

Pulmonary Function Tests

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Symptoms of Lung Disease

- Cough, productive or unproductive
- Increased sensitivity to odors and irritants
- Pleuritic chest pain
- Shortness of breath on exertion
- Wheezing and chest tightness

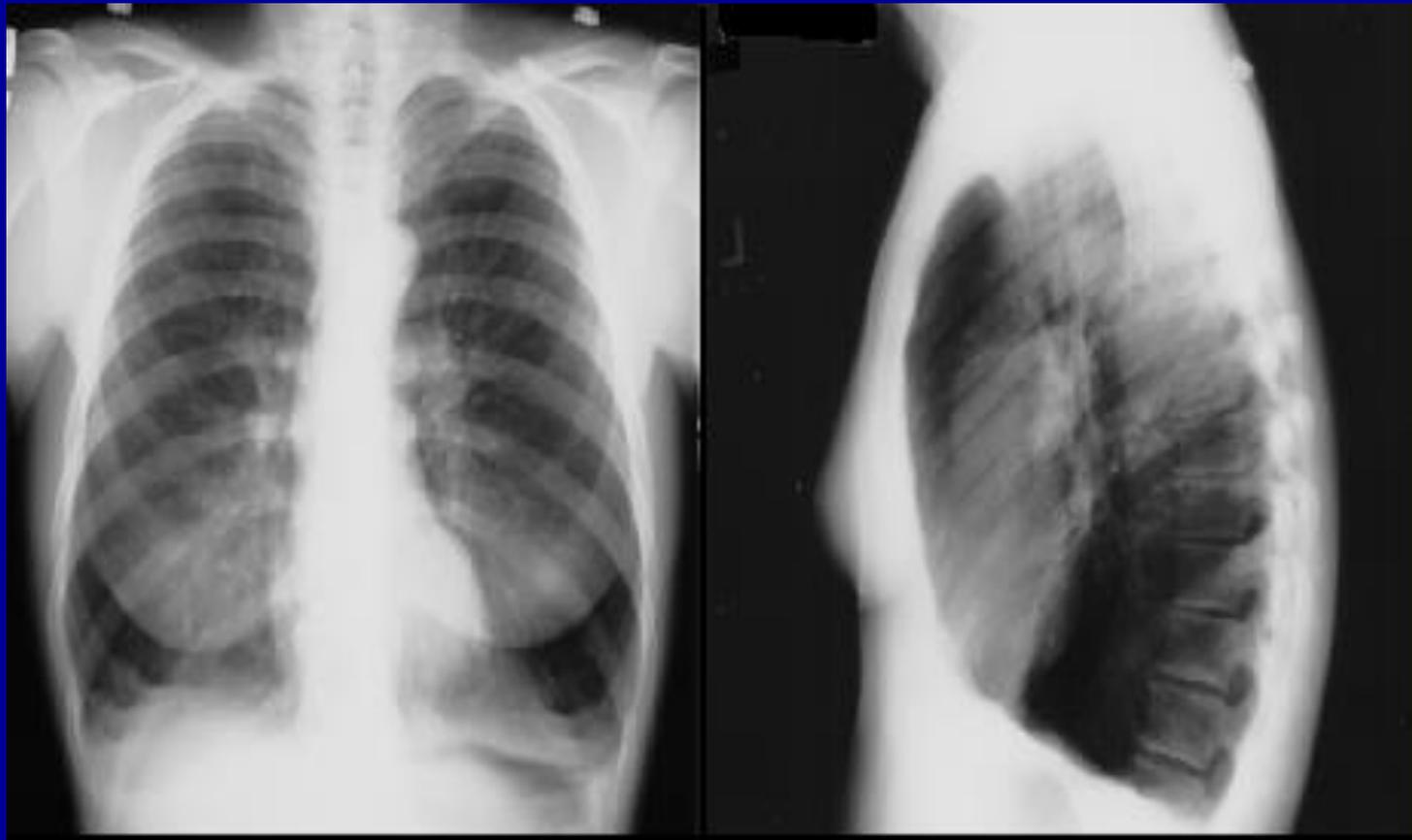
Assessing Lung Symptoms

- Physical examination
- Radiographic studies-CXR and Chest CT
- Pulmonary function studies-provide an objective assessment of lung function and help to determine whether dyspnea is caused by lung disease or other causes

CASE

- A 60 year old woman with a 50 pack year history of smoking presents with a two month history of shortness of breath on exertion. She has a morning cough productive of yellow sputum
- Physical examination: Chest has an increased AP diameter, lungs are hyper-resonant to percussion and breath sounds are diminished. Scattered expiratory wheezes are noted on auscultation

Chest X-ray



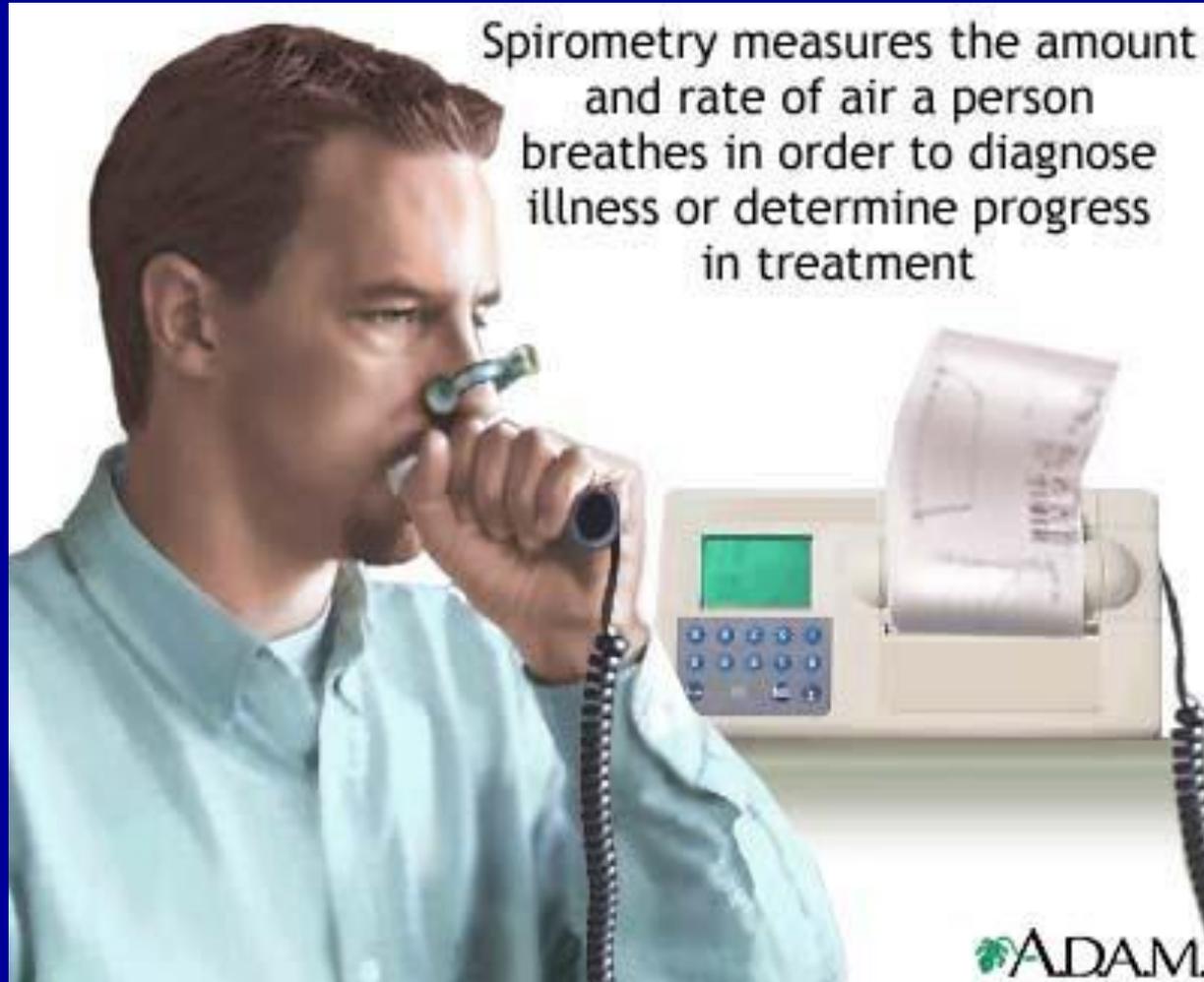
- Diagnosis: Emphysema
- How severe? What is the prognosis

- This is where PFT's are helpful

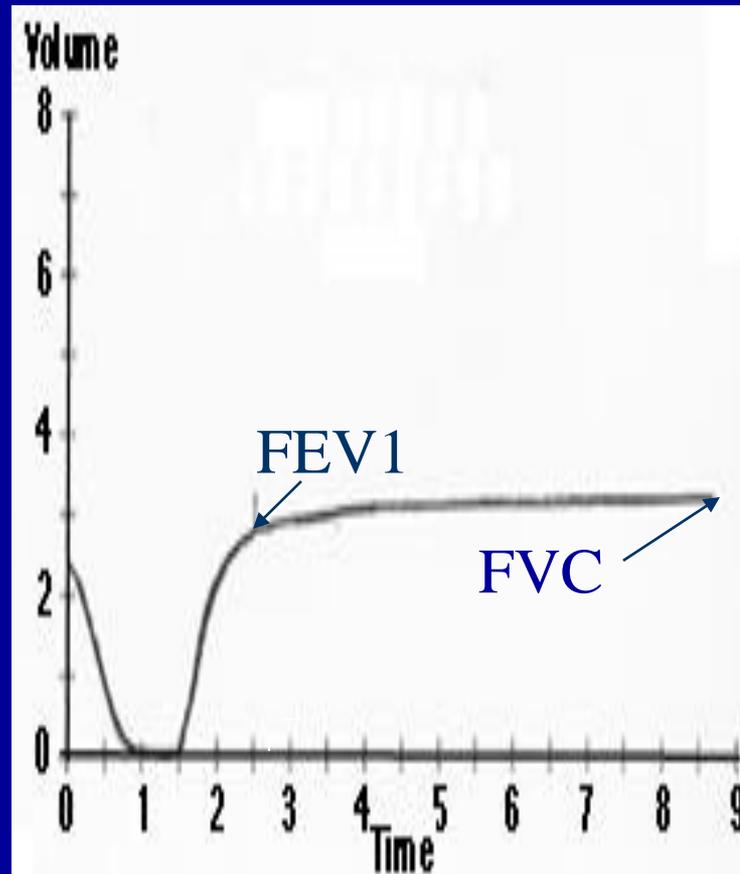
Types of Pulmonary Functions

- Spirometry
- Lung volumes
- Diffusing capacity
- Arterial blood gases
- Challenge tests (tests of airway reactivity)
- Exercise testing

