14.02.2025

PULMONARY FUNCTION TESTS

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WHY DO WE NEED THEM?

- DIAGNOSIS
- SEVERITY ASSESSMENT AND PROGNOSTICATION
- FOLLOW UP AND MONITORING
- PRE-OPERATIVE EVALUATION

"The interpretation of PFTs should focus on values of airflow, lung volume and gas transfer measurements to recognize patterns of altered physiology. PFTs alone should not be used to diagnose a specific pathological condition."

TESTS IN THE DOMAIN

Respiratory function	Parameters	Tests
Ventilation	Flow	- Spirometry (post bronchodilator, FV loop, BCT, supine and sitting)
	Volume	- Gas dilution methods - Body plethysmography - Radiographic methods
	Elastic recoil	- Impulse oscillometry - Forced oscillation methods
Diffusion	Transfer factor	- DLCO
Others	Exercise	- 6 minute walk test - Incremental shuttle walk test - Endurance shuttle walk test - CPET
	Oxygenation	- Pulse oximetry - ABG

AMERICAN THORACIC SOCIETY DOCUMENTS

Standardization of Spirometry 2019 Update

An Official American Thoracic Society and European Respiratory Society Technical Statement

Brian L. Graham, Irene Steenbruggen, Martin R. Miller, Igor Z. Barjaktarevic, Brendan G. Cooper, Graham L. Hall, Teal S. Hallstrand, David A. Kaminsky, Kevin McCarthy, Meredith C. McCormack, Cristine E. Oropez, Margaret Rosenfeld, Sanja Stanojevic, Maureen P. Swanney[†], and Bruce R. Thompson; on behalf of the American Thoracic Society and the European Respiratory Society

THIS OFFICIAL TECHNICAL STATEMENT WAS APPROVED BY THE AMERICAN THORACIC SOCIETY AND THE EUROPEAN RESPIRATORY SOCIETY SEPTEMBER 2019

There are 3 key elements to obtain high quality pulmonary function data:

Accurate and precise instrumentation

A patient/subject capable of performing acceptable and repeatable measurements

A motivated technologist to elicit maximum performance from the patient

Ruppel GL, Enright PL. Pulmonary function testing. Respir Care 2012; 57:165–175.

WHEN TO DO AND WHEN NOT TO DO?

Table 1. Indications for Spirometry

Diagnosis
- To evaluate symptoms, signs, or abnormal laboratory test results
- To measure the physiologic effect of disease or disorder
- To screen individuals at risk of having pulmonary disease
- To assess preoperative risk
- To assess prognosis

Monitoring
- To assess response to therapeutic intervention
- To monitor disease progression
- To monitor patients for exacerbations of disease and recovery from exacerbations
- To monitor people for adverse effects of exposure to injurious agents
- To watch for adverse reactions to drugs with known pulmonary toxicity

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

Other
- Research and clinical trials
- Epidemiological surveys
- Derivation of reference equations
- Preemployment and lung health monitoring for at-risk occupations
- To assess health status before beginning at-risk physical activities

Table 2. Relative Contraindications for Spirometry

Due to increases in myocardial demand or changes in blood pressure
- Acute myocardial infarction within 1 wk
- Systemic hypotension or severe hypertension
- Significant atrial/ventricular arrhythmia
- Noncompensated heart failure
- Uncontrolled pulmonary hypertension
- Acute cor pulmonale
- Clinically unstable pulmonary embolism
- History of syncope related to forced expiration/cough

Due to increases in intracranial/intraocular pressure
- Cerebral aneurysm
- Brain surgery within 4 wk
- Recent concussion with continuing symptoms
- Eye surgery within 1 wk

Due to increases in sinus and middle ear pressures
- Sinus surgery or middle ear surgery or infection within 1 wk

Due to increases in intrathoracic and intraabdominal pressure
- Presence of pneumothorax
- Thoracic surgery within 4 wk
- Abdominal surgery within 4 wk
- Late-term pregnancy

Infection control issues
- Active or suspected transmissible respiratory or systemic infection, including tuberculosis
- Physical conditions predisposing to transmission of infections, such as hemoptysis, significant secretions, or oral lesions or oral bleeding

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ACTIVITIES TO AVOID BEFORE A SPIROMETRY APPOINTMENT

- Smoking and/or vaping and/or water pipe use within 1 h before testing (to avoid acute bronchoconstriction due to smoke inhalation)
- Consuming intoxicants within 8 h before testing (to avoid problems in coordination, comprehension, and physical ability)
- Performing vigorous exercise within 1 h before testing (to avoid potential exercise-induced bronchoconstriction)
- Wearing clothing that substantially restricts full chest and abdominal expansion (to avoid external restrictions on lung function)

WHEN TO STOP BRONCHODILATORS?

Bronchodilator Medication	Withholding Time
SABA (e.g., albuterol or salbutamol)	4–6 h
SAMA (e.g., ipratropium bromide)	12 h
LABA (e.g., formoterol or salmeterol)	24 h
Ultra-LABA (e.g., indacaterol, vilanterol, or olodaterol)	36 h
LAMA (e.g., tiotropium, umeclidinium, aclidinium, or glycopyrronium)	36–48 h

PROCEDURE

Wash hands

Prepare patient

Dispense hand sanitizer
Confirm identification data including ethnicity
Height and weight
Rule out contraindications, note activities and medication use
Note respiratory symptoms

Instruct and demonstrate the test

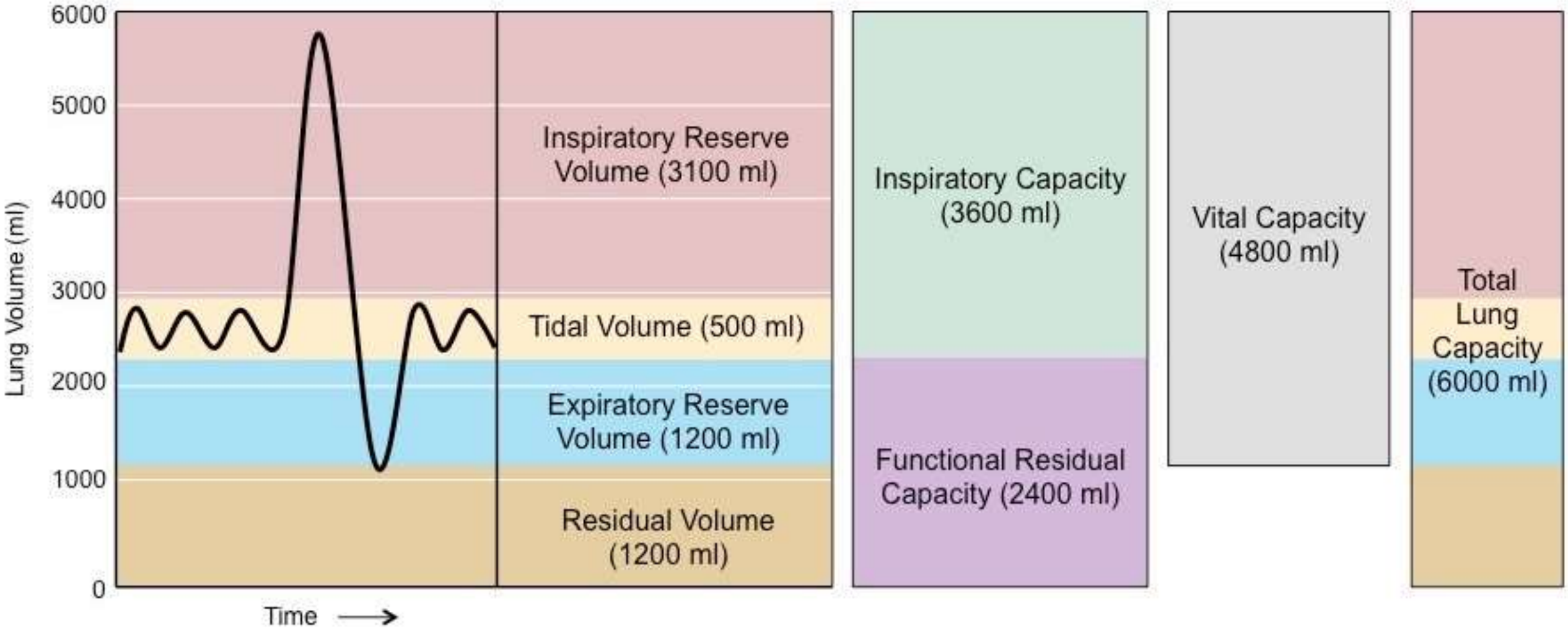
Mouthpiece and nose clip
Posture
Inspire→Expire→Inspire rapidly and maximally

Check for repeatability, acceptability and usability

Perform manoeuvre

Coach vigorously
Pause between maximal inspiration and expiration ≤2 s

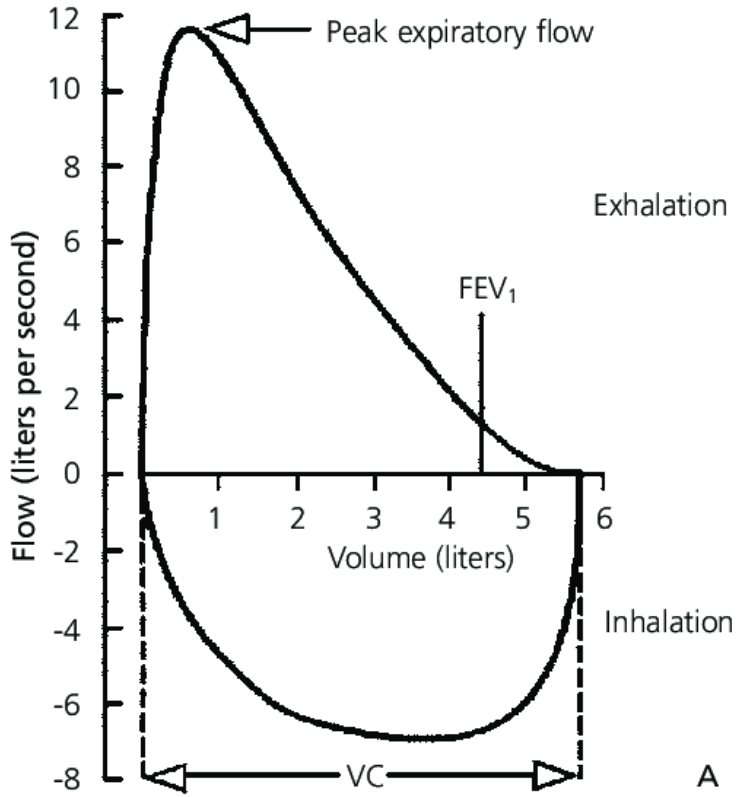
Repeat minimum 3x, maximum 8x

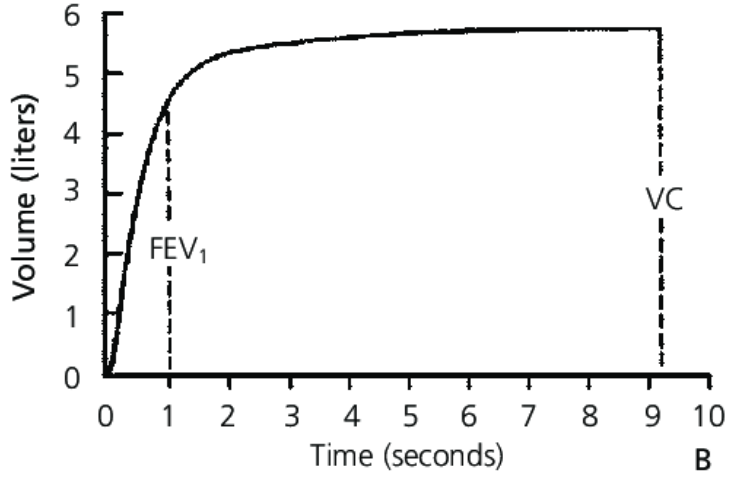

6000
5000
4000
3000
2000
1000
0
Lung Volume (ml)
Time
Inspiratory Reserve Volume (3100 ml)
Tidal Volume (500 ml)
Expiratory Reserve Volume (1200 ml)
Residual Volume (1200 ml)
Inspiratory Capacity (3600 ml)
Functional Residual Capacity (2400 ml)
Vital Capacity (4800 ml)
Total Lung Capacity (6000 ml)

- **FVC:** maximal volume of air exhaled with **forced effort** from a maximal inspiration
- **FEV1:** maximal volume exhaled in the first second of a forced expiration from a position of full inspiration
- **FEV6:** when a subject doesn't fully exhale, the volume measured over 6 seconds can be used as an approximate estimate of forced vital capacity (FVC)
- **PEF:** maximum expiratory flow achieved from a maximum forced expiration
- **Lower limit of normal:** < 5 percentile for a gender, height, weight and BTPS

NORMAL SPIROMETRIC DIAGRAM

- A= FLOW-VOLUME LOOP
- B= VOLUME-TIME CURVE





WITHIN MANOEUVRE EVALUATION

ACCEPTABLE vs **USABLE**

Do not meet all of the criteria, but may be the best that the patient is able to do on that occasion, and although the FEV1 and/or FVC measurements are not technically acceptable, they may be clinically useful

ACCEPTABILITY CRITERIA:

- BEV <5% of FVC or 100 mL, whichever is greater
- Hesitation time less than 2 sec
- EOFE standards
- No cough in the 1st second
- No glottic closure
- No evidence of leak or obstructed mouthpiece
- If the maximal inspiration after EOFE is greater than FVC, then FIVC-FVC must be <100 mL or 5% of FVC, whichever is greater

Table 7. Summary of Acceptability, Usability, and Repeatability Criteria for FEV_1 and FVC

Acceptability and Usability Criterion	Required for Acceptability		Required for Usability	
	FEV_1	FVC	FEV_1	FVC
Must have BEV ≤5% of FVC or 0.100 L, whichever is greater	Yes	Yes	Yes	Yes
Must have no evidence of a faulty zero-flow setting	Yes	Yes	Yes	Yes
Must have no cough in the first second of expiration*	Yes	No	Yes	No
Must have no glottic closure in the first second of expiration*	Yes	Yes	Yes	Yes
Must have no glottic closure after 1 s of expiration	No	Yes	No	No
Must achieve one of these three EOFE indicators: 1. Expiratory plateau (≤0.025 L in the last 1 s of expiration) 2. Expiratory time ≥15 s 3. FVC is within the repeatability tolerance of or is greater than the largest prior observed FVC†	No	Yes	No	No
Must have no evidence of obstructed mouthpiece or spirometer	Yes	Yes	No	No
Must have no evidence of a leak	Yes	Yes	No	No
If the maximal inspiration after EOFE is greater than FVC, then FIVC − FVC must be ≤0.100 L or 5% of FVC, whichever is greater‡	Yes	Yes	No	No

Repeatability criteria (applied to acceptable FVC and FEV_1 values)

Age >6 yr: The difference between the two largest FVC values must be ≤0.150 L, and the difference between the two largest FEV_1 values must be ≤0.150 L

Age ≤6 yr: The difference between the two largest FVC values must be ≤0.100 L or 10% of the highest value, whichever is greater, and the difference between the two largest FEV_1 values must be ≤0.100 L or 10% of the highest value, whichever is greater

