Pulmonary Function Test

Geisinger

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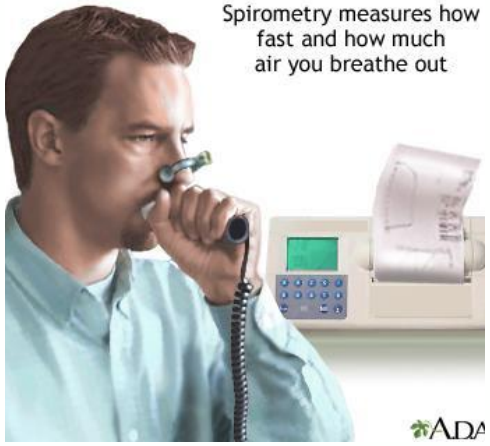
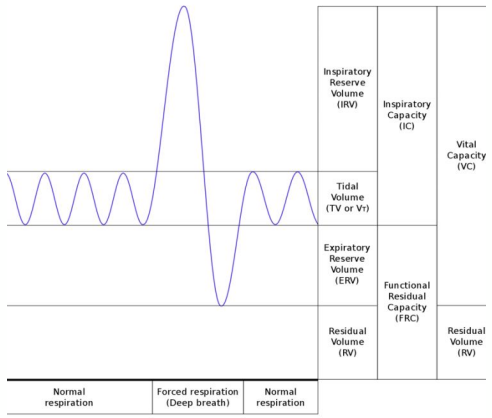
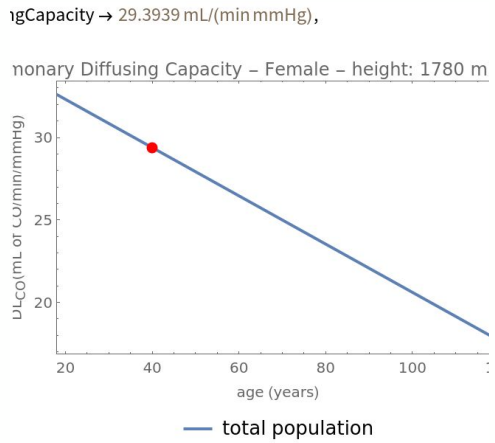
Pulmonary Function Testing



Spirometry

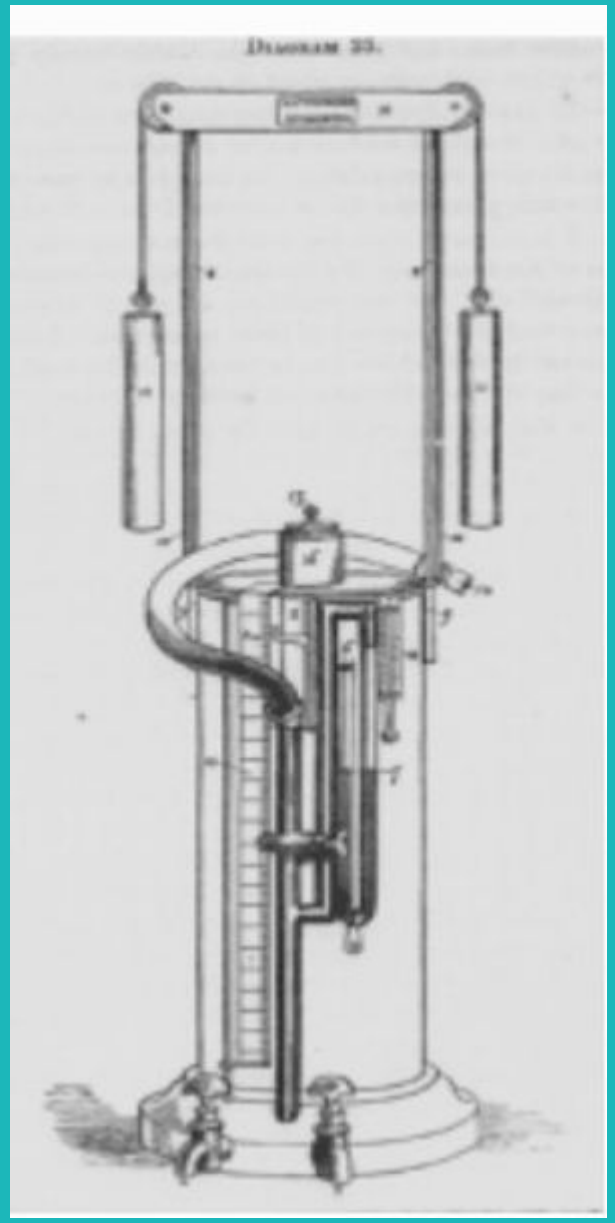


Static Lung Volumes



Diffusion Capacity

Spirometry



Spirometry

Indications

TABLE 1 Indications for spirometry

Diagnostic
- To evaluate symptoms, signs or abnormal laboratory tests
- To measure the effect of disease on pulmonary function
- To screen individuals at risk of having pulmonary disease
- To assess pre-operative risk
- To assess prognosis
- To assess health status before beginning strenuous physical activity programmes

Monitoring
- To assess therapeutic intervention
- To describe the course of diseases that affect lung function
- To monitor people exposed to injurious agents
- To monitor for adverse reactions to drugs with known pulmonary toxicity

Disability/impairment evaluations
- To assess patients as part of a rehabilitation programme
- To assess risks as part of an insurance evaluation
- To assess individuals for legal reasons

Public health
- Epidemiological surveys
- Derivation of reference equations
- Clinical research

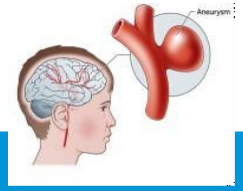
Eur Respir J 2005; 26: 319-338

Contraindications

Increase in myocardial demand or changes in BP

- Acute MI within 1 wk
- ↓BP or severe HTN
- Significant arrhythmia
- Non-compensated heart failure
- Uncontrolled PH
- Acute cor pulmonale
- Clinically unstable Pulmonary embolism
- History of syncope related to forced expiration/cough

Increased intracranial/intraocular/sinus pressure



- Cerebral aneurysm
- Brain surgery within 4 wks
- Recent concussion with continuing symptoms
- Eye surgery within 1 wk
- Sinus surgery or middle ear surgery or infection within 1 wk

Increased Intrathoracic or intraabdominal

- Presence of pneumothorax
- Thoracic surgery within 4 wks
- Abdominal surgery within 4 wks
- Late-term pregnancy

Infection Control Issues

- Active or suspected transmissible infection, including TB
- Conditions predisposing to transmission of infections, e.g. hemoptysis, significant secretions, or oral lesions or oral bleeding

Standardization of Spirometry 2019 Update An Official American Thoracic Society and European Respiratory Society Technical Statement

Activities to be Avoided Before PFT

Activity	Reason	Time
Smoking/Vaping	To avoid acute bronchoconstriction due to smoke inhalation	1 hour
Consuming intoxicants	To avoid problems in coordination, comprehension, and physical ability	8 hours
Vigorous exercise	To avoid potential exercise-induced bronchoconstriction	1 hour
Tight/Restrictive clothing	To avoid external restrictions on lung function)	

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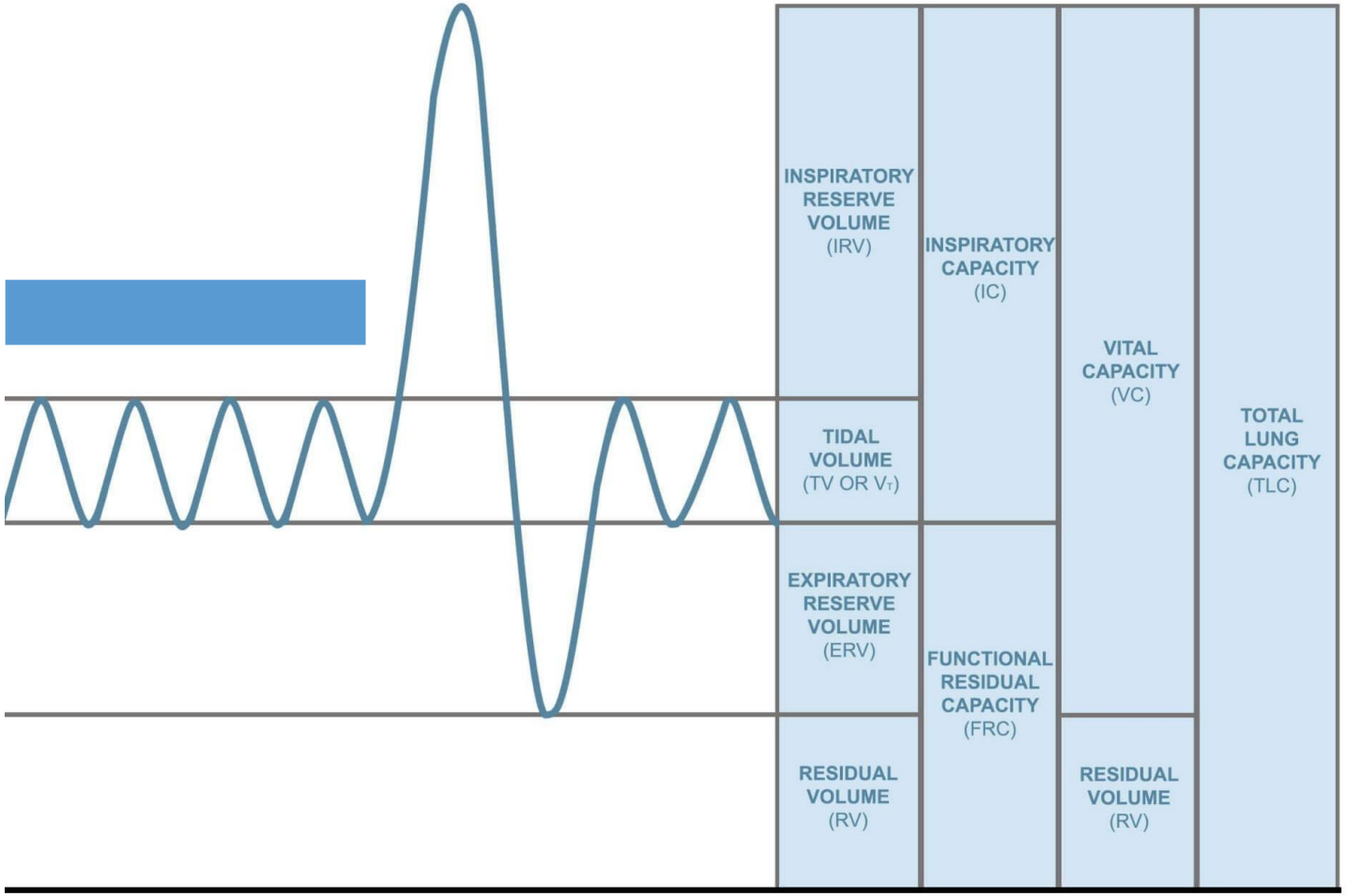
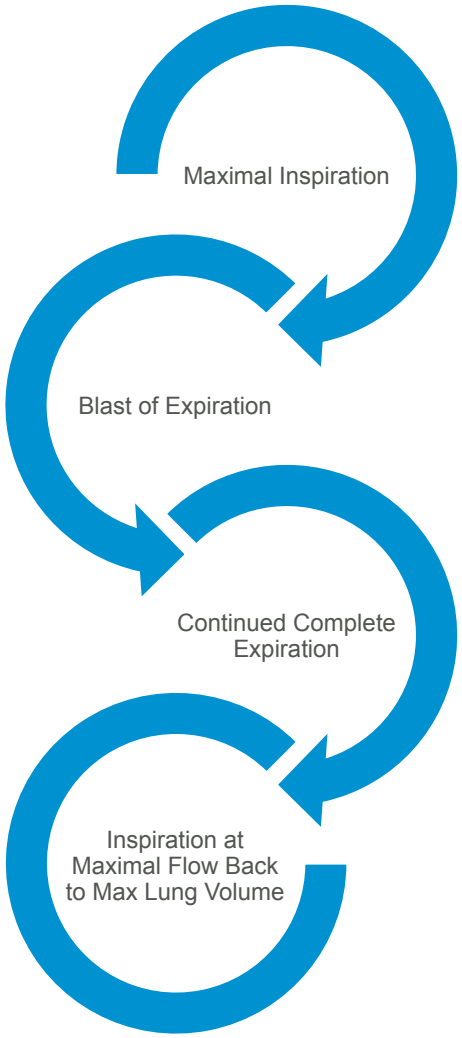
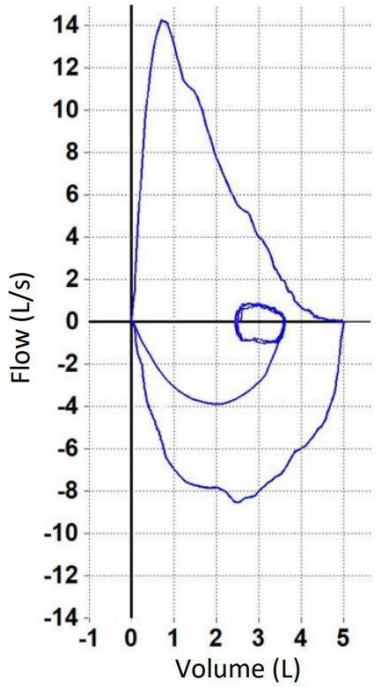
Lung Volumes and Capacities

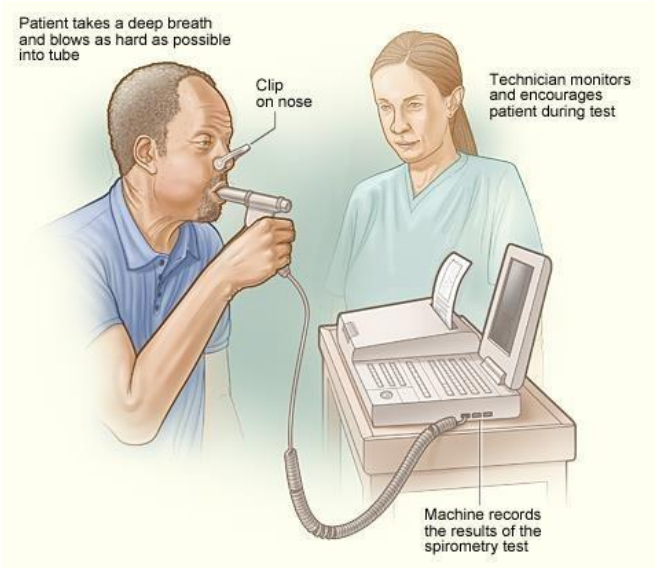


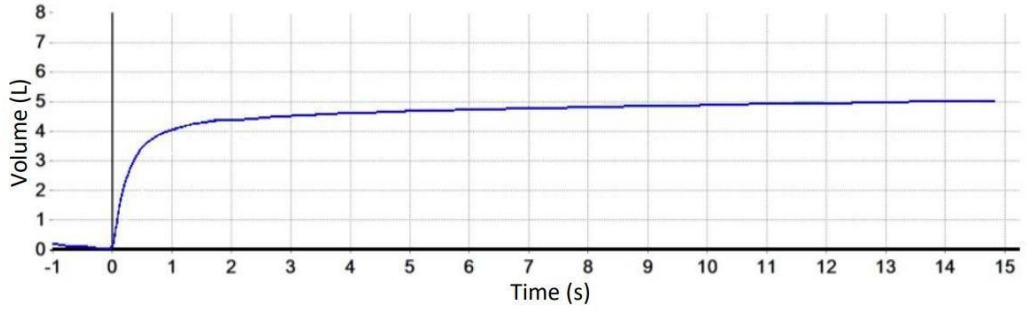
FVC Maneuver

Four distinct phases of the FVC maneuver









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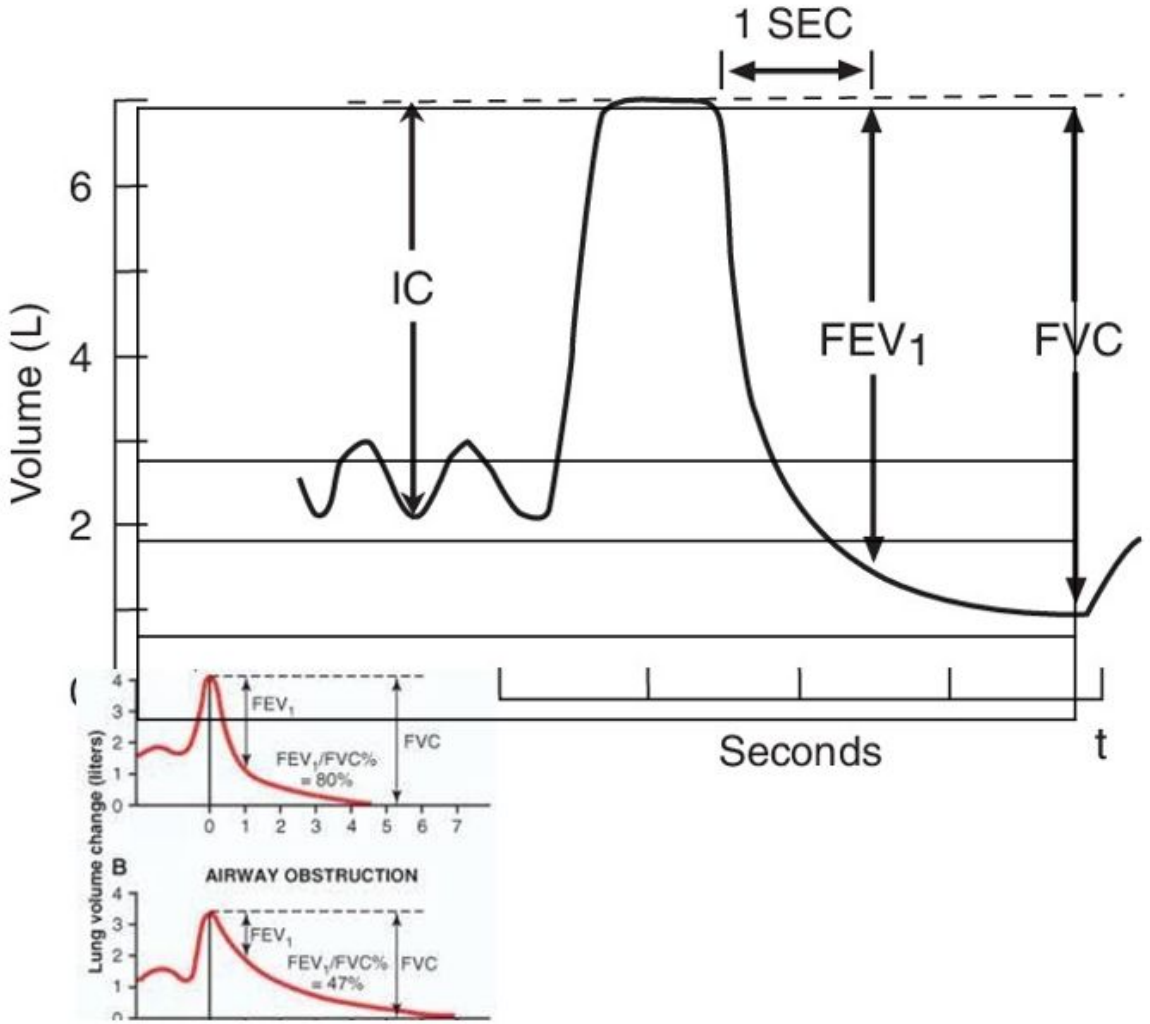
Indices Measured by Spirometry

- FVC and FEV1
- From a maximal inspiration,
  - Maximal volume of air exhaled with maximally forced effort: FVC
  - Maximal volume exhaled in 1st second of a forced expiration: FEV1
- FEV_1/FVC ratio: Ratio of FEV_1 to FVC X 10((expressed as a percent)



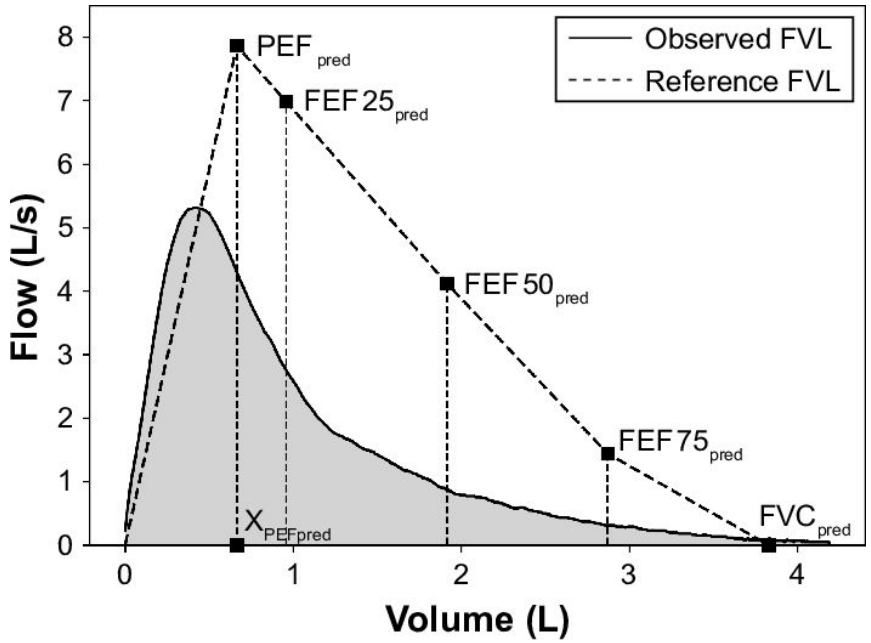
FEV1/FVC Ratio

- This ratio is used to differentiate an obstructive from a restrictive pattern.
  - In obstructive disorders, FEV1 decreases more significantly.
  - In restrictive disorders, the ratio is either normal or increased.

