Pulmonary Function Tests

Jason Ryan, MD, MPH

Boards & Beyond
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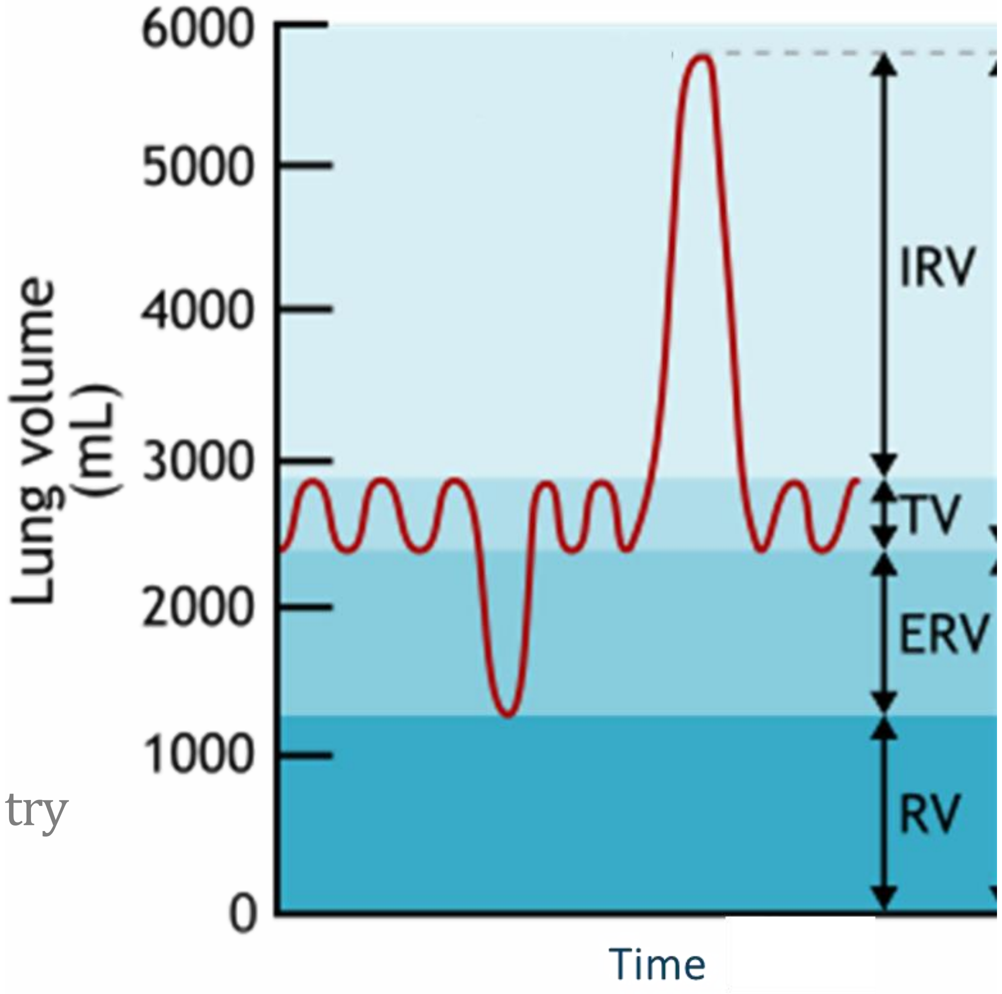
Lung Volumes

- Tidal volume (TV)
  - In/out air with each quiet breath
- Expiratory reserve volume (ERV)
  - Extra air pushed out with force beyond TV
  - RV remains in lungs
- Inspiratory reserve volume (IRV)
  - Extra air can be drawn in with force beyond TV
  - Lungs filled to capacity
- Residual volume (RV)
  - Air that can't be blown out no matter how hard you try

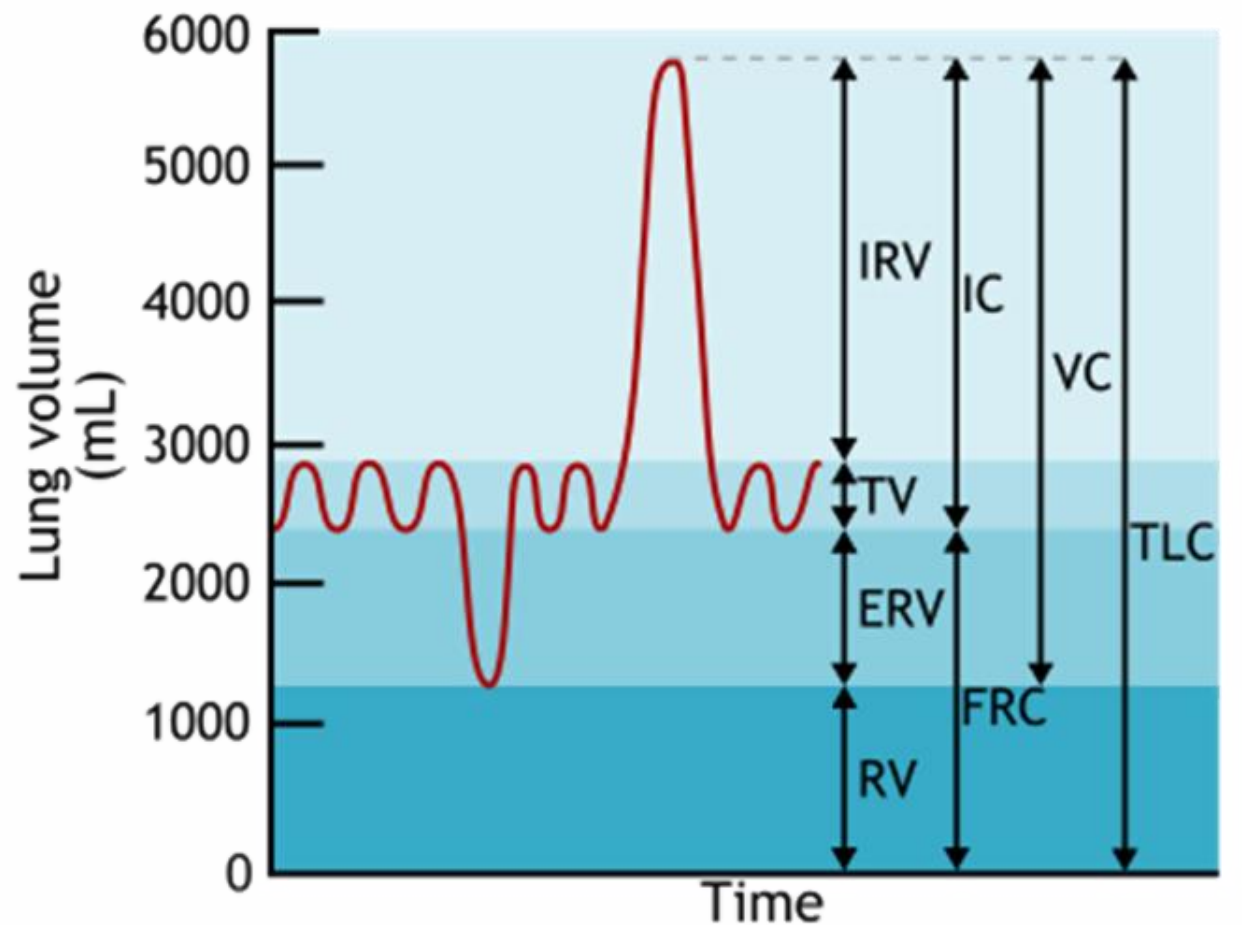


Michal Komorniczak, Medical Illustrations

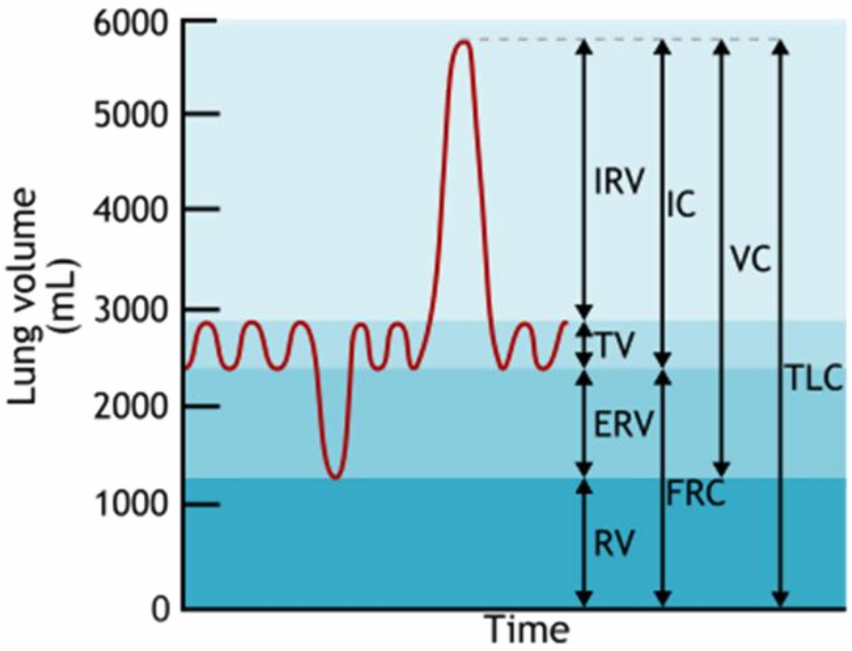
Lung Capacities

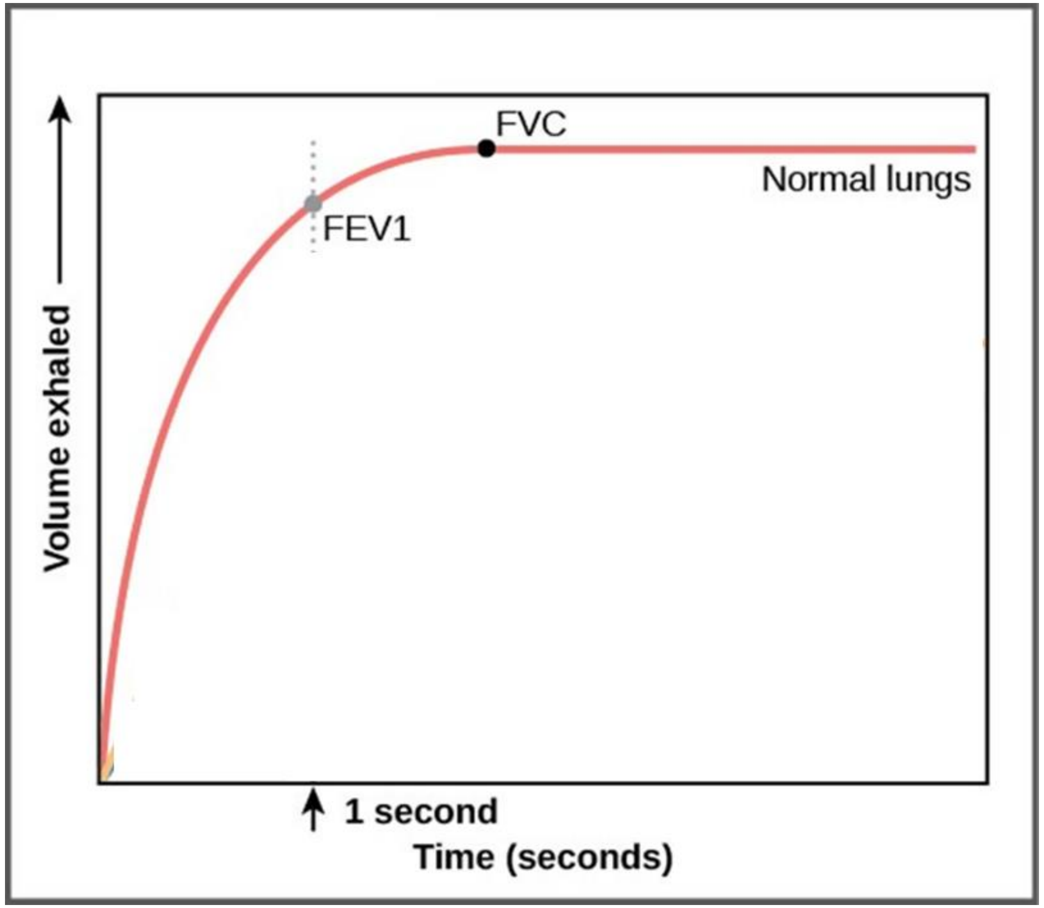
Capacity = sum of two volumes

- Total lung capacity
  - Sum of all volumes
  - RV + ERV+ IRV + TV
- Inspiratory capacity
  - Most air you can inspire
  - TV + IRV
- Forced vital capacity (FVC)
  - Most you can exhale
  - TV + IRV + ERV
- Functional residual capacity
  - RV plus ERV



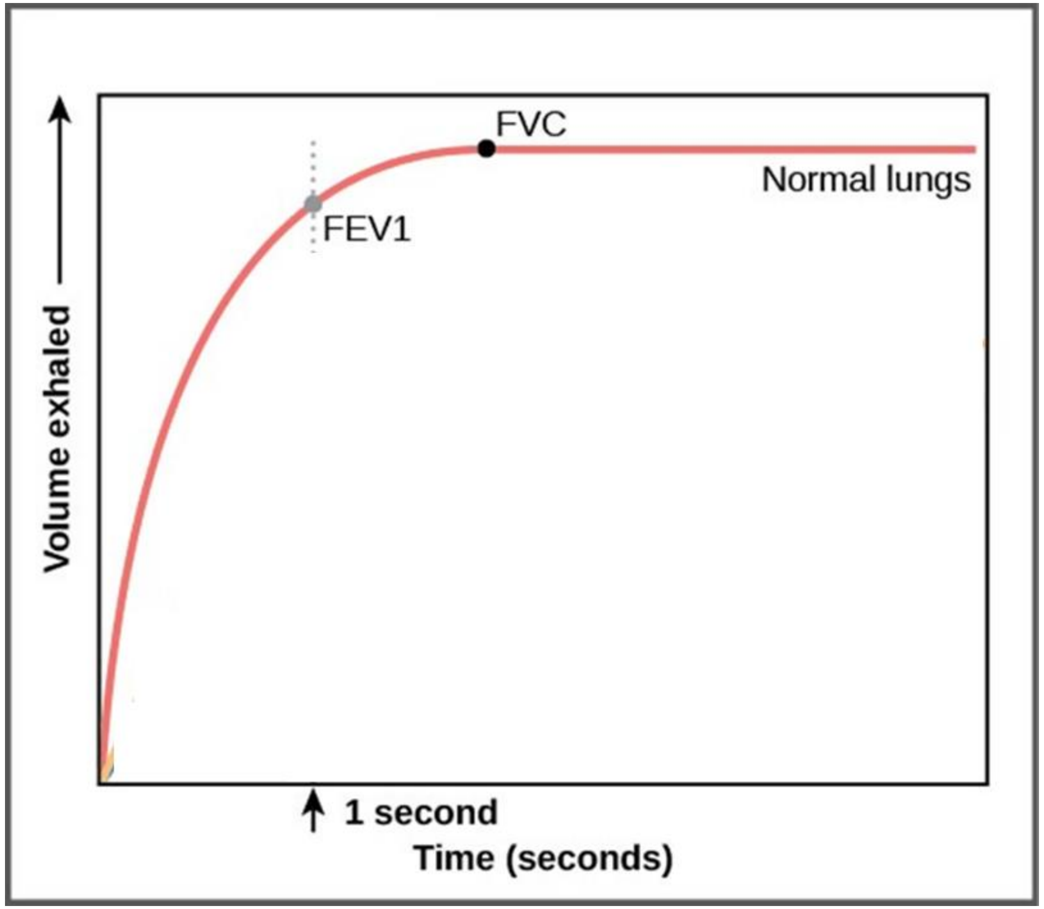
Pulmonary Function Testing





Pulmonary Function Testing

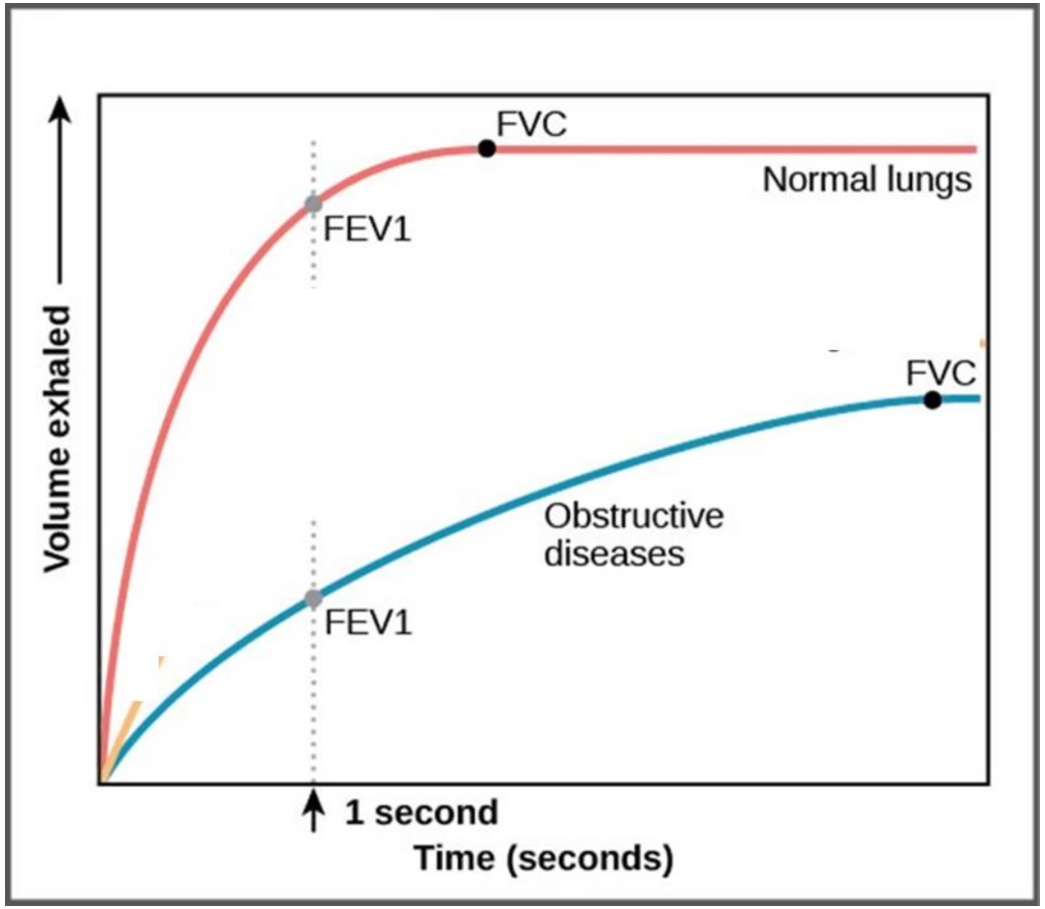
- Must meet criteria for adequate test
- Sharp peak in flow curve
- Expiratory duration **more than six seconds**
- Inadequate test should be repeated



Obstructive Lung Diseases

Asthma, COPD

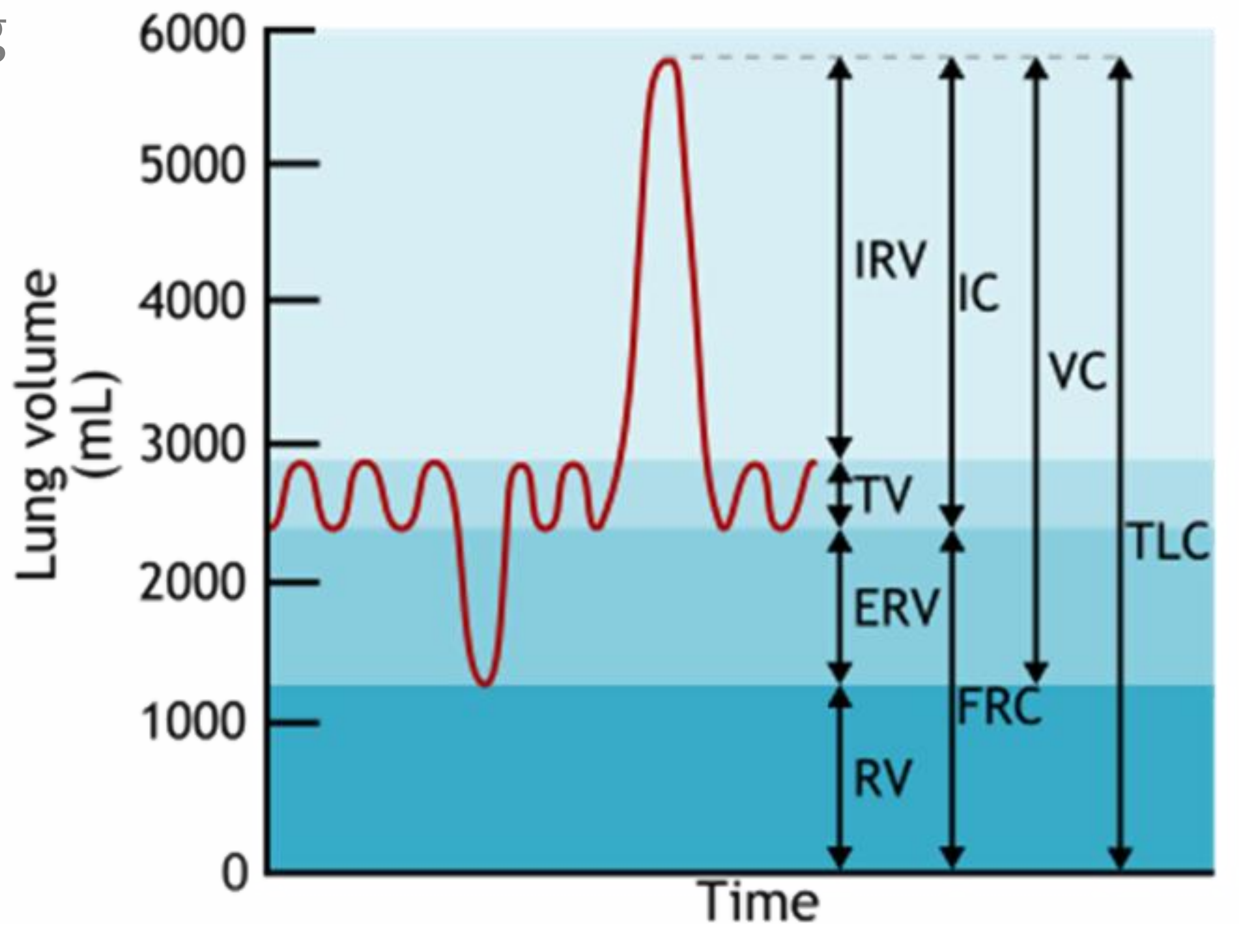
- Reduced FEV1 (slow flow out)
- Reduced FVC (less air out)
- Reduced FEV1/FVC (hallmark)
- Asthma: reversible obstruction
  - ↑ FEV1 with bronchodilators
- COPD: partial/no change bronchodilators



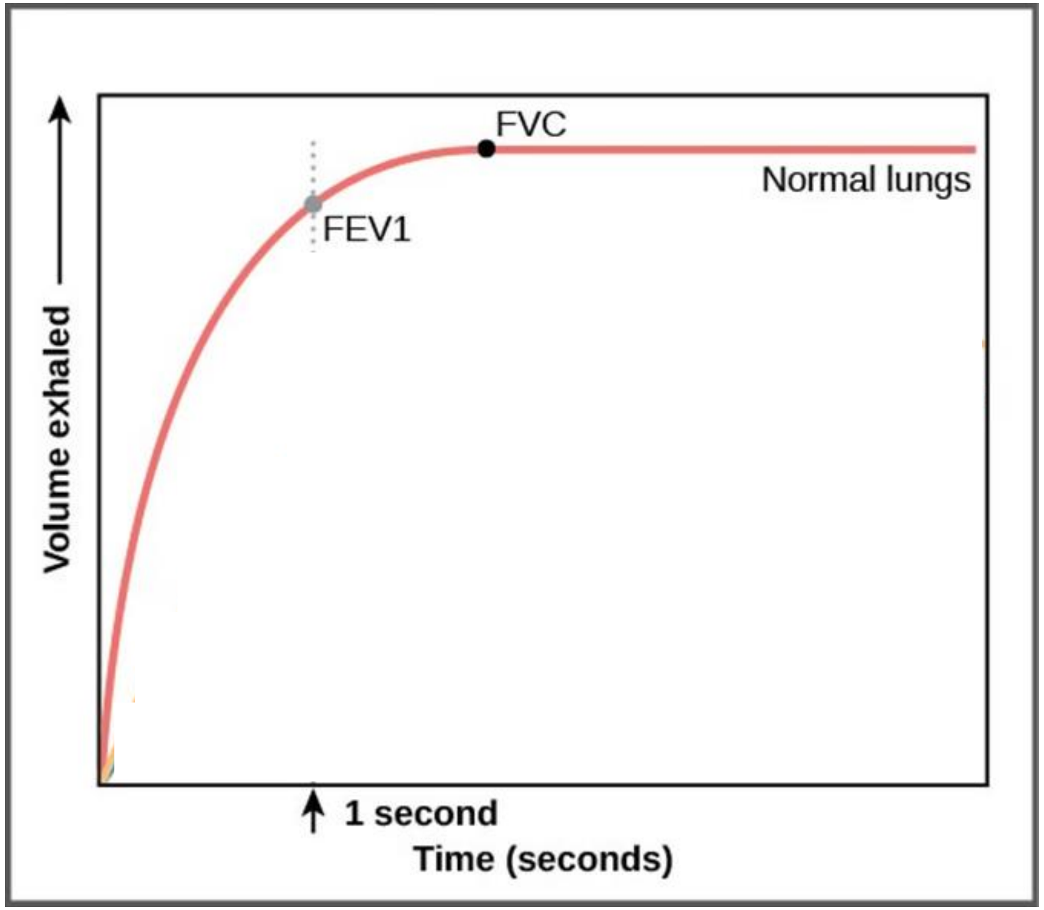
Obstructive Lung Diseases

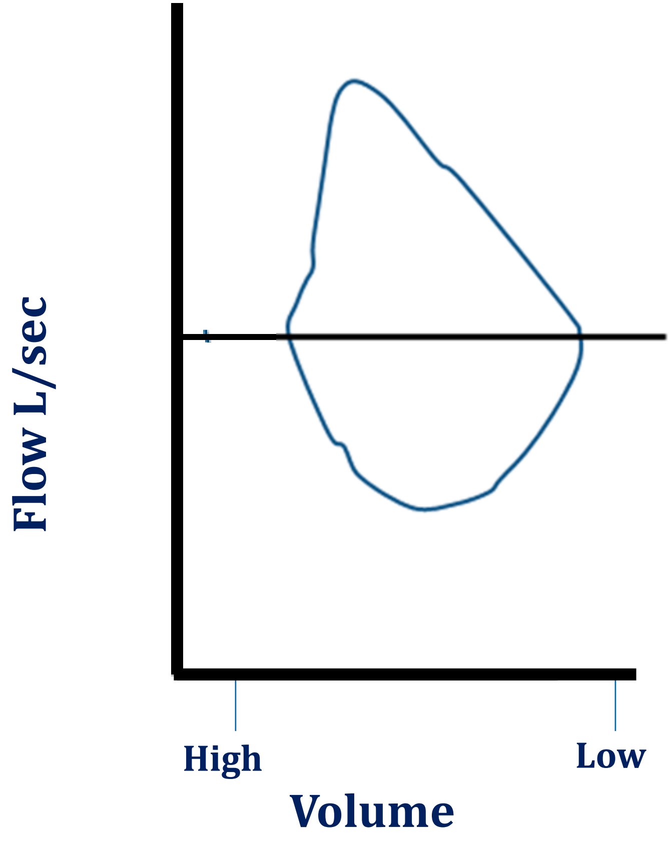
Asthma, COPD

- Increased volumes from air trapping
- Total lung capacity
- Functional residual capacity
- Residual volume



Flow Volume Loops





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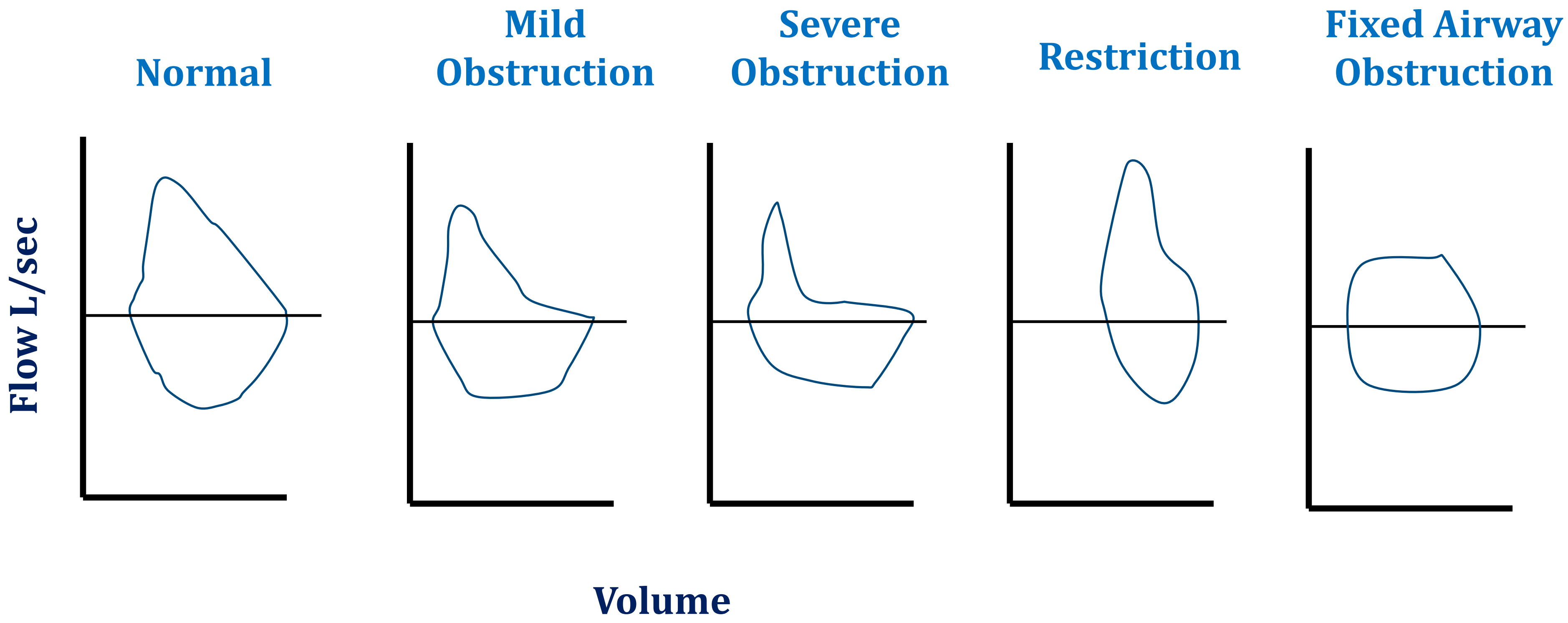
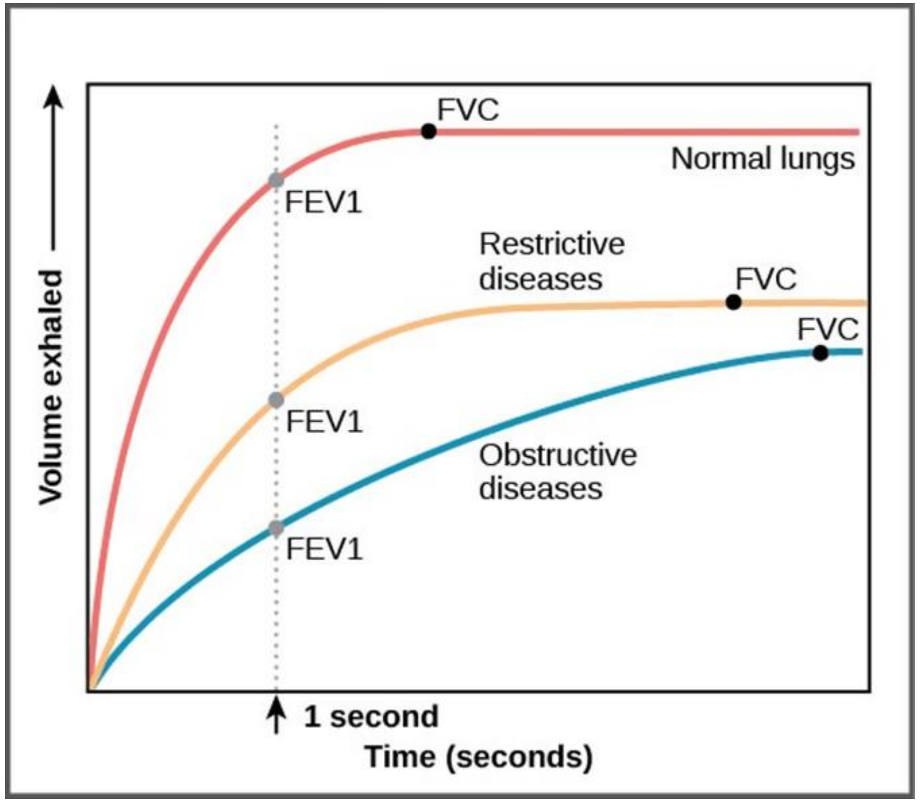


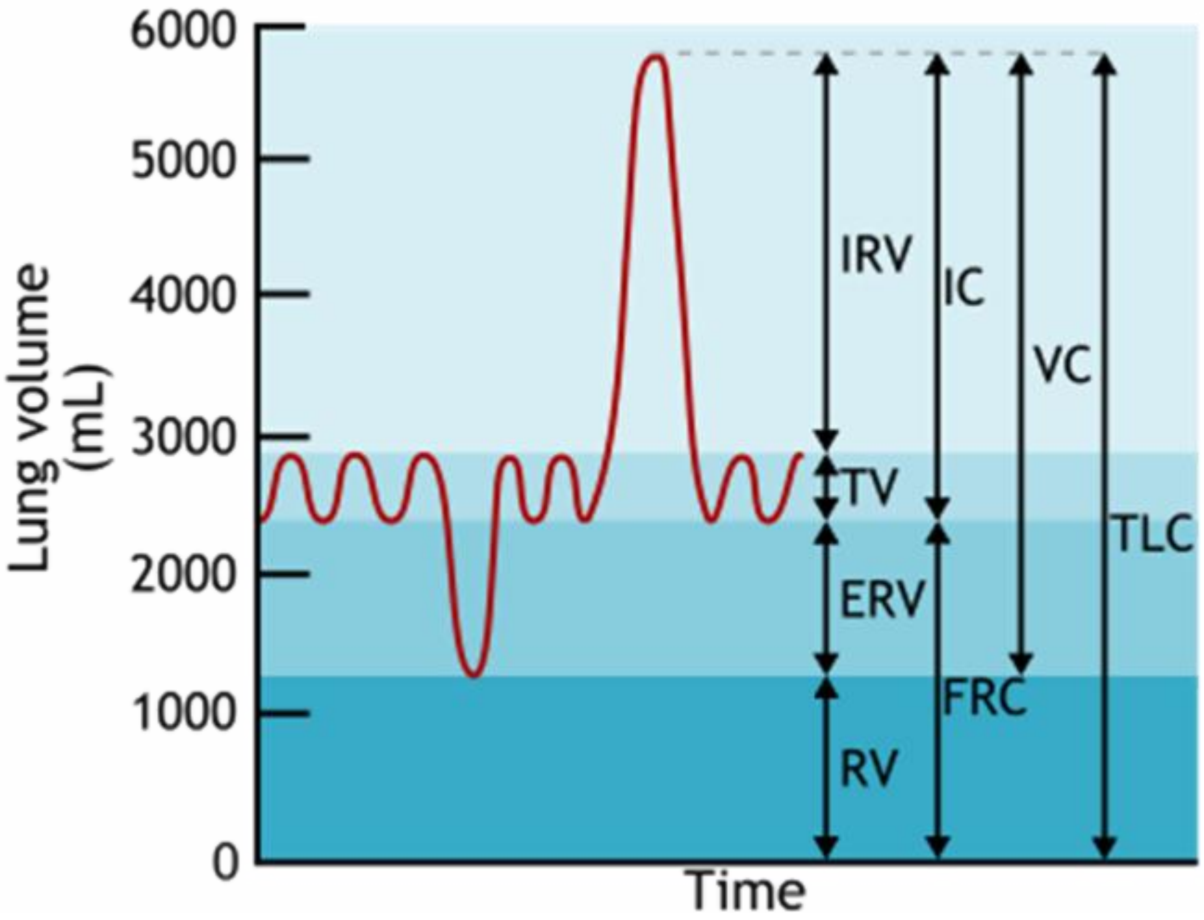
Restrictive Lung Diseases

- Disorders where air cannot get in → less air out
- Reduced FEV1 (less air in/out)
- Reduced FVC (less air in/out)
- Normal (> 80%) FEV1/FVC (hallmark)



Restrictive Lung Diseases

- Reduced volumes
- Total lung capacity
- Functional residual capacity
- Residual volume



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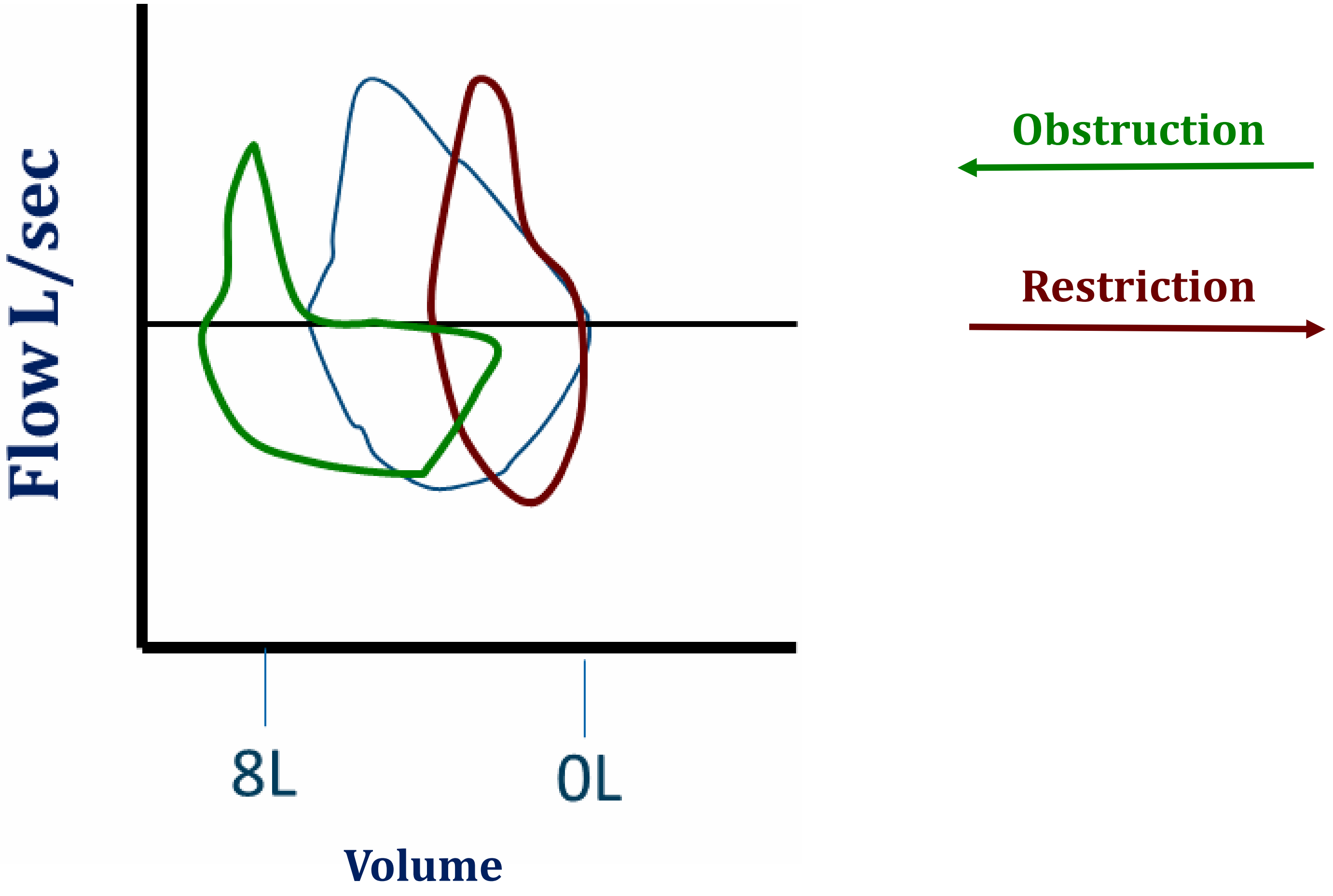

Restrictive Lung Disease

Causes

1. Poor breathing mechanics
2. Interstitial lung diseases

DLCO

Diffusing capacity of carbon monoxide

- Measures ability of lungs to transfer gas
- Patient inhales small amount (not dangerous) CO
- Machine measures CO exhaled
- Normal = 75–140% predicted
- Severe disease < 40% predicted

Low DLCO Conditions

- Interstitial lung disease
- Emphysema
- Abnormal vasculature
  - Pulmonary hypertension
  - Pulmonary embolism
- Prior lung resection
- Anemia
  - Corrects when adjusted for Hb level

Asthma

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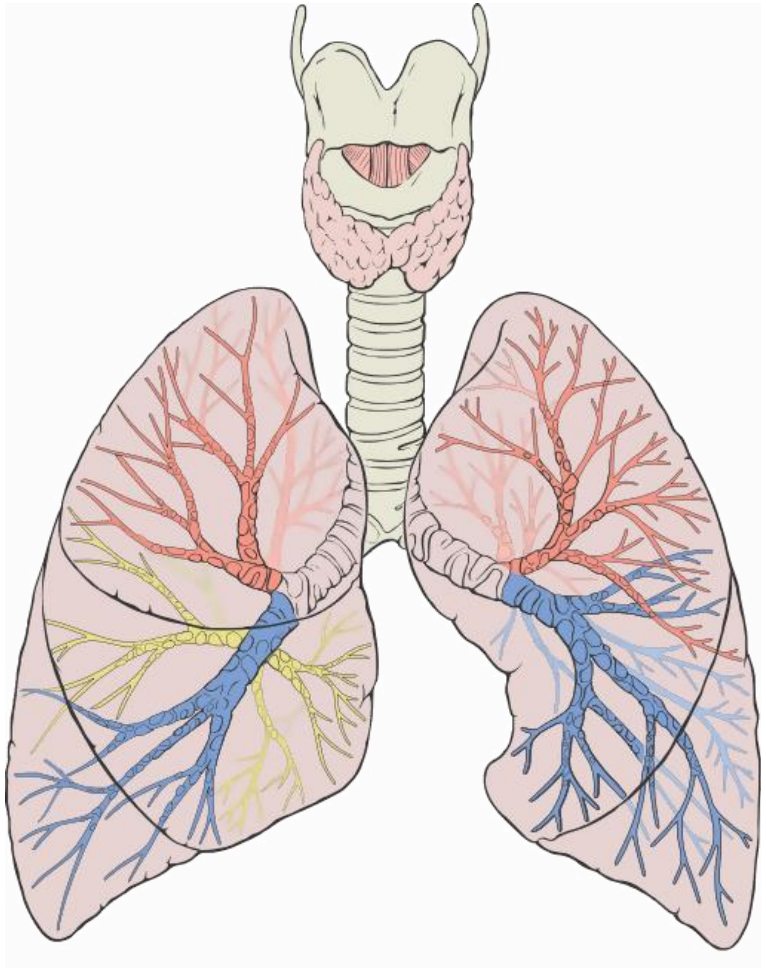
Asthma

- ***Reversible*** bronchoconstriction
- Usually triggered by **allergic stimulus**
  - Type I hypersensitivity reaction
- Common in children
- Associated with other allergic (atopic) conditions
  - Rhinitis, eczema
  - May have family history of allergic reactions



Patrick Lynch/Wikipedia

Asthma Symptoms

- *Episodic* symptoms
- Dyspnea, **wheezing**, cough
- Hypoxemia
- Increased expiratory phase
  - Decreased I/E ratio
- **Reduced peak flow**
- Mucous plugging (airway obstruction/shunt)
- Death: status asthmaticus