Spirometry measures the amount and rate of air a person breathes in order to diagnose illness or determine progress in treatment



Spirometry



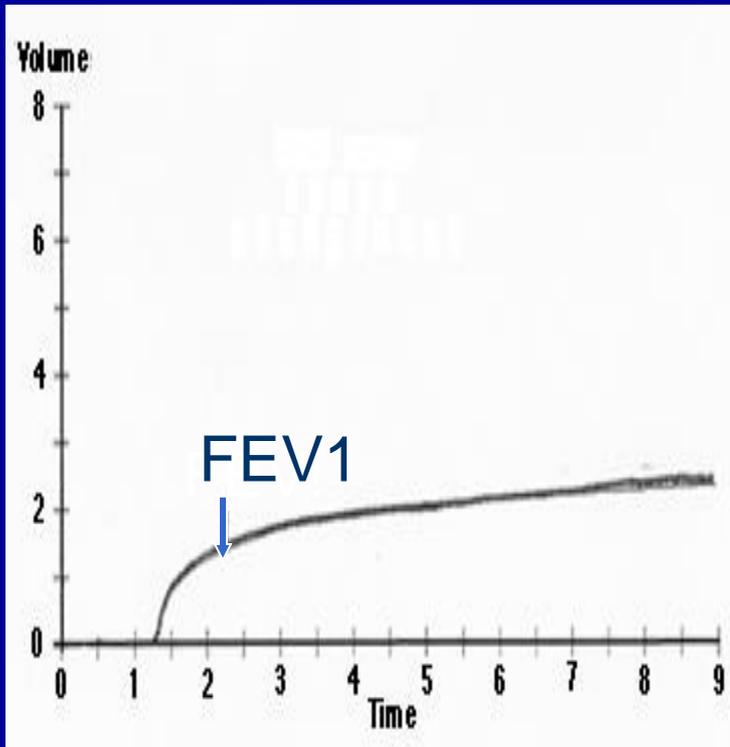
Spirometry

- FVC: Volume of air forcefully exhaled after deep inspiration
- FEV1: Volume exhaled in the first second
- FEV1/FVC ratio-defines obstruction
- PEF-peak rate of airflow in liters per minute during forced exhalation
- FEF 25-75: flow rate over the mid-portion of the exhalation curve

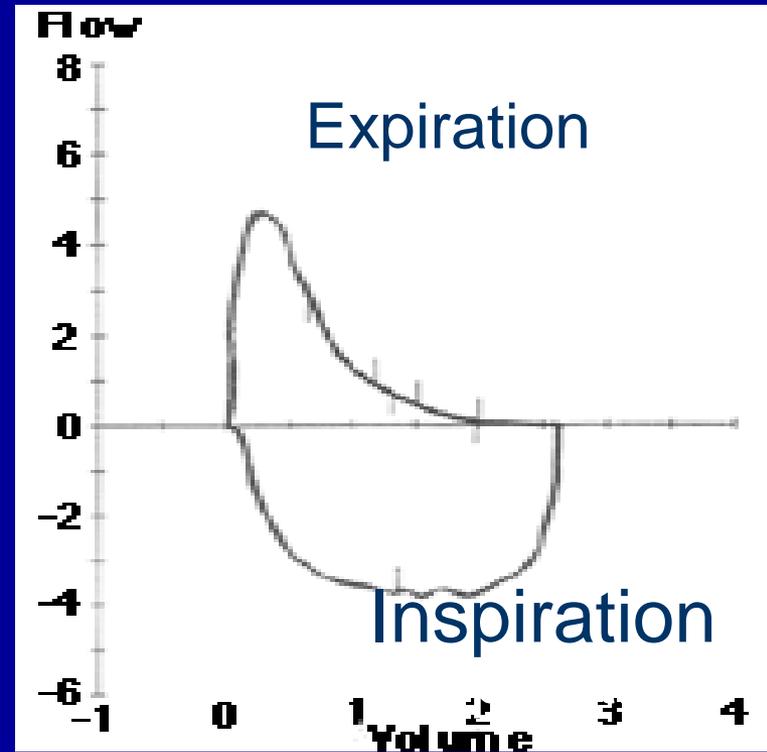
Interpreting Spirometry

- Normal (predicted) values have been defined for large populations and are based upon sex, age, height and race.
- Spirometric values are expressed as percent of predicted
- Generally $>80\%$ of predicted is normal, 60-79 is mildly reduced, 40-59% moderately reduced and $<40\%$ severe

Spirometry Curves



Volume/Time



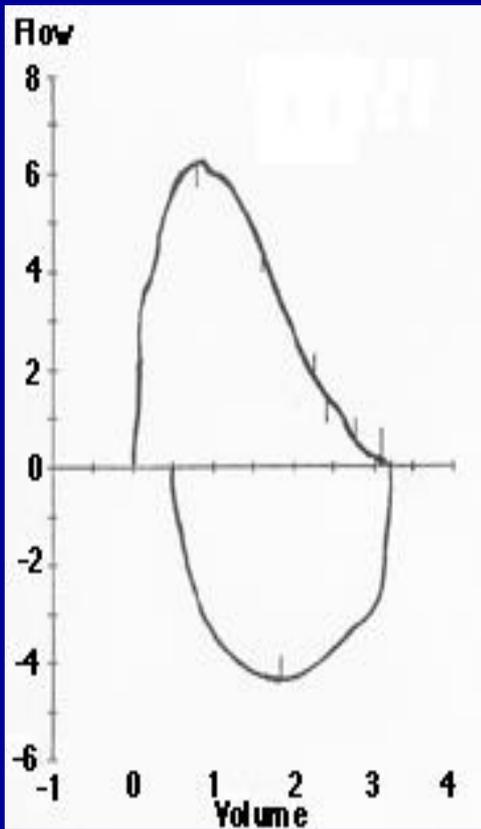
Flow/volume

Two General Patterns

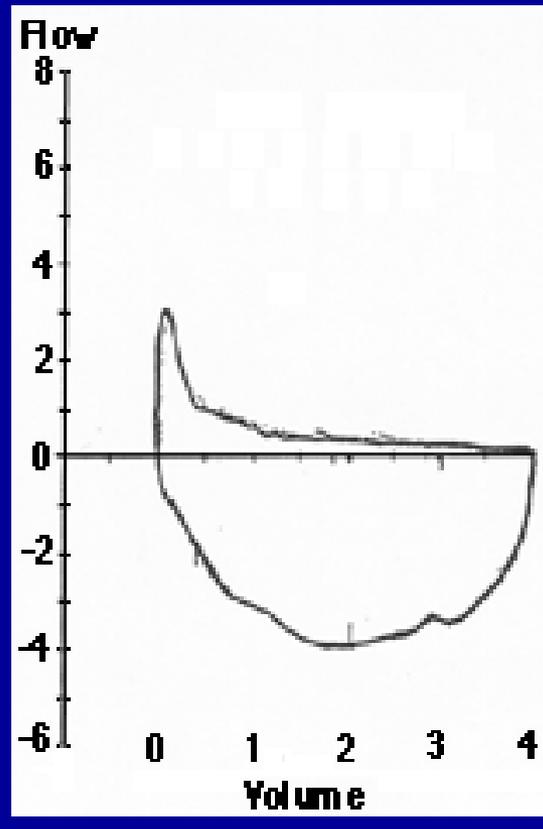
- Obstructive: Cannot get the air out because airways collapse on expiration, lungs are hyperinflated because gas is trapped
- Restrictive disease: Can't get the volume in because lungs are scarred or infiltrated or muscles are weak. Characterized by decreased lung volumes

Flow/Volume Loops

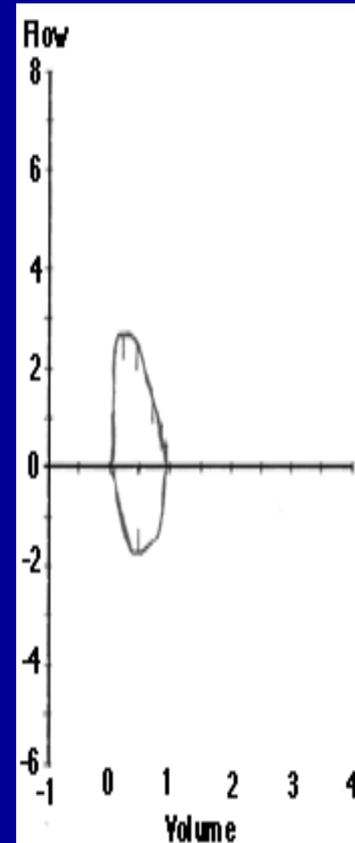
Normal



Obstructive



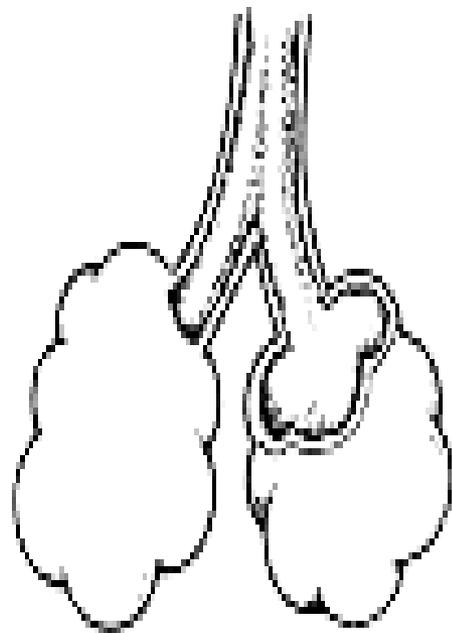
Restrictive



Obstructive Diseases

- Asthma-an airway disease characterized by reversible inflammation and bronchoconstriction
- Chronic bronchitis-chronic cough and sputum production usually in smokers
- Emphysema-an airway disease that leads to destruction of alveoli, gas trapping. May have component of bronchospasm but never completely reversible