- Normally, the FEV1/FVC ratio is greater than 0.7, but it decreases (to values <0.7) with normal aging . In children, however, it is higher and can reach as high as 0.9 . The decline in this ratio as we age reflects the decrease in elastic recoil of the lungs that occurs with aging.

Other Measurements: FEF 25-75%

- **F.E.F. 25-75%:** Forced expiratory flow 25-75%
- Mean forced expiratory flow between 25% and 75% of the FVC
- Also called maximal mid expiratory flow rate (MMEFR)
- Represents the average of all instantaneous flow rates measured from the time when 25 % of the vital capacity has been exhaled to the point when 75% vital capacity has been exhaled
- Used to be considered as a measure of small airways function



BUT

Highly dependent on the validity of the FVC measurement and the level of expiratory effort

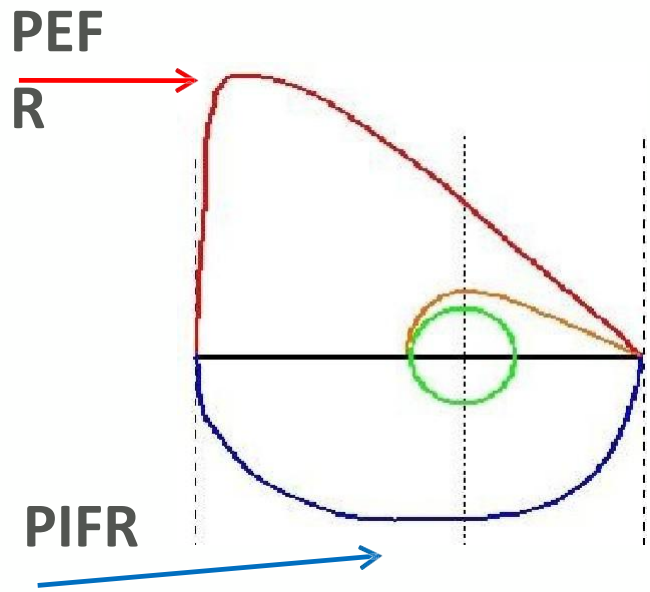
Other Measurements: PEFR, PIFR

Peak Expiratory Flow Rate:

- The highest flow achieved from a maximum forced expiratory manoeuvre started without hesitation **from a position of maximal inspiration.**
  - Normally, it takes place immediately after the start of the exhalation and it is effort-dependent.
  - PEF drops with a submaximal effort in obstructive and, to a lesser extent, restrictive disorders. PEF measured in the laboratory is similar to the peak expiratory flow rate (in liters/minute)

Peak Inspiratory Flow Rate:

- Highest inspiratory flow achieved from a maximum forced inspiration, starting without hesitation **from the point of maximal lung deflation**, expressed in $L*s^{-1}$



Other Flows and Volumes

- FIF50: Flow at 50% inhaled vital capacity
  - The ratio of FEF at 50% VC to forced inspiratory flow at 50% VC (FEF50/FIF50) is sometimes used as an indicator of upper airway obstruction

- SVC: Slow vital capacity also called the Vital Capacity (VC) is similar to the FVC, but the exhalation is intentionally slow. In a normal subject, the SVC is equivalent to the FVC while in patients with an obstructive lung disorder, the SVC is usually larger than the FVC.

- Timed VCs -**FEV6 – Forced expiratory volume in six seconds**: FEV6 is defined as the volume of air exhaled in the first 6 seconds of the FVC and its only significance is that it can sometimes substitute for the FVC in patients who fail to exhale completely or to be substituted for FVC for “office” spirometry

Possible Side Effects of Spirometry

- Feeling Light-Headed
- Headache
- Facial Redness
- Fainting: Reduced Venous Return or Vasovagal Attack (Reflex)
- Transient Urinary Incontinence

Spirometry – Usual Patterns

Normal Pattern

Obstructive Pattern

Restrictive Pattern

Mixed Pattern

The ideal VT Curve should either have a plateau for 1 s or show and effort of at least 6 s

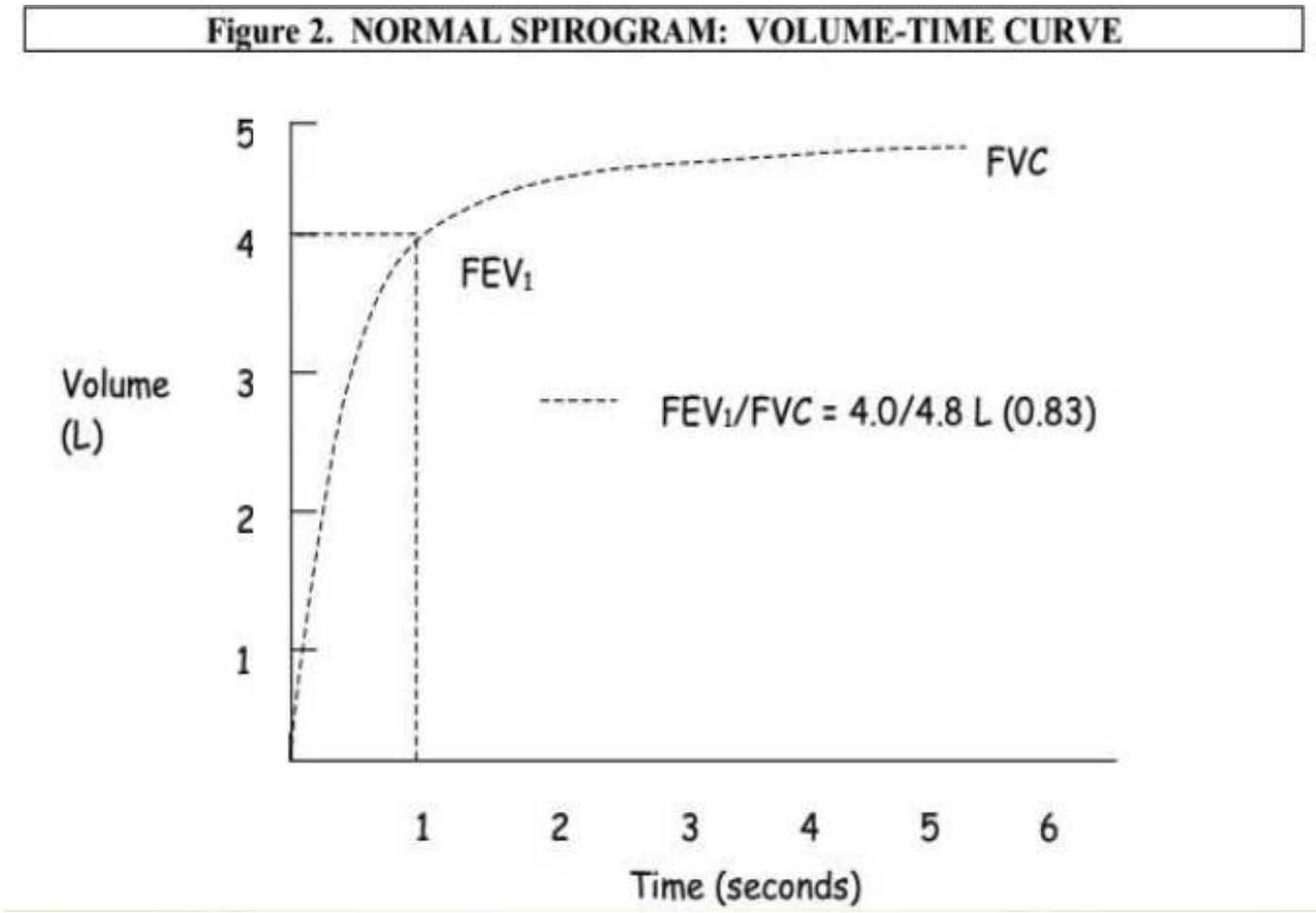
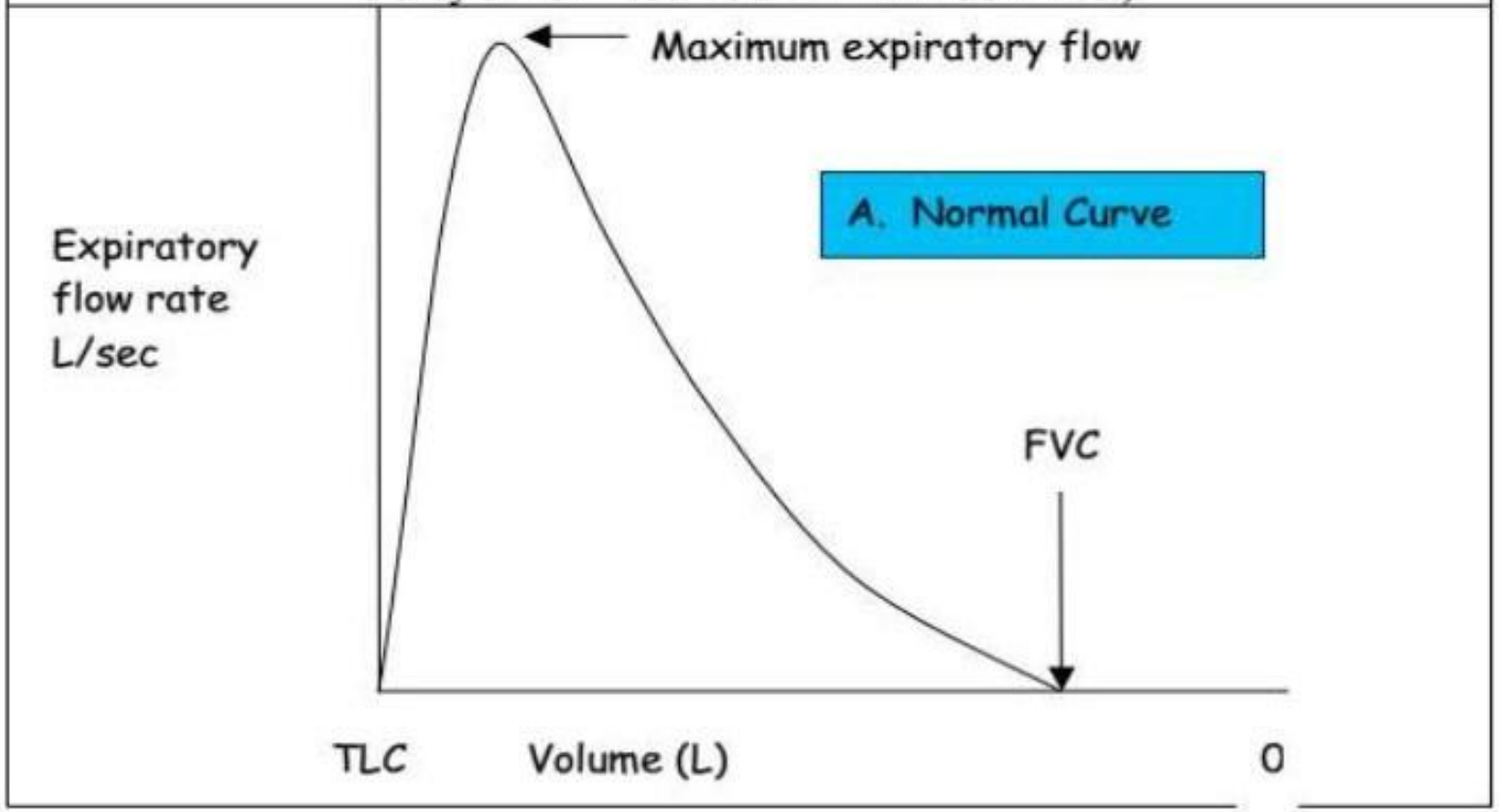
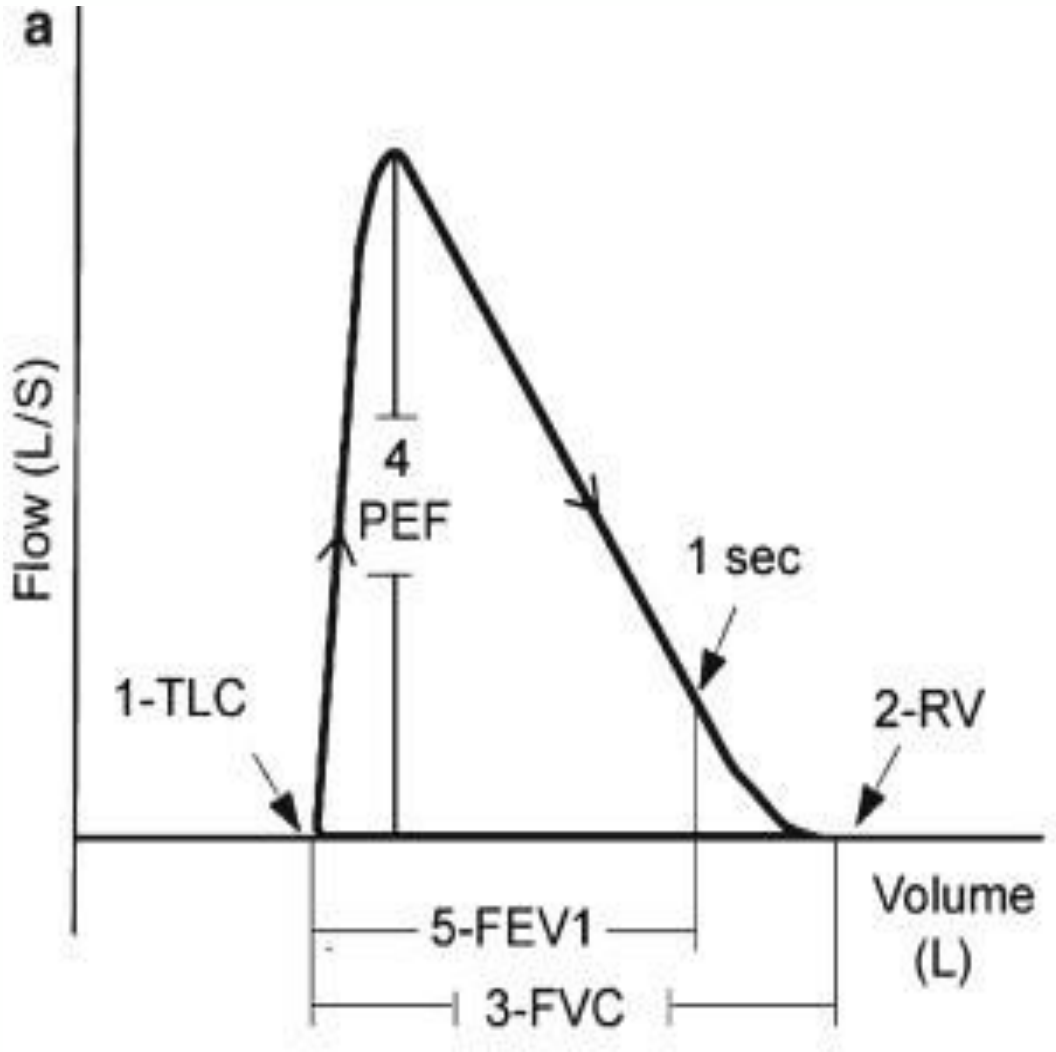


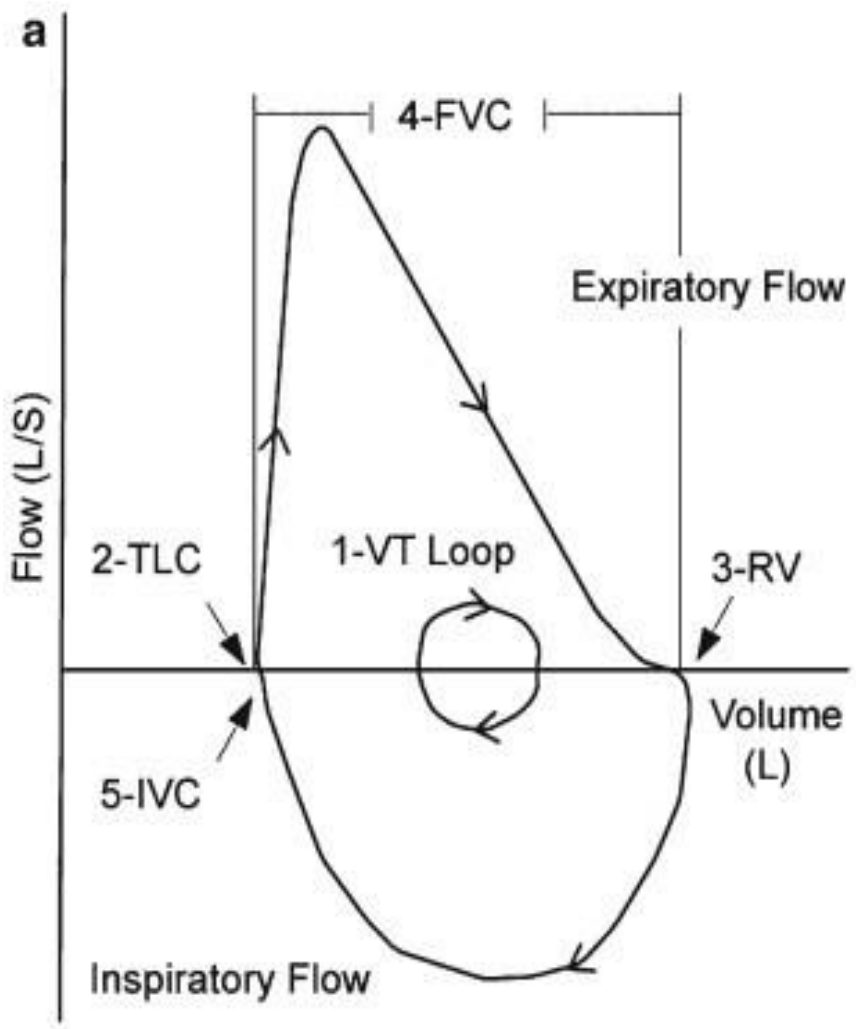
FIGURE 6A. NORMAL FLOW–VOLUME CURVE
(On exhalation there is a rapid rise to the maximal expiratory flow followed by a steady uniform decline until all air is exhaled.)



