syndrome and open abdominal incisions. *Critical Care Nurse*, June 2002; 22 (3): 52-56.
- From *Cardiopulmonary Anatomy & Physiology* 4th edition by DESJARDINS. ©2002. Reprinted with permission of Delmar Learning, a division of Thomson Learning: www.thomsonrights.com. Fax 800 730-2215
- Anzueto, A., and Gattinoni, L. Prone position and acute respiratory distress syndrome. *Acute Respiratory Distress Syndrome*. 2003. New York: Marcel Dekker, Inc.

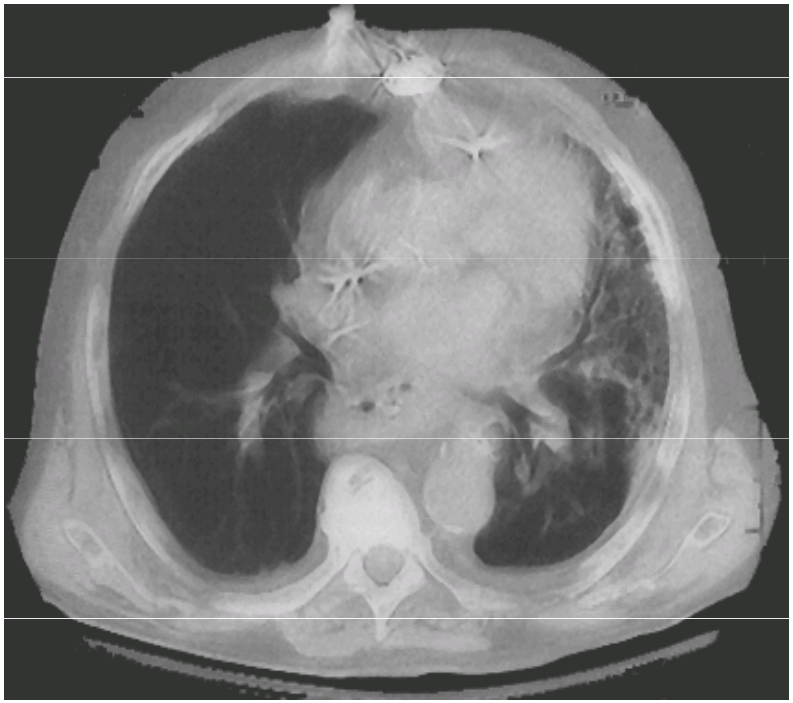
## Physiologic effects prone vs. supine

| Supine | Prone |
|---|---|
| Decreased lung volumes | Increased lung volumes |
| Accumulation of atelectasis in dependent regions | Facilitation of secretion drainage |
| Refractory hypoxemia exacerbated by accumulation of secretions in dependent regions of lungs | Increased oxygenation due to mobilization of secretions and alveolar recruitment |
| Regional and gravitational differences in lungs increase V/Q mismatch and increased stress and strain on the lung | Optimized ventilation due to smaller vertical pleural pressure gradient, increased FRC and more even gas volume distribution |

# ARDS lung and effect of proning



At enrollment



After 2 days of proning

Images courtesy of Frank Sebat, M.D.

# Restrictive lung diseases

1. Alteration in lung parenchyma.

2. Diseases of the pleura, chest wall or neuromuscular apparatus.

Physiologically restrictive lung diseases are defined by reduced total lung capacity, vital capacity and functional residual capacity, but with preserved air flow.

Restrictive lung diseases may be divided into the following groups:

- Intrinsic lung diseases (diseases of the lung parenchyma)

- Extrinsic disorders (extra-parenchymal diseases)

# Intrinsic lung diseases

These diseases cause either:

- Inflammation and/or scarring of lung tissue (interstitial lung disease)

or

- Fill the air spaces with exudate and debris (pneumonitis).

- These diseases are classified further according to the etiological factor.

# Extrinsic lung disorders

The chest wall, pleura and respiratory muscles are the components of respiratory pump.

Disorders of these structures will cause lung restriction and impair ventilatory function.

These are grouped as:

- Non-muscular diseases of the chest wall.
- Neuromuscular disorders.