Asthma Triggers

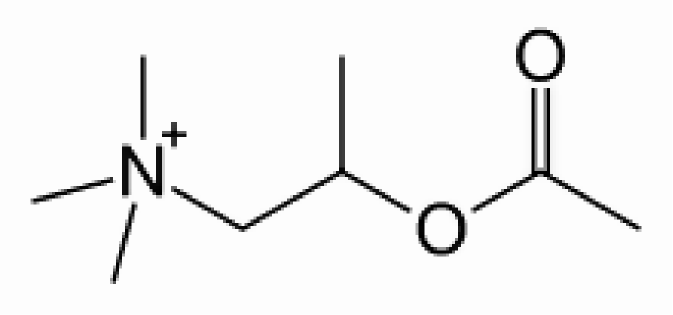
- Respiratory infection
- Allergens (animal dander, dust mites, mold, pollens)
- Stress
- Exercise
- Cold
- Aspirin
- Treatment: **avoidance of triggers**

Asthma Diagnosis

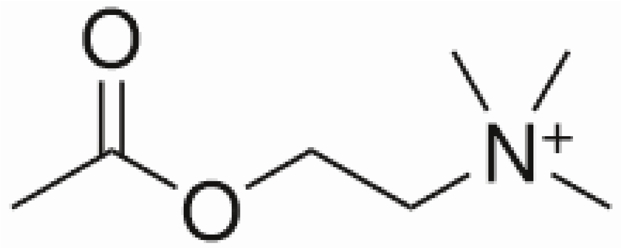
- Usually classic history/physical exam, improvement with albuterol
- **Peak flow**
- Pulmonary function tests
    - Reduced FEV1
    - Reduced FEV1/FVC ratio
    - FEV1 improvement 12% **after albuterol**

Asthma Diagnosis

- **Methacholine challenge**
  - Muscarinic agonist (similar to acetylcholine)
  - Causes bronchoconstriction
  - Administer increasing amounts of nebulized drug
  - Spirometry after each dose
  - Look for dose at which **FEV1 falls by 20%**
  - If provocative dose is 20 mcg or less → positive test



Methacholine



Acetylcholine

Asthma Diagnosis

Other Testing

- CBC may show increased eosinophils
- Serum IgE levels may be increased
- Pulsus paradoxus
  - Fall in systolic blood pressure $\geq$ 10 mmHg with inspiration
  - Most frequent non-cardiac causes are asthma/COPD

Asthma Treatment

Major drug types

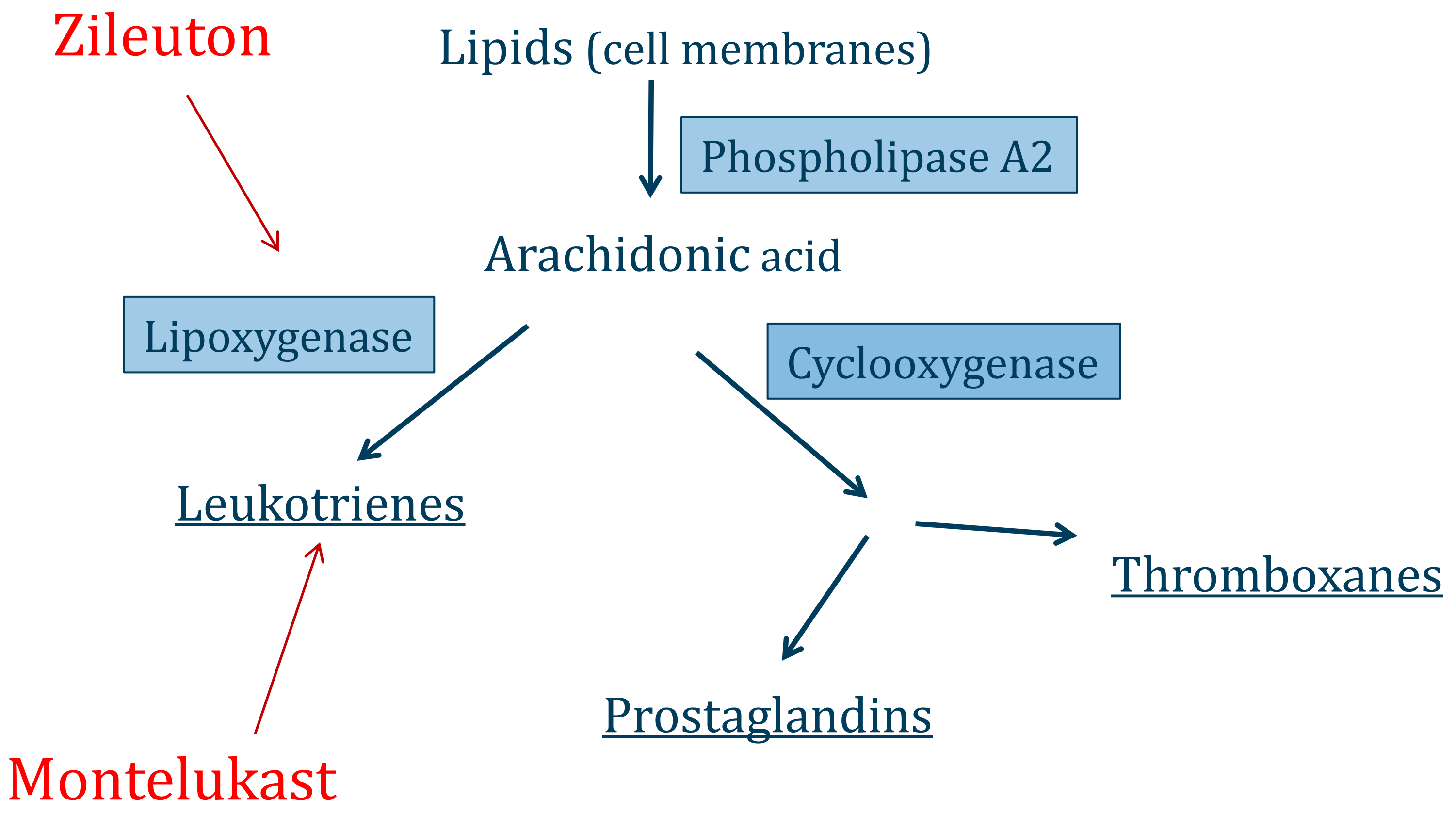
- **Beta-agonists**
  - Short-acting beta-agonist (SABA): albuterol
  - Long-acting beta-agonist (LABA): salmeterol, formoterol
  - Side effects rare
  - Sometimes tremor, palpitations
- **Corticosteroids**
  - Inhaled corticosteroids (ICS)
  - Oral corticosteroids
  - Intravenous corticosteroids
  - Often causes thrush
  - Prevention: rinse, spacers

James Heilman, MD

Other Asthma Drugs

- **Leukotriene receptor antagonists (PO)**
  - Montelukast (Singulair)
  - Useful in aspirin sensitive asthma
- **Zileuton (PO)**
  - 5-lipoxygenase inhibitors
  - Blocks conversion of arachidonic acid to leukotrienes

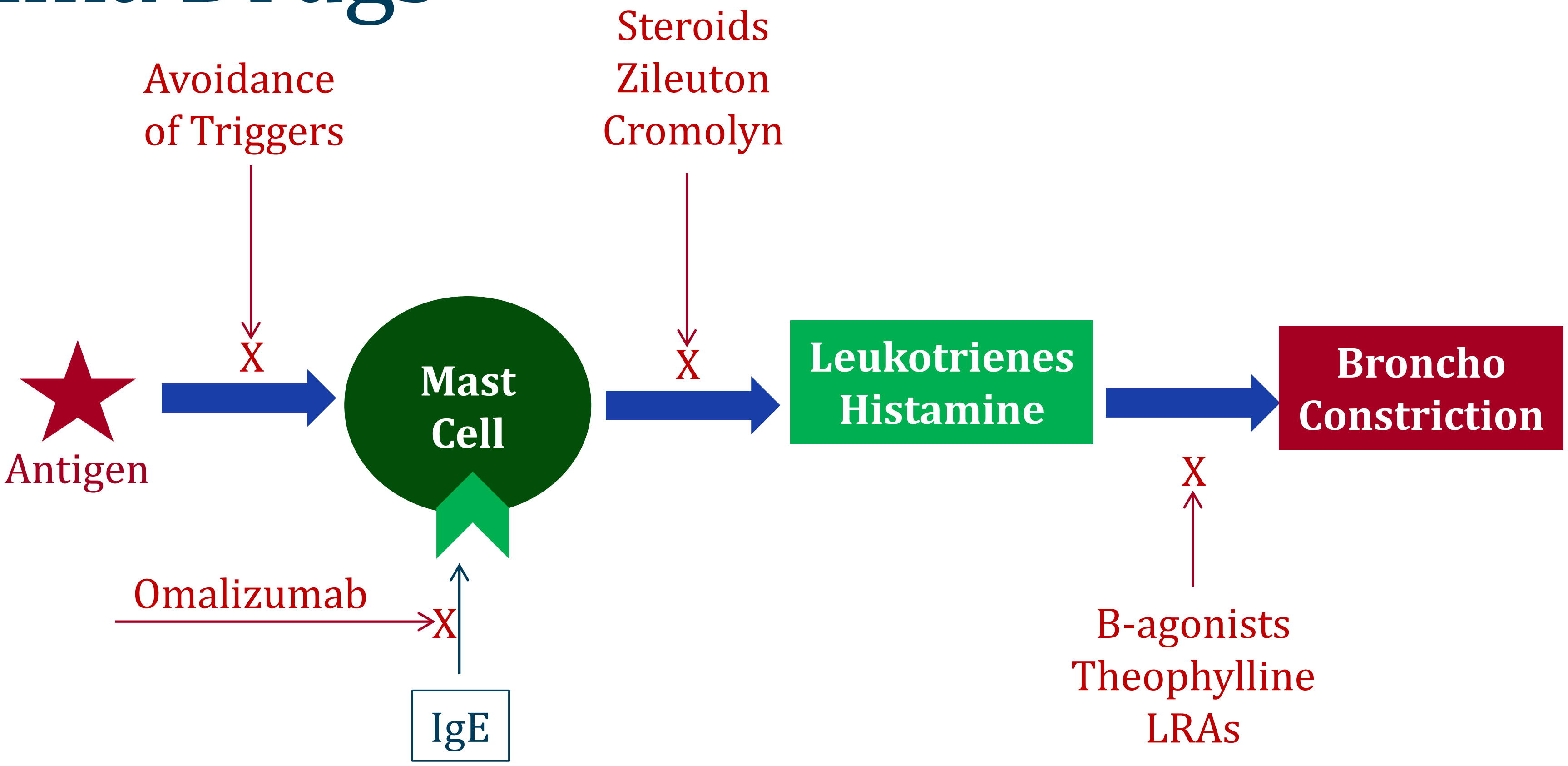
Eicosanoids



Other Asthma Drugs

- **Omalizumab (SQ injection)**
  - IgG monoclonal antibody
  - Inhibits IgE binding to IgE receptor on mast cells & basophils
- **Cromolyn (inhaler/nebulizer)**
  - Inhibits mast cell degranulation
  - Blocks release of histamine, leukotrienes
- **Theophylline**
  - Bronchodilator

Asthma Drugs



Asthma Treatment

Asthma

Acute Exacerbations

Chronic Therapy

Asthma Acute Exacerbations

- Shortness of breath
- Wheezing
- Cough
- Chest tightness
- **Decrease in peak flow from baseline**
- Diagnosis: clinical
- Chest X-ray: evaluate for pneumonia/infection

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Asthma Acute Exacerbations

- Oxygen
- Nebulized albuterol
- IV or oral corticosteroids
  - Prednisone 60 mg daily
  - Methylprednisolone 80 mg IV q8hrs
- Rarely used:
  - Ipratropium
  - IV Magnesium sulfate
- ABG showing normal or increased $PaCO_2$ → intubation

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Asthma Acute Exacerbations

- Empiric antibiotics not recommended
  - Contrast with COPD exacerbations
  - Antibiotics only indicated with evidence of infection

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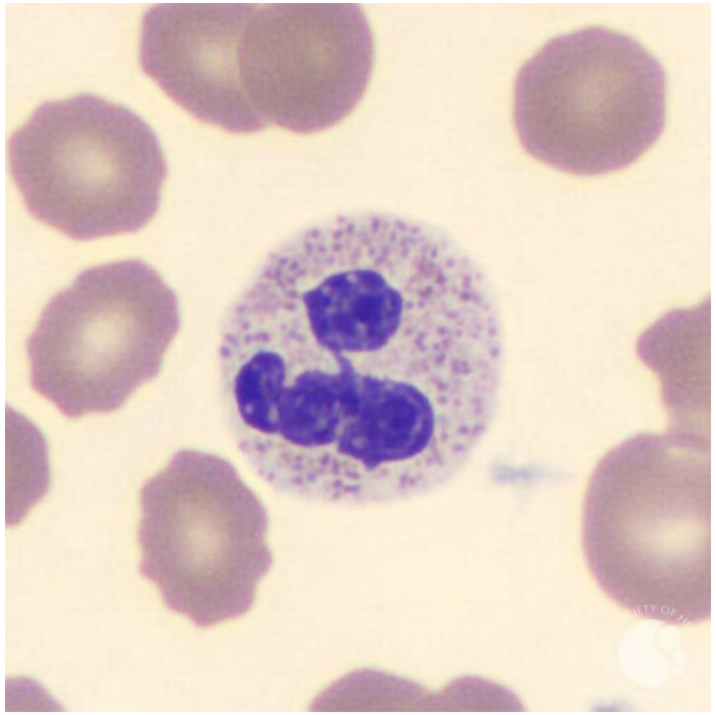
Corticosteroids

- Causes increased WBC
  - Left shift
- Normal response to therapy
- Does not indicate infection



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Asthma Severity

	Daytime Symptoms	Nighttime Symptoms	Therapy
Intermittent*	≤ 2 per week	≤ 2 per month	Step 1
Mild persistent	> 2 per week	3-4 per month	Step 2
Moderate persistent	Daily	> 1 per week	Step 3
Severe persistent	Daily	4-7 per week	Steps 4+

Intermittent Asthma

≤ 2 daytime/week
≤ 2 nighttime/month
No activity limitations
Normal PFTs

Asthma: Chronic Therapy

- Treated in a **stepwise manner**
- Increase to next step until symptoms controlled

Step 1
SABA as needed

Step 2
Add Low dose ICS

Step 3
Medium ICS or Low ICS + LABA

Step 4
Medium ICS + LABA

Step 5
High ICS + LABA

Step 6
High ICS + LABA + Oral Steroids

← Persistent Asthma →

LTRA, Zileuton, Theophylline, Omalizumab

AERD

Aspirin Exacerbated Respiratory Disease

- Asthma, chronic rhinosinusitis, nasal polyposis
  - Chronic asthma/rhinosinusitis symptoms
  - Acute exacerbations after ingestion **aspirin or NSAIDs**
- Dysregulation of arachidonic acid metabolism
- Overproduction leukotrienes
- Treatment: **leukotriene receptor antagonists**
  - Montelukast, Zafirlukast

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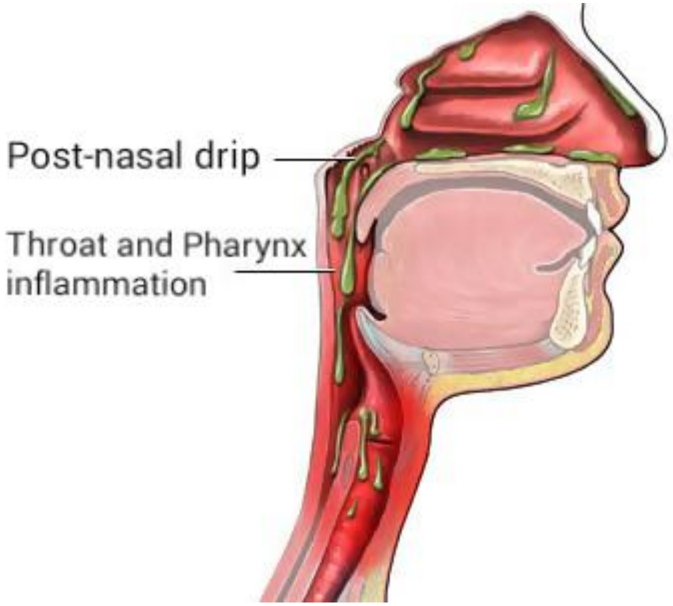
Chronic Cough

- Asthma
- Postnasal drip
    - Common in patients with allergic rhinitis
    - Improves with intranasal glucocorticoids
- Gastroesophageal reflux disease (GERD)
    - Can cause wheezing
    - Sore throat
    - Hoarseness
    - Occurs at night or after meals
    - Treatment: proton pump inhibitors
- ACE-inhibitors



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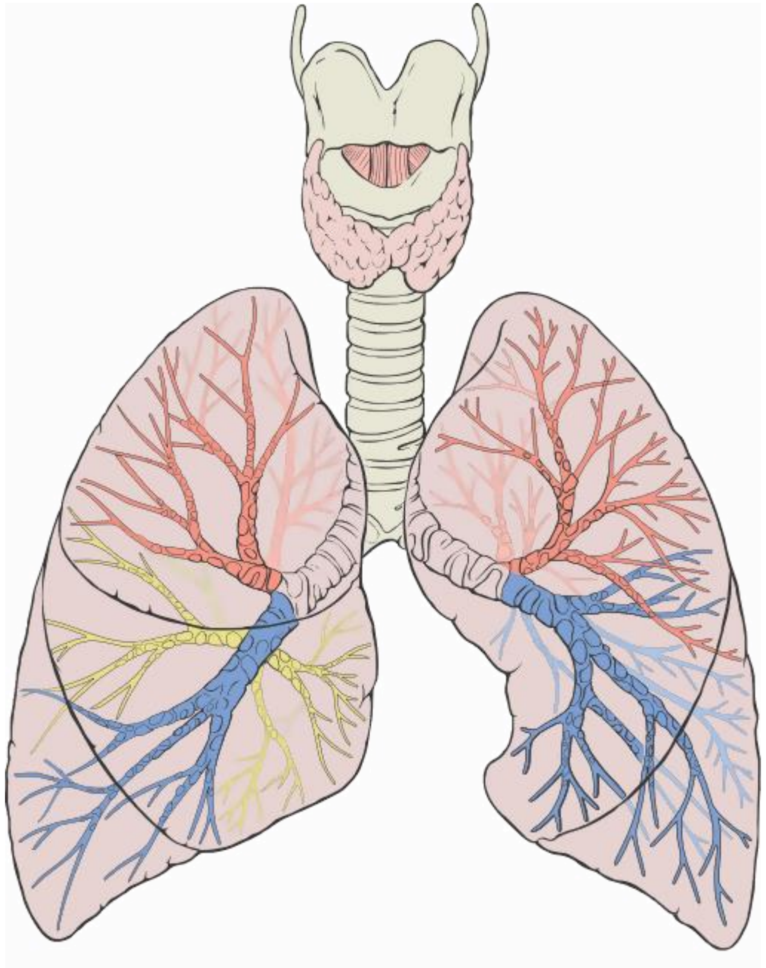
COPD Diagnosis

Jason Ryan, MD, MPH

COPD

Chronic Obstructive Pulmonary Disease

- Chronic lung disorder
- Causes dyspnea, cough
- Several subtypes
- Chronic bronchitis
- Emphysema
- Asthma-COPD

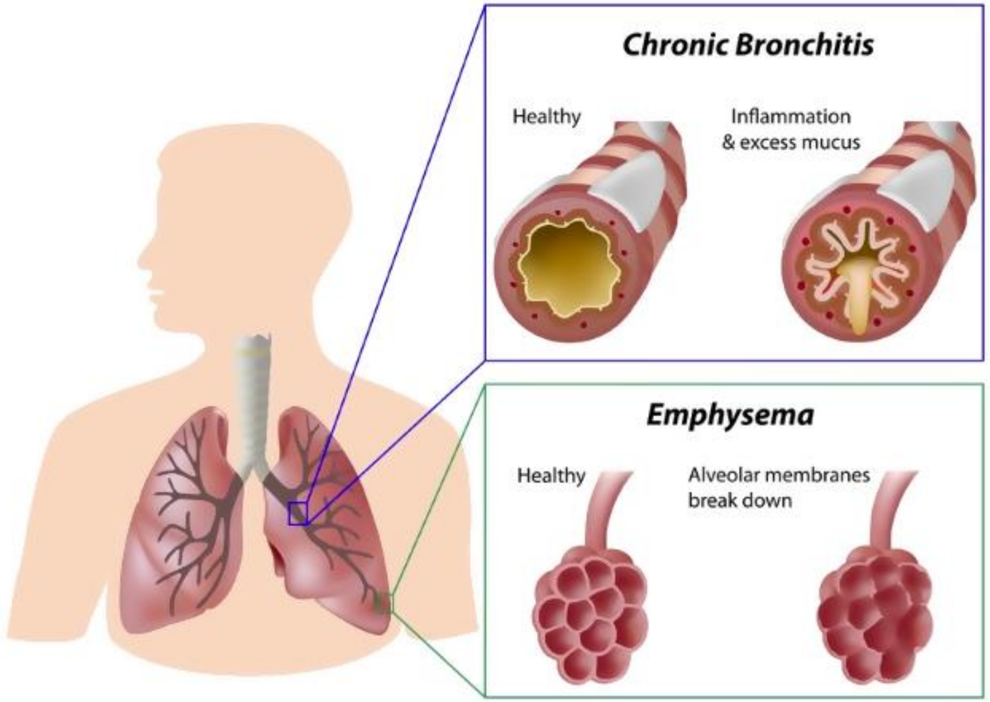


Patrick Lynch/Wikipedia

Chronic Bronchitis

COPD Subtype

- Inflammation of airways
- Chronic cough
- Productive of sputum
- At least 3 months per year
- Over two consecutive years
- No other cause of cough present



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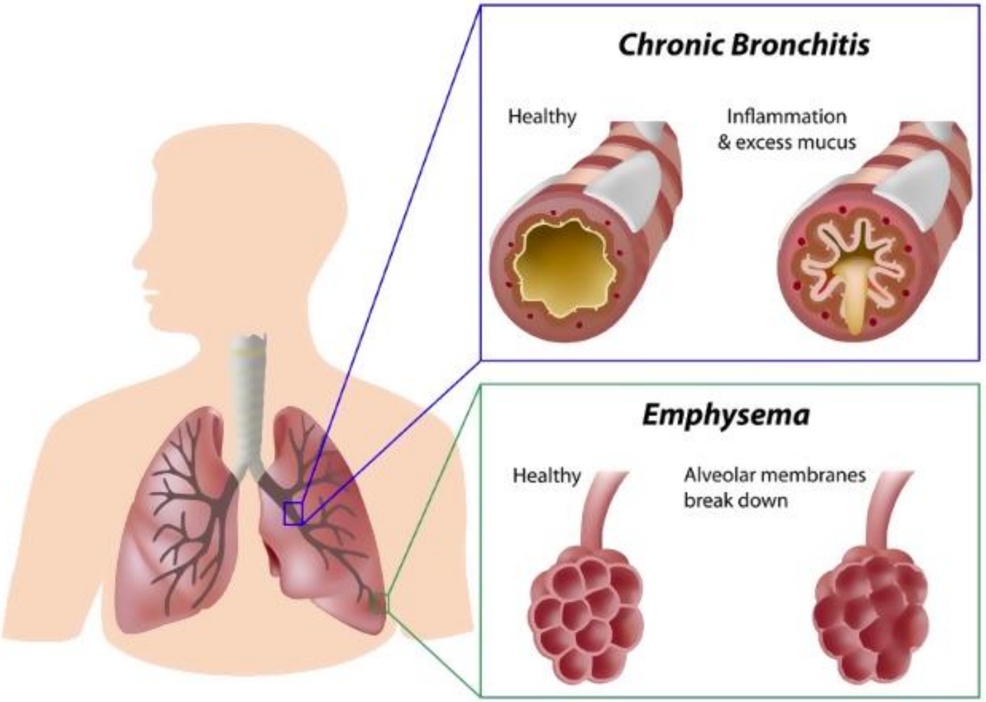
Emphysema

COPD Subtype

- Destruction of alveoli walls
- Inflammatory cells release proteases
- Loss of elastin → loss of elastic recoil
- Small airways collapse on exhalation
- Air "trapped" in lungs
- Dyspnea
- Hyperventilation
- Some cough (less than chronic bronchitis)



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COPD

Risk Factors

- **Cigarette smoking**
- Other rare associations
  - Environmental exposures
  - Alpha-1 antitrypsin deficiency

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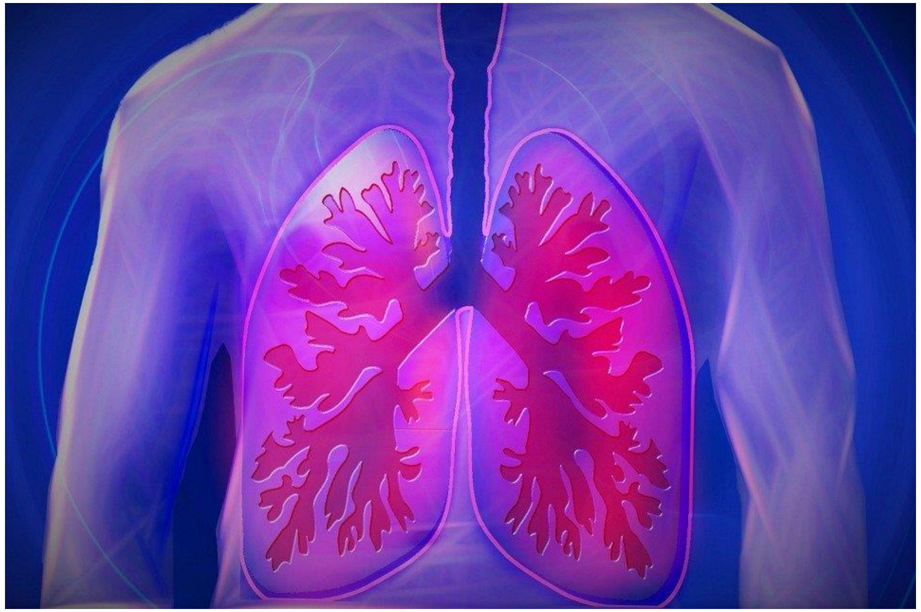
COPD

Clinical Features

- Chronic condition with **intermittent exacerbations**
- Dyspnea and cough



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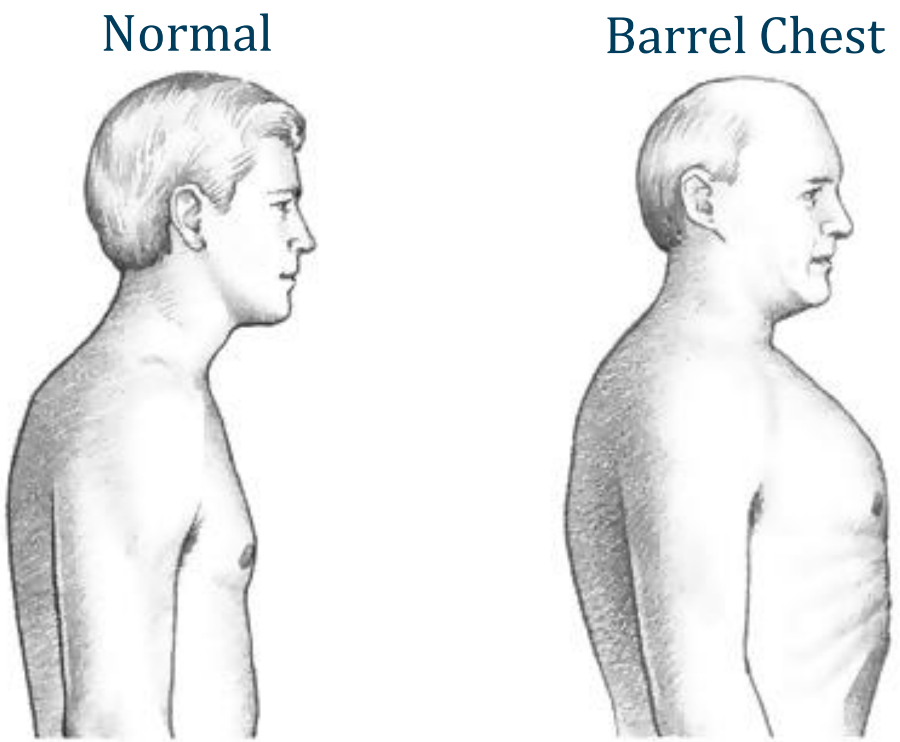
COPD

Clinical Features

- Chronic bronchitis features
  - Prolonged expiratory phase
  - Rhonchi
  - Wheezes
- Emphysema features
  - Decreased breath sounds
  - Barrel chest from air trapping
  - Pursed-lip breathing



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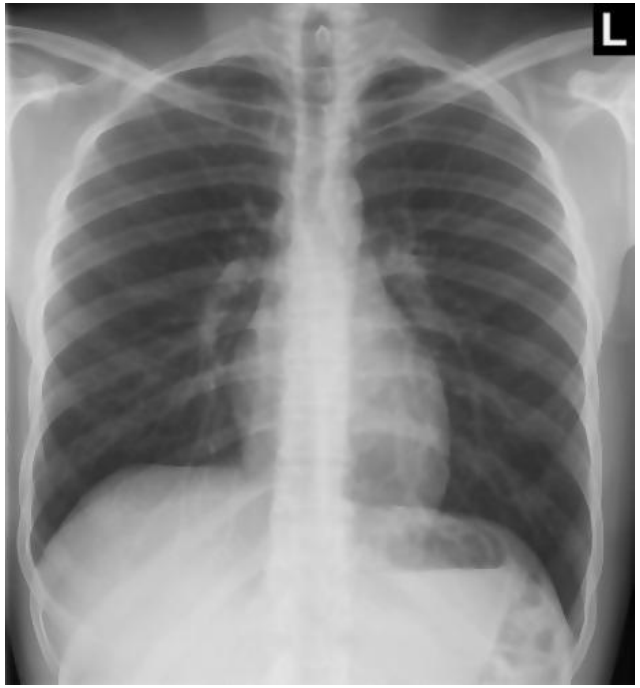
Blue Bloater and Pink Puffer

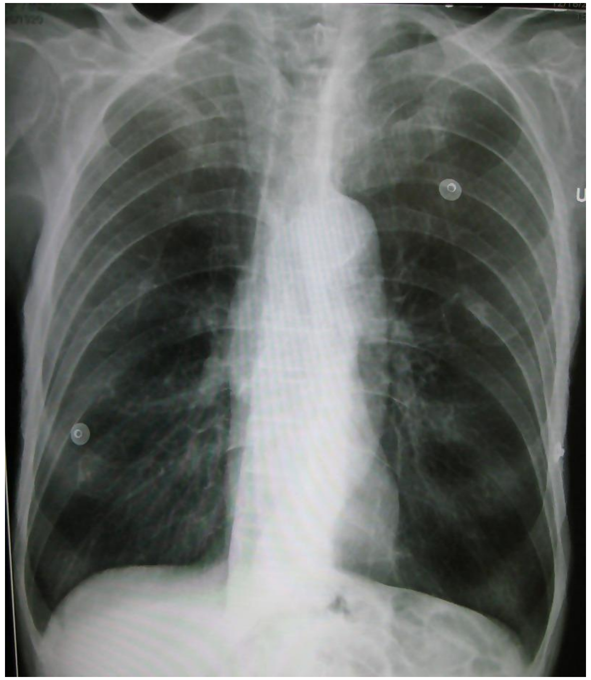
- Chronic Bronchitis – Blue Bloater
  - Cyanosis/hypoxemia from **shunting** (blue)
  - Hypoxemia → pulmonary vasoconstriction
  - Edema from right heart failure
- Emphysema – Pink Puffer
  - Loss of alveoli
  - Loss of surface area for O2 absorption (**dead space**)
  - Hyperventilation to compensate (puffer)
  - Initially this maintains O2 level (pink)

COPD

Diagnosis

- Best initial test: **chest X-ray**
- Hyperinflation
- Flattened diaphragm
- Increased AP diameter





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COPD

Diagnosis

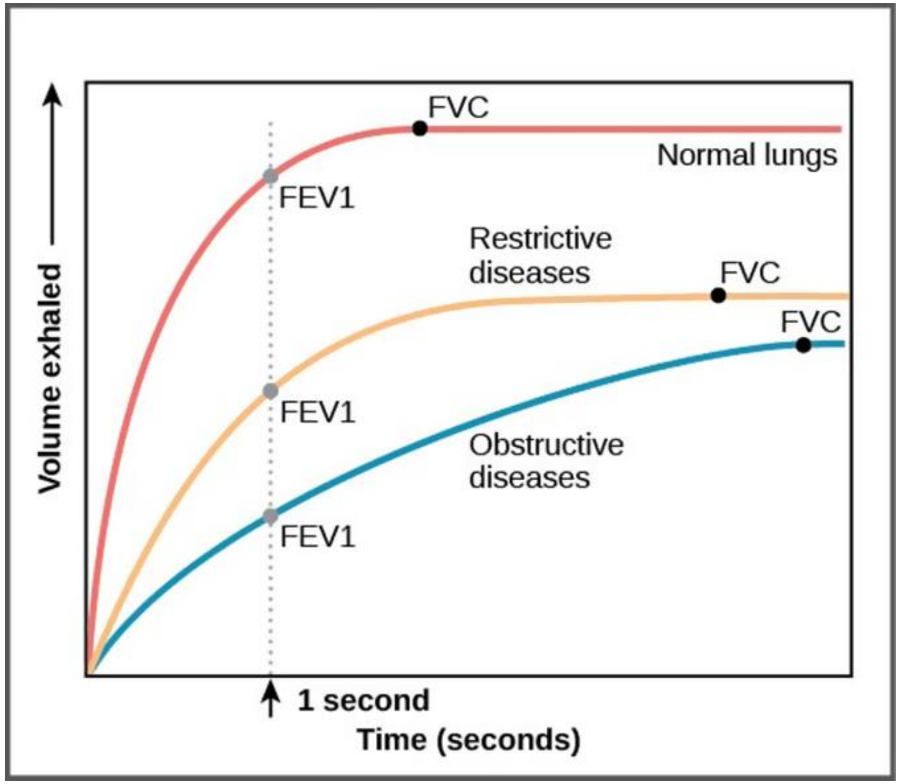
Normal

COPD

COPD

Pulmonary Function Testing

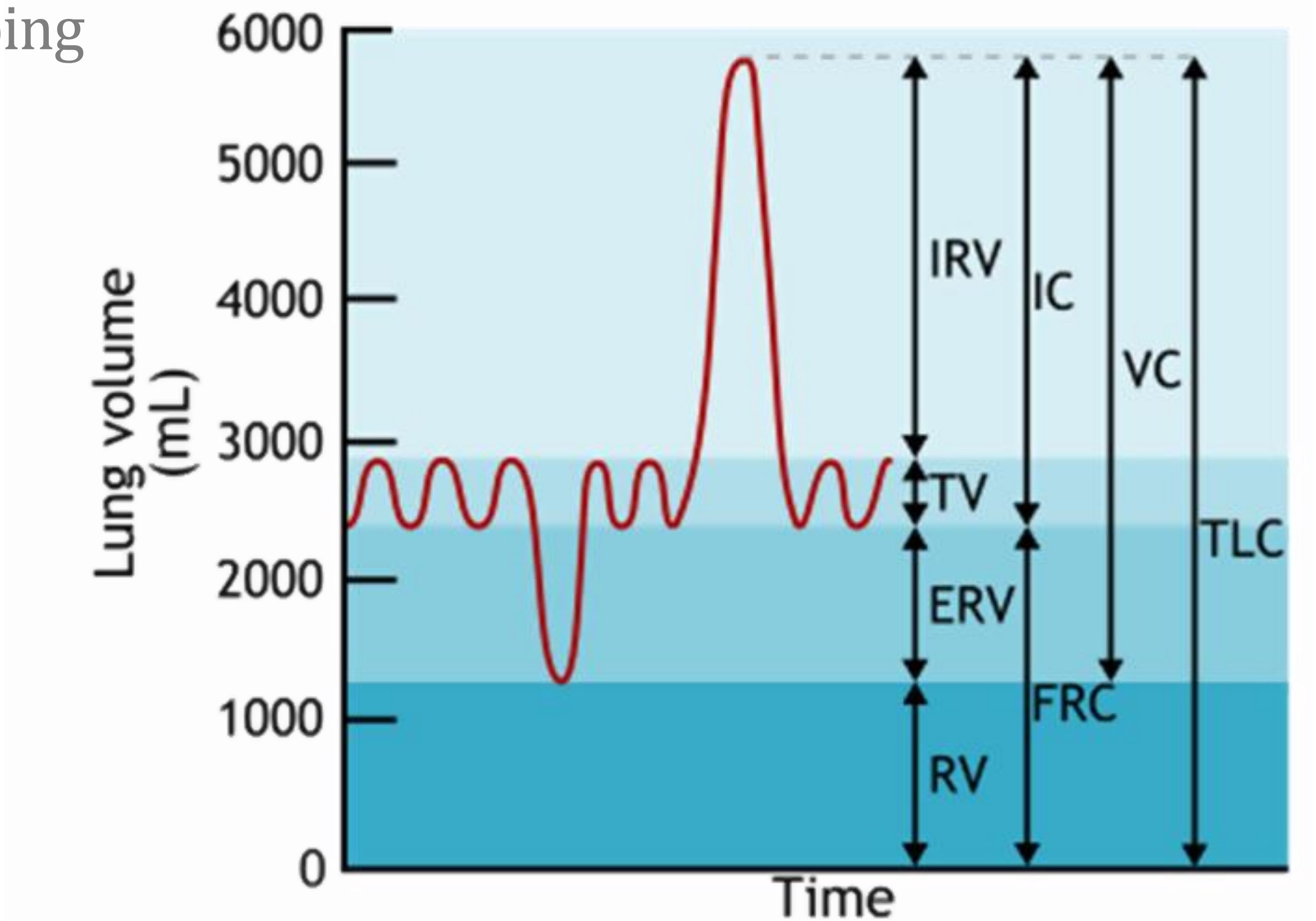
- Reduced FEV1 (slow flow out)
- Reduced FVC (less air out)
- **Reduced FEV1/FVC less than 70% (hallmark)**
- **Partial/no change FEV1 with bronchodilators**
    - No change in FEV1
    - Contrast with asthma



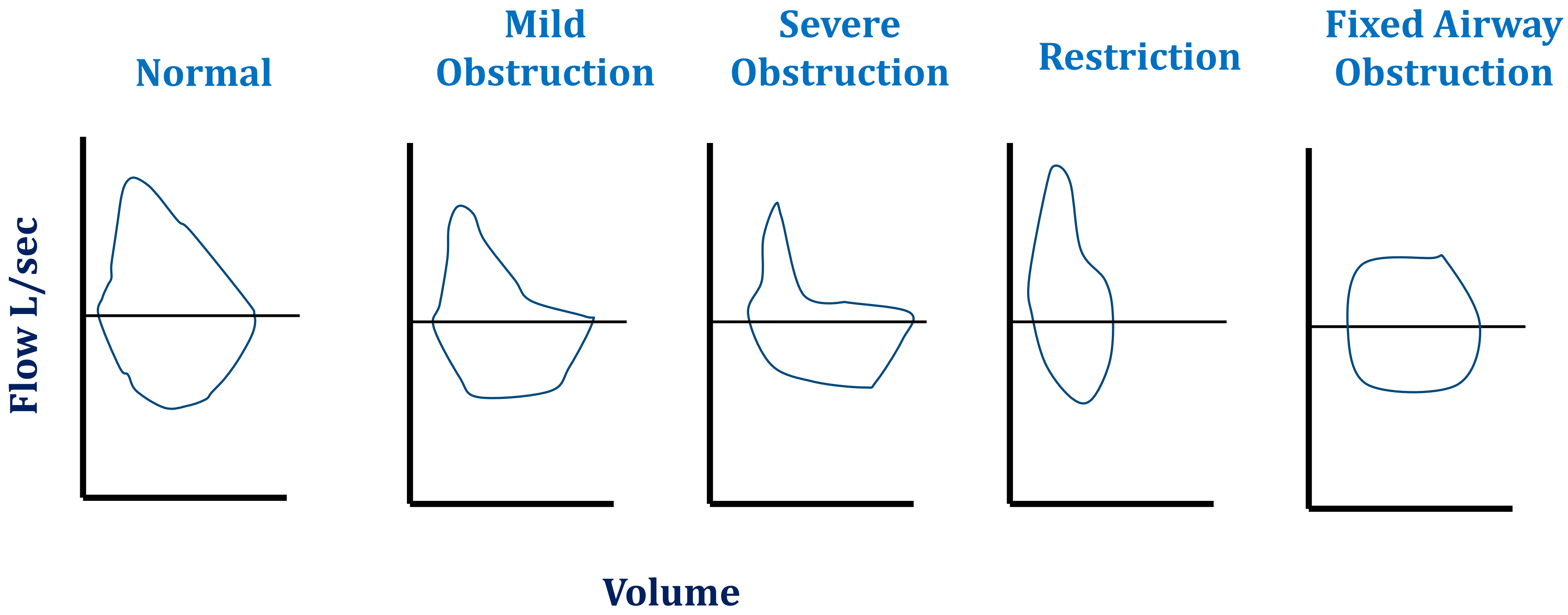
COPD

Pulmonary Function Testing

- Increased volumes from air trapping
- Total lung capacity
- Functional residual capacity
- Residual volume



Flow Volume Loops



DLCO

Diffusing capacity of carbon monoxide

- Measures ability of lungs to transfer gas
- Patient inhales small amount (not dangerous) CO
- Machine measures CO exhaled
- Normal = 75 – 140 % predicted
- Severe disease < 40% predicted
- Decreased in many forms of restrictive lung disease
- Decreased in **emphysema** but not chronic bronchitis

COPD

Arterial Blood Gas

- Decreased PaO2
- Increased PaCO2 (chronic respiratory acidosis)
- Increased bicarbonate (metabolic alkalosis)
  - Renal compensation for chronic respiratory acidosis
- Arterial pH slightly reduced or low normal

	Normal	COPD
PaO2	90	↓
PaCO2	40	↑
HCO3	24	↑
pH	7.4	↓/-

COPD

Disease Severity

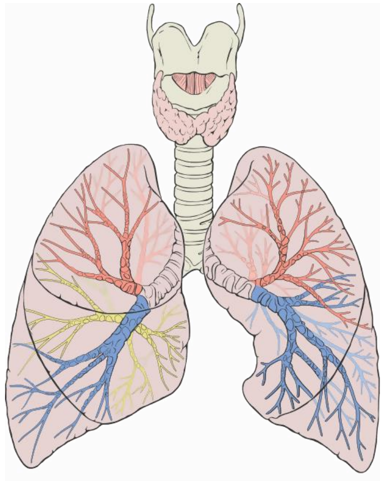
Class	Severity	FEV1
1	Mild	$\geq$ 80%
2	Moderate	50-79%
3	Severe	30-49%
4	Very Severe	< 30%

COPD versus CHF

	Heart Failure	COPD
Symptoms	Orthopnea, PND Cough possible	No orthopnea/PND
Lung Exam	Bibasilar Rales Decreased breath sounds at base (effusion) Some wheezing possible	Diffuse wheezing Rhonchi
JVP	Increased	Increased or normal
BNP	Increased	Normal
CXR	Pulmonary edema	Hyperinflation Diaphragm flattening
ABG	Hypoxemia with low CO2	Hypoxemia with high CO2
PCPW	Increased	Normal

Alpha-1 Anti-trypsin Deficiency

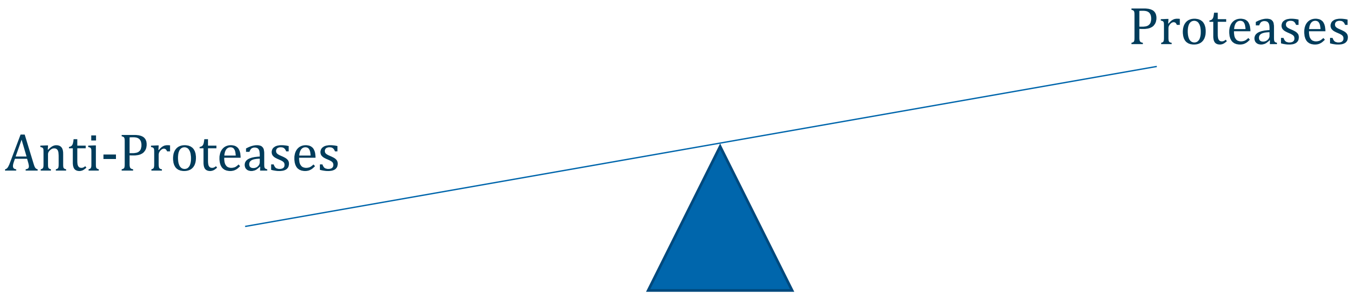
- Inherited (autosomal co-dominant)
  - Normal: M allele
  - Abnormal: Z allele
  - MM (normal), MZ, ZZ
- Decreased or dysfunctional AAT
- AAT balances effects of elastase
- Elastase found in neutrophils & alveolar macrophages