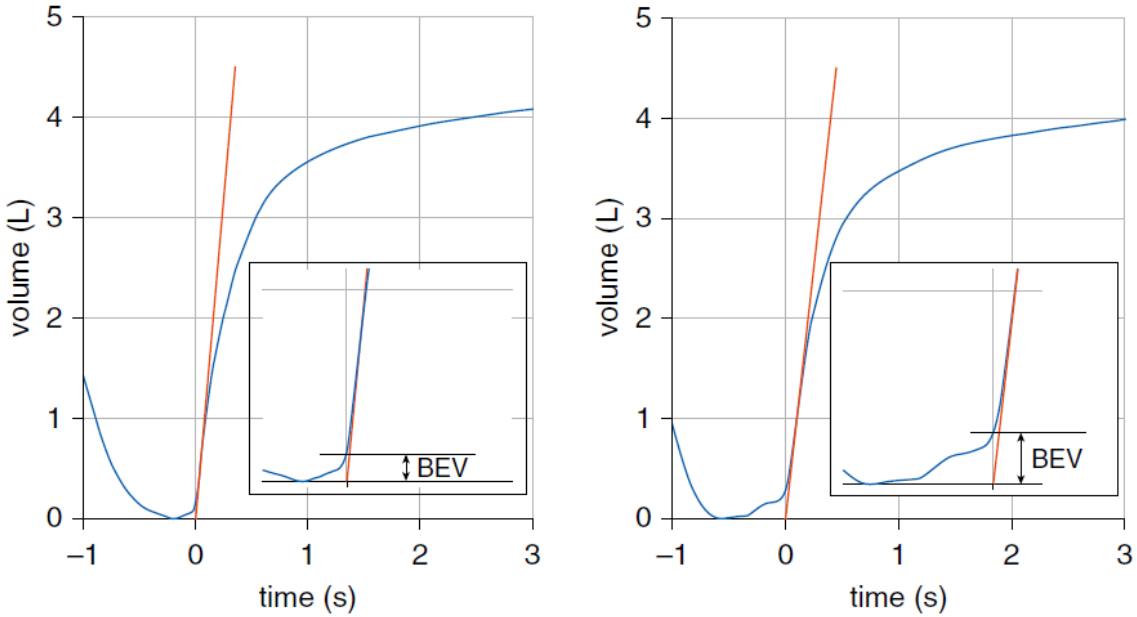
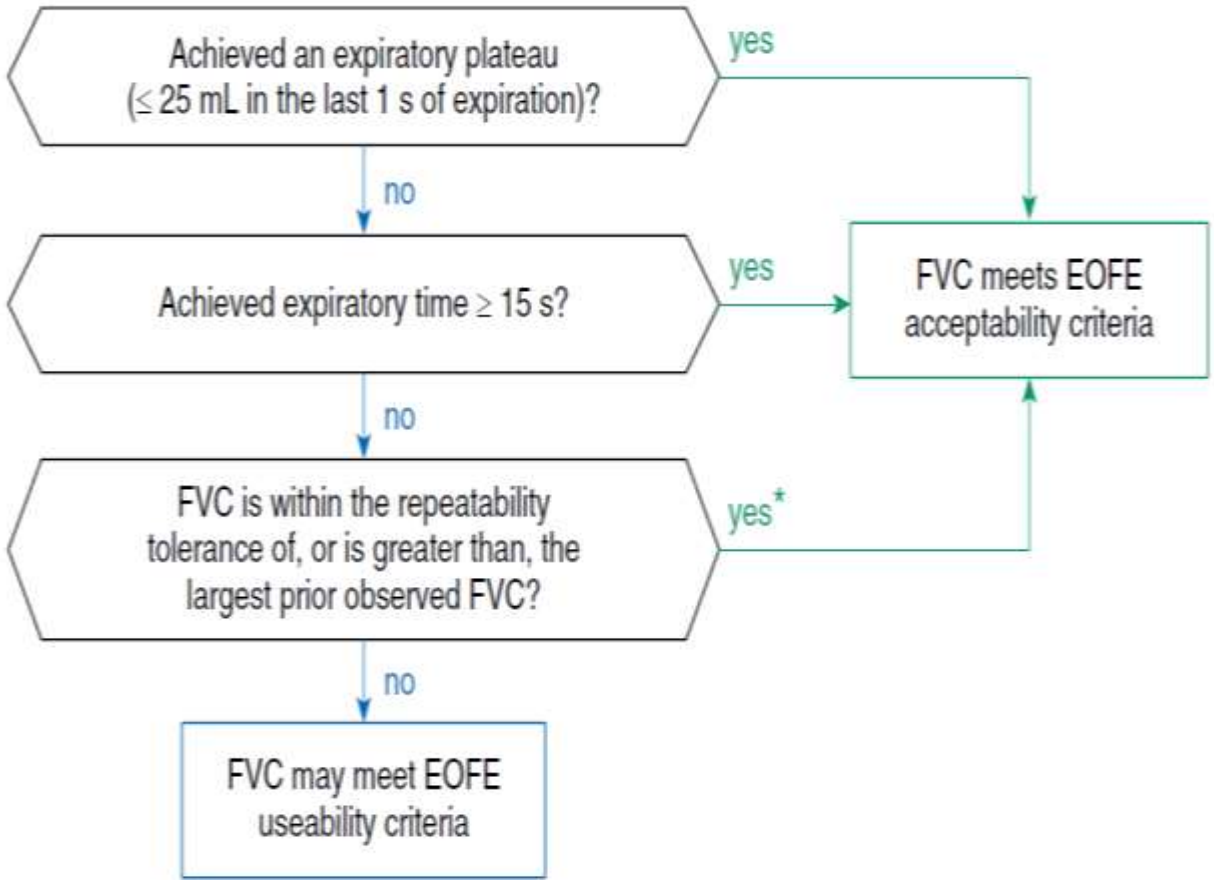


Figure 1. Back-extrapolated volume (BEV). Time 0 is found by drawing a line with a slope equal to peak flow through the point of peak flow (red line) on the volume–time curve and setting Time 0 to the point where this line intersects the time axis. The BEV is equal to the volume of gas exhaled before Time 0 (inset), which, in these two examples from the same patient, is 0.136 L for the left panel (acceptable) and 0.248 L for the right panel (unacceptable). For this patient, the BEV limit is 5% FVC = 0.225 L.

BACK-EXTRAPOLATED VOLUME

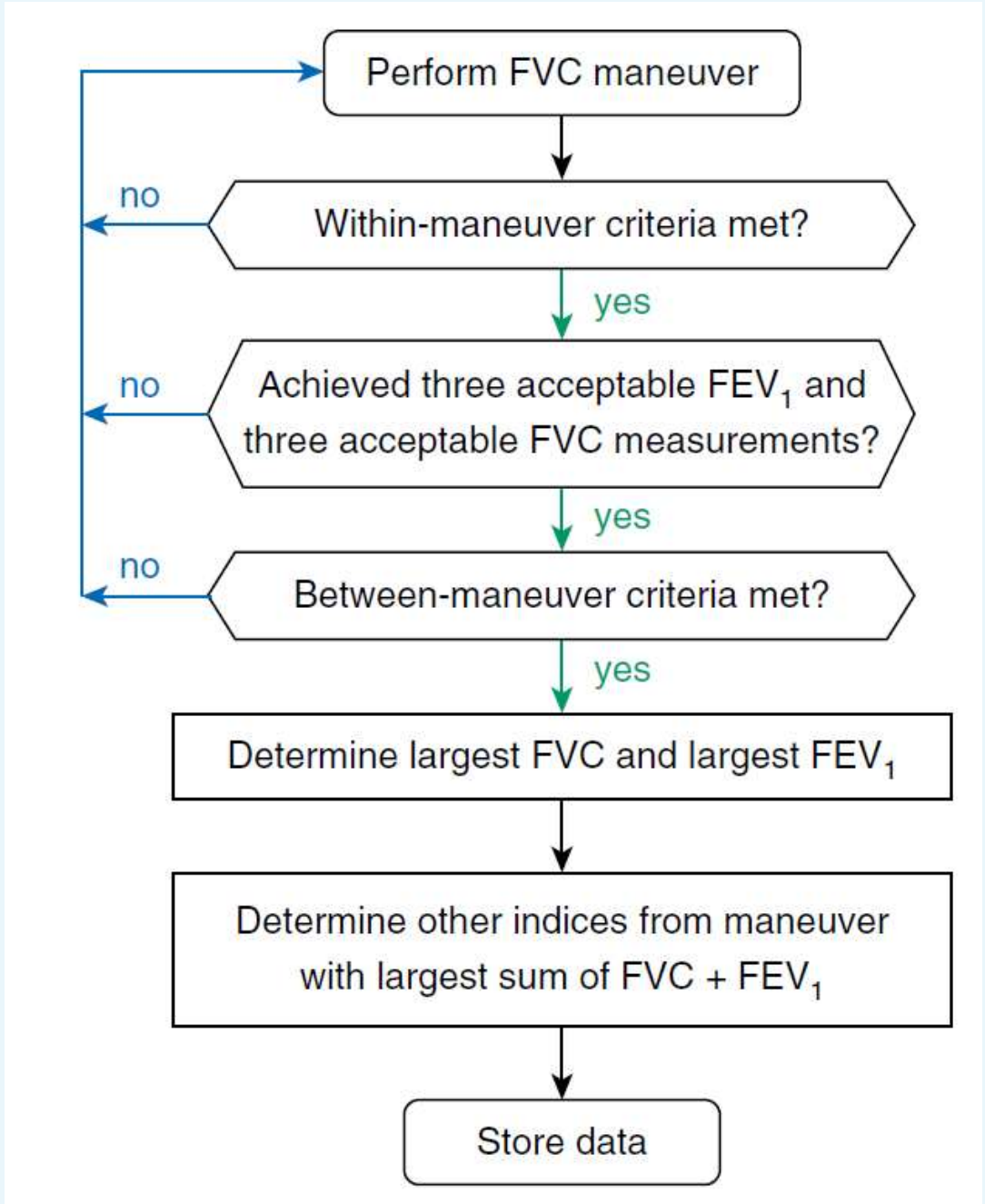
EOFE CRITERIA



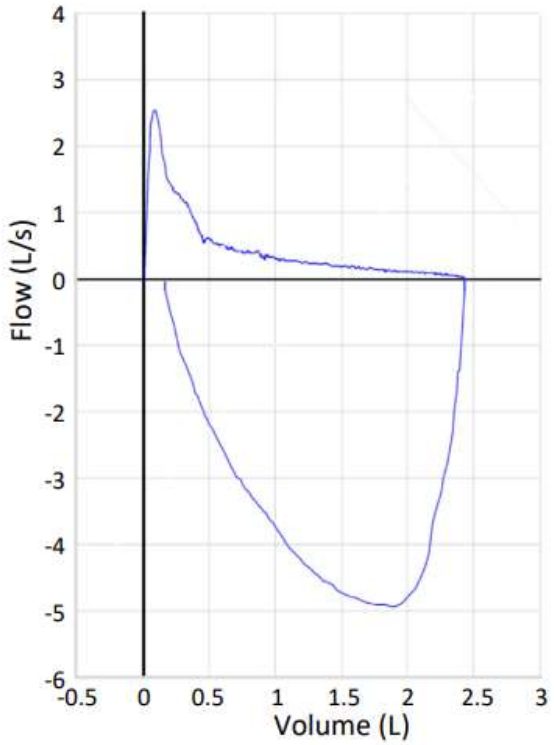
BETWEEN MANOUEVRE EVALUATION

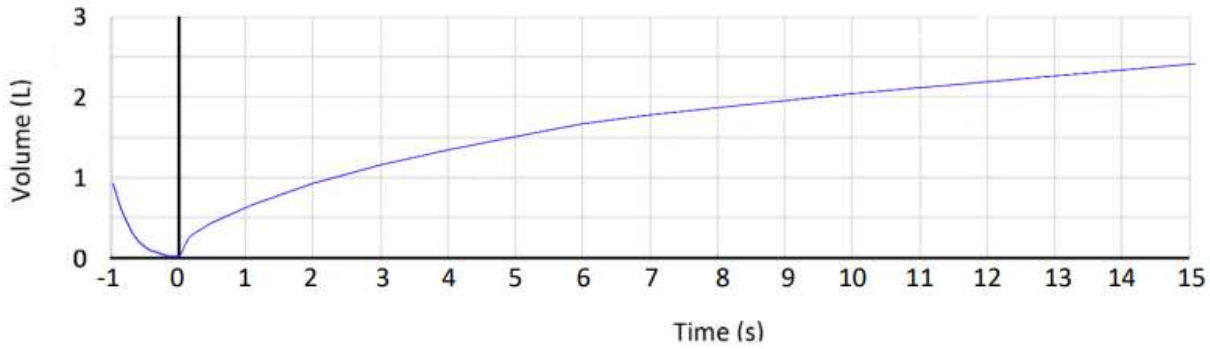
REPEATABILITY CRITERIA

Age >6 yr: the difference between the two largest FVC values must be <150 ml, and the difference between the two largest FEV1 values must be <150 ml



Q. A 46 year old lady with history of episodic wheezing and breathlessness for 30 years presented with worsening breathlessness. She also gives history of recurrent sneezing and nasal discharge. Examination reveals diffuse wheeze. A spirometry was performed. Interpret the same.





- ACCEPTABLE, >15 S

  OBSTRUCTIVE PATTERN

  FEV1- LOW

  FVC- NORMAL

  FEV1/FVC- LOW

  “SCOOPED OUT”/”STEEPLE SIGN”

D/D OF OBSTRUCTIVE PATTERN

- BRONCHIAL ASTHMA
- COPD
- BRONCHIECTASIS
- BRONCHIOLITIS
- CYSTIC FIBROSIS

Bronchodilator Responsiveness

- **Bronchodilator administration –**
  Salbutamol (4 puff =400 mcg) – spirometry after 15 min
  Ipratropium bromide (160 mcg)- spirometry after 30-45 min

- **Bronchodilator responsiveness-** $\frac{\text{Post B.D. FEV1} - \text{Pre B.D. FEV1}}{\text{Predicted FEV1 (acc. to GLI)}} \times 100$

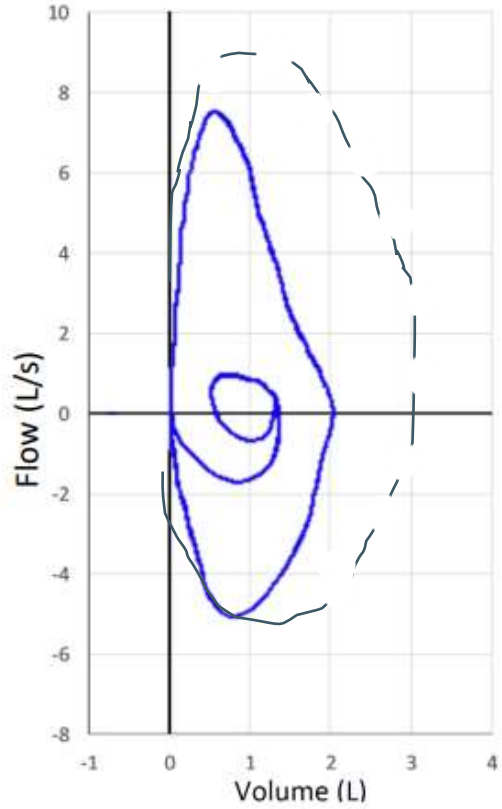
Increase 10 % in FEV1 or FVC (ERS/ATS Technical Standard Committee)

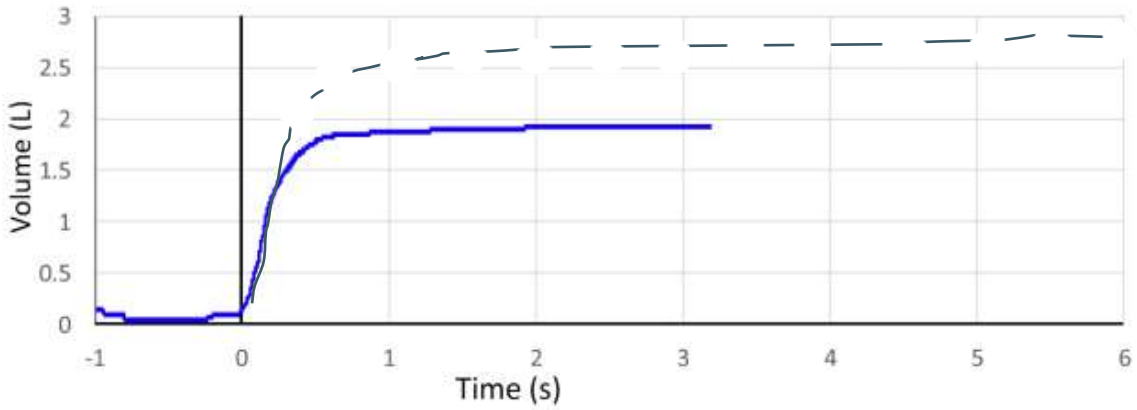
Increase 12% and 200 ml in FEV1 or FVC (GINA 2024)- For diagnosis of Asthma

Z-SCORE

	2005 ATS/ERS statement	2021 ATS/ERS technical standard
Severity of lung function impairment	• Using FEV_1 (includes obstruction or restriction): Mild: FEV_1 >70% predicted Moderate: 60–69% predicted Moderate-to-severe: 50–59% predicted Severe: 35–49% predicted Very severe: <35% predicted	• For all measures use z-score: Mild: −1.65 to −2.5 Moderate: −2.51 to −4.0 Severe: <−4.1

Q. A 62 year old gentleman presented with progressive dyspnoea and dry cough for 1 year. You note clubbing and velcro crackles on examination. A spirometry was done, interpret the same.





