



This Job really Blow's

Intracies of the PFT exam.

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- ▶ Staff Salem Health Svc's
- ▶ Pulmonary Lab Coordinator
- ▶ No Disclosures

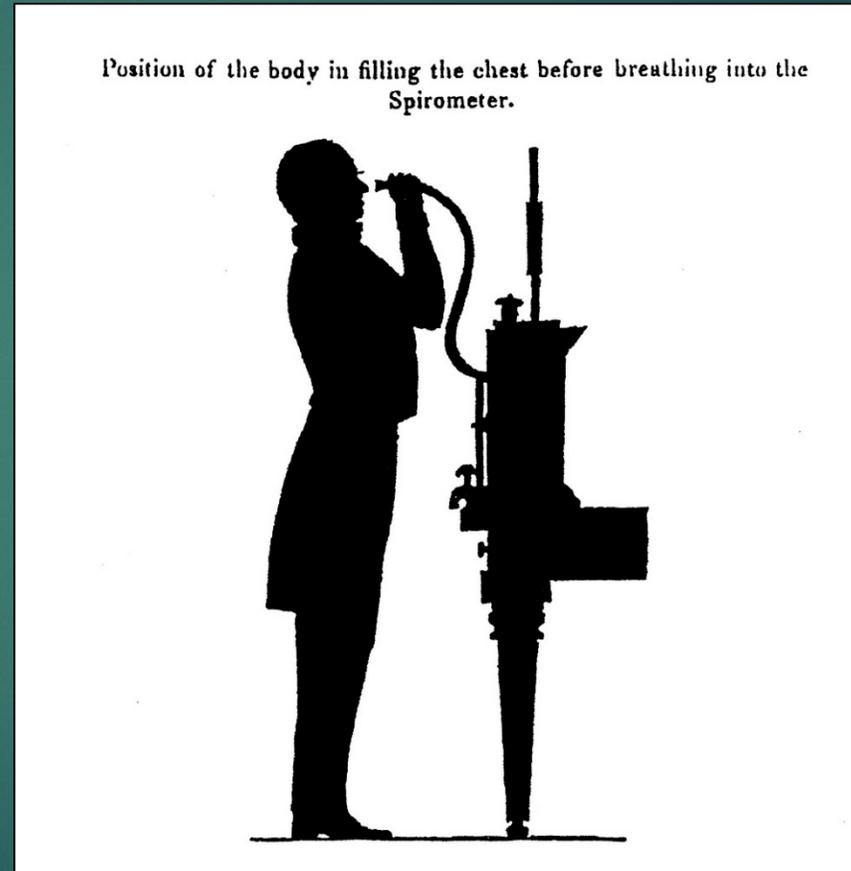
Objectives of this presentation

- ▶ Types of Pulmonary Function Testing
- ▶ Spirometry
- ▶ DLCOsb
- ▶ Lung Volumes
- ▶ Exercise Testing
- ▶ Bronchoprovocation
- ▶ ABG's

Objectives continued

- ▶ Familiarity of ATS/ERS 2005 Acceptability and Repeatability Guidelines
- ▶ Identify Obstructive vs Restrictive disease processes
- ▶ Pediatric Testing
- ▶ Disability Testing
- ▶ Quality Control

Where it all began....



Acknowledgement's to Pulmonary Function's

- ▶ Dr. John Hutchison In 1846 invented the Spirometer and coined the term Vital Capacity. He reported his measurements of 2130 patients.
- ▶ His observations allowed him to recognize that Vital Capacity was related to height and inversely proportional to age.
- ▶ Recognized that reductions in Vital Capacity predicted premature morbidity and mortality.
- ▶ Later marketed to Insurance companies in London when it failed to take off. He abandoned his invention left his wife and children for Australia.
- ▶ Died in Fiji at the age of 50 for TB or murdered.

Acknowledgement's cont.

- ▶ Edward Gaensler 1951 initiated the concept of the timed vital capacity, which became recognized as the forced expiratory volume as a function of time.
- ▶ Proposed that measurements of airflow were as important as air volume.
- ▶ Derived the standard for FEV1
- ▶ Thus over 100 years we discovered 2 Spirometric values the FVC and FEV1.

Modern Day PFT Champions.

- ▶ Greg Ruppel, Med, RRT, RPFT, Director Pulmonary Functions Lab at St. Lois University Health Sciences Center. Authored “Manual of Pulmonary Function Testing.” Edition’s 1-9
- ▶ Susan Blonshine RRT RPFT cAed, President – TechEd Consultants, Inc. NBRC Board of Trustees- PFT Exam Committee, NAECB Exam Committee, Past Board Chair

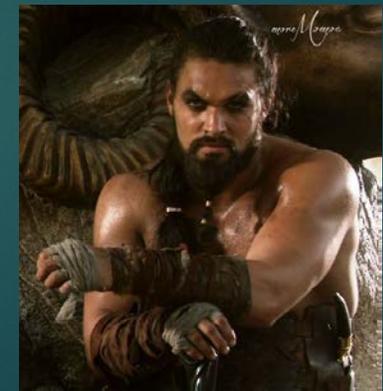


Modern Day PFT Champions

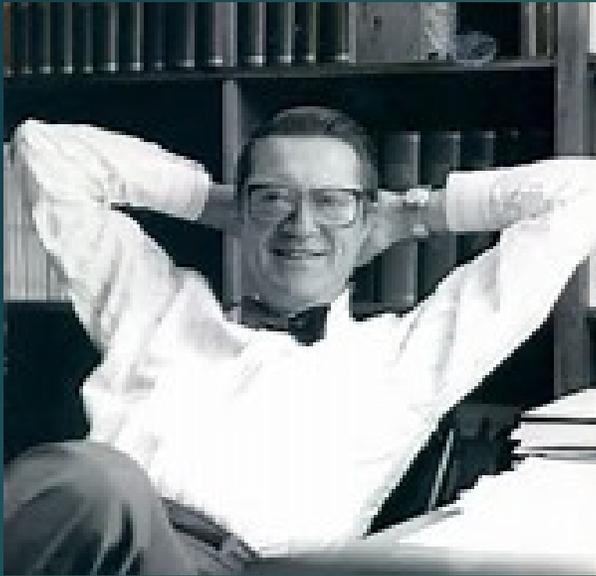
Carl Mottram RRT RPFT FAARC, Director
- Pulmonary Function Labs– Mayo
Clinic, NBRC Board member and Vice
Chair PFT Exam committee, Author
editor Ruppel Manual of PFT 10th
edition.



Jack Wegner MS, RRT, RPFT. PRA
International, Lenexa, Kansas, and
National Jewish Medical and Research
Center, Denver, Colorado



Spirometry Champion



THOMAS L. PETTY, M.D.
December 24, 1932 – December 12, 2009

Thomas L. Petty, M.D., a Pulmonologist, was Professor of Medicine at the University of Colorado Health Sciences Center in Denver, Rush-Presbyterian-St. Luke's Medical Center in Chicago, and Emeritus Professor of Medicine at National Jewish Medical & Research Center. He was previously head of the Division of Pulmonary Sciences at the University of Colorado and Director of the Fellowship Training Program from 1964-1989. He was Director of the Health ONE Center for Health Sciences Education from 1988 to 1998. He continued medical research in lung cancer, writing medical articles and books, and consultation practice from 1998 until his death in 2009

Dr. Petty was the founding Chairman of the National Lung Health Education Program (NLHEP).

What can PFT's tell you.

- ▶ Normal or abnormal
- ▶ What diseases can you diagnose?
COPD or Asthma
- ▶ Estimation of impairment, or severity of disease
- ▶ Response to therapy
- ▶ Occupational surveillance

What PFT's can't tell you.