Patrick Lynch/Wikipedia

Alpha-1 Anti-trypsin Deficiency

- Smokers
  - Too many proteases created
  - Overwhelm anti-proteases
  - Upper lung damage
- α1 anti-trypsin deficiency
  - Ineffective anti-proteases
  - Lower lobe damage



Alpha-1 Anti-trypsin Deficiency

- **Lung**
  - Emphysema
  - Imbalance of neutrophil elastase (destroys elastin) and elastase inhibitor AAT (protective)
  - Lower lung damage
- **Liver cirrhosis**
  - Abnormal α1 builds up in liver
  - Only in phenotypes with pathologic polymerization of AAT in endoplasmic reticulum
  - Some patients have severe AAT deficiency but no intra-hepatocytic accumulation

Alpha-1 Anti-trypsin Deficiency

Diagnosis and Treatment

- Diagnosis:
  - **Serum AAT level**
  - Genetic testing
- Timing of manifestations
  - Up to 40 years of age: liver disease
  - After age 40: pulmonary disease
- These patients should **NEVER smoke**
  - Many nonsmokers never develop lung disease
- Treatment:
  - Usual COPD care
  - Intravenous infusion of pooled human AAT

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Alpha-1 Anti-trypsin Deficiency

- Classic case
  - Typical COPD symptoms: cough, sputum, wheeze
  - Younger patient (40s)
  - Prior/current smoking
  - Imaging: emphysematous changes most prominent at bases
  - Obstructive PFTs

COPD Treatment

Jason Ryan, MD, MPH

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COPD Treatment

- **Smoking cessation**
  - Does not cure disease
  - Slows rate of decline in FEV1
  - Prolongs survival
- Only smoking cessation and **oxygen** decrease mortality


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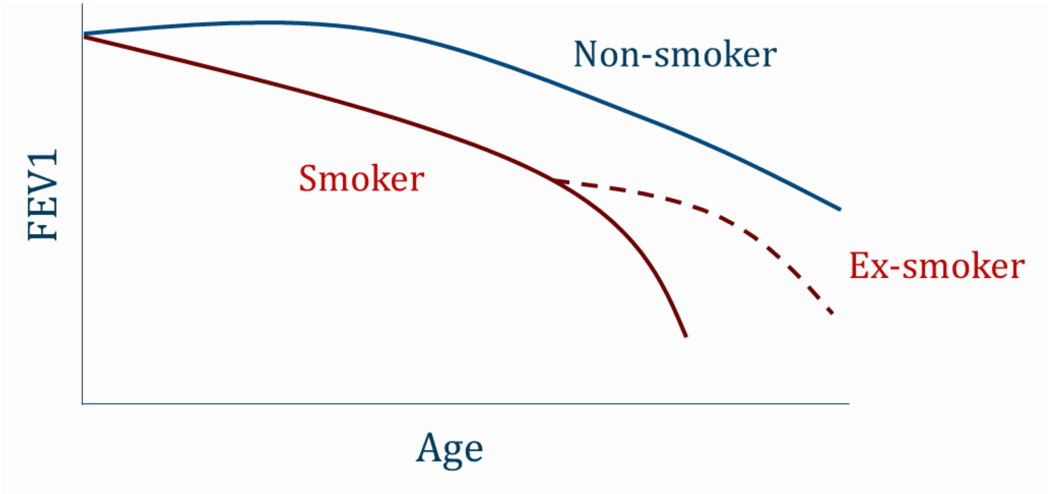

COPD Treatment

- **Bronchodilators**
  - Beta-agonists (BA)
    - Short-acting BA (SABA): albuterol
    - Long-acting BA (LABA): salmeterol, formoterol
  - Muscarinic antagonists (MA)
    - Short-acting MA (SAMA): ipratropium
    - Long-acting MA (LAMA): tiotropium
- **Corticosteroids**
  - Inhaled corticosteroids (ICS)
  - Oral corticosteroids
  - Intravenous corticosteroids

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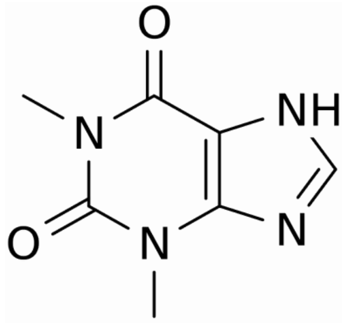
Corticosteroids

- Many side effects from long term use
  - Osteoporosis, cataracts, hyperlipidemia, adrenal suppression
- Few side effects when inhaled
  - **Oral candidiasis**
  - Dysphonia (voice changes)

James Heilman, MD

Theophylline

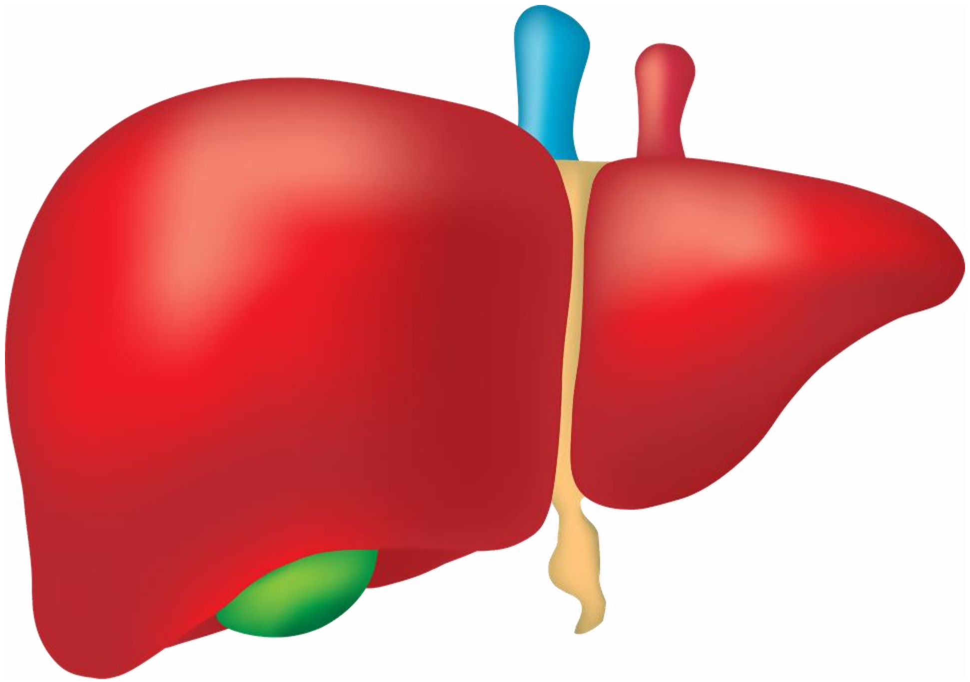
- **Bronchodilator**
- Multiple, complex mechanisms
- Narrow therapeutic index
- Levels must be monitored
- Dose must be titrated
- Goal is a peak serum concentration 10 to 20 mg/L
- Used in severe COPD



Theophylline

Theophylline

- Metabolized by P450
- Many drug-drug interactions
- Common culprits:
  - Cimetidine
  - Ciprofloxacin
  - Erythromycin
  - Clarithromycin
  - Verapamil
  - St. John's Wart



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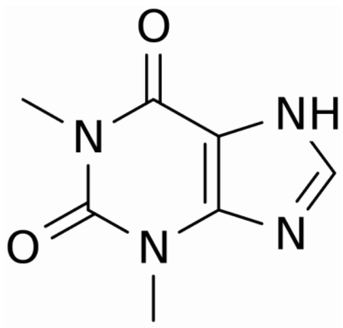
Theophylline

- GI toxicity
  - Nausea, vomiting
- Neurotoxicity
  - Seizures
- Overdose scenario: Nausea, vomiting, seizures

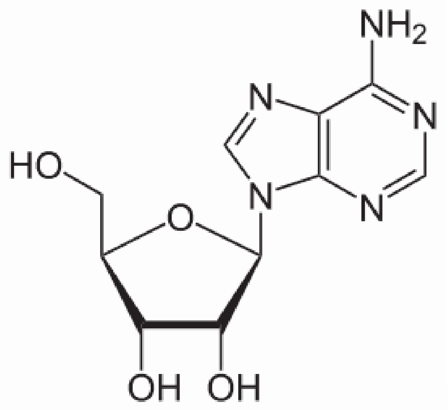
Public Domain

Theophylline

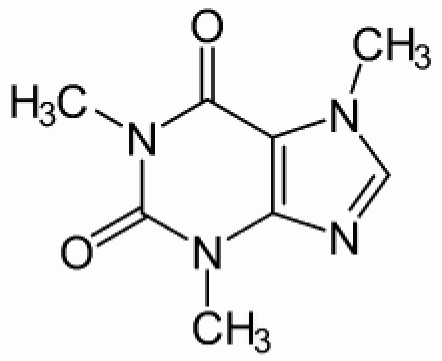
- **Cardiotoxicity**
  - Blocks adenosine receptors
  - Increased heart rate
  - Arrhythmias (atrial tachycardia, atrial flutter)
  - Cause of death in overdose/poisoning
- Key clinical scenario
  - Patient on theophylline for asthma/COPD
  - SVT
  - Adenosine fails to slow heart rate



Theophylline



Adenosine



Caffeine

Roflumilast

- Oral medication for COPD
- Phosphodiesterase-4 (PDE-4) inhibitor
- Decreases inflammation
- May relax airway smooth muscle
- Used in severe COPD

COPD Treatment

<u>COPD</u>

Acute Exacerbations

Chronic Therapy

COPD Acute Exacerbations

- Increased cough, sputum production or dyspnea
- Often triggered by viral or bacterial pulmonary infection
- Diagnosis: **clinical**

Public Domain

COPD Acute Exacerbations

Treatment

- Oxygen titrated to 88-92% O2 saturation
- Nebulized albuterol +/- ipratropium (Combivent)
- IV or oral corticosteroids
    - Prednisone 60 mg daily
    - Methylprednisolone 80 mg IV q8hrs
- **Antibiotics** (severe, hospitalized patients)

Public Domain

Noninvasive Ventilation

- Positive pressure ventilation
- Administered through mask not ETT
- Used in acute respiratory failure
- Often avoids intubation
- Patient must be awake, alert, cooperative

Wikipedia/Public Domain

COPD Exacerbations: Antibiotics

- Viruses cause up to 50% of episodes
- Bacteria: S. pneumoniae, H. influenzae, and Moraxella catarrhalis
- Fluoroquinolones (levofloxacin)
- Macrolides (azithromycin)
- Amoxicillin/clavulanic acid

COPD Chronic Therapy

- Based on assessment of **symptoms** plus **exacerbations per year**

Grade	Symptoms
0	Breathlessness with strenuous exercise only
1	Shortness of breath when hurrying on level ground or walking up a slight hill
2	On level ground, slower walking than others, or needing to stop for breath
3	Breathlessness after walking about 100 yards or after a few minutes on level ground
4	Too breathless to leave the house, or breathlessness when dressing

COPD Chronic Therapy

	Symptoms	Exacerbations	Treatment
A	Mild (0-1)	0 or 1	SABA or SAMA prn
B	Moderate to severe ($\geq$ 2)	0 or 1	SABA or SAMA prn plus LABA or LAMA
C	Mild (0-1)	2 or more	SABA or SAMA prn plus LAMA or LABA + ICS or LABA + LAMA
D	Moderate to severe ($\geq$ 2)	2 or more	Multiple drugs

Refractory Disease ONLY
Theophylline
Roflumilast

Never give ICS alone

COPD

Disease Severity

Class	Severity	FEV1
1	Mild	$\geq$ 80%
2	Moderate	50-79%
3	Severe	30-49%
4	Very Severe	< 30%

COPD Chronic Therapy

- Chronic oxygen therapy
  - Associated with **increased survival**
  - Only used in patients with hypoxemia
  - Indications: $PaO_2 < 55$ mmHg or O_2 sat < 88%
- Pulmonary rehabilitation
  - Improves exercise capacity, quality of life
  - Decrease dyspnea
- Vaccinations
- Smoking cessation
  - Associated with **increased survival**

Public Domain

Surgical Treatment

- Advanced "end-staged" COPD
- Lung volume reduction surgery/bullectomy
  - Remove diseased lung tissue
  - Allow healthy lung tissue more room to expand
- Lung transplantation

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Multifocal Atrial Tachycardia

- Irregular rhythm
- Multiple p wave morphologies
- Common during COPD exacerbations
- **Treat underlying condition**
- No specific cardiac therapy indicated

Mutifocal Atrial Tachycardia

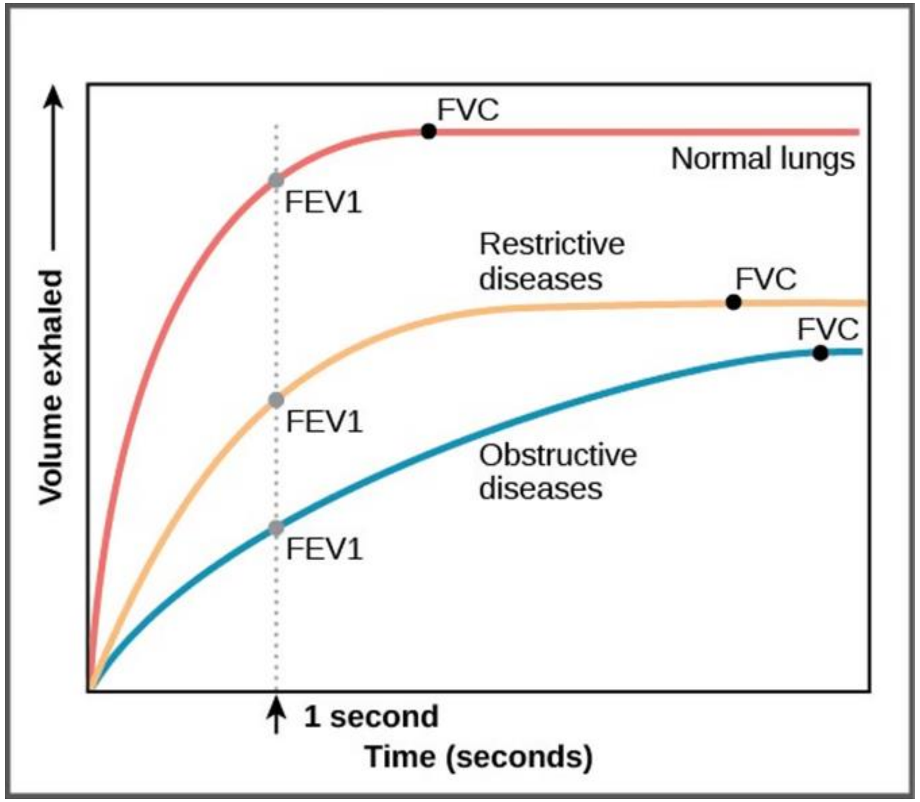
Restrictive Lung Disease

Jason Ryan, MD, MPH

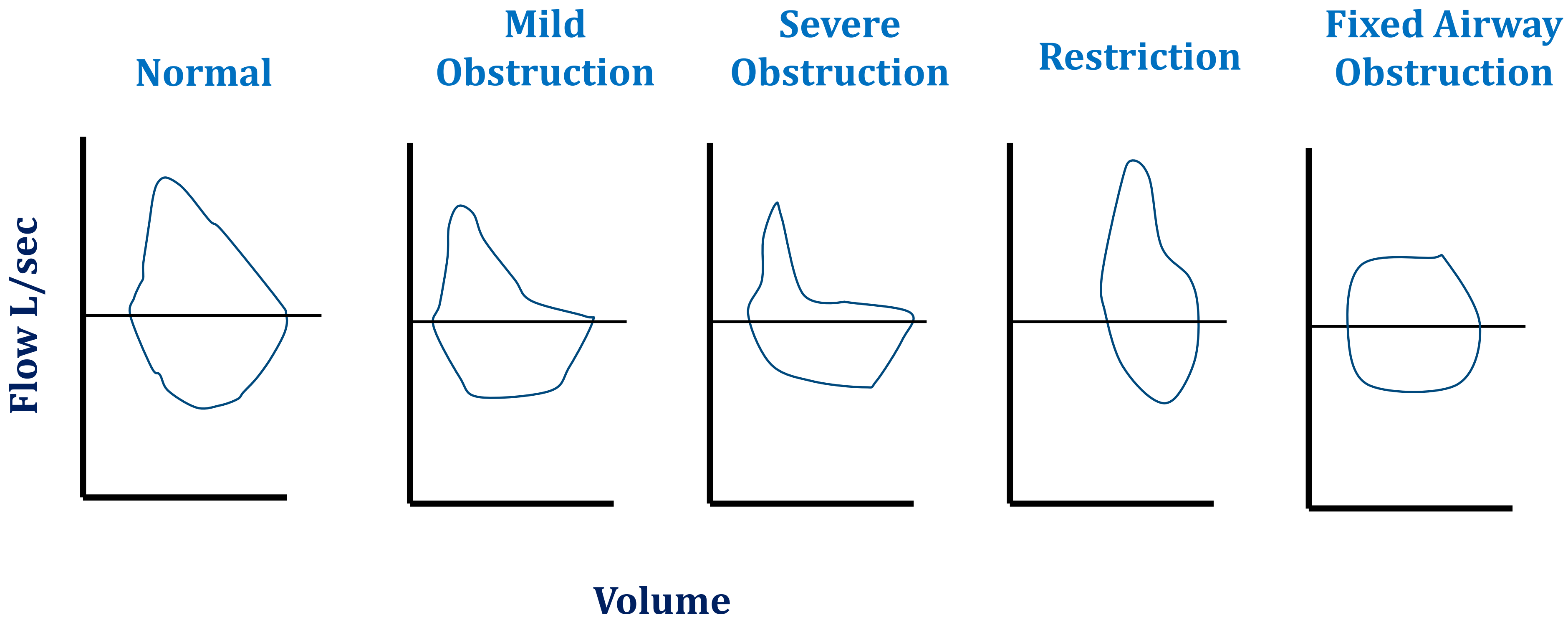
Boards & Beyond
STUDY SMARTER

Restrictive Lung Diseases

- Disorders where air cannot get in → less air out
- Dyspnea with restrictive spirometry
- Reduced FEV1 (less air in/out)
- Reduced FVC (less air in/out)
- Normal (> 80%) FEV1/FVC (hallmark)
- Reduced TLC



Flow Volume Loops



Restrictive Lung Physiology

Causes

1. Poor breathing mechanics
2. Interstitial lung diseases

DLCO

Diffusing capacity in lung of carbon monoxide

- DLCO = diffusing capacity of carbon monoxide
  - Separates cases restrictive disease
  - Measures ability of lungs to transfer gas to RBCs
  - Normal = 75–140% predicted
  - Severe disease < 40% predicted
- Restriction with normal DLCO
  - Poor breathing mechanics
  - Extra-pulmonary cause: obesity, weakness
- Restriction with low DLCO
  - Interstitial lung disease

Low DLCO Conditions

- **Interstitial lung disease**
- Emphysema
- Abnormal vasculature
  - Pulmonary hypertension
  - Pulmonary embolism
- Prior lung resection

Dyspnea/Hypoxemia

↓

<u>Restrictive Spirometry</u>
Low FEV1
Low FVC
Normal FEV1/FVC

↓

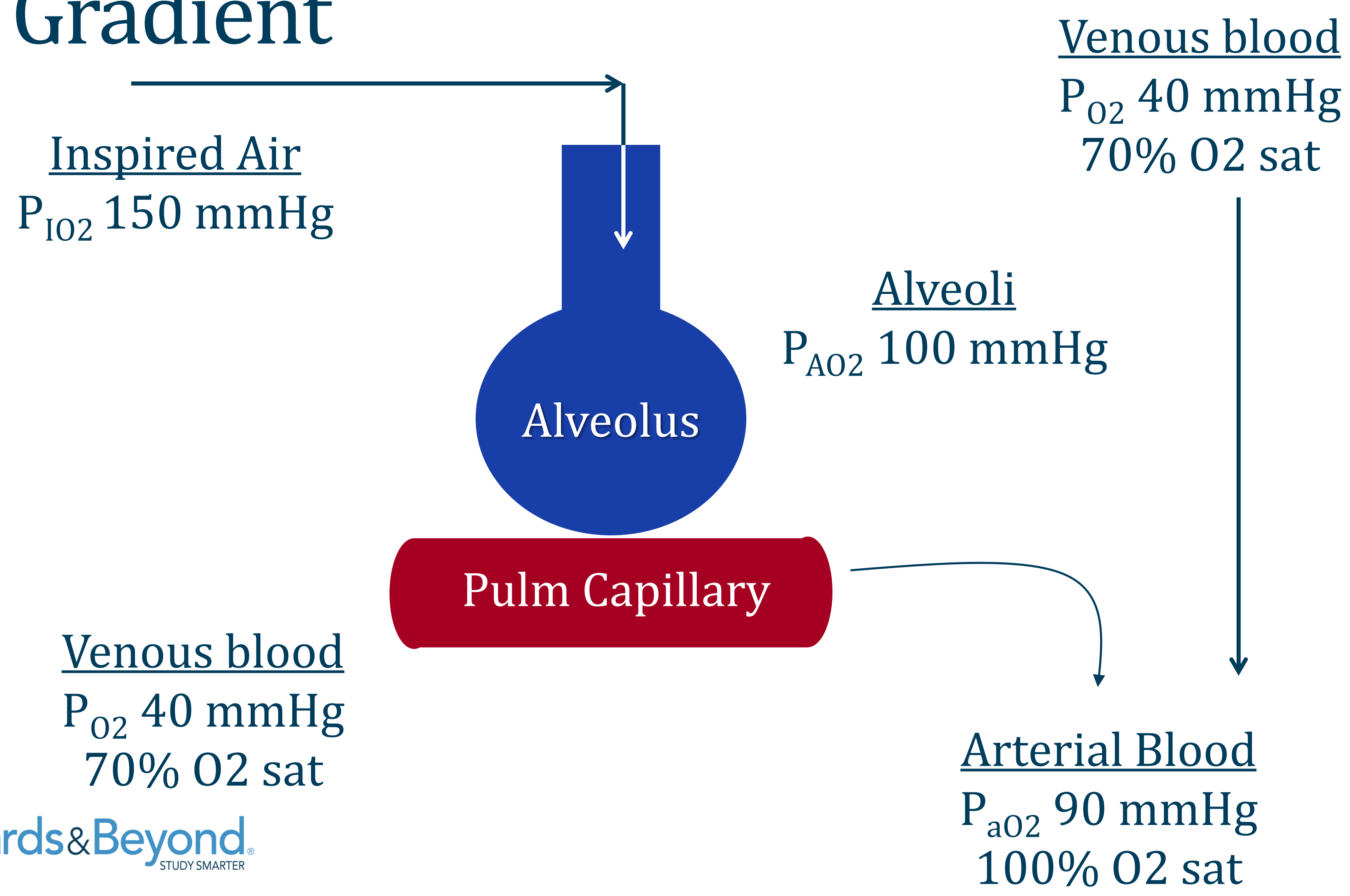
DLCO

Low ↙ ↘ Normal

Interstitial Lung Disease

Chest wall
Neuromuscular

A-a Gradient



Inspired Air
P_{IO2} 150 mmHg
Alveolus
Alveoli
P_{AO2} 100 mmHg
Venous blood
P_{O2} 40 mmHg
70% O2 sat
Pulm Capillary
Venous blood
P_{O2} 40 mmHg
70% O2 sat
Arterial Blood
P_{aO2} 90 mmHg
100% O2 sat

Alveolar Gas Equation

$$P_{AO2} = P_{IO2} - \frac{P_{aCO2}}{R} = 150 - \frac{P_{aCO2}}{0.8}$$

A-a Gradient

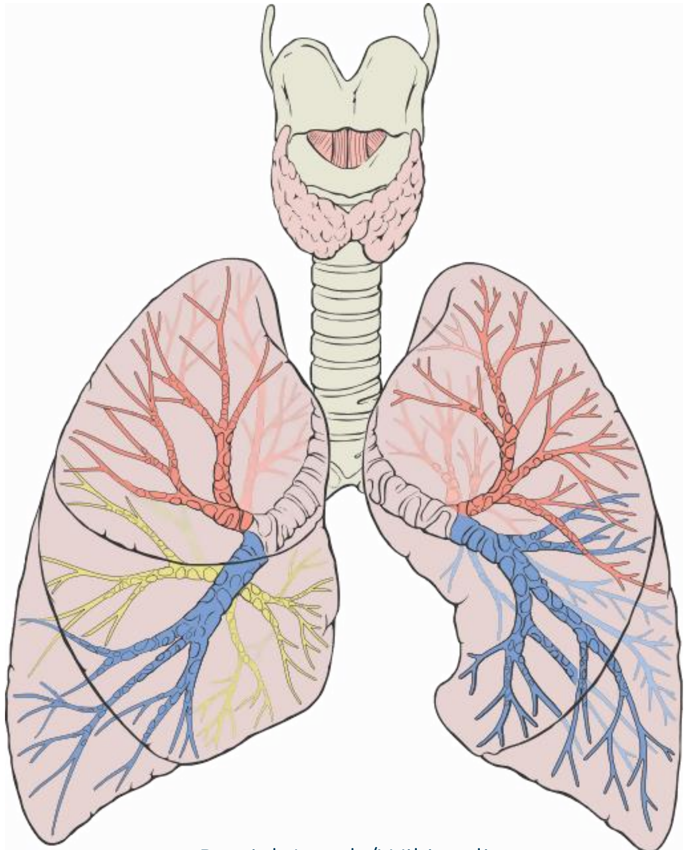
- Difference between alveolar (A) and arterial (a) O_2
- Helpful for evaluating hypoxemia
- Step 1: Measure $P_{aO2,}$ P_{aCO2}
- Step 2: Determine P_{AO2} from gas equation
- Step 3: A-a gradient = $P_{AO2} - P_{aO2}$
- Normal 10-15 mmHg
  - Shunting from thebesian and bronchial veins

Hypoxemia: Normal A-a Gradient

- **Decreased oxygen content of air**
  - High altitude
  - P_{IO2} sea level = 150 mmHg
  - P_{IO2} high altitude ~ 100 mmHg
- **Hypoventilation**
  - Reduced respiratory rate
  - Reduced tidal volume
  - Narcotics, neuromuscular weakness, obesity
- **Always improves with oxygen**

Hypoxemia: High A-a Gradient

- **Lung disease**
  - Interstitial lung disease
  - Pneumonia
  - COPD



Patrick Lynch/Wikipedia

Restrictive Lung Disease

A-a Gradient

Dyspnea/Hypoxemia

↓

<u>Restrictive Spirometry</u>

Low FEV1

Low FVC

Normal FEV1/FVC

↓

Aa Gradient

High ↙ ↘ Normal

Interstitial Lung Disease

Chest wall

Neuromuscular

Obesity Hypoventilation Syndrome

- Common cause of dyspnea
- Restrictive pattern of PFTs
- Normal A-a gradient
- Normal DLCO
- ABG: hypercapnia from hypoventilation
    - Compensatory increased bicarbonate
- Treatment: **weight loss**

Tibor Végh

Interstitial Lung Diseases

- Large group of disorders
- “Diffuse parenchymal lung diseases”
- Inflammatory disorders of alveolar wall → fibrosis → restriction
- Similar clinical, radiographic, physiologic, or pathologic manifestations
- Restrictive PFTs
- Low DLCO
- Increased A-a gradient

Interstitial Lung Disease

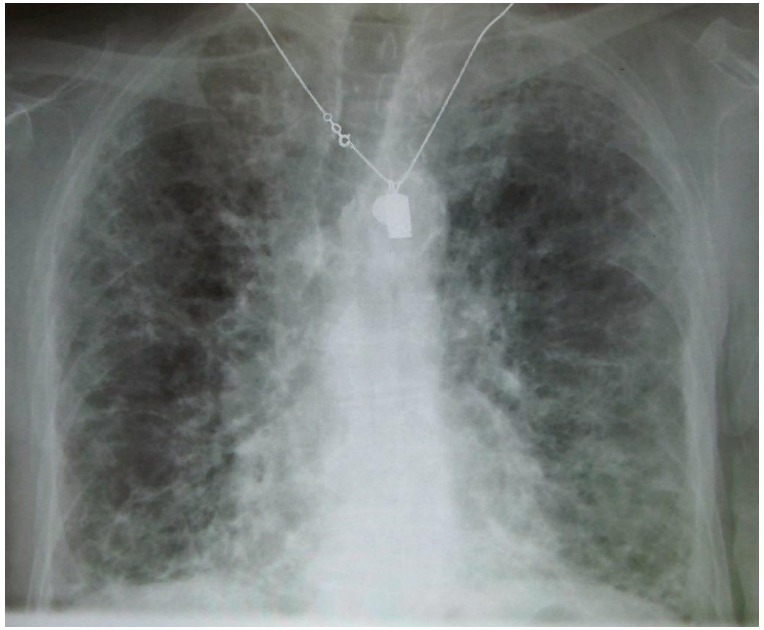
Clinical Presentation

- Dyspnea
- Nonproductive cough
- Diffuse crackles on lung exam
- “Velcro-like” rales at lung bases
- Clubbing (especially in IPF)
- Right heart failure

Interstitial Lung Disease

Clinical Presentation

- Chest X-ray: usually non-specific findings



Bilateral, diffuse pattern
Small, irregular opacities (reticulonodular)
"Honeycomb" lung appearance

Interstitial Lung Disease

Diagnosis

- Best first test: **chest CT**
- Lung biopsy for definitive diagnosis

Interstitial Lung Disease
Etiologies

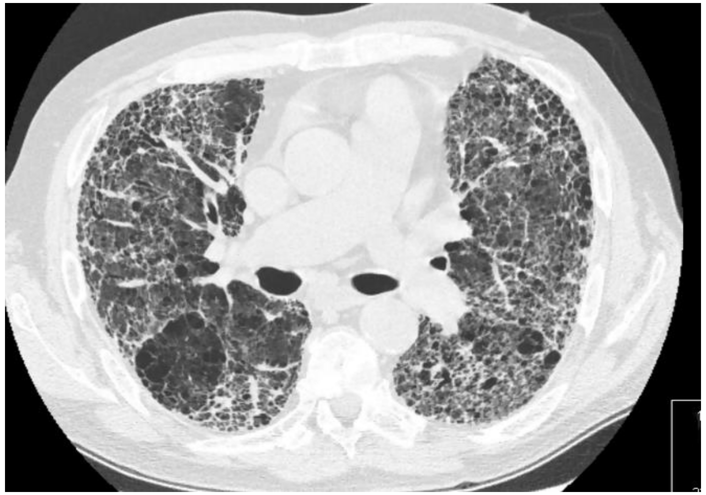
Key Steps in Work-Up
Medication History
Occupational History
Past Medical History

- Environmental exposure
  - Coal worker's pneumoconiosis
  - Silicosis
  - Asbestosis
  - Berylliosis
- Granulomatous
  - Sarcoid
  - Vasculitis
- Alveolar disease
  - Goodpasture
- Drug-induced
  - Amiodarone
  - Bleomycin
  - Methotrexate
- Autoimmune-related
  - RA
  - SLE
  - Scleroderma
- Others
  - IPF
  - COP
  - Radiation pneumonitis

Idiopathic Pulmonary Fibrosis

IPF

- ***Slow-onset* dyspnea** and nonproductive cough
- Typically affects adults aged 60s/70s
- Progressive disease: mean survival 3 to 7 years
- Associated with digital clubbing
- Diagnosis: Chest CT plus biopsy
- Treatment: supportive +/- lung transplant
- Anti-fibrotic agents: pirfenidone and nintedanib
  - Inhibit fibroblast activity
  - Slow progression



James Heilman, MD

Cryptogenic Organizing Pneumonia
COP

- Granulation tissue deposited in alveolar wall
- Cough, dyspnea, malaise over weeks/months
- CXR: Bilateral patchy infiltrates
- Lack of response to antibiotics
- Diagnosis: lung biopsy
- Treatment: **corticosteroids**

Public Domain

Pneumoconiosis

Occupational lung diseases

- Coal miner's lung
- Silicosis
- Asbestosis
- Berylliosis
- Environmental contaminants → inflammation and fibrosis
- Mainstay of treatment: avoid additional exposure
- Most have no specific treatment

Asbestosis

- Inhalation of asbestos fibers
- Shipbuilding, roofing, plumbing
- Causes dyspnea
- Often causes clubbing
- Classic X-ray finding: **pleural plaques**
- Asbestos also associated with lung cancer
  - Bronchogenic carcinoma
  - Mesothelioma (pleural malignancy)

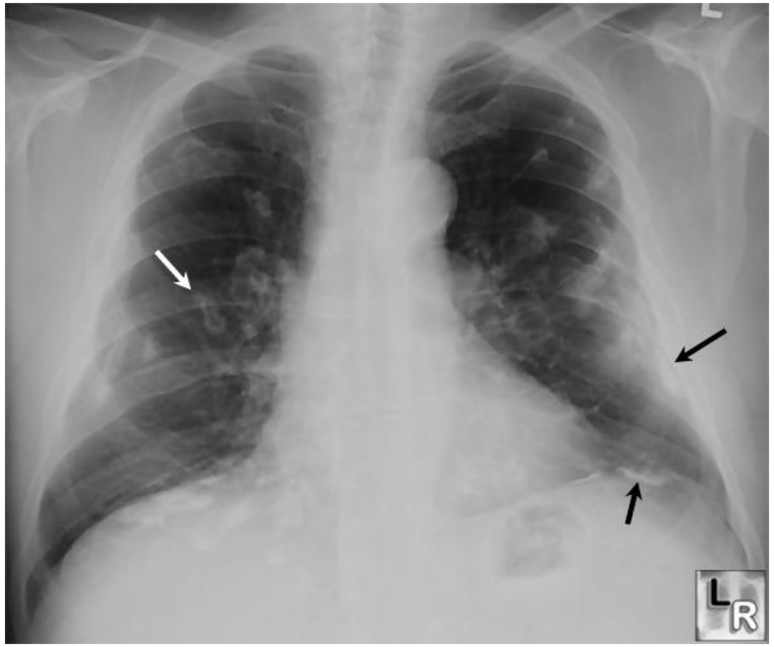


Image courtesy of www.learningradiology.com

Hypersensitivity Pneumonitis

- Hypersensitivity reaction to environmental antigen
- Classic case is a **farmer's lung**
  - Moldy hay, grain exposure
- Also common in **bird/poultry handlers**
  - Waste from birds → dried, finely dispersed dust

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Hypersensitivity pneumonitis

- Classic case
  - Farmer or bird handler
  - Cough, dyspnea
  - Diffuse crackles
  - CXR: interstitial infiltrates
- Treatment:
  - Avoid exposure
  - Steroids

Public Domain

Pneumonia

Jason Ryan, MD, MPH

Boards & Beyond
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Pneumonia

Treatment Categories

- **Community acquired**
  - Onset outside hospital or within 72 hours
  - Typical: **S. Pneumoniae**, H. Influenza, S. Aureus
  - Atypical: Mycoplasma, Chlamydia, Legionella (atypicals)
- **Nosocomial**
  - Hospital-acquired pneumonia (HAP)
  - Ventilator-associated pneumonia (VAP)
  - Healthcare-associated pneumonia (HCAP; nursing homes)
  - Often gram-negatives (pseudomonas, Klebsiella, E. Coli) or S. Aureus

Typical CAP

Community Acquired Pneumonia

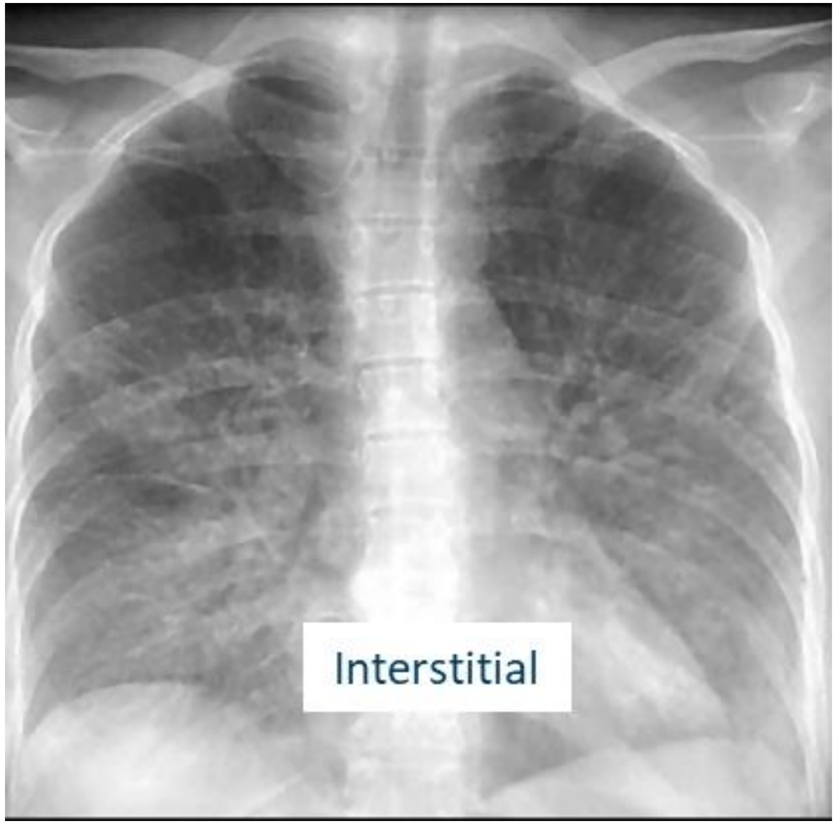
- Fever, cough, dyspnea
- Pleuritic chest pain
- Best first test: **chest X-ray**
  - Distinguishes PNA from bronchitis (no abx)
- Sputum culture: rarely necessary

RUL Consolidation

Effusion	Consolidation
Decreased/absent breath sounds Dullness to percussion Decreased fremitus Egophony present	Bronchial breath sounds Dullness to percussion Increased fremitus Egophony present

Atypical Pneumonia

- Pneumonia caused by:
  - Legionella pneumophila
  - Mycoplasma pneumoniae
  - Chlamydophila pneumoniae
- Usually milder than strep pneumonia
- Respiratory distress rare
- Interstitial infiltrates on CXR
- “Walking pneumonia”



drahmed142010

Procalcitonin

- Serum biomarker
- Precursor of calcitonin
- Elevated in bacterial lower respiratory tract infections
- Sometimes used for diagnosis or to guide therapy

Hospitalization

- Most patients with CAP treated as outpatients
- **Hypoxemia = hospitalize**
- CURB65 criteria for hospitalization
  - **C**onfusion (new onset)
  - Blood **U**rea nitrogen greater than 19 mg/dL
  - **R**espiratory rate of 30 or greater
  - Systolic **B**lood pressure < 90 mmHg systolic
  - Or diastolic blood pressure < 60 mmHg
  - Age **65** or older
- CURB65 $\geq$ 2 = hospitalize

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Typical CAP

Community Acquired Pneumonia

- Treatment covers S . pneumo, H. flu plus atypicals
- Healthy with mild symptoms
    - Outpatient oral therapy
    - Macrolide (azithromycin) or doxycycline
    - Three- to five-day course
    - Patient should be afebrile 48hrs at end of treatment

RUL Consolidation

Typical CAP

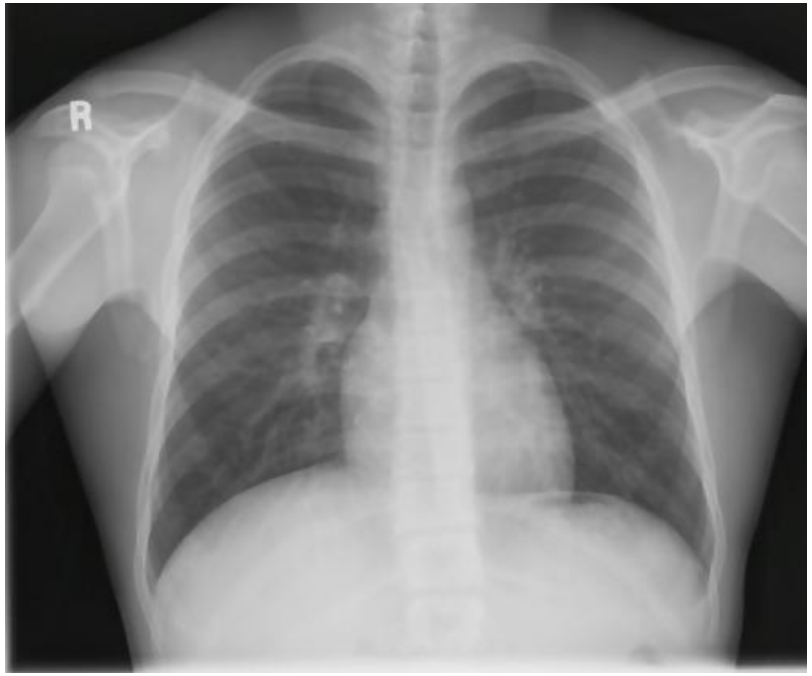
Community Acquired Pneumonia

- Comorbidities (e.g., COPD)
  - Outpatient oral therapy
  - Fluoroquinolone (levofloxacin)
  - B-lactam (amoxicillin) plus azithromycin
- Inpatient
  - Fluoroquinolone (levofloxacin)
  - B-lactam (ceftiaxone) plus azithromycin

RUL Consolidation

Pneumonia Follow-up

- **X-ray resolution takes 4-6 weeks**
- Patients > 50 → repeat chest x-ray 6 to 12 weeks
  - Exclude malignancy



Recurrent Pneumonia

- Different lung regions
  - Immunodeficiency (HIV, cystic fibrosis)
- Same lung region
  - Airway obstruction (e.g., malignancy)
  - Bronchiectasis
  - Best next test: **CT scan**
- Recurrent right middle/lower lobe
  - Aspiration

Nosocomial Pneumonia

- Often resistant to antibiotics
- Gram-negative rods including pseudomonas
- Staph Aureus including MRSA
- Hospital-acquired
  - Onset > 72 hours after hospitalization
- Ventilator-acquired
  - Onset > 48 hours after ventilation

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Nosocomial Pneumonia

- Old guidelines: empiric coverage MRSA/pseudomonas
- New guidelines 2019:
  - Cover MRSA/pseudomonas selectively
  - Use "locally validated risk factors"
  - Goal: avoid overuse of broad spectrum antibiotics

Diagnosis and Treatment of Adults with Community-acquired Pneumonia

An Official Clinical Practice Guideline of the American Thoracic Society and Infectious Diseases Society of America

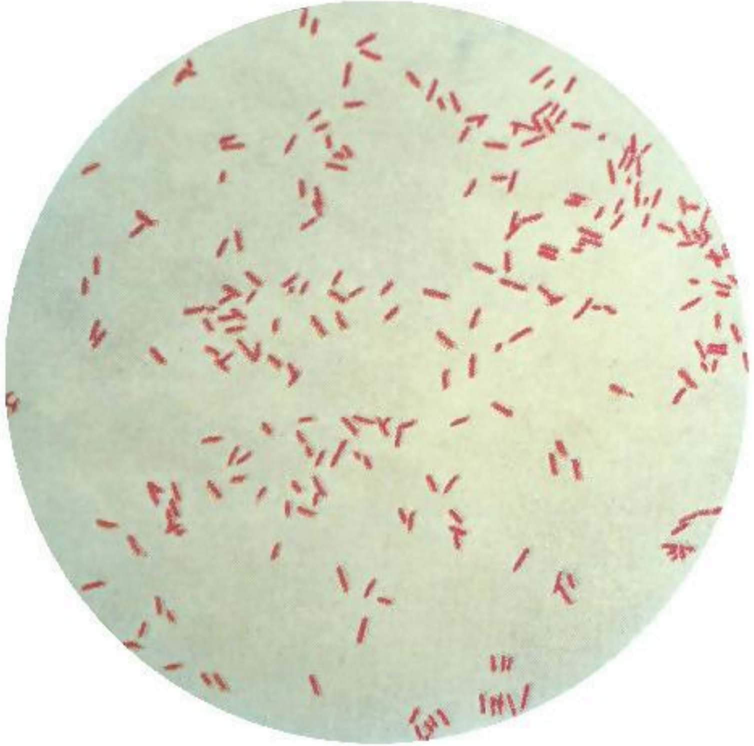
Joshua P. Metlay*, Grant W. Waterer*, Ann C. Long, Antonio Anzueto, Jan Brozek, Kristina Crothers, Laura A. Cooley, Nathan C. Dean, Michael J. Fine, Scott A. Flanders, Marie R. Griffin, Mark L. Metersky, Daniel M. Musher, Marcos I. Restrepo, and Cynthia G. Whitney; on behalf of the American Thoracic Society and Infectious Diseases Society of America