ANSWER- RESTRICTIVE PATTERN

- ACCEPTABLE, PLATEAU REACHED
- DECREASED FVC WITH MINIATURE F-V LOOP

- FEV1- Low, FVC- Low, FEV1/FVC- Normal
- Need TLC < LLN to confirm

Pulmonary

- Fibrosing lung diseases/ Fibrothorax
- Pneumoconioses
- Pulmonary edema
- Parenchymal lung tumors
- Lobectomy or pneumonectomy

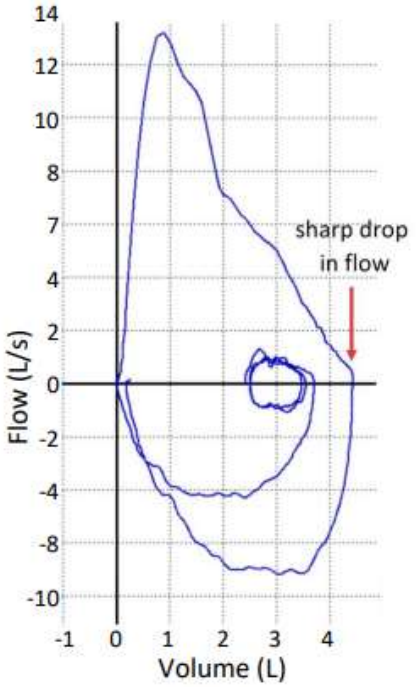
Extrapulmonary

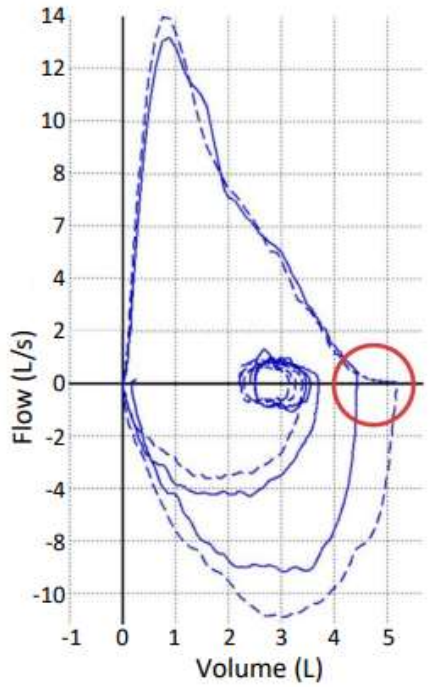
- Thoracic cage deformity
- Obesity
- Pregnancy
- Neuromuscular disorders

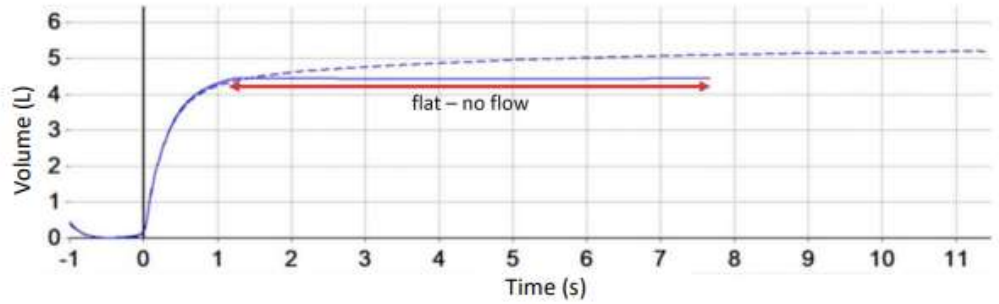
Q. A 45 year old patient with longstanding history of smoking presented with productive cough and shortness of breath for 2 years. A spirometry was performed. Interpret the same.

GLOTTIC CLOSURE

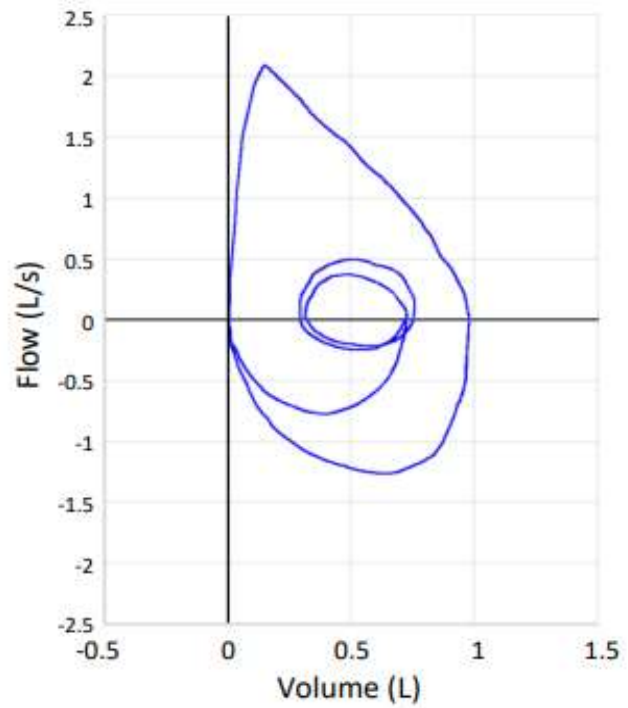
NOT ACCEPTABLE







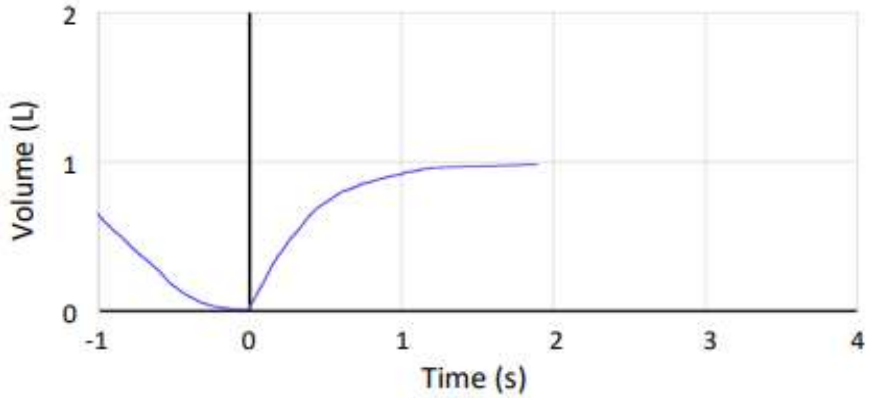
Q. A 6 year old boy presented with history of recurrent hospitalization for shortness of breath. A spirometry was performed. Interpret.