1. TLC is represented by the leftmost end of the curve (cannot be measured by spirometry);
2. RV is represented by the rightmost end of the curve (cannot be measured by spirometry);
3. FVC is represented by the width of the curve;
4. PEF is represented by the height of the curve;
5. FEV1 is the distance from TLC to the 1st second mark (normally located at ~ 80% of the FVC)



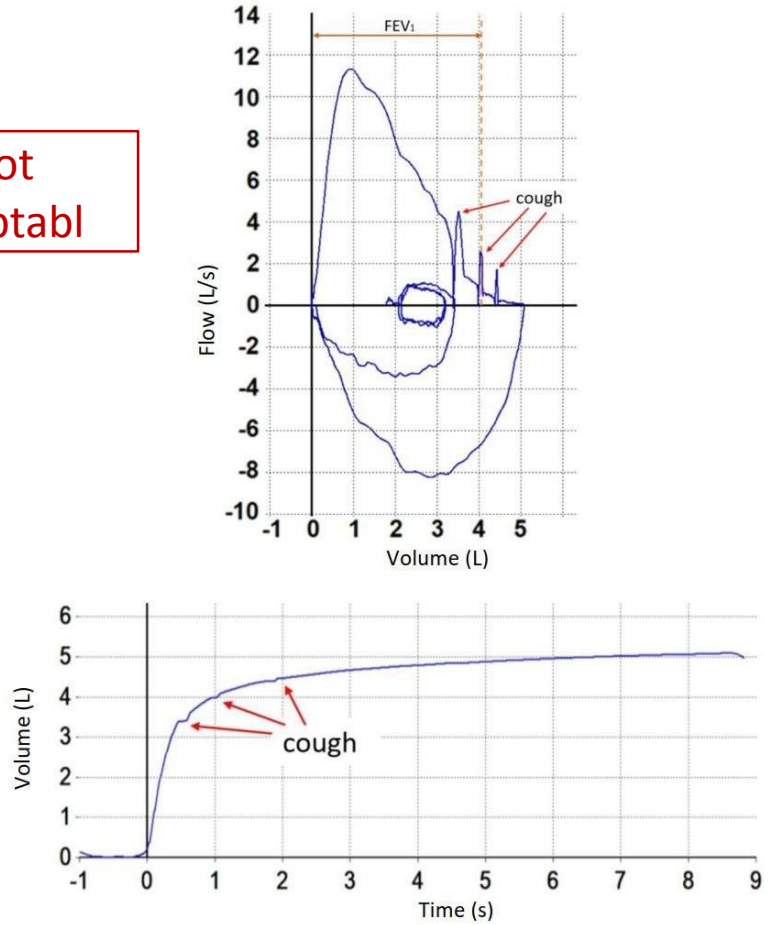
- The expiratory curve forming the upper and having a peak (maximum flow = PEFR)
- **Ascending limb** – effort dependent
- **Descending limb** – effort independent
- The inspiratory curve is saddle shaped forming the lower parts of that loop
- Curve starts at residual volume And ends at TLC



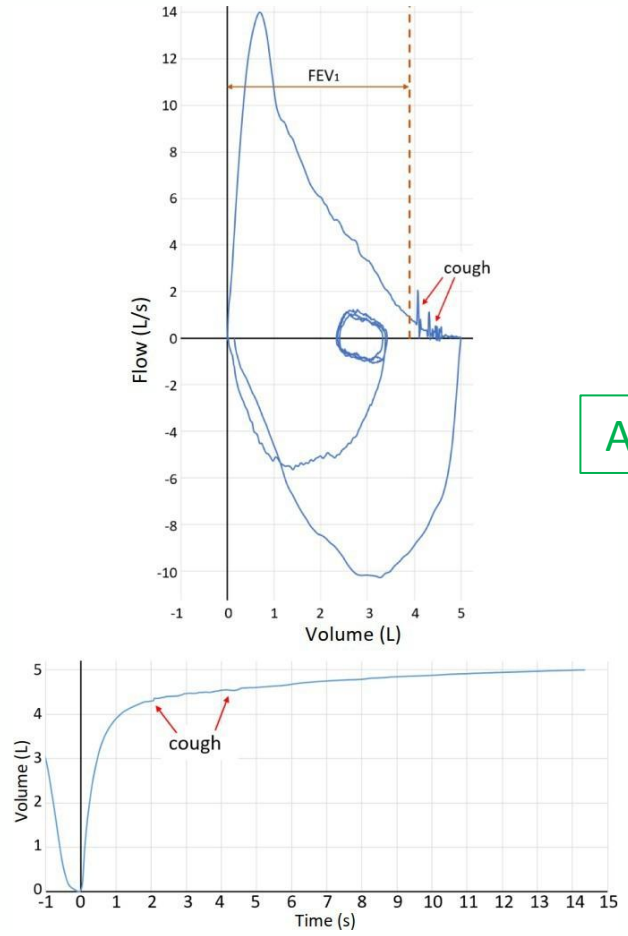
Errors

Cough in 1st Second

Not Acceptable



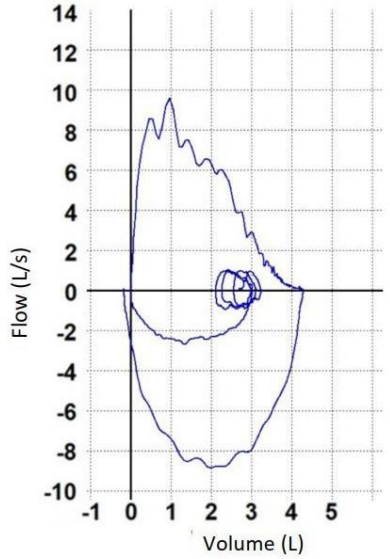
Cough After 1st Second



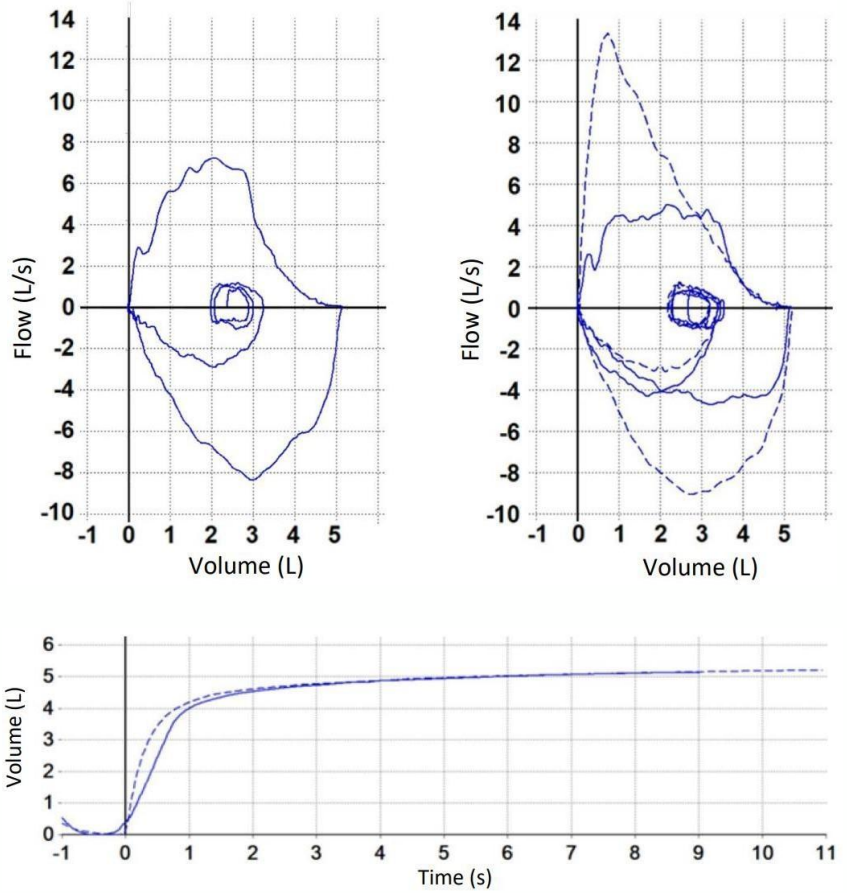
Acceptable

Errors

Tongue Obstructing Mouthpiece



Submaximal Effort



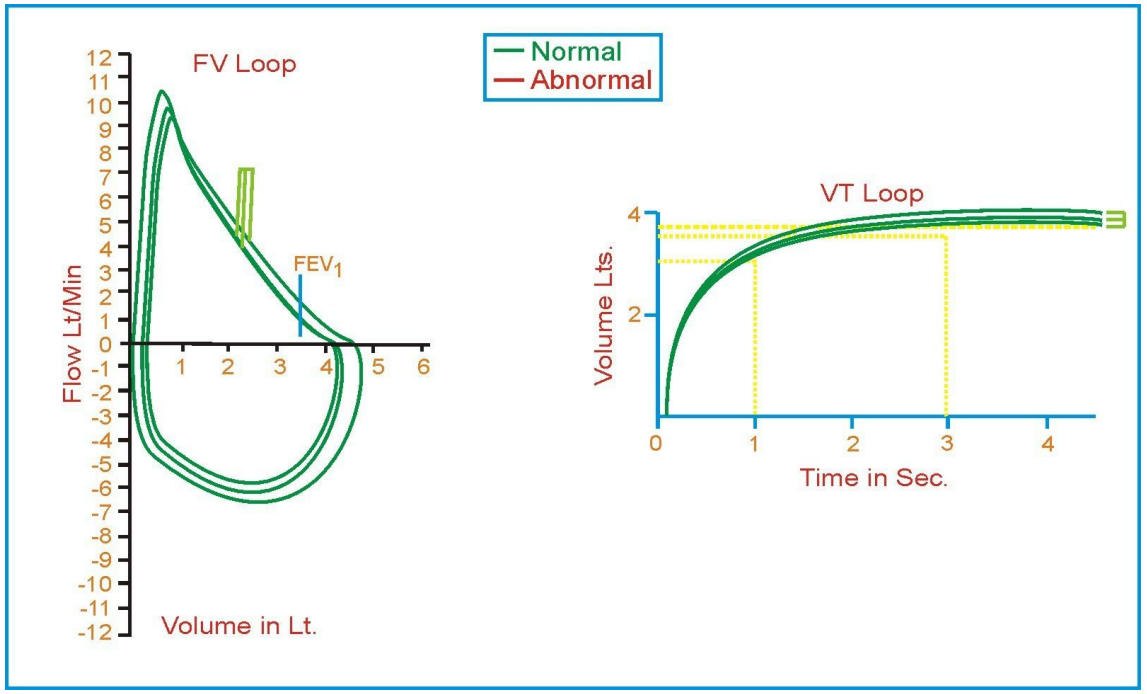
- ***Rounded*** flow-volume curve
- ***Less steep*** slope at the start of the V-T curve.
- Rise time >150 ms

Reproducible Spirometry

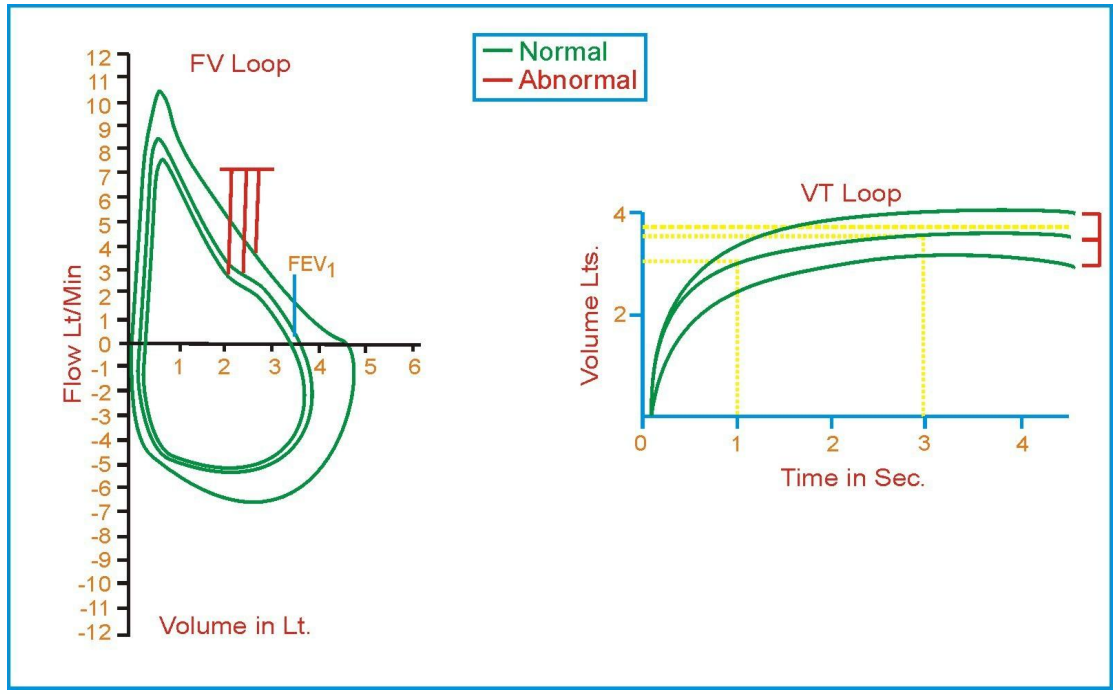
- Three accepted tests should be obtained
- The two largest FVC should be within 150 ML and 5% difference
- The two largest FEV1 should be within 150 ML and 5% difference
- If above is not possible, continue to repeat effort until 8 attempts performed or patient cannot continue, then save the best 3 maneuvers

Is Test Reproducible?

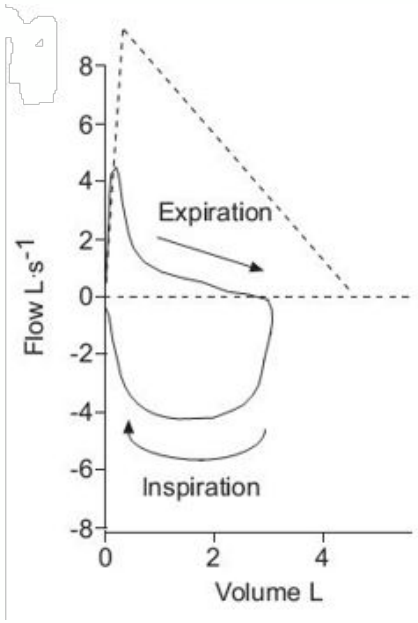
Reproducible Test



Non-Reproducible Test



Ventilatory Impairments on Spirometry



Obstructive

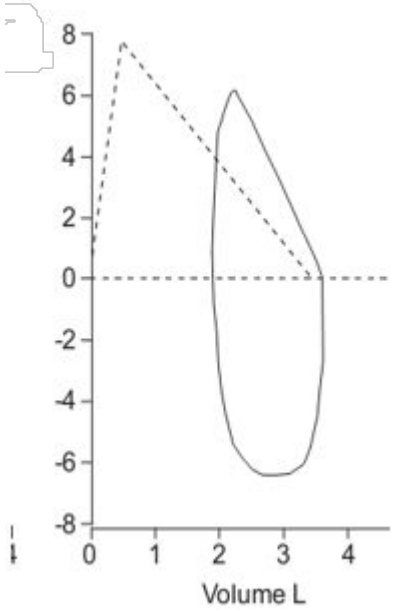
- FEV_1/FVC: <LLN
- FVC: >LLN
- FEV_1: <LLN