This official clinical practice guideline was approved by the American Thoracic Society May 2019 and the Infectious Diseases Society of America August 2019

Nosocomial Pneumonia

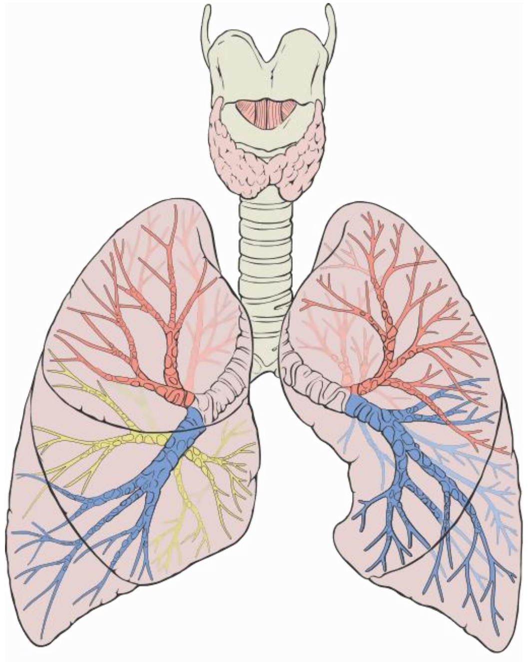
- MRSA coverage: vancomycin or linezolid
- Pseudomonas coverage:
  - Piperacillin-Tazobactam
  - Cefepime
  - Gentamycin

Pseudomonas Aeruginosa



Aspiration

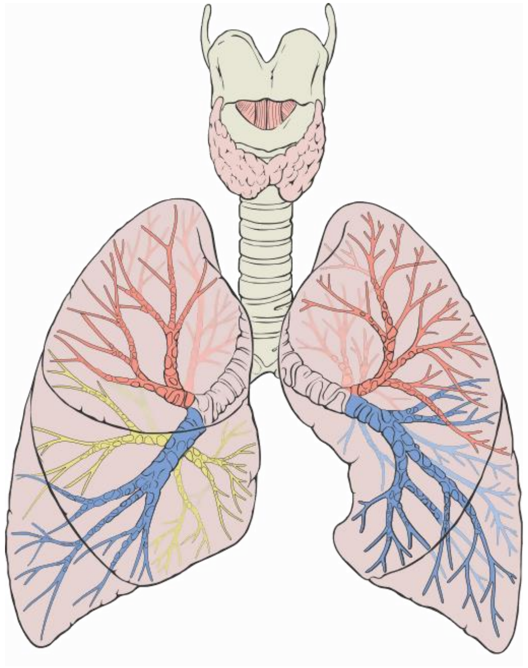
- Aspiration of stomach acid and microorganisms
- May cause pneumonitis or pneumonia
- Risk factors:
    - Reduced consciousness (anesthesia)
    - Seizures
    - Heavy alcohol use
    - Dysphagia from neuromuscular weakness



Patrick Lynch/Wikipedia

Aspiration Pneumonia

- Slow-onset symptoms over days
- Foul-smelling sputum
- Klebsiella
- Staph Aureus
- Anaerobic bacteria
  - Peptostreptococcus
  - Fusobacterium
  - Prevotella
  - Bacteroides
- Treatment: **ampicillin-sulbactam**



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Pneumonitis versus Pneumonia

	Pneumonitis	**Pneumonia**
General Pathogenesis	Irritation from aspiration of gastric acid	Aspiration of bacteria
Clinical Features	Acute onset dyspnea and hypoxemia after witnessed aspiration	Slow onset of pneumonia symptoms in patient with aspiration risk factors
Diagnosis	Clinical	X-ray
Treatment	Suctioning, oxygen	Antibiotics

Lung Abscess

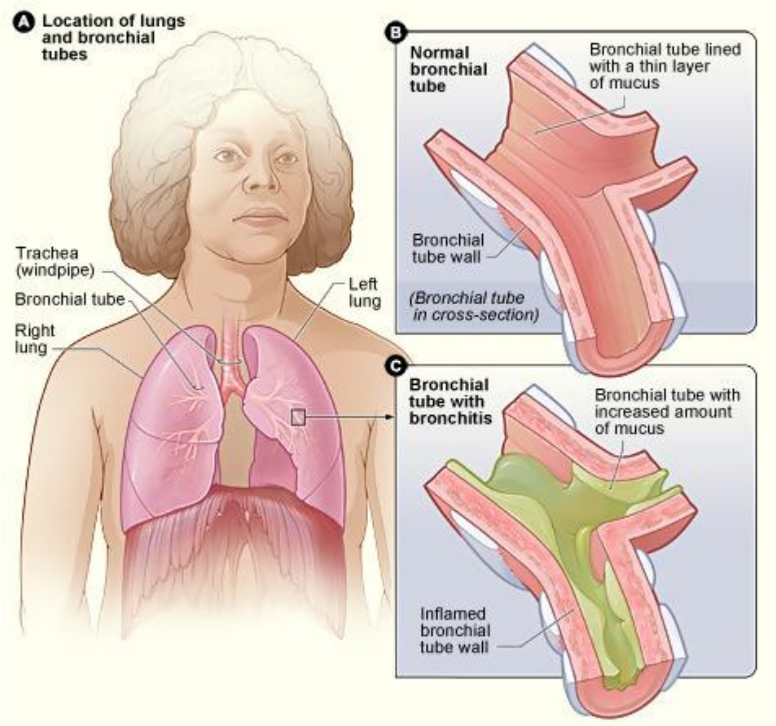
- Contained, fluid-filled space in lungs
  - “Air fluid level” on imaging
- Most commonly a consequence of **aspiration**
- Rarely due to bronchial obstruction from cancer
- Predominantly anaerobes
  - Peptostreptococcus
  - Prevotella
  - Bacteroides
  - Fusobacterium
- Sometimes S. Aureus, Klebsiella

Lung Abscess

- Diagnosis: CXR or CT
- Treatment:
  - Ampicillin-sulbactam
  - Piperacillin-tazobactam
- Surgery rarely indicated

Acute Bronchitis

- Viral infection
- Often follows a URI (nasal congestion, sore throat)
- Persistent cough > 5 days
- Blood-tinged sputum
- **Normal chest x-ray**
- Self-limited
- Supportive treatment
- **No antibiotics**



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Lung Cancer

Jason Ryan, MD, MPH

Boards & Beyond
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Common Cancers

	Women		Men	
Cancer	US Incidence #/yr	US Deaths #/yr	US Incidence #/yr	US Deaths #/yr
Breast	268,600	41,760	2,670	500
Colon	51,690	23,380	51,690	27,640
Lung	116,070	67,130	130,370	80,380
Prostate	--	--	174,460	31,620

Source: American Cancer Society, 2019

Lung Cancer

Risk Factors

- **Cigarette smoking**
- Radiation therapy
    - Hodgkin lymphoma and breast cancer survivors
- Environmental toxins
    - Asbestos
    - Radon

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Lung Cancer
Clinical Presentation

- Usually advanced at presentation
- Cough, dyspnea, rarely hemoptysis
- Symptoms usually lead to chest imaging

Digital Clubbing

- Lung Cancer
- Idiopathic pulmonary fibrosis
- Cystic fibrosis
- Congenital heart disease

James Heilman, MD

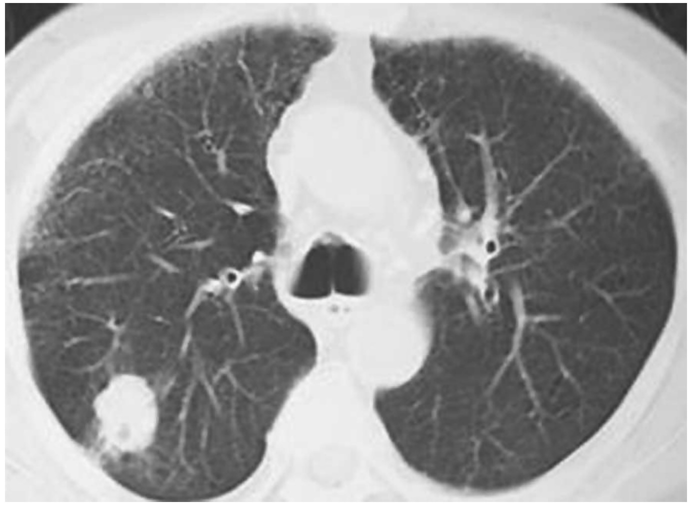
Recurrent Pneumonia

- Same lung region: airway obstruction
  - Possible malignancy
  - Best next test: CT scan

Lung Cancer

Diagnosis

- Chest X-ray
  - Pulmonary nodule
  - “Coin lesion”
  - **Compare with prior**
- Chest CT
- Biopsy



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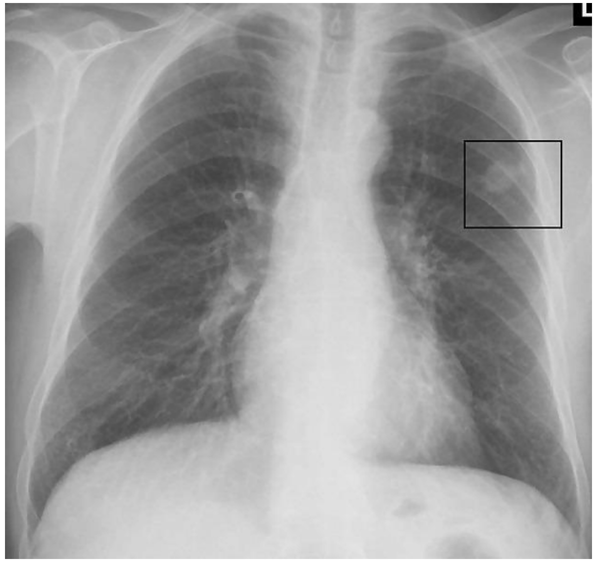
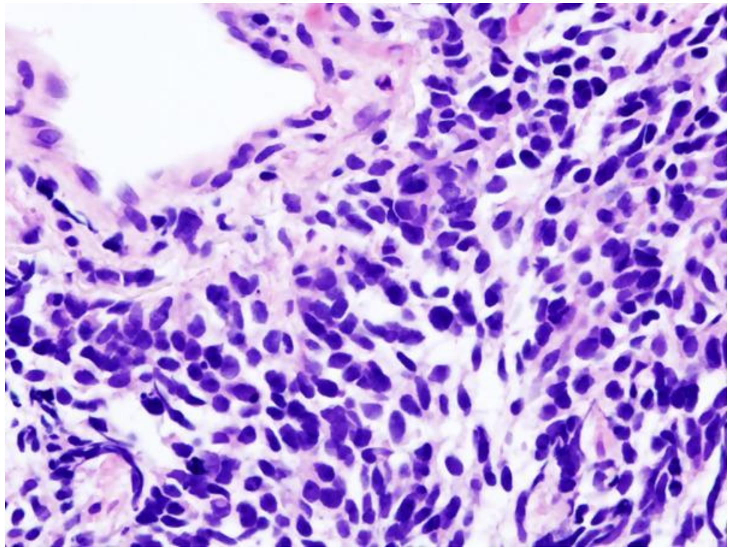


Lange123

Lung Cancers
Subtypes

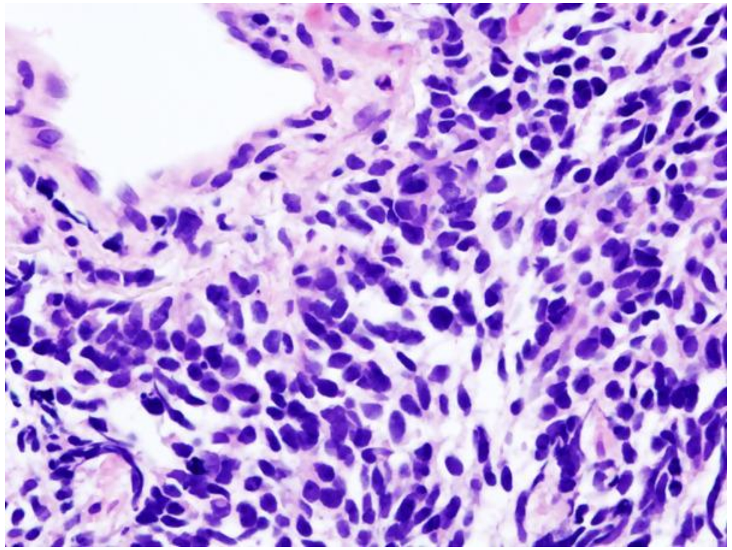
- Small cell (~15%)
  - Rarely resectable (95% cases)
  - Poor prognosis
- Non-small cell (most common: ~85%)
  - Can sometimes be resected
  - Better prognosis
  - Squamous Cell Carcinoma
  - Adenocarcinoma
  - Large cell carcinoma



Small Cell Cancer

Small Cell Cancer

- Fast growing with early metastasis
- Non amenable to surgical resection
- Occurs in **smokers**
- Treated with chemotherapy
- Poor prognosis
- Many paraneoplastic syndromes

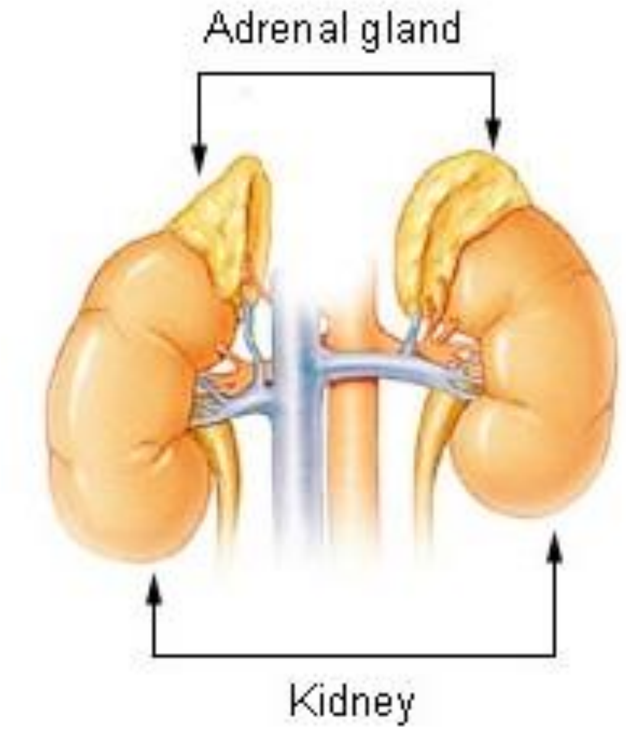


Small Cell Cancer

Small Cell Cancer

Paraneoplastic Syndromes

- **ACTH**
  - Cushing syndrome
  - Progressive obesity
  - Hyperglycemia
- **ADH**
  - SIADH
  - Hyponatremia (confusion)
- **Antibodies**
  - Antibodies against pre-synaptic Ca channels in neurons
  - Block release of acetylcholine
  - Lambert-Eaton syndrome
  - Main symptom is weakness



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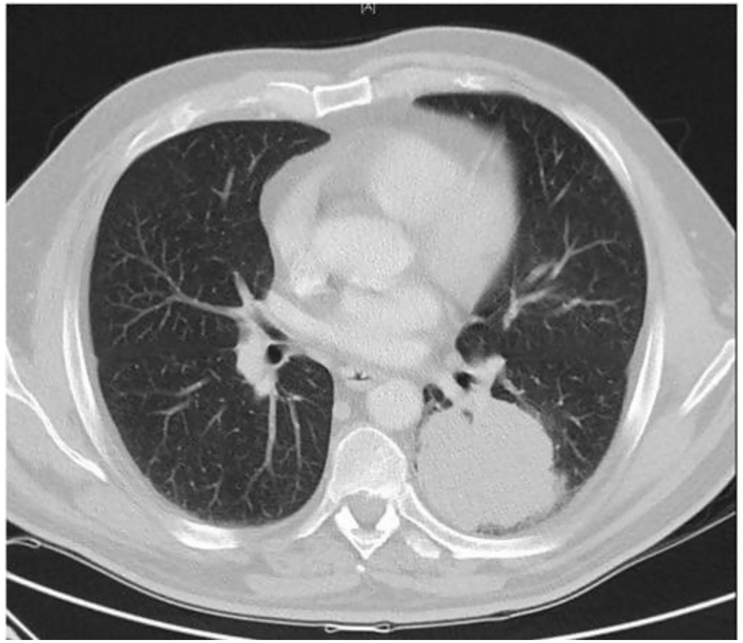
Squamous Cell Carcinoma

- Hilar mass arising from bronchus
- Key pathology
  - Keratin production ("pearls") by tumor cells
  - Intercellular desmosomes ("intercellular bridges")
- Common in **male smokers**
- Can produce PTHrP
  - **Hypercalcemia**
  - Bone and abdominal pain, confusion



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Adenocarcinoma

- Glandular tumor
- Most common lung cancer in **nonsmokers**
- Weakest association with smoking
- Peripheral

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Large Cell Carcinoma

- Poorly differentiated
    - Lacks glandular or squamous differentiation
    - Lacks small cells
- Smoker's cancer
- Peripheral
- Poor prognosis

Lung Cancer
Treatment

- Surgery, chemotherapy and radiation
- Most important question is **whether to perform surgery**
- Surgery not indicated with:
  - Metastatic disease
  - Bilateral disease
  - Malignant pleural effusion (must tap effusions!)
- Small cell cancer unresectable in 95% of cases
  - Metastasis at time of diagnosis
- Note: size not a major determinant

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Complications

- Pleural effusions
  - Tap fluid, send for cytology
- Phrenic nerve compression
  - Diaphragm paralysis
  - Dyspnea
  - Hemidiaphragm elevated on CXR
  - Sniff test
- Recurrent laryngeal nerve compression
  - Hoarseness

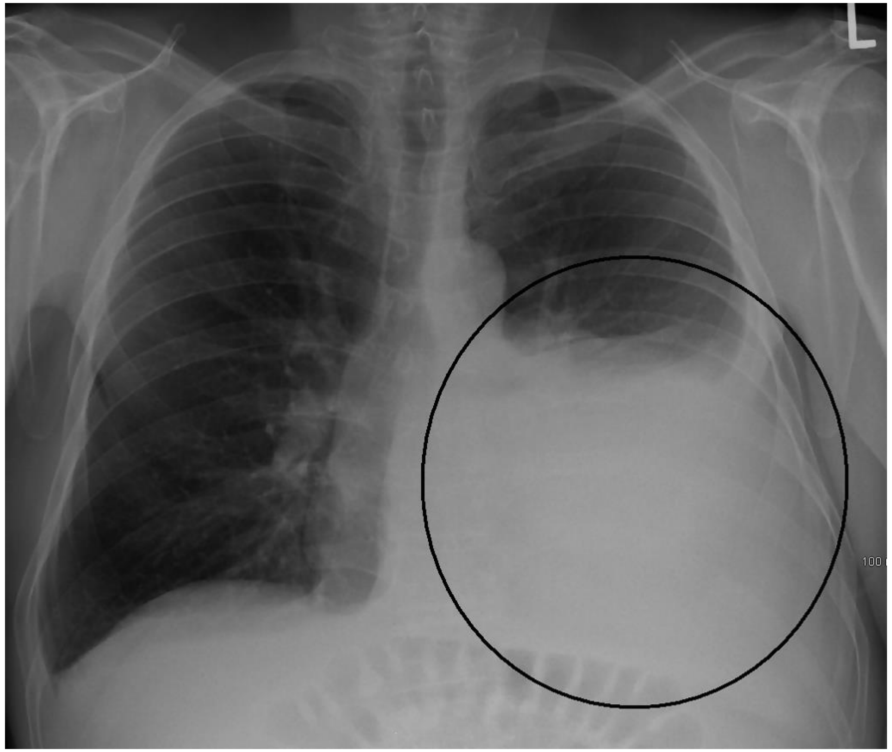
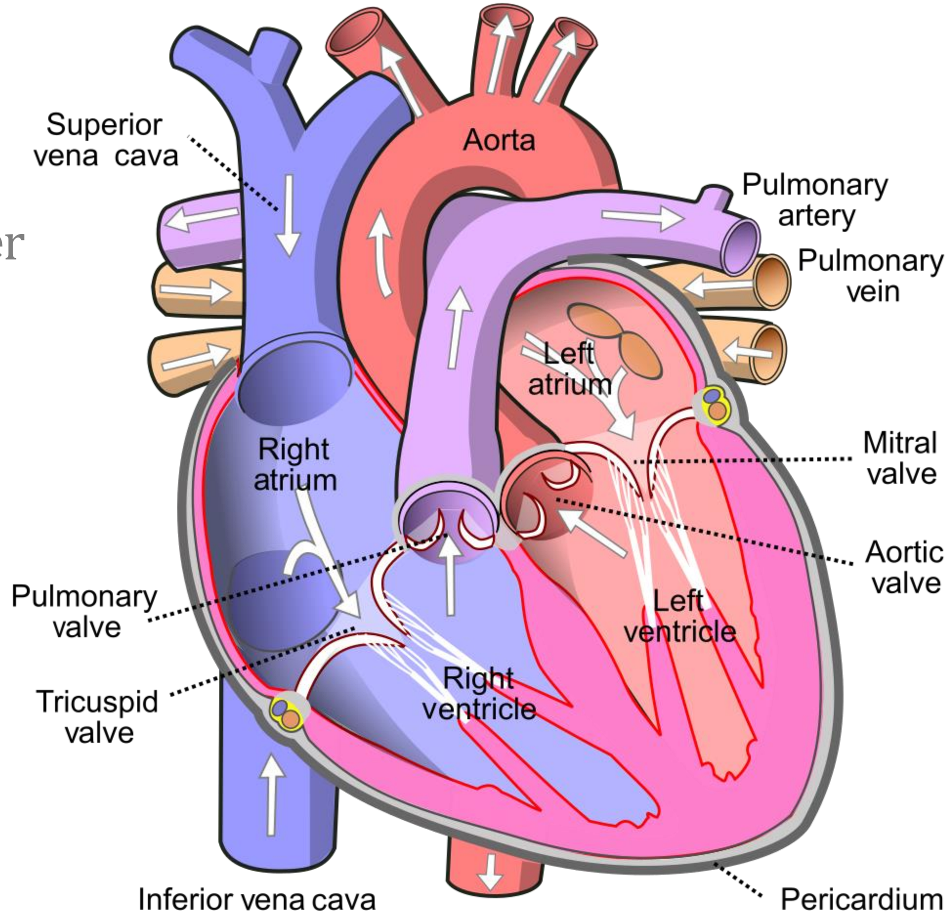


Image courtesy of James Heilman, MD

SVC Syndrome

- Obstruction of blood flow through SVC
- Can be caused by compression from tumor
  - Lung Masses: more common with small cell cancer
  - Mediastinal Masses: lymphoma
- Other causes include thrombosis
  - Indwelling catheters, pacemaker wires



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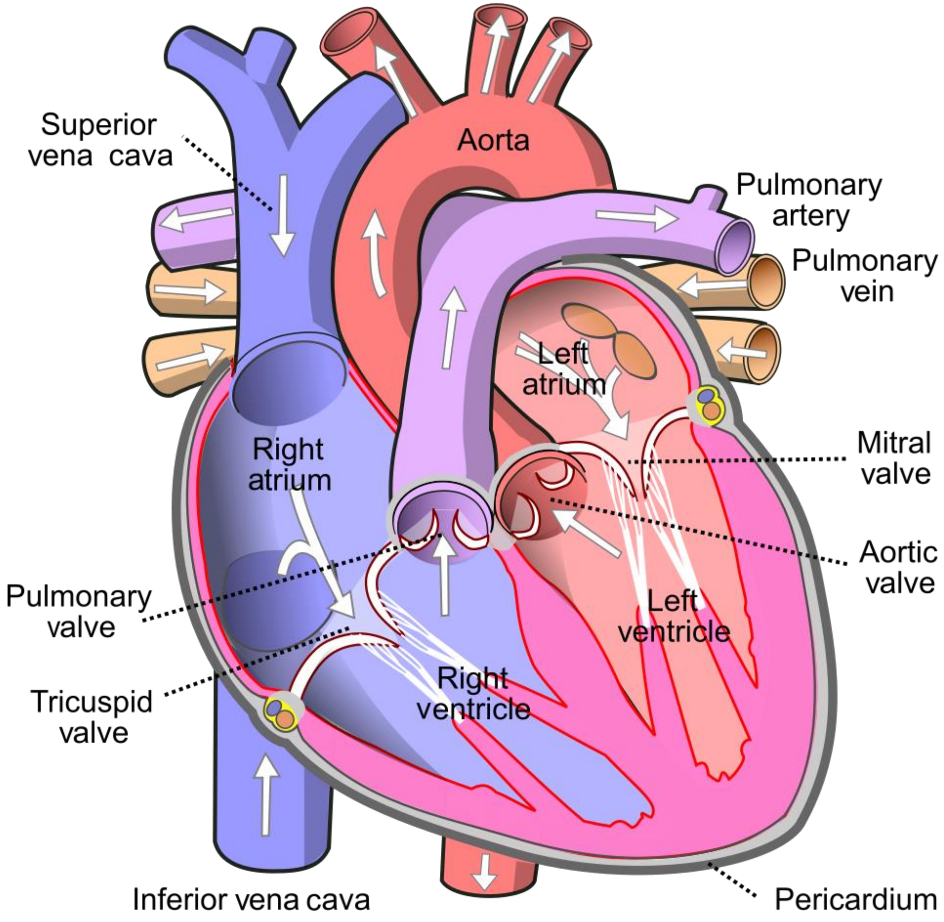
SVC Syndrome

- Facial swelling or head fullness
- Arm swelling
- Can cause increased ICP
  - Headaches, confusion, coma
  - Cranial artery rupture



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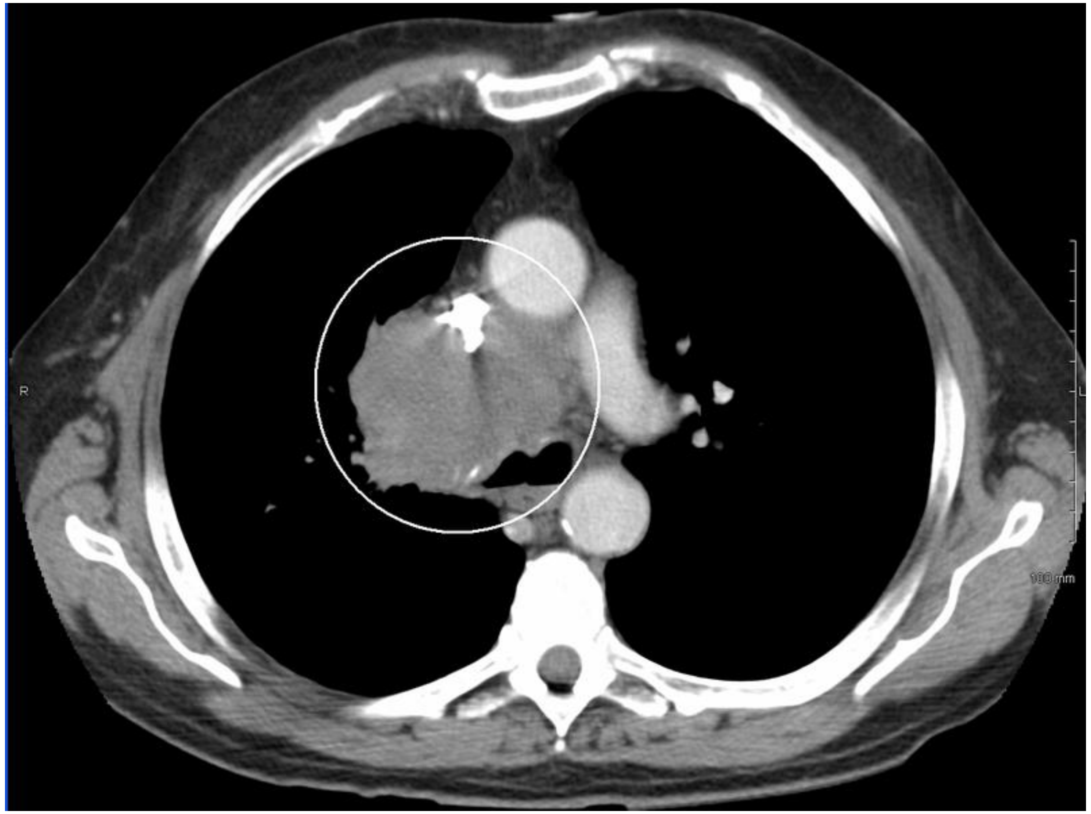
SVC Syndrome

- Usually diagnosed CXR or CT Chest
- Various treatment options:
  - Anticoagulation for thrombus
  - Steroids (lymphoma)
  - Chemo/Radiation
  - Endovascular stenting



Wikipedia/James Heilman, MD

Pancoast Tumor

- Tumor at **apex of lung**
- Involve superior sulcus
    - Groove formed by subclavian vessels
- **Arm edema** affected side
- Shoulder pain, arm paresthesias, weakness
- Horner's syndrome (sympathetic nerve compression)
    - Miosis
    - Ptosis
    - Anhidrosis

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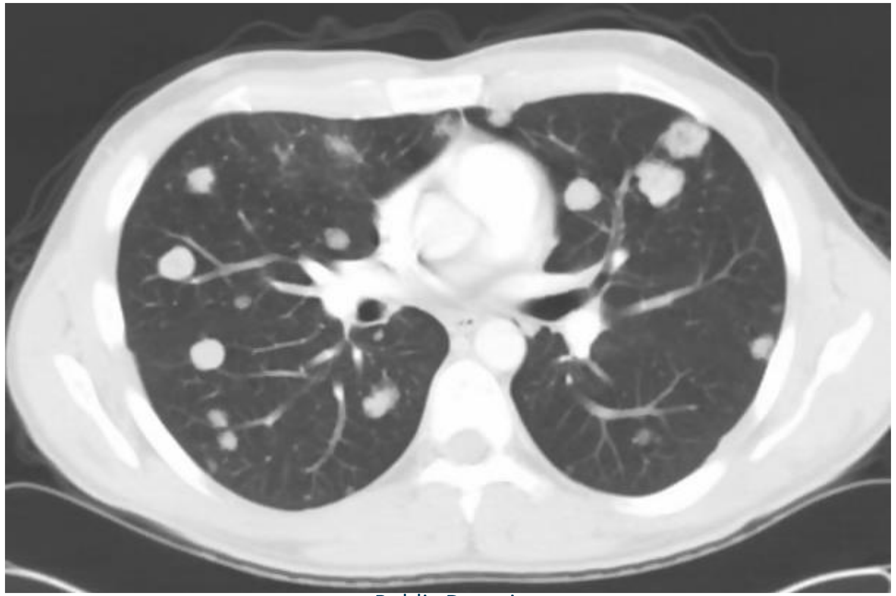
Metastasis to Lung

- More common than primary lung tumors
- Most commonly from breast or colon cancer
- Usually multiple lesions on imaging



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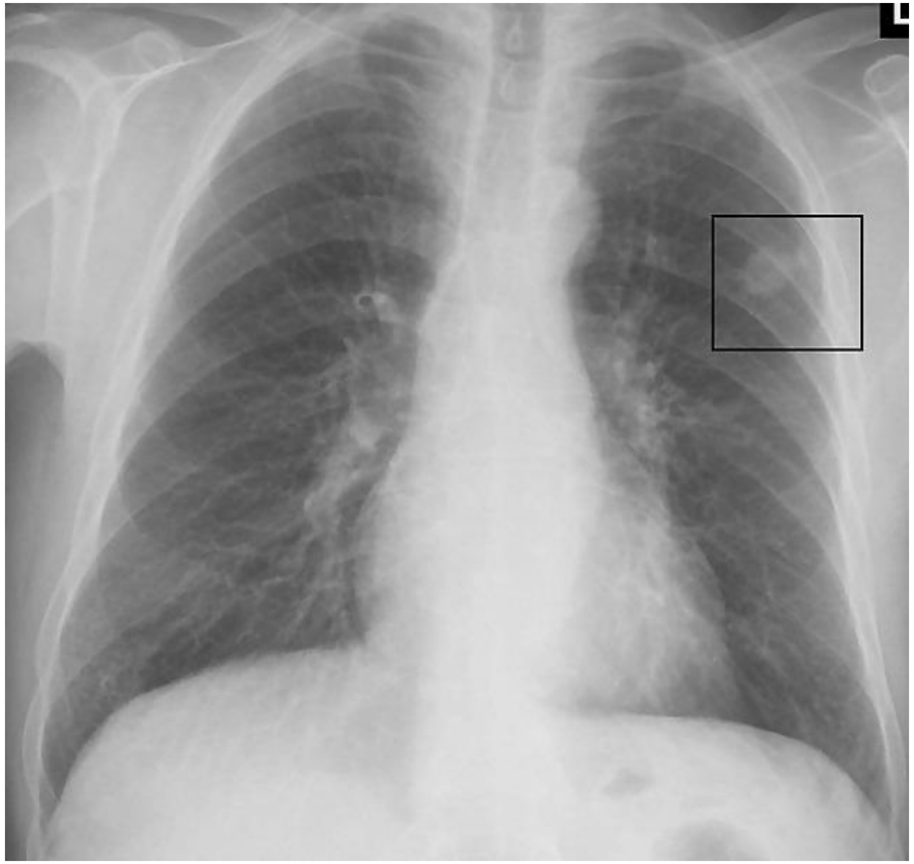
Pulmonary Nodules

- Small (≤3 cm) well-defined lung lesions
- Often identified on chest X-ray
  - Always compare with prior X-ray
- Further evaluation: chest CT
  - Size
  - Location



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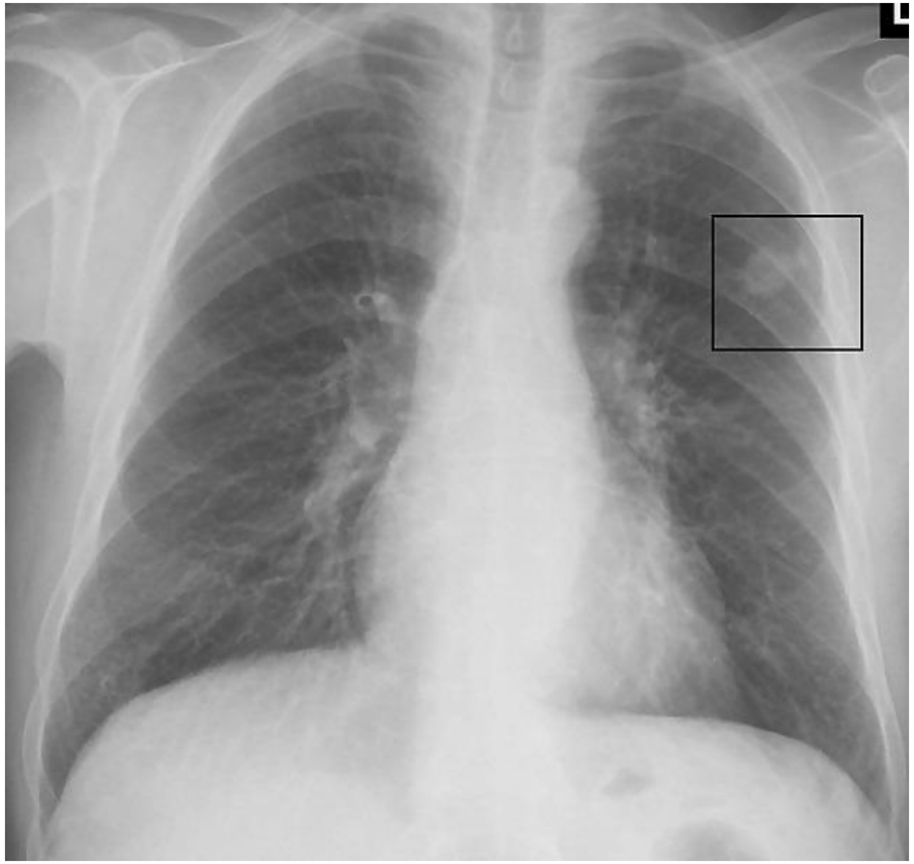
Pulmonary Nodules

- Differential diagnosis
  - Granuloma
  - Hamartoma
  - Malignancy
- Management:
  - Serial testing with biopsy of expanding lesions
  - Biopsy



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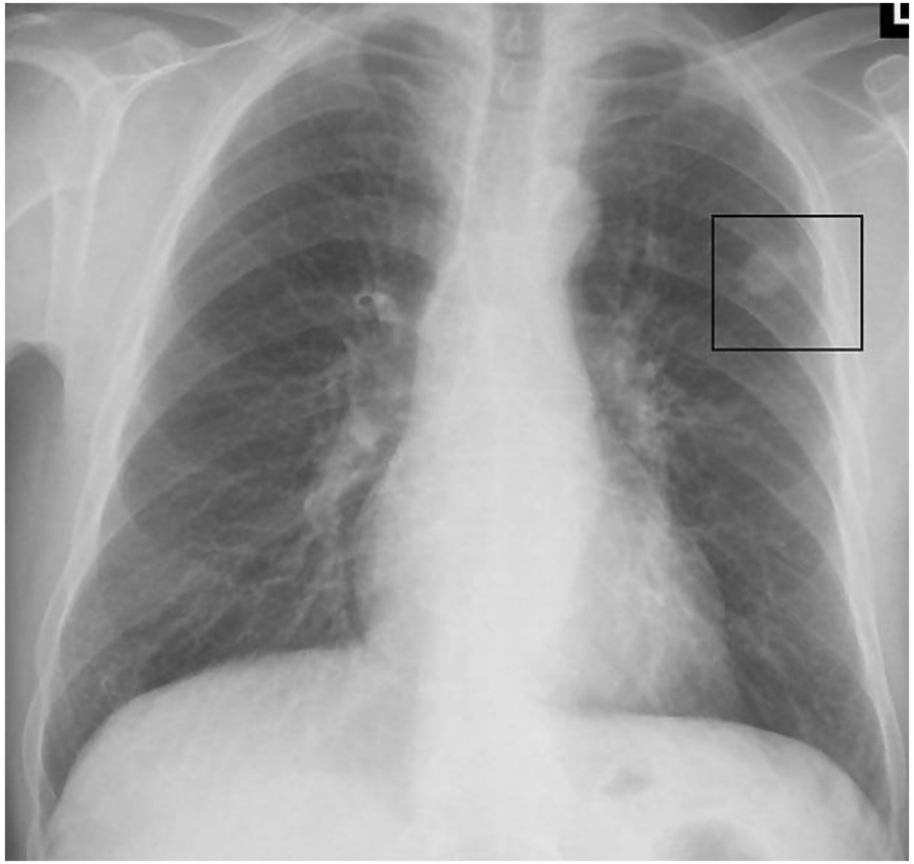
Pulmonary Nodules

- Low risk lesions
  - < 40 years old
  - Non-smoker
  - Small lesions < 1cm
  - Smooth borders
  - Calcifications
- High risk lesions
  - > 40 years old
  - Smoker
  - Large lesions
  - Spiculated



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Mediastinal Structures

- Mediastinum: space between lungs
- Divided into 3 anatomical compartments
  - Anterior
  - Middle
  - Posterior
- Differential diagnosis of mass varies by compartment

Mediastinal Compartments

Mediastinal Structures

Compartment	Major Structures	Masses
Anterior	Thymus, internal mammary arteries, lymph nodes	Thyroid, Thymic neoplasm, Teratoma, Lymphoma
Middle	Pericardium, heart, aorta, trachea, esophagus lymph nodes	Lymphadenopathy: lymphoma, sarcoid, or metastatic lung cancer
Posterior	Spine, nerves and spinal ganglia	Neurogenic tumors: schwannoma, neuroblastoma

Anterior Mediastinal Masses

Terrible Ts

- **Thymic masses**
  - Half of anterior masses derive from thymus
  - Thymoma: associated with myasthenia gravis
- Teratoma or germ cell tumors in adults
  - Mediastinum: most common location extragonadal GCT
  - Teratomas, seminomas
- Terrible lymphomas
- Thyroid growths
  - Enlarged or ectopic thyroid tissue may present as mass
  - Usually connected to thyroid gland

Bronchiectasis

Jason Ryan, MD, MPH

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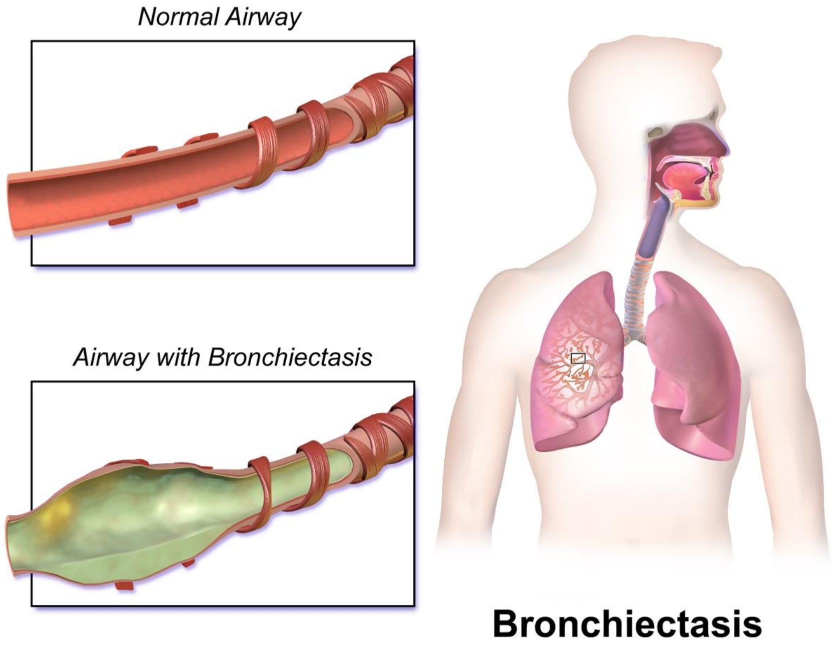
Bronchiectasis

- Permanent, abnormal airway dilation
- Poor mucous clearance → recurrent infections
- Causes **obstruction**
    - Large airways dilated
    - Small/medium airways thickened bronchial walls
- Many similarities to COPD
    - Obstructive PFTs
    - Frequent exacerbations
    - Key distinction: dilated airways



BruceBlaus/Wikipedia

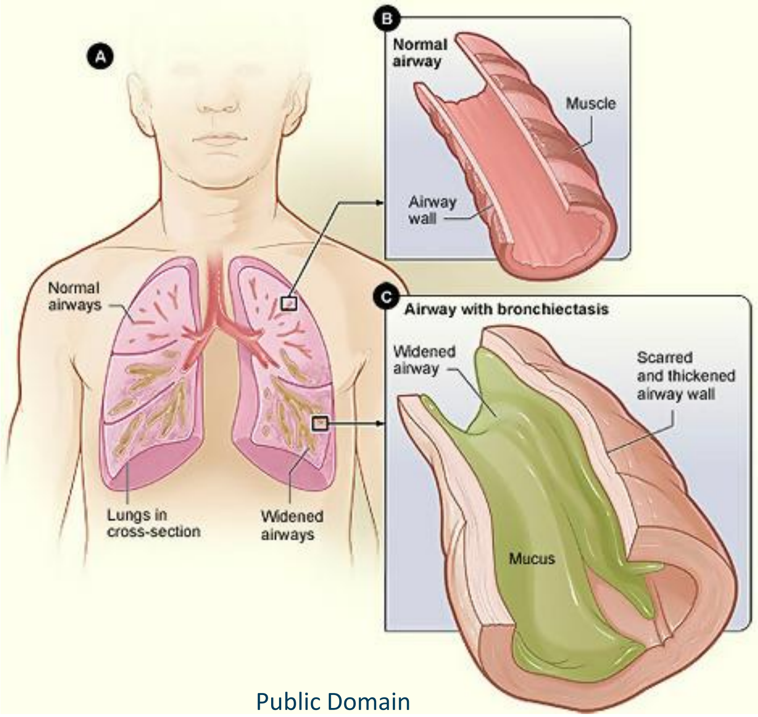
Bronchiectasis Etiologies

- **Cystic fibrosis** (~50% cases)
- Many cases idiopathic
- Autoimmune disorders (RA, SLE)
- Primary ciliary dyskinesia
- Allergic bronchopulmonary aspergillosis