CHILDREN HAVE HIGH ELASTIC RECOIL, HENCE ACCEPTABLE

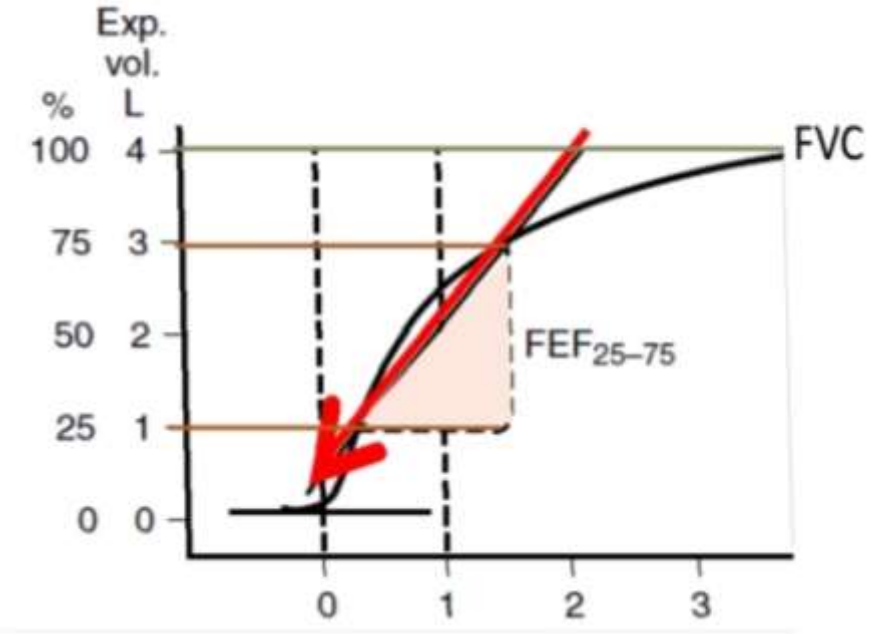
FEV0.75/FEV0.5 USED

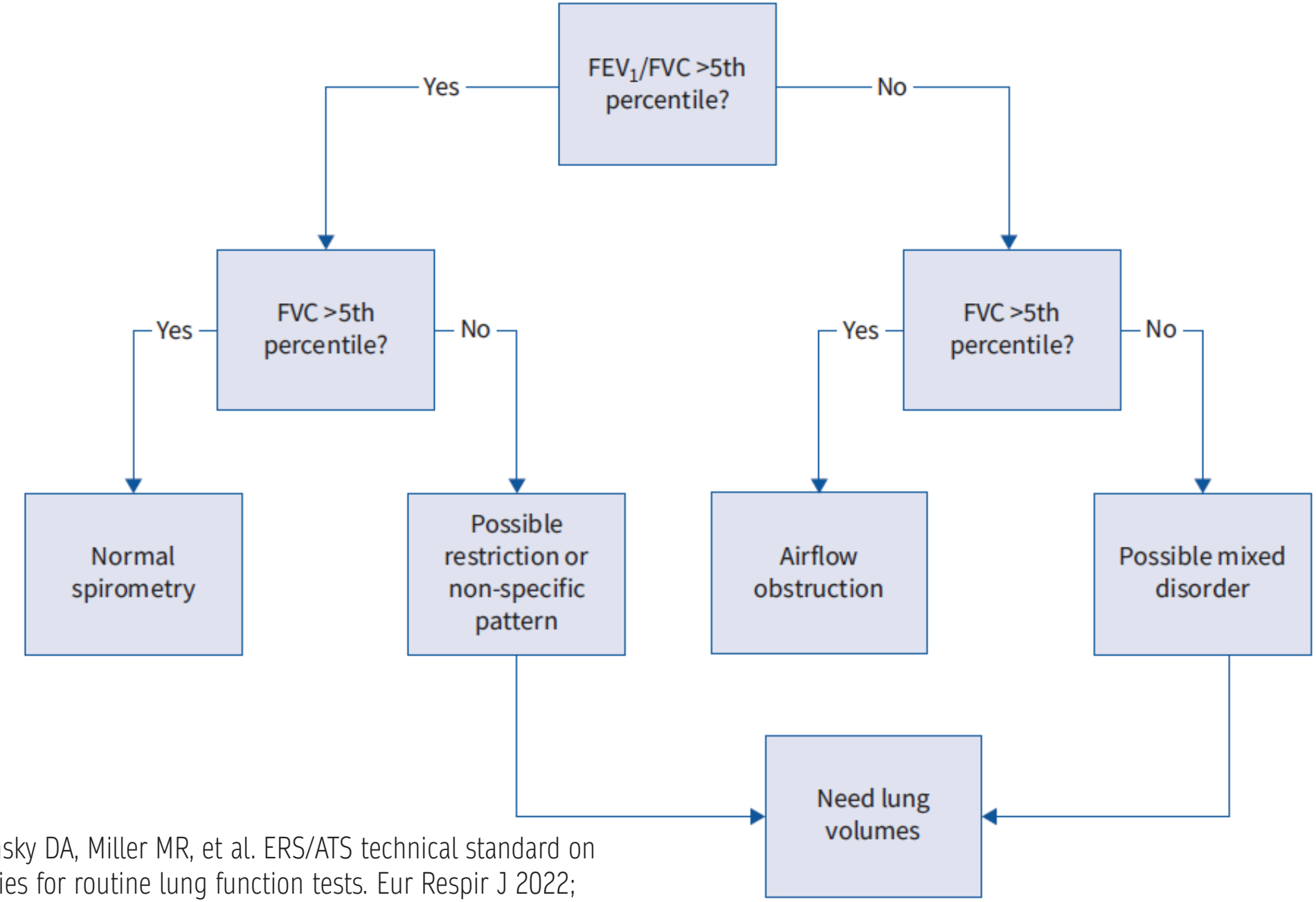
NORMAL SPIROMETRY



FEF_{25-75}

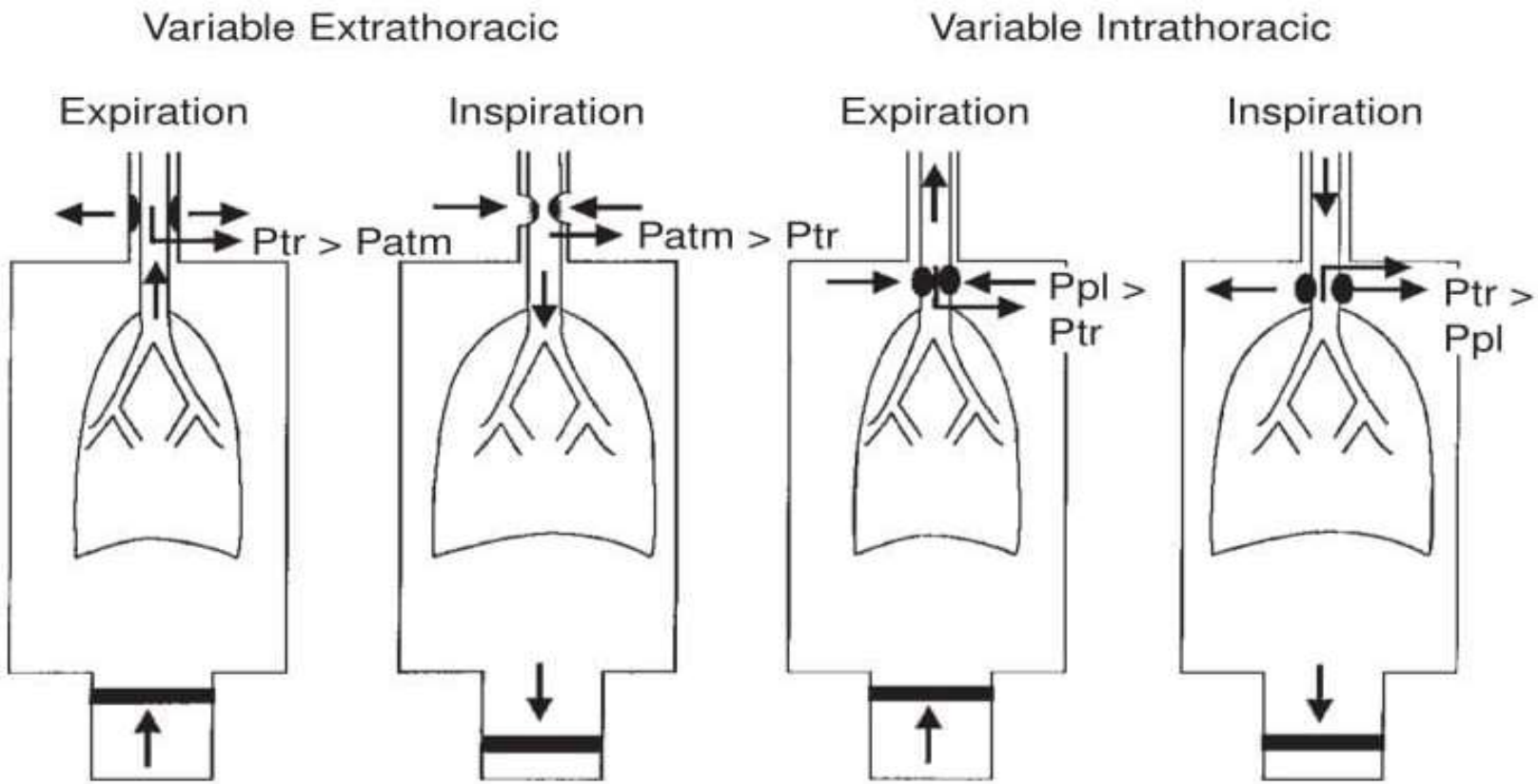
- Small airway has a large surface area so contribute to resistance at smaller lung volumes
- FEF 25-75 is average flow between between 25% and 75% of exhaled FVC
- This index is taken from the blow with the largest sum of FEV1 and FVC
- Non specific, poorly reproducible and highly variable





Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J 2022;

Upper Airway Obstruction



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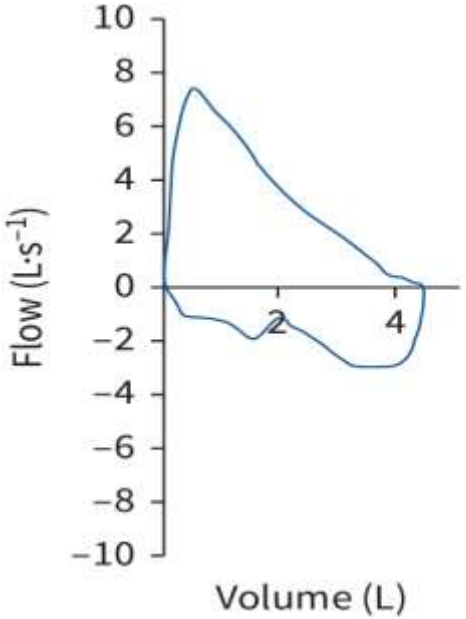
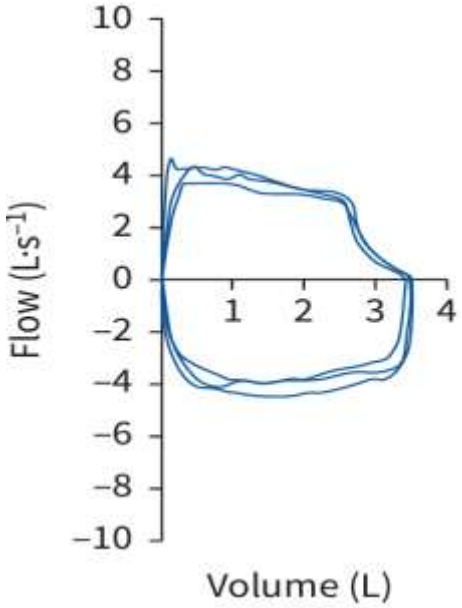
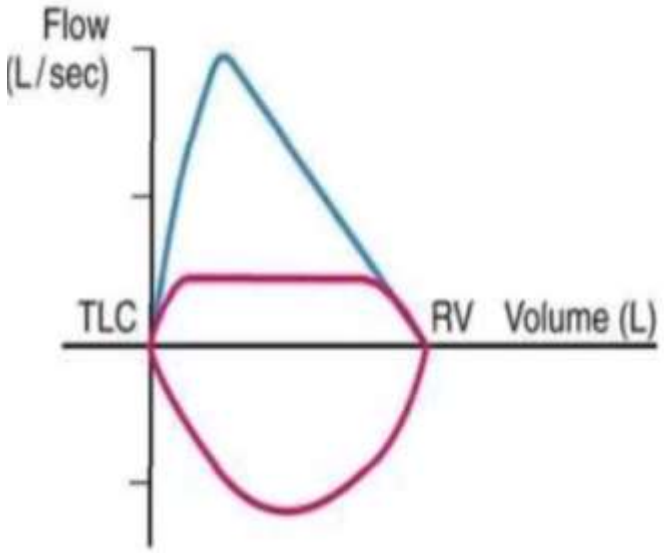


Variable extra-thoracic obstruction



Fixed Obstruction



Variable intra-thoracic obstruction

- **Bronchoprovocation challenge** — used to assess the airway hyperresponsiveness to a variety of stimuli, such as methacholine, mannitol, and exercise
- **Supine and sitting spirometry** — to evaluate respiratory muscle weakness

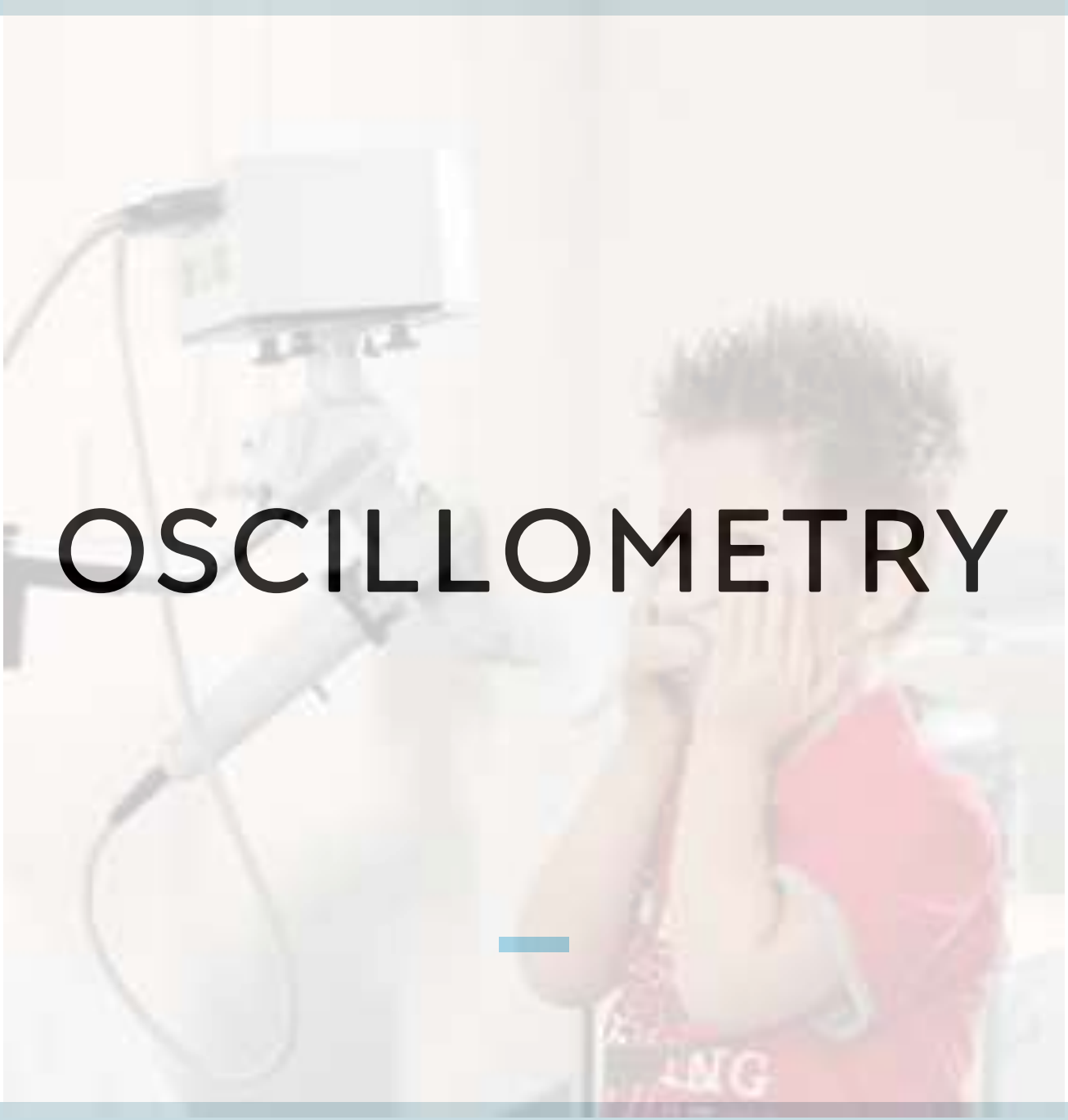
- Diaphragmatic weakness is suggested by a decrease in the supine vital capacity (VC) **>10%**
- Unilateral diaphragmatic paralysis- decrease of **15 to 25%**
- Bilateral diaphragmatic paralysis- decrease OF **50%**

ADVERSE EVENTS

- Light-headedness
- Headache
- Facial congestion
- Syncope
- Transient urinary incontinence

SHORTCOMINGS

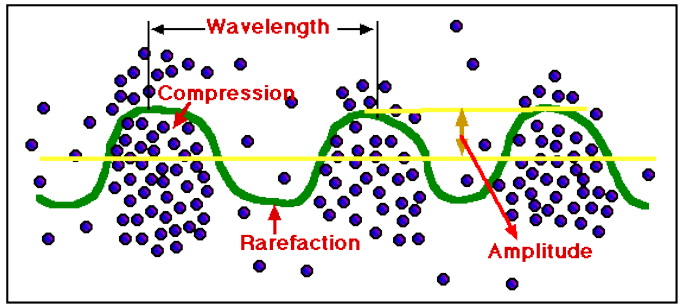
- Does not tell about RV, FRC, TLC
- Low sensitivity for small airway diseases
- Effort dependent
- Difficult for children, elderly, differently abled

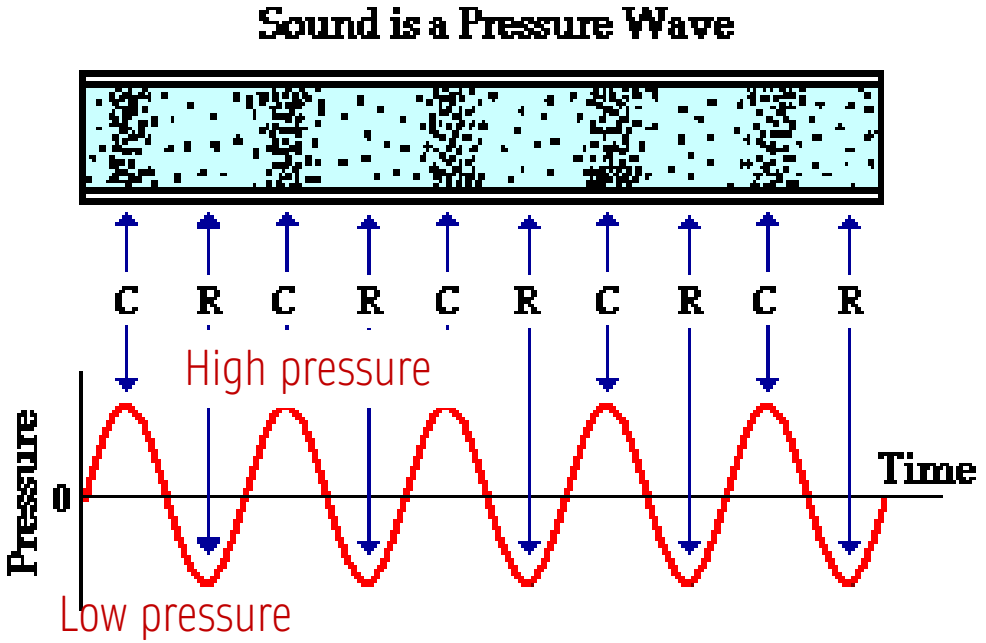


OSCILLOMETRY

PRINCIPLE: *SOUND WAVE TRAVELS AS PRESSURE WAVE*

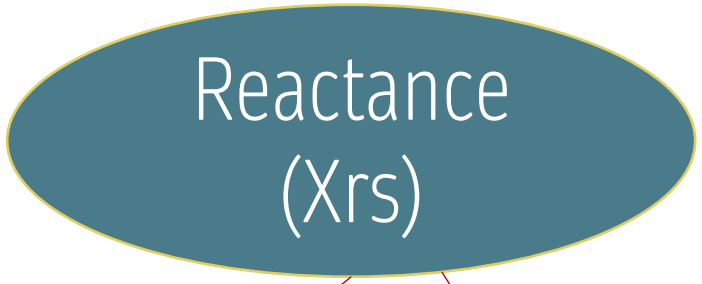
Vibrations set particles in motion



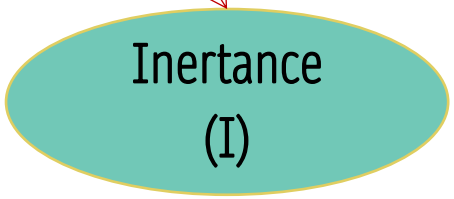


(Always do oscillometry first followed by spirometry)

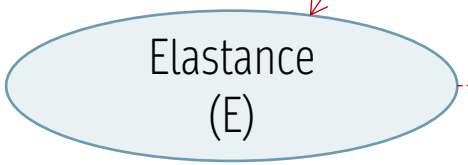
Respiratory impedance(Zrs)



Capacitance: elastic properties of the lung and of the chest wall, mobility of the ribcage, lung compliance