# Pathophysiology

## Intrinsic lung diseases:

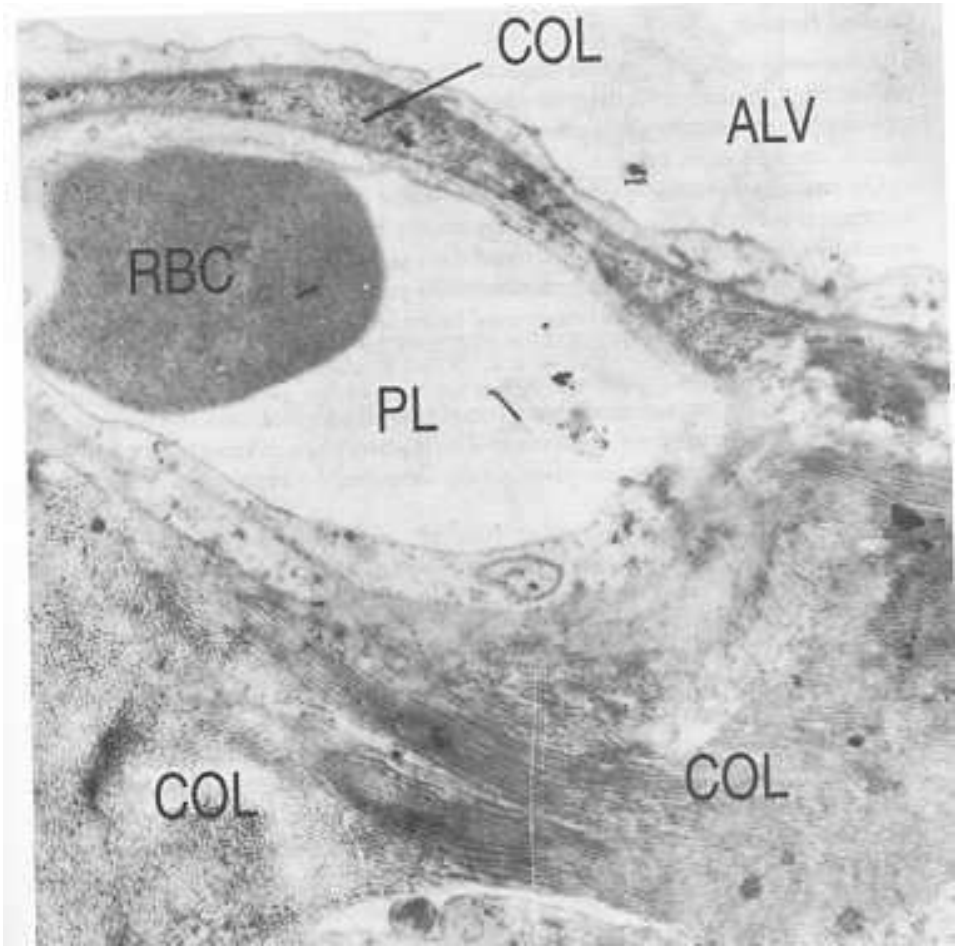
- Diffuse parenchymal disorders cause reduction in all lung volumes.
- This is produced by excessive elastic recoil of the lungs.
- Expiratory flows are reduced in proportion to lung volumes.
- Arterial hypoxemia is caused by ventilation/perfusion mismatch.
- Impaired diffusion of oxygen will cause exercise-induced desaturation.
- Hyperventilation at rest secondary to reflex stimulation.