- ▶ Does the degree of abnormality explain the patients symptoms?
- ▶ "Normality" does not exclude the presence of disease
- ▶ Abnormal test may not reflect loss of lung function

Patient instructions for PFT exam

- ▶ Should not drink alcohol for four hours prior to test
- ▶ Should not smoke at least one hour before test
- ▶ Do not eat a large meal two hours prior to test
- ▶ No vigorous exercise 30 minutes before test
- ▶ Do not wear tight form fitting clothes
- ▶ May need to remove loose dentures for test
- ▶ Should wait at least one month post MI, consider impact of problems that may affect results (chest/abdominal pain, oral or facial pain, stress incontinence, dementia, physical deformities or medical conditions)
- ▶ Bring a list of all medications – potentially withhold bronchodilators, corticosteroids

Factors to Include in the PFT

- ▶ Gender
- ▶ Age
- ▶ Height or Arm Span
- ▶ Weight and body size
- ▶ Race
- ▶ Effort
- ▶ References

Before you test...

Calibrate your instrument

Syringe accuracy: The syringe used to check the volume calibration of spirometers must have an accuracy of at least 0.5% of full scale (15 mls for a 3 L syringe).

Linearity: Pneumotach systems, at extremes of flow (both high and low), may become inaccurate (i.e. 3 L injected at a high speed or a low speed may produce an inaccurate reading as opposed to 3 L injected at a moderate speed). An instrument is considered *linear* if its output is directly proportional to its input.

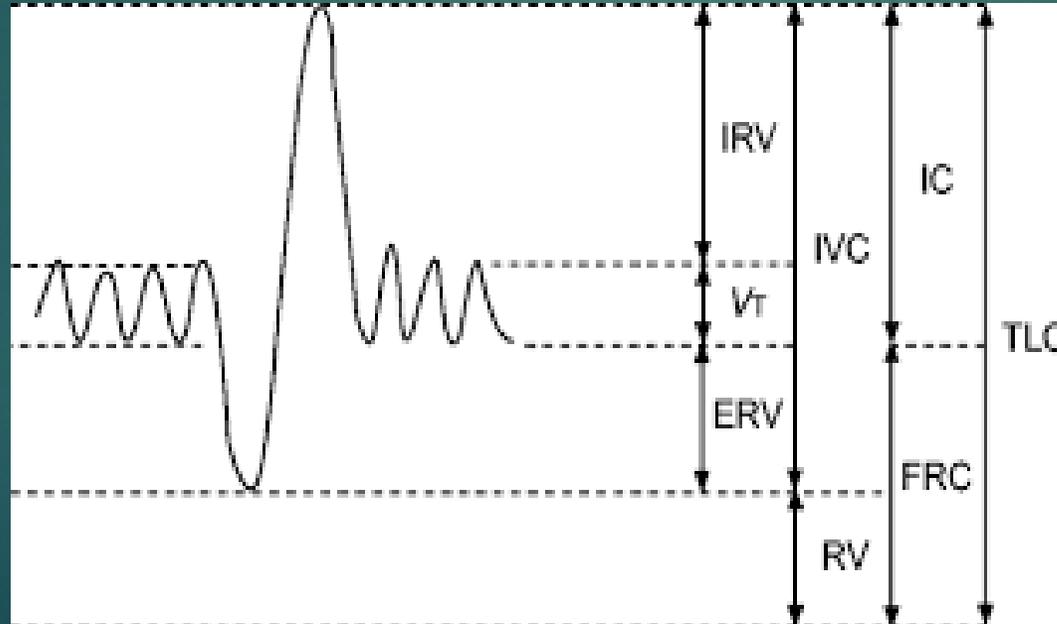
Pneumotach systems must have their linearity determined whenever calibration is done. This is done by injecting the volume from a 3 L syringe at several different speeds. Most pneumotach systems compensate for this nonlinear flow signal electronically or through software corrections. The linearity is considered acceptable if the volume injected does not vary by more than $\pm 3\%$.

Pneumotachs must be visually checked for moisture or other debris. This can alter its flow sensing



Volumes and Capacities

- ▶ 4 volumes
- ▶ 4 capacities. Each the sum of 2 or more volumes



Spirometry Measurements

- ▶ FVC: The total amount of air exhaled as quickly as possible after taking the deepest possible breath.
- ▶ FEV1: expresses how much air is expelled from the lungs in 1 second of a forced expiratory maneuver.
- ▶ FEV1/FVC: indicates the percentage of the FVC expelled in the first one second of forced exhalation. This parameter helps to indicate Obstructive or Restrictive lung disease.
- ▶ FEF 25-75: The amount of air expelled from the lungs in the middle half of the forced expiratory maneuver
- ▶ PEF: airflow that is maximally forced from the lungs over a measure of time.

Spirometry Indications

- ▶ Evaluate Dyspnea
- ▶ Detect Pulmonary Disease
- ▶ Evaluate Operative Risks
- ▶ Evaluate Pulmonary Impairment
- ▶ Monitoring of Occupational Lung disease

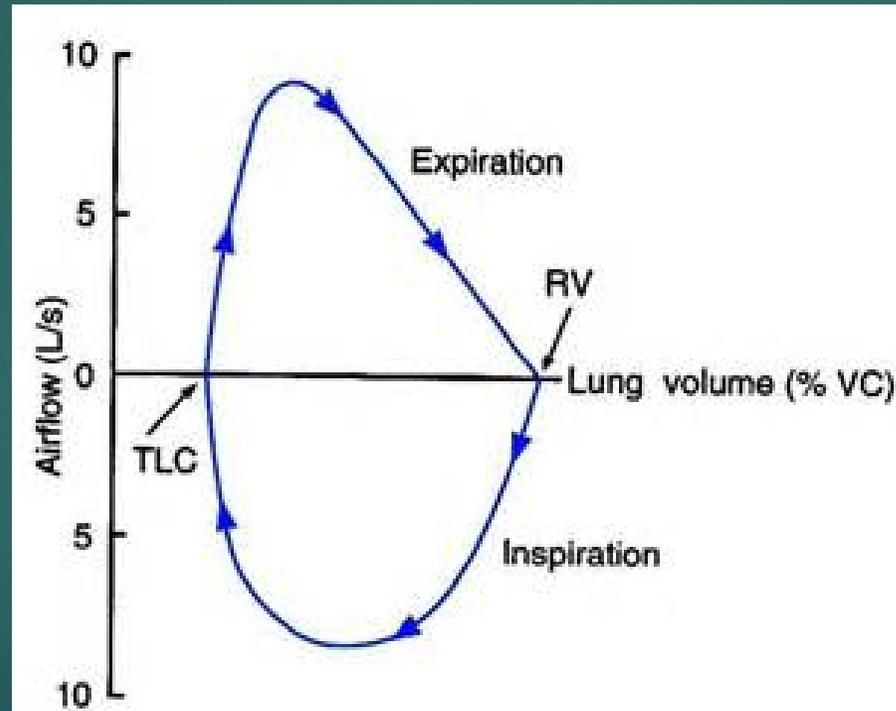
Spirometry Contraindications

- ▶ Hemoptysis
- ▶ Pneumothorax
- ▶ Recent MI
- ▶ Abdominal Aneurysm
- ▶ Recent Eye Surgery
- ▶ Recent Thoracic or Abdominal Surgery