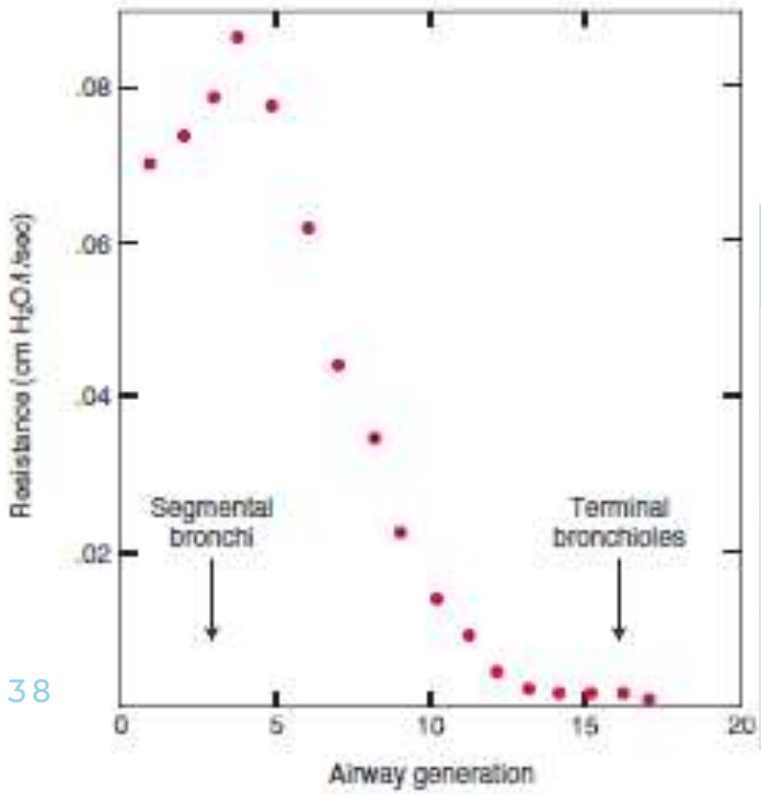


Inertance: mass-inertia of the moving air columns, due to the physical properties of inhaled air

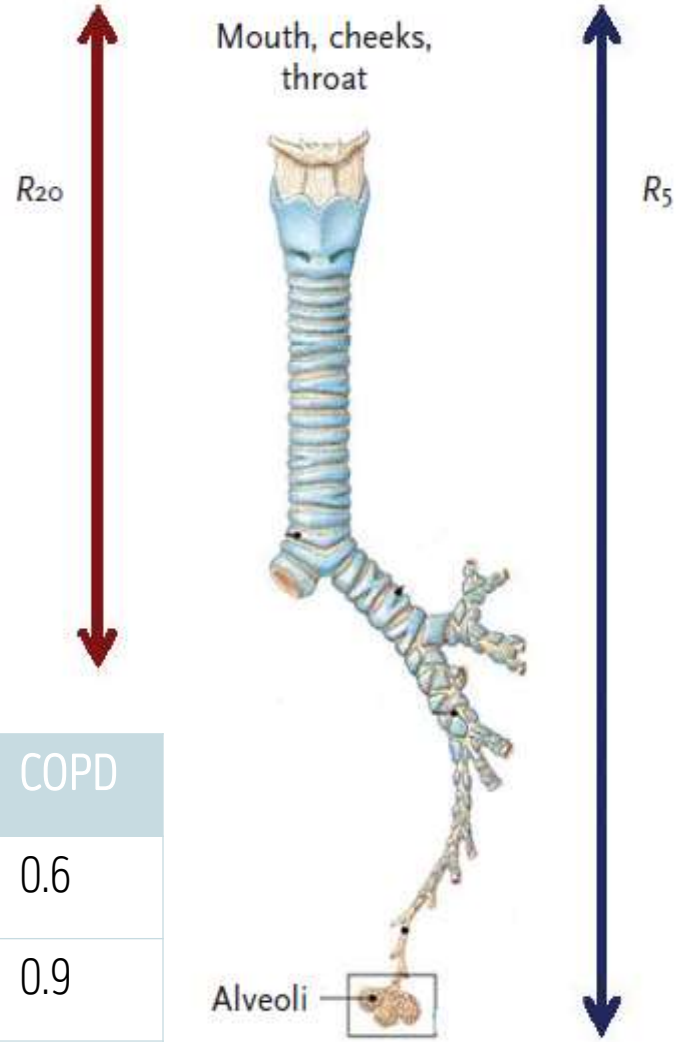


RESISTANCE

- 80% by central airways and only 20% by small airways (<2 mm diameter) in adults



Location	Normal	COPD
Pharynx-Larynx	0.6	0.6
Airways> 2mm	0.6	0.9
Airways<2mm	0.3	3.5
Total Airway Resistance	1.5	5.0

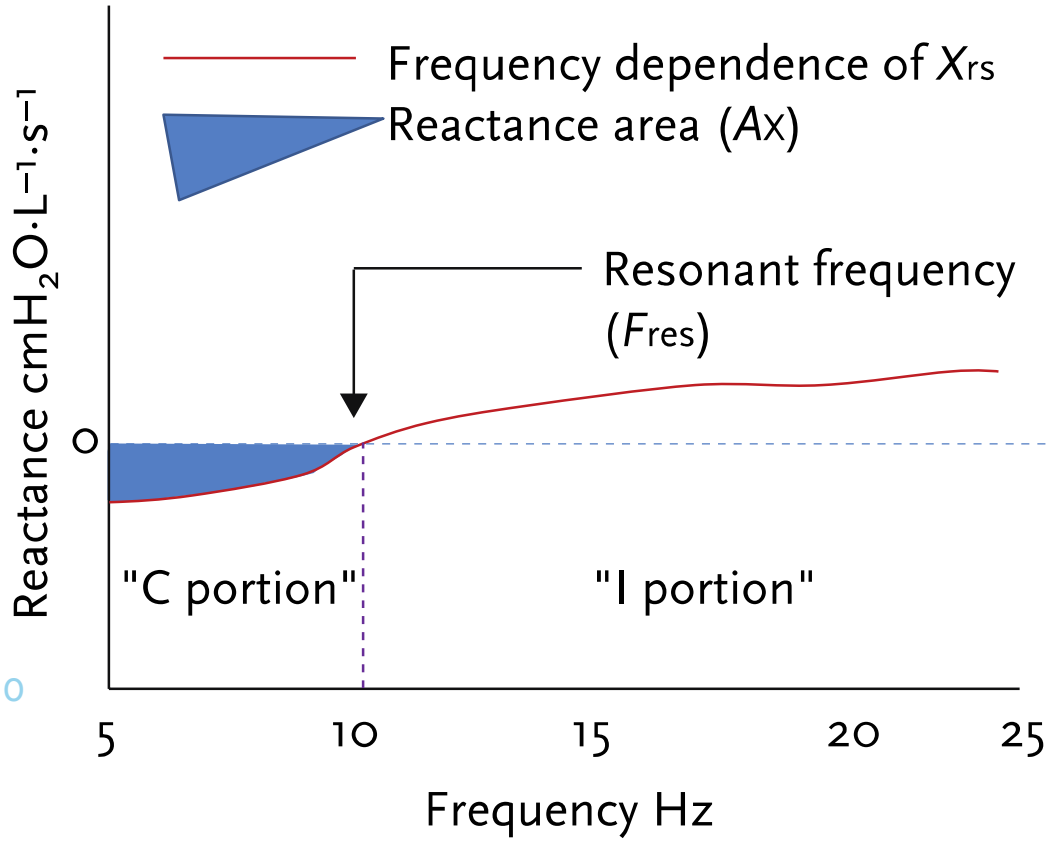


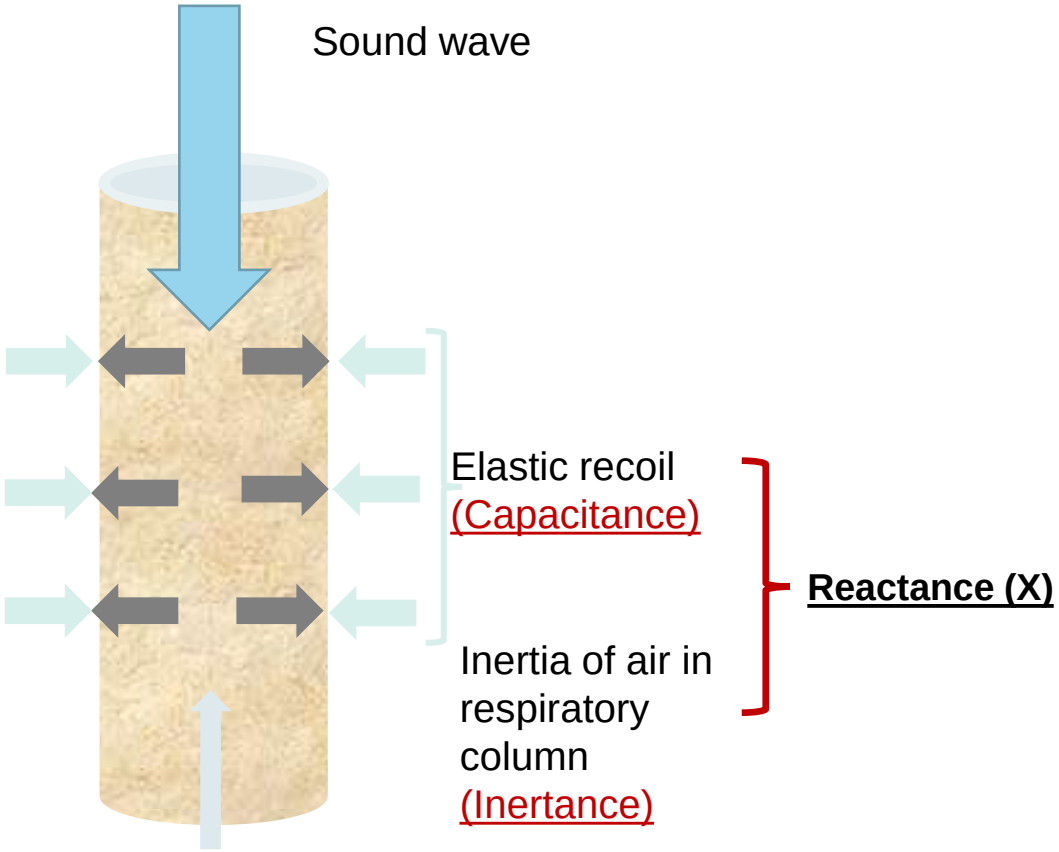
J. B. West, Respiratory Physiology, 9/e, 2012

REACTANCE (X)

1. Inertance in the large, central airways
2. Elastic properties of lung tissue (capacitance)

- Reactance is more frequency-dependent than resistance



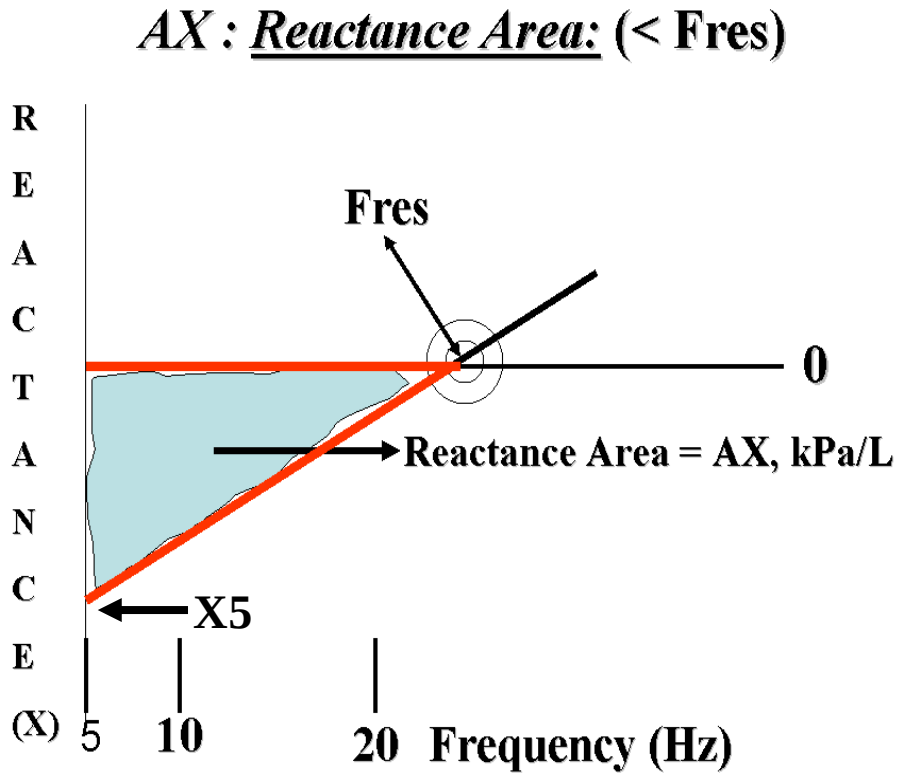


Reactance (X)= Capacitance + Inertance

In either fibrosis, emphysema or small airway disease, the reactance at lower frequencies would change in the same direction, i.e., become even more negative

AREA OF REACTANCE (AX) AND RESONANT FREQUENCY (FRES)

- Area under the curve between the reactance values for 5Hz and the resonance frequency
- It includes the total area dominated by the capacitance and reflects the elastic properties of the lung
- Increases in any disease of lung periphery



- Resonant frequency (Fres) is defined as the frequency at which the inertial properties of the airway and the capacitance of the lung periphery are equal
- The frequency at which total reactance is zero

In both obstructive and restrictive lung diseases, *fres* is increased above normal

PARAMETERS

- R5 – Total respiratory resistance
- R20 – Large airway resistance
- R5 – R20 – Small airway resistance
- X5 – Small airway obstruction, Lung elastance and stiffness, Lung heterogeneity
- Fres – Airflow obstruction, Lung restriction
- AX – What is happening in the distal portion of the lungs, both – small airways and lung parenchyma
- X5 inspiratory more than X5e – restrictive
- X5 expiration more than X5i - obstructive
- Delta X5

CENTRAL VS PERIPHERAL AIRWAY OBSTRUCTION

Parameter	Healthy	Central airway obstruction	Peripheral airway obstruction with alveolar damage
R5	Normal	> 150 % predicted	> 150 % predicted
R20	Normal	> 150 % predicted	Normal
R5-R20	Close to zero	Close to zero	Increased
X5	Normal	Normal	Increased
AX	Normal	Normal	Increased
Resonant frequency	7-12 Hz	Normal	Increased

ADVANTAGES

- Anyone who can breathe can do oscillometry- children, old age, mentally and physically challenged
- Clinically obstructive airway disease with normal spirometry
- To determine level of obstruction (large airways vs small airways) – Role of ultra-fine particle inhaler therapy
- Lung transplant rejection earlier than spirometry

LIMITATIONS

- A newer less standardized methodology
- Limited reference standard values and high intra-subject variability
- Cost