# Extrinsic Disorders

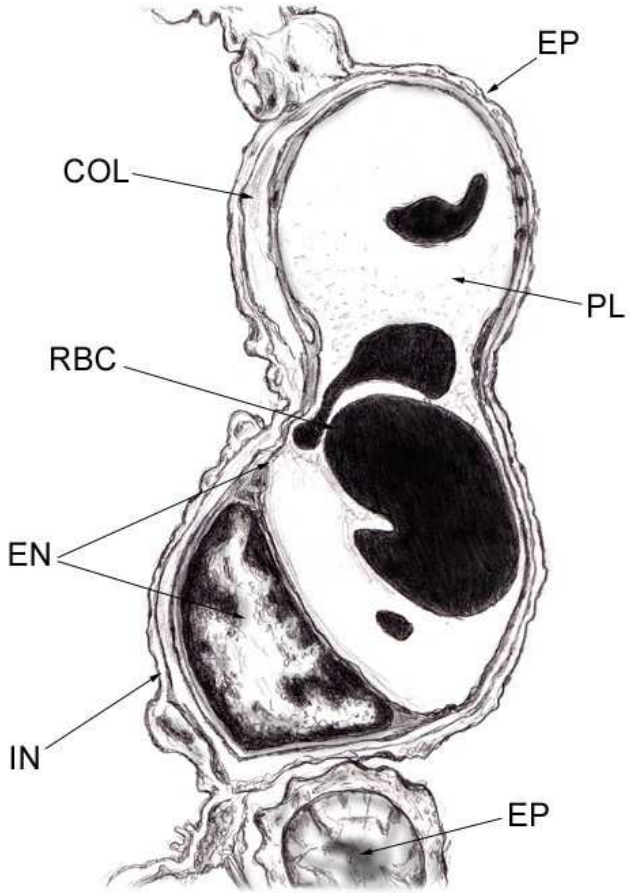
- Diseases of the pleura, thoracic cage, decrease compliance of respiratory system.
- There is reduction in lung volumes.
- Secondarily, atelectasis occurs leading to V/Q mismatch ➜ hypoxemia.
- The thoracic cage and neuromuscular structures are a part of respiratory system.
- Any disease of these structures will cause restrictive disease and ventilatory dysfunction.

# Diseases of the Lung Parenchyma

# EM in Pulmonary Fibrosis




# Structure of the Alveolar Wall



# Diffuse Interstitial Pulmonary Fibrosis

- Synonyms: idiopathic pulmonary fibrosis, interstitial pneumonia, cryptogenic fibrosing alveolitis.

## Pathology

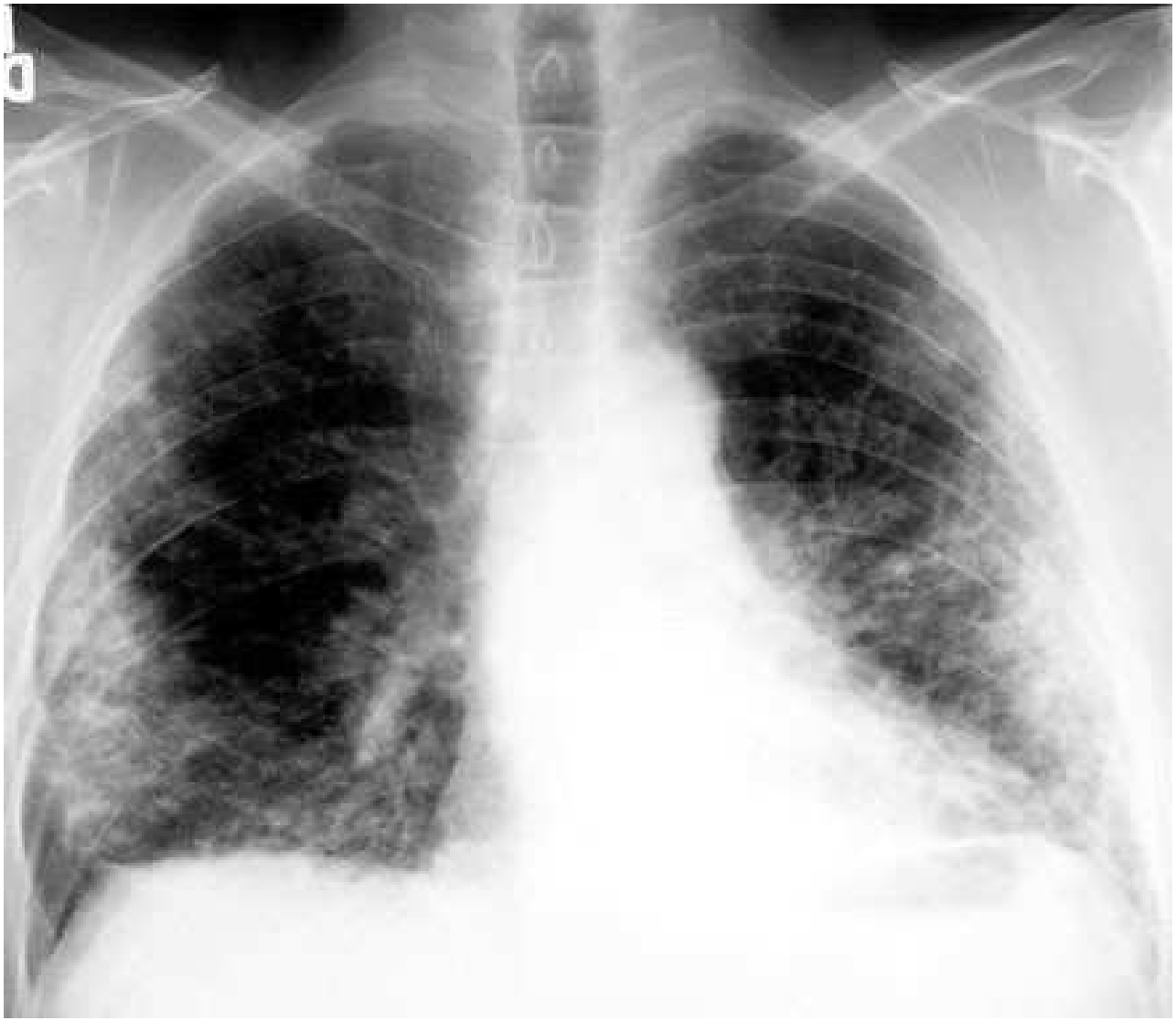
- Thickening of interstitium.
- Initially, infiltration with lymphocytes and plasma cells.
- Later fibroblasts lay down thick collagen bundles.
- These changes occur irregularly within the lung.
- Eventually alveolar architecture is destroyed – honeycomb lung