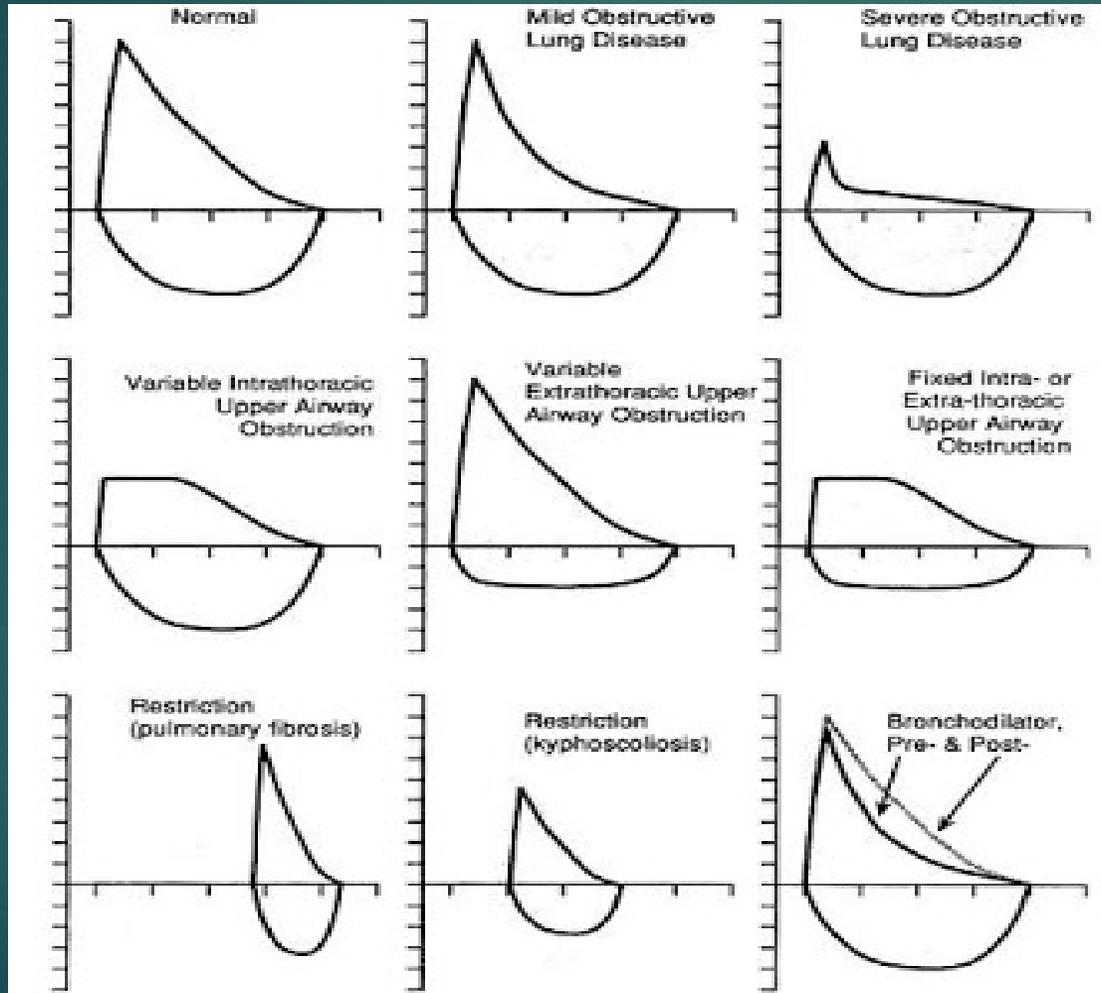
Spirometry Additional information

- ▶ Spirometry (SVC, FVC, and MVV) is an effort-dependent test. It requires cooperation and understanding by the patient; appropriate patient effort depends on instruction and communication with the technologist.
- ▶ Interaction between the technologist and patient are important in obtaining acceptable and reproducible data; technologists should display a high level of motivation in regard to eliciting maximal effort from the patient

Anatomy of Flow Volume Loop



Morphology of Flow Volume Loops



FVC Maneuver

Patient assumes the position (typically sitting)

- ▶ Puts nose clip on
- ▶ Puts mouthpiece in mouth and closes lips around mouthpiece (open circuit)
- ▶ Inhales maximally
- ▶ Exhales as hard and fast and long as possible
- ▶ Repeat instructions if necessary – effective coaching is essential
- ▶ Give simple instructions
- ▶ Repeat minimum of three times (check for repeatability)

ATS/ERS Standard of Acceptance and Repeatability of FVC

- ▶ **Free from artifacts, such as**
 - ▶ Cough during the first second of exhalation
 - ▶ Glottis closure that influences the measurement
 - ▶ Early termination or cut-off
 - ▶ Effort that is not maximal throughout
 - ▶ Leak
 - ▶ Obstructed mouthpiece
- ▶ **Good starts**
 - ▶ Extrapolated volume < 5% of FVC or 0.15 L, whichever is greater
- ▶ **Satisfactory exhalation**
 - ▶ Duration of ≥ 6 s (3 s for children < 10) or a plateau in the volume–time curve or If the subject cannot or should not continue to exhale

Spirometry Interpretation

- ▶ *Obstructive Disorders*

- ▶ Characterized by a limitation of expiratory airflow so that airways cannot empty as rapidly compared to normal (such as through narrowed airways from bronchospasm, inflammation, etc.)

Examples:

- ▶ Asthma
- ▶ Emphysema
- ▶ Cystic Fibrosis

- ▶ *Restrictive Disorders*

- ▶ Characterized by reduced lung volumes/decreased lung compliance

Examples:

- ▶ Interstitial Fibrosis
- ▶ Scoliosis
- ▶ Obesity
- ▶ Lung Resection
- ▶ Neuromuscular diseases
- ▶ Cystic Fibrosis

Spirometry Interpretation: Obstructive vs. Restrictive Defect.

▶ *Obstructive Disorders*

- ▶ FVC nl or ↓
- ▶ FEV1 ↓
- ▶ FEF_{25-75%} ↓
- ▶ FEV1/FVC ↓
- ▶ TLC nl or ↑

▶ *Restrictive Disorders*

- ▶ FVC ↓
- ▶ FEV1 ↓
- ▶ FEF_{25-75%} nl to ↓
- ▶ FEV1/FVC nl to ↑
- ▶ TLC ↓

Take a Deep Breath in and BLOW it out HARD and FAST!!!