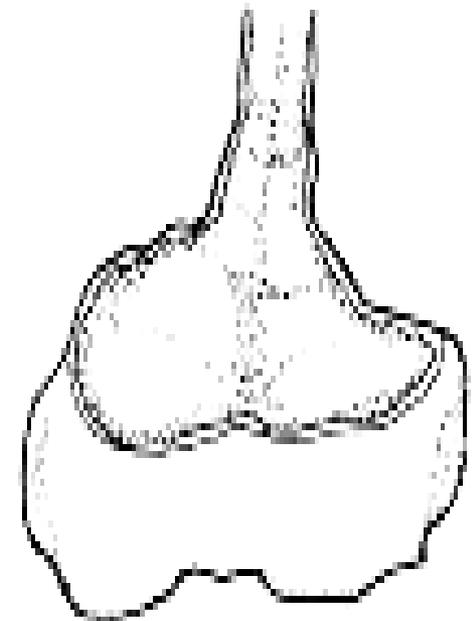
NORMAL



CHRONIC BRONCHITIS



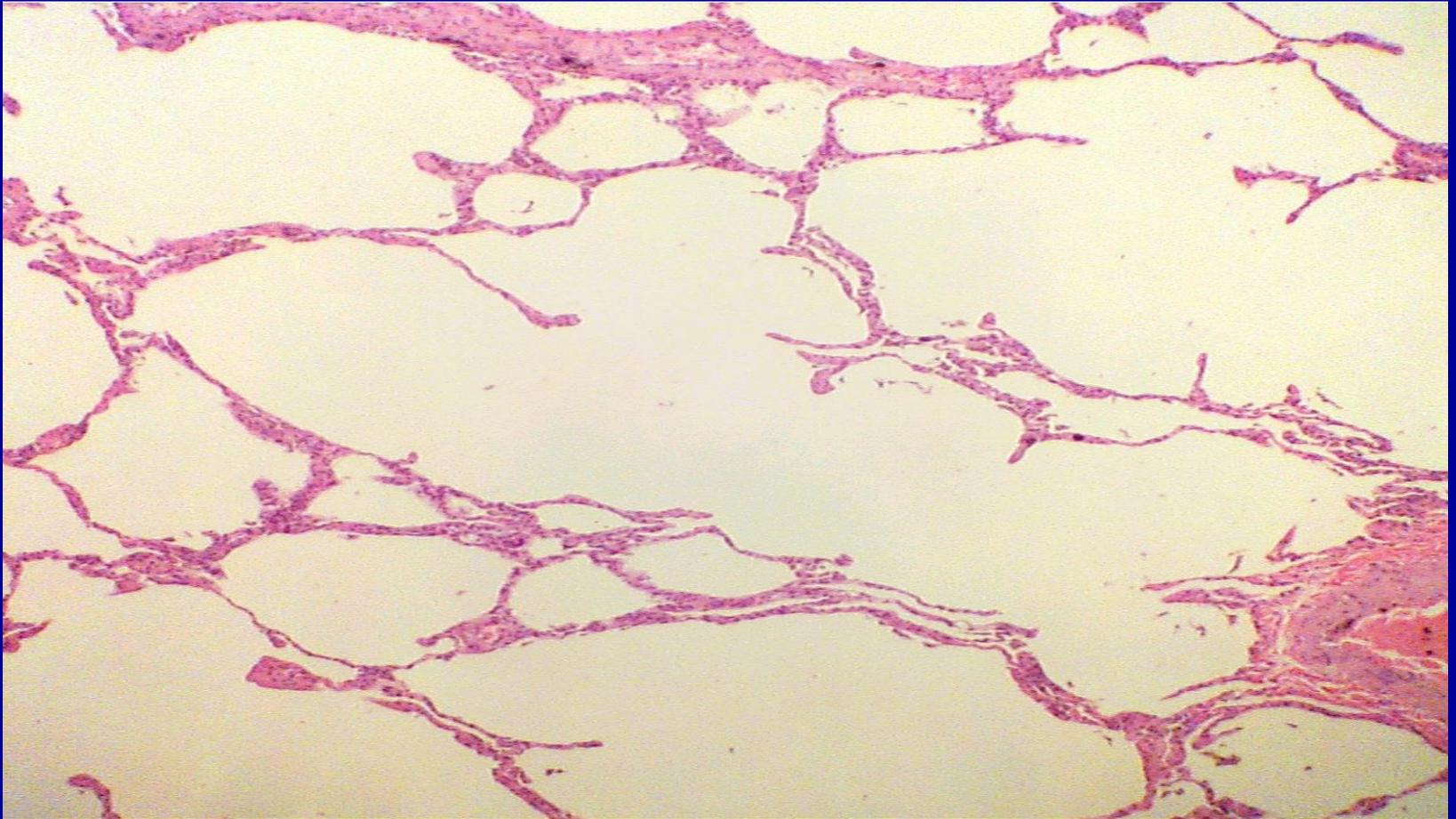
EMPHYSEMA



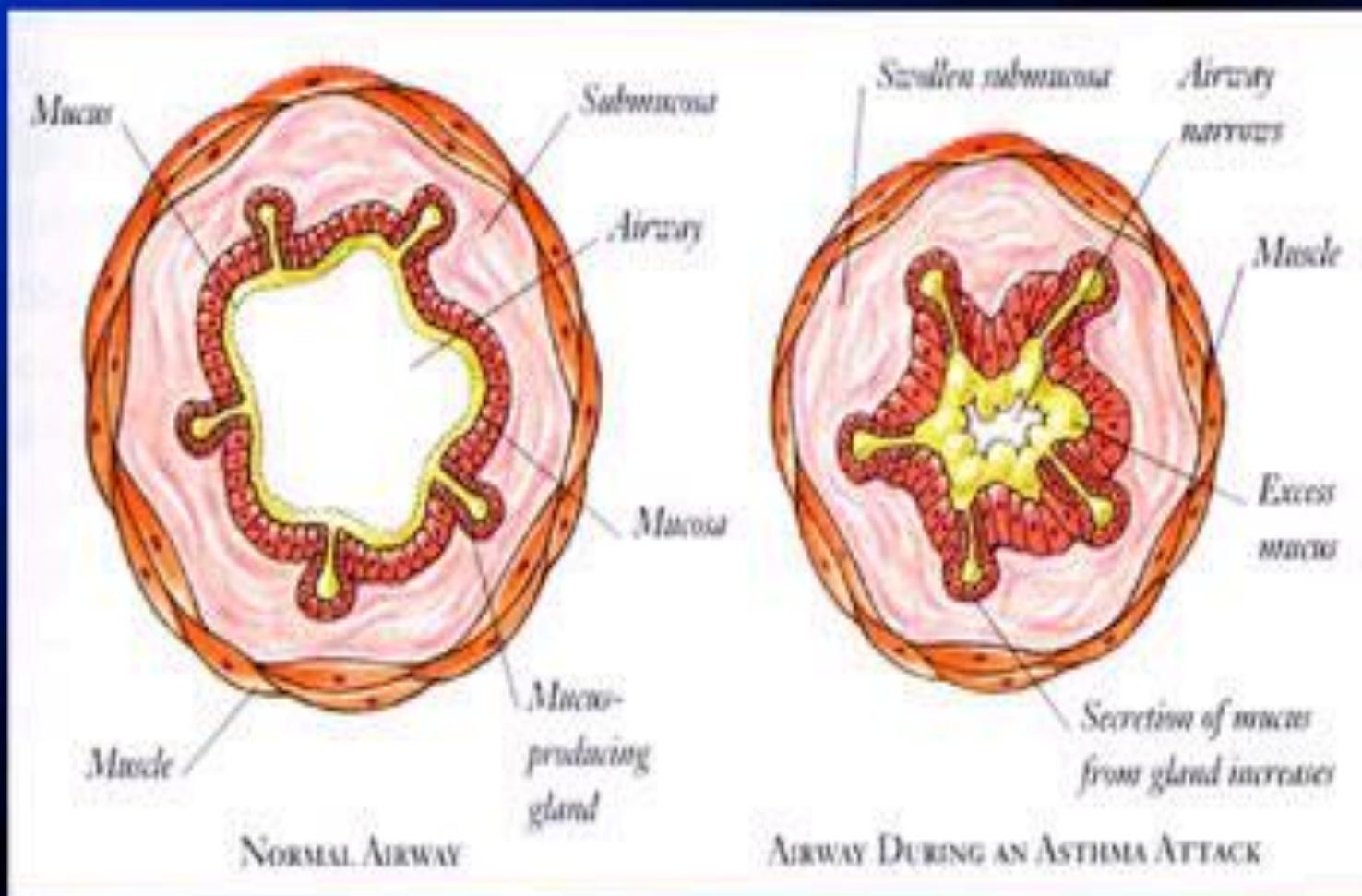
Spirometry in Obstructive Disease

- Normal or decreased FVC
- Reduced FEV₁/FVC ratio-less than 75% indicates obstruction
- The severity of obstruction is defined by the decrease in FEV₁.
- An FEV₁ of less than one liter is associated with disabling dyspnea
- We look for whether the obstruction is reversible by administering bronchodilator and repeating the test

