ABC's of Pulmonary Function Testing (PFTs)

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Source of Slides: Pulmonary Function Testing by Wagner

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Clinical Assessment in Resp Care by Heuer & Scanlan.

Learning Objectives:

- Describe the indications for PFT's
- Categorize pulmonary function tests according to specific purposes
- List the indications for spirometry, lung volumes, and diffusing capacity
- Identify at least three obstructive and restrictive pulmonary disorders
- Relate pulmonary history to indications to performing pulmonary function tests
- Less heavy emphasis on instrumentation