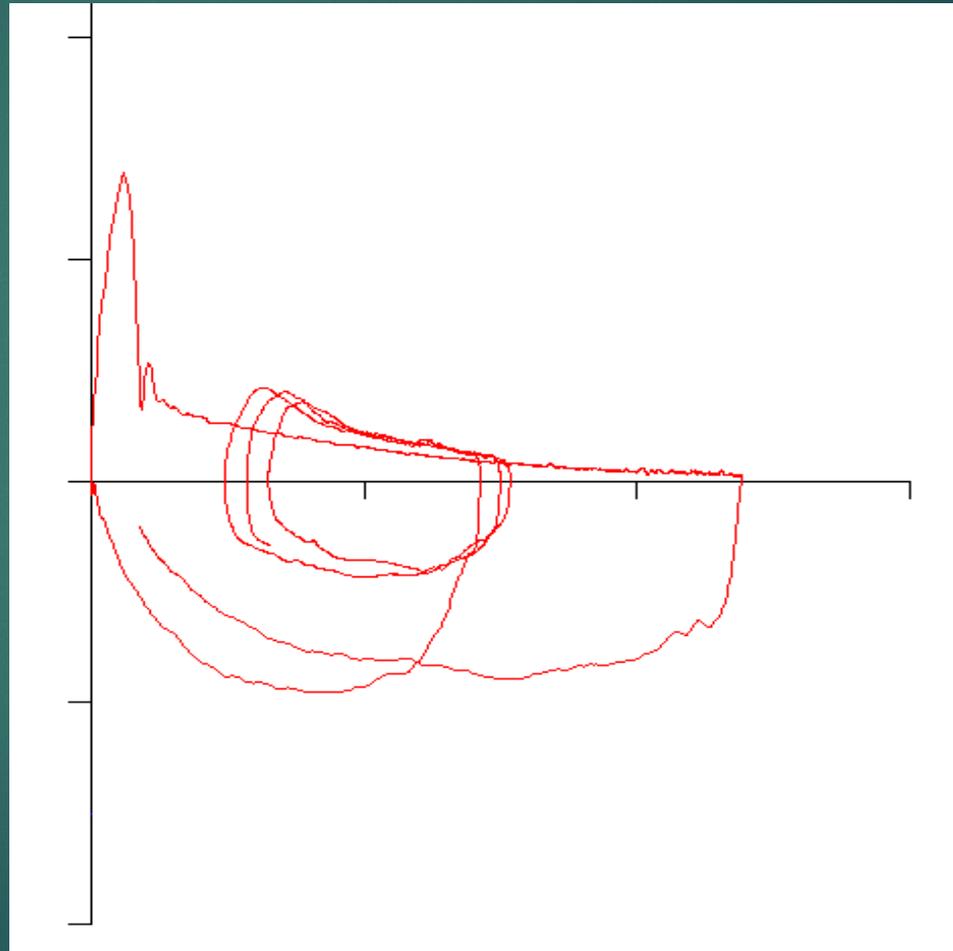
GOLD Criteria for COPD

Global initiative for chronic obstructive lung disease

Stage I	Mild COPD	FEV ₁ /FVC < 0.70	FEV ₁ ≥ 80% normal
Stage II	Moderate COPD	FEV ₁ /FVC < 0.70	FEV ₁ 50-79% normal
Stage III	Severe COPD	FEV ₁ /FVC < 0.70	FEV ₁ 30-49% normal
Stage IV	Very Severe COPD	FEV ₁ /FVC < 0.70	FEV ₁ < 30%

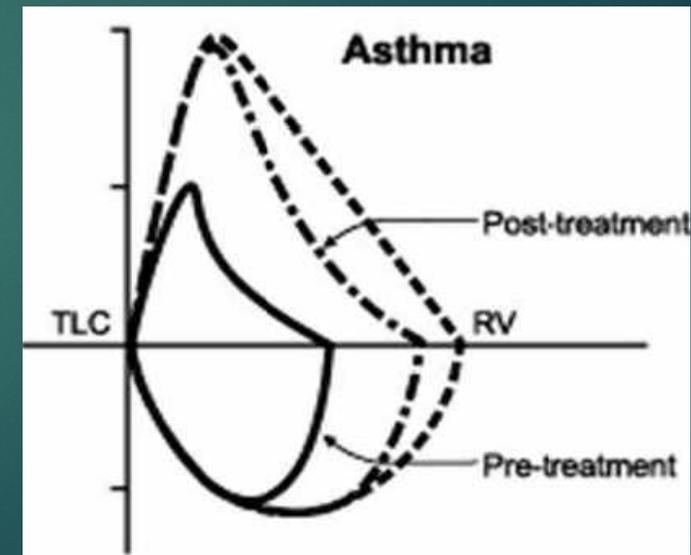
Common Obstructive Lung Diseases

- ▶ Asthma
- ▶ COPD
- ▶ Cystic Fibrosis



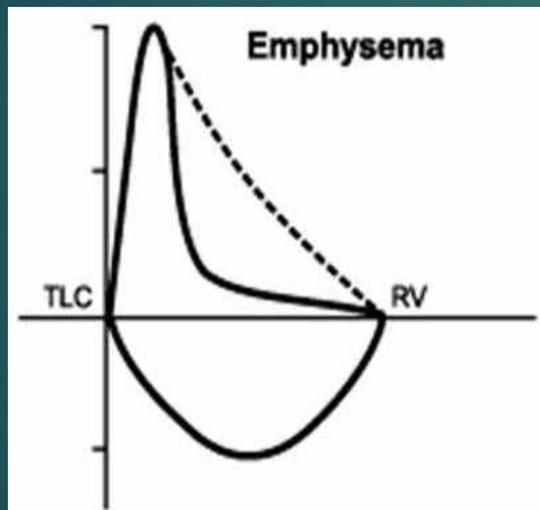
Asthma

- ▶ Peak expiratory flow reduced so maximum height of the loop is reduced
- ▶ Airflow reduces rapidly with the reduction in the lung volumes because the airways narrow and the loop becomes concave
- ▶ Concavity or coving may be the indicator of airflow obstruction and may present before the change in FEV1 or FEV1/FVC



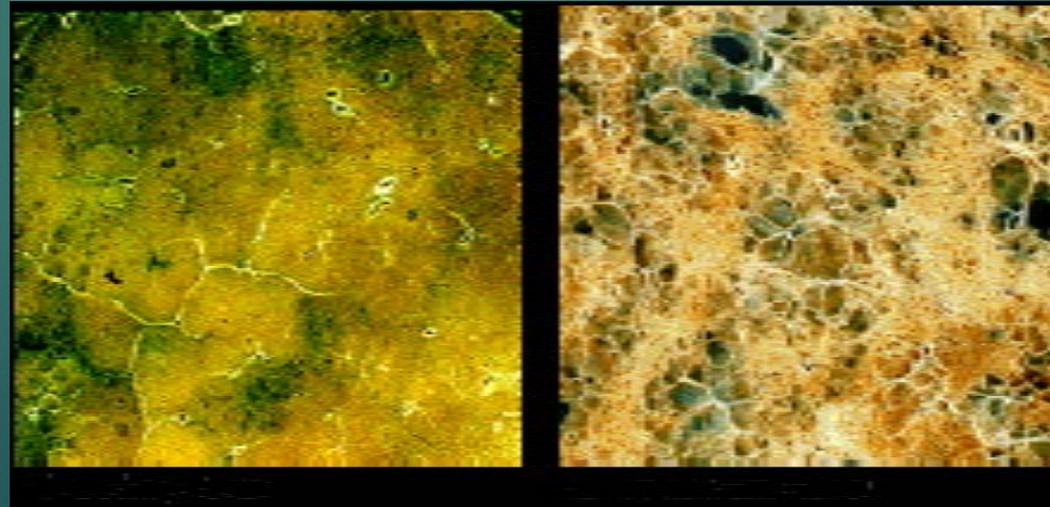
Severe COPD, Emphysema.

- ▶ Airways may collapse during forced expiration because of destruction of the supporting lung tissue causing very reduced flow at low lung volume and a characteristic (dog-leg) appearance to the flow volume curve.