Emphysematous Lung



Asthma: Pathological changes

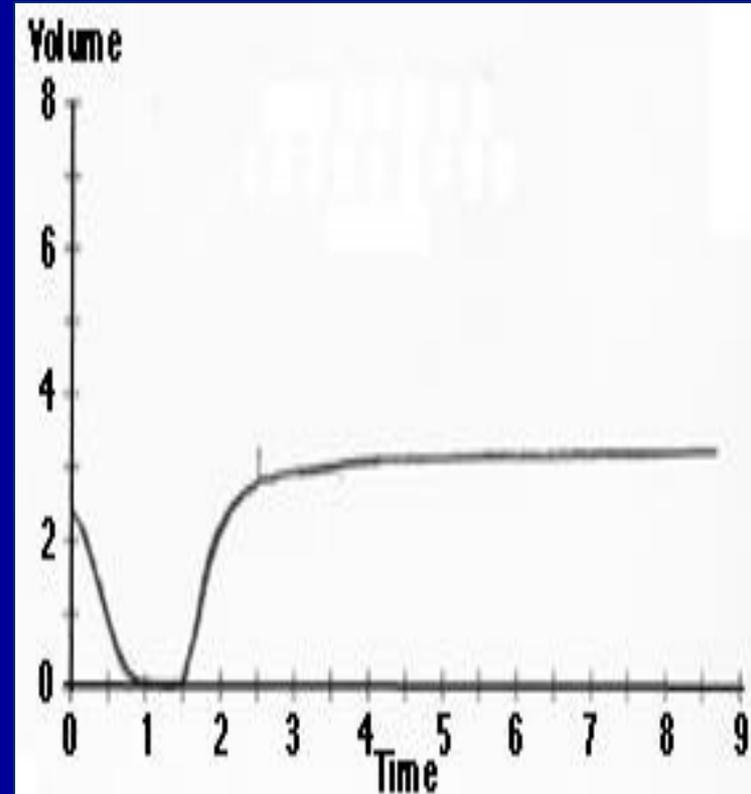
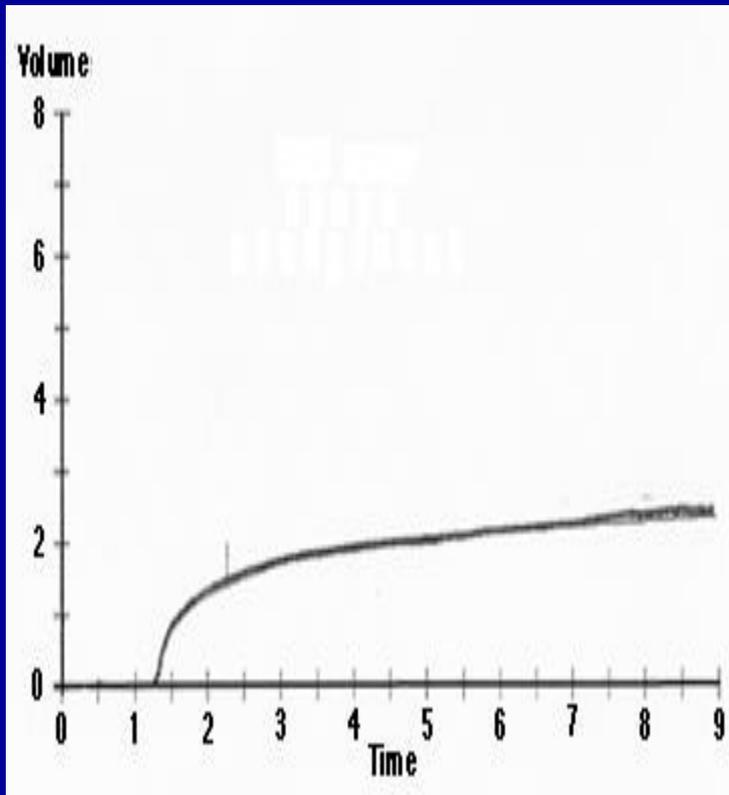


Asthma: Definition

- Reversible Airway Obstruction: Defined by decreased FEV1/FVC ratio and at least 12% improvement in FEV1 post bronchodilator

Spirometry

Pre-bronchodilator



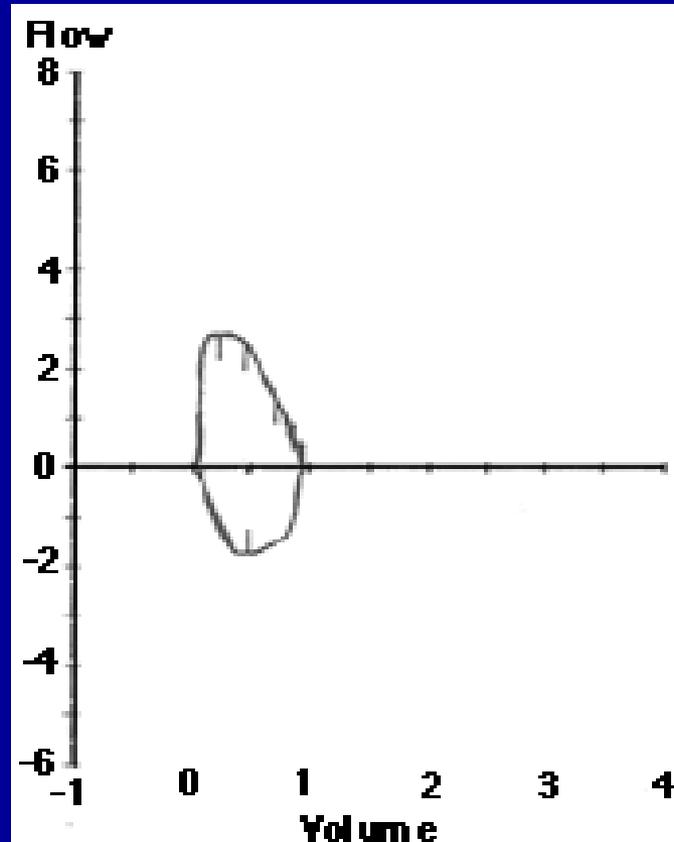
Asthma: More Advanced Definitions

- Cough variant (cough rather than wheeze): decreased FEF 25-75 with 20% improvement post bd
- RADS: Normal spirometry but increased airway reactivity defined by a challenge with methacholine or histamine
- Exercise asthma: occurs after exercise. May have normal function at rest

Airway Reactivity

- An objective measurement of increased sensitivity to odors and irritants
- Determined by serially measuring spirometry after gradually increasing inhaled doses of methacholine or histamine
- More sensitive than spirometry, may be abnormal during asymptomatic periods
- If you don't have increased airway reactivity, you don't have asthma