Restrictive

- FEV_1/FVC: >LLN
- FVC: <LLN

Possible Restriction

- FEV_1: <LLN



Mixed

- FEV_1/FVC: <LLN
- FVC: <LLN

Possible Mixed

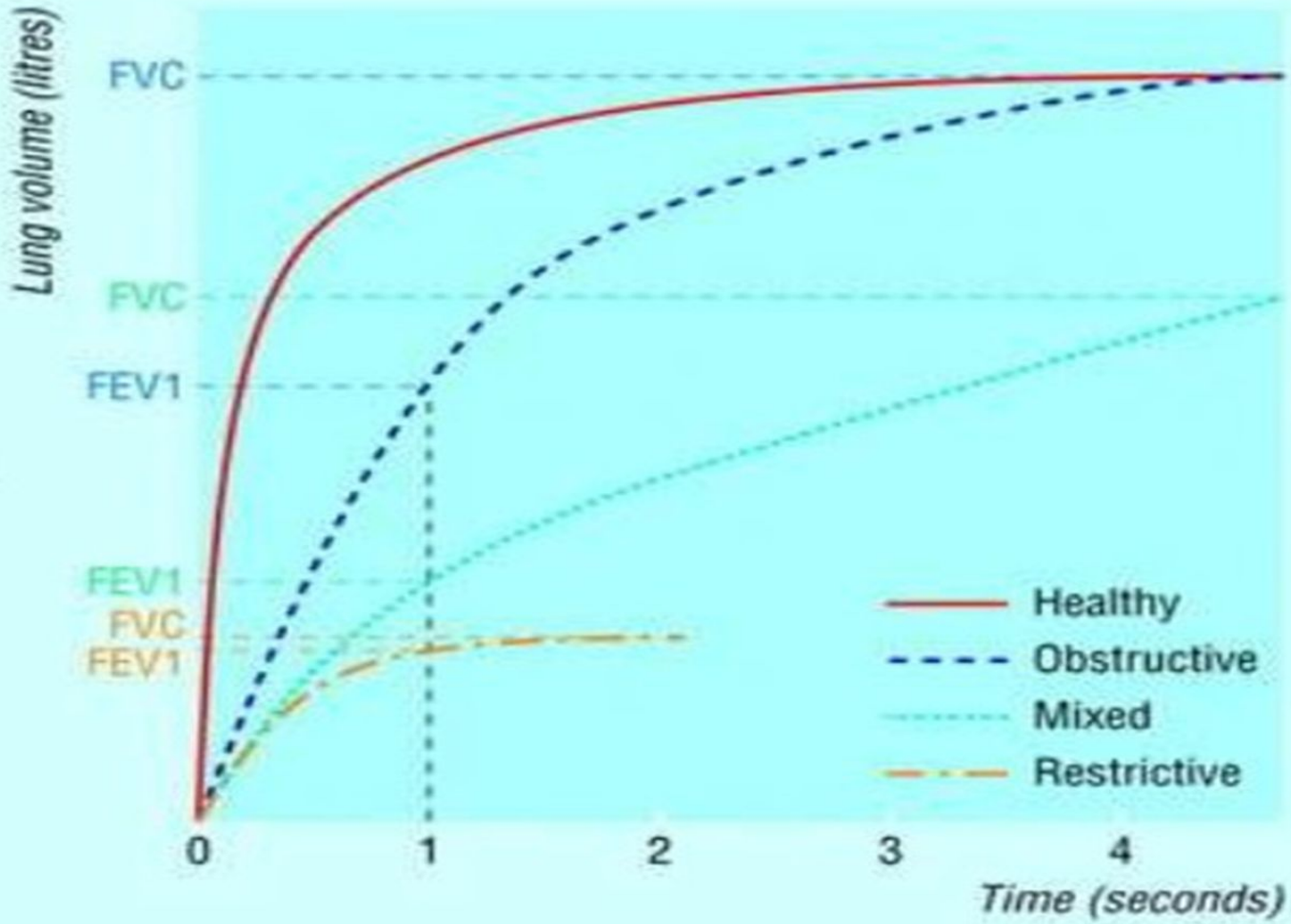
- FEV_1: <LLN

Interpretation

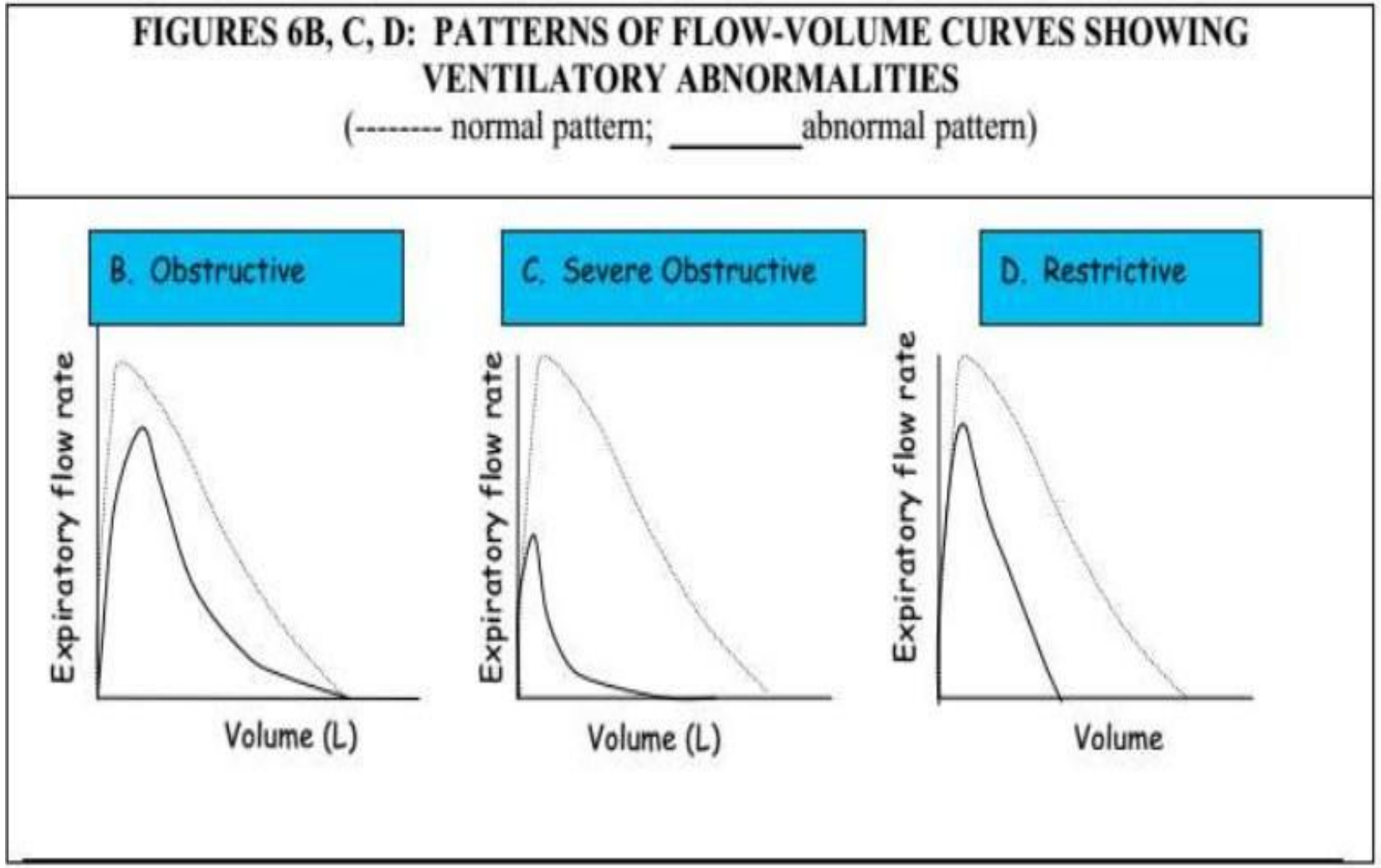
Obstructive disorders
- FEV_1 reduced
- FVC normal
- FEV_1/FVC ratio reduced
- Exhalation prolonged (normal volume, exhaled more slowly)

Restrictive disorders
- Both FEV_1 and FVC reduced
- FEV_1/FVC ratio normal or increased
- Full exhalation achieved rapidly (in 2-3 seconds)

Mixed disorders
- Both FEV_1 and FVC reduced
- FEV_1/FVC ratio reduced
- Exhalation prolonged



Abnormal Flow – Volume Patterns



Obstructive Disorders (FV Curve)

There are five features that make the diagnosis of a significant airway obstruction definite based on this curve alone

- **Decreased PEF** when compared to the predicted curve
- **Scooping of the curve after PEF** indicating airflow limitation
- The 1st second mark is almost the middle of the curve indicating **the FEV1 and FEV1/FVC ratio are slightly decreased**
- **FVC is decreased** when compared to the predictive curve
- The **inspiratory component of the curve is normal** excluding a central airway obstruction

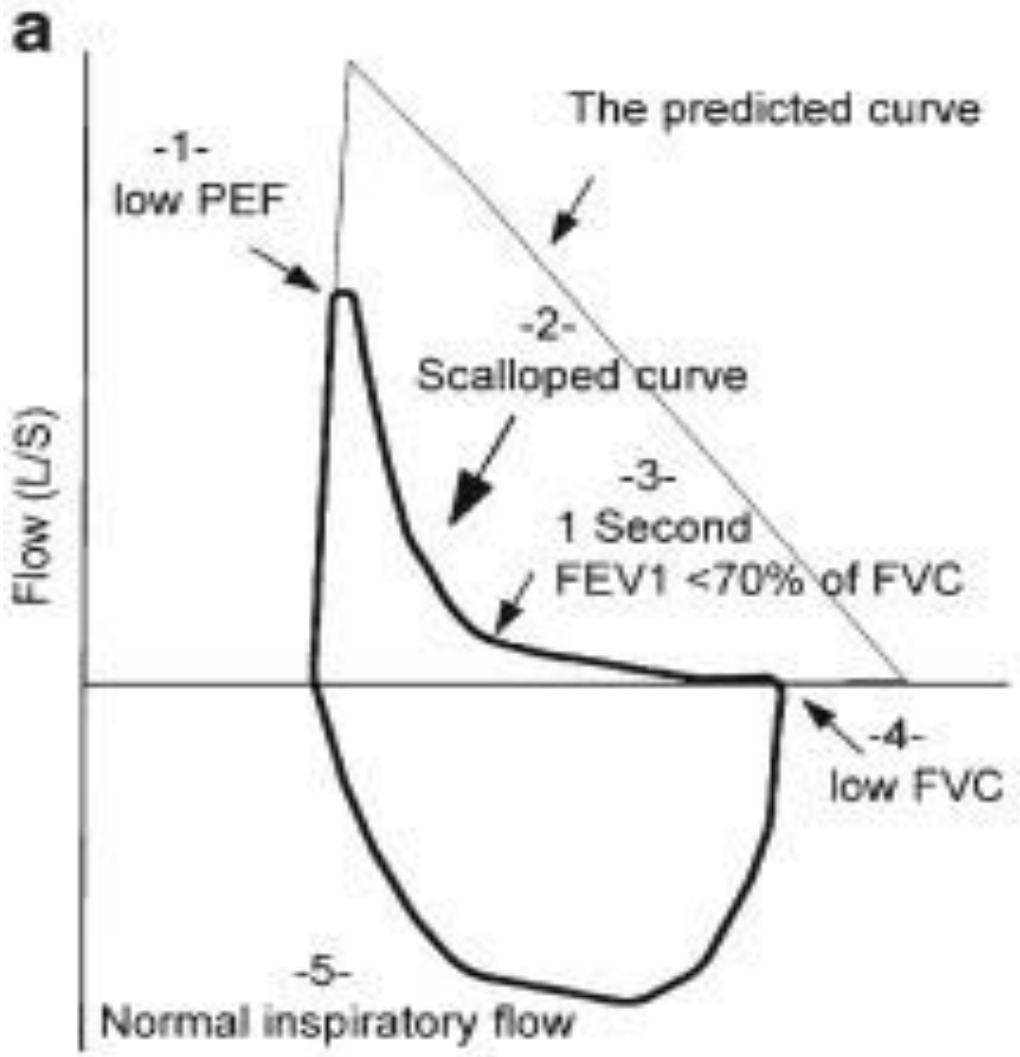
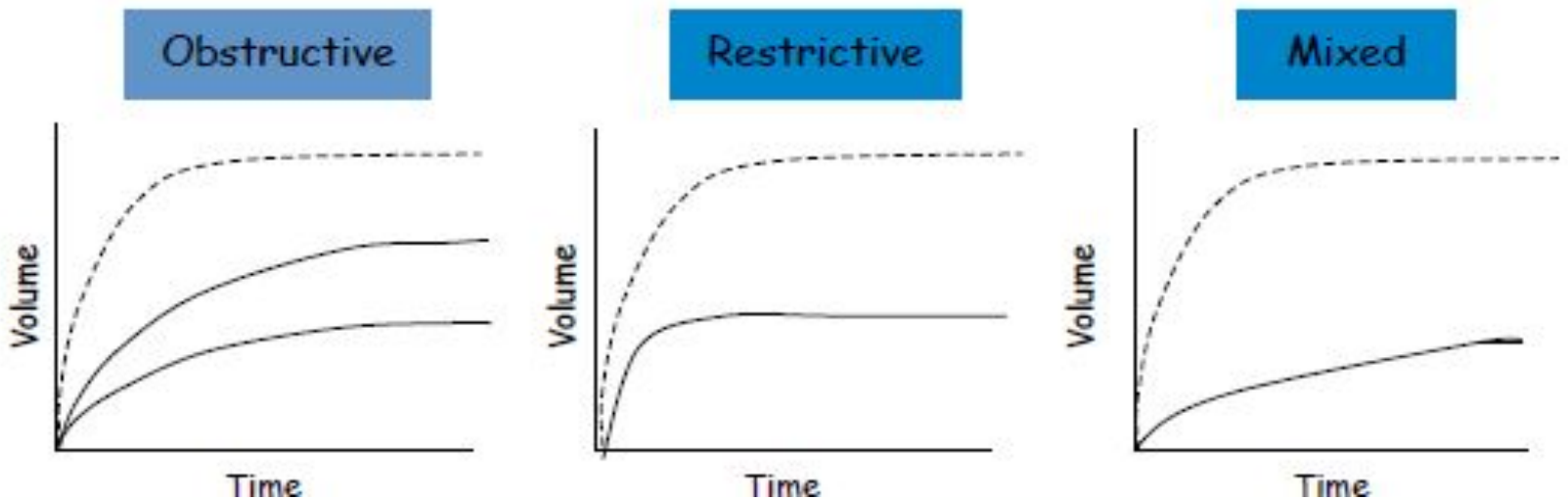
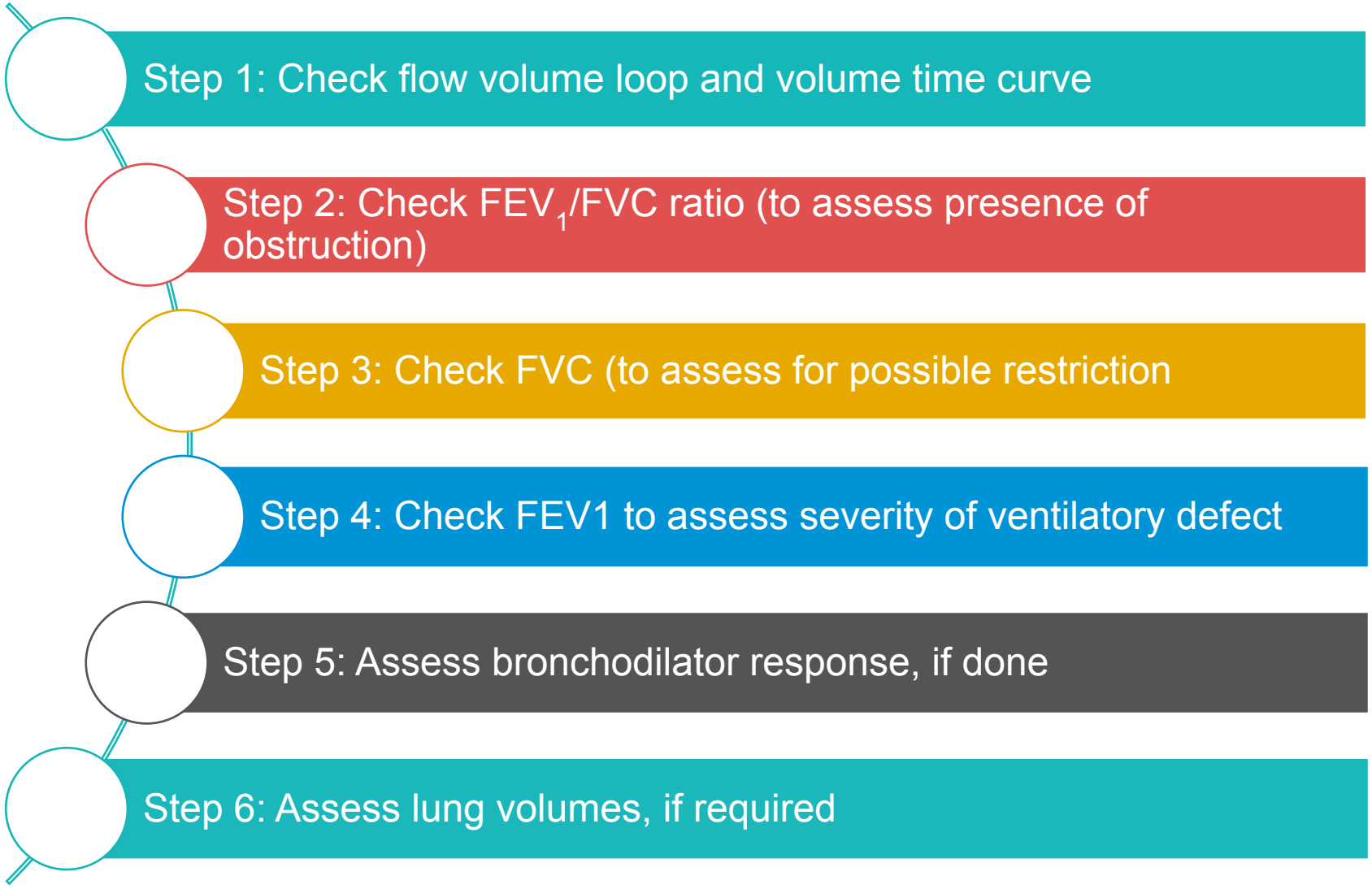


FIGURE 4. FEATURES OF VENTILATORY ABNORMALITY IN SPIROMETRY			
	OBSTRUCTIVE	**RESTRICTIVE**	**MIXED**
FEV_1	REDUCED	REDUCED OR NORMAL	REDUCED
FVC	REDUCED OR NORMAL	REDUCED	REDUCED
FEV_1/FVC	REDUCED	NORMAL OR INCREASED	REDUCED

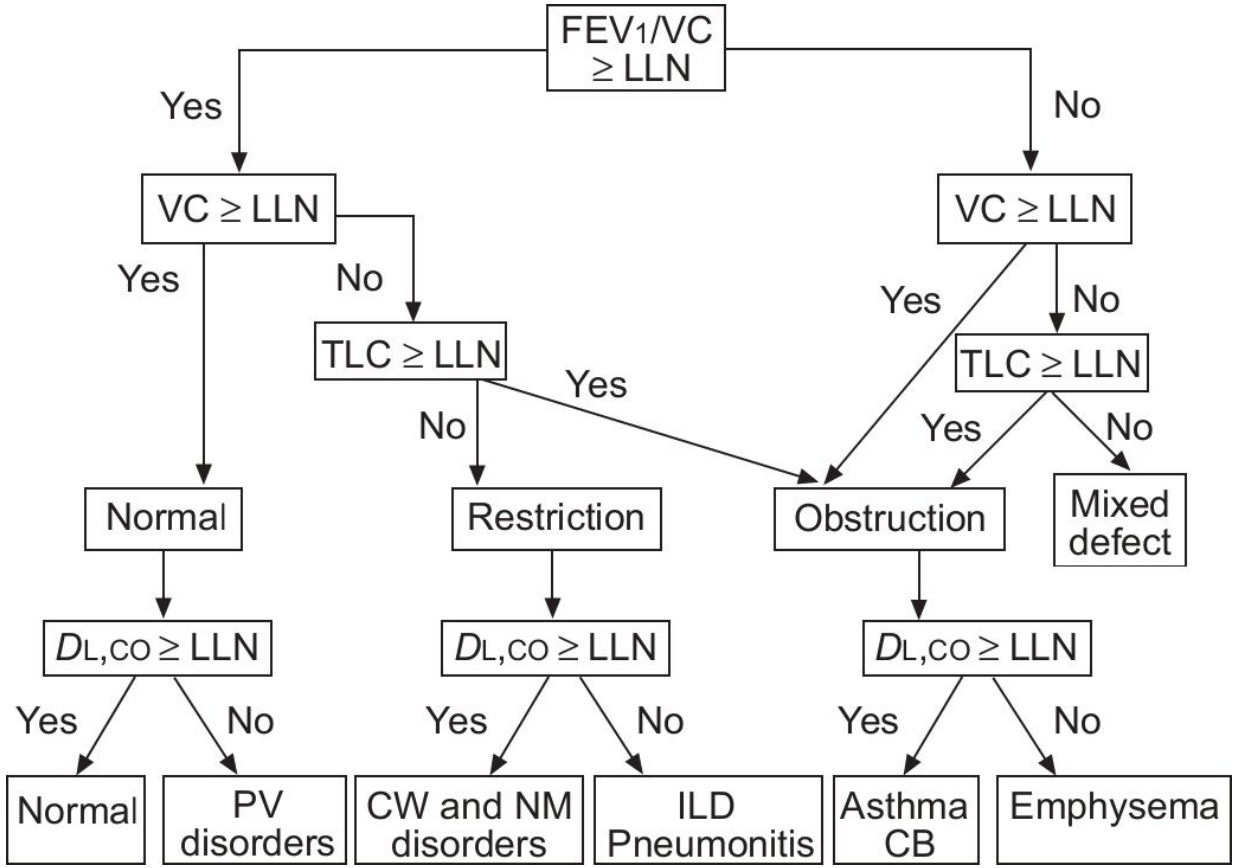
FIGURE 5. PATTERNS OF VENTILATORY ABNORMALITIES
(------- normal pattern; _____ abnormal pattern)



Sequence of Assessment



2005 Algorithm



- Use of VC (i.e., the largest VC of the SVC and FVC) in place of FVC in the ratio (i.e., FEV1/VC) (2005 ATS/ERS document)

<u>But 2021</u>

- Using VC more sensitive but not as specific compared to FEV1/FVC
- So FVC to be used for the FEV1/FVC ratio as they both should come from forced expiratory manoeuvres
- Robust reference equations for the FEV1/FVC ratio but not for FEV1/VC

ATS/ERS task force: standardisation of lung function testing. 2005

ERS/ATS technical standard on interpretive strategies for routine lung function tests. *Eur Respir J* 2021

Diseased Associated with Airflow Obstruction

- COPD (Chronic Bronchitis & Emphysema)
- Asthma
- Bronchiectasis
- Cystic Fibrosis
- Post Tuberculosis
- Lung Cancer (Greater Risk in COPD)
- Obliterative Bronchiolitis

Bronchodilator Responsiveness

- Determination of the degree of improvement of airflow in response to bronchodilator administration
- Measured by changes in FEV1 and FVC

Drugs to Avoid	Time
SABA	4-6 hrs
SAMA	12 hrs
LABA	24 hrs
uLABA	36 hrs
LAMA	36-48 hrs

	MDI	Jet nebulizer
1. Bronchodilator	Salbutamol MDI	Salbutamol
2. Bronchodilator dose	400 µg delivered as 4 MDI actuations of 100 µg	5mg
3. Method of bronchodilator administration	Separate MDI actuations delivered at ~30 s intervals via a holding chamber	Nebulization for 10 min, driving gas air at 6-10L/min
4. Wait time prior to post bronchodilator maneuvers	15 minutes after administration of the final MDI actuation	15 minutes after completion of the administration of the nebulized dose

Alternate bronchodilator: ipratropium bromide 160mcg MDI, wait time 30 mins

Changes in Recommendations

ATS/ERS 2005 Recommendations	ATS/ERS 2021 Recommendations
⩾12% and 200 mL in FEV1 or FVC from baseline	>10% of predicted value in FEV1 or FVC