Normal

Emphysema

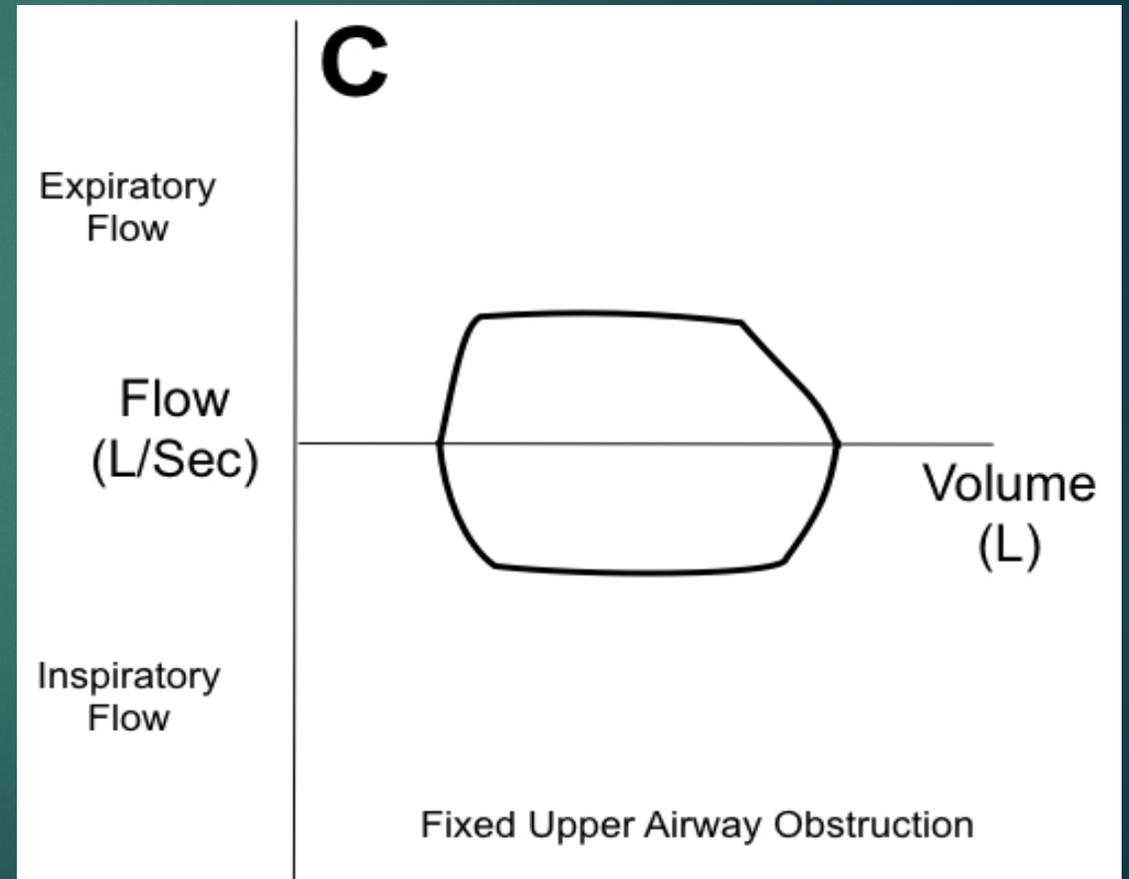


Degree of Obstruction. Based on FEV1

Degree of severity	FEV1 % predicted
▶ Mild	>70-79
▶ Moderate	60-69
▶ Mod severe	50-59
▶ Severe	35-49
▶ Very Severe	< 35

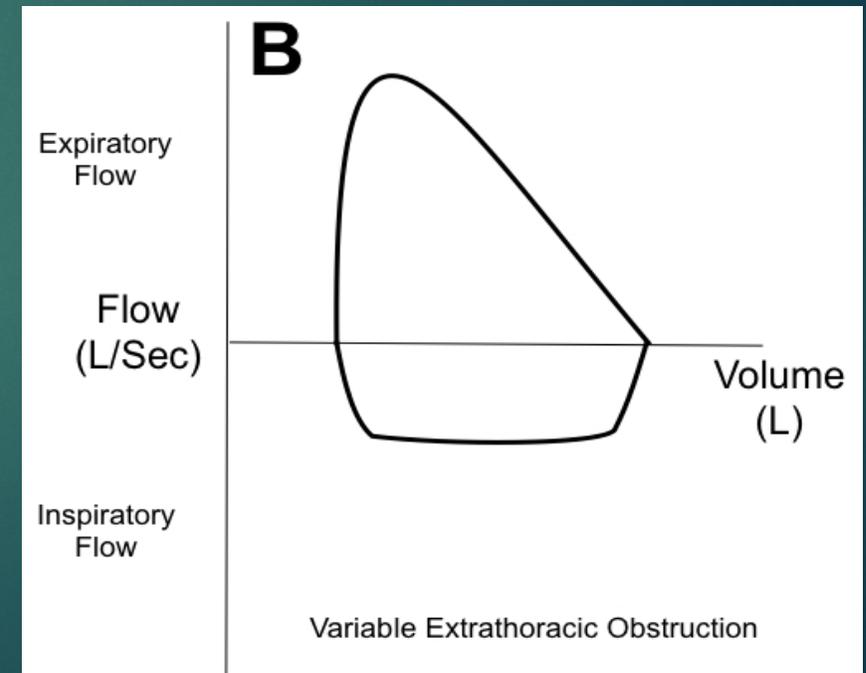
Upper airway obstructions

- ▶ Fixed obstruction: Maximum airflow is limited to a similar extent in both inspiration and expiration
- ▶ Post intubation stenosis
- ▶ Goiter
- ▶ Endotracheal neoplasms
- ▶ Bronchial stenosis



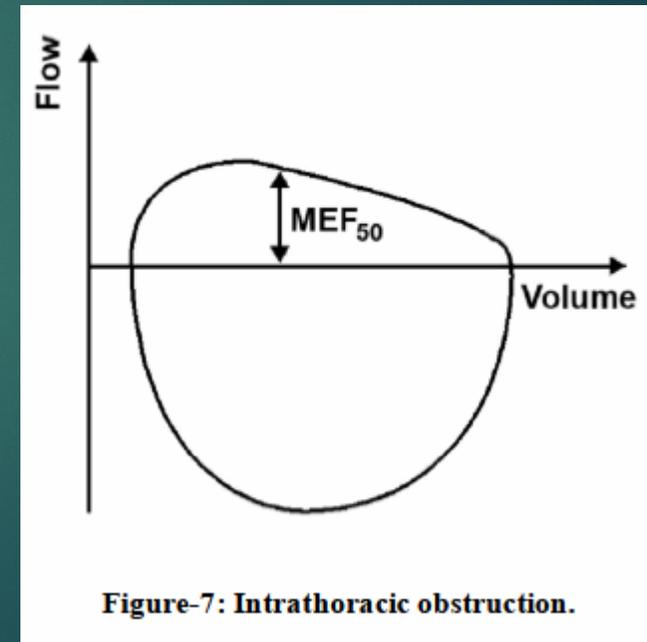
Other UAO

- ▶ Variable Extrathoracic obstruction: The obstruction worsens in inspiration because the negative pressure narrows the trachea and inspiratory flow is reduced to a greater extent than expiratory flow
- ▶ Bilateral and unilateral vocal cord paralysis
- ▶ Vocal cord constriction
- ▶ Reduced pharyngeal cross sectional area
- ▶ Airway burns



UAO cont.

- ▶ Variable Intrathoracic Obstruction The narrowing is maximal in expiration because of increased intrathoracic pressure compressing the airway. The flow volume loop shows a greater reduction in the expiratory phase
- ▶ Tracheomalacia
- ▶ Polychondritis
- ▶ Tumors of the lower trachea or main bronchus.



Restrictive Disorders

- ▶ Characterized by reduced lung volumes/decreased lung compliance.