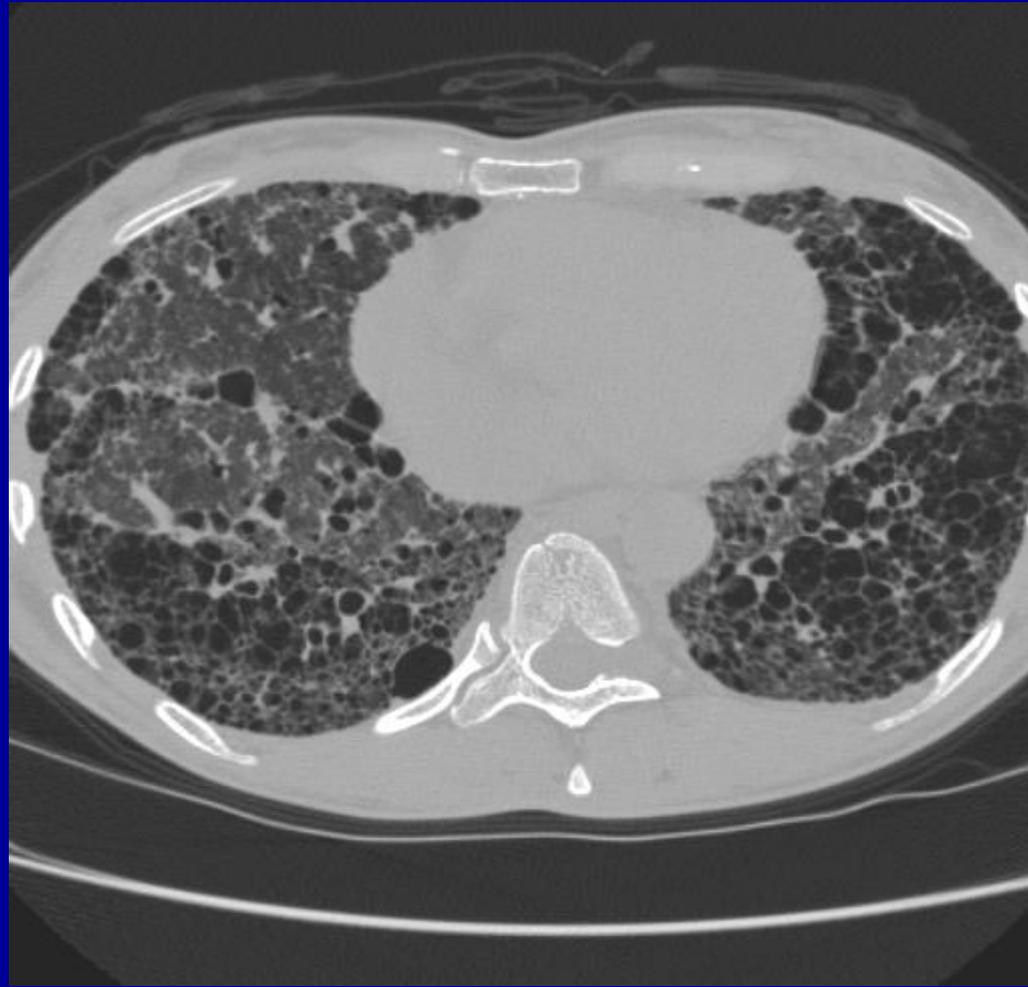
Restrictive Disease



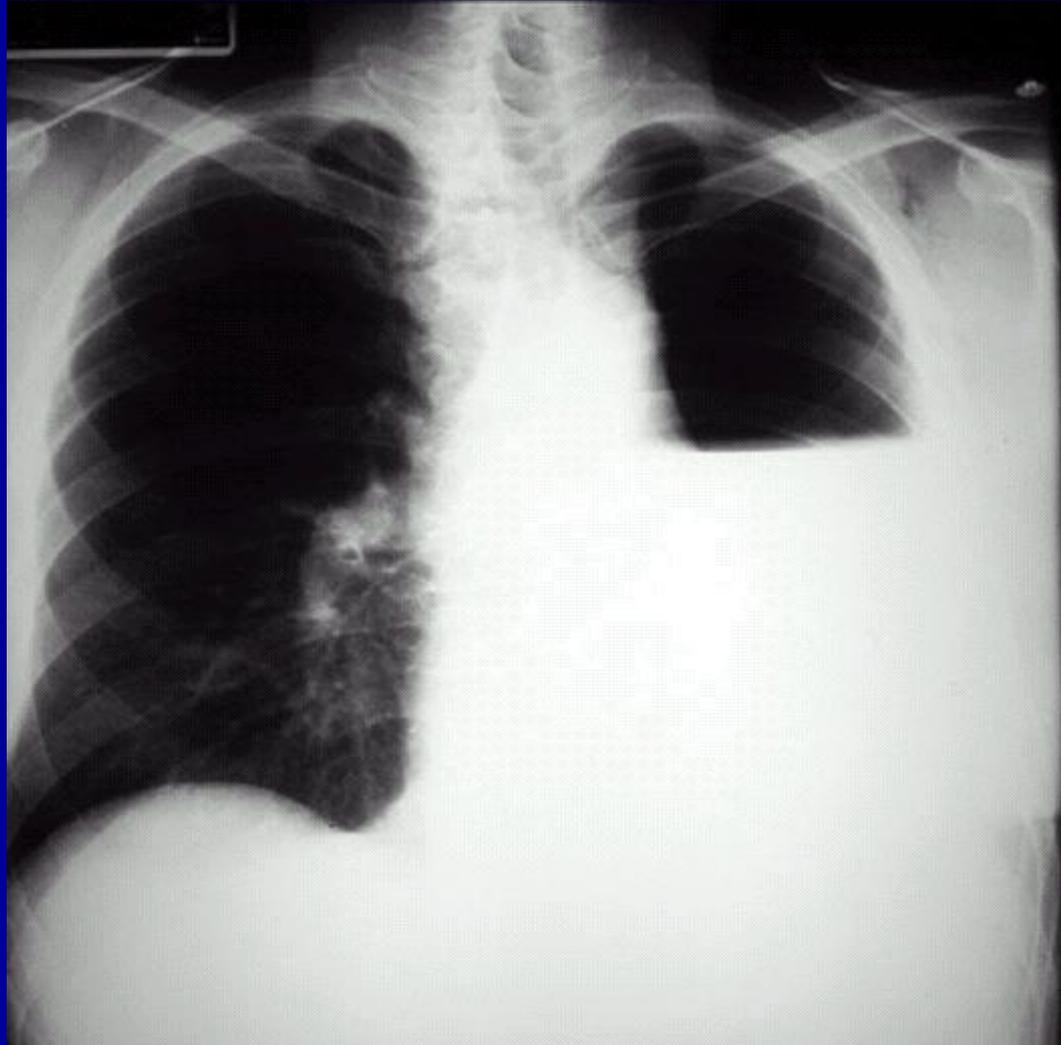
Restrictive Diseases

- Interstitial lung disease: pulmonary fibrosis, pulmonary edema, interstitial pneumonias
- Neuromuscular weakness: myasthenia gravis, ALS, diaphragm paralysis

Interstitial Lung Disease



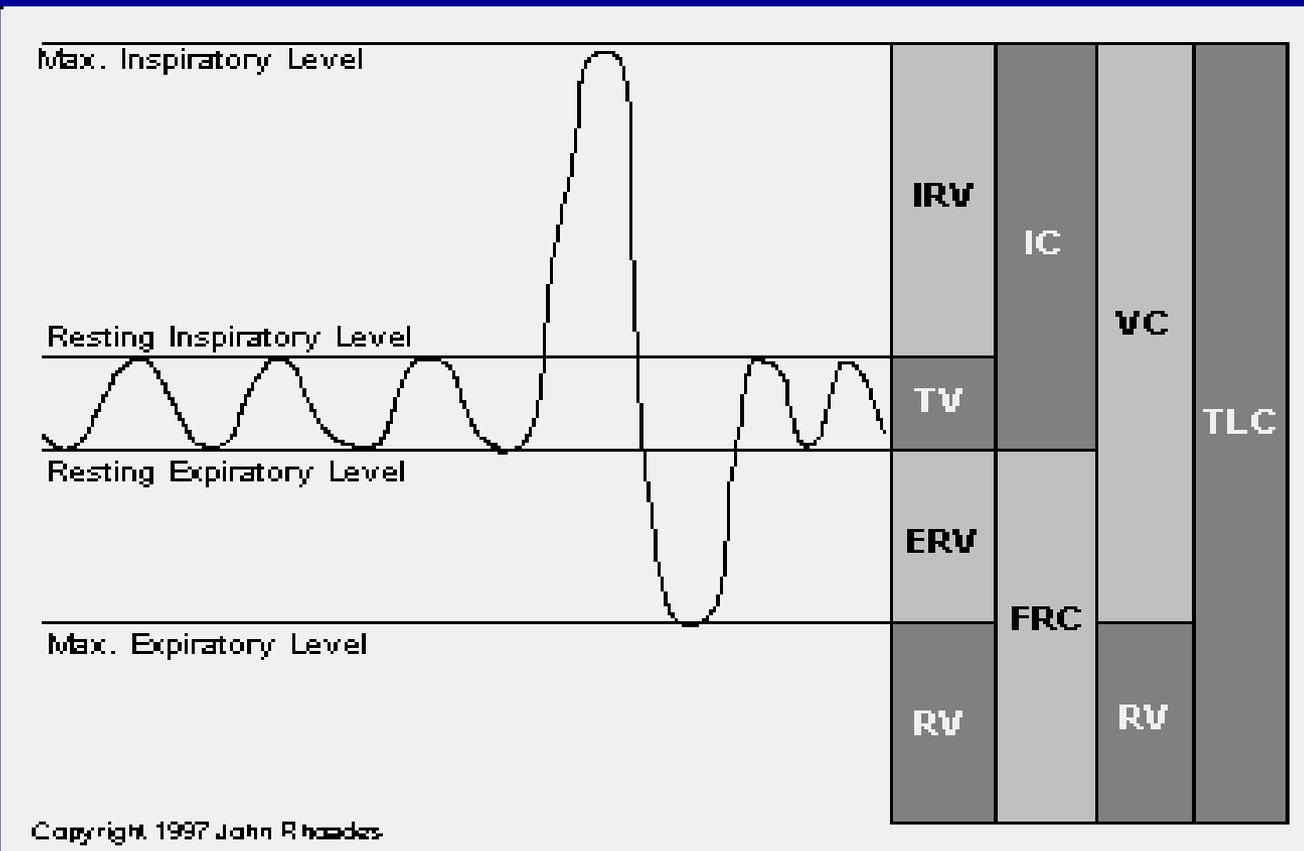
Obstructive or restrictive?



Spirometry in Restrictive Disease

- Decreased FVC and FEV1
- Normal FEV1/FVC ratio
- More advanced testing needed to completely define: lung volumes and diffusing capacity measurements

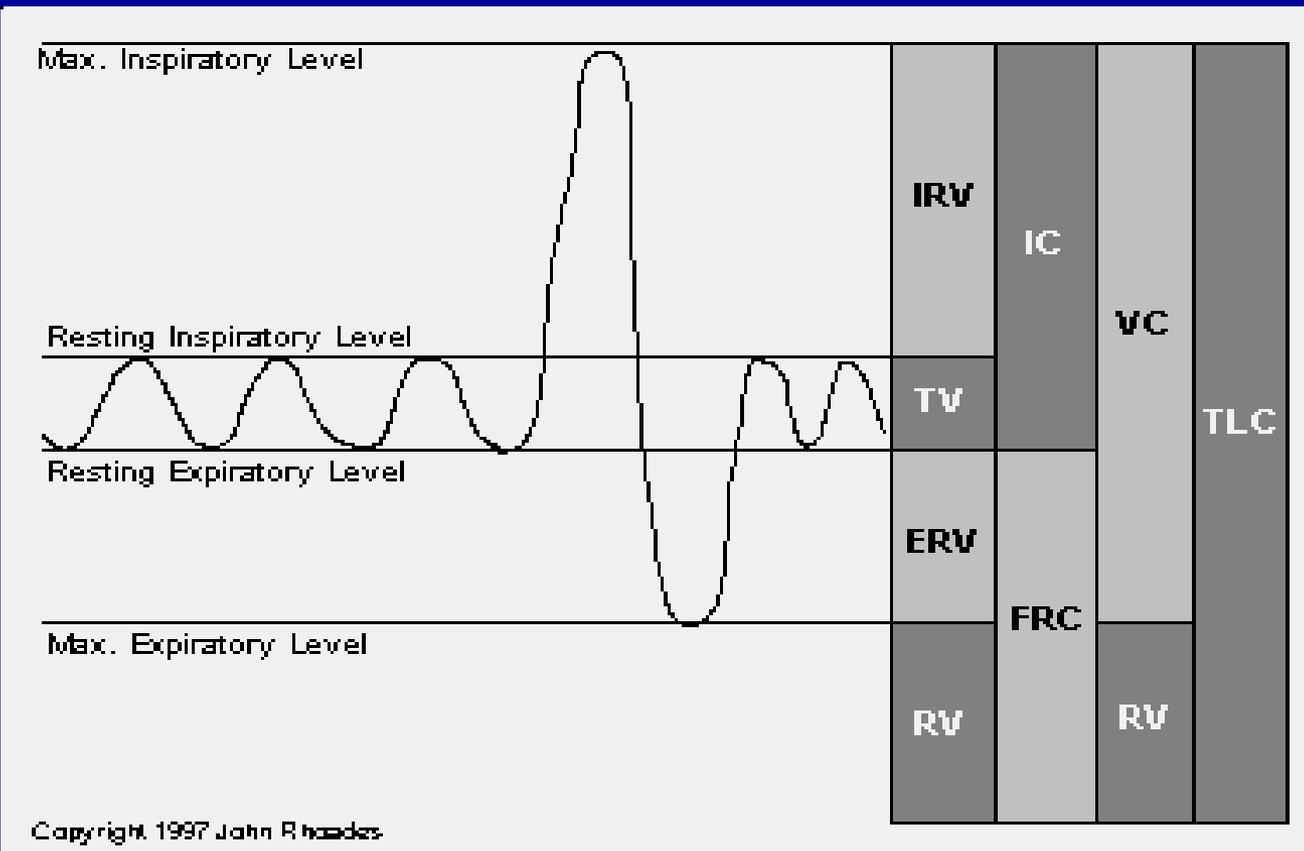
Lung volumes



Lung Volume Measurements

- Measured by dilutional techniques (helium dilution or nitrogen washout) or by displacement techniques in a body box
- The FRC is measured and then the other measurements are determined:
- $TLC = \text{inspiratory capacity} + FRC$
- $RV = FRC - ERV$ (expiratory reserve volume)