Bronchiectasis

Clinical Features

- Recurrent episodes (often > 3/year) of bronchitis
- **Cough with persistent, excessive sputum (often foul smelling)**
- Hemoptysis
- Halitosis



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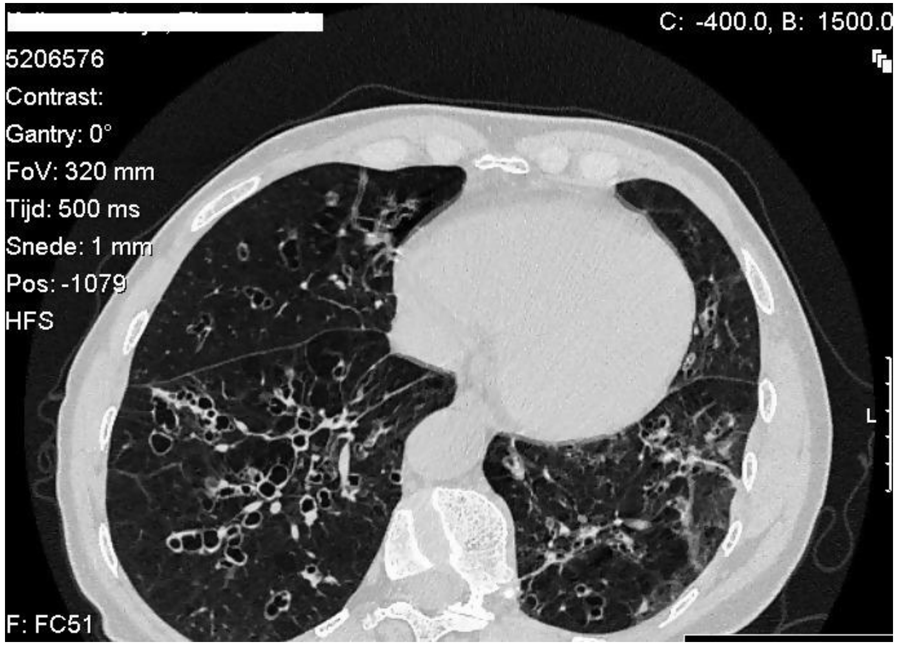
Bronchiectasis

Diagnosis

- Chest X-ray usually abnormal but non-diagnostic
  - Classic, rare finding: tram lines
- Most accurate test: **chest CT**
  - Widening of bronchi
  - Bronchial wall thickening
- PFTs
  - Obstruction (↓ FEV1, ↓ FEV1/FVC)



Laura Fregonese, Jan Stolk

Bronchiectasis

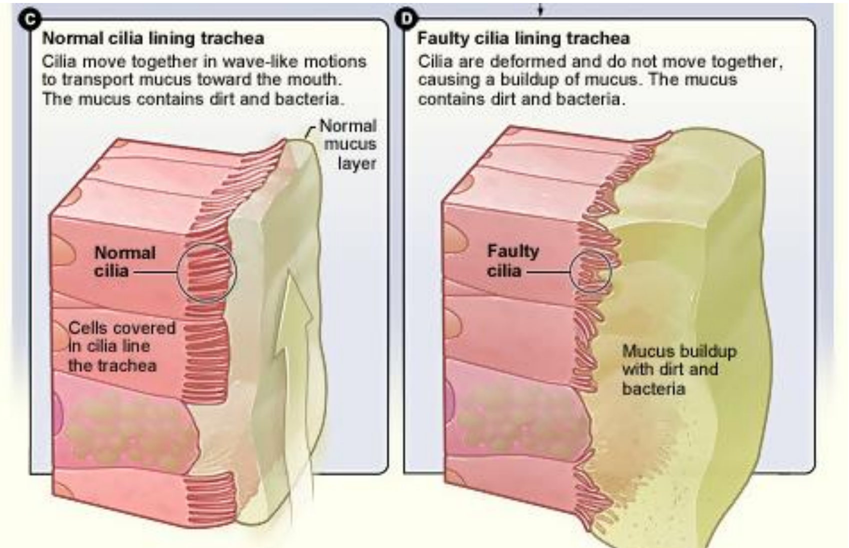
Treatment

- Acute exacerbations
  - Obtain sputum culture
  - Appropriate antibiotics
- Chronic treatment
  - Suppressive, long-term antibiotics
  - **Airway clearance therapy** (chest physiotherapy)
    - Loosens airway secretions
- Rarely used therapies
  - Bronchodilators
  - Corticosteroids

Primary Ciliary Dyskinesia

Immotile-cilia syndrome

- Inherited, autosomal recessive disorder
- Cilia unable to beat, beat normally, or absent
- Gene mutations dynein structure/formation
- Dynein = motor protein creates movement



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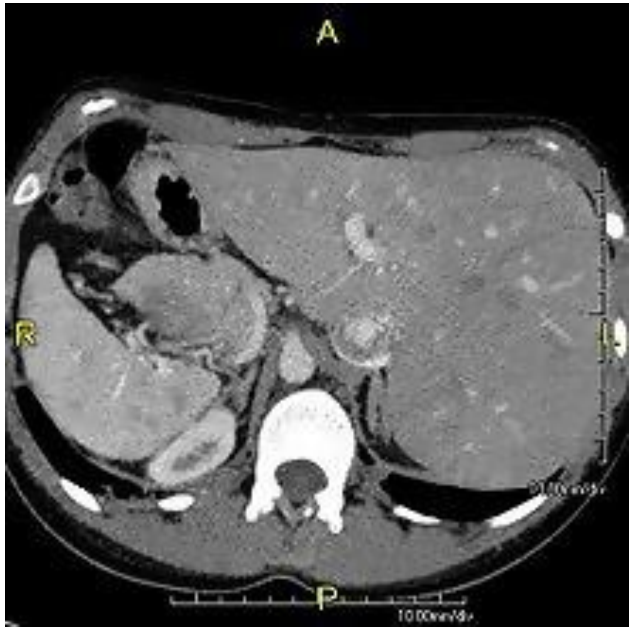
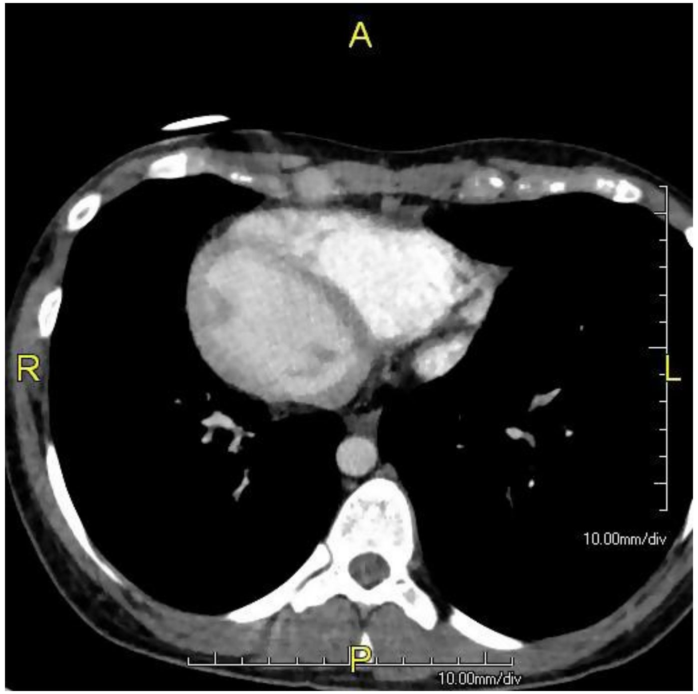
Kartagener's syndrome

- Bronchiectasis
- Chronic sinusitis
- Situs inversus
- Infertility





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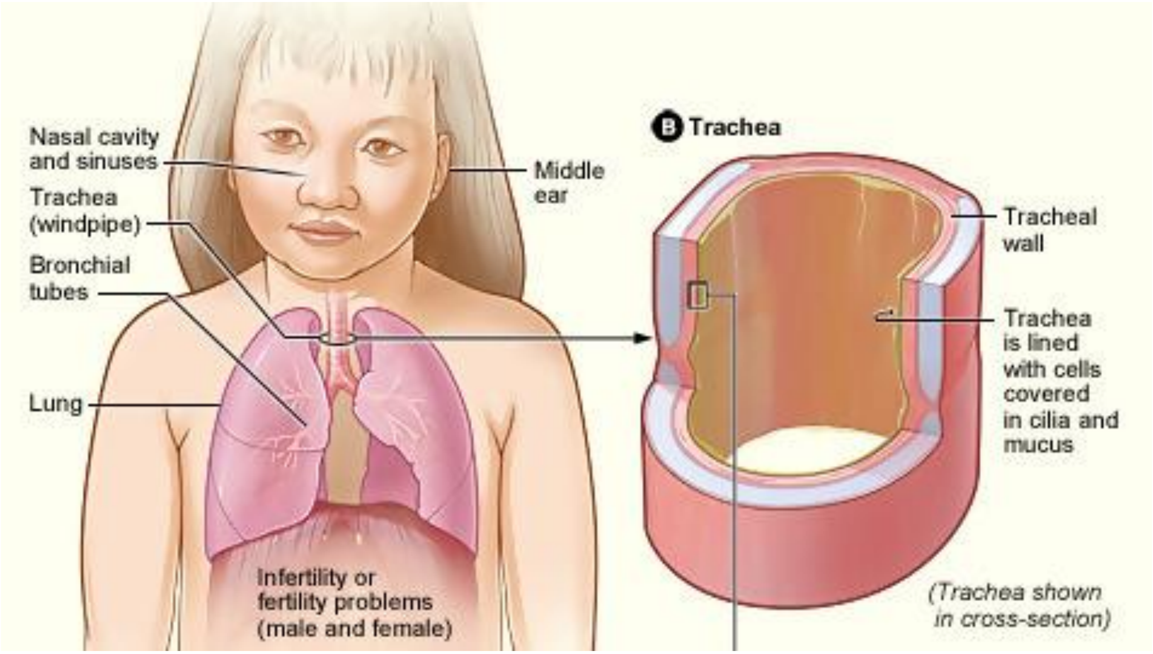
Primary Ciliary Dyskinesia

Immotile-cilia syndrome

- Classic case:
    - Child
    - Recurrent sinus/ear infections
    - Chronic cough
    - Bronchiectasis on chest CT
    - Obstruction on PFTs
    - Situs inversus



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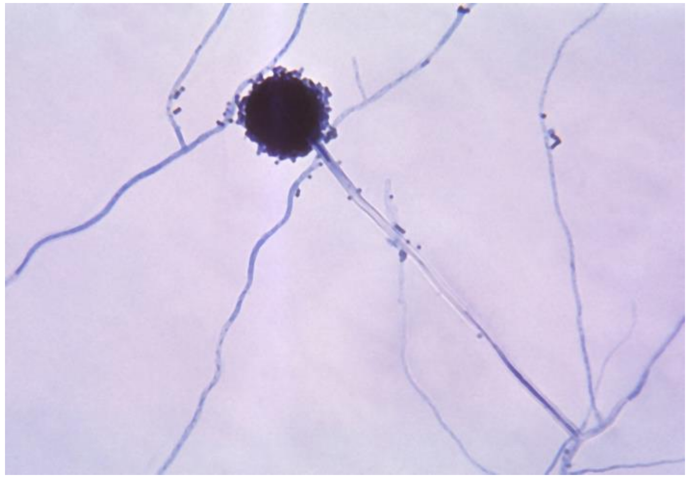
ABPA

Allergic bronchopulmonary aspergillosis

- Hypersensitivity (allergic) reaction to **aspergillus**
- Lungs become colonized with aspergillus fumigatus
  - Low virulence fungus
  - Only colonizes immunocompromised or debilitated lungs
- Occurs in **asthma and CF patients**
- Presents as difficult-to-treat asthma
- Untreated ABPA leads to bronchiectasis



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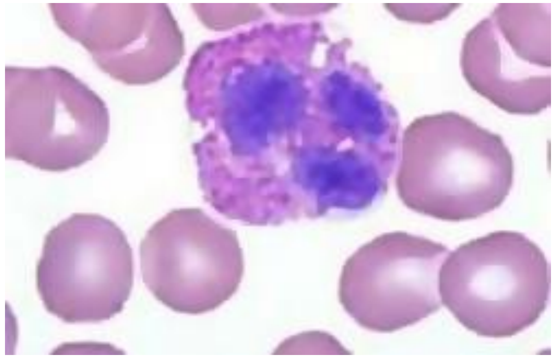
ABPA

Allergic bronchopulmonary aspergillosis

- **Diagnostic criteria:**
  - Predisposing conditions: asthma or cystic fibrosis
  - *Aspergillus* skin test positivity or IgE against *Aspergillus*
  - Elevated serum IgE concentration (typically >1000 IU/mL)
  - X-ray opacities consistent with ABPA
  - Eosinophil count > 500 cells/microL
- Key diagnostic tests: skin testing, IgE levels, eosinophil counts



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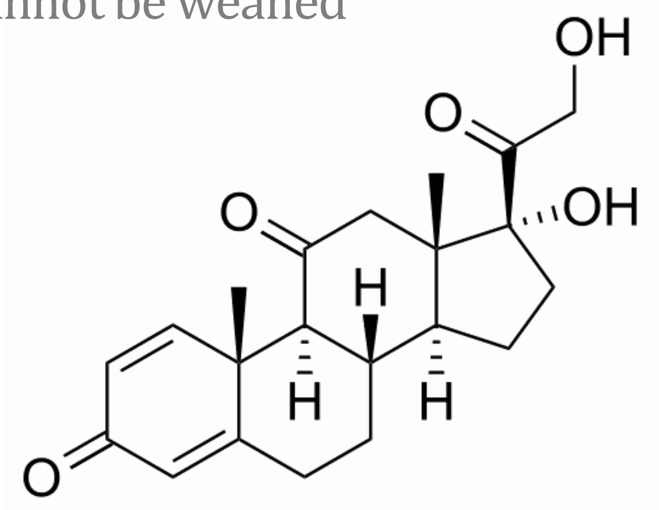
ABPA

Allergic bronchopulmonary aspergillosis

- **Oral glucocorticoids** - usually prednisone
- Inhaled steroids not effective
- Antifungals (itraconazole or voriconazole) in select patients
  - Usually when steroids cannot be weaned

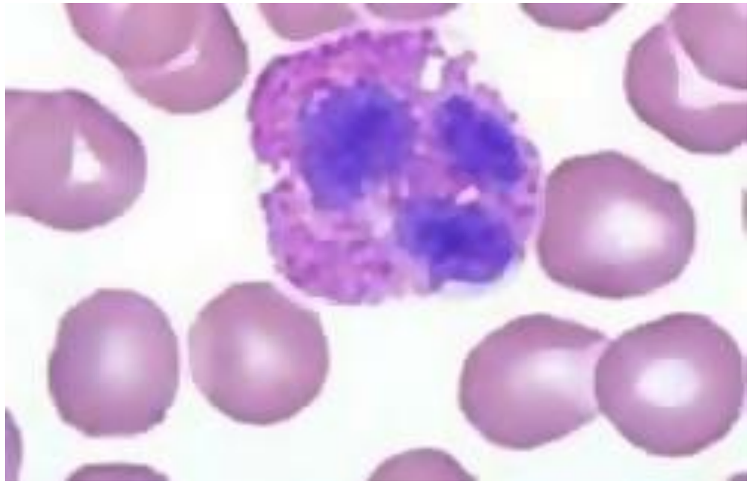


Prednisone

ABPA

Allergic bronchopulmonary aspergillosis

- Classic case
  - Asthma or CF patient
  - Recurrent episodes cough, wheezing
  - **Brownish mucus plugs**
  - Hemoptysis
  - Peripheral blood eosinophilia
  - High IgE level
  - Bronchiectasis on imaging
  - PFTs with obstruction



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Shock

Jason Ryan, MD, MPH

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Shock

- Life-threatening fall in blood pressure
- Poor tissue perfusion
- **Low cardiac output**
  - Loss of contractility
  - Low intravascular volume
- **Peripheral vasodilation**

BP = CO X TPR

Types of Shock

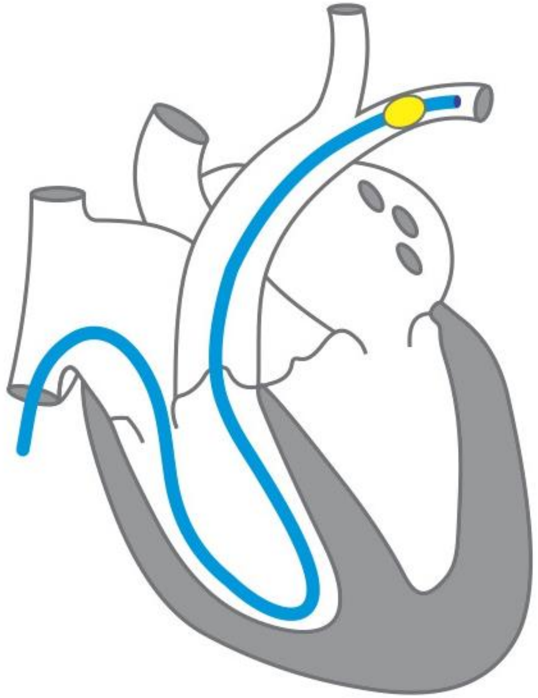
- Cardiogenic
  - Cardiac disorder → fall in cardiac output
- Hypovolemic
  - Fall in intravascular volume → fall in cardiac output
  - Hemorrhage
- Distributive
  - Peripheral vasodilation
  - Capillary leak
  - Septic, anaphylactic
- Obstructive

Types of Shock

- **Different treatments** for different types of shock
- Often can determine type from **history**
  - Myocardial infarction → cardiogenic shock
  - Massive bleeding → hypovolemic shock
- Shock of unclear etiology: Swan-Ganz catheter

Swan-Ganz Catheter

Pulmonary artery catheter



Pulmonary Capillary Wedge Pressure
PCWP
"Wedge Pressure"
Equal to LA pressure

Swan-Ganz Data

- RA pressure: normal ~ 5 mmHg
- RV pressure: 20/5
- PA pressure: 20/10
- PCWP: 10
- Mixed venous O2 sat: 65-75%
    - Oxygen concentration after all veins mix
    - Falls with low cardiac output

Fick Equation

Oxygen Consumed = O2 Out Lungs – O2 In Lungs
= CO (Art O2 – Ven O2)

$$\textbf{Cardiac Output} = \frac{\text{O2 Consumption}}{(\text{Art O2} - \text{Ven O2})}$$

O2 Consumption α body size
Arterial O2 Content = O2 sat on finger probe
Venous O2 Content = O2 from Swan-Ganz

Swan-Ganz catheter gives cardiac output

Flow Equation

- Used to determine **total peripheral resistance (systemic vascular resistance)**

$$\Delta P = CO * TPR$$

$$MAP - RAP = CO * TPR$$

$$TPR = \frac{MAP - RAP}{CO}$$

Swan-Ganz Catheter gives TPR

Swan-Ganz Data

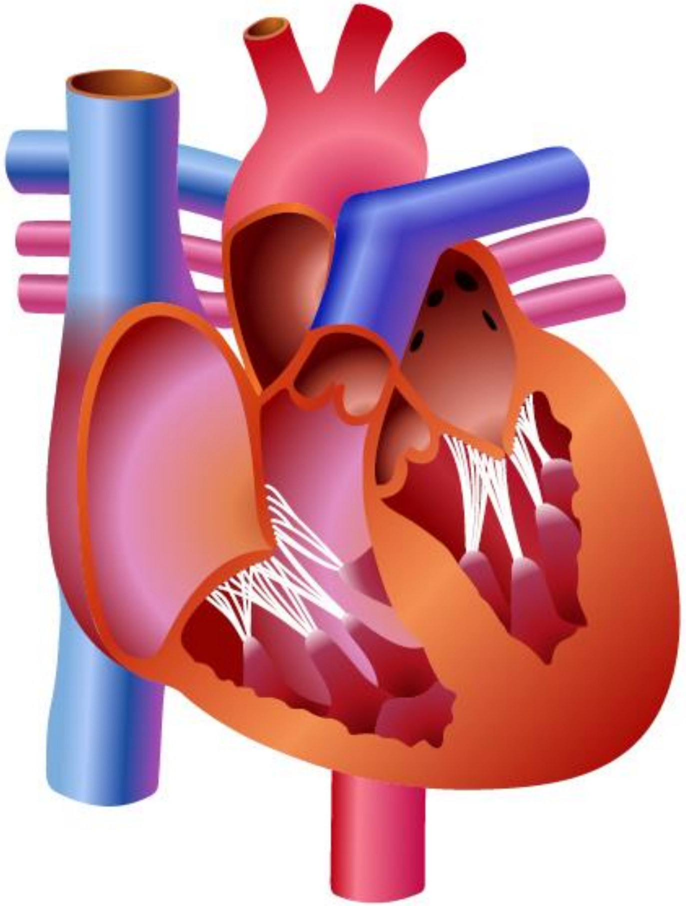
- Direct
  - RA pressure: normal ~ 5 mmHg
  - RV pressure: 20/5
  - PA pressure: 20/10
  - PCWP: 10
  - Mixed venous O2 sat: 65-75%
- Calculated
  - Cardiac output
  - Total peripheral resistance/systemic vascular resistance (SVR)

Hemodynamics of Shock

- Four major classes of shock
  - Cardiogenic
  - Hypovolemic
  - Distributive
  - Obstructive
- All have different hemodynamics
- Swan-Ganz catheter can be used to determine etiology of shock

Cardiogenic Shock

- **Low cardiac output**
- **High cardiac pressures**
- High SVR (sympathetic response)
- Classic cause: large myocardial infarction
- Also seen in advanced heart failure (depressed LVEF)
- Treatment: inotropes
    - Dobutamine
    - Milrinone
- Do not give fluids!



Hypovolemic Shock

- **Low cardiac output**
- **Low cardiac pressures**
- High SVR (sympathetic response)
- Poor fluid intake
- High fever, insensible losses
- Hemorrhage
- Treatment: fluids or blood transfusion

Distributive Shock

- **Low SVR**
  - Diffuse vasodilation and/or endothelial dysfunction
- **Sepsis (most common)**
- Anaphylaxis
- Cardiac output classically high (but variable)
  - Depends on degree of capillary leak
- Cardiac pressures also variable

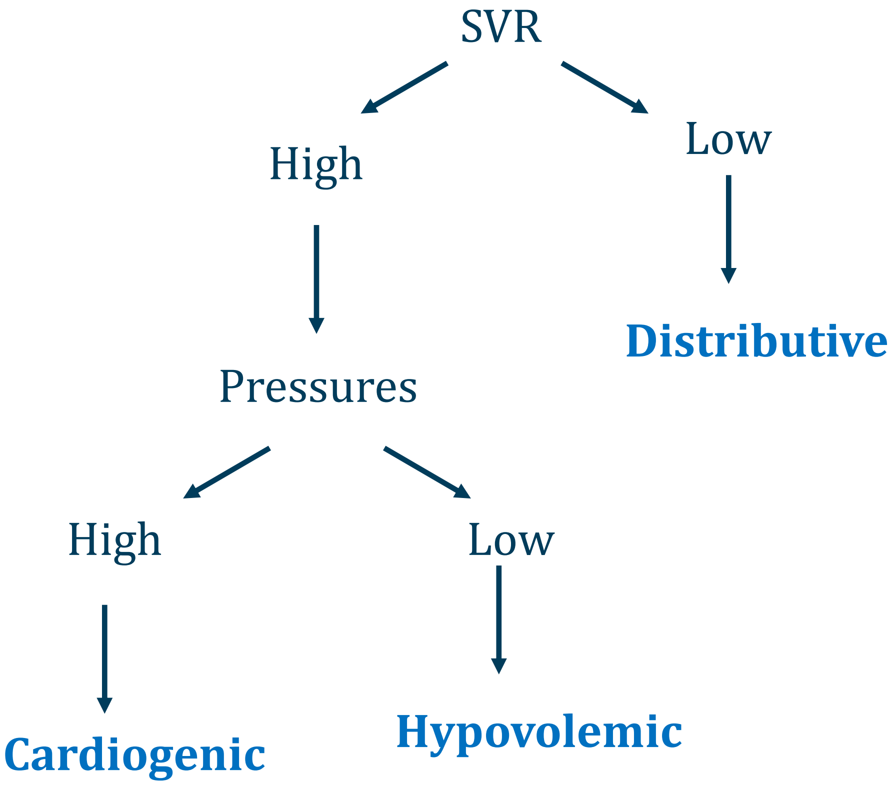
Distributive Shock

- Treatment based on cause
- Septic shock: fluids, antibiotics, vasopressors
- Anaphylaxis: epinephrine

Type of Shock

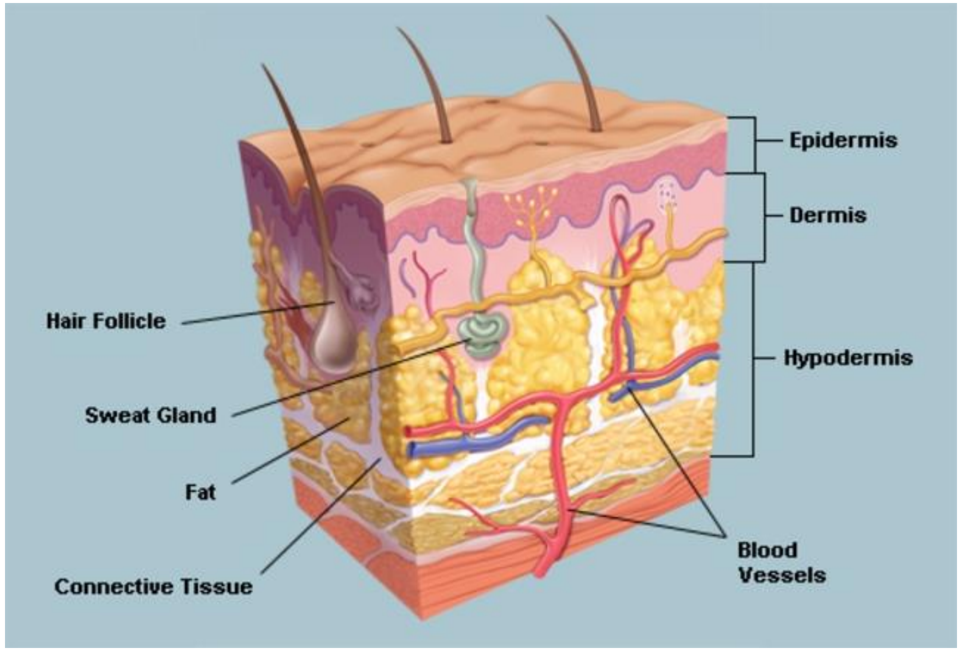
	Cardiogenic	Hypovolemic	Distributive
Blood Pressure	↓	↓	↓
HR	↑	↑	↑
RA/RV/PCWP	↑	↓	↓/-
Cardiac Output	↓	↓	↑
SVR	↑	↑	↓

Major Shock Types



Physical Exam and Labs

- Cold skin → poor perfusion
  - High SVR and low CO
  - Cardiogenic
  - Hypovolemic
- Warm skin → good perfusion
  - Low SVR and high CO
  - Distributive
- Elevated serum lactate



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Physical Exam and Labs

- Jugular venous pressure → high RA pressure
- Pulmonary rales → high LA pressure
- Pulses
  - Bounding pulses → high cardiac output (sepsis)
  - Weak or small pulse → low cardiac output
- Pulse pressure
  - Systolic – diastolic pressure
  - High = high cardiac output
  - Low = low cardiac output

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Obstructive Shock

- Obstruction to blood flow from heart
- **Low cardiac output** despite normal contractility
- Tamponade
- Tension pneumothorax
- Massive pulmonary embolism
- Low cardiac output
- High SVR

Large Pericardial Effusion

Treatment of Shock

- Cardiogenic: inotropes
  - Milrinone, dobutamine
- Hypovolemic: volume
  - Blood transfusions, IV fluids
- Distributive: volume and vasopressors
  - Phenylephrine, epinephrine, norepinephrine
- Obstructive: resolve obstruction
  - Treat tamponade, embolism, tension pneumothorax

Adrenergic Vasopressors and Inotropes

Hemodynamic Effects

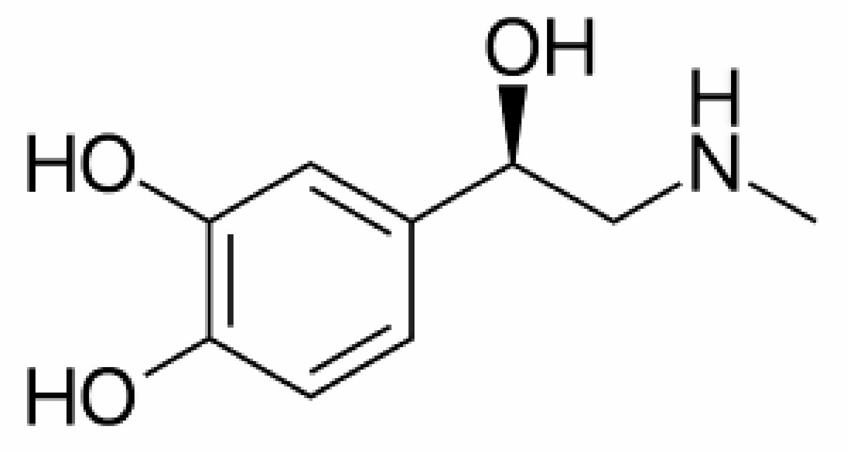
- α1: vasoconstriction
- β1: ↑ heart rate/contractility
- β2: vasodilation

Adrenergic Vasopressors and Inotropes

Drug	Alpha (↑BP)	Beta-1 (↑CO/HR)	Beta-2 (↓BP)	Uses
Phenylephrine	+++++			Septic shock, especially if tachycardic
Norepinephrine	+++++	+++	++	Septic shock
Epinephrine	+++++	++++	+++	Anaphylaxis
Dopamine	+++	++++	++	Cardiogenic shock
Dobutamine		++++	++	Cardiogenic shock

Epinephrine

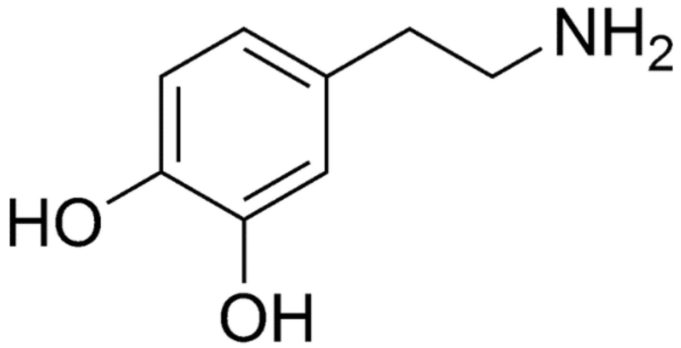
- Dose dependent effects
- Low dose: beta-1 and beta-2 agonist
  - Increased heart rate/contractility
  - Vasodilation
- High dose: alpha-agonist
  - Vasoconstriction



Epinephrine

Dopamine

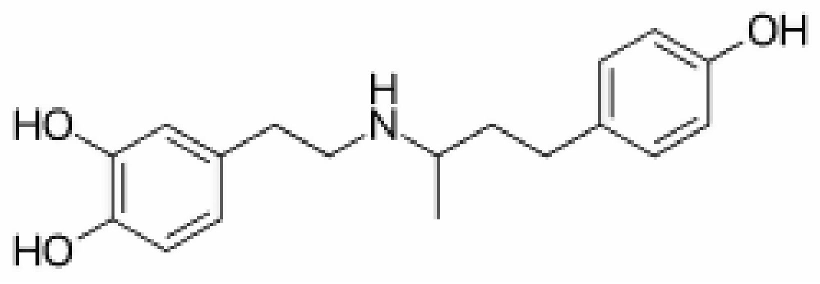
- Does not cross blood brain barrier (no CNS effects)
- Peripheral effects highly dependent on dose
- Low dose: dopamine agonist
  - Vasodilation in kidney vessels
- Medium dose: beta-1 agonist
  - Increased heart rate and contractility
- High dose: alpha-agonist
  - Vasoconstriction



Dopamine

Dobutamine

- Mostly β1
- ↑ cardiac output
- ↑ heart rate
- MAP pressure usually falls
    - ↓ TPR (β2)
- Myocyte effect > SA node
- More inotropy than chronotropy



Dobutamine

Vasopressin

- Used in septic shock
- V1 receptor agonist
- Vasoconstrictor → ↑ SVR

Milrinone

- Used in cardiogenic shock
- Phosphodiesterase 3 inhibitor
- Increase cAMP in myocytes and vascular smooth muscle
- Increased contractility
- Systemic vasodilation
  - Arteriolar vasodilation → decreased SVR

Respiratory Failure

Jason Ryan, MD, MPH

Boards & Beyond
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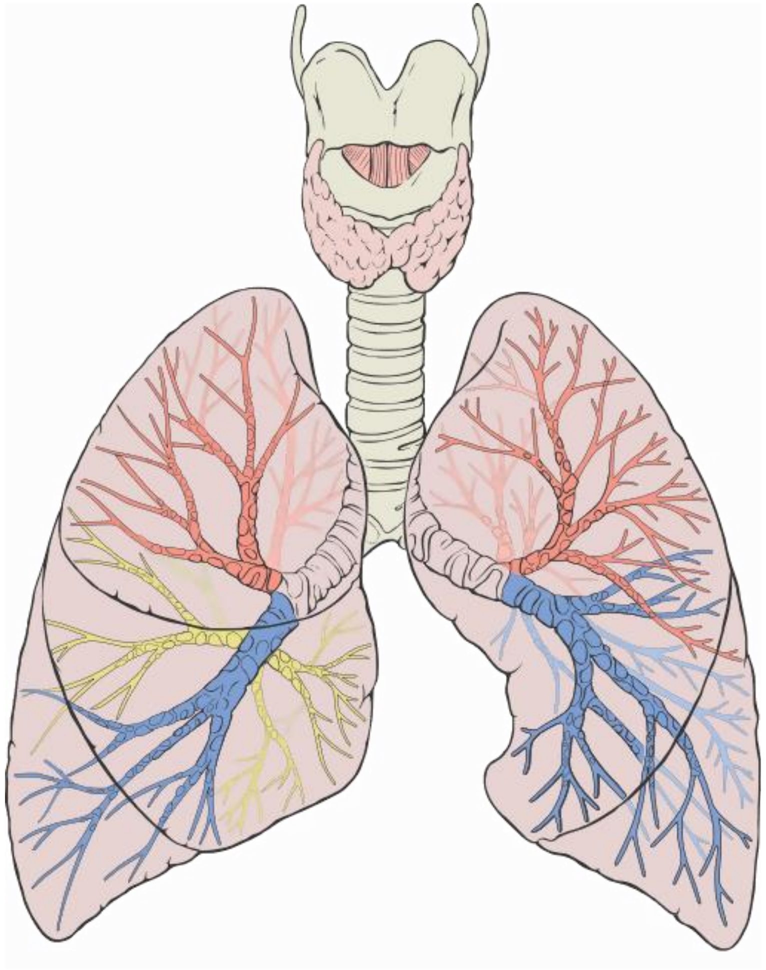
Acute Respiratory Failure

Clinical Features

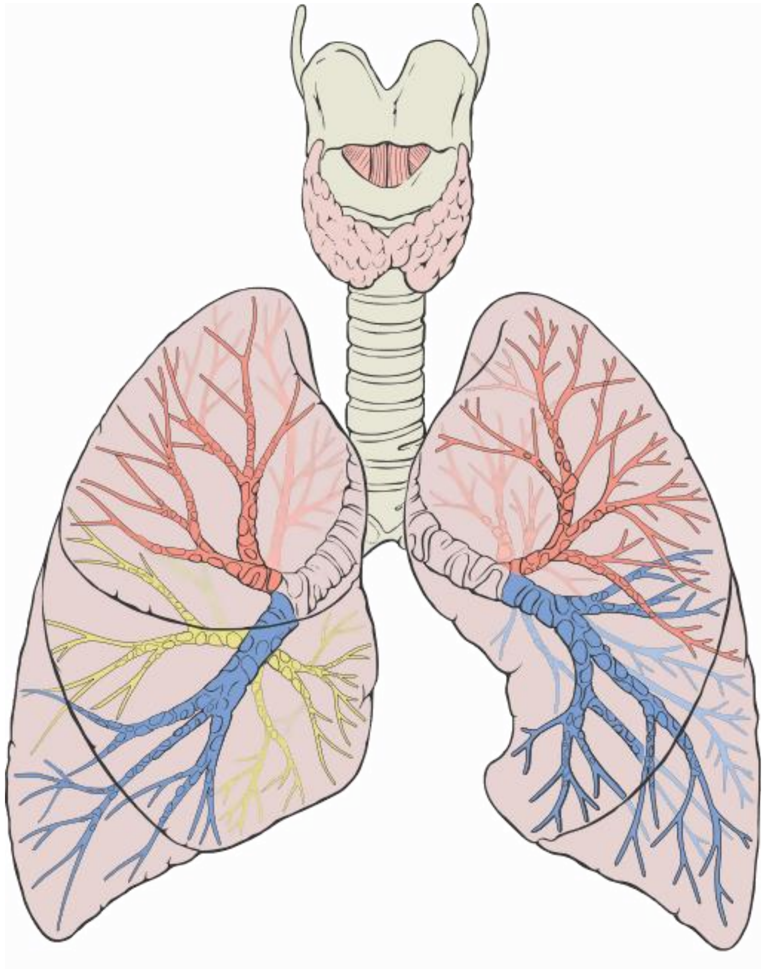
- Dyspnea
- Accessory muscle use
- Confusion and lethargy
  - CO_2 narcosis
  - Occurs with ↑ $PaCO_2$ (> 60)
  - O_2 may be normal!