Examples:

- Interstitial Fibrosis
- Scoliosis
- Obesity
- Lung Resection
- Neuromuscular diseases
- Cystic Fibrosis

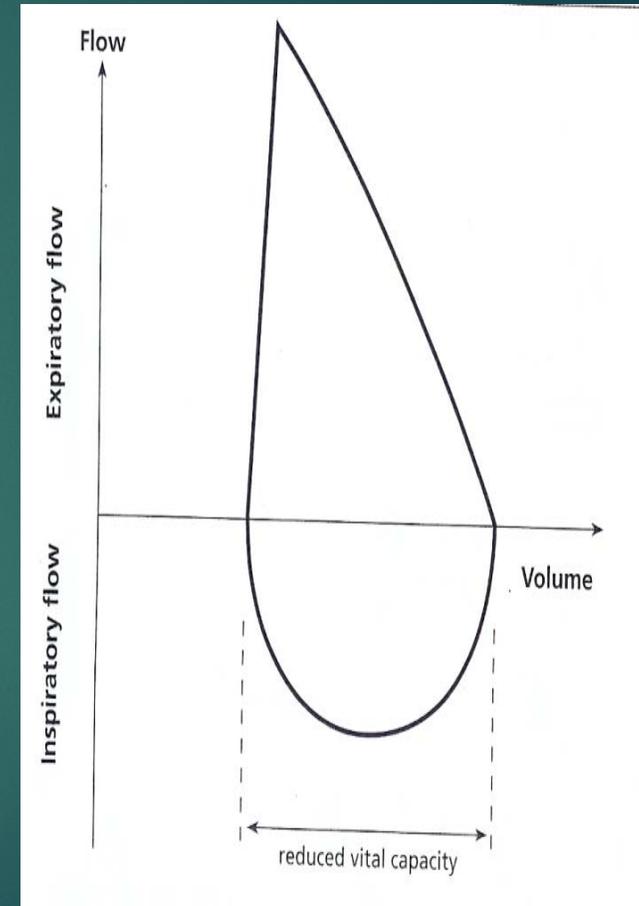


Restrictive Flow Volume Curves

- Forced vital capacity (FVC) may be low; however, FEV1/FVC is often normal or greater than normal due to the increased elastic recoil pressure of the lung
- Peak expiratory flow may be preserved or even higher than predicted. Leads to tall, narrow and steep flow volume loop in expiratory phase.

Also exhibits the following.

low total lung capacity
low functional residual capacity
low residual volume.



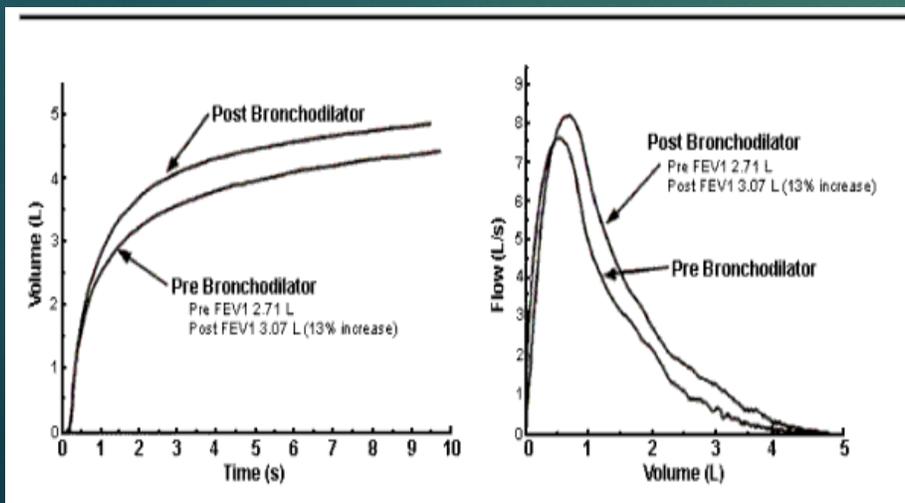
Restrictive Lung Disease Summary

- ▶ Characterized by diminished lung volume due to: – change in alteration in lung parenchyma (interstitial lung disease) – disease of pleura, chest wall (e.g. scoliosis), or neuromuscular apparatus (e.g. muscular dystrophy)
- ▶ Decreased TLC, FVC
- ▶ Normal or increased: FEV1/FVC ratio

Pre and Post Bronchodilator Studies

- ▶ Beta agonist are the most common form for testing.
- ▶ Minimum of 10-15 minutes between pre and post tests.
- ▶ Reversibility can be assessed with the use of bronchodilators.

Noted by a 12% increase in FEV1 or increase of 200ml improvement of FEV1 OR A 12% increase of FVC or 200 ml improvement of FVC



Does this really BLOW yet?



DLco-sb

- ▶ **DLco:** measures the ability of the lungs to diffuse gas from inhaled air across the A/C membrane to the red blood cells in pulmonary capillaries.
- ▶ CO combines with Hb 210 times faster than Oxygen.
- ▶ DLco is reported as: ml of CO/ minute/mmHg/(stpd)
- ▶ Average Adult DLco-sb is 25 ml CO/min/mmHg (STPD)
- ▶ DLco-sb is affected by
 - Hemoglobin corrections for Hb should be applied.
 - CO-Hb Corrections for CO-Hb should be applied.

Dlco-sb Indications

- ▶ Differentiate Asthma from Emphysema
- ▶ Evaluate the severity of restrictive lung disease
- ▶ Detect early stages of Pulmonary Hypertension.

DLCO cont.

Decreased DLCO

(<80% of predicted)

Obstructive Lung Disease
Parenchymal Disorders
Pulmonary Vascular Disease
Anemia



Increased DLCO

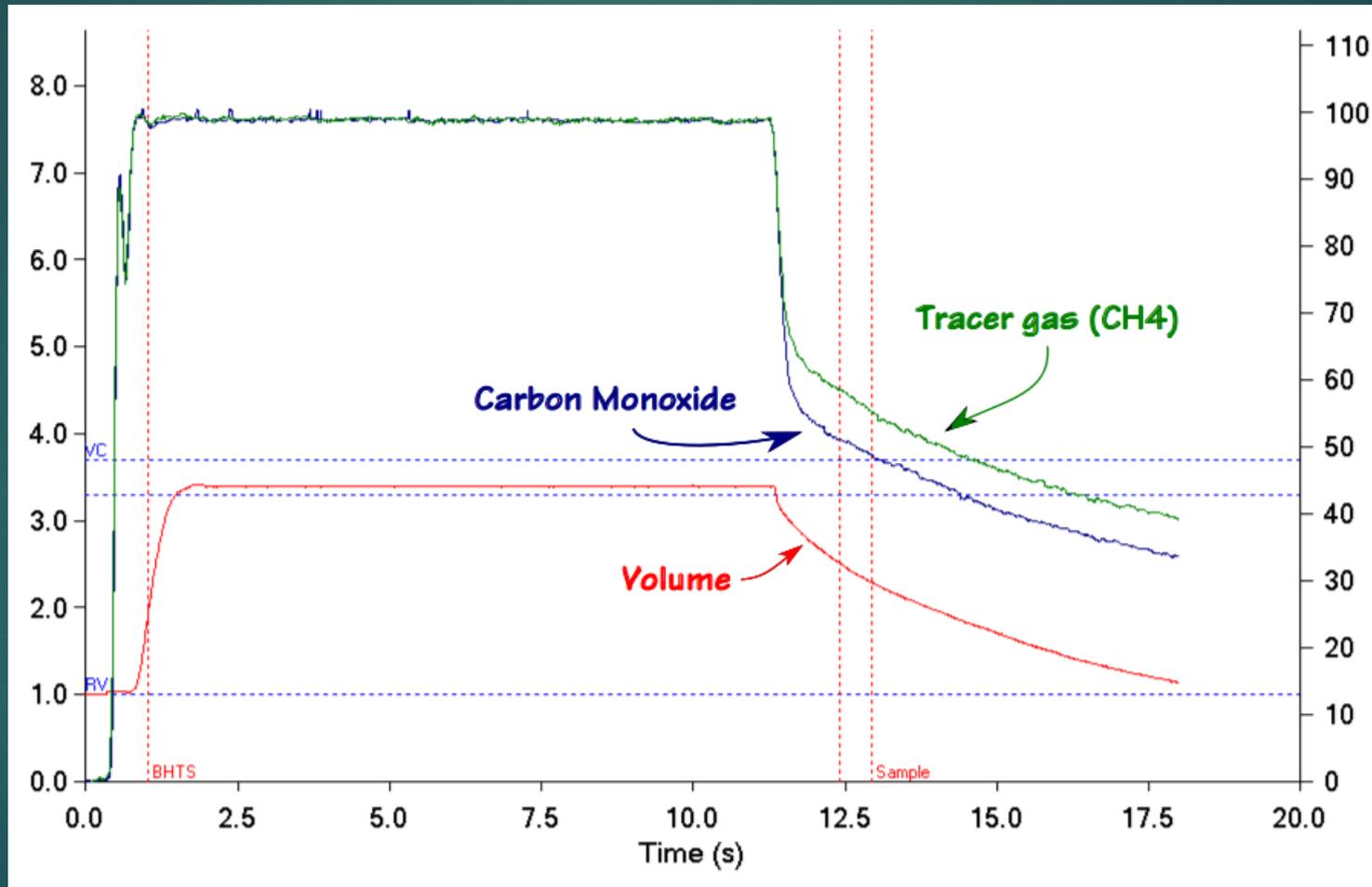
(>80% of predicted)