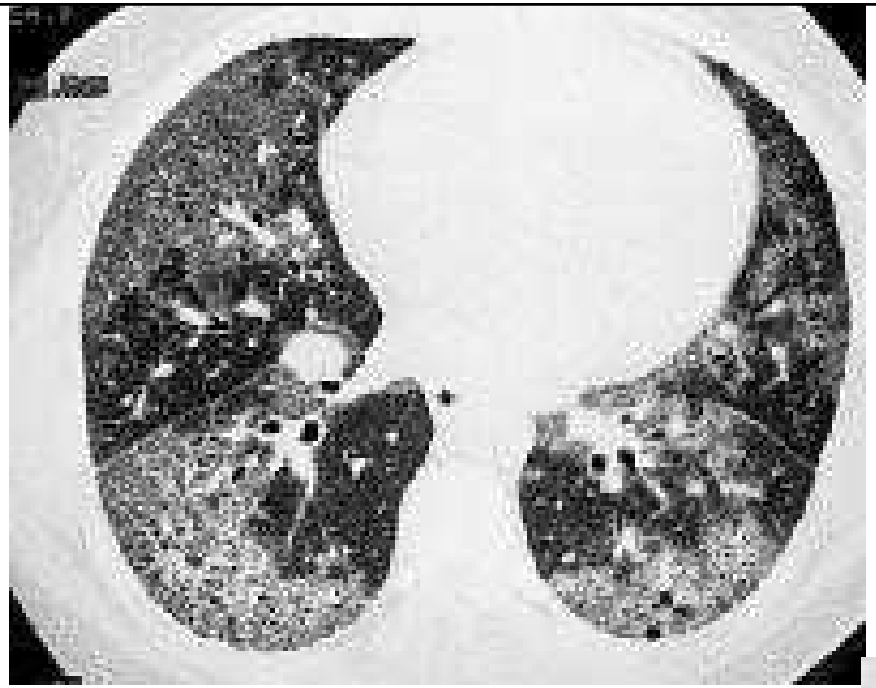
## Pathogenesis

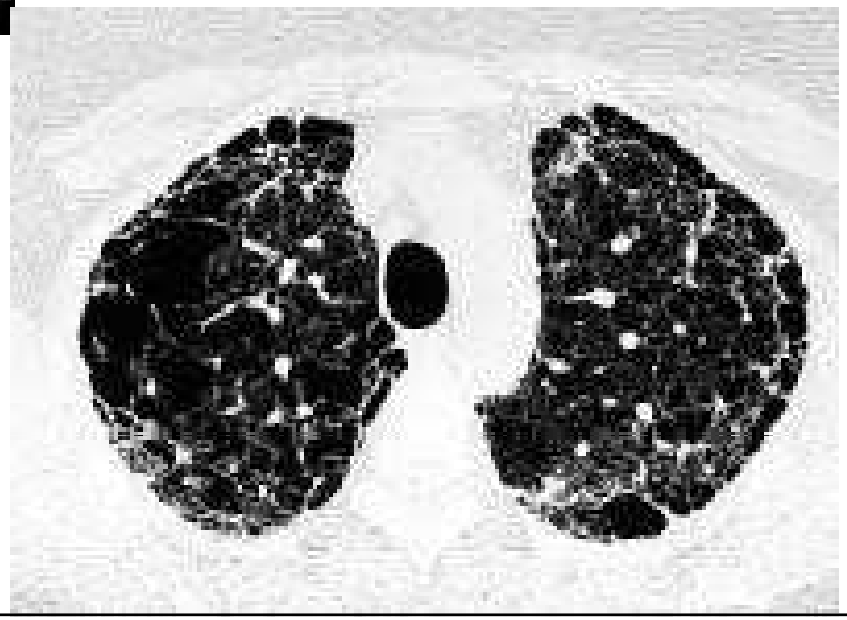
Unknown, may be immunological reaction.

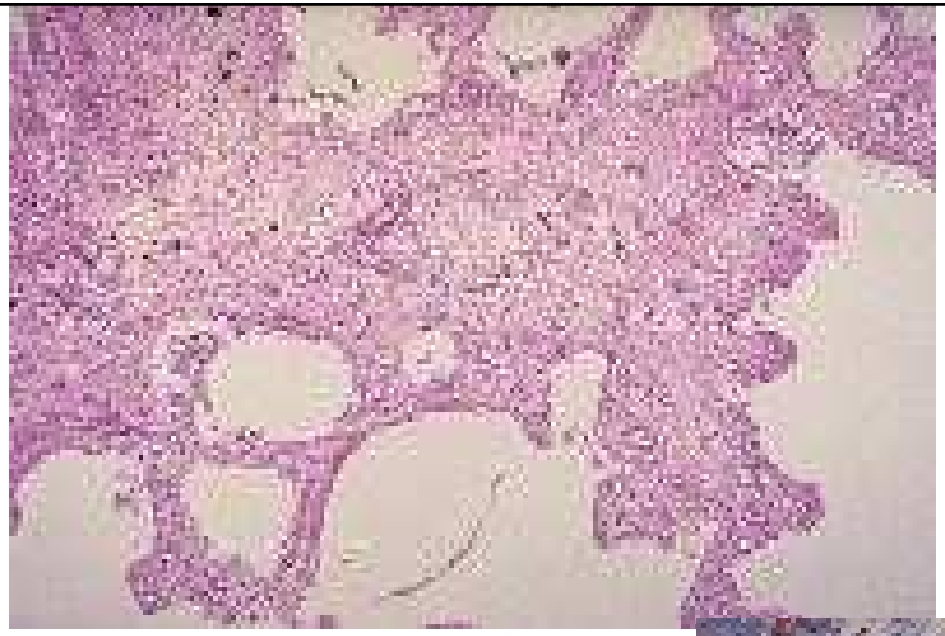
### Clinical Features

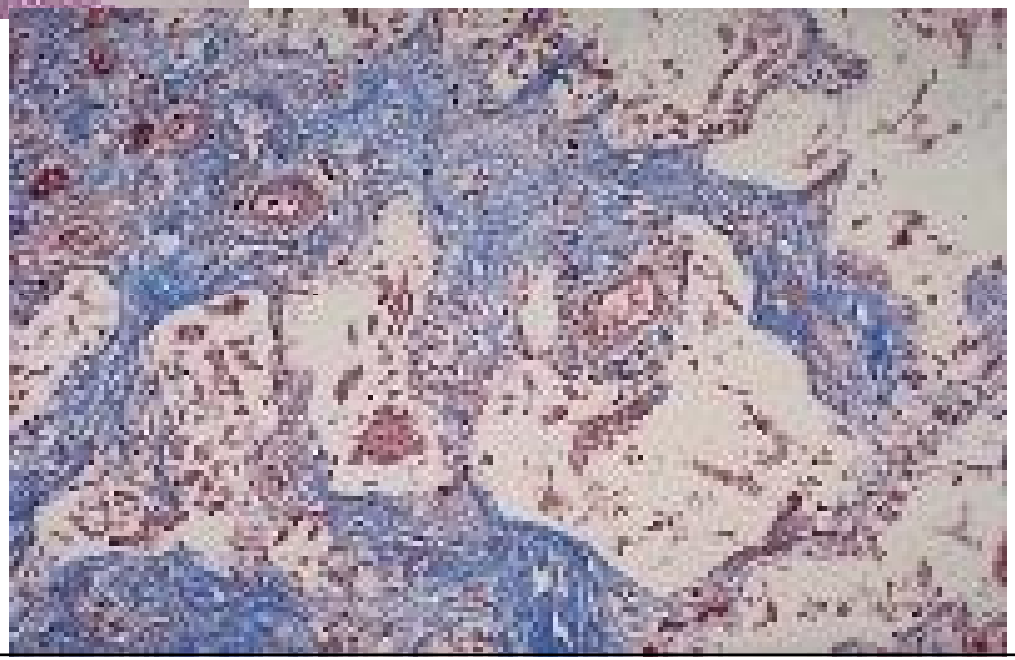
- Uncommon disease, affects adults in late middle age.
- Progressive exertional dyspnea, later at rest.
- Non-productive cough.
- Physical examination shows finger clubbing, fine inspiratory crackles throughout both lungs.
- Patient may develop respiratory failure terminally.
- The disease progresses insidiously, median survival 4-6 years.