Patrick Lynch/Wikipedia

Acute Respiratory Failure

- **Inadequate oxygenation of blood**
  - Low PaO2 or O2 sat %
  - V/Q mismatch
  - Shunting
  - Diffusion impairment
- **Inadequate excretion of CO2**
  - Elevated PaCO2
  - **Always indicates hypoventilation**
  - Increased dead space



Patrick Lynch/Wikipedia

Oxygen Delivery Devices

Nasal Cannula

Wikipedia/Public Domain

Face Mask

Wikipedia/Public Domain

Venti Mask

LiveO2.com/Public Domain

Non-Rebreather

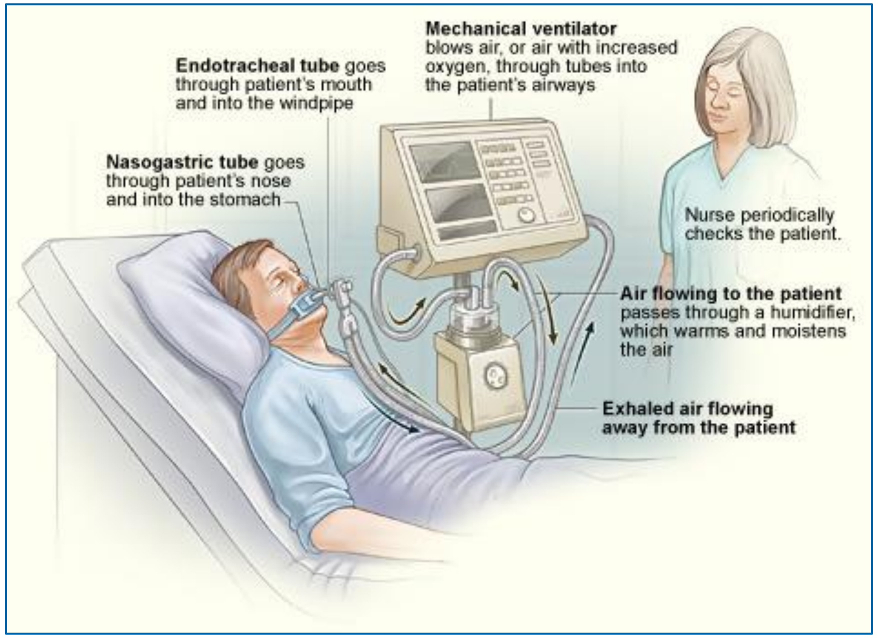
Wikipedia/Public Domain

High Flow
Nasal Cannula

Medexsupply.com/Public Domain

Ventilation

Non invasive Ventilation



Mechanical Ventilation

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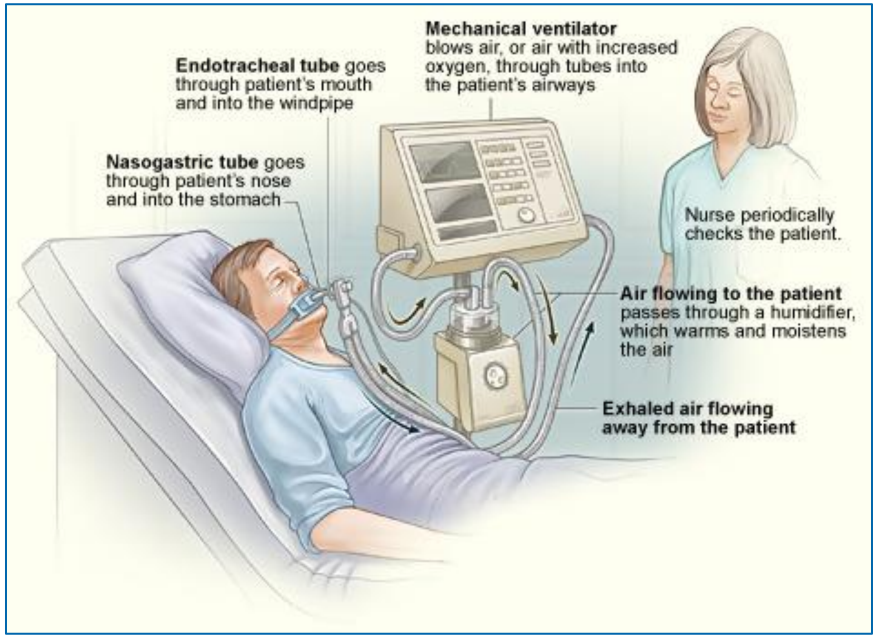
Acute Respiratory Failure

Treatments

Method	O2 Delivery
Nasal cannula	2-6 L/min (FiO2 24-40%)
Face mask	5-8 L/min (FiO2 30-50%)
Venti mask	6-10 L/min (FiO2 24-50%)
Non-rebreather	8-10 L/min (FiO2 60-80%)
High flow nasal cannula	10-60 L/min (FiO2 up to 100%)
Noninvasive Ventilation	FiO2 up to 100%
Mechanical Ventilation	FiO2 up to 100%

Mechanical Ventilation

- Ventilation via endotracheal tube (ETT)
- Ventilator forces air into lungs
- Set inspired O2 content (FiO2)
- Set PEEP
- Choose ventilator mode
  - Assist Control (Volume Control)
  - Pressure Control
  - Pressure support



Positive End-Expiratory Pressure

PEEP

- Alveolar collapse occurs in many lung diseases
  - Impairs gas exchange
- Collapse often occurs at end-expiration
  - Lowest pressure in respiratory system
- End-expiratory pressure normally zero
- PEEP increases end-expiratory pressure
  - 5 mmHg, 10 mmHg
  - Limits collapse of alveoli
- **PEEP and FiO2 improve oxygenation**

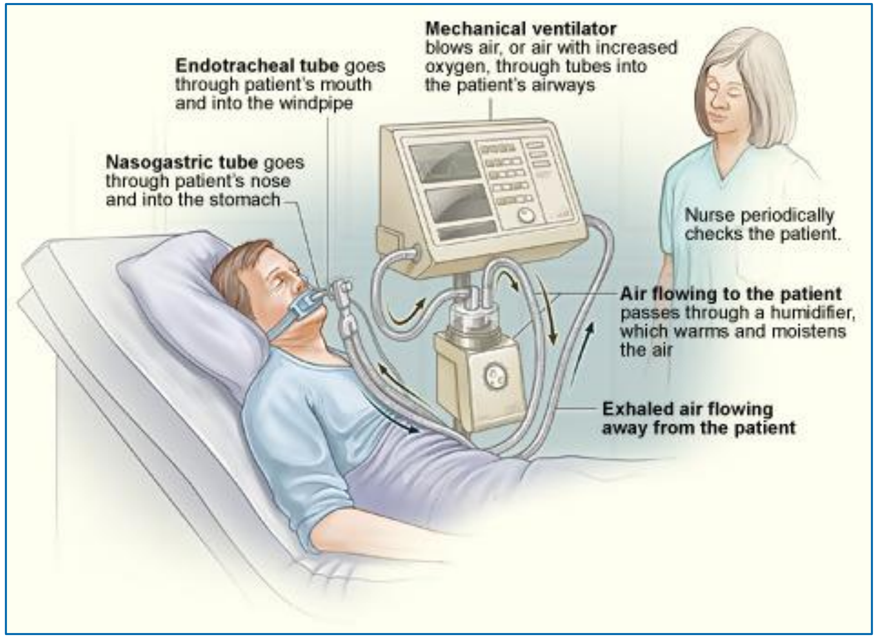
PEEP

Pressure Support

- **Positive inspiratory pressure** when patient inspires
  - Delivers more air into lungs; helps overcome resistance of ET tube
- Settings:
  - PEEP
  - O2 content of inspired air
  - Inspiratory pressure
- Patient determines respiratory rate and tidal volume
  - Stiff/non-compliant lungs: low tidal volume
- Air delivered at inspiratory pressure until flow decreases
  - Usually by 25% from peak value
  - Pressure removed when this occurs → exhalation

Pressure Support

- **Patient must be spontaneously breathing**



Pressure Control

- Positive inspiratory pressure when patient inspires
- **Minimum respiratory rate set**
- Settings:
  - PEEP
  - O2 content of inspired air
  - Inspiratory pressure
  - Minimum respiratory rate
- Tidal volume variable
  - Stiff/non-compliant lungs: low tidal volume

Volume Control

- Lungs filled until **set tidal volume reached**
  - Often initial setting used
  - Guarantees a set tidal volume
- **Minimum respiratory rate set**
- Settings:
  - Tidal volume
  - PEEP
  - O2 content of inspired air
  - Minimum respiratory rate
- Airway pressure variable
  - Stiff/non-compliant lungs: high airway pressures

Volume Control Modes

- Spontaneous breath
  - Patient triggers inspiration
- Triggered breath
  - Machine initiates inspiration based on minimum respiratory rate
- **Assist-Control Ventilation (ACV)**
  - All breaths same volume
- **Synchronized Intermittent-Mandatory Ventilation (SIMV)**
  - If patient triggers a breath, volume set by patient

Mechanical Ventilation

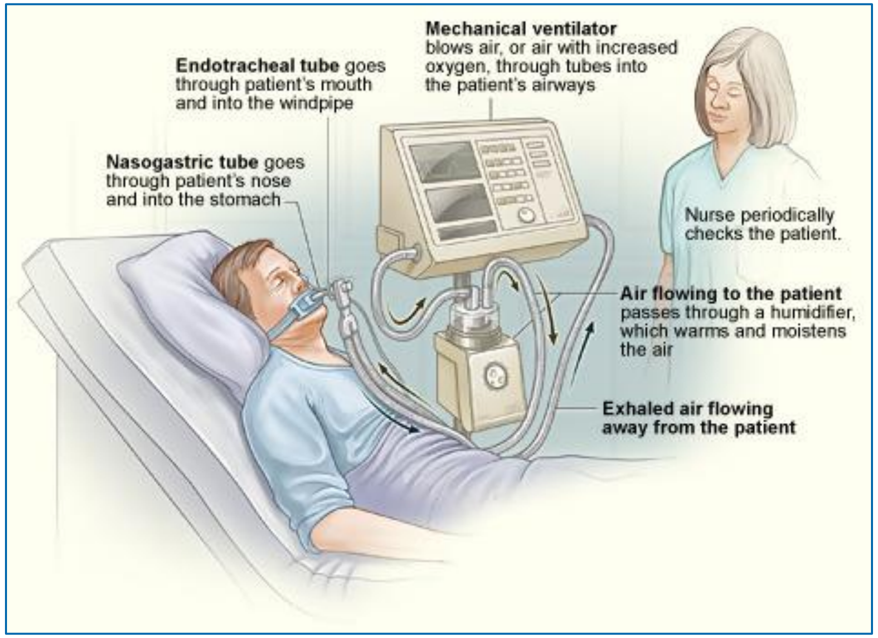
Mode	Respiratory Rate	Set Variable	Example Settings
Pressure Support	Patient	Inspiratory Pressure	15/5, FIO2 50%
Pressure Control	Set	Inspiratory Pressure	15/5 rate of 12, FIO2 50%
Volume control	Set	Tidal Volume	TV 500, rate of 12, PEEP 5, FIO2 50%

*Always set FIO_2, PEEP

Mechanical Ventilation

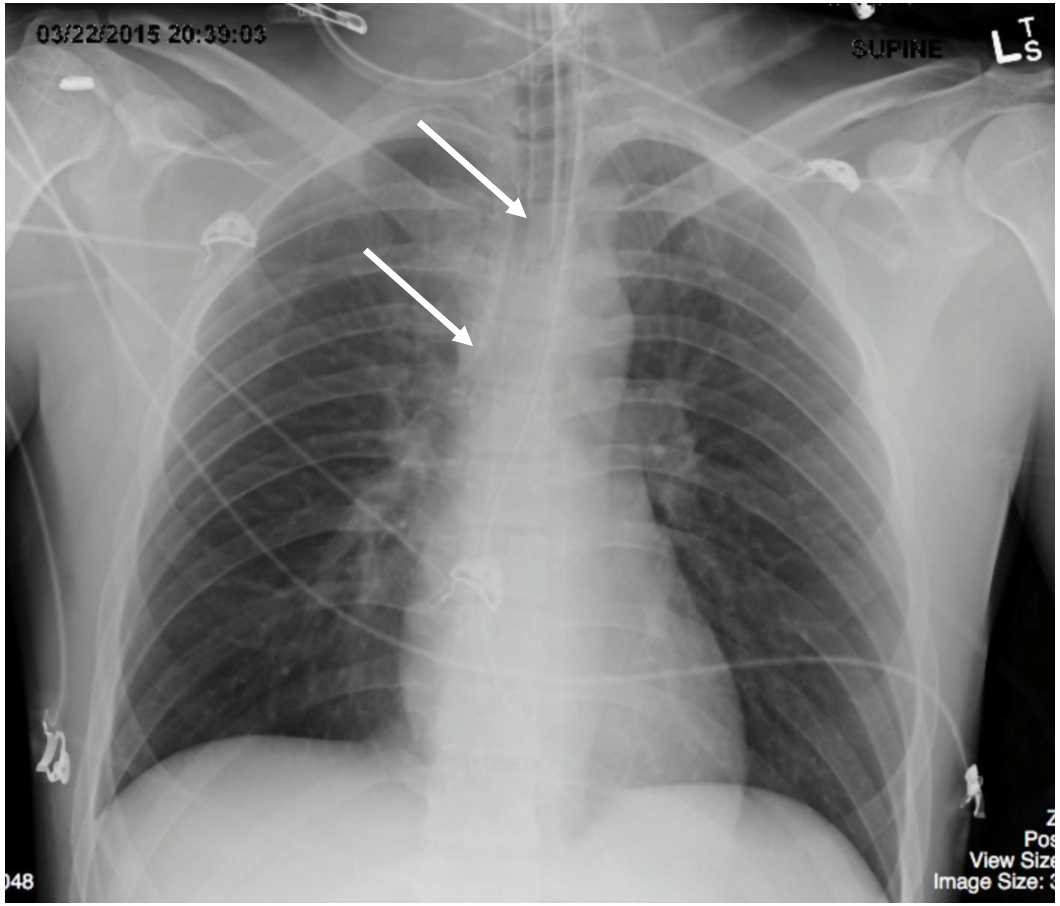
Indications

- Hypoxemia or hypoventilation
  - Ongoing or anticipated
- Protection of the airway
  - Protective reflexes prevent aspiration
  - Loss of airway tone → aspiration
  - Neurologic impairment



Mechanical Ventilation

- After intubation:
  - Check for equal breath sounds
  - Check tube placement with CXR
  - Normal: 2-5 cm above carina
- Monitor patient via ABG



Ventilator Changes

- **Hypoxemia**
  - Goal PaO2 > 60 mmHg
  - Increase FiO2
  - Increase PEEP
- **Hypercapnia**
  - Goal PaCO2 = 40 mmHg
  - Increase respiratory rate
  - Increase tidal volume

Oxygen Toxicity

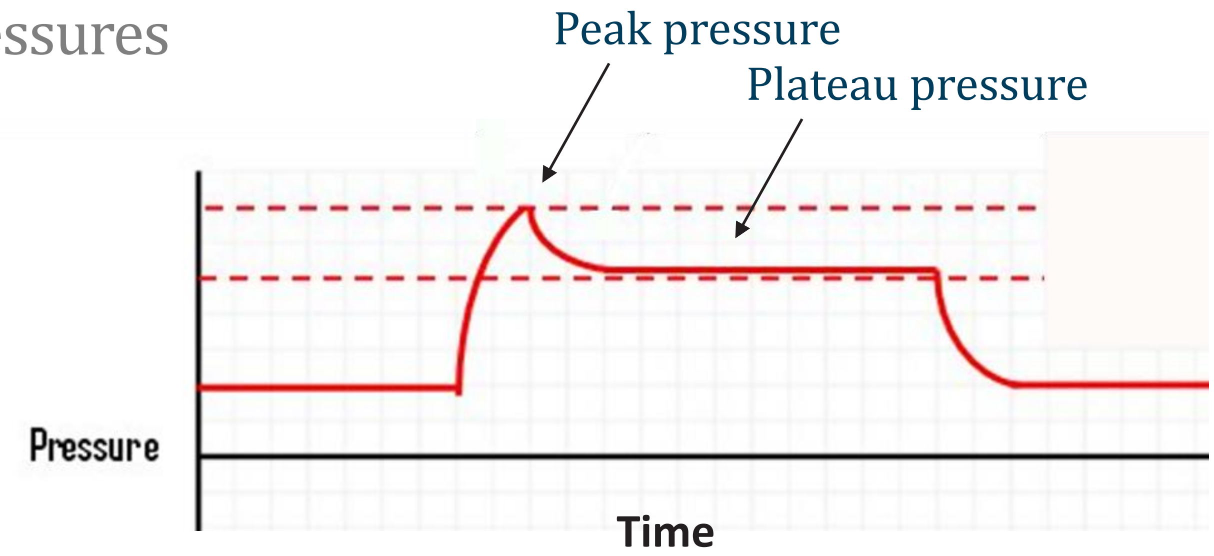
- High concentrations inspired oxygen (FiO_2)→ lung damage
- Initial FiO_2 often 100%
- FiO_2 < 60% usually safe
- Titrate down as tolerated
- **Can increase PEEP to allow lower FiO_2**

Ventilator Weaning

- Patient must be arousable
- **Spontaneous breathing trial**
  - Spontaneously breathing through ET tube
  - Usually for 30 minutes
  - Minimal ventilator support – often pressure support

Inspiratory Hold

- Ventilator technique to evaluate high pressures
- Set tidal volume delivered
- Airflow stopped
- Eliminates flow resistance
- Peak pressure measured
- “Plateau pressure” measured
    - Elastic pressure plus PEEP



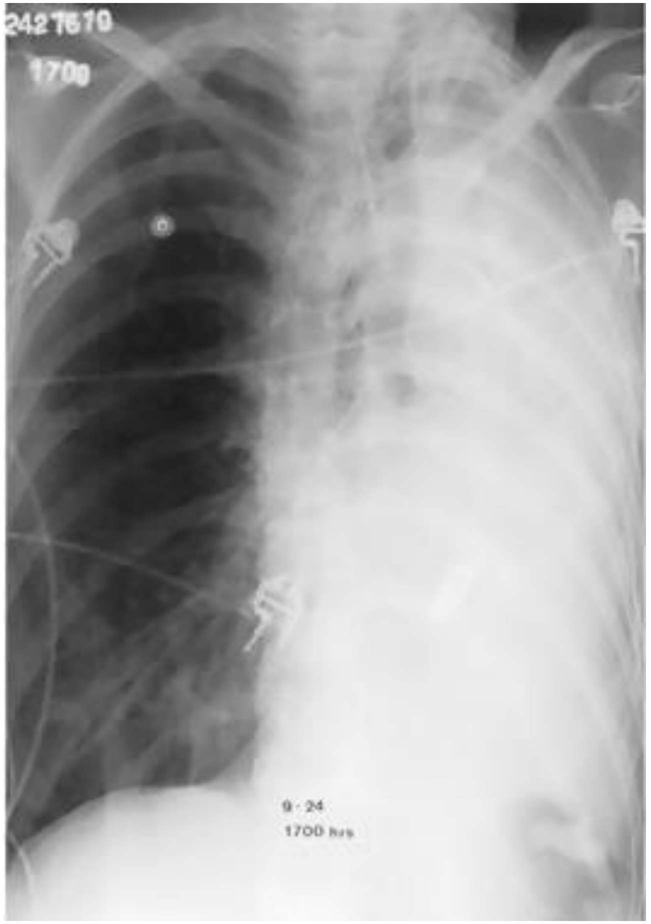
Peak Pressure	Plateau Pressure	Significance
High	High	Low compliance
High	Normal	Airway Resistance

Mechanical Ventilation Indications

- Persistent hypoxemia
- Unresponsiveness
- Respiratory distress with **normal/increased CO2**
  - Patient with asthma/COPD/pneumonia
  - Increased respiratory rate
  - Accessory muscle use
  - ABG: $PaCO_2 = 40$ mmHg
  - Next step: intubation and mechanical ventilation

Mucous Plugging

- Occurs in many lung diseases
- Causes alveolar collapse
- Trachea/mediastinum deviation toward affected side
- Decreased breath sounds
- Dullness to percussion
- CXR: Opacification of affected area
- Treatment: suction or bronchoscopy



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Sepsis and ARDS

Jason Ryan, MD, MPH

Boards & Beyond
STUDY SMARTER

Sepsis Terminology

- Infection: invasion of sterile tissue by organisms
- Bacteremia: bacteria in blood
- **Sepsis:** organ dysfunction due to infection
  - Lungs - ARDS
  - Hematology – reduced blood counts
  - Liver – increased AST/ALT, liver failure
  - Renal – acute renal failure
  - Brain – confusion
  - Cardiovascular – hypotension/shock
- **Septic shock:** sepsis plus hemodynamic compromise

Sepsis Definitions

- Difficult to define organ dysfunction due to infection
- Diagnosis often made **empirically**
  - Evidence of local infection
  - Positive blood cultures
  - Response to antibiotics
  - Organ dysfunction improves with therapy

Sepsis Definitions

- **Early identification** of septic patients improves outcomes
- Systemic inflammatory response syndrome (SIRS)
  - Need 2 of 4 criteria
  - Sepsis = SIRS plus infection
- Quick sequential organ failure assessment (qSOFA)
  - Need 2 of 3 criteria

SIRS	qSOFA
Temperature > 38C or < 36C Heart rate > 90 Respiratory rate > 20 or pACO2 < 32 WBC >12k, < 4k or > 10% bands	Respiratory Rate > 22 Altered mentation SBP < 100 mmHg

SOFA Score

SOFA Score (ICU mortality increases with increased score)

Variable	0	1	2	3	4
Respiratory - PaO_2/FiO_2	> 400	≤ 400	≤ 300	≤ 200	≤ 100
Coagulation - Platelets x 10^3	> 150	≤ 150	≤ 100	≤ 50	≤ 20
Liver - Bilirubin	< 1.2	1.2-1.9	2.0-5.9	6.0-11.9	> 12.0
CV - Hypotension	None	MAP < 70	Dop < 5 Dob (any)	Dop > 5 Epi ≤ 0.1 Norepi ≤ 0.1	Dop > 15 Epi > 0.1 Norepi > 0.1
CNS - Glasgow Coma	15	13-14	10-12	6-9	< 6
Renal - Creatinine/UO	< 1.2	1.2-1.9	2.0-3.4	Cr 3.5-4.9 UO < 500mL/d	Cr > 5.0 UO < 200mL/d

*Dop=Dopamine, Dob=Dobutamine, Epi=Epinephrine, Norepi=Norepinephrine. All rates in ug/kg/min

Sepsis

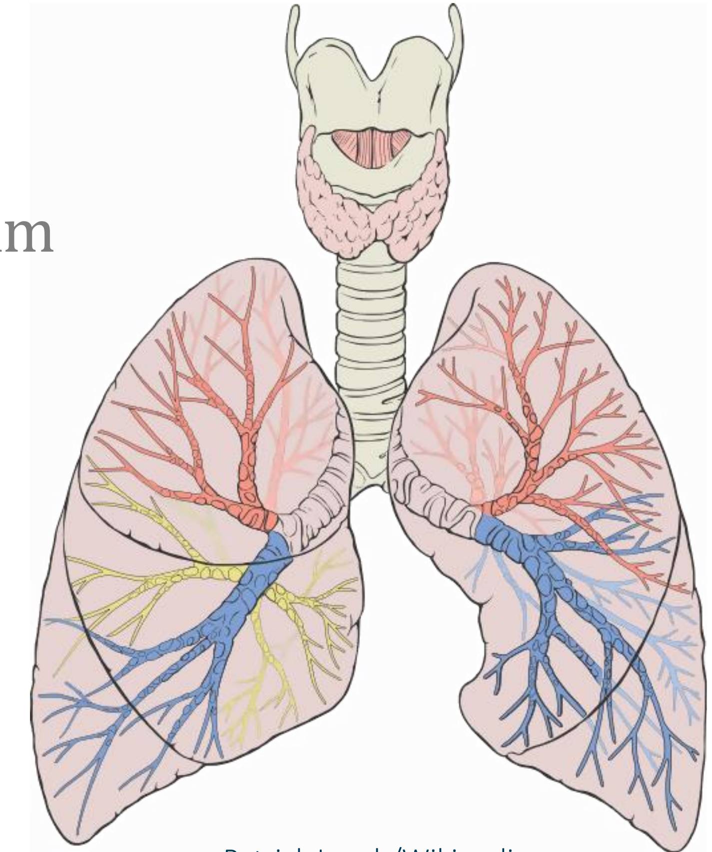
Management

- **Broad spectrum antibiotics**
- **Vascular access and IV fluids**
  - Goal is MAP > 65 mmHg and urine output > 0.5 ml/kg/hr
  - Blood transfusion is HgB < 7 g/dL
- Vasopressors (septic shock)
  - Norepinephrine
  - Phenylephrine
  - Vasopressin
  - Dopamine
  - Epinephrine

ARDS

Acute Respiratory Distress Syndrome

- Triggered by various lung injuries
- Injury → release of pro-inflammatory cytokines
- Damage to capillary endothelium and alveolar epithelium
- Protein escapes from vascular space
- Fluid pours into the interstitium
- Massive shunting → hypoxemia



Patrick Lynch/Wikipedia

ARDS

Triggers

- **Sepsis (most common)**
- Infection (PNA)
- Aspiration
- Trauma
- Acute pancreatitis
- Transfusion-related acute lung injury (TRALI)

ARDS

Berlin Diagnostic Criteria

- Acute onset (< 1 week)
- Bilateral infiltrates on chest imaging
- Pulmonary edema without heart failure
  - Normal PCPW
- Decreased PaO2/FiO2 ratio
  - Normal > 300
  - Mild: 200-300
  - Moderate: 100-200
  - Severe: < 100

Looks like pulmonary edema but PCPW is normal

Wikipedia/James Heilman, MD

ARDS

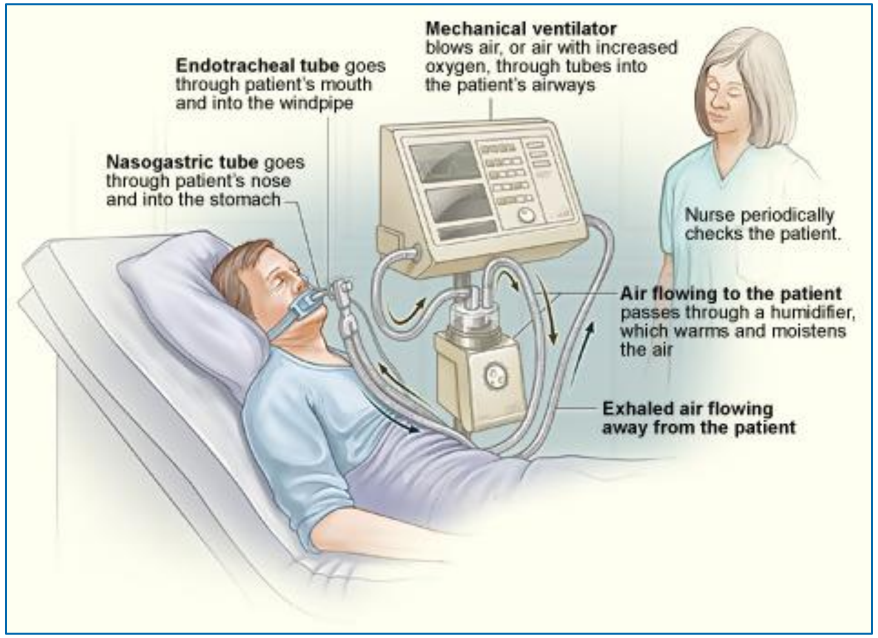
Treatment

- Mechanical ventilation
- "Lung protective strategies"
- **Low tidal volume**
    - 6 ml/kg
    - Limits overexpansion of alveoli
    - Avoids "barotrauma"
    - Shown to improve mortality
- Often requires high PEEP
    - Shunting → lack of improvement with O2
    - PEEP opens airways → improved gas exchange

ARDS

Treatment

- Treat underlying condition
- Supportive care (fluids, nutrition)
- **VAP** is serious complication



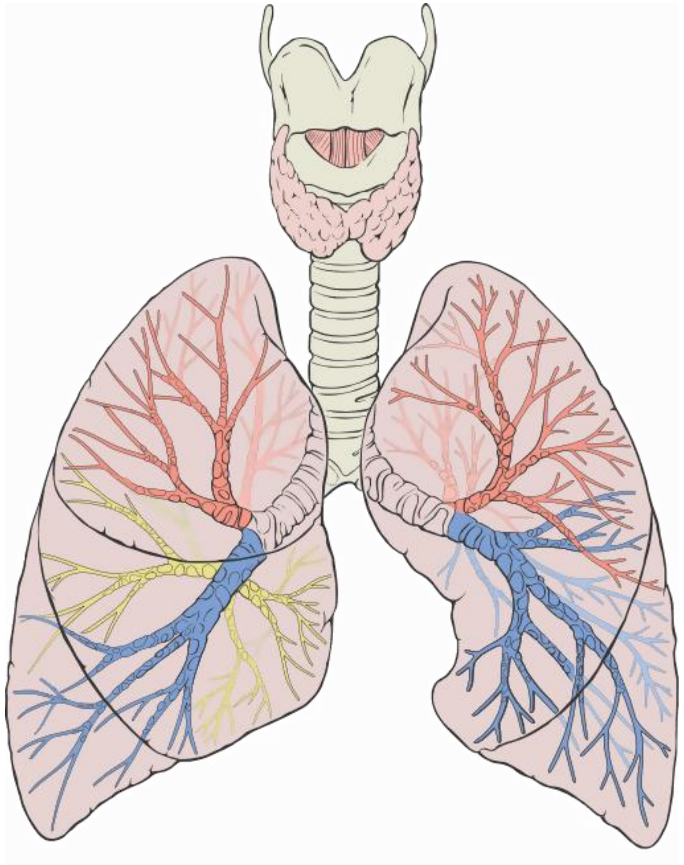
Mechanical Ventilation

Pulmonary Hypertension

Jason Ryan, MD, MPH

Pulmonary Hypertension

- Normal PA pressure
  - 24/12 mmHg
  - Mean 10-14 mmHg
- **Pulmonary hypertension**
  - Mean pressure > 25 mmHg



Patrick Lynch/Wikipedia

Pulmonary Hypertension

Diagnosis

- Gold standard diagnosis: **right heart catheterization**
- Non-invasive diagnosis by **echocardiography**
  - Estimate PA pressure
  - Visualize right heart structures

Pulmonary Hypertension

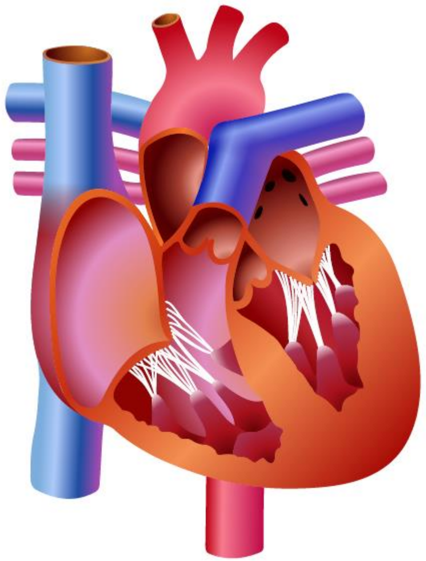
- **Loud P2 = pulmonary hypertension**
  - "Accentuated" or "loud" second heart sound
  - Left upper sternal border
- Holosystolic murmur (TR)

Pulmonary Hypertension

- Right-sided S3
- Right ventricular lift/heave
  - Left parasternal lift/heave
- Right ventricular failure
  - Elevated JVP
  - Hepatomegaly
  - Pitting edema

Pulmonary Hypertension

- Main symptom is dyspnea
- Untreated can lead to **"cor pulmonale"**
  - Chronic high pressure in right ventricle
  - Right ventricle hypertrophies
  - Eventually dilates and fails
  - Jugular venous distension
  - Lower extremity edema
  - Hepatomegaly
- Death from heart failure or arrhythmia



Pulmonary Hypertension

<u>High PVR</u>
Hypoxemia
Chronic emboli
Pulmonary arterial hypertension

↓

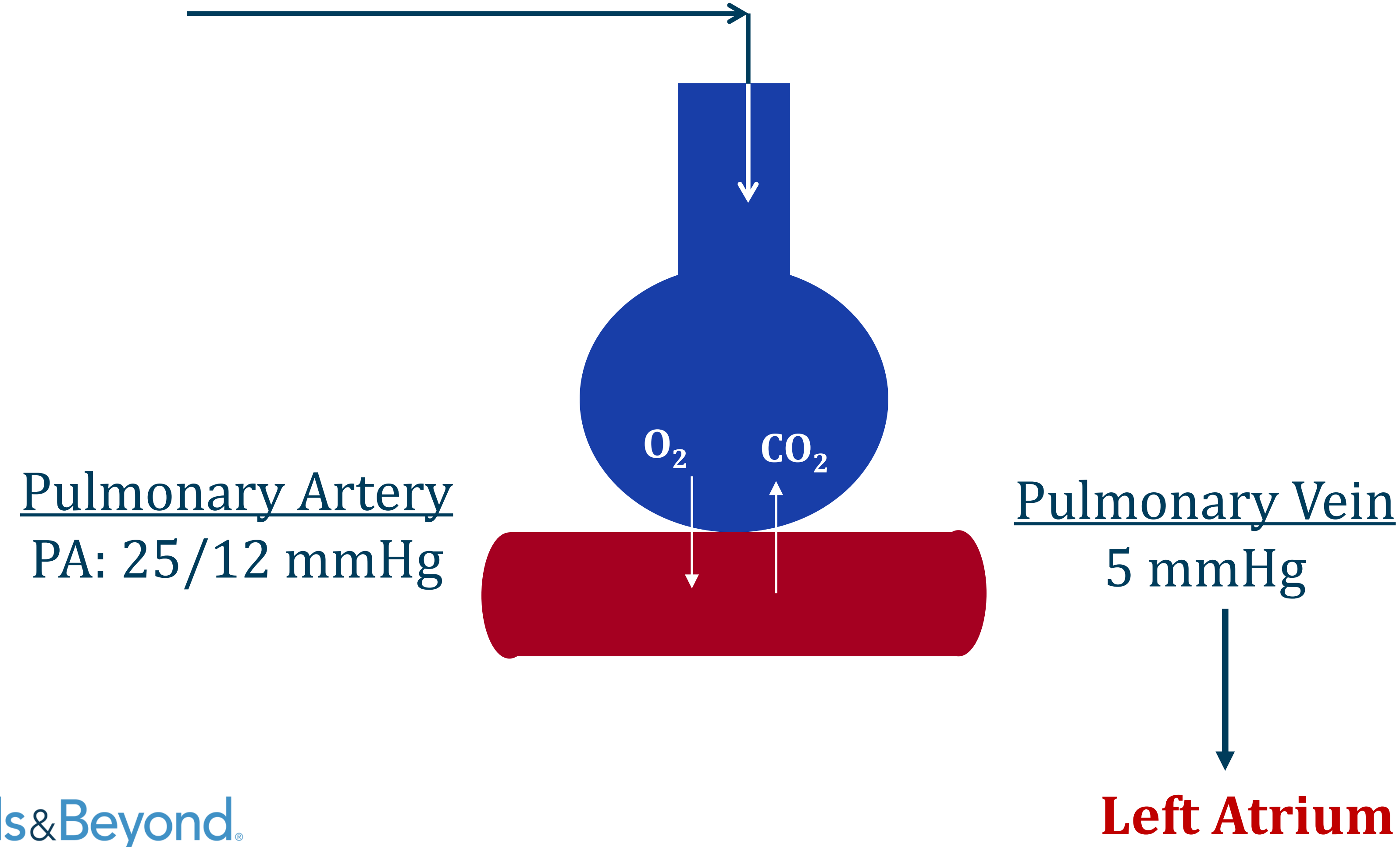
$$P_{PA} = CO * PVR + P_{LA}$$

↑

<u>High LA Pressure</u>
Most common cause PHTN
"Pulmonary Venous HTN"
Heart Failure
Valve Disease

Left Heart Disease

Pulmonary *Venous* Hypertension



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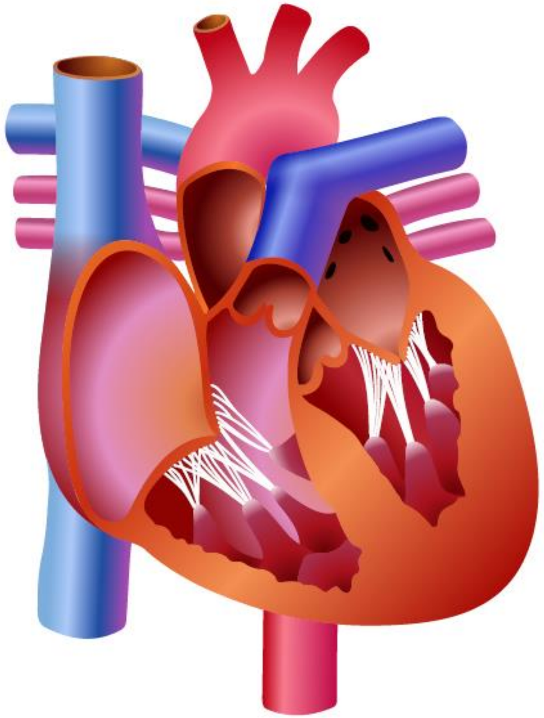
Left Heart Disease

- Most common cause of pulmonary hypertension
- "Pulmonary *venous* hypertension"
- Any cause of **high left atrial pressure**
    - Heart failure
    - Mitral stenosis
    - Mitral regurgitation



High PVR

Lung disease or thrombosis

- **Hypoxemia** → vasoconstriction
  - COPD, other chronic lung diseases
  - Sleep apnea or high altitude (chronic hypoxia)
- **Chronic pulmonary emboli**
  - Decreased area for blood flow

Pulmonary Hypertension

Mean PAP	PCWP	Interpretation
20	10	Normal
40	10	High PVR – Lung disease, CTEPH, PAH
40	25	High PCWP – Left Heart Disease
60	20	Mixed

PAH

Pulmonary Arterial Hypertension

- High pulmonary vascular resistance
- No chronic lung disease or thrombosis
- Hyperplasia of intimal smooth muscle
- Key associations:
  - **Connective tissue disease (scleroderma)**
  - Human immunodeficiency virus
  - Congenital heart disease (shunts)
  - Schistosomiasis
  - Drugs (amphetamines, cocaine)

Idiopathic PAH

- Rare disease
- Classically affects young women
- **High pulmonary vascular resistance**
- Increased activity vasoconstrictors (endothelin)
- Decreased activity vasodilators (nitric oxide)

BMPR2 gene mutations

- Bone morphogenetic protein receptor type II
  - Inhibits smooth muscle proliferation
  - Mutations → abnormal growth (endothelium, smooth muscle)
- Up to 25% of idiopathic cases
- Up to 80% **familial cases**

WHO Classification

Class	Mechanism	Description
1	Pulmonary Arterial Hypertension	Idiopathic, Connective Tissue Disease
2	Pulmonary Venous Hypertension	Left Heart Disease, ↑ LAP
3	Chronic Lung Disease	COPD, ILD, OSA
4	Chronic Thromboembolism	Multiple PEs
5	Unclear Mechanism	

Pulmonary Hypertension Treatments

- Most target **underlying disease**
  - Heart failure: diuretics
  - COPD: inhalers, steroids
  - Thromboembolism: anticoagulants

PAH Treatments

WHO Class I Patients

- All lower PVR
- Epoprostenol: prostacyclin (IV)
  - PGI_2
  - Potent vasodilator
- Bosentan:
  - Antagonist endothelin-1 receptors (PO)
  - Vasodilator
- Sildenafil:
  - Inhibits PDE-5 in smooth muscle of lungs (PO)
  - Vasodilator

Class	Mechanism	Description
1	Pulmonary Arterial Hypertension	Idiopathic, Connective Tissue Disease
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4	Chronic Thromboembolism	Multiple PEs
5	Unclear Mechanism	

DVT and Pulmonary Embolism

Jason Ryan, MD, MPH

Boards & Beyond
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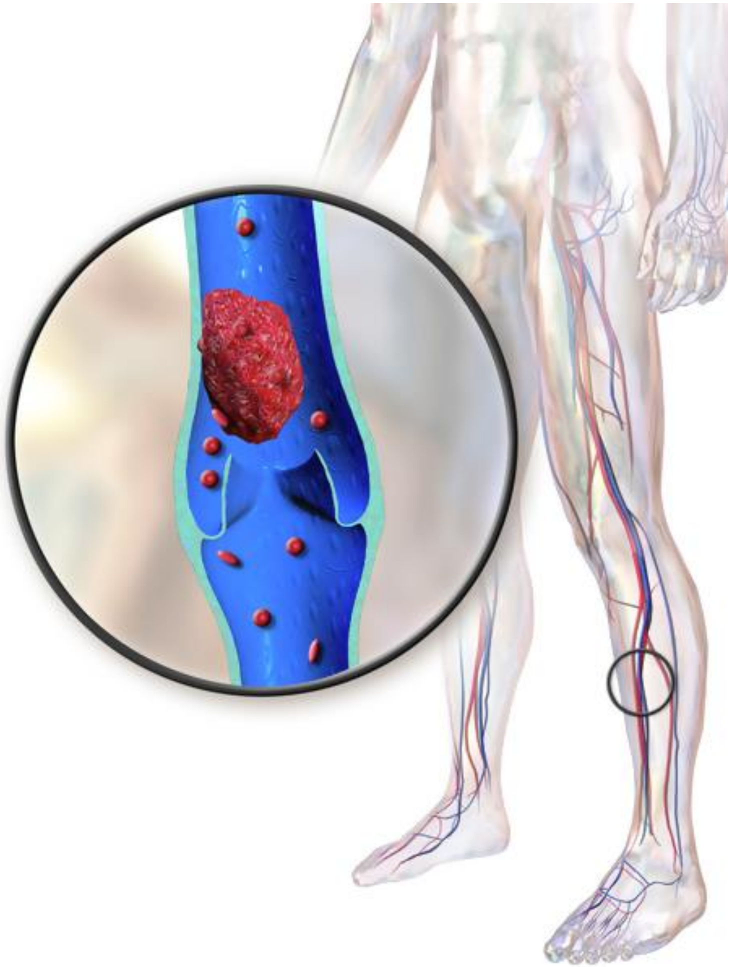
Deep Vein Thrombosis

- Thrombus within a deep vein
- Usually occurs in calf or thigh
- Commonly iliac/femoral/popliteal veins
- Can extend or "grow"
- May cause pulmonary embolism
- Often 2° hypercoagulable state

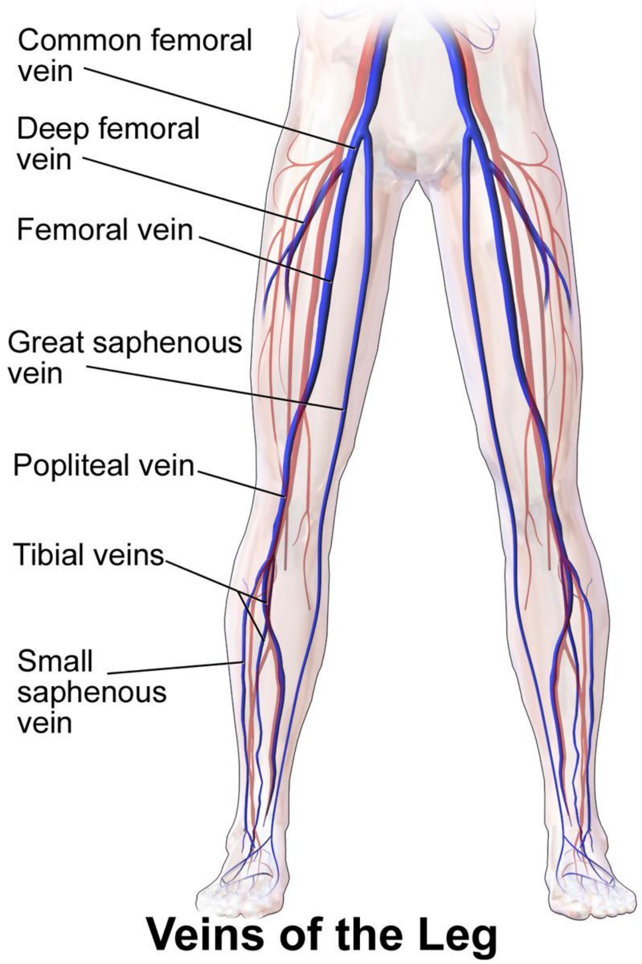


Bruce Blaus/Wikipedia

Deep Vein Thrombosis

Clinical Features

- Often asymptomatic until PE
- Calf pain
- Palpable cord (thrombosed vein)
- Unilateral edema
- Warmth, tenderness, erythema
- Homan's sign: calf pain with dorsiflexion of foot

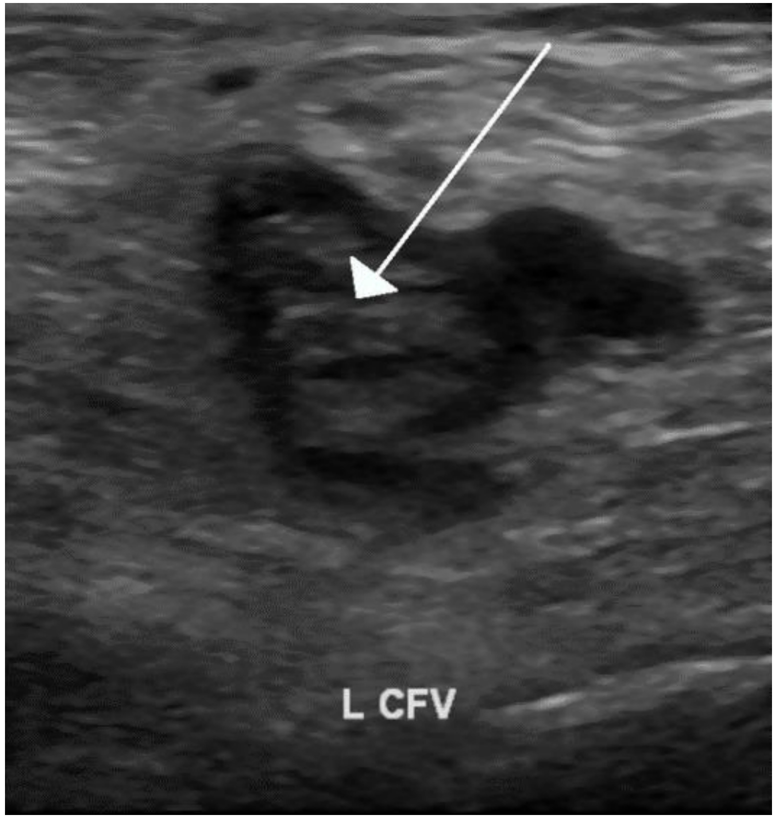


Bruce Blaus/Wikipedia

Deep Vein Thrombosis

Diagnosis

- **Lower extremity ultrasound**
- D-dimer
  - Degradation product of fibrin
  - Sensitive but not specific
  - Levels elevated in DVT/PE
  - Levels also elevated in many, many other conditions
  - <u>Useful when normal</u> in setting of low-mod Wells score
- Rarely used tests
  - CT venogram
  - MR venogram
  - Contrast venography



James Heilman, MD

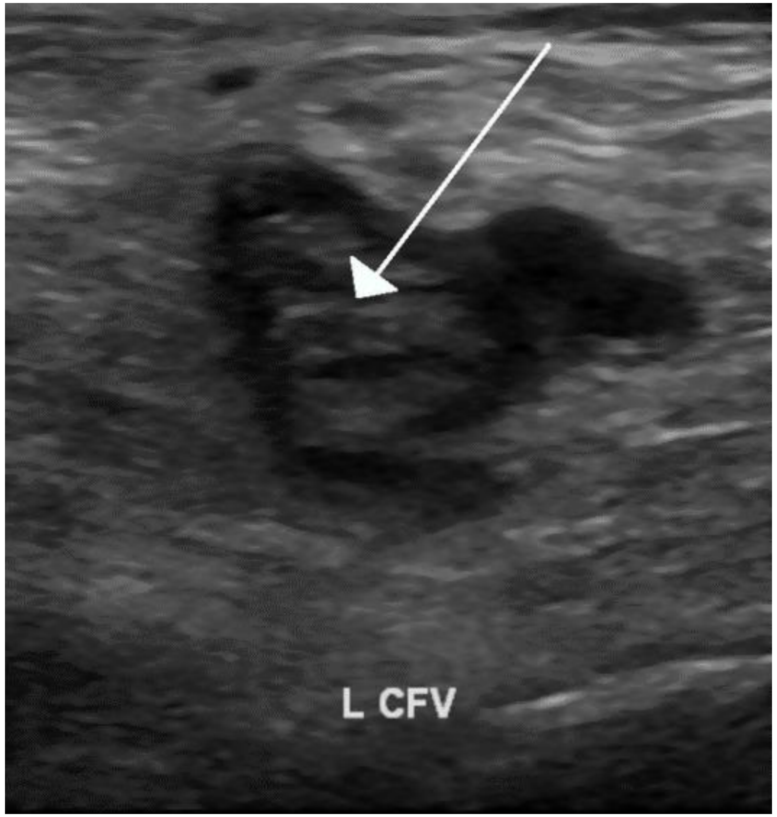
Modified Wells Score

Prior DVT	1
Active cancer	1
Recent immobilization or bedridden	1
Localized tenderness along venous distribution	1
Leg swelling	1
One leg swollen > other	1
Pitting edema	1
Superficial veins visible	1
Alternative diagnosis likely	-2

Score $\geq$ 3 High Probability
1-2 Mod Probability
0 Low Probability

Modified Wells Score

- Low to moderate probability
  - D-dimer
  - Elevated D-dimer → ultrasound
- High probability
  - Ultrasound



James Heilman, MD

Deep Vein Thrombosis

Treatment

- Initial treatment with **heparin or LMWH**
- Transition to oral anticoagulation
  - Dabigatran
  - Rivaroxaban or apixaban
  - Warfarin
- Patients with CKD (low GFR)
  - Unfractionated heparin
  - Warfarin or apixaban
- Massive proximal DVT: thrombolysis or surgical thrombectomy