Asthma
Pulmonary Hemorrhage
Polycythemia
Left to Right Shunt

DLco

- ▶ The maneuver requires the patient to exhale to RV then an actuated dose of CO is administered having a patient inhale to TLC. The patient then holds their breath for 10 seconds and then exhales normally.
- ▶ There need to be a 4 minute wait between maneuvers for CO to degrade.
- ▶ ATS/ERS Acceptability Inspired volume should be 85% of of largest VC. I time < 4 seconds, BHT 8-12 seconds, Exp. Time < 4 seconds, No Leaks, Valsalvas, or Mueller maneuvers
- ▶ ATS/ERS Repeatability The values should be within 10% of the highest value recorded or 3ml/min/mmHg

DLCOs_b maneuver



Lung Volumes

- ▶ **Lung Volume Measurements:**
- ▶ Lung Volume Measurements Common measurements include total lung capacity (TLC), functional residual capacity (FRC), and residual volume (RV).
- ▶ Decreased lung volumes suggest restrictive disease if accompanied by a normal or increased FEV₁ /FVC ratio.
- ▶ Increased lung volumes suggest static hyperinflation due to obstructive airways disease if accompanied by decreased FEV₁ /FVC ratio.
- ▶ Coexisting restriction and obstruction can be detected, but requires both spirometry and lung volumes.

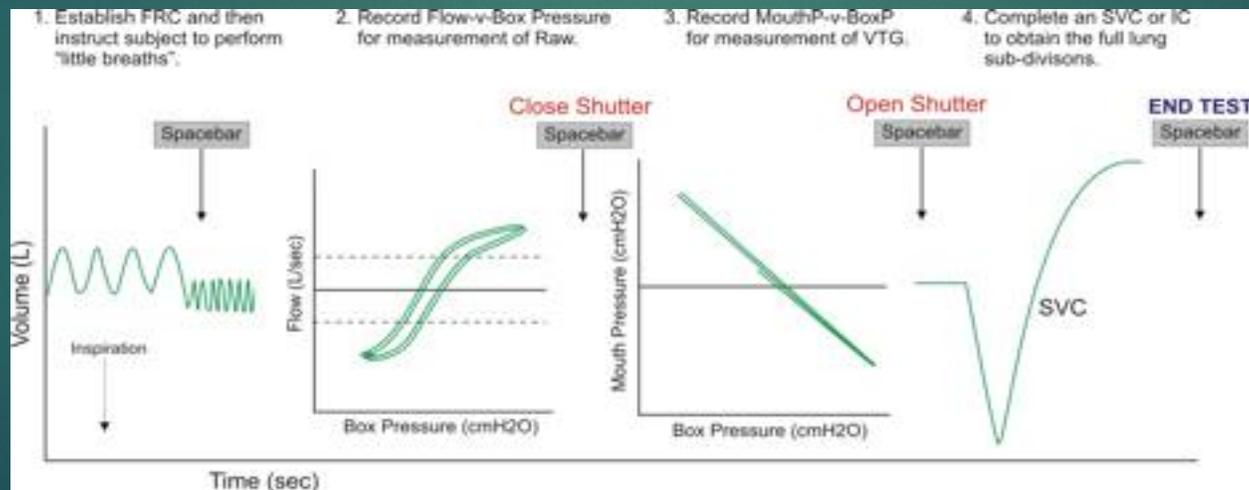
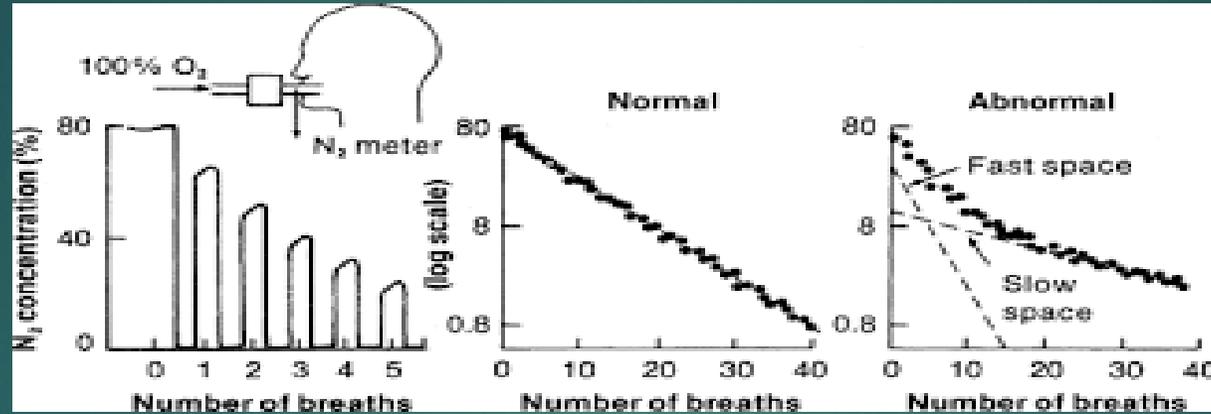
Types of Lung Volume testing.

- ▶ Nitrogen Washout. Lung volume can also be measured when you breathe nitrogen gas through a tube for a certain period of time. The concentration of the gas in a chamber attached to the tube is measured to estimate the lung volume
- ▶ Plethysmography, The most accurate way of lung volume testing. You sit in a clear airtight box that looks like a phone booth. The technologist asks you to breathe in and out of a mouthpiece. Changes in pressure inside the box help determine the lung volume. Also referred to as the "Body Box".

Nitrogen Washout

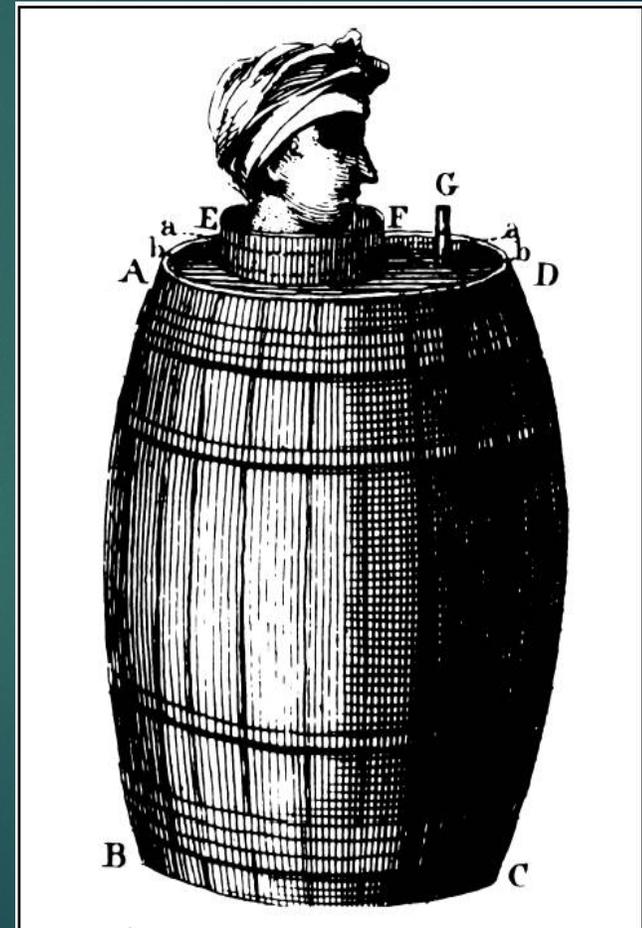
- ▶ Method by which replacing the Nitrogen in the lungs with Oxygen.
- ▶ Pt breathes 100% O₂ for up to 7 minutes or until the N₂ concentration is less than 1% to washout the nitrogen from the lungs.
- ▶ A patient with normal lung function will washout in 3 minutes or less.
- ▶ Pts. with O.L.D. (emphysema may not washout even after 7 minutes
- ▶ Switch in occurs at the end of normal expiration.
- ▶ Breath by breath analysis is utilized by the rapid N₂ analyzer.
- ▶ If N₂ analyzer fails to drop or spikes during the maneuver there is a leak in the system.