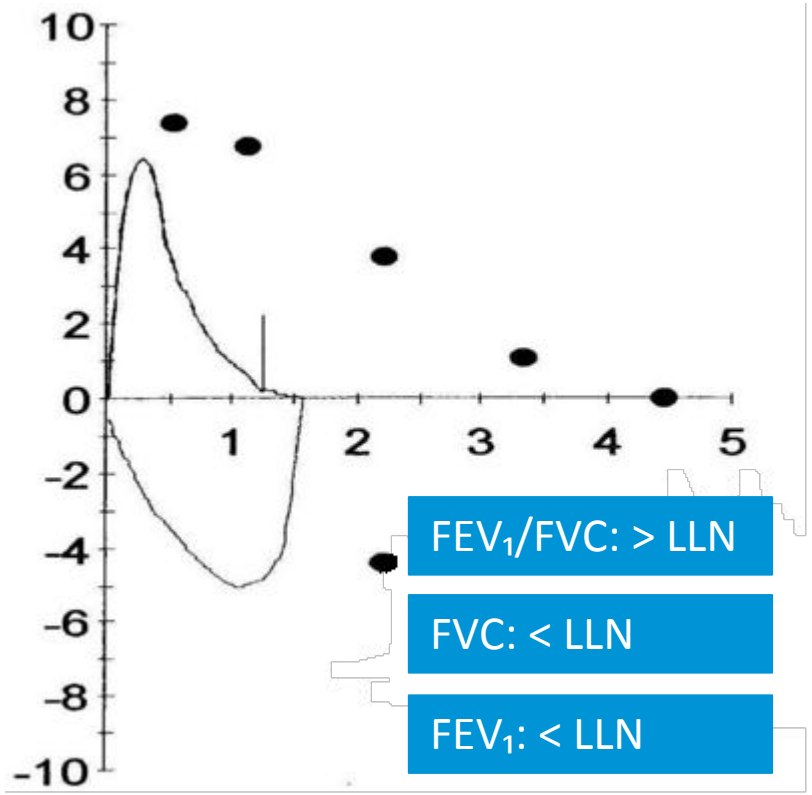
- The absolute and relatives change in FEV1 and FVC
  - Inversely proportional to baseline lung function, and are associated with height, age and sex in both health and disease

$$\text{Bronchodilator Response} = \frac{(\text{Post-bronchodilator value (l)} - \text{Pre-bronchodilator value (l)}) * 100}{\text{Predicted value (l)\#}}$$

minimizes sex and height difference in assessing BDR

Restrictive Ventilatory Defect

	Pre-Bronchodilator (BD)		
Test	Obs.	Pred.	% Pred.
FVC (L)	1.57	4.46	35
FEV_1 (L)	1.28	3.39	38
FEV_1/FVC (%)	82	76	
FRC	1.73	3.80	45
RV (L)	1.12	2.59	43
TLC (L)	**2.70**	**6.45**	**42**
RV/TLC (%)	41	42	98
DLCO corr	5.06	31.64	16



Diseases Associated with a Restrictive Defect

Pulmonary

- Fibrosing lung diseases
- Pneumoconiosis
- Pulmonary edema
- Parenchymal lung tumors
- Lobectomy or pneumonectomy

Extrapulmonary

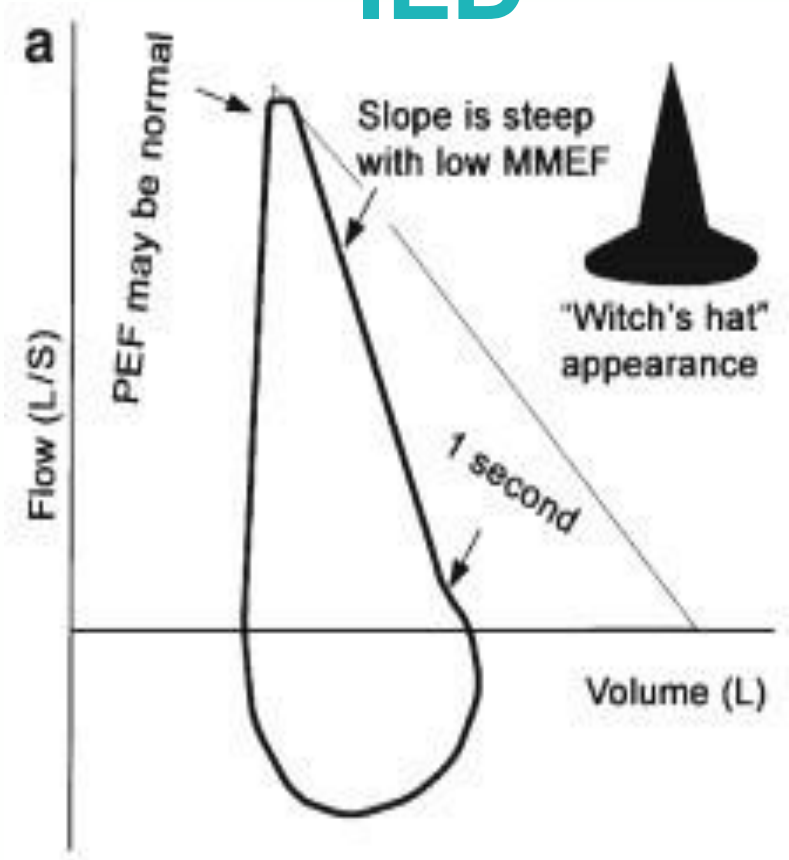
- Thoracic cage deformity
- Obesity
- Pregnancy
- Neuromuscular disorders

FV Curve Features of Different Forms of Restriction

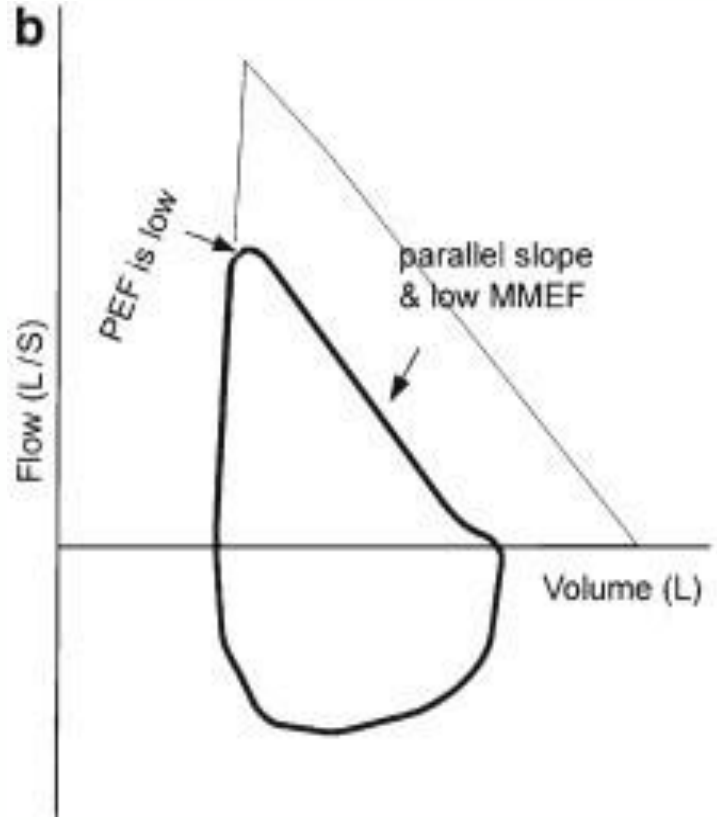
ILD

1. The **PEF can be normal or high** because of the increased elastic recoil that increases the initial flow of exhaled air
2. The **width of the curve (FVC) is decreased** and the 1st second mark (FEV1) on the descending limb of the curve is close to the residual volume indicating a normal or high FEV 1/FVC ratio.
3. The slope of the descending limb of the curve is steeper than usual due to high lung recoil or elastance (i.e., low MMEF)

The reduction in MMEF, in this case, does not indicate airflow obstruction and is related to the reduced volumes.



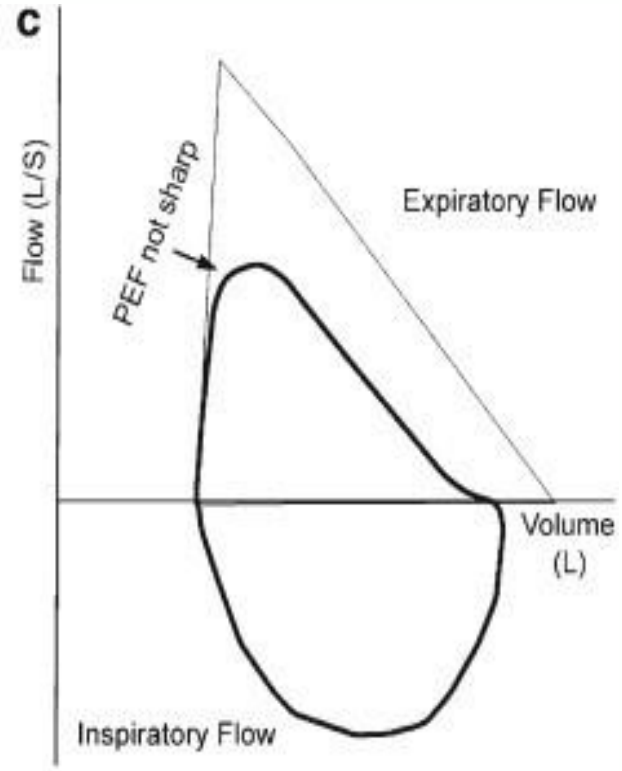
Chest Wall Restriction (Including Musculoskeletal Disorders, Diaphragmatic Distention & Obesity



1. PEF is decreased as the elastic recoil of the lung is not increased here The slope of the descending limb of the curve is steeper than usual due to high lung recoil or elastance (i.e., low MMEF)
2. The slope of the curve is parallel to the predicted curve, making the whole curve looking like the predicted curve but smaller. The MMEF is similarly decreased.

NMD (or Poor Effort Study)

e.g., muscular dystrophy, amyotrophic lateral sclerosis (ALS), old poliomyelitis, paralyzed diaphragm etc.



1. The PEF is low and not sharp (the curve is convex in shape)
2. The MMEF is low

Upper Airway Obstruction

- The morphology of the flow–volume curve is very useful in identifying upper airway disorders.
- There are three types of upper airway obstruction recognizable in the FV curve

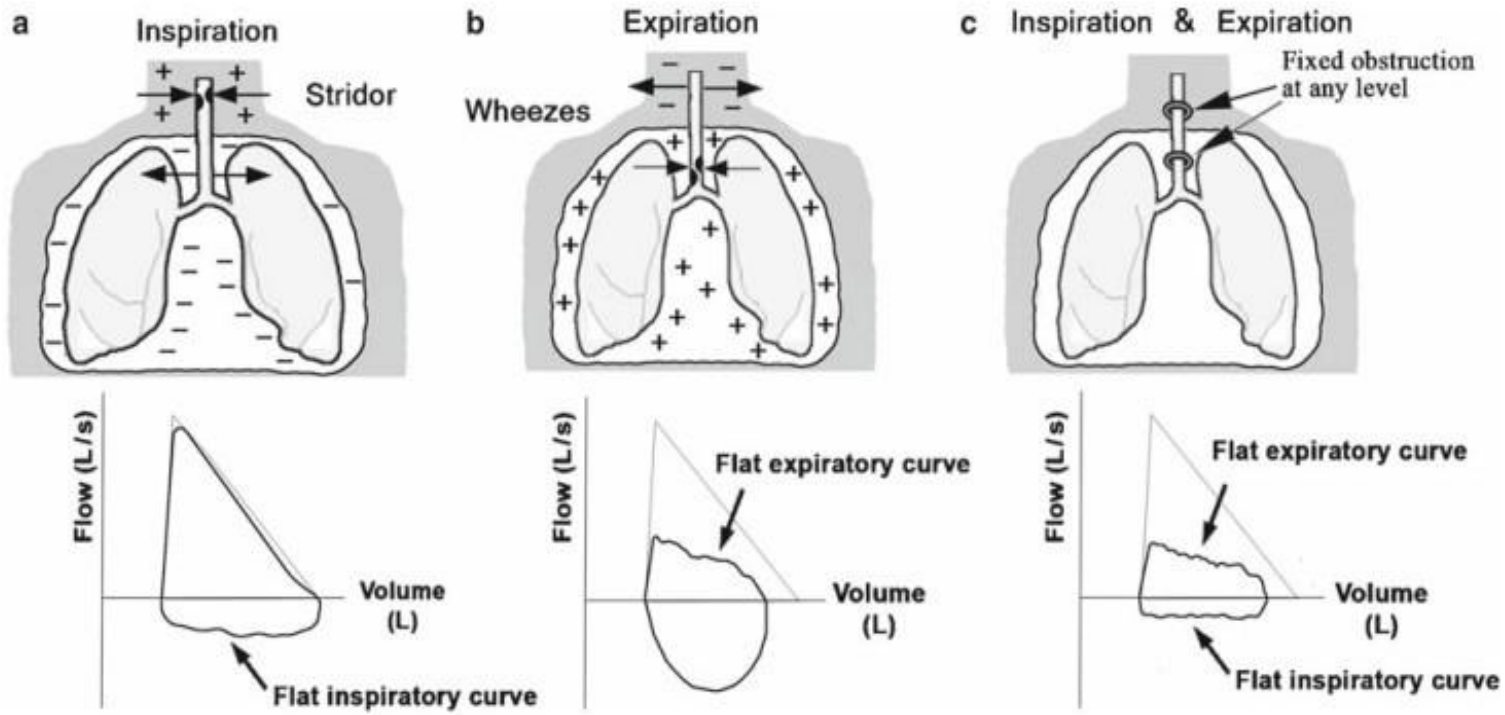


FIGURE 1.20. Upper airway obstruction: (**a**) variable extrathoracic obstruction; (**b**) Variable intrathoracic obstruction; (**c**) Fixed upper airway obstruction.

Causes of Upper Airway Obstruction

Variable Extrathoracic Lesions (*Lesions Above the Sternal Notch*)	**Variable Intrathoracic Lesions** (*Lesions Below the Sternal Notch*)	**Fixed Lesions** (*Lesions at Any Level in the Major Airways*)
• Dynamic tumors of hypopharynx or upper trachea • Vocal cord paralysis • Dynamic subglottic stenosis • External compression of upper trachea (e.g., by goiter)	• Dynamic tumors of the lower trachea • Tracheomalacia • Dynamic tracheal strictures • Chronic inflammatory disorders of the upper airways (e.g., Wegener granulomatosis, relapsing polychondritis) • External compression of lower trachea (e.g., by retrosternal goiter)	• Non-dynamic tumors at any level of upper airways • Fibrotic stricture of upper airways

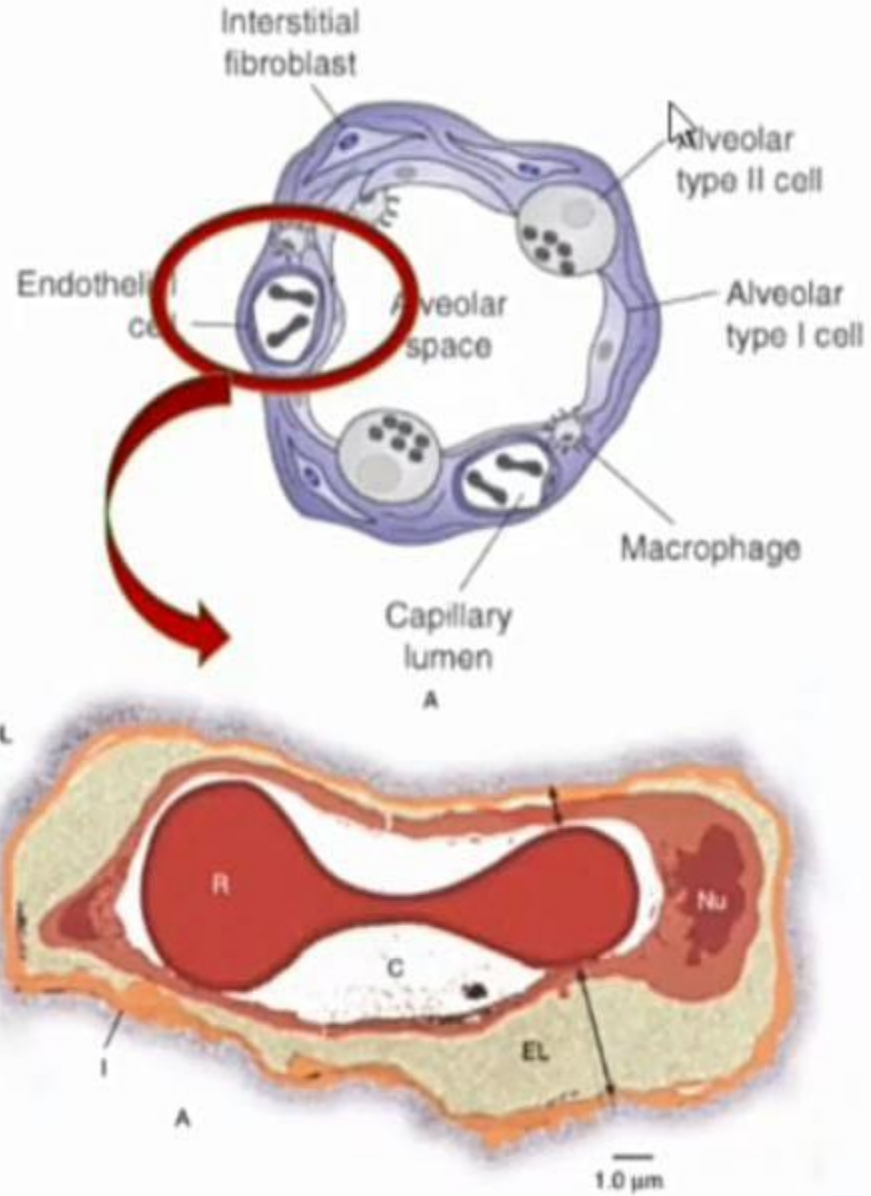
Diffusion Capacity

DL_{CO} Test : Diffusion Capacity

- Measurement of Gas Exchange in lungs

Volume of a *'diffusion limited'* gas that will diffuse through the membrane each minute for a partial pressure difference of 1 mm Hg standardized to conditions of temperature, pressure, humidity

ml / min / mm Hg at STBD



Diffusion Capacity if Lung for Carbin Monoxide (DLCO)

The DLCO measures the ability of the lungs to transfer gas from inhaled air to the red blood cells in pulmonary capillaries

- Diffusing capacity is intended to provide an estimate of the rate at which test molecules move by diffusion from alveolar gas to pulmonary capillary blood flow.