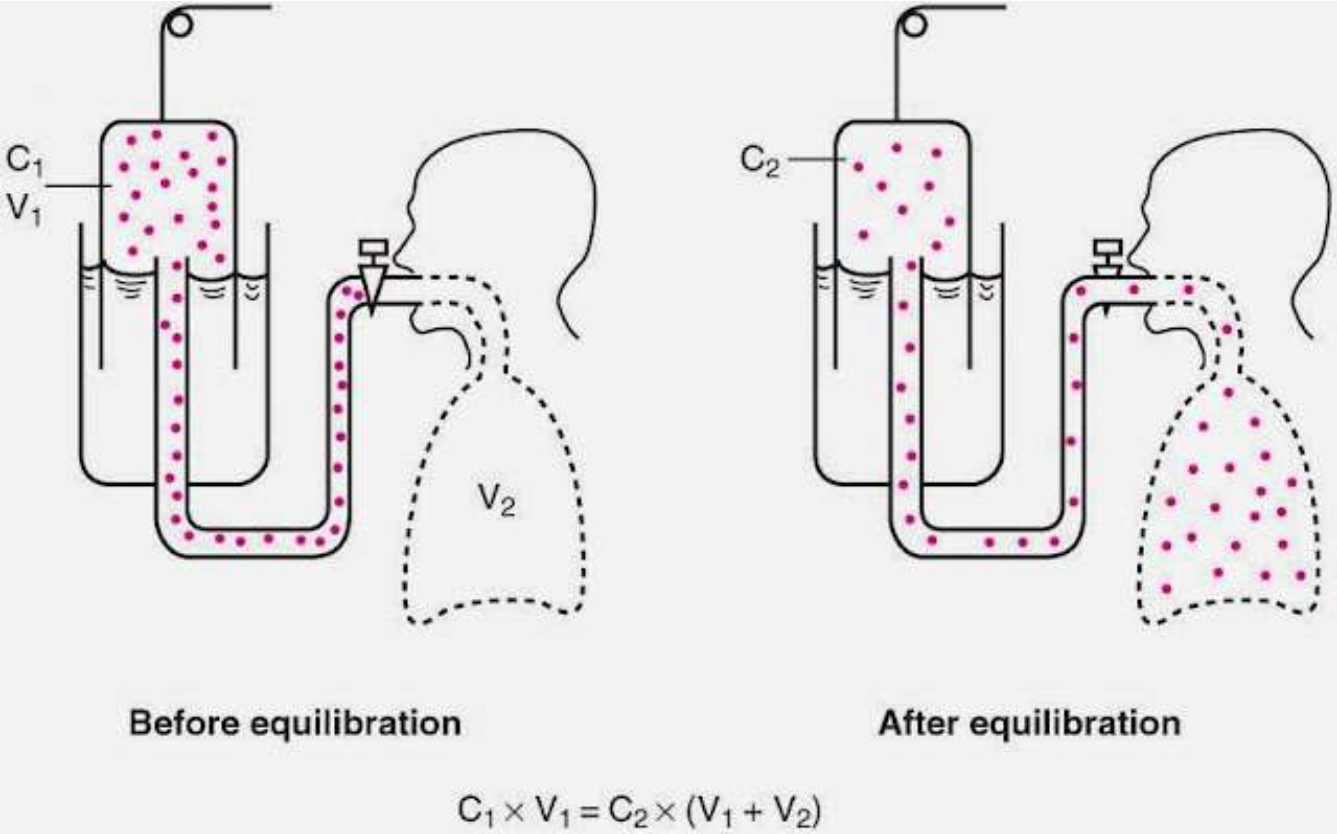
LUNG VOLUME MEASUREMENTS

INDICATIONS

- Determination of lung volumes – measurement of FRC with TLC and RV– add to information from spirometry
- A reduced FVC on spirometry may be- restrictive ventilatory defect, air trapping, or the combined obstructive and restrictive defects
- A reduced TLC establishes the presence of a restrictive ventilatory defect
- May enhance the assessment of obstructive ventilatory defects through the detection of air trapping and hyperinflation
- Can be measured using a variety of techniques: body plethysmography, MBW and inert gas dilution, radiographic techniques

HELIUM DILUTION TECHNIQUE

- Closed circuit method based on equilibrium of gas in the lung with a known volume of gas containing a known amount (or fraction) of Helium



PRINCIPLE

•A spirometer of known volume (V) contains 9–12% helium (He) in air.

•The patient breathes normally through a mouthpiece (with a nose clip) to get used to the system

•At the end of a normal tidal breath, a valve opens, and the patient begins breathing the helium mixture.

•The unknown lung volume (FRC) dilutes the helium, resulting in a new, lower helium concentration

•Equation-

$$FRC = \frac{(C1 \times V1) - (C2 \times V1)}{C2}$$

where C1 = initial helium concentration, C2 = final concentration, and V1 = known spirometer volume

- After FRC measurement, the patient performs three vital capacity (VC) maneuvers to calculate TLC and RV
- In obstructive diseases (e.g., COPD, emphysema), equilibration takes longer due to poor gas mixing, and FRC may be underestimated due to air trapping

MULTIPLE BREATH WASHOUT METHOD

- Based on washing out an inert tracer gas from the lungs over multiple tidal breaths.
  - Endogenous gas(N2): Washed out by breathing 100% O2
  - Exogenous gas (Sulfur hexafluoride): Washed out using room air

.

- The difference between the initial alveolar tracer gas concentration and the amount of tracer gas washed out is used to calculate FRC

MEASUREMENT TECHNIQUE

1. The patient breathes tidally to establish a stable end-expiratory lung volume (~30–60 sec).
2. The patient first breathes room air (pre-washout) ⟶ then switched to 100% O_2 ⟶ N_2 is gradually washed out.
3. Tracer gas concentration is continuously monitored
4. The washout ends when end-tidal tracer gas concentration <1/40th of the starting concentration for 3 consecutive tidal breaths
5. After FRC is determined, the patient performs linked maneuvers to calculate TLC and RV
6. Waiting period of 2× the washout time between maneuvers (longer for severe obstruction)

$$FRC_{MBW}{}^{*} = \frac{(\text{net volume of inert gas exhaled})}{(Fet_{start} - Fet_{end})}$$

Fet is the concentration at end-tidal volume of the tracer gas, at the start (Fet_{start}) and end (Fet_{end}) of the MBW measurement

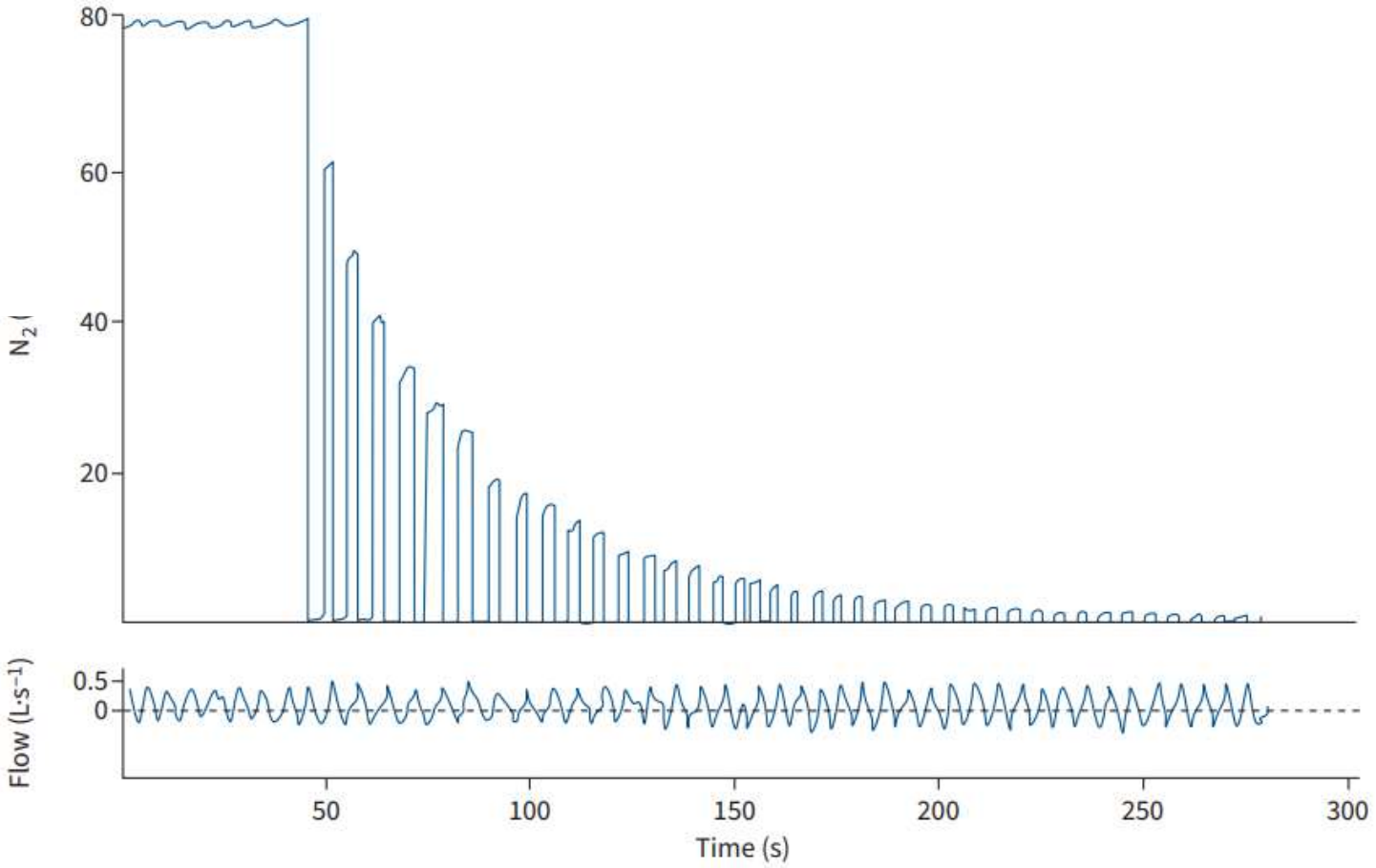


FIGURE 5 Display of the time course of nitrogen (N_2) (%) and flow ($L \cdot s^{-1}$) throughout the standard multiple breath washout measurement with the patient breathing 100% oxygen. When expressed as N_2% *versus* volume instead of time (not shown), the area under the curve would be the N_2 volume washed out.

LUNG CLEARANCE INDEX (LCI)

- A measure of ventilation efficiency obtained from MBW testing
- Reflects how evenly gas is distributed and cleared from the lungs
- Particularly useful in detecting early small airway disease, even before spirometry shows abnormalities
- Normal LCI values range from 6–7 in healthy individuals
- A higher LCI means that more breaths (or volume) are needed to wash out the lungs, indicating ventilation inhomogeneity, suggesting airway obstruction or small airway disease
- LCI is more sensitive than spirometry in detecting early lung disease, especially in Asthma, COPD, CF, BPD

BODY PLETHYSMOGRAPHY

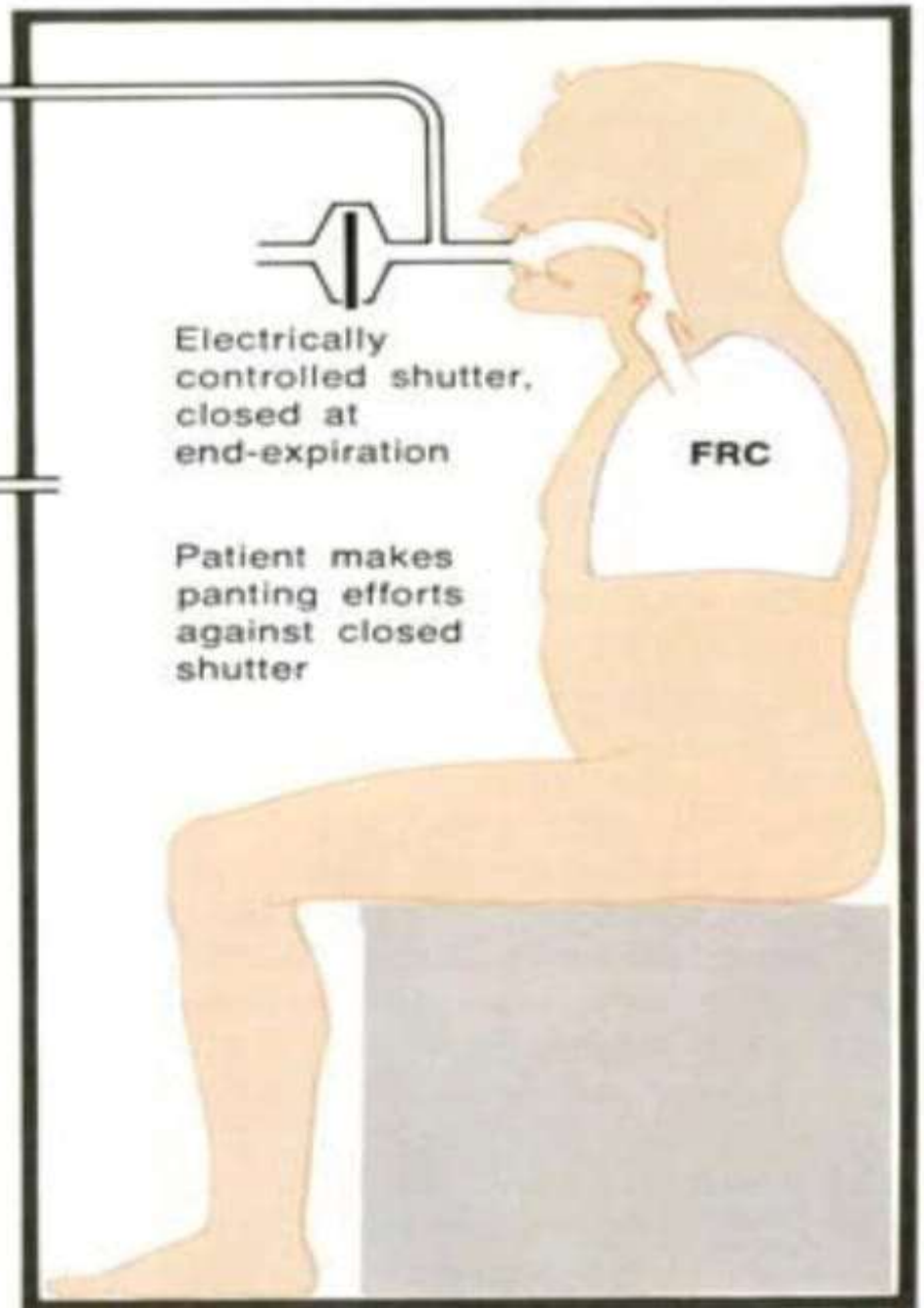
PRINCIPLE:

- Changes in alveolar pressure(PA) may be inferred from changes in plethysmograph pressure.
- A shutter mechanism is placed close to the mouth following which voluntary respiratory efforts are performed against closed shutter.
- The change in PA is estimated by recording the change in mouth pressure.
- ΔPA is plotted against simultaneous plethysmographic pressure changes during respiratory effort against a closed shutter to measure absolute intrathoracic gas volume
- Based on Boyle's law (P1V1=P2V2)

Body Plethysmograph Method for Determination of FRC

Mouth pressure (Pm)
Change in mouth pressure (ΔPm) reflects change in alveolar pressure