N₂ and Pleth Graphs



Body Plethysmography

- The first example of plethysmography recognized by the scientific community dates back to 1790. Scientist **Robert Menzies** immersed a person up to the chin in a barrel of water and measured the rise and fall of the level of water and thus determining the amount of air inhaled and exhaled during normal breathing



Body Plethysmography

Modern plethysmography is based on innovations brought by three American scientists, **Arthur B. DuBois**, **Stella Y. Botelho** and **Julius H. Comroe, Jr.**, who in 1956 used their knowledge of mathematics and fluid dynamics to solve technical problems associated with plethysmography at that time.



Lung Volumes

- ▶ Body Plethysmography (BP)
- ▶ Measurement of FRC by body plethysmograph is based on an application of Boyle's law

$$P_1V_1 = P_2V_2$$

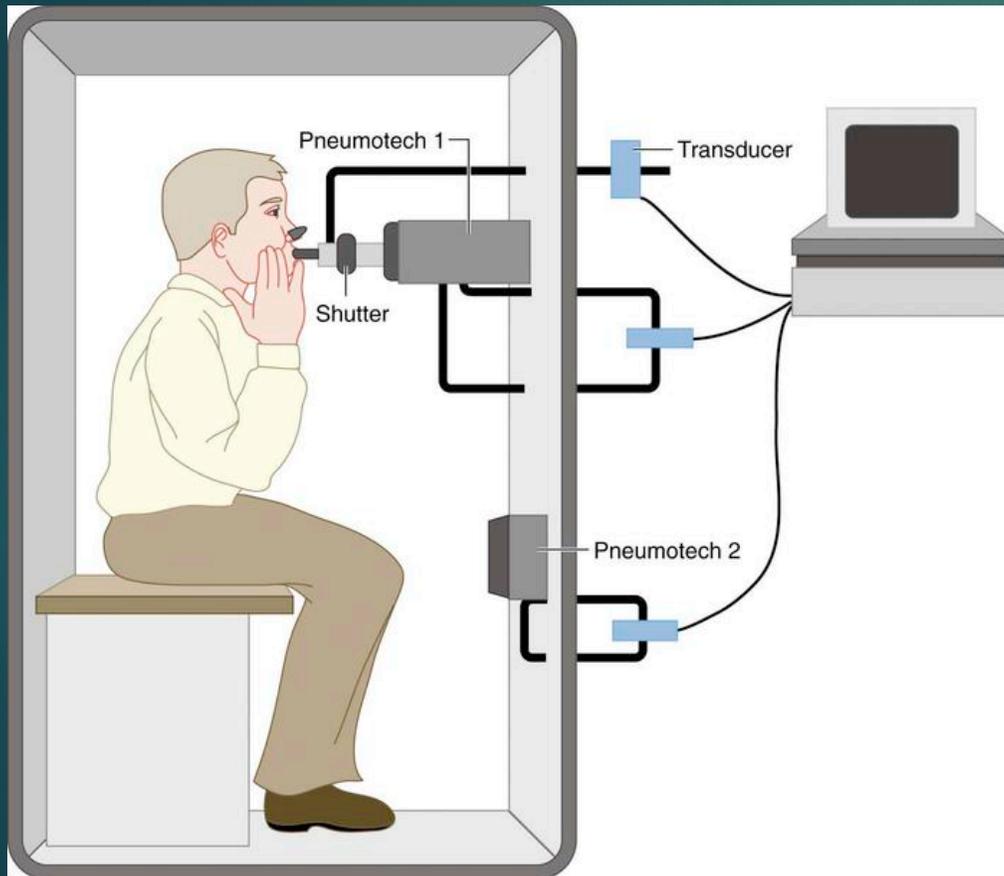
or

$$V_1 = \frac{P_2V_2}{P_1}$$

Body Plethysmography (BP)

- ▶ Unlike gas dilution tests, BP includes both air in communication with open airways as well as air trapped within non-communicating thoracic compartments
- ▶ In patients with air trapping, plethysmography lung volumes are usually larger than those measured with gas dilution methods
- ▶ Volume measured is referred to as *thoracic gas volume* (TGV or VTG)
- ▶ ATS is recommending term be dropped and changed to "*plethysmographic lung volume*" (VL, pleth), and "*FRC by body plethysmography*" or TGV at FRC (FRCpleth)

Body Plethysmography (Body Box)



- The patient sits inside a fully enclosed rigid box and breathes through a mouthpiece connected through a shutter to the internal volume of the box
- The subject makes respiratory efforts against the closed shutter (like panting), causing their chest volume to expand and decompressing the air in their lungs.
- While breathing in and out again into a mouthpiece. The volume of all gas within the thorax can be measured by changes in pressure inside the box and allow determination of the lung volume.

Clinical Applications and Interpretations

↑ FRC

gas trapping
due to
intrathoracic
airway
obstruction

cystic lung
disease

↓ FRC

abnormal
alveolar
development

reduced recoil of
chest-wall

decreased lung
compliance

atelectasis

The Infant plethysmograph



Bronchoprovocation; Methacholine Challenge

- ▶ Bronchoprovocation Test-Indications Diagnosis of asthma:
- ▶ Typical symptoms but normal spirometry and no response to IBD.
- ▶ Atypical symptoms eg. nocturnal awakening, cough;
- ▶ Evaluate occupational asthma, reactive airways dysfunction syndrome, or irritant-induced asthma; screening test for asthma, such as scuba divers, military personnel.
- ▶ Assessment of asthma therapy identification of specific asthma triggers.

Exercise Testing

- ▶ **Exercise Challenge Test:**
- ▶ Exercise Challenge Test An exercise challenge test is the most direct way to establish a diagnosis of EIB.
- ▶ This usually involves six to eight minutes of ergometer or treadmill exercise, sufficient to raise the heart rate to 85 percent of the predicted maximum.
- ▶ A test is generally considered positive if the FEV1 falls by 10 percent or more, although a fall of 15 percent is more diagnostic After a baseline value has been established,
- ▶ FEV1 can be measured before and 2.5, 5, 10, 15, and 30 minutes after exercise and correlated with symptoms.

ABG:

- ▶ ABG Arterial blood gases (ABGs) may be a helpful adjunct to pulmonary function testing in selected patients.
- ▶ The primary role of measuring ABGs in stable outpatients is to confirm hypoventilation when it is suspected on the basis of clinical history (eg , respiratory muscle weakness, advanced COPD), an elevated serum bicarbonate level, and/or chronic hypoxemia.
- ▶ ABGs also provide a more accurate assessment of the severity of hypoxemia in patients who have low normal oxyhemoglobin saturation

Thank You OSRC, It's members, and
all Oregon RCP's who attended!