Lung volumes



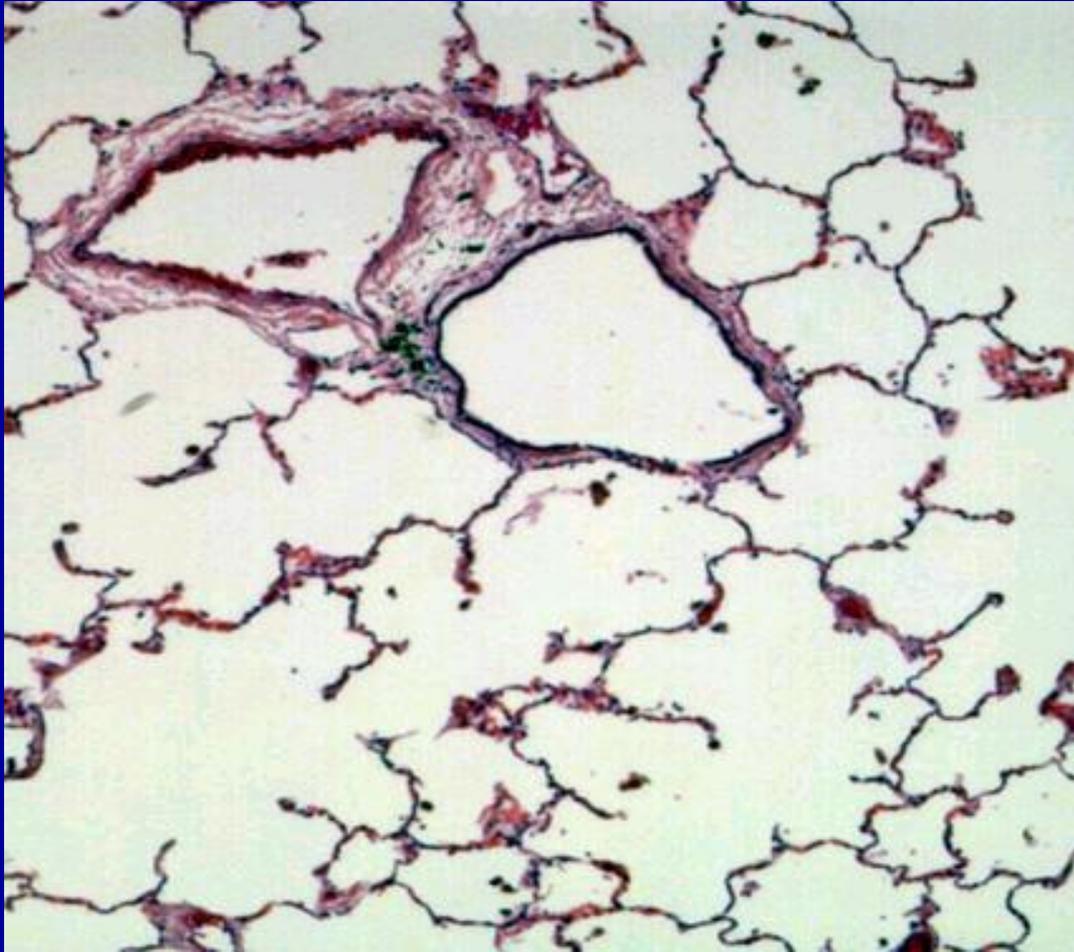
Lung Volume Patterns

- Obstructive Disease: Characterized by hyperinflation and gas trapping (increased TLC and RV/TLC)
- Restrictive Disease: Characterized by generalized reduction in lung volume (decreased TLC, RV and FRC)

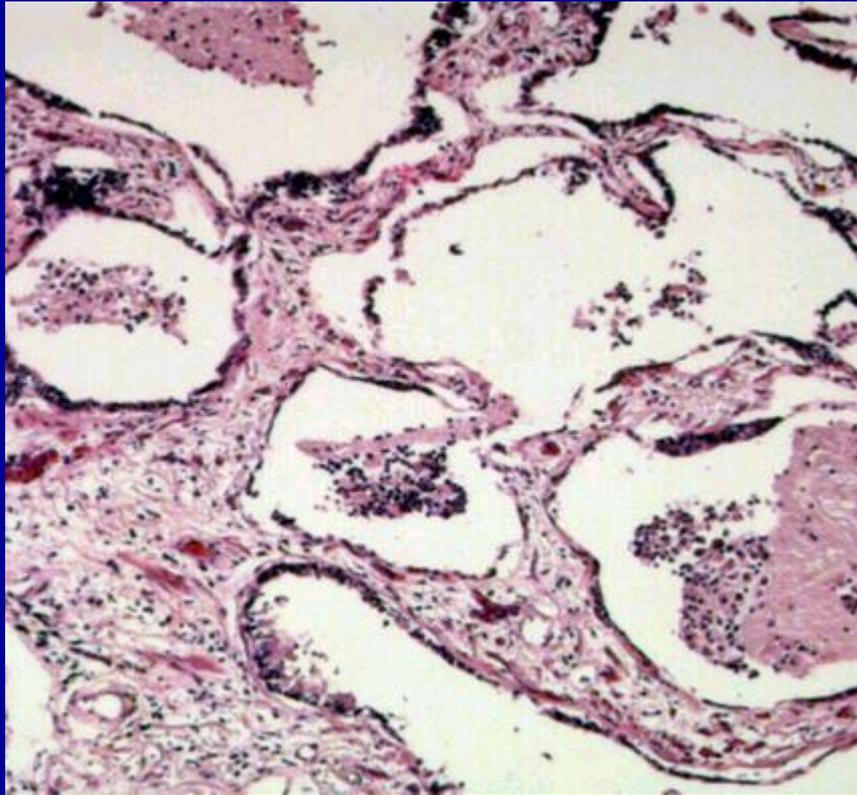
Diffusing Capacity

- Oxygen diffuses from the alveolus into the pulmonary capillaries and is bound to hemoglobin.
- In the laboratory, CO, which also binds to hemoglobin, is used to measure diffusing ability by either a single breath test or rebreathing test.

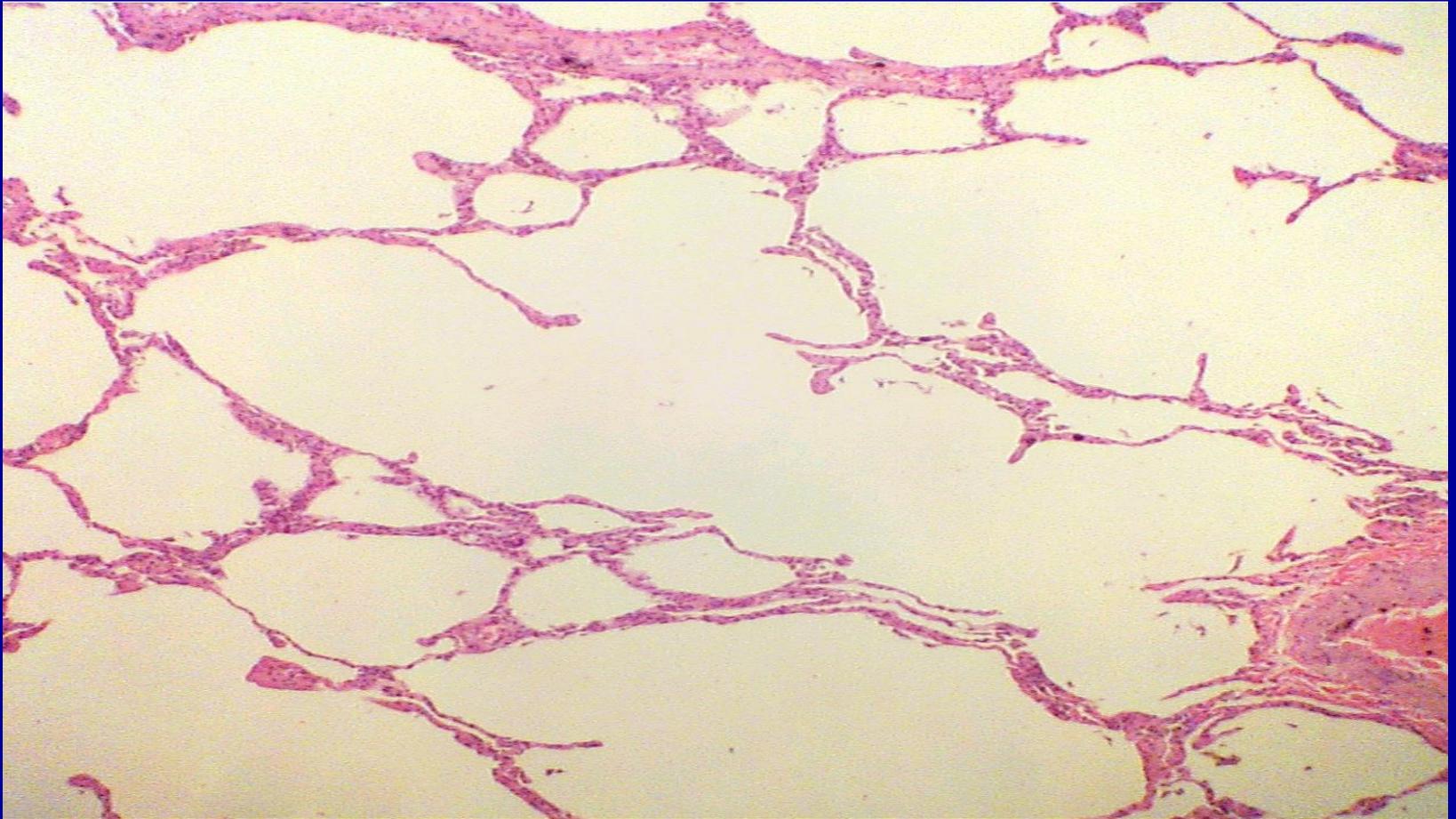
Normal Lung



Interstitial Fibrosis



Emphysematous Lung



Diffusing Capacity in Disease

- In asthma, an airway disease, diffusion is normal
- In both interstitial lung disease and emphysema, diffusing capacity is decreased
- Clinically, a reduced diffusing capacity is characterized by marked exertional dyspnea and exercise-induced decreases in oxygen