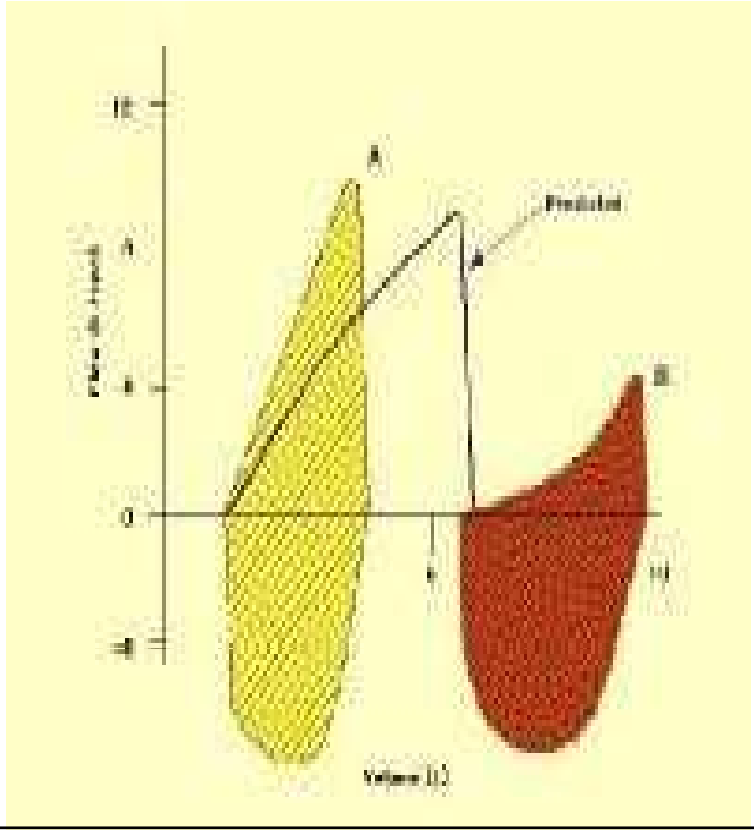






# Pulmonary Function

- Spirometry reveals a restrictive pattern. FVC is reduced, but $FEV_1/FVC$ supernormal.
- All lung volumes – TLC, FRC, RV – are reduced.
- Pressure volume curve of the lung is displaced downward and flattened.



# Gas Exchange

- Arterial $PaO_2$ and $PaCO_2$ are reduced, pH normal.
- On exercise $PaO_2$ decreases dramatically.
- Physiologic dead space and physiologic shunt and VQ mismatch are increased.
- Diffuse impairment contributes to hypoxemia on exercise.
- There is marked reduction in diffusing capacity due to thickening of blood gas barrier and VQ mismatch.

# Diagnosis

- Diagnosis is often suggested by history, chest radiograph and high resolution CT scan of the lungs.

- If old chest x-rays show classical disease, absence of other disease processes on history and no occupational or environmental exposure – clinical diagnosis can be made.

- In other cases a surgical lung biopsy is obtained.

# Thank you for attention