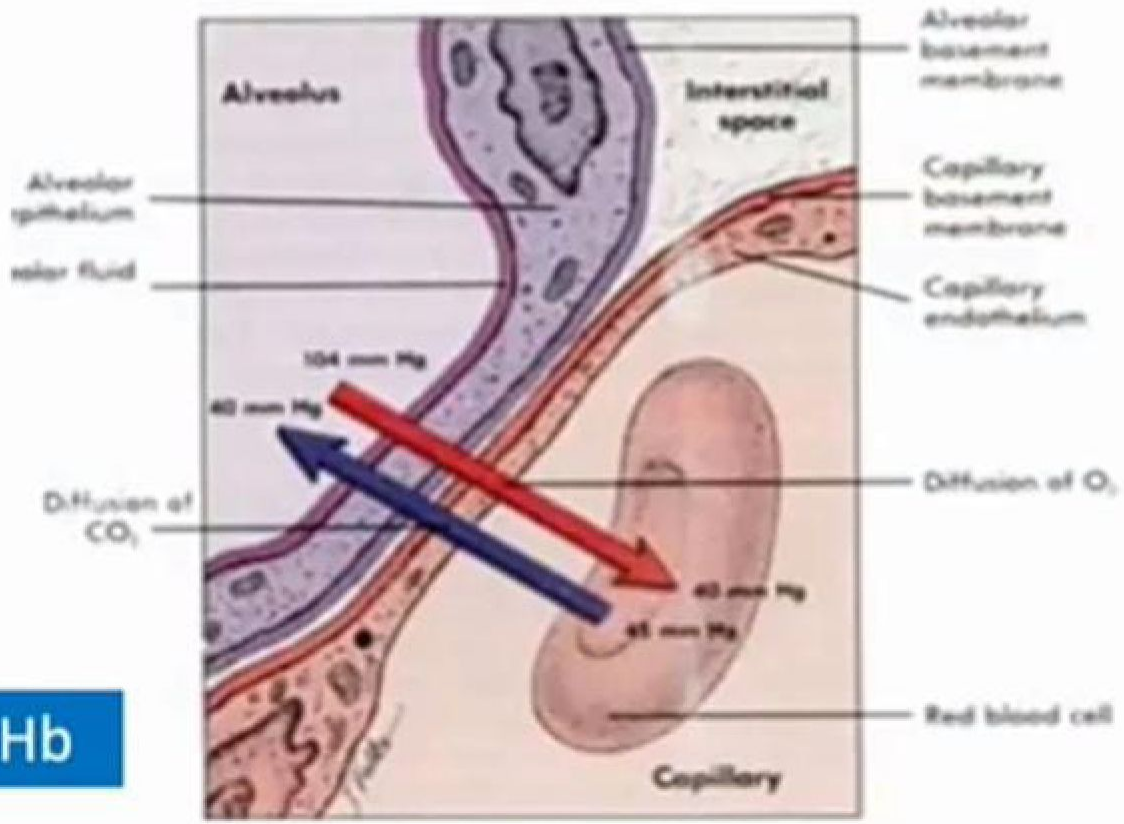
What's so special about CO?

- CO is diffusion limited gas while oxygen is perfusion limited gas
- Has a high Haldane constant
- Binds with Hb 200-300 time more avidly than Oxygen
- Reverse reaction being extremely slow.
- Practically no back pressure/tension

Determinants of Diffusion Capacity

1. *Area* of Alveolar-capillary membrane
2. *Thickness* of membrane
3. *Driving pressure* created by oxygen across gas in alveolus to blood in venous capillary
4. Flow in Pulmonary vasculature
5. *Area* of RBC membrane
6. *Coupling* with Hemoglobin

'Transfer Factor' : O_2 in air to O_2 on Hb



Physiology

Two Major Factors to be Considered in DL_{CO} Measurements

Diffusion capacity will be dependent upon characteristics of alveolar-capillary membrane, provided :

1. Ventilatory lung function
2. Hemoglobin

Both are *NORMAL*

- *Membrane Conductance* (Dm):
  - Diffusion across membrane
- *CO & Hb Reaction* (øQC):
  - Uptake of CO by Hb which is determined by
    - Reaction rate (ø)
    - Pulmonary Capillary Blood volume (QC)

$$1/DL = 1/ Dm + 1/øQC$$

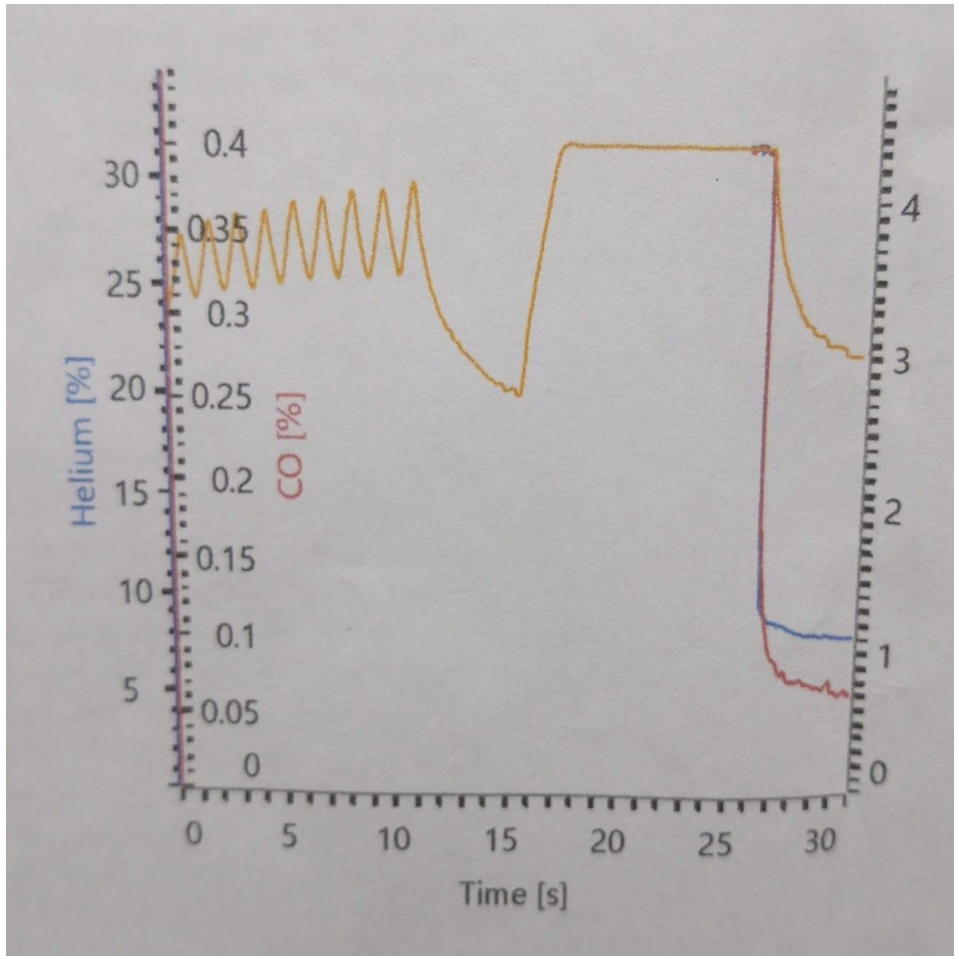
80%

Precautions While Doing DLco Test

1. No more than 5 tests must be performed in the same subject
2. At least 4 mins should be allowed between two tests
3. Subjects must be asked to refrain from smoking or other sources of carbon monoxide exposure on the day of the test
4. For patients having obstructive lung disease sufficient time (up to 12 secs) should be given for exhalation to RV
5. Inhalation of test gas should be maximal
6. During the breath-hold, both the Valsalva and Müller maneuvers can affect DLco calculation

Steps

1. A few cycles of tidal breathing
2. Subject exhales to RV
3. Inhales a mixture of predetermined tracer gas and CO up to vital capacity
4. Patient is asked to hold breath for 10 seconds at TLC during which
5. CO mixes with RV
6. CO reaches alveolar membrane and diffuses across it
7. CO crosses RBC membrane
8. Binds with Hemoglobin
9. Subject exhales to RV
10. Exhaled sample is analyzed

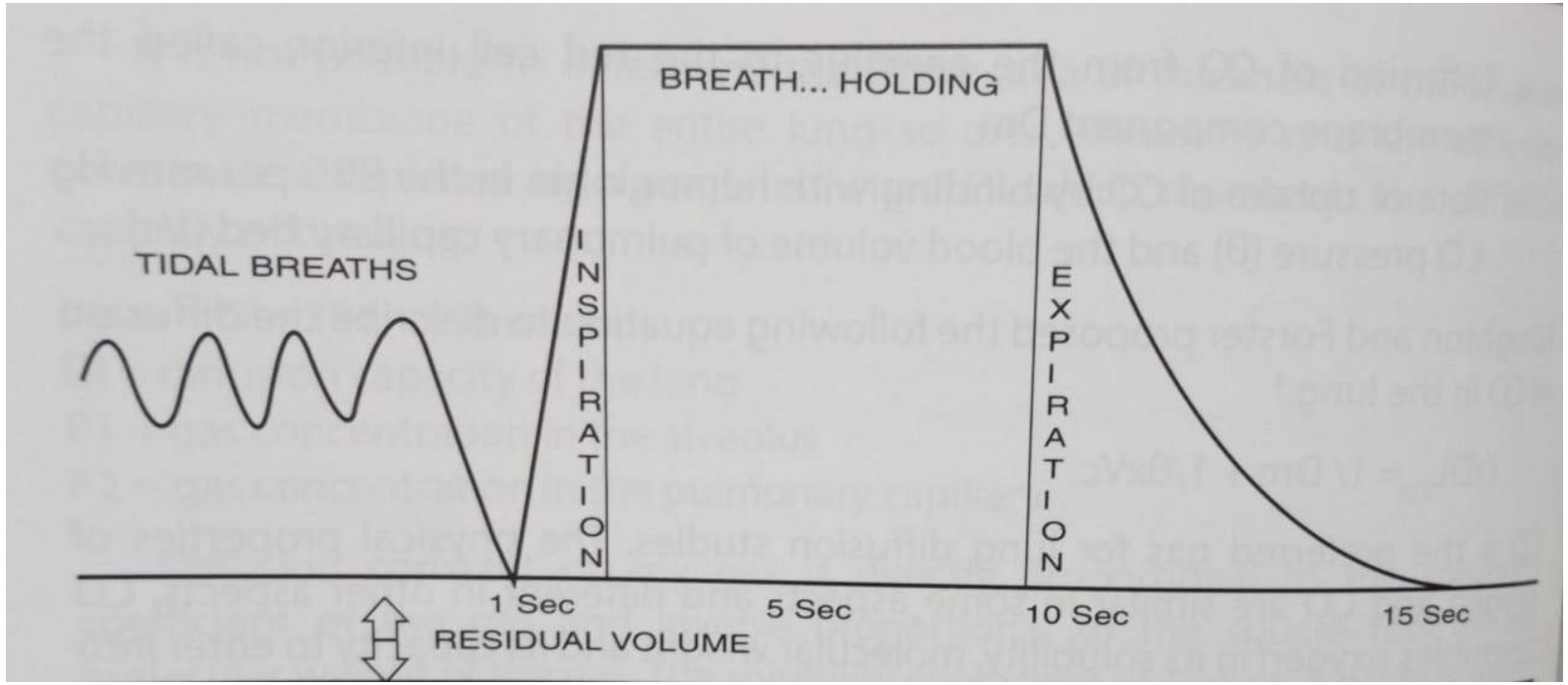


- In DLCO four parameter are estimated
- Alveolar CO concentration at the beginning
- Alveolar CO end of breath holding
- Duration of breath holding
- Alveolar volume during the procedure

Rapid inhalation time < 4 seconds

Initial portion of expirate (approx. 750 ml) containing dead space gas is discarded and remainder is collected for analysis

Normal value of DLCO – 20-30 ml co / min / mmHg



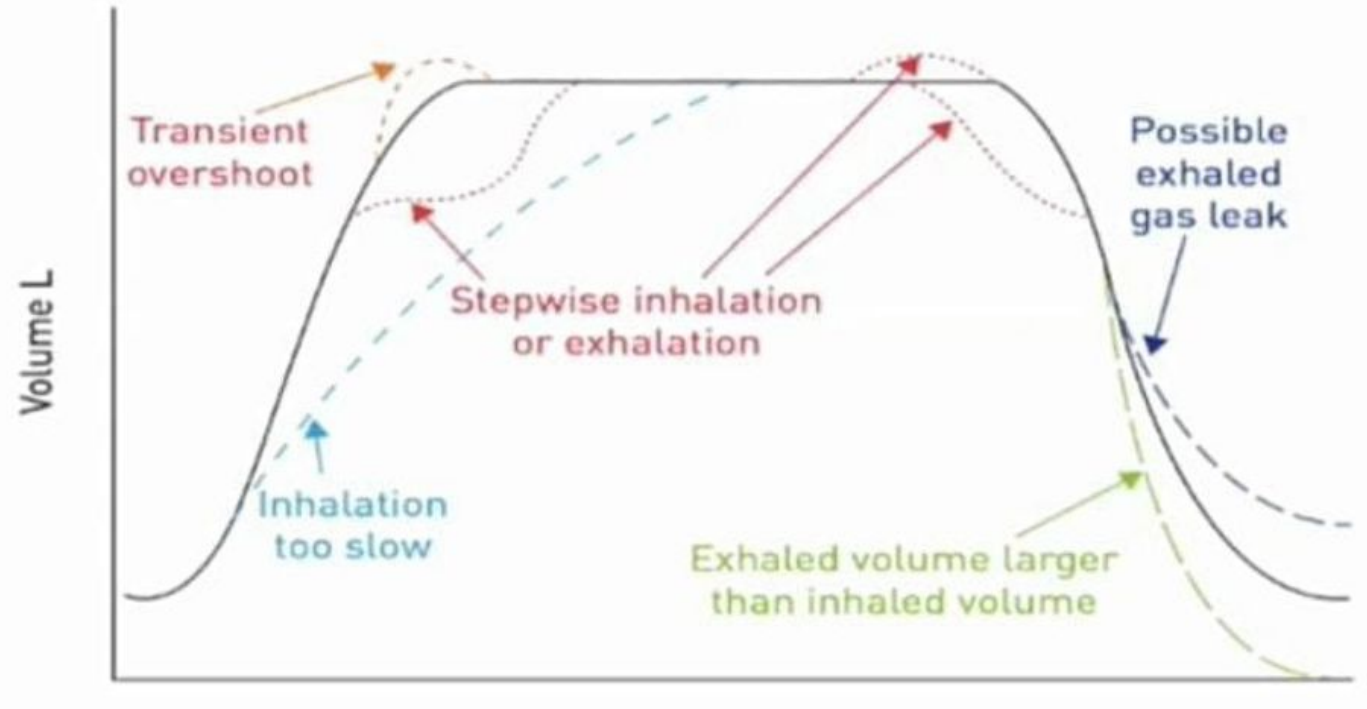
Acceptability criteria

1. Inspired volume should be >85% of largest VC and obtained within 4 sec
2. A stable breath hold for 10 ±2 sec
3. No evidence of leaks, or Valsalva /Mueller manoeuvres during breath holds
4. Two such acceptable tests with inter test interval time of 4 min.

Repeatability criteria

Two acceptable test reports should be within 2 mL CO /min / mmHg or within 10% of the highest value.

Potential Problems During Breath Maneuver



- No Valsalva-maneuver (exhale) → decrease diffusion
- No Muller-maneuver (inhale) → increase diffusion

Indications of DLCO

Obstructive Disease

- Differentiating chronic bronchitis from emphysema – smokers with airway obstruction but normal DLCO usually have chronic bronchitis
- Differentiating asthma from COPD – Asthmatics have normal or high DLCO Values

Restrictive Disease

- A low DLCO with reduced lung volume suggests ILD
- Extrapulmonary cause of restriction has normal DLCO with reduced lung volumes

Pulmonary Vascular Diseases

- Have reduced DLCO

Prior to Lung Cancer Surgery

- A low DLCO increases the risk of post-op morbidity and mortality

Disability Evaluation

- A DLCO below 30% predicted (<9ML/MIN/MMHG) may qualify total disability

Contraindications

Terminologies

DLCO: Diffusing capacity of the lungs for carbon monoxide

VA: The alveolar volume (VA) can be considered the number of contributing alveolar units measured by tracer gas (helium)

KCO: The carbon monoxide transfer coefficient is often written as DLCO/VA. Which indicate the efficiency of C0 transfer by alveoli

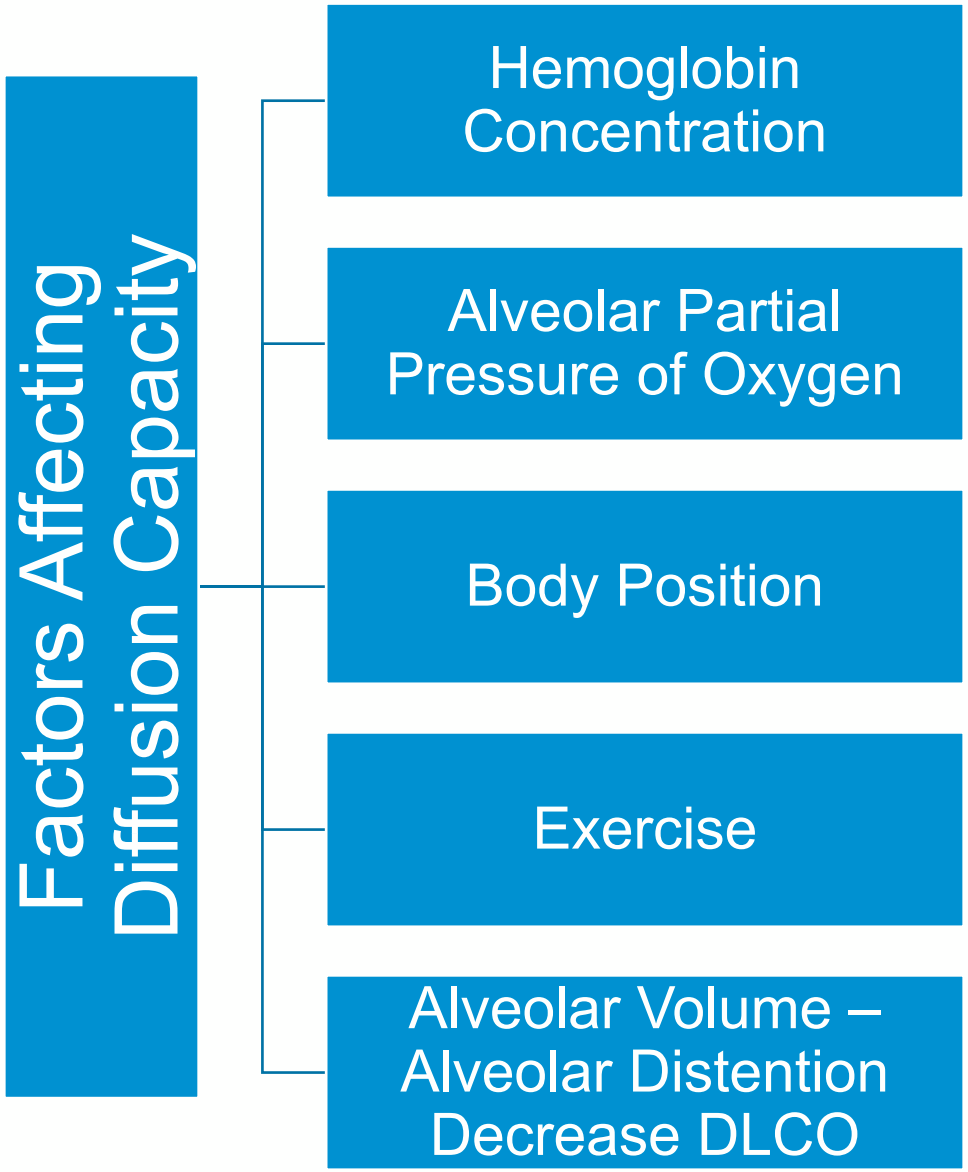
Severity & Classification of DLCO Reduction

Normal DLCO: >75% of predicted, up to 140%

Mild: 60% to LLN (lower limit of normal

Moderate: 40% to 60%

Severe: <40%


Factors Affecting Diffusion Capacity
Hemoglobin Concentration
Alveolar Partial Pressure of Oxygen
Body Position
Exercise
Alveolar Volume – Alveolar Distention Decrease DLCO

Adjustments to the Measurement of DLCO

DLco = Kco x VA
Kco = Rate of Uptake by Blood
Va = Area of Lung for Gas Exchange

- Age
- Gender
- Height
- Race
- Hb: Every 1G Less of Hg - ↓ 7% DLco Uptake
- Lung Volume (Alveolar Volume)
- COHb: Every 1% ↑ in COHb - ↓ 1% in DLco
- PIO_2 (e.g., Altitude)
- Alveolar pCO_2: ↑ pCO_2 - ↑ DLco
- Exercise
- Body Position

Hemoglobin Concentration

- The adjusted value estimates the DLCO if the patient were to be having normal hemoglobin
- DLCO predicted for Hb = (DCLO predicted x factor) where factor = (1.7 x Hb)/(10.22 + Hb)
- In children under 15 yrs of age and females is: corrected DLco = Predicted DLco * (1.7 x Hb)/(9.38 + Hb) where Hb is expressed in gm/dl