Arterial Blood Gases

- Measurement of pH, pCO₂ and pO₂ on room air is often done along with spiro, lung volumes and diffusing capacity to help characterize the severity of disease

MVV

- Maximal voluntary ventilation is a test which measures how many liters/ minute a person can breath with maximum effort
- It reflects the FEV1, muscle strength, motivation and ability to follow directions and therefore gives useful information, especially regarding operative risk

Exercise Testing

- May be very helpful in evaluation of dyspnea, disability, operative risk and exercise asthma
- Exercise bronchoprovocation challenge looks at spirometry after exercise and is used to evaluate EIB
- Cardiopulmonary exercise testing looks at maximal oxygen consumption, anaerobic threshold, breathing reserve and other parameters which may help to define whether dyspnea is caused by deconditioning, cardiac or respiratory causes

22 yo with DOE

- Pre-bronchodilator
- FVC 4.0(80%)
- FEV1 2.0 (66%)
- FEV1/FVC 50%
- MVV 70L (665)
- Post bd
- FVC 4.2
- FEV1 3.0 (100%)
- FEV1/FVC 73%
- MVV 105 L

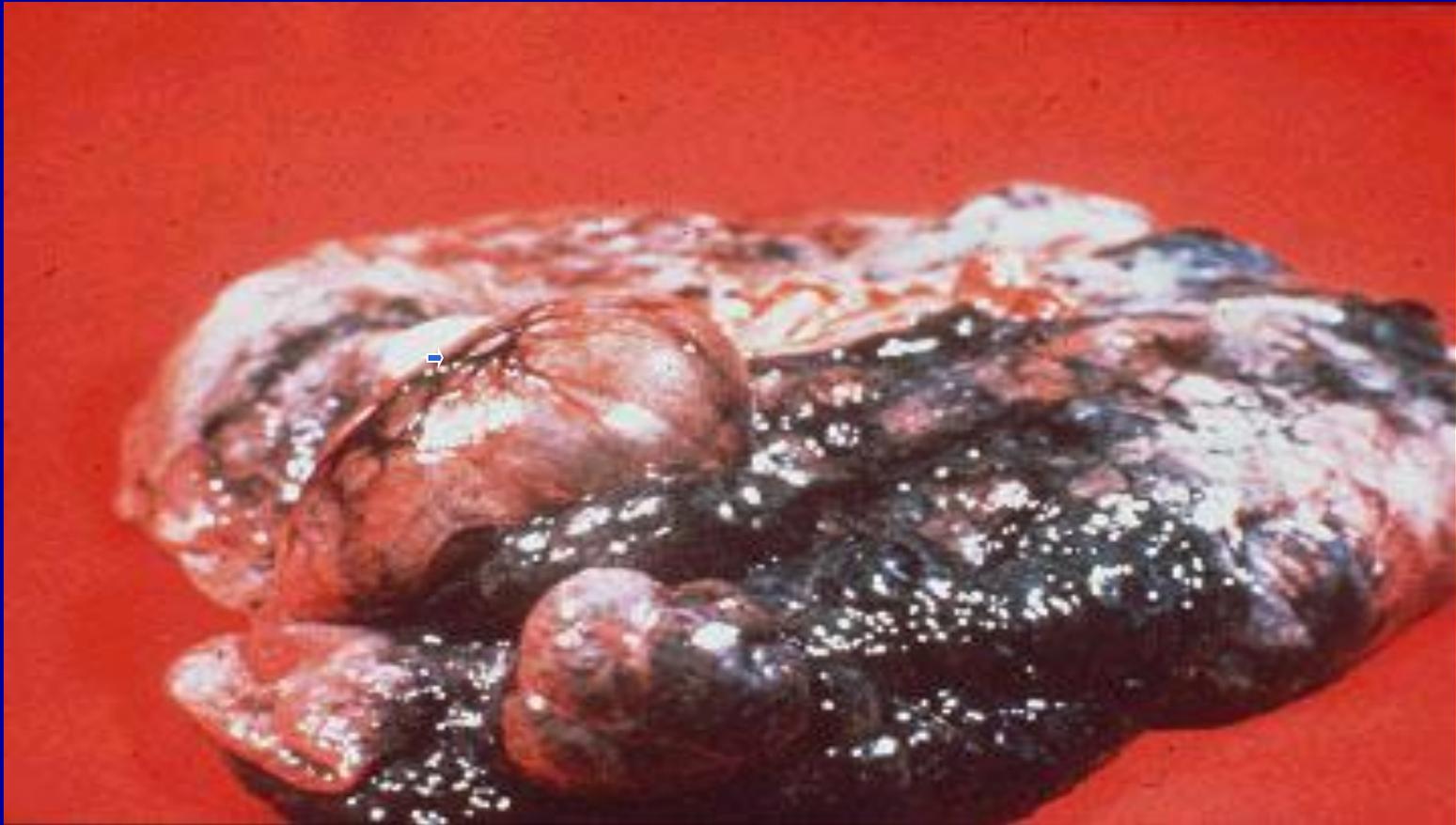
Interpretation

- Moderate obstructive ventilatory defect with bronchospasm, consistent with asthma

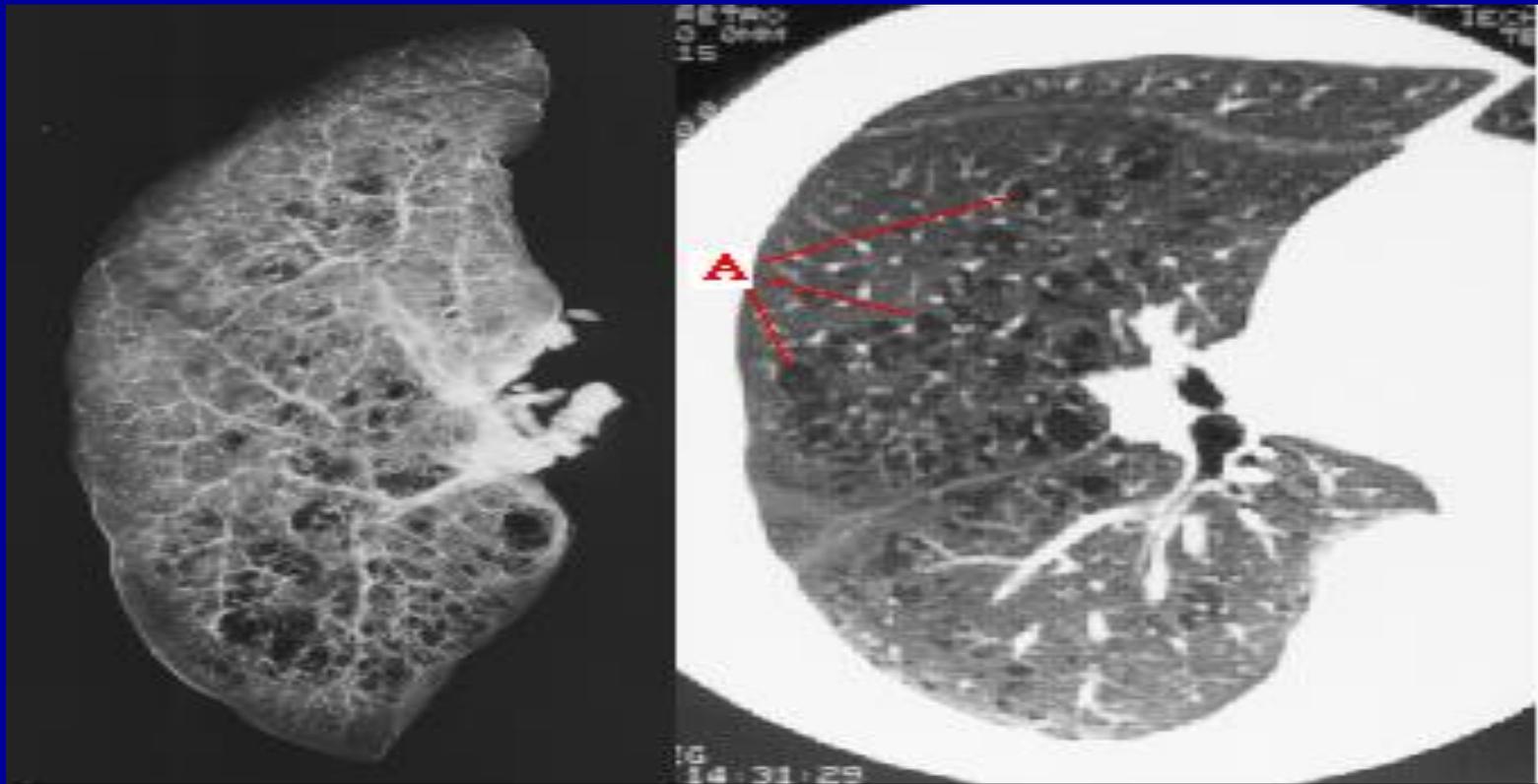
Other Uses of Pulmonary Functions

- Evaluate disability
- Assess operative risk, particularly for lung resection
- Objectively assess effect of therapy
- Assess potential lung toxicity of therapy
- Evaluate for rejection in lung transplant