Box pressure (Pb)
Change in box pressure (ΔPb) reflects change in lung volume



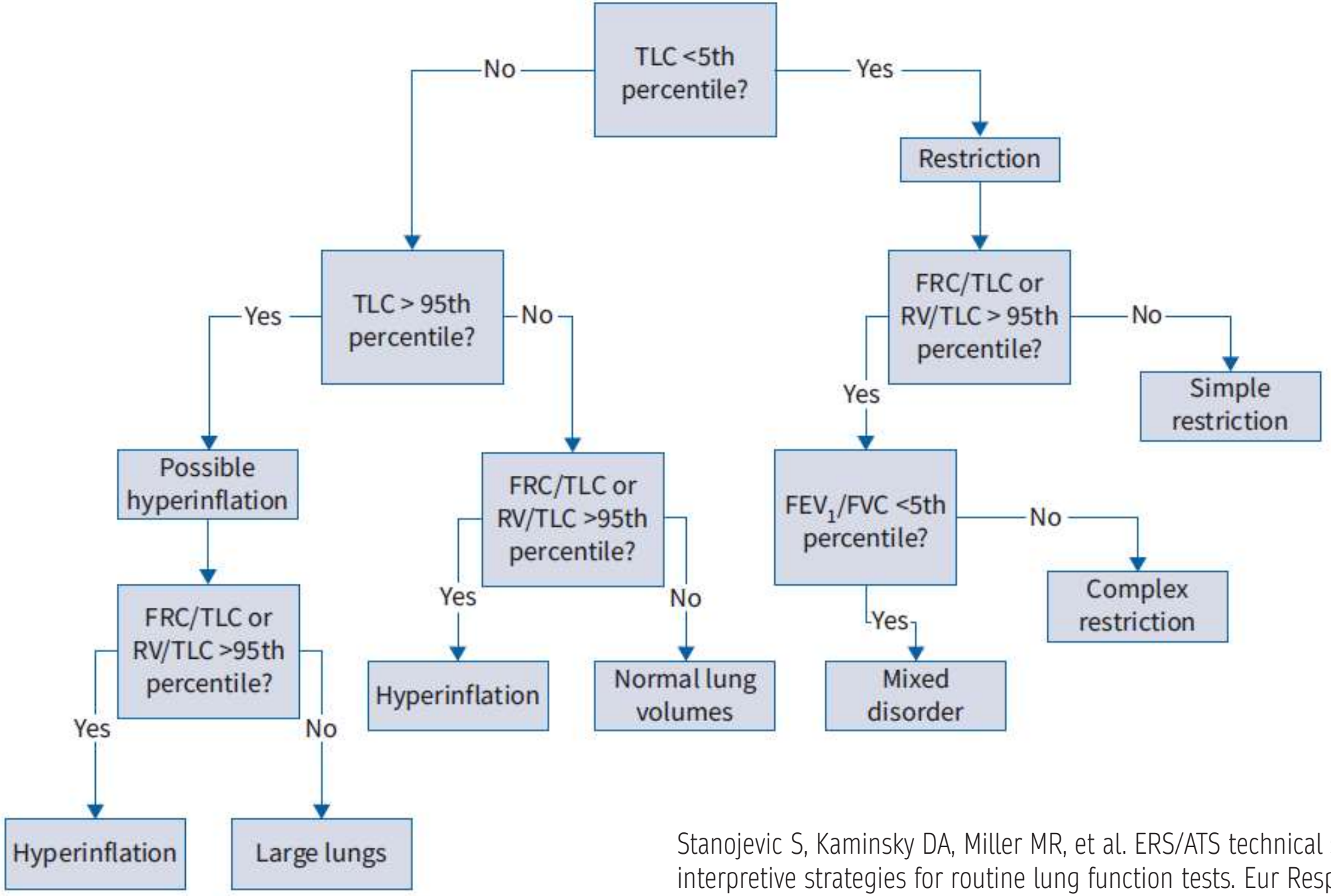
F. Netter M.D. © CIBA

$$\text{FRC} = \text{atmospheric pressure} \times \frac{\Delta Pb}{\Delta Pm}$$

TABLE 1 Advantages and disadvantages of lung volume measurement techniques

	Advantages	Disadvantages
Body plethysmography: measures volume of all compressible gas	Shorter testing period Measures all thoracic gas Requires only short time to repeat measurements	Technically challenging to administer and perform Potential for claustrophobia Can overestimate FRC in severe obstruction Higher equipment cost and space requirements Cabin may not accommodate patient's weight or size
Multiple breath washout: measures volume of gas in ventilated areas	Quiet breathing technique for measurement of FRC	Requires slightly larger tidal volumes Longer testing period Requires more time to repeat measurements Can underestimate FRC in obstructive lung disease Potential risk to patients with ventilation sensitive to high level of inspired oxygen
Helium dilution: measures volume of gas in ventilated areas	Quiet breathing technique for measurement of FRC	Longer testing period Requires CO_2 absorber, desiccant and O_2 bleed-in Requires more time to repeat measurements Can underestimate FRC in obstructive lung disease

FRC: functional residual capacity; CO_2: carbon dioxide; O_2: oxygen.



Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J 2022;

MAXIMAL RESPIRATORY PRESSURES

- Indicated whenever there is an unexplained decrease in vital capacity or respiratory muscle weakness is suspected clinically
- Maximal inspiratory pressure (MIP), measured near RV, is the maximal pressure that can be produced by the patient trying to inhale through a blocked mouthpiece after a full exhalation
- Maximal expiratory pressure (MEP) is the maximal pressure measured during forced expiration through a blocked mouthpiece after a nearly full inhalation to TLC
- Average MIP and MEP for adult men are -100 and +170 cm H2O, respectively, while the corresponding values for adult women are approximately -70 and +110 cm H2O, respectively

DLCO/TRANSFER FACTOR

- The DLCO measures the ability of the lungs to transfer gas from inhaled air to the red blood cells in pulmonary capillaries
- Misnomer- usually obtained at rest when the index is submaximal so it is not a capacity measurement + Several processes contribute to the rate constant, not only diffusion
- CO has a high Haldane constant, binds with Hb 200-300 times more avidly than O2
- Reverse reaction being extremely slow, practically no back pressure/tension

PREPARATION

- No cigarette smoking on the day of the test
- No use of inhaled bronchodilators on the day of the test
- No supplemental oxygen for at least 15 minutes prior to and during the test

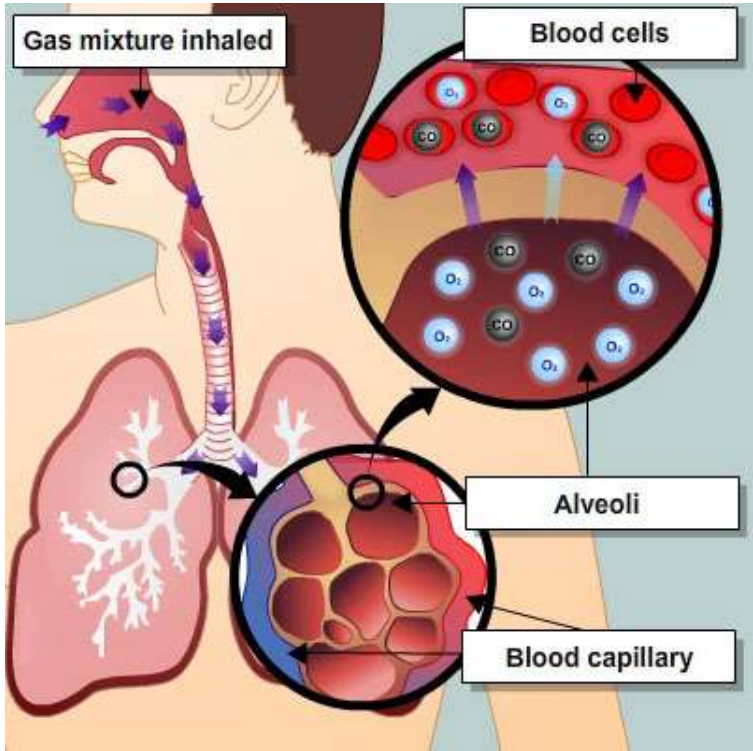
(Use of supplemental oxygen can decrease DLCO by 0.35 %/mmHg change)

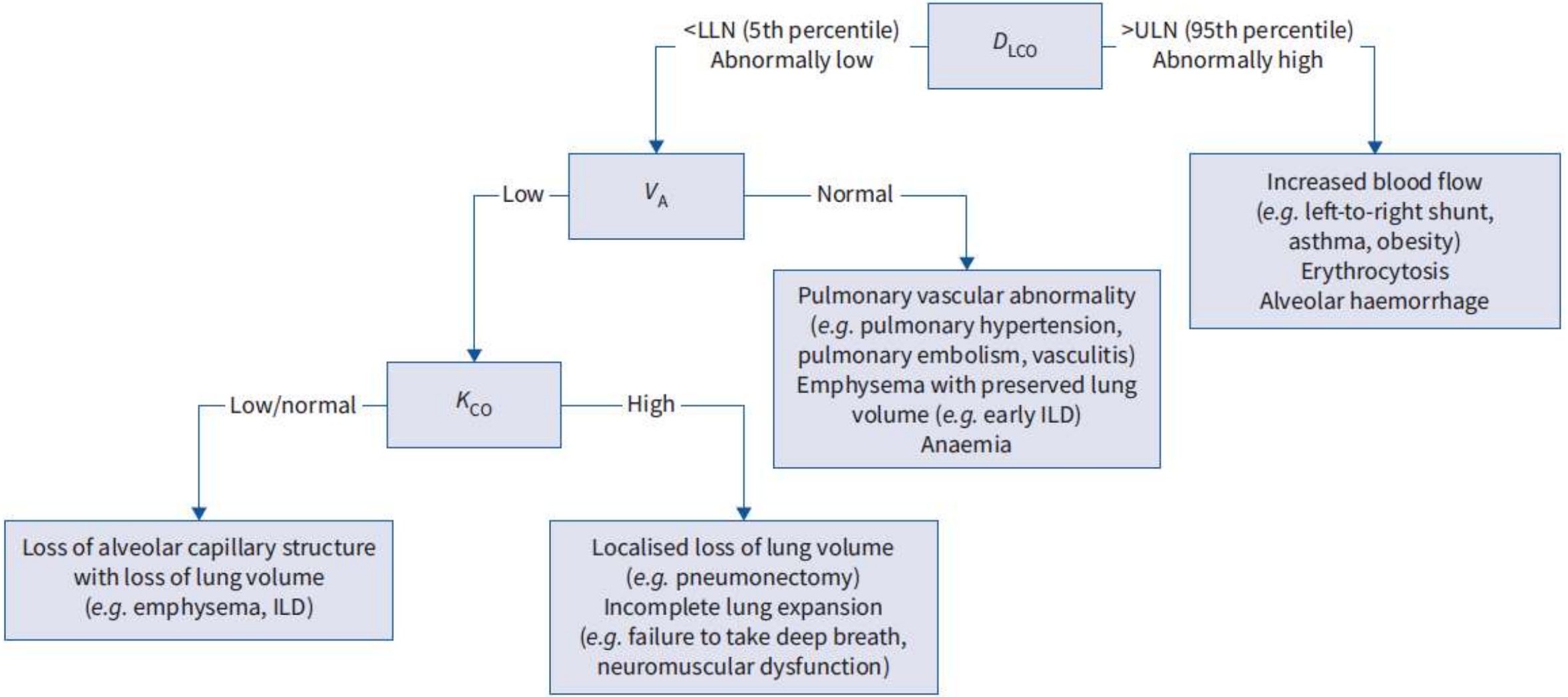
DLCO MANOUEVRE

- 3 to 4 normal breaths
- Followed by full inspiration, full expiration and than full inspiration and hold for 10 sec ±2, followed by forceful exhalation
- Gas: 0.3% CO, 0 to 14% helium, 21% O2, rest N2

WHAT AFFECTS DLCO

- Thickening of the alveolar-capillary membrane
- Loss of alveolar membrane surface area
- Reduction in volume of RBC in pulmonary capillaries
- Altitude
- Lung volume
- Carboxyhemoglobin levels





DLCO=KCO×VA
KCO = transfer co-efficient
VA =Alveolar volume → no. of contributing alveoli

6-MINUTE WALK TEST

- Objective evaluation of submaximal functional exercise capacity
- Simple to perform, better tolerated, more reflective of activities of daily living and requires no advance training to technicians
- Assesses global & integrated response of all systems (pulmonary, cardiovascular, systemic & peripheral circulation, blood, neuromuscular & muscle metabolism)

INDICATIONS

- **Pre & post treatment comparisons**

1. Lung transplantation
2. Lung resection
3. Lung volume reduction surgery
4. ILD
5. Pulmonary rehabilitation
6. COPD
7. Pulmonary hypertension
8. Heart failure

- **Functional status**

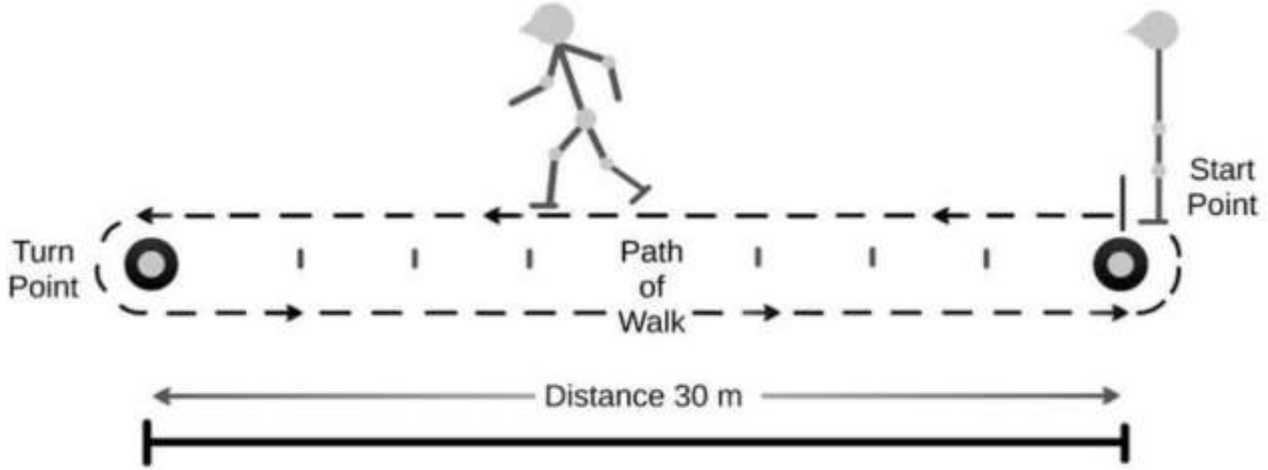
1. ILD
2. COPD
3. Heart failure
4. Peripheral vascular disease
5. Fibromyalgia

- **Mortality prediction**

1. Heart failure
2. COPD
3. Primary pulmonary hypertension

PRE-REQUISITES & PRECAUTIONS

- Long, flat, straight , enclosed corridor
- 30 m walking course, length marked every 3 m
- Turn around points marked with cone



- Line denoting starting and ending of 60 m lap marked with bright tape
- Rapid and appropriate response to emergency facility in place
- Oxygen, sublingual nitroglycerin, aspirin & inhalers etc must be available
- Technician should be certified in BLS
- In those on chronic oxygen therapy, oxygen should be given at their standard rate

HOW DO WE PERFORM THE TEST?