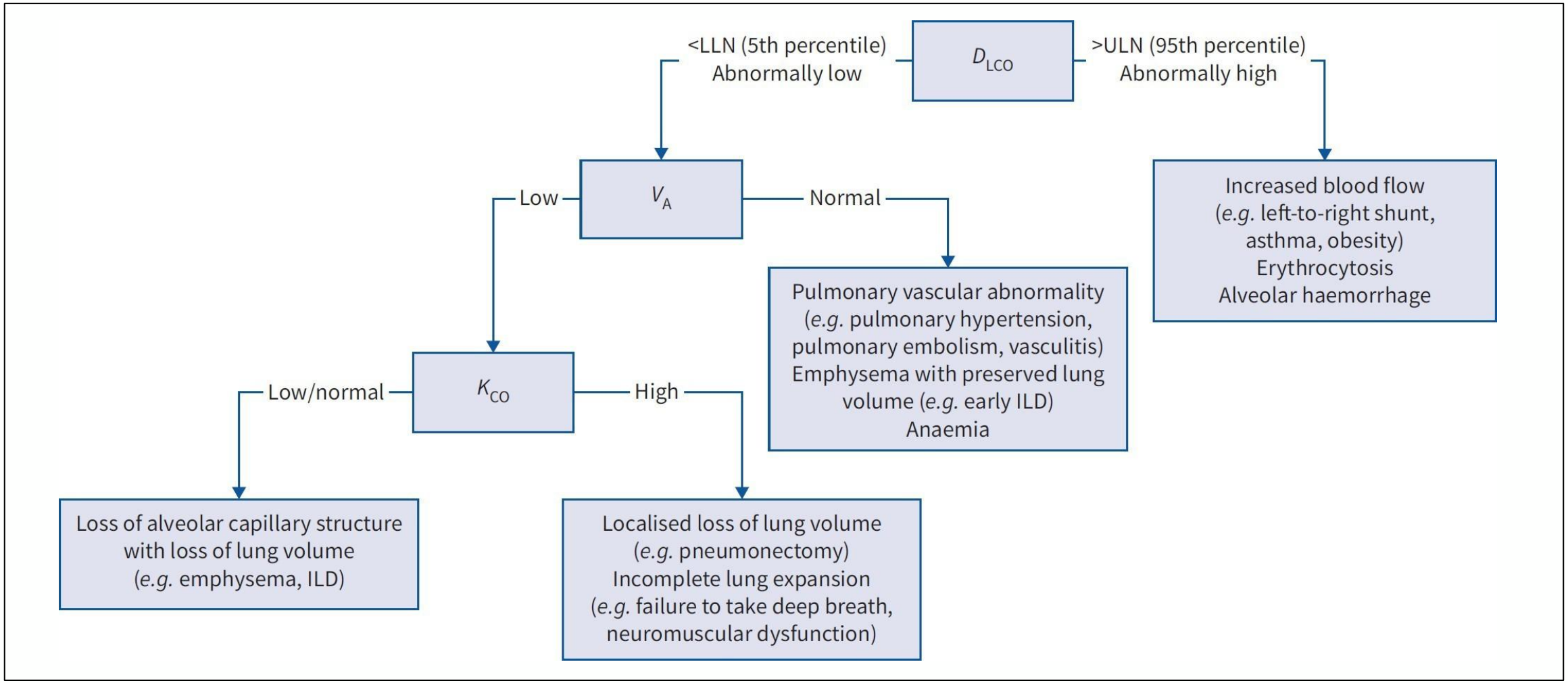
Carboxyhemoglobin & Cigarette Smoking

- The carboxyhemoglobin level may be elevated in the blood if the patient was smoking just prior to the DLCO measurement
- An increase of 1% in COHb results in a proportionate 1% decrease in the measured DLCO
- Smoking cessation results in a mean DLCO increase of 2 to 4 mL/min per mmHg within a few days High altitude

High Altitude & Alveolar Partial Pressure of Oxygen

- If the laboratory is located at high altitude, the ambient, alveolar, and arterial oxygen concentrations are lower than at sea level
- The lower arterial oxygen concentration results in less competition for CO binding to hemoglobin, increased CO uptake and increased DLCO
- And higher measured DLCO compared to a test done at sea level
    - DLCO is lowered in patients receiving supplemental oxygen during the test

Interpretation of DLCO



ERS/ATS technical standard on interpretive strategies for routine lung function tests. *Eur Respir J* 2021

Interpretation of DLCO

DLCO = VA * KCO

VA – None of contributing alveolar units measures by tracer gas.

KCO – CO transfer factor which indicates the efficiency of CO transfer by alveoli. A decrease in DLCO will be due to a decrease in VA, KCO, or both.

Low DLCO and Low KCO: Seen n COPD with emphysema due to alveolar destruction (usually normal in chronic bronchitis with an obstructive pattern on PFT). Smoking can also cause a decrease in DLCO.

DLCO and KCO: Are also reduced in interstitial lung diseases, pulmonary fibrosis due to the thickening of the alveolar-capillary membrane with a restrictive pattern on PFT.

A Normal DLCO With A Restrictive Pattern: On PFT suggests neuromuscular or chest wall disorder.

In **Dyspnea Cases Of Unknown Etiology, The Pattern Of Normal Spirometry With low DLCO** Increases The Likelihood Of Pulmonary Vascular Disease. However, This Pattern May Also Present In Other Disorders, e.g., Mild ILD.

High DLCO Is Seen In Conditions Like Obesity , Asthma, Which Are Characterized by Large Lung Volumes.

KCO May Be Raised In Conditions Involving Profuse pulmonary Hemorrhage (Eg, Goodpasture Syndrome, Systemic Lupus erythematosus, Granulomatosis With Polyangiitis). This Is Due To The Uptake Of CO By Free RBCs Lining The Alveoli.

Emphysema – The DLCO is reduced by loss of gas exchanging surface due to alveolar capillary damage and the KCO is low

Interstitial Lung Disease (ILD) – In ILD, the DLCO is decreased by diffuse alveolar capillary damage. The KCO is often reduced.

Pulmonary Vascular Disease – In pulmonary hypertension, the DLCO is reduced. The VA is typically normal, and the KCO (DLCO/VA) is reduced.

Increased DLCO

- Altitude
- Asthma
- Polycythemia
- Pulmonary hemorrhage
- Left-to-right intracardiac shunting
- Mild left heart failure - increased pulmonary capillary blood volume
- Exercise just prior to the test - increased cardiac output
- Mueller maneuver

Low DLCO With Normal Spirometry

- Anemia - mild decrease
- Pulmonary vascular disease - mild to severe decrease
- Increased carboxyhemoglobin level
- Valsalva maneuver

Low DLCO With Obstruction

- Bronchiolitis
- Combined pulmonary fibrosis and emphysema (CPFE)
- Cystic fibrosis
- Emphysema
- Sarcoidosis
- Alpha 1 anti trypsin

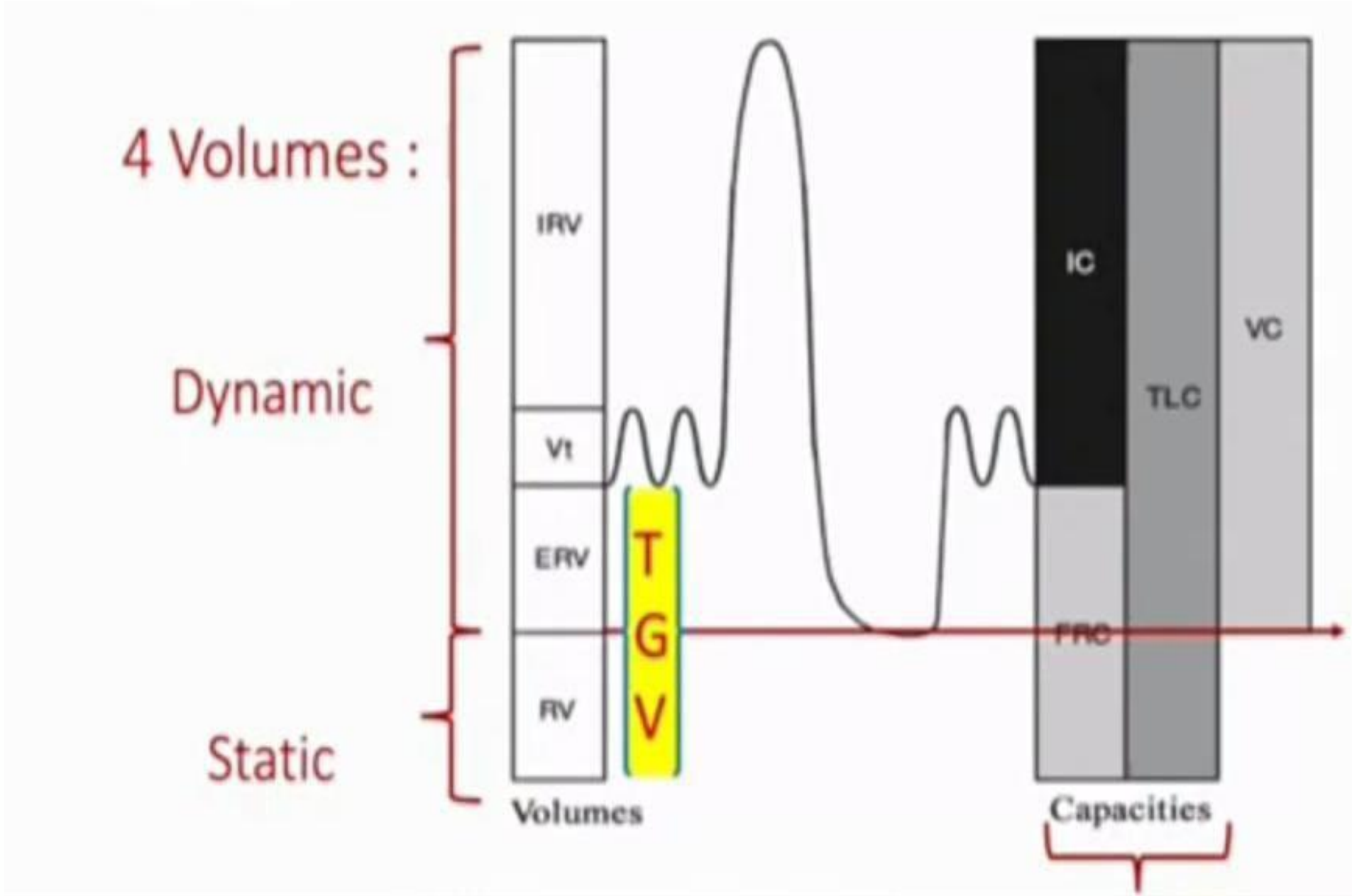
Low DLCO With Restriction

- Interstitial lung disease
- Pneumonitis

Low DLCO With Both Restriction & Obstruction

- Sarcoidosis (stage II through IV)
- Asbestosis
- Miliary tuberculosis

Body Plethysmography


4 Volumes :
Dynamic
Static
IRV
Vt
ERV
RV
TGV
IC
TLC
VC
FRC
Volumes
Capacities

Rationale of Body Plethysmography

- Spirometry is considered the gold standard in lung function. It can, however, not provide information on, e.g., lung residual volume (RV) and total lung capacity (TLC), while body plethysmography allows to determine these and other characteristics, such as airway resistance and intrathoracic gas volume (ITGV).

- The determination of lung function by body plethysmography starts with breathing at rest, followed by the shutter maneuver continue this with spirometric measurements.

- After opening of the shutter, an expiratory reserve volume (ERV) effort and an inspiratory vital capacity effort (IVC) are performed; this allows the computation of RV and TLC

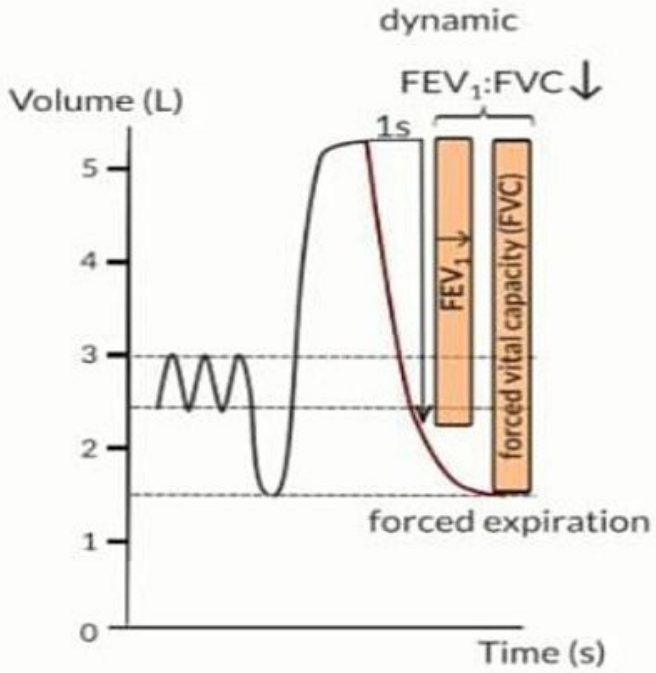
Apparatus

- The volume-constant whole-body plethysmograph is a chamber resembling a glass-walled telephone box in shape and volume (about 700 TO 1000 L).
- During measurement, the box is closed with an airtight seal.
- One pressure transducer serves to measure the pressure inside the box relative to ambient pressure, another one is placed close to the mouth for recording mouth pressure during a shutter maneuver.
- Respiratory flow rate is recorded by conventional equipment, such as pneumotachograph, anemometer, all are calibrated via syringe to deliver a definite volume

Indications

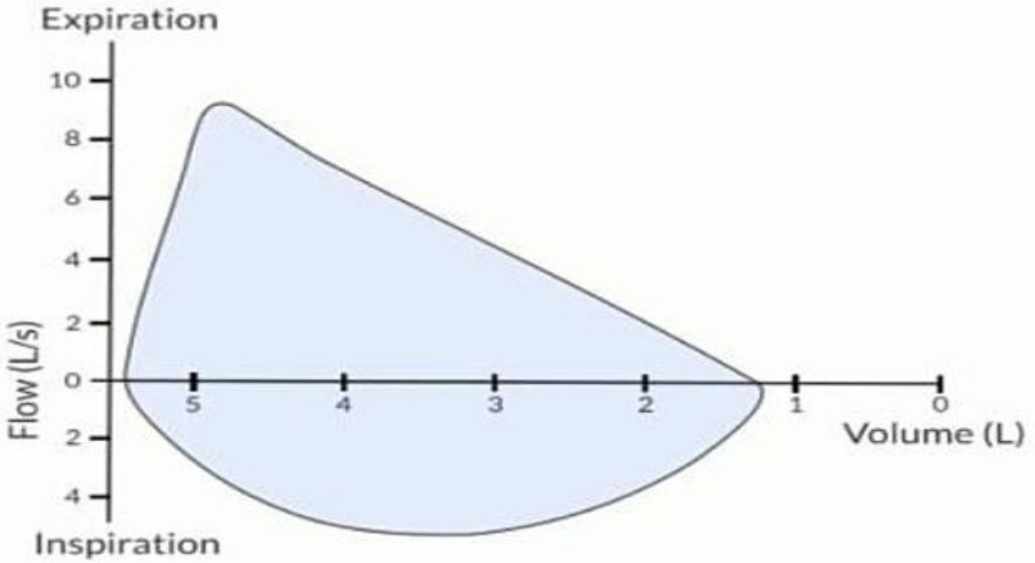
Airway resistance during measurement of obstruction

Indication: - Lack of compliance
- Objectifying measurement data



Total lung capacity

Indication: - Differentiation between **restriction** & **hyperinflation**
(Spirometry: only for reduced VC)



Hyperinflation of the lung

Restriction

Contraindications for Body Box Plethysmography

Preventing Patient Entering the Box

- Mental Confusion
- Poor Muscular Coordination
- Body Cast
- Wheelchair
- Claustrophobia
- Extreme Obesity

Presence of Devices – Continuous IV Infusion

Conditions That Interfere With Pressure Changes

- Chest Tube
- Trans-tracheal O_2 Catheter

Continuous O_2 Therapy That Cannot be Removed

Restrictive Lung Diseases

- Can be suspected when FVC is reduced and FEV1/FVC is normal or elevated
- However, can be ***confirmed*** only by demonstration of a reduced TLC by plethysmography
- TLC below 5th percentile of normal value is considered as restrictive lung disease

Obstructive Diseases

- Characterized by a normal or elevated FRC, TLC, and RV, and elevated Raw and sRaw

- Additionally, determination of RV and RV%TLC allows to determine the degree of hyperinflation

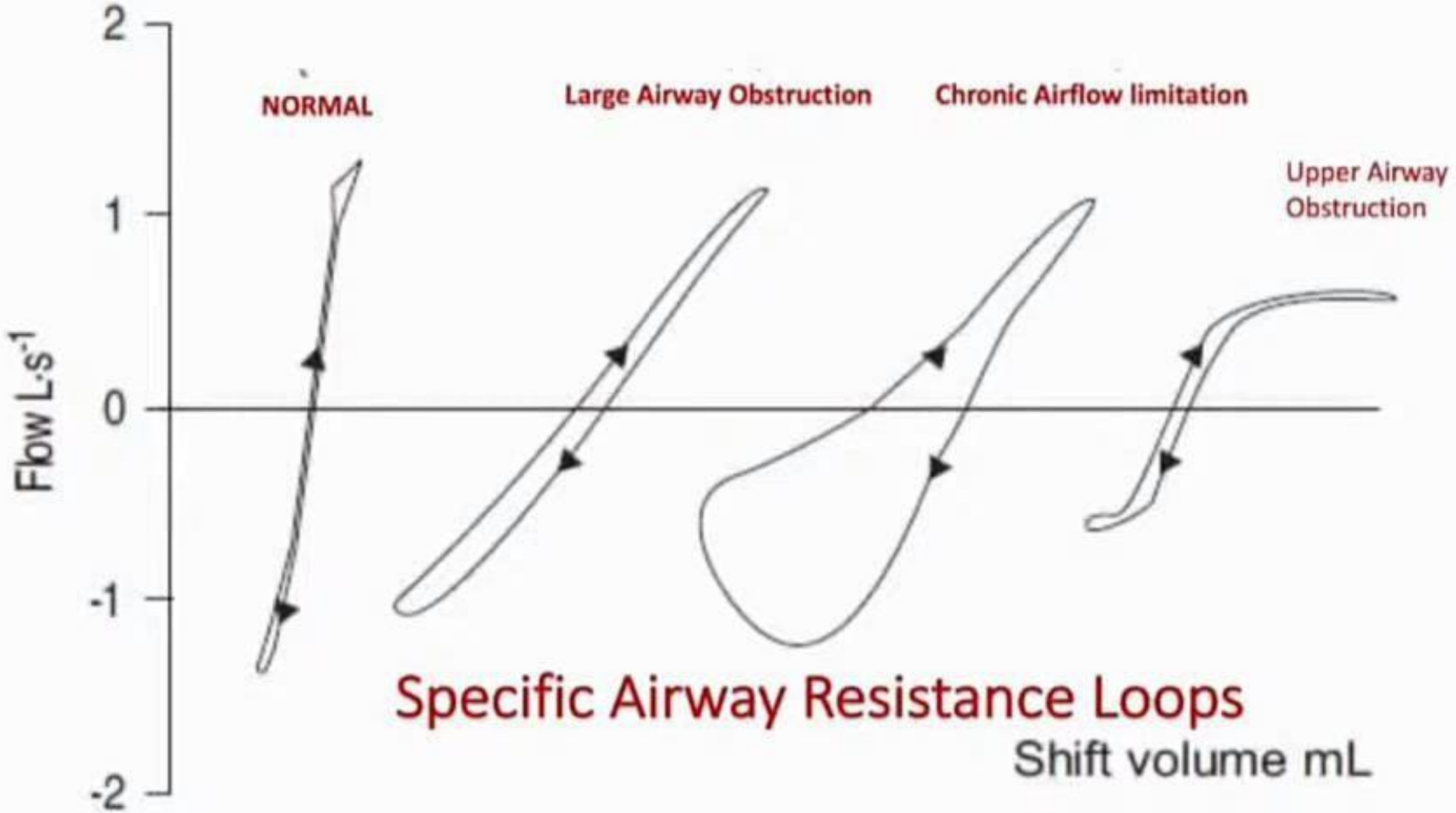
	Mild	Moderate	Severe
RV/TLC	>95th percentile - < 140%	140 -170 %	>170 %