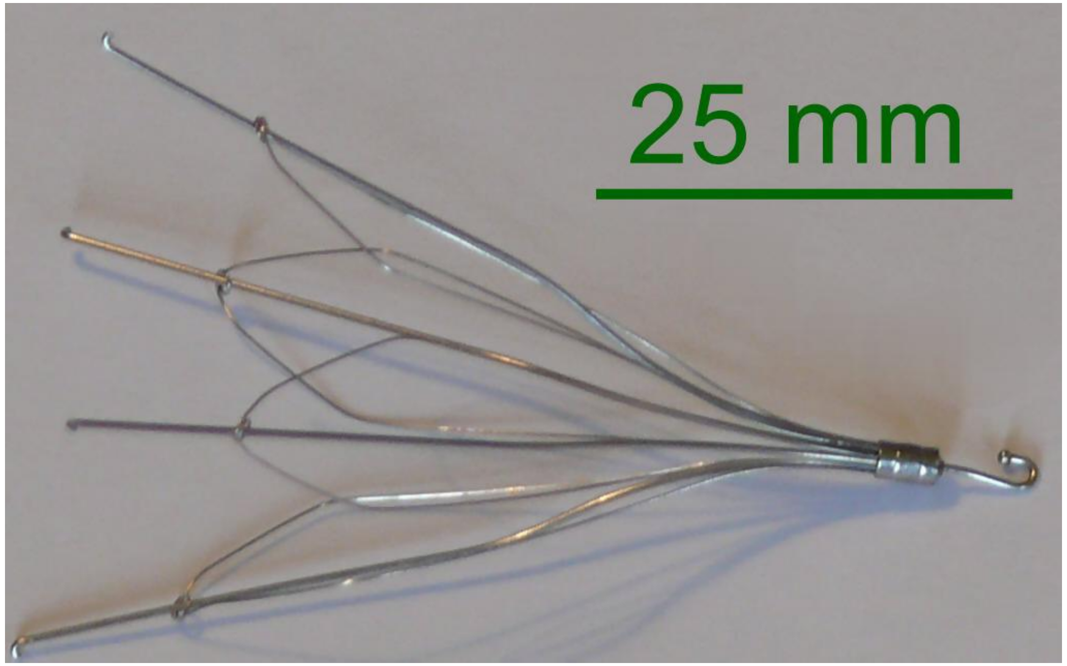
Deep Vein Thrombosis
Prophylaxis

- Used in hospitalized patients
  - DVTs common among immobilized, ill patients
- Medications
  - SQ heparin
  - LMWH
- Mechanical compression
- Early ambulation

Public Domain

IVC Filter

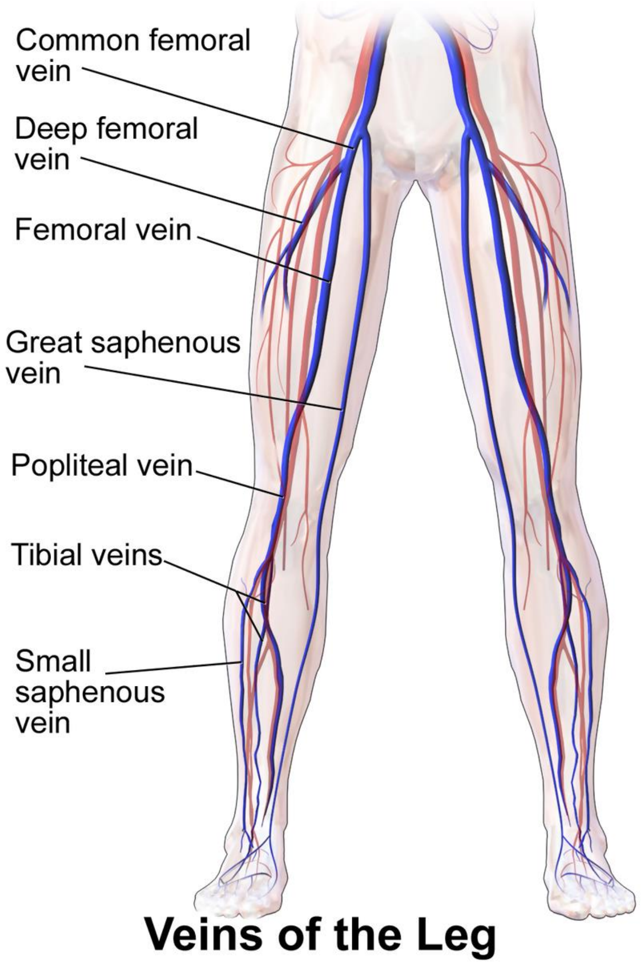
- Used in high-risk DVT patients
- Also patients with contraindication to anticoagulation
- Placed to prevent pulmonary embolism



BozMo/Wikipedia

Pulmonary Embolism

- Thrombus in pulmonary artery
- Rarely formed in heart or pulmonary vasculature
- Majority come from **lower extremity proximal veins**
    - Iliac
    - Femoral
    - Popliteal
- Travels to lung via IVC → RA → RV
- Can be "unprovoked"
- Often secondary to a hypercoagulable state



Bruce Blaus/Wikipedia

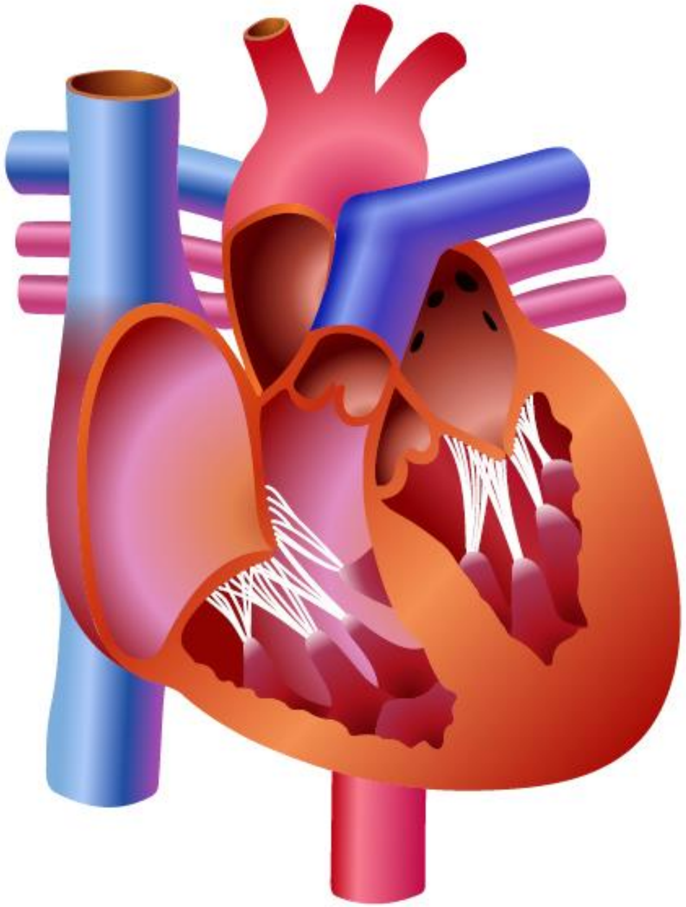
Pulmonary Embolism

- **Chest pain**
  - Classic presentation: pleuritic chest pain
- Respiratory distress
  - Dyspnea
  - Hypoxemia
  - Tachypnea
- Hemoptysis

Pixabay/Public Domain

Pulmonary Embolism

- Right heart failure
    - Elevated jugular venous pressure
- Massive PE can cause **sudden death**
    - Obstruction to flow through pulmonary arteries
    - Right heart failure
    - Arrhythmias
- Small, chronic emboli: **pulmonary hypertension**



Pulmonary Embolism

Arterial blood gas

- V/Q mismatch → hypoxemia
- Hyperventilation → hypocapnia
- Classic findings: **low PaO_2** and **low PCO_2**
  - High pH: respiratory alkalosis
- Actual blood gas findings variable

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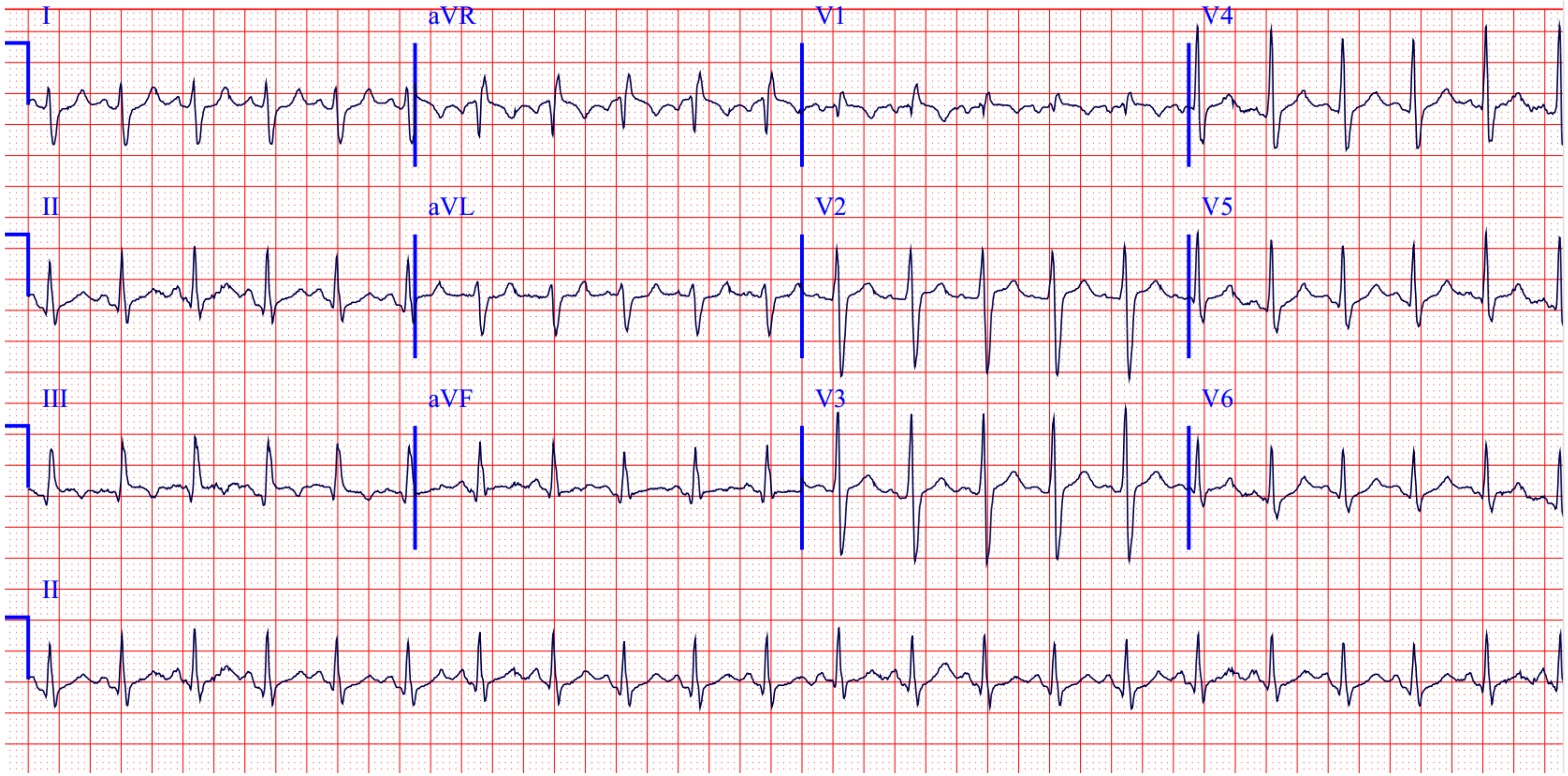
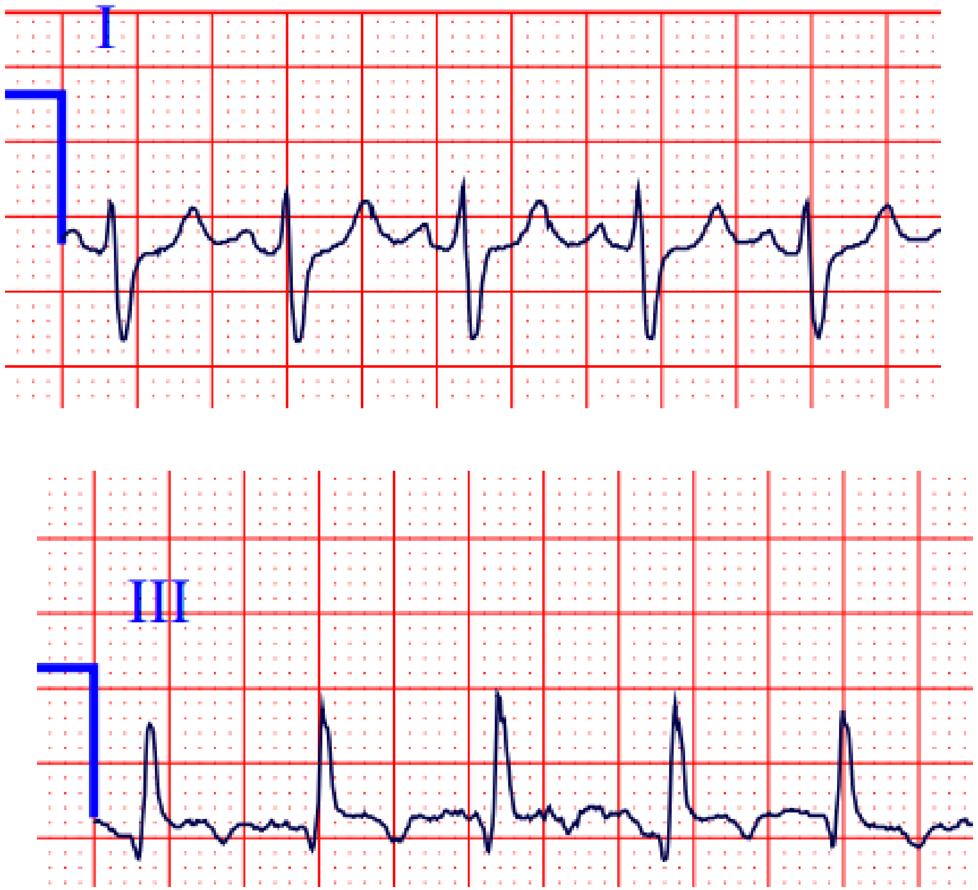
S1Q3T3

Occurs in massive PE



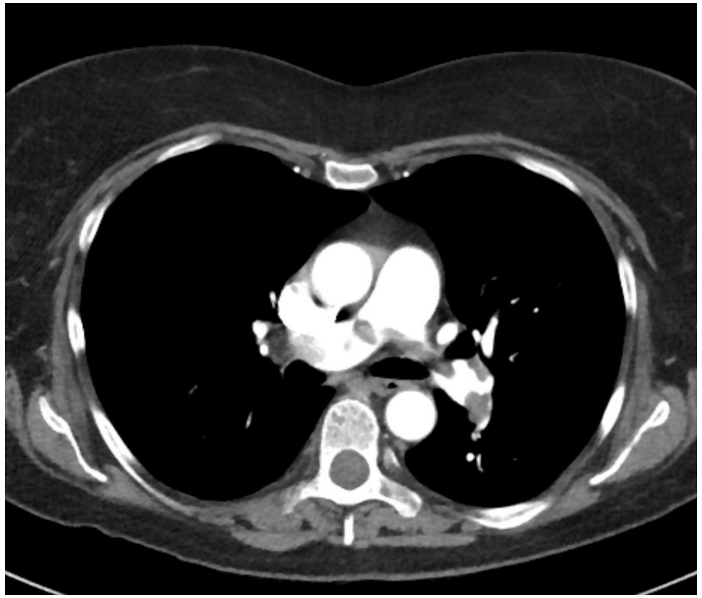
S1Q3T3

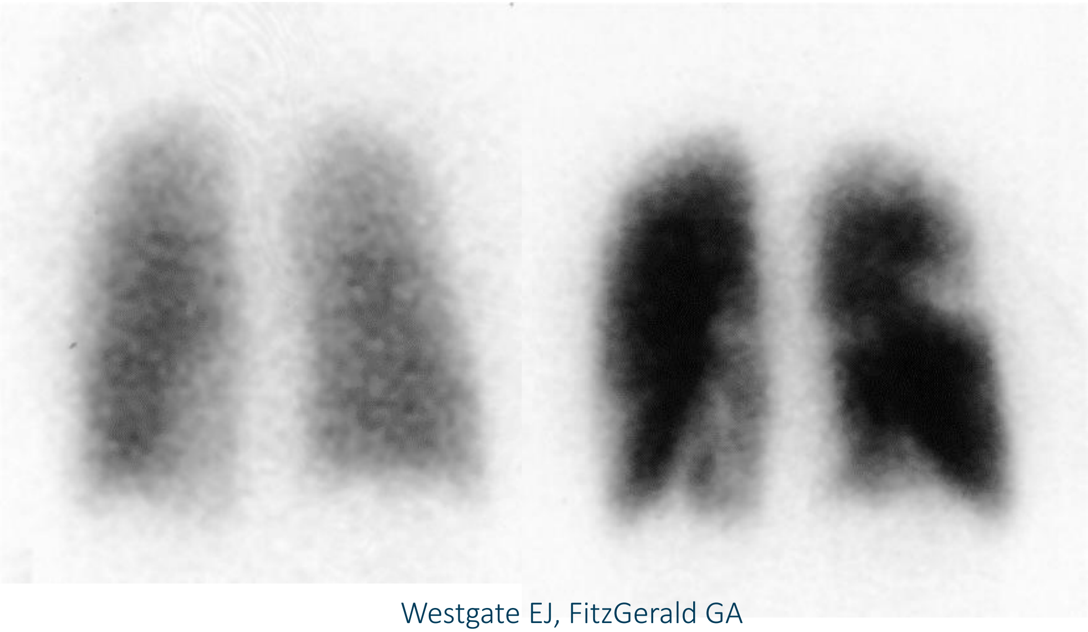


Pulmonary Embolism

Diagnosis

- **CT angiogram**
- VQ Scan
  - Pregnancy
  - CKD

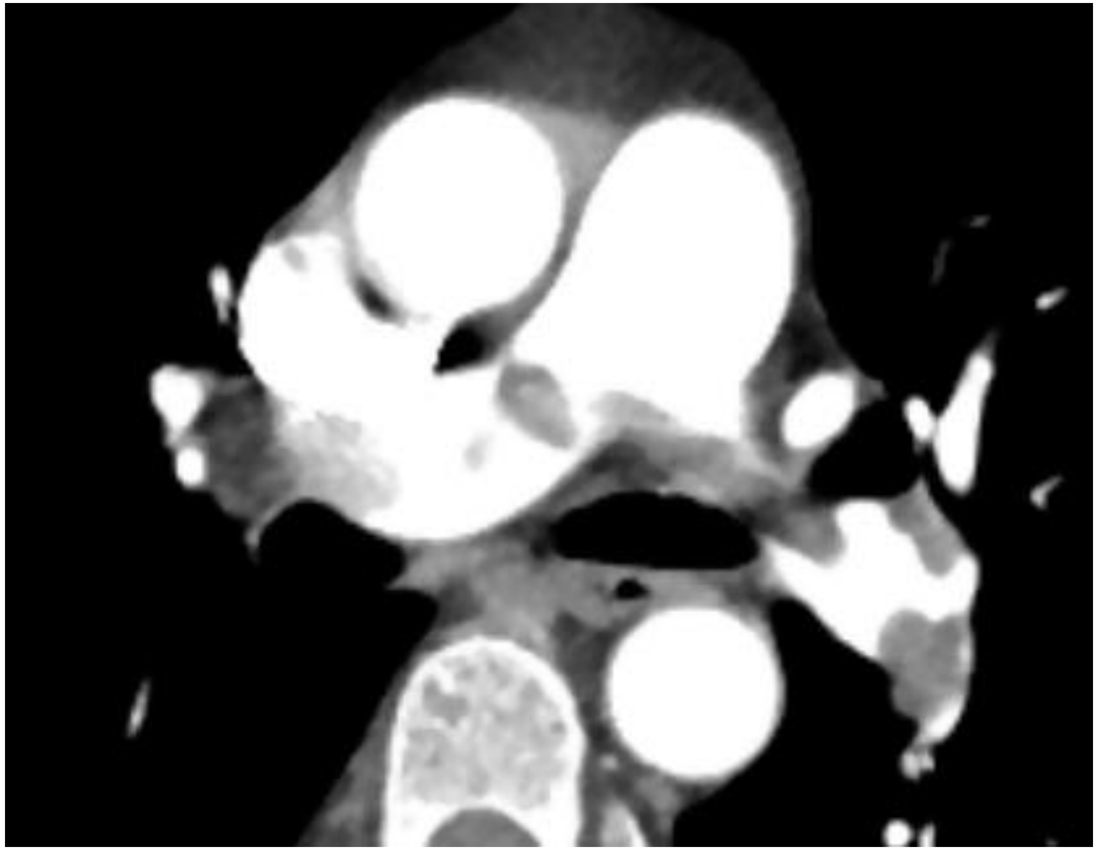




Westgate EJ, FitzGerald GA
Pulmonary Embolism in a Woman Taking Oral Contraceptives and Valdecoxib.
PLoS Medicine Vol. 2, No. 7, e197. doi:10.1371/journal.pmed.0020197

Pulmonary Embolism

CT Angiogram



Pulmonary Embolism

Diagnosis

- CXR usually normal
- Lower extremity ultrasound
    - Helpful if positive
    - Negative ultrasound in 50% PEs
- Pulmonary angiography
    - Gold standard
- D-dimer

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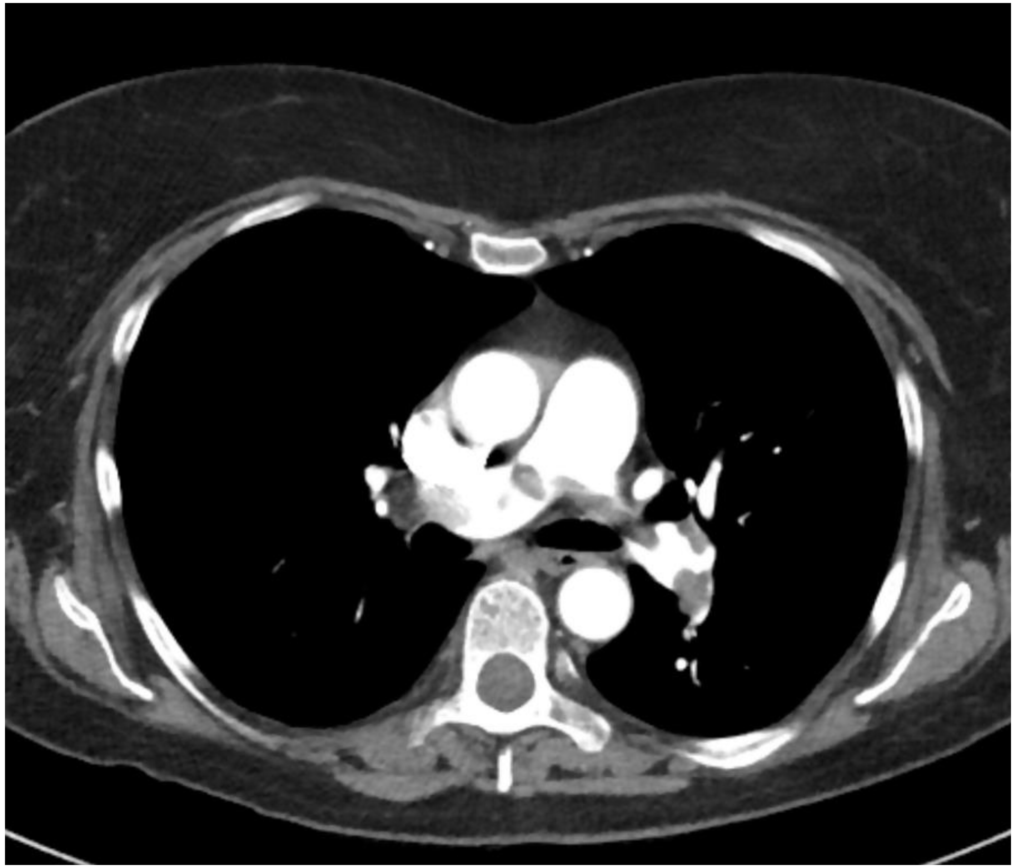
Pulmonary Embolism Wells Criteria

Symptoms of DVT	3
No alternative diagnosis better explains the illness	3
HR > 100	1.5
Immobilization or recent surgery	1.5
History of DVT/PE	1.5
Hemoptysis	1
Malignancy	1

Score > 6 High Probability
2-6 Mod Probability
<2 Low Probability

Pulmonary Embolism Wells Criteria

- Low probability
  - No further workup or D-dimer
- Moderate probability
  - D-dimer
  - Elevated D-dimer → CT angiogram
- High probability
  - CT angiogram



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Pulmonary Embolism Rule-out Criteria

PERC

Age > 50
Prior DVT/PE
O2 sat < 95%
Hemoptysis
Leg swelling
Recent surgery/trauma
Estrogen use (OCPs)

If all criteria negative, risk of PE very low

Massive Pulmonary Embolism

Hemodynamics

Parameter	Change
Cardiac Output	Decreased
SVR	Increased
Right Atrial Pressure	Increased
Pulmonary artery pressure	Increased
Left atrial pressure (PCPW)	Decreased

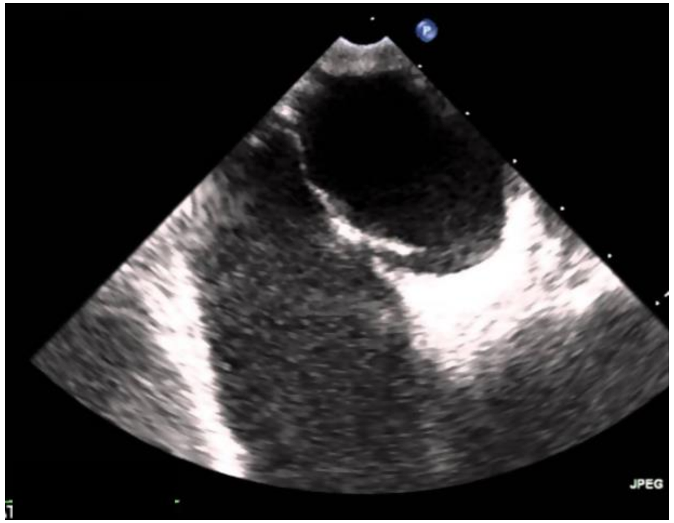
Pulmonary Embolism

Treatment

- Similar treatment to DVT
  - "DVT/PE"
  - "Venous thromboembolism" (VTE)
  - Initial treatment with **heparin or LMWH**
  - Transition to warfarin or NOAC
- Massive PE: thrombolysis (tPA)
- Most PE deaths due to recurrent PE
  - Often hours after first PE
- Start treatment ***immediately*** if high clinical suspicion

Patent Foramen Ovale

- Found in ~25% adults
- Failure of foramen ovale to close after birth
- Can allow venous clot to reach arterial system (brain)
- Rarely causes **stroke** in patients with DVT/PE



Fat Embolism

- Often occurs after a **long bone fracture**
- Fat may cross lungs → small artery infarctions
- Fat embolism syndrome: pulmonary, neuro, skin

Hellerhoff /Wikipedia

Fat Embolism

- **Lung**
  - Dyspnea, hypoxemia
  - Diffuse capillary leak (ARDS)
  - Often requires mechanical ventilation
- Neurological
  - Usually **confusion**
  - May develop focal deficits
- **Petechiae**

James Heilman, MD/Wikipedia

Amniotic Fluid Embolism

- During labor or shortly after
- Amniotic fluid, fetal cells, fetal debris enter maternal circulation
- Inflammatory reaction
- Often fatal

Wikipedia/Public Domain

Amniotic Fluid Embolism

- Phase I
  - Left and right heart failure
  - Acute respiratory distress syndrome
  - Key features: **respiratory distress, ↓O_2, hypotension**
- Phase II
  - Key feature: **bleeding**
  - Massive hemorrhage
  - DIC
  - **Seizures** also often occur

Øyvind Holmstad/Wikipedia

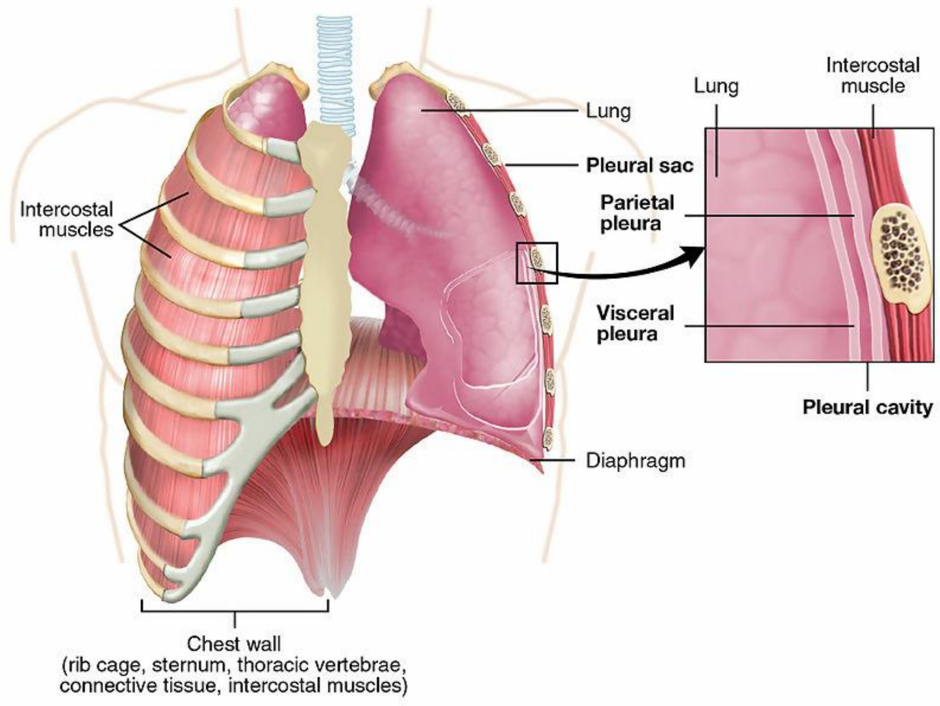
Pleural Disease

Jason Ryan, MD, MPH

Boards & Beyond
STUDY SMARTER

What are the pleura?

- Two layers of tissue surrounding lungs
  - Visceral pleura – attached to lung
  - Parietal pleura – attached to chest wall
- Pleural space/cavity – between layers
- Pleural lined by mesothelial cells
- Secrete pleural fluid for lubrication



Wikipedia/OpenStax College

Pleural Effusion

- Accumulation of fluid in pleural space
- Dyspnea
- Abnormal lung exam

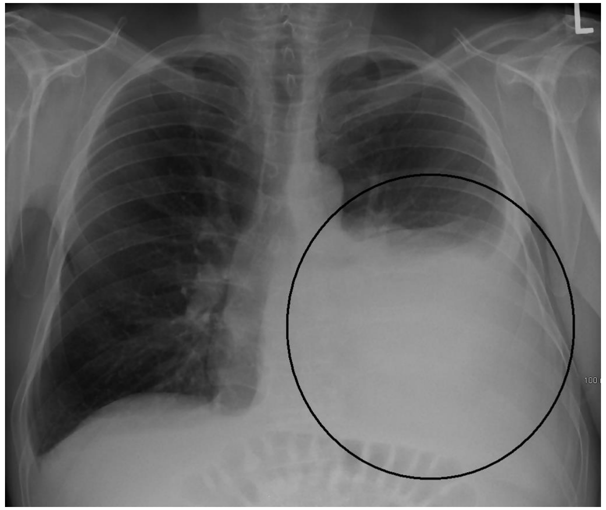


Image courtesy of James Heilman, MD

Effusion
Dullness to percussion Decreased/absent breath sounds Decreased fremitus Egophony present

Pleural Effusion

Diagnosis

- Chest X-ray
- CT scan (smaller effusions)
- Thoracentesis
  - Diagnostic
  - Therapeutic
  - May cause PTX

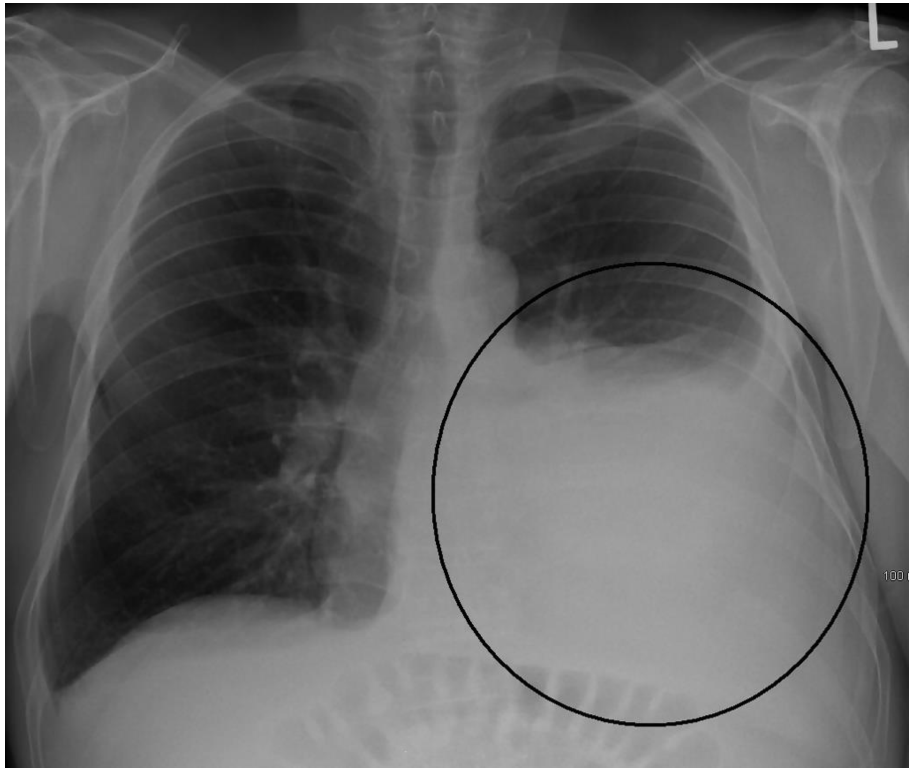


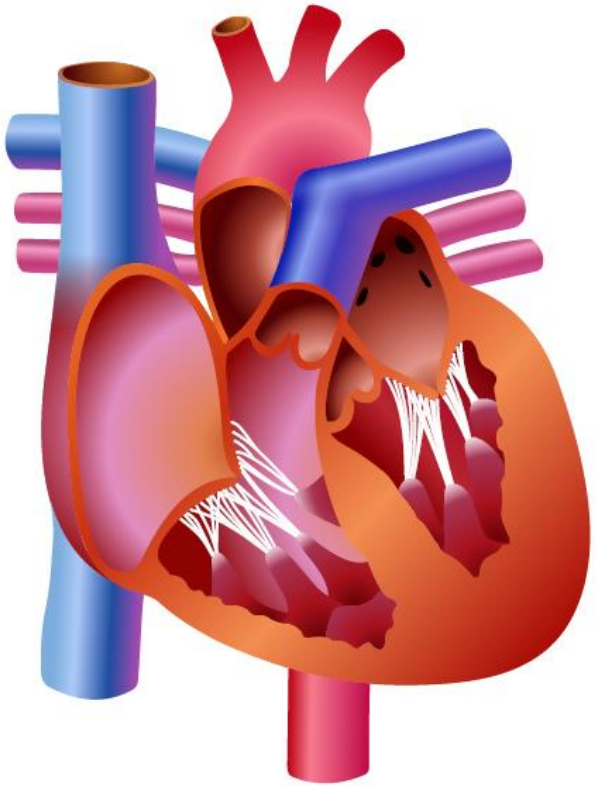
Image courtesy of James Heilman, MD

Pleural Effusion

- **Transudative**
  - Fluid forced out of capillaries from high pressure
- **Exudative**
  - Capillary leak

Transudative Effusion

- Something driving fluid into pleural space
- Most commonly due to **heart failure** (high capillary pressure)
- Other causes:
  - Nephrotic syndrome (low protein)
  - Cirrhosis (low albumin)
- Mostly fluid in effusion
- Very little protein in effusion
- Usually treat for underlying cause (no drainage)

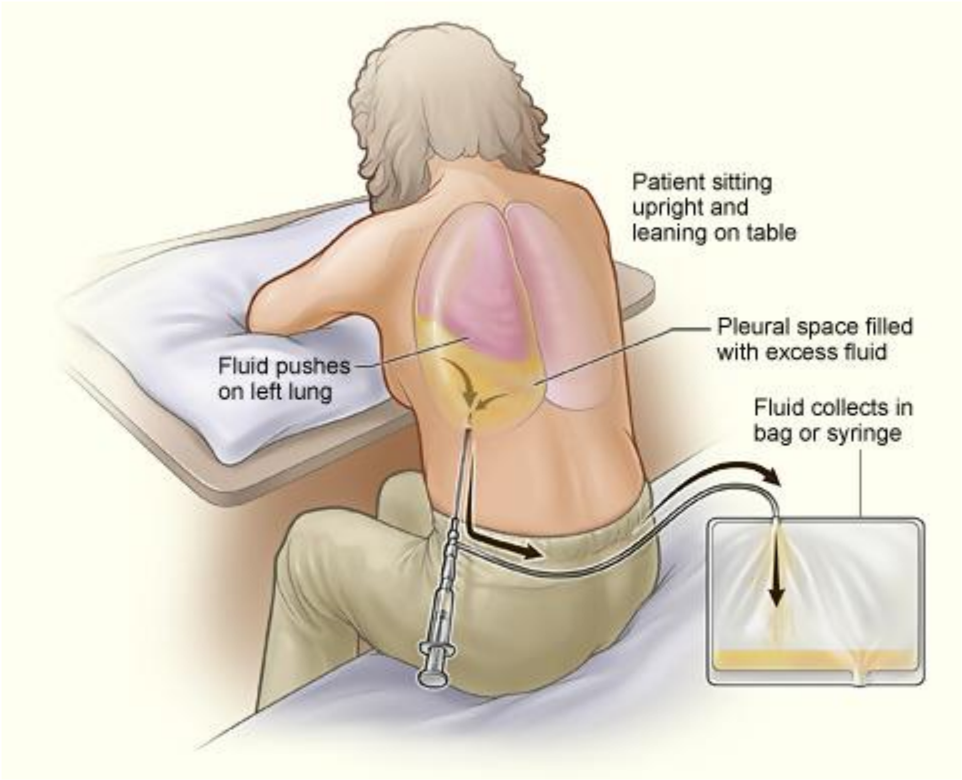


Exudative Effusion

- Fluid *leaking* into pleural space
  - High vascular permeability
- Many causes
- Malignancy
- Pneumonia
- More protein in pleural fluid vs. transudative
- Usually requires drainage

Transudate vs. Exudate

- Thoracentesis to obtain fluid sample
- Test for protein, LDH
- Light's Criteria – Exudate if:
  - Pleural protein/serum protein greater than 0.5
  - Pleural LDH/serum LDH greater than 0.6
  - Pleural LDH greater than 2/3 upper limits normal LDH



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Pleural Fluid

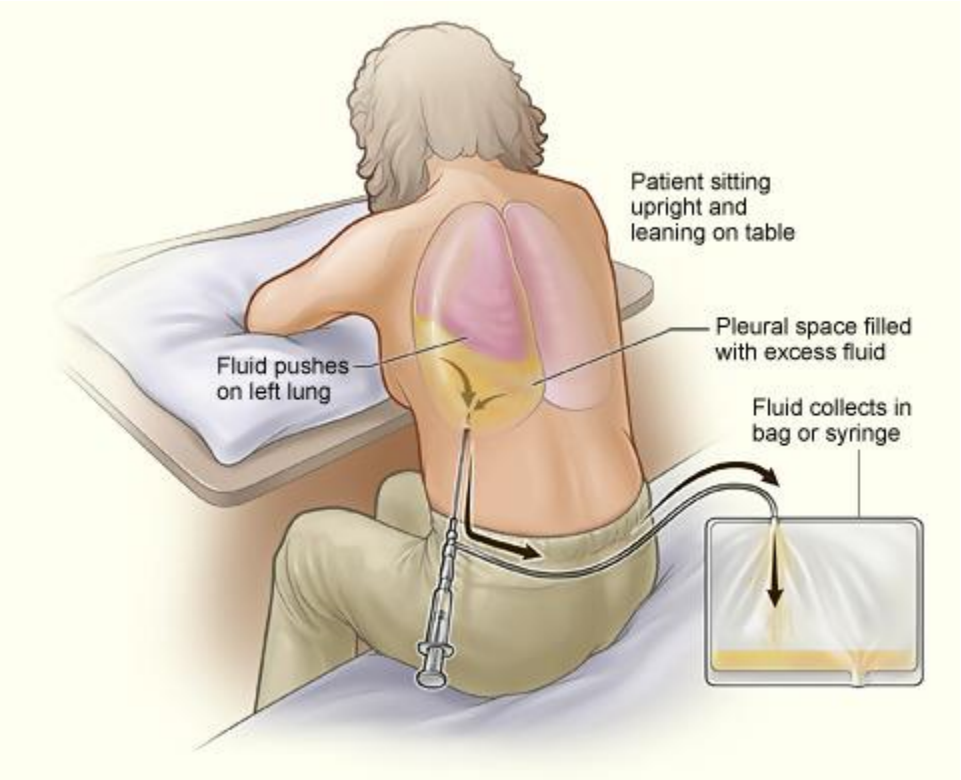
Other Findings

- Glucose normally close to serum level
  - Low glucose with infection or malignancy
  - Consumption by cells
  - Low in effusions associated with rheumatoid arthritis
- Cytology
  - Screen for malignant cells
- Elevated amylase
  - Occurs with esophageal rupture and pancreatitis
- Lymphocytosis with exudative effusion
  - Tuberculosis

Pleural Effusion

Management

- Transudative effusions
  - Treat underlying cause
  - Thoracentesis in large effusions
  - Fluid often re-accumulates
- Exudative effusions
  - Thoracentesis
  - Chest tube placement
  - Surgical treatment
- Intrapleural fibrinolysis (e.g. streptokinase)
  - May accelerated drainage
  - Consider if drainage is poor



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Parapneumonic Effusion

- Pleural effusion adjacent to pneumonia
- May be sterile or contain bacteria
- May cause empyema – pus in pleural space

	Uncomplicated	**Complicated**	**Empyema**
General	Sterile exudate	Bacterial invasion	Frank pus
Pleural fluid	WBC < 50k pH > 7.2	WBC > 50k pH < 7.2	Pus
Gram stain/culture	Negative	Positive/Negative*	Positive
Management	Antibiotics	Antibiotics +/- Drainage	Antibiotics + Drainage

* Depends on bacterial count

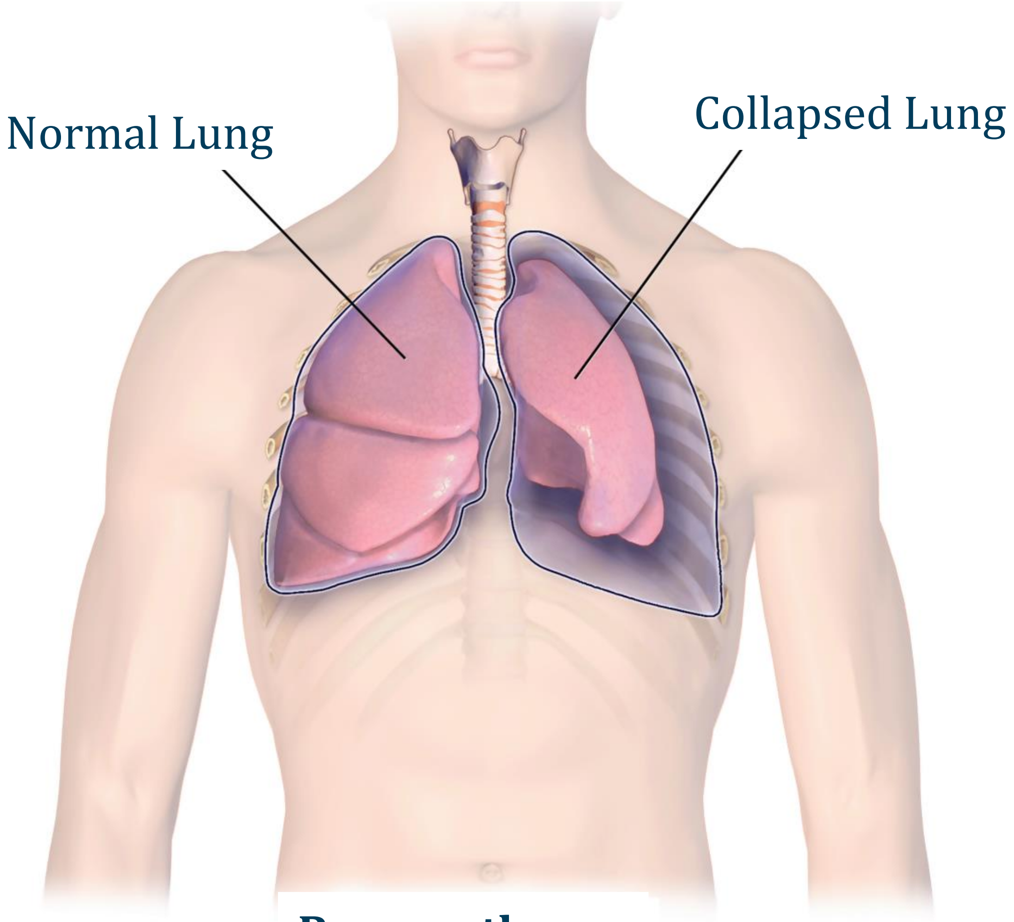
Parapneumonic Effusion

Major Drainage Indications

- Empyema
- Pleural fluid pH of <7.2 (from infection)
- Positive Gram stain or culture
- Loculated effusion
- Large effusions
- Effusions with thickened pleura
- Sepsis from pleural source