- Ask the patient rate their dyspnea & fatigue using Borg scale
- Set lap counter to 0 & timer to 6 minutes
- Instruct the patient to walk at own pace in 6 minutes. Patient can slow, stop, rest and resume again
- Start the timer when the patient starts to walk and click lap every time the patient reaches the starting line
- When the test is done, grade the dyspnea & fatigue with Borg scale again
- If pulse oximetry used, measure SpO2 & pulse rate

The modified Borg Scale for assessing the intensity of dyspnea or fatigue

0	Nothing at all
0.5	Very, very slight (just noticeable)
1	Very slight
2	Slight (light)
3	Moderate
4	Somewhat severe
5	Severe (heavy)
6	
7	Very severe
8	
9	
10	Very, very severe (maximal)

INTERPRETATION OF SCORES:

- Primary outcome is the distance covered in meters over 6 mins
- Normal norms: healthy adult has a reported range from 400 to 700m
- Age and sex specific reference standards are available for final interpretation
- A lower score reflecting less distance covered in 6 min indicates worse prognosis

WAKE UP… AND INTERPRET THESE REPORTS

Department of Pulmonary Medicine

Postgraduate Medical Edu. & Research, Chandigarh

ID: Age: 65

Sex at Birth	Female	Height	153 cm		Asthma	--
Ethnicity	South-East Asian	Weight	45 kg	BMI 19.2	COPD	--

FVL (ex/in)

Your FEV1 / Predicted: 66%

Test Date	07-02-2025 10:51:56	Interpretation	GOLD(2000)/Hardie	BTPS (IN/EX) 1.12/1.02
Post Time	07-02-2025 11:27:02	Predicted	Cihuitra (India), 2014 * 1.00	

	Pre							Post						
Parameter	**Best**	**LLN**	**%Pred**	**Pred**	**Trial 3**	**Trial 4**	**Trial 1**	**Best**	**%Pred**	**Chg**	**%Chg**	**Trial 3**	**Trial 2**	**Trial 1**
Time		-			10:54:22	10:55:44	10:53:18					11:28:53	11:28:15	11:27:39
FVC [L]	**2.11**	1.72	94	2.24	**2.11**	**1.99**	2.11	**2.41**	108	0.31*	14*	**2.41**	1.90	1.64*
FEV1 [L]	**1.03***	1.08	66	1.55	**1.03***	**0.92***	**1.02***	**1.27**	82	0.25*	16*	**1.27**	1.05*	1.08*
FEV1/FVC	**0.488***	0.635	-	0.718	0.488*	0.460*	0.486*	**0.527***	-	0.040	4	0.527*	0.552*	0.655
FEF25-75 [L/s]	**0.26***	0.71	22	1.18	0.26*	0.21*	0.24*	**0.42***	36	0.17	65	0.42*	0.46*	0.35*
PEF [L/min]	**134***	156	62	215	120*	134*	117*	**144***	67	10	-	144*	139*	163
FET [s]	**15.7**	-	-	-	15.7	15.2	14.5	**12.8**	-	-3.0	-	12.8	13.0	12.7

PVC and FEV1 Quality: **Bold is Acceptable**, Normal is Usable, Strikethrough is Not Usable

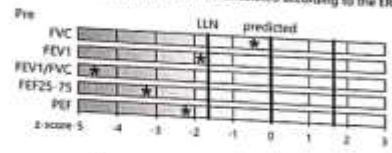
* Indicates value outside normal range or significant post change.

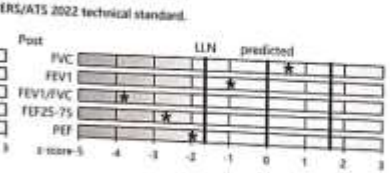
Session Quality — Pre

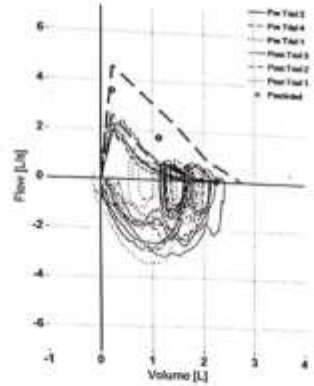
System Interpretation — Post: FEV1 - A, FVC - B (FVC Var=0.11L (5.4%); FEV1 Var=0.00L (0.2%))

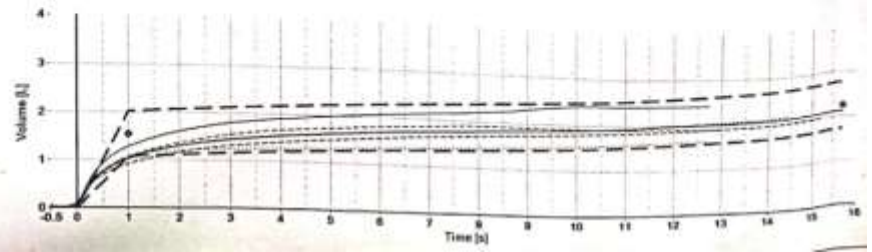
Overall Syst. Interpret. — Pre: FEV1 - E, FVC - E (FVC Var=0.51L (21.1%); FEV1 Var=0.20L (15.5%))

Pre-post %changes for FEV1, FVC are calculated according to the ERS/ATS 2022 technical standard.









Department of Pulmonary Medicine

Postgraduate Medical Edu. & Research, Chandigarh

ID: :

Age: 27

Sex at Birth	Female	Height	155 cm	Asthma	--
Ethnicity	South-East Asian	Weight	38 kg BMI 15.8	COPD	--

FVL (ex/in)

Your FEV1 / Predicted: 32%

Test Date	05-02-2025 10:11:13	Interpretation	GOLD(2008)/Hardie	BTPS (IN/EX)	1.12/1.02
Post Time	05-02-2025 10:32:09	Predicted	Chhabra (India), 2014 * 1.00		

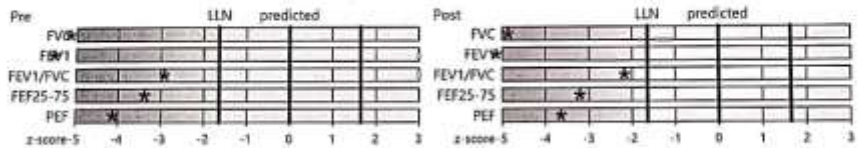
	Pre							Post						
Parameter	Best	LLN	%Pred	Pred	Trial 2	Trial 4	Trial 3	Best	%Pred	Chg	%Chg	Trial 1	Trial 2	Trial 3
Time					10:12:33	10:14:06	10:13:19					10:32:50	10:33:38	10:34:23
FVC [L]	**1.07***	2.18	40	2.70	**1.06***	**1.07***	**1.05***	**1.17***	43	0.09	3	**1.17***	**1.14***	**1.12***
FEV1 [L]	**0.76***	1.86	32	2.33	**0.76***	**0.73***	**0.71***	**0.87***	37	0.11	5	**0.87***	**0.84***	**0.81***
FEV1/FVC	**0.704***	0.768	-	0.852	0.710*	0.680*	0.672*	**0.741***	-	0.038	4	0.741*	0.736*	0.727*
FEF25-75 [L/s]	**0.52***	1.69	19	2.81	0.52*	0.46*	0.42*	**0.64***	23	0.12	23	0.64*	0.62*	0.60*
PEF [L/min]	**103***	243	31	336	96*	102*	103*	**130***	39	27	-	130*	124*	99*
FET [s]	**8.4**	-	-	-	6.5	8.4	7.9	**7.9**	-	-0.5	-	7.9	8.3	8.4

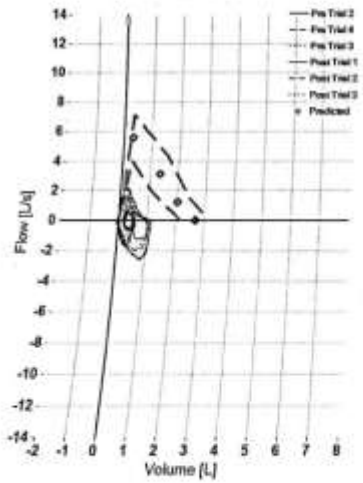
FVC and FEV1 Quality: **Bold is Acceptable**, Normal is Usable, Strikethrough is Not Usable

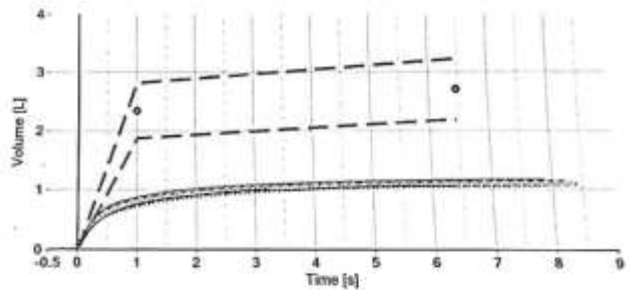
* Indicates value outside normal range or significant post change.

Session Quality	Pre	FEV1 - A, FVC - A (FVC Var=0.01L (0.5%); FEV1 Var=0.03L (3.4%))
	Post	FEV1 - A, FVC - A (FVC Var=0.03L (2.2%); FEV1 Var=0.02L (2.9%))
System Interpretation	Pre	
	Post	

Pre-post %changes for FEV1, FVC are calculated according to the ERS/ATS 2022 technical standard.







Department of Pulmonary Medicine

Postgraduate Medical Edu. & Research, Chandigarh

ID: ▲ Age: 25

Sex at Birth	Female	Height	152.5 cm	Asthma	--
Ethnicity	South-East Asian	Weight	61 kg BMI 26.2	COPD	--

FVL (ex/in) — **Your FEV1 / Predicted: 118%**

Test Date	12-02-2025 10:16:07	Interpretation	GOLD(2008)/Hardie	BTPS (IN/EX) 1.12/1.02
Post Time	12-02-2025 10:52:56	Predicted	Chhabra (India), 2014 * 1.00	

	Pre							Post						
Parameter	Best	LLN	%Pred	Pred	Trial 3	Trial 2	Trial 4	Best	%Pred	Chg	%Chg	Trial 4	Trial 3	Trial 1
Time					10:18:57	10:18:15	10:20:34					10:55:59	10:55:22	10:53:36
FVC [L]	**3.46**	2.10	132	2.62	**3.45**	**3.46**	**3.44**	**3.43**	131	-0.03	-1	**3.43**	**3.43**	**3.38**
FEV1 [L]	**2.70**	1.82	118	2.29	**2.70**	**2.69**	**2.59**	**2.97**	129	0.27*	12*	**2.97**	**2.96**	**2.92**
FEV1/FVC	**0.779**	0.754	-	0.838	0.781	0.776	0.754	**0.864**	-	0.085	8	0.865	0.863	0.862
FEF25-75 [L/s]	**2.36**	1.72	82	2.86	2.36	2.33	2.13	**3.29**	115	0.93	40	3.29	3.30	3.21
PEF [L/min]	**322**	232	100	321	322	315	293	**339**	105	17	-	339	330	311
FET [s]	**9.0**	-	-	-	9.4	9.0	9.6	**7.5**	-	-1.5	-	7.6	7.5	7.9

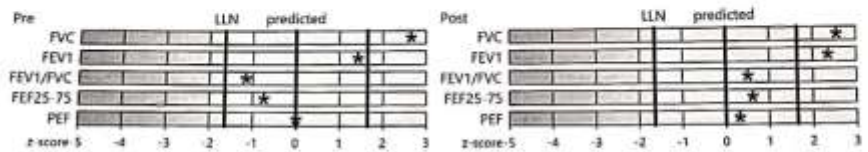
FVC and FEV1 Quality: **Bold is Acceptable**, Normal is Usable, ~~Strikethrough is Not Usable~~

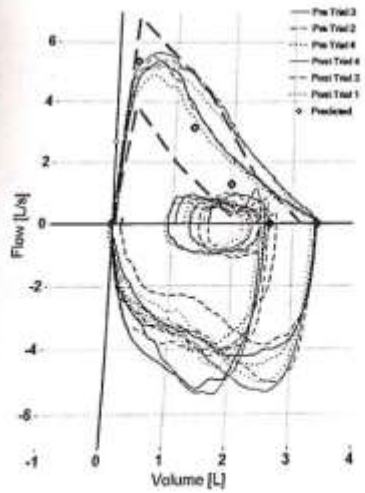
* Indicates value outside normal range or significant post change.

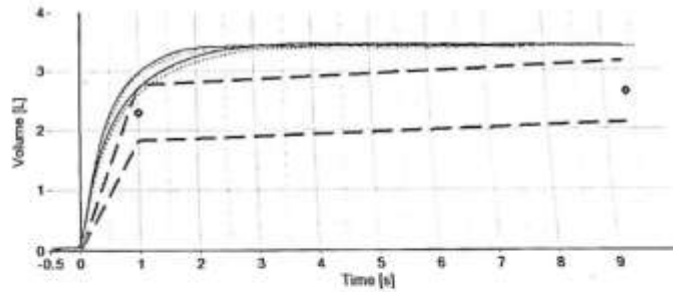
Session Quality	Pre	FEV1 - A, FVC - A (FVC Var=0.01L (0.2%); FEV1 Var=0.01L (0.5%))
	Post	FEV1 - A, FVC - A (FVC Var=0.00L (0.1%); FEV1 Var=0.00L (0.2%))
System Interpretation	Pre	
	Post	

Overall Syst. Interpret.

Pre-post %changes for FEV1, FVC are calculated according to the ERS/ATS 2022 technical standard.







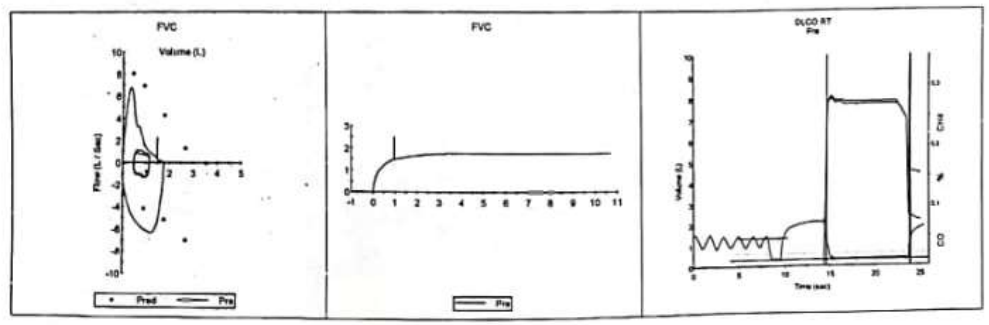
DEPARTMENT OF PULMONARY MEDICINE

Postgraduate Institute of Medical Education and Research

Chandigarh

Name	**Age:** 43	**Sex:** Male	**Date:-** 27-01-2025	**Visit Time**	10:56:13
CR No.	**Height:** 159.50	**Weight:** 53.00		**BSA:**	1.54

	Pre-Bronch			Post-Bronch	
	Actual	**Pred**	**%Pred**	**Actual**	**%Pred**
---- SPIROMETRY ----					
FVC (L)	1.76	3.53	49		
FEV1 (L)	1.50	2.96	50		
FEV1/FVC (%)	85	84	101		
PEF (L/min)	407.1				
FEF Max (L/sec)	6.79	8.05	84		
FIVC (L)	1.88	4.12	45		
Expiratory Time (sec)	10.74				
---- LUNG VOLUMES ----					
SVC (L)	1.80	3.53	50		
IC (L)	1.01	2.86	35		
ERV (L)	0.79	0.67	117		
---- DIFFUSION ----					
DLCOunc (ml/min/mmHg)	11.45	26.24	43		
DLCOcor (ml/min/mmHg)		26.24			
DL/VA (ml/min/mmHg/L)	4.66	5.81	80		
VA (L)	2.46	5.43	45		
IVC (L)	1.76				
BHT (sec)					



THANK YOU