- In the presence of severe defect, plethysmographic volumes tends to overestimated, as pressure changes are not properly transmitted to the mouth

- Body plethysmography can also demonstrate the effects of Rx on hyperinflation
  - Decrease in FRC following bronchodilator Rx
  - Decrease following successful Rx of AE-COPD

- These determinations are not influenced by the patient effort, which may be substantially decreased in the presence of hyperinflation

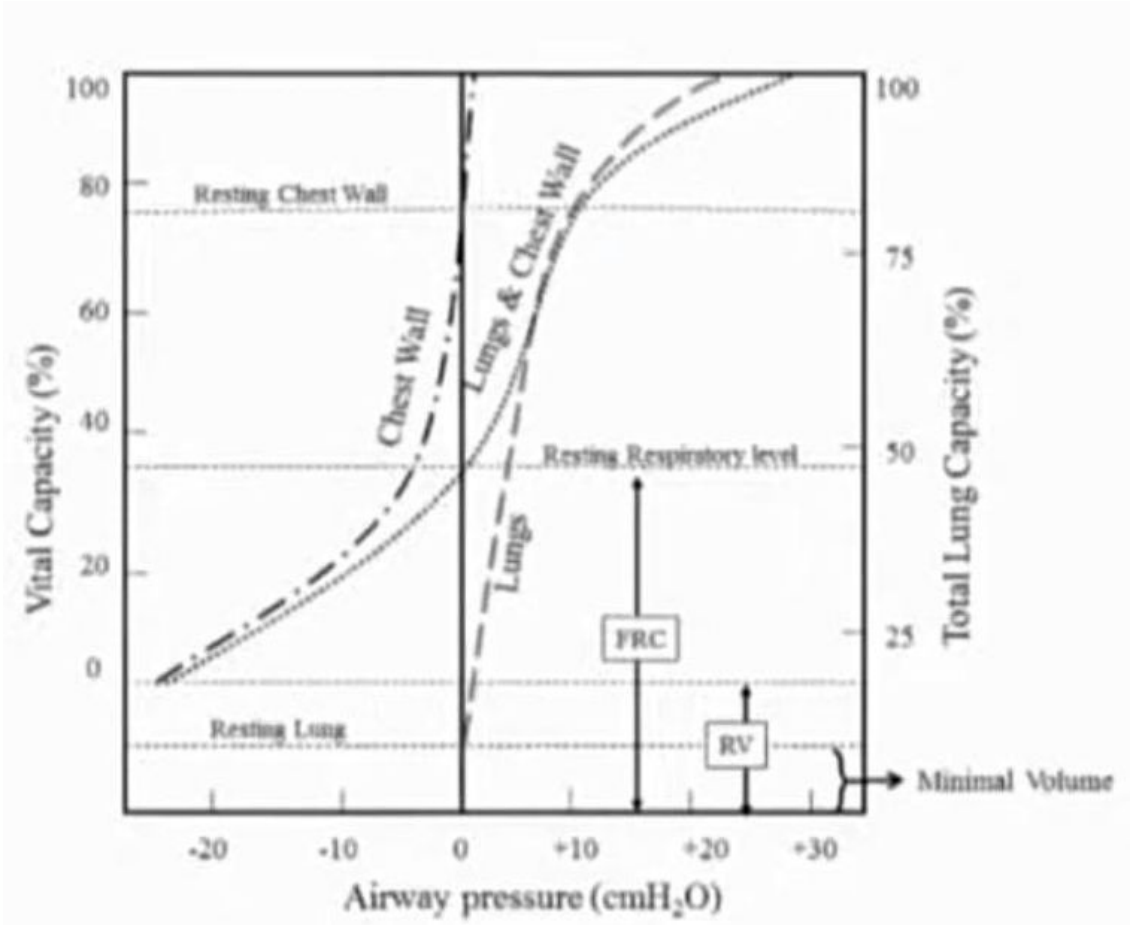
- Body plethysmography directly measures the FRC


NORMAL
Large Airway Obstruction
Chronic Airflow limitation
Upper Airway Obstruction
2
1
0
-1
-2
Flow L·s-1
Specific Airway Resistance Loops
Shift volume mL

Determinants of FRC

↑ FRC
- Gas trapping due to intrathoracic airway obstruction
- Cystic lung disease

↓ FRC
- Reduced recoil of chest-wall
- Decreased lung compliance
- Atelectasis



Residual Volume: RV

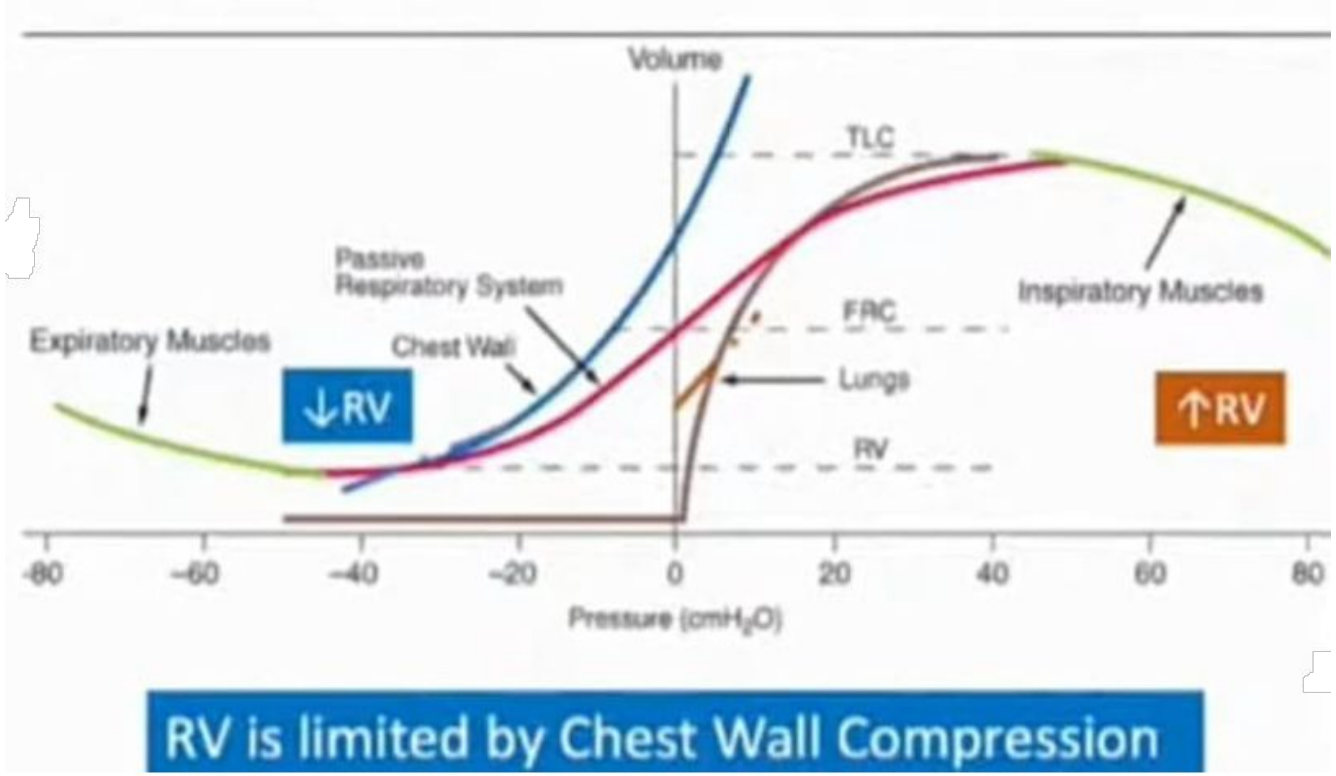
RV is normally 25% of TLC, amount air left in lungs after maximum exhalation

RV Increased

- Air Trapping (Asthma)
- Loss of Elastic Recoil (Emphysema)

RV Decreased

- Increase Elastic Recoil
- Pulmonary Fibrosis



Total Lung Capacity: TLC

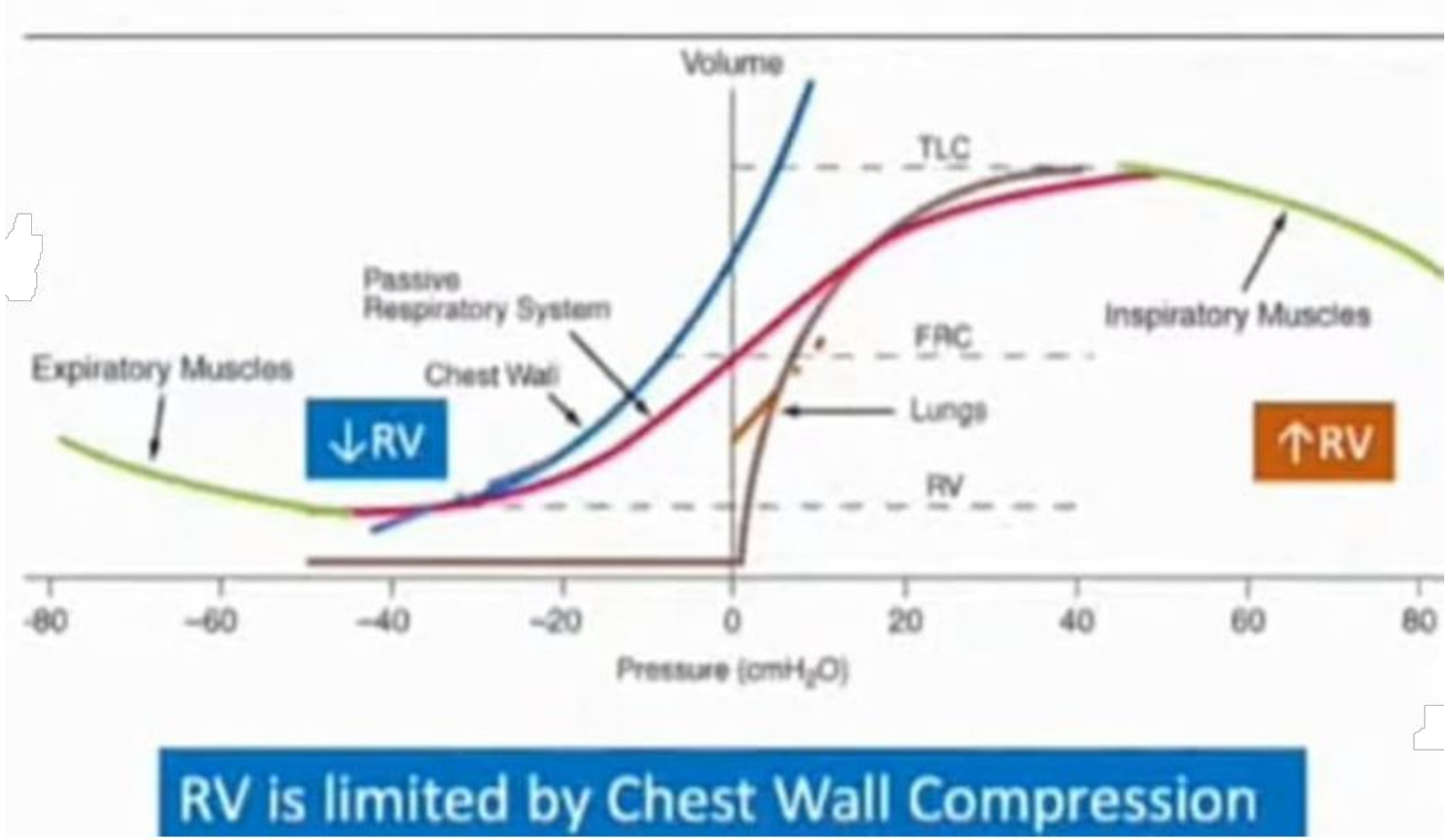
TLC is the total volume of air within the lung after maximum inspiration

TLC Increased

- Airway Narrowing With Air Trapping (Asthma)
- Loss of Elastic Recoil (Emphysema)

TLC Decreased

- ILD
- Muscle Weakness
- Obesity



Interpretation of Lung Volumes

Look at TLC
High or Low or Normal

Look at RV and RV/TLC
High or Low or Normal

Look at ERV and FRC
High, Low or Normal

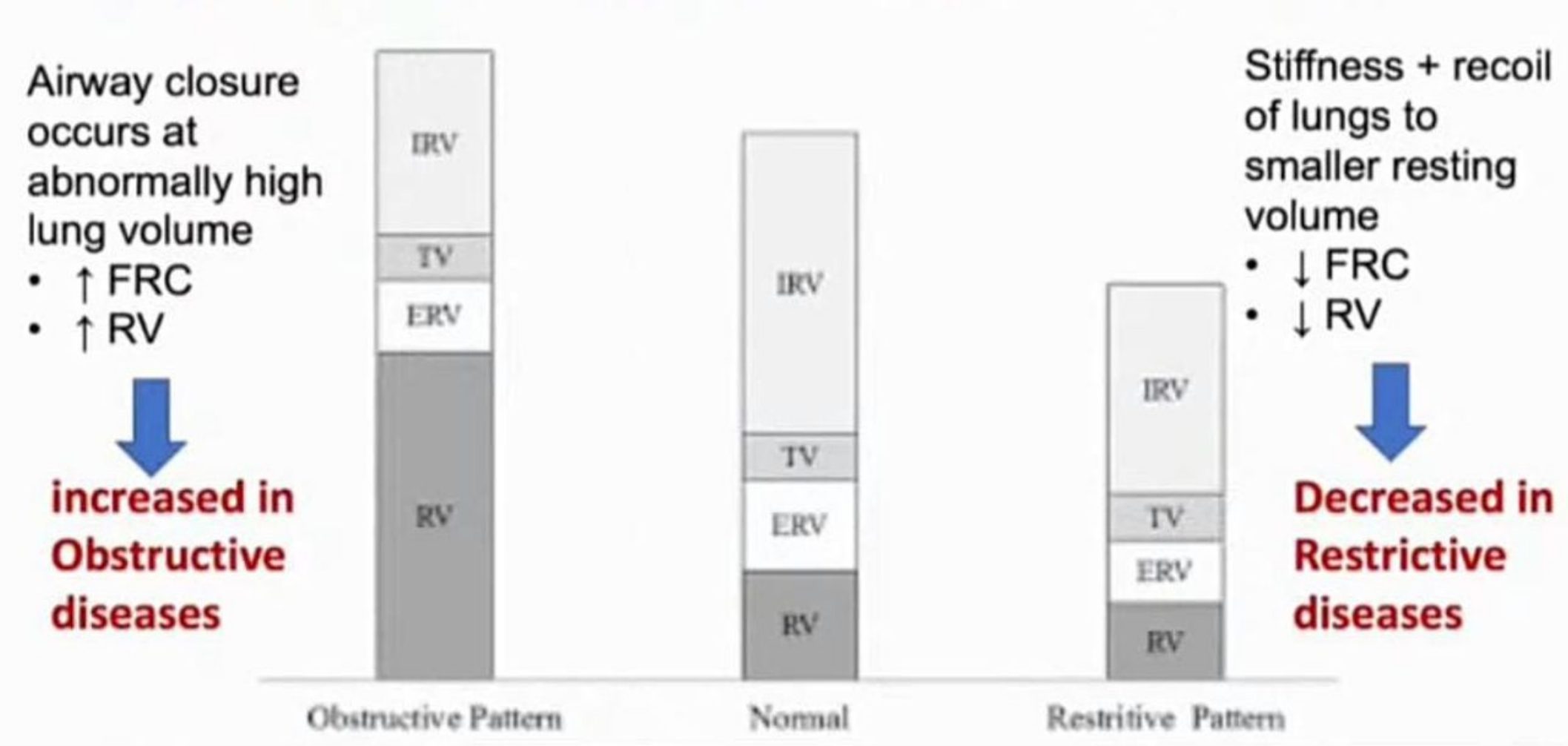
Look at Appropriateness
Reduction / Increase in Proportionate in All Lung Volumes

Normal Range = 80 – 120% Predicted

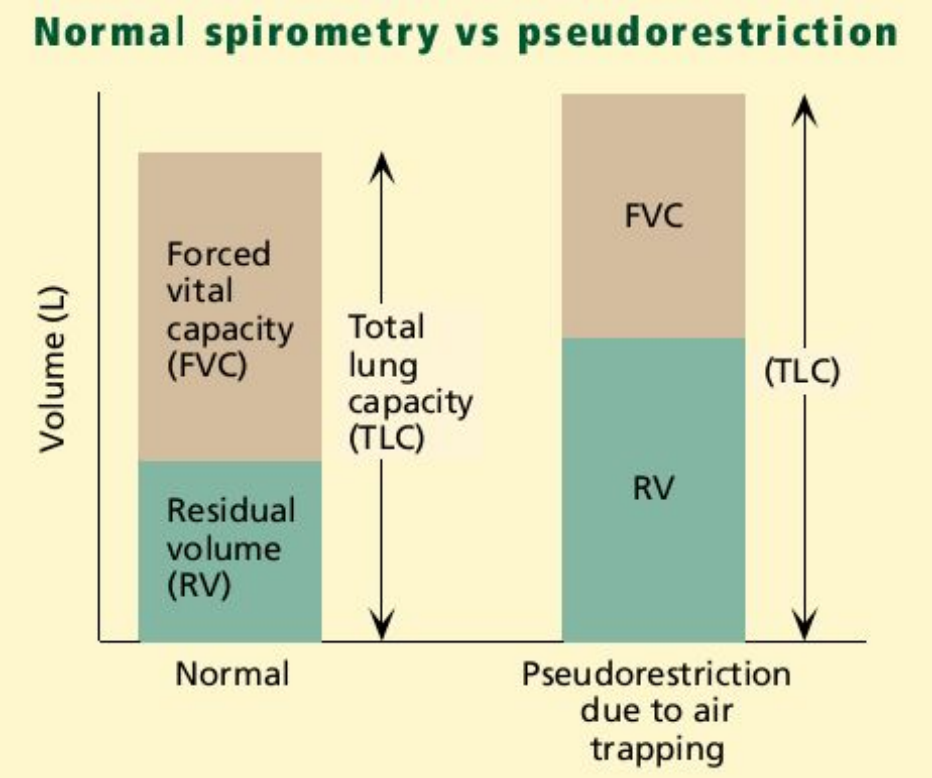
Normal Range for Predicted Values of Lung Volumes

- RV and TLC Normal Range = 80 – 120% Predicted
- RV/TLC and IC/TLC Normal Range = 80 – 120% Predicted
- Raw = 130% Predicted
- Gaw = 80% Predicted

Lung Volumes in Clinical Practice: FRC & RV



Pseudorestriction



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- An increase in RV or RV/TLC above the 95th percentile may indicate hyperinflation or air trapping due to the presence of airway obstruction
- Increase in RV or RV/TLC: one of the earliest manifestations of small airway disease
- With progression, lung hyperinflation and air trapping are reflected by increases in FRC or FRC/TLC and often in TLC.
- An increased FRC/TLC indicates a reduced inspiratory capacity (IC), which is a hallmark of COPD

Table 2 Alterations in body plethysmographic measures as observed in major disorders (see also Fig. 4).

	FRC	RV	TLC	*Raw*	*sRaw*
Obstructive airway diseases	Normal or elevated	Normal or elevated	Normal	Elevated	Elevated
Hyperinflation	Elevated	Elevated	Normal or elevated	Normal	Elevated
Restrictive disorders	Reduced	Reduced or normal	Reduced	Normal	Normal

Thank you

Geisinger