Pneumothorax

- Air in pleural space
- Spontaneous
  - Primary or secondary
- Traumatic
- Iatrogenic (ventilator, central line)
- Tension



Pneumothorax

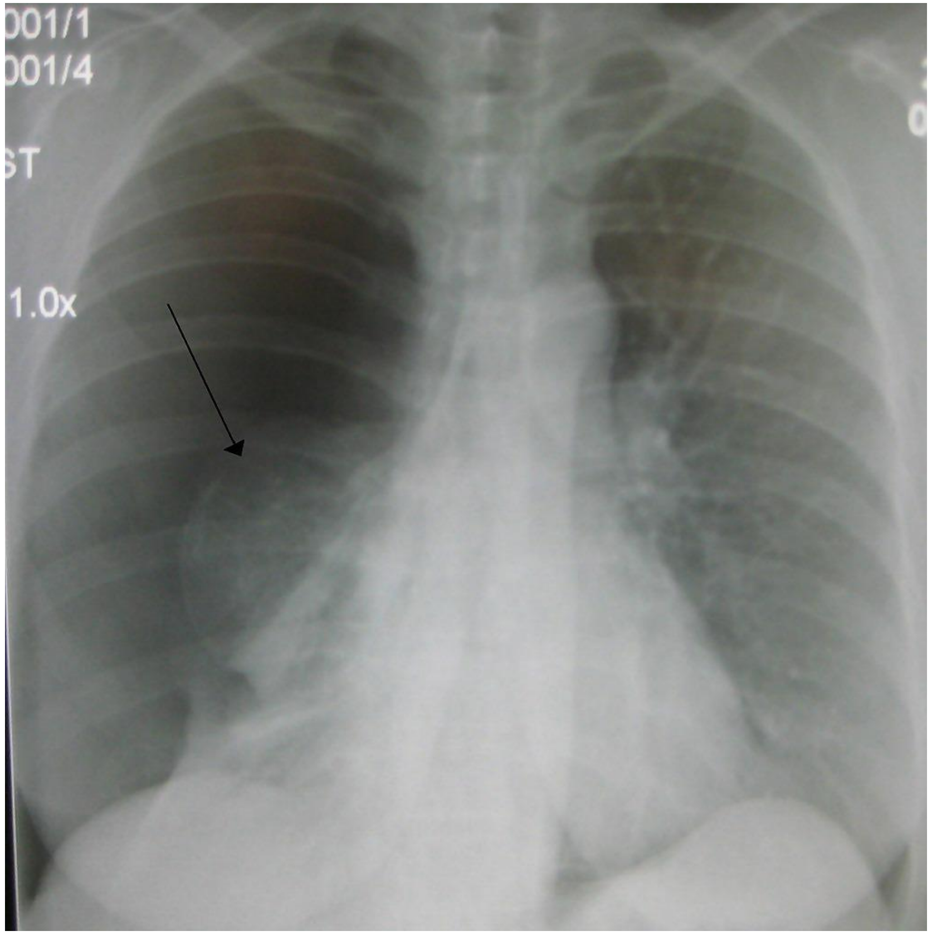
BruceBlaus/Wikipedia

Spontaneous PTX

- **Primary**
  - Rupture of subpleural bleb
  - Common in tall, thin young males
  - High recurrence rate (50% in 2 years)
- **Secondary**
  - Older patients with underlying pulmonary disease
  - COPD
  - Dangerous due to lack of reserve lung function

Spontaneous PTX

- **Sudden onset dyspnea**
- Sometimes pleuritic chest pain
- Decreased breath sounds
- Hyperresonance to percussion
- CXR for diagnosis



Pneumothorax

Treatment

- **100% Oxygen**
  - Displaces nitrogen from capillary blood
  - ↑ gradient for nitrogen reabsorption from pleural space
- **Chest tube**
  - Larger pneumothoraces (> 15% lung volume)

Public Domain

Tension Pneumothorax

- Usually from trauma
- Air enters pleural space but cannot leave
- Medical emergency
  - Decreased venous return
  - Decreased cardiac output
- Trachea deviates AWAY from affected side
- Distended neck veins

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Tension Pneumothorax

Treatment

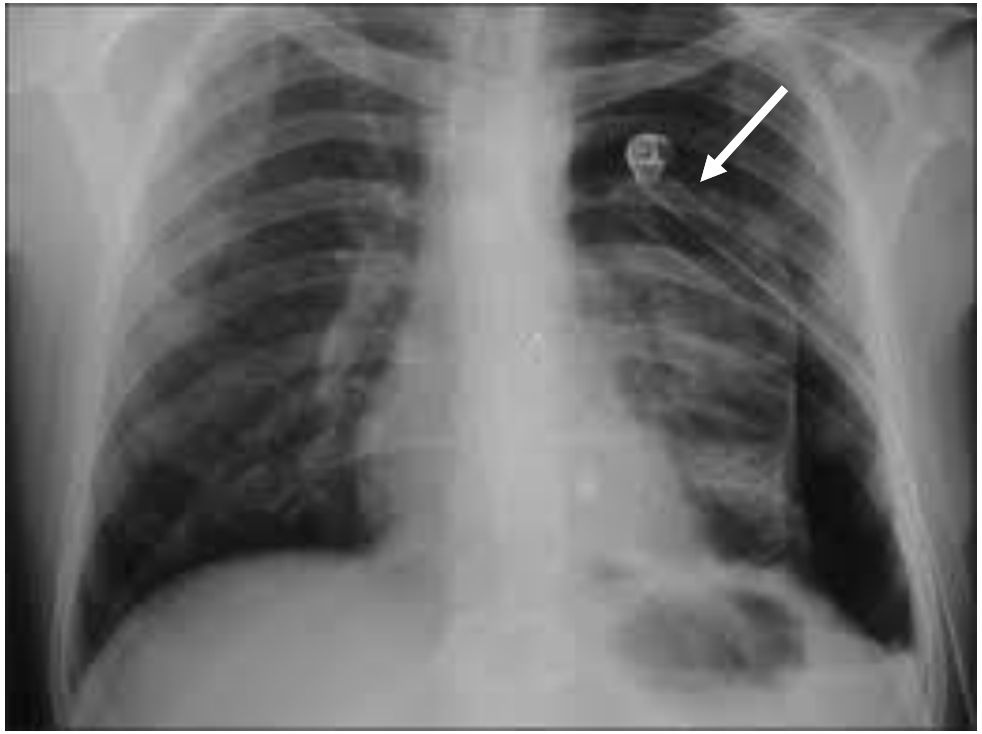
- Emergent thoracentesis/chest tube placement
- **Do not delay treatment for chest X-ray**

KOMUNews/Flikr

Chest Tube

- Tube or catheter placed through chest wall into pleural cavity
- Used to drain air or fluid
- Indications:
  - Pneumothorax
  - Hemothorax
  - Pleural effusion

Left-Sided Chest Tube



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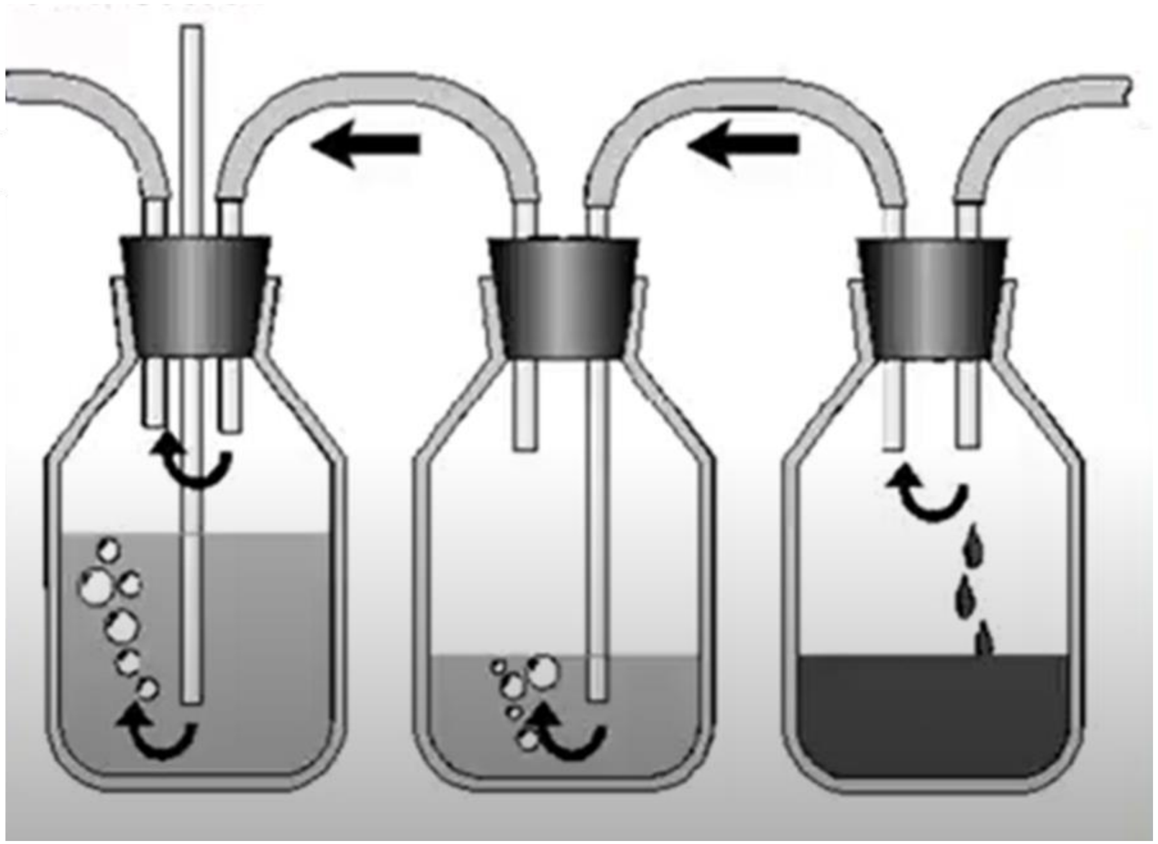
Chest Drain

- Drain attached to the vacuum regulator on wall
- Suction pressure controlled by water level
- Prevents over-suction which could damage lung

Chest Drain

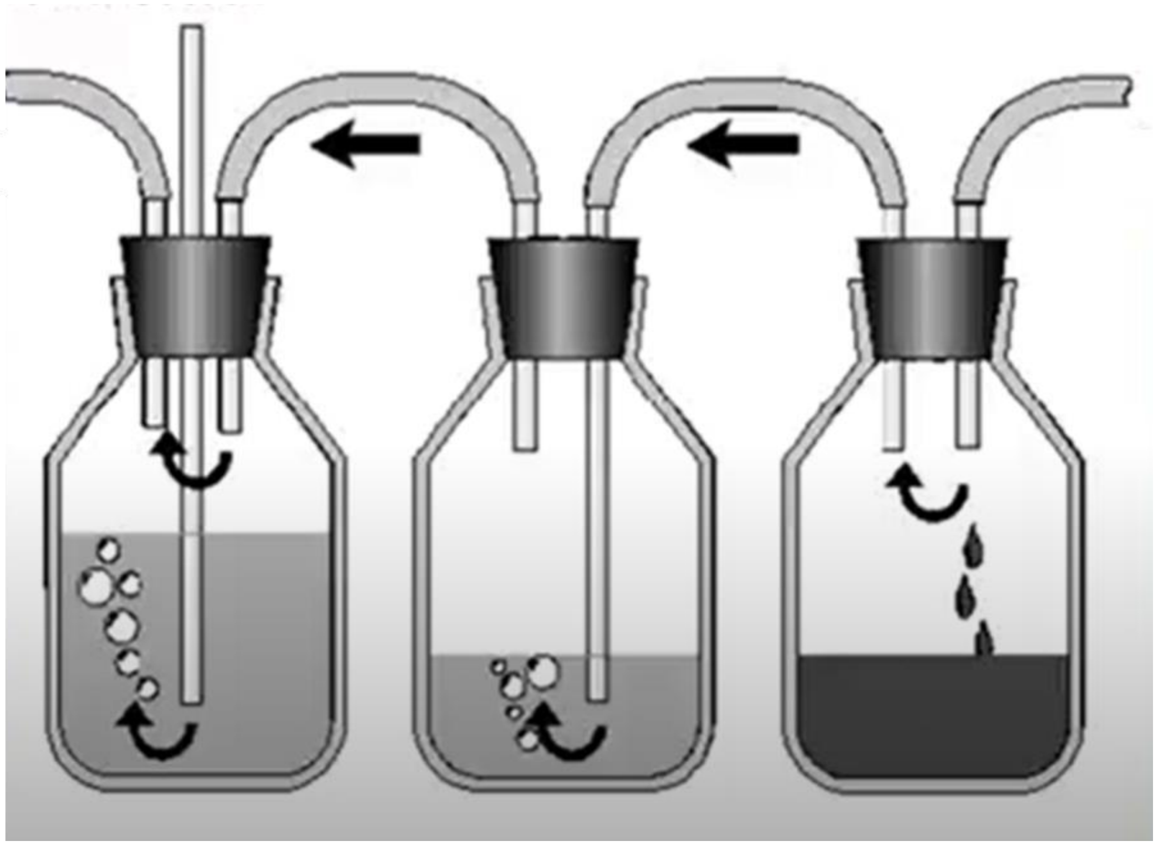
- Three chamber system
- First chamber: collects fluid
- Second chamber: **water seal**
  - Prevents air from going backward
  - Backward flow can occur during breathing
  - Allows air out but not in to patient
  - Up and down with breathing ("tidaling")
  - Bubbles indicate air leak



Suction Control Water Seal Drain

Chest Drain

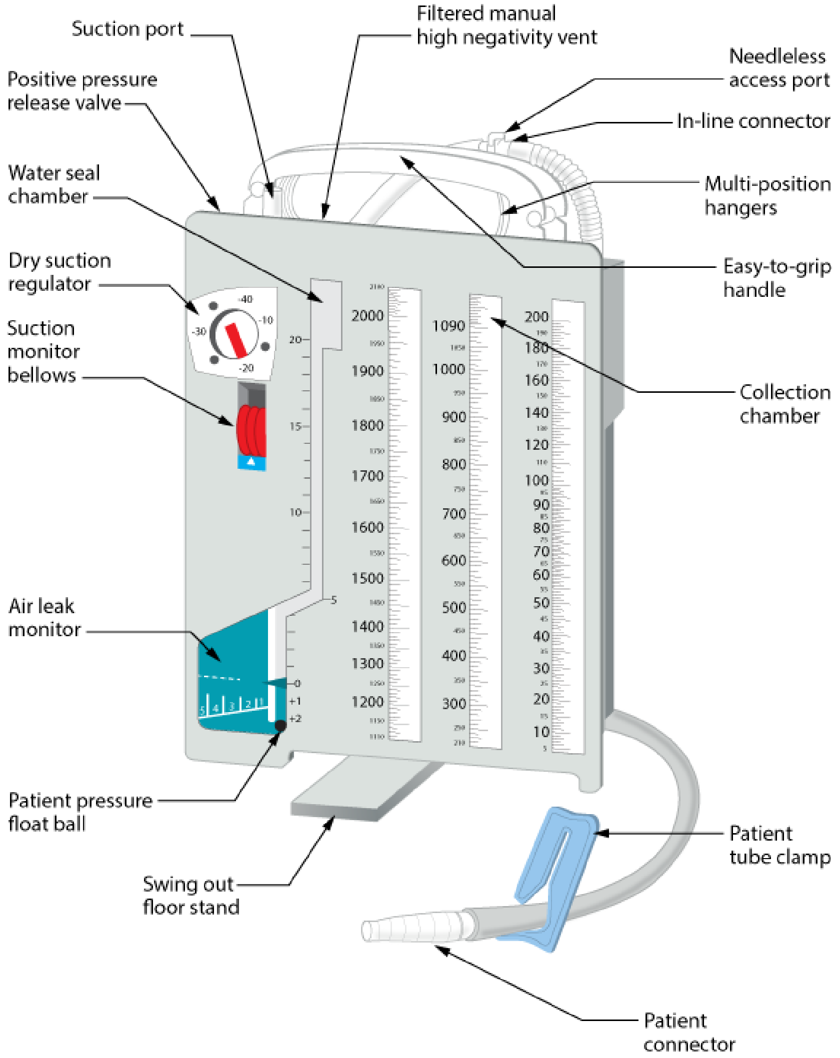
- Third chamber: **suction control**
  - Regulates amount of suction
  - Determined by water level
  - Excess wall suction only causes more bubbles
  - Normal to see bubbling



Suction Control Water Seal Drain

Chest Drain

- Drain attached to the vacuum regulator on wall
- Suction pressure controlled by water level
- Prevents over-suction which could damage lung
- Attach to "water seal"
  - Turn off suction

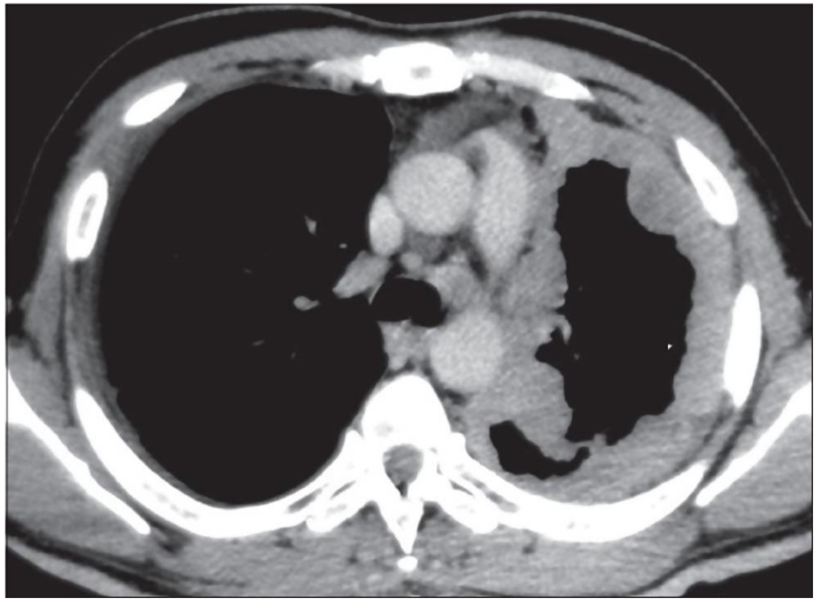


Pleurodesis

- Obliteration of pleural space
- Treatment for recurrent pleural effusion or recurrent pneumothorax
- Pleurodesis agent injected to pleural space
    - Talc
    - Tetracycline
    - Silver nitrate
    - Many others

Mesothelioma

- **Pleural tumor**
- **Asbestos** is only known risk factor
  - Decades after exposure
- Imaging: pleural thickening/pleural effusion
- Slow onset symptoms
  - Dyspnea, cough, chest pain
- Poor prognosis
  - Median survival 4 to 13 months untreated
  - 6 to 18 months treated with chemo



Radiological review of pleural tumors
Sureka Binit, Thukral Brij Bhushan, Mittal Mahesh Kumar, Mittal Aliza, Sinha Mukul
Inidan Journal Radiology and Imaging
Year : 2013 | Volume: 23 | Issue Number: 4 | Page: 313-320

Cystic Fibrosis

Jason Ryan, MD, MPH

Boards & Beyond
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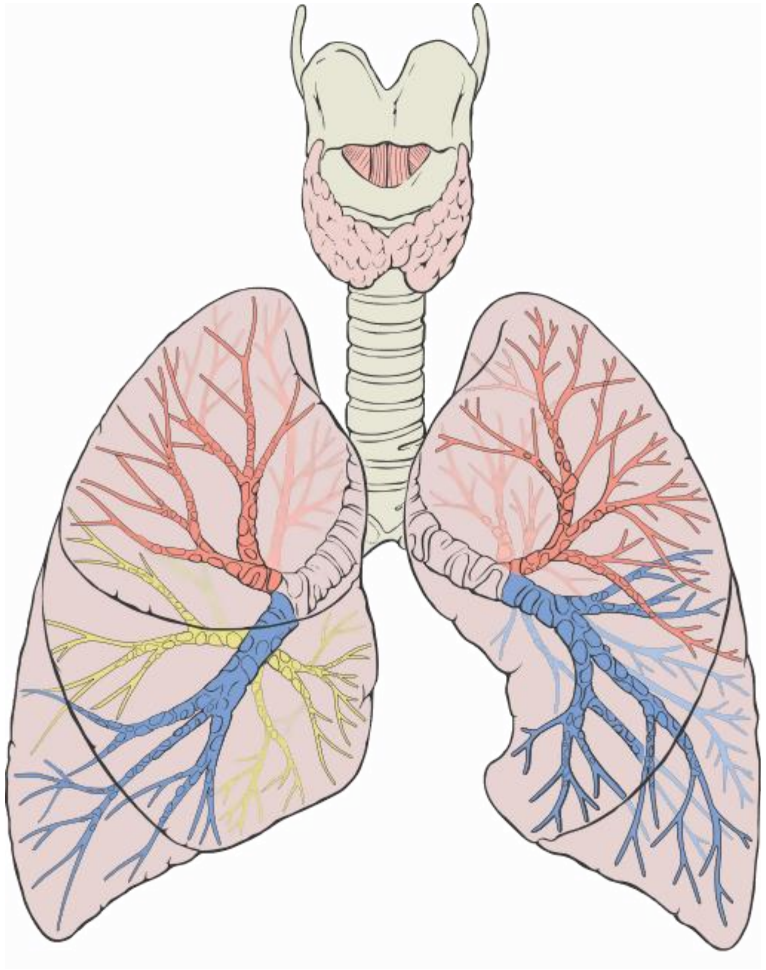
Cystic Fibrosis

- Genetic disorder
    - Autosomal recessive pattern
    - Both parents must be carriers
- Results in thick, sticky mucus in **lungs/GI tract**
- Common cause of **chronic lung disease** in children

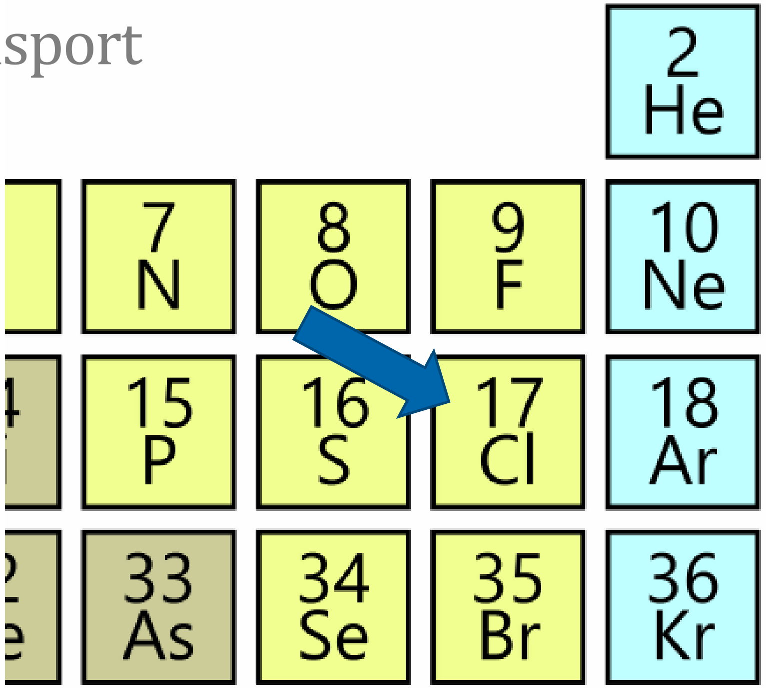


Patrick Lynch/Wikipedia

CFTR

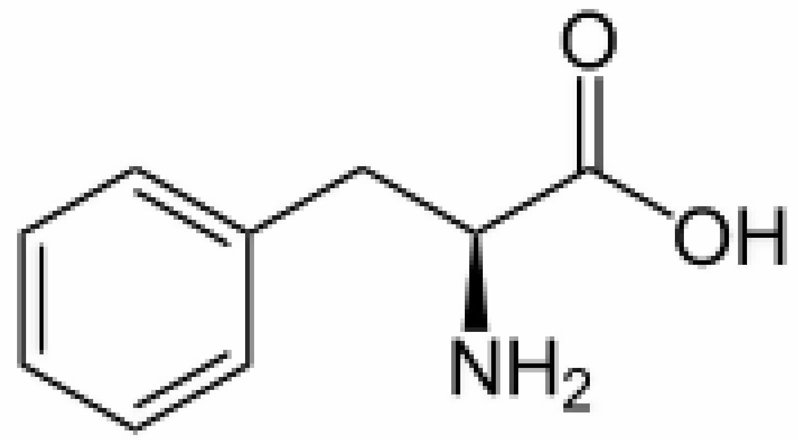
Cystic Fibrosis Transmembrane Regulator

- CFTR gene mutations → abnormal CFTR protein
- CFTR protein: chloride ion channel
- Mutation → impaired chloride-sodium-water transport
  - Thick, viscous secretions
  - Impaired mucociliary clearance in lungs
  - Impaired pancreatic secretions
  - Abnormal sweat



CFTR Mutations

- Many mutations identified
- Most common mutation: **delta F508**
  - Deletion of 3 DNA bases
  - Codes for 508th amino acid: phenylalanine



Phenylalanine

CF Pathophysiology

- Thick mucus in **lungs**
  - Recurrent pulmonary infections (Pseudomonas)
  - Chronic bronchitis
  - Bronchiectasis
- Thick mucus in **GI tract**
  - Impaired flow of bile and pancreatic secretions
  - Malabsorption especially fats
  - Loss of fat-soluble vitamins (A, D, E, K)
  - Steatorrhea

CF Presentation

- Usually diagnosed < 2 yo
- Respiratory disease (45%)
- Failure to thrive (28%)
- Meconium ileus (20%)

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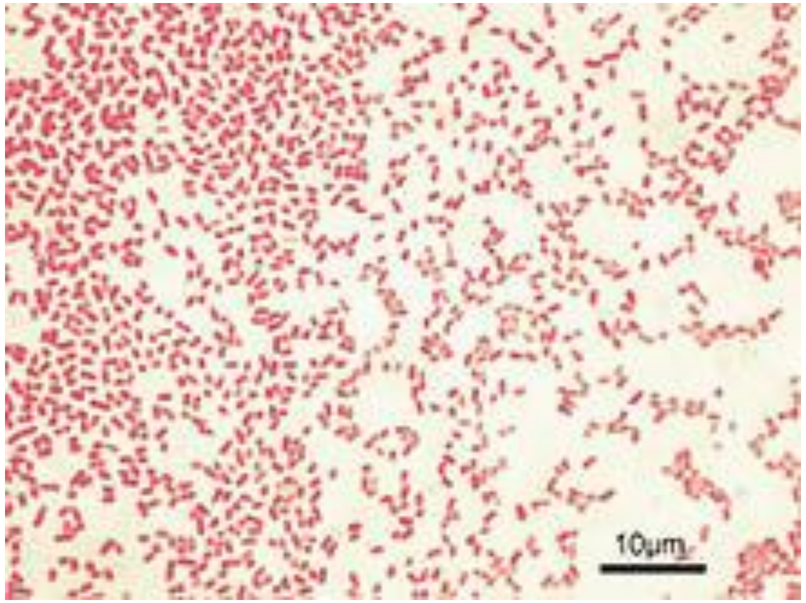
CF Respiratory Disease

- Productive cough
- Hyperinflation of lungs on CXR
- Obstructive disease pattern
- Later disease
  - Chronic bronchitis
  - Bronchiectasis

CF Respiratory Disease

- Productive cough
- Hyperinflation of lungs on CXR
- Obstructive disease pattern
- Later disease
  - Chronic bronchitis
  - Bronchiectasis
- **Acute exacerbations**
- Key pathogens:
  - **Pseudomonas aeruginosa**
  - **Staphylococcus aureus (including MRSA)**

Pseudomonas
Gram-negative rod



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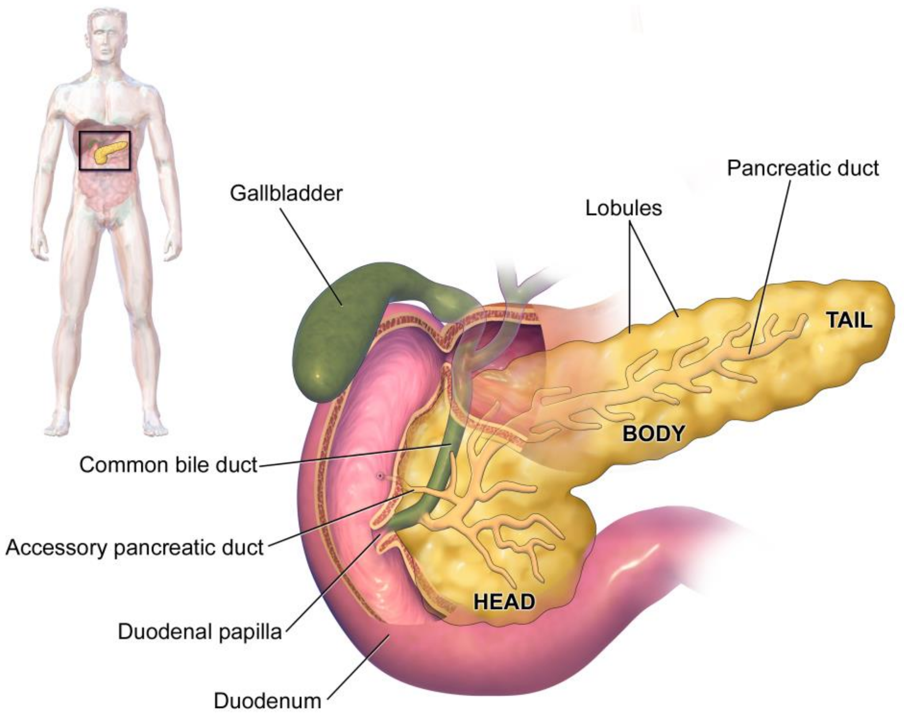
Pancreatic insufficiency

- Chronic pancreatitis
- CF-related diabetes
- Fat malabsorption
- Steatorrhea:
    - Frequent stools
    - Foul-smelling stools
    - Oily or greasy
    - Stools may float



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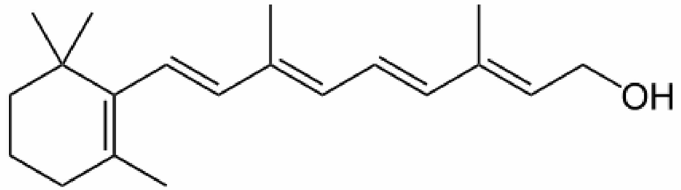
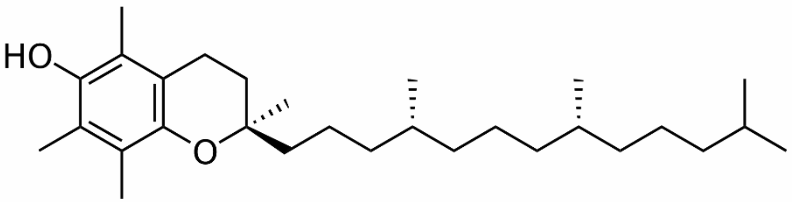
Pancreatic insufficiency

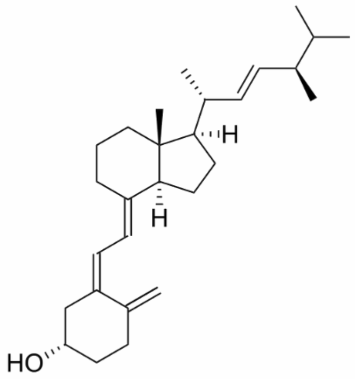
- Deficiencies of fat-soluble vitamins: A, D, E, and K
- Vitamin K: coagulopathy
- Vitamin D: rickets
- Vitamin A: night blindness
- Vitamin E: ataxia, hemolysis



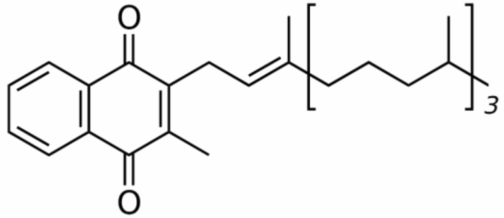
Vitamin A



Vitamin E



Vitamin D



Vitamin K

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Meconium ileus

- Meconium
  - Meconium: first stool of newborn
  - Very thick and sticky
- Meconium ileus = bowel obstruction
  - Meconium too thick/sticky
  - Meconium plug forms
- Abdominal distension
- Vomiting
- Air fluid levels of X-ray
- Failure to pass meconium

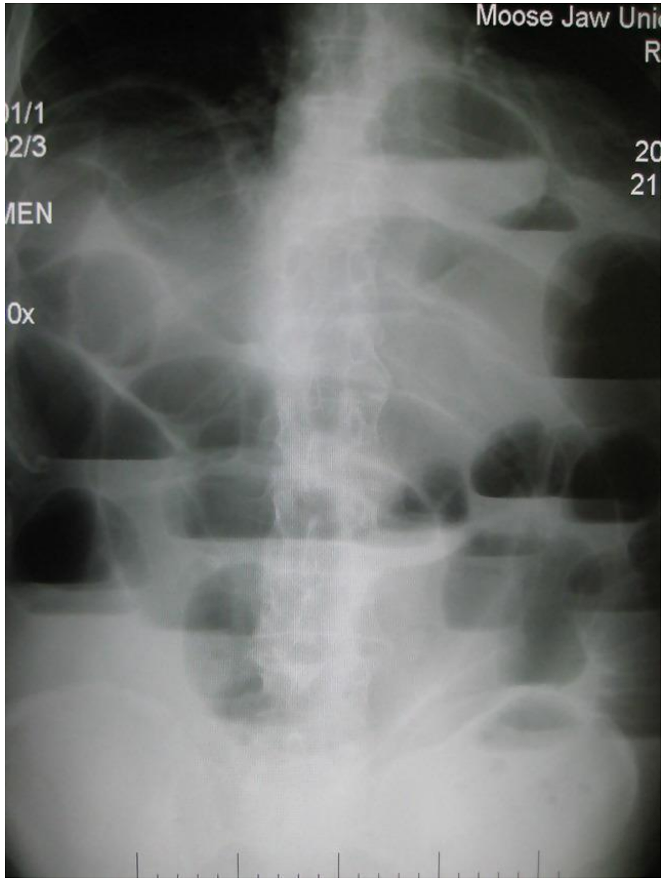

Image courtesy of James Heilman, MD

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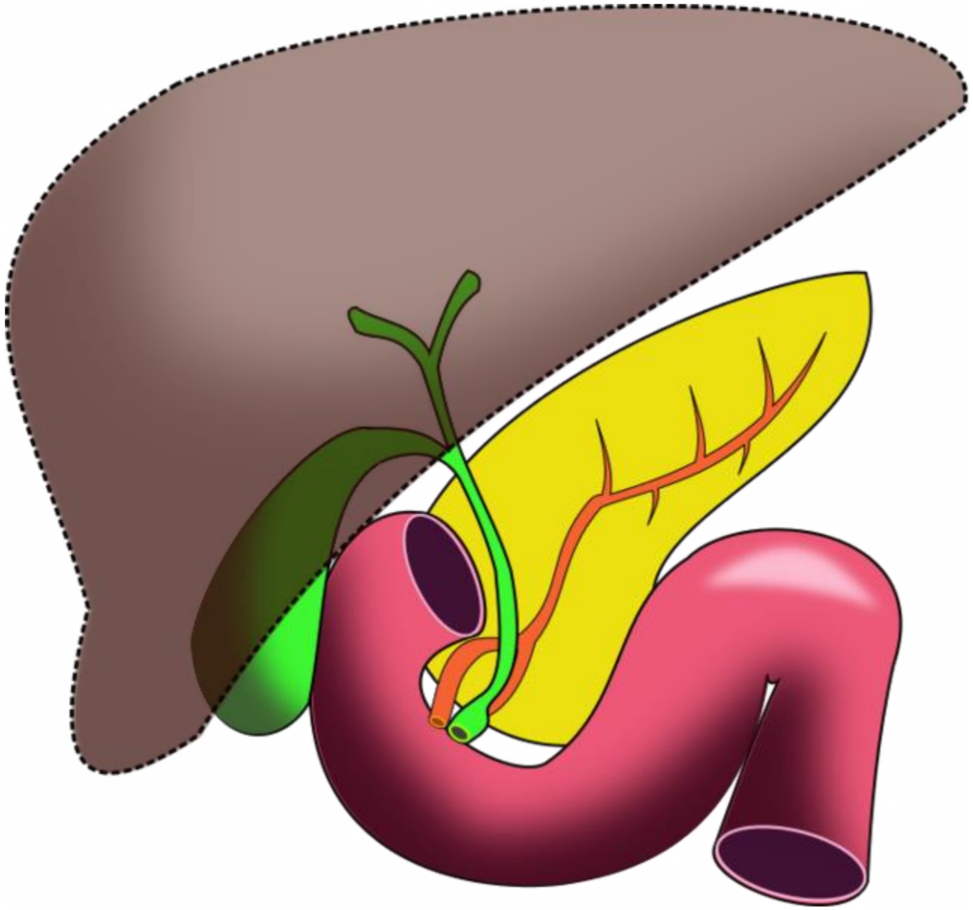
Other symptoms

- Biliary disease
  - Bile duct obstruction
  - Pale or clay colored stool
  - Elevation of LFTs
  - Hepatomegaly
  - Cirrhosis
  - Gallstones



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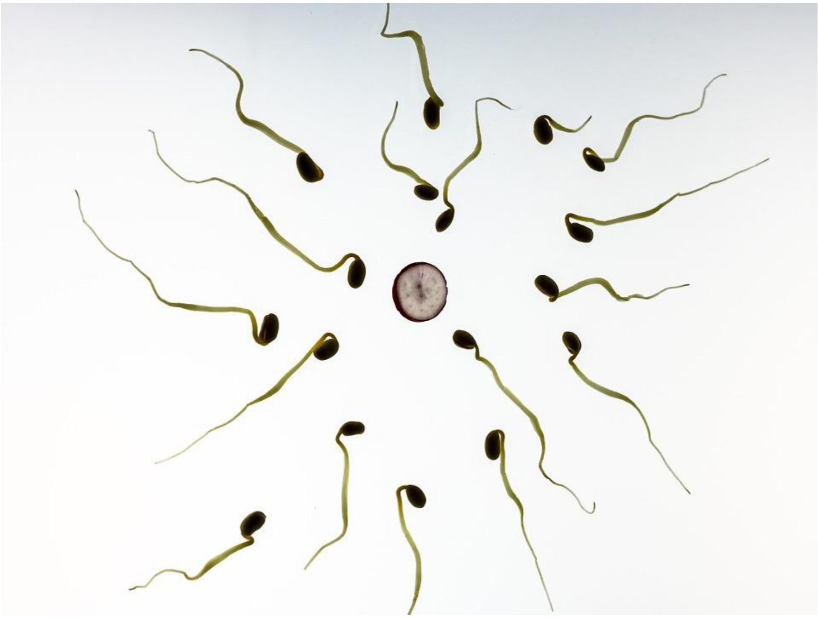
Other symptoms

- **Male infertility**
  - 95% of males with CF are infertile
  - Absent vas deferens
  - Can have children with assisted techniques
- Decreased female fertility
  - Abnormal cervical mucus



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Digital Clubbing

- **Occurs in cystic fibrosis**
- Other causes
  - Lung Cancer
  - IPF
  - Congenital Heart Disease

James Heilman, MD

Diagnosis

- **Sweat chloride test**
- Pilocarpine iontophoresis
  - Pilocarpine gauze placed on skin
  - Electrode placed over gauze
  - Small electrical current drives pilocarpine into skin
  - Sweating occurs
  - Sweat collected on filter paper
  - Chloride content analyzed
- High chloride level suggests CF
- DNA testing done if sweat test abnormal

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Diagnosis

- Rare CF patients have negative sweat test
  - Usually have milder disease
  - Often recurrent pulmonary and sinus infections
- **Nasal transepithelial potential difference**
  - Done if symptoms highly suggestive
  - Measure nasal voltage
  - CF patients: more negative voltage
  - Due to abnormal sodium processing

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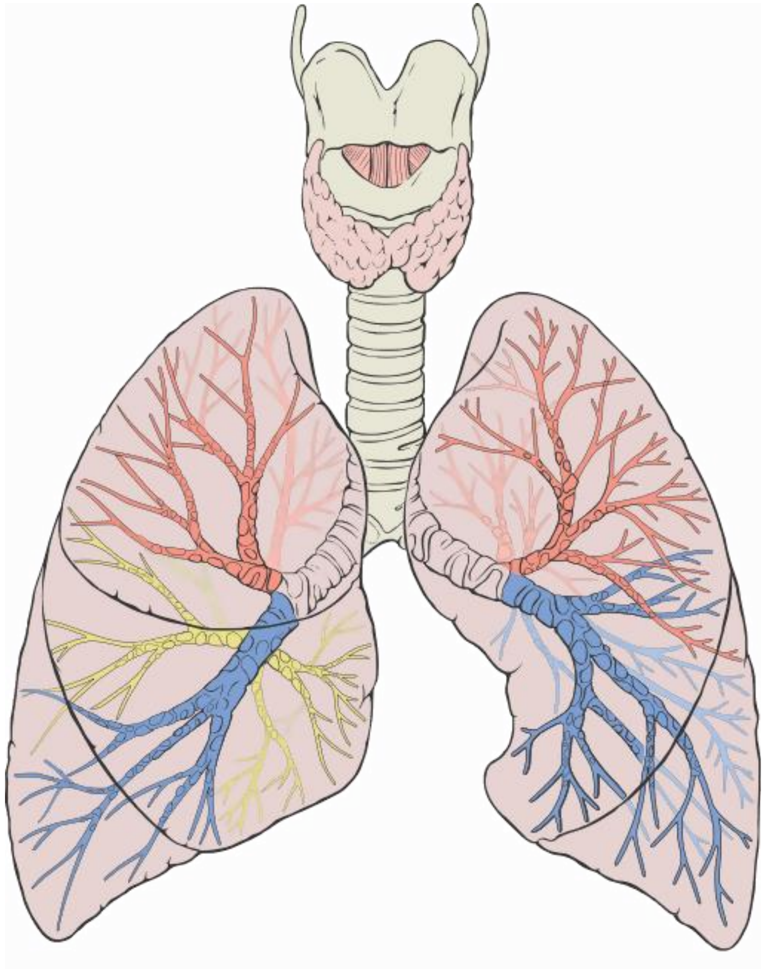
Treatment

- Promote clearance of airway secretions
  - Inhaled DNase (dornase alfa)
  - Inhaled saline
  - Chest physiotherapy
- Ivacaftor (CFTR modulator)
  - Modify chloride ion flux
  - Only for patients with specific mutations
- Exacerbations are treated with antibiotics
- Lung transplantation



Patrick Lynch/Wikipedia

Other Treatments

- Pancreatic enzyme replacement
- Vitamins (A, D, E, K)
- Vaccinations

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Screening

- Prenatal
  - Test for 23 most common CF mutations in US
  - Often test mother first and stop if negative
- Newborn
  - ↑ blood levels immunoreactive trypsinogen (IRT)
  - Blood test → if positive → sweat test

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