Smoker's Lung with Emphysema

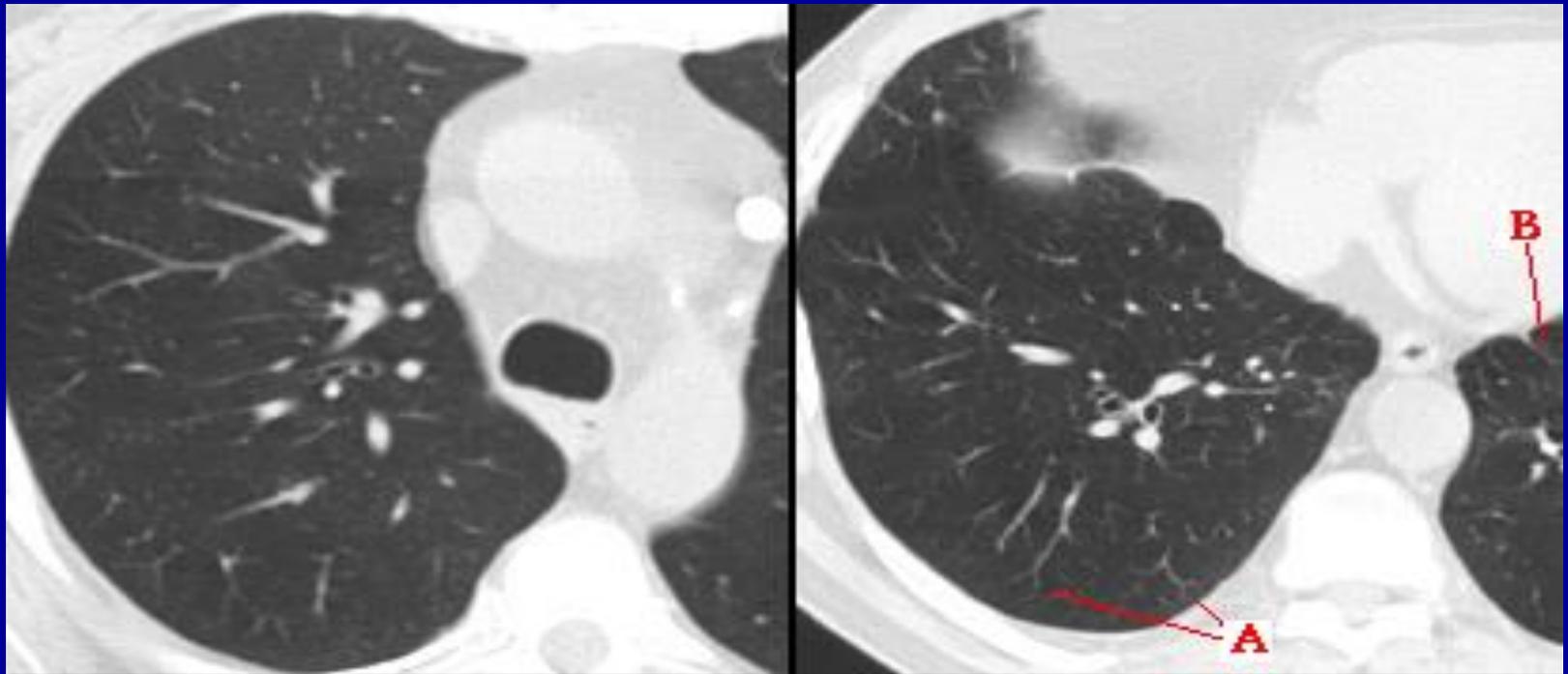


Emphysema on CT scan



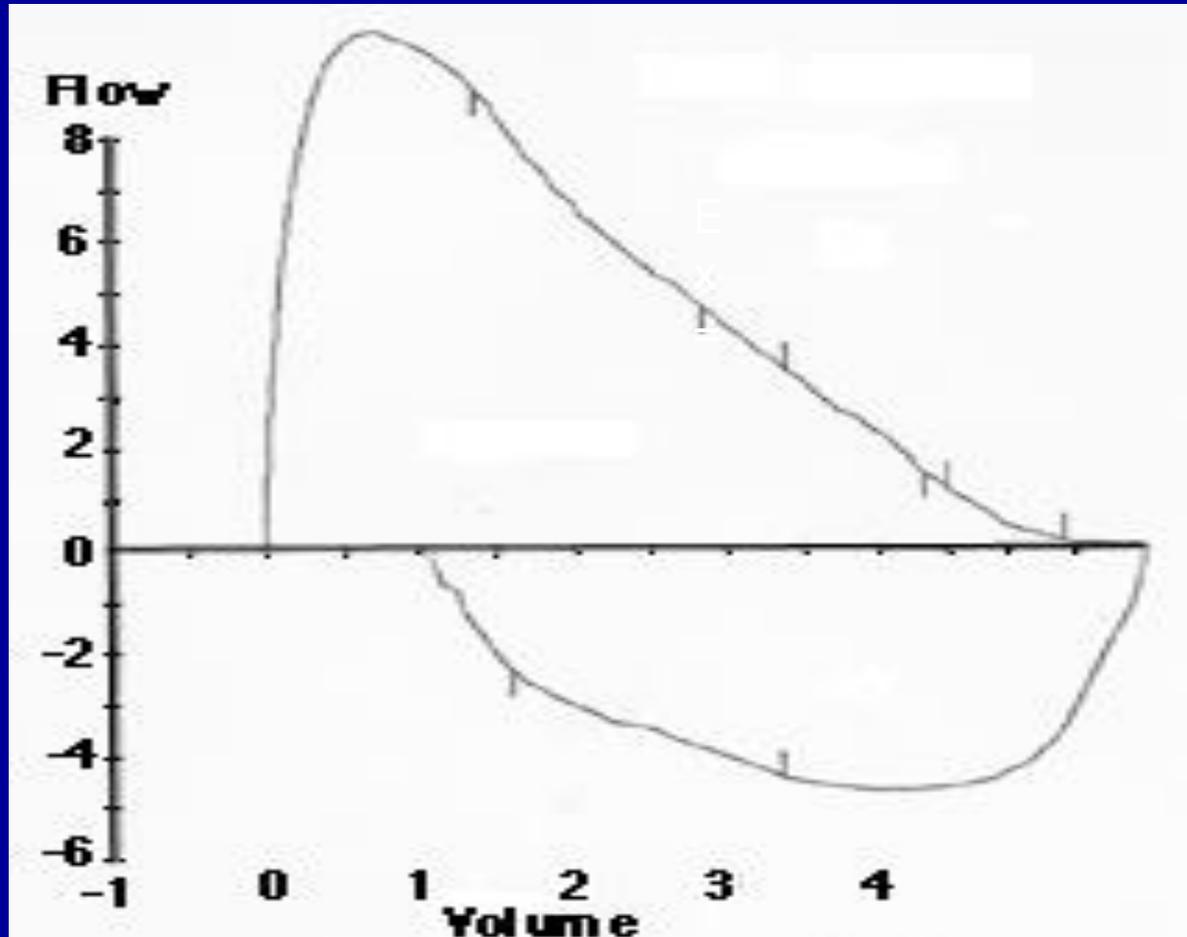
Specimen radiograph (left) and HRCT scan (right) shows the typical, poorly defined, low-attenuation lesions of emphysema (A). Note the absence of definable walls around the areas of low attenuation.

Normal Lung on CT

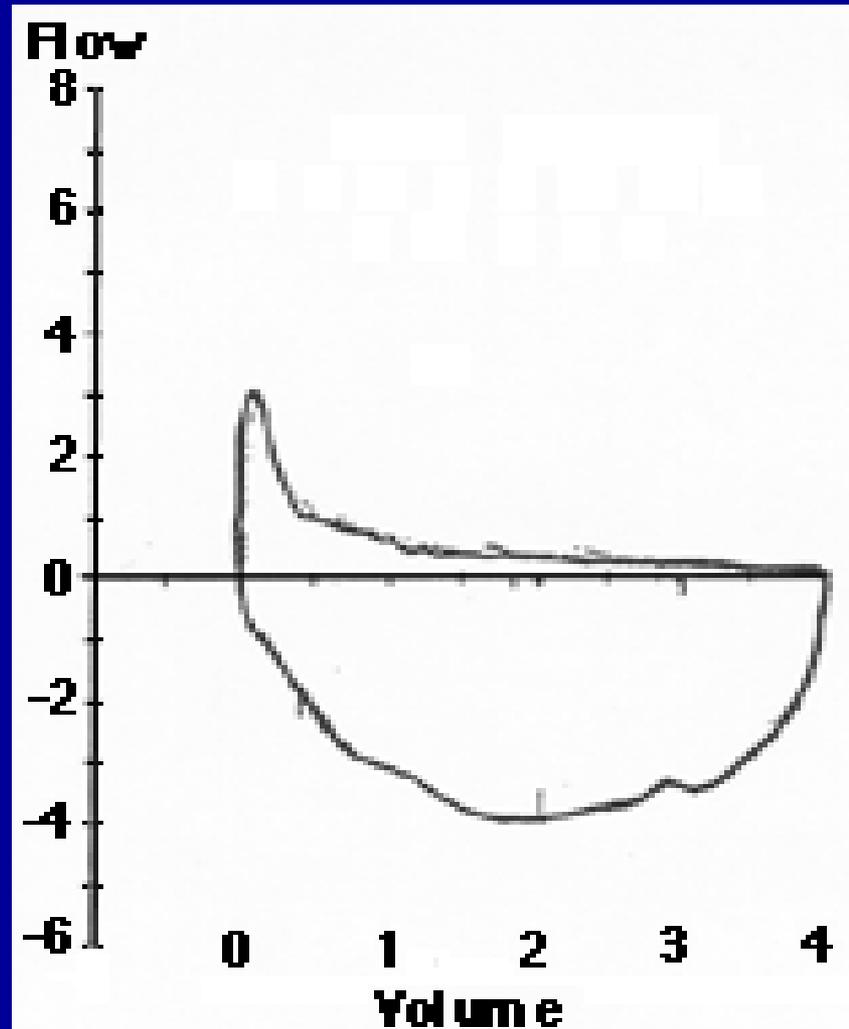


Normal upper (left) and lower (right) HRCT scans obtained in the prone position. The center of a pulmonary lobule is defined by the presence of a distal pulmonary artery (A). The faint outline of a distal interlobular septum is noted in the lower lobes (B). A subpleural clear space is normally present in the nondependent lung.

Normal Flow Volume LOOP



Severe Obstruction



Normal Lung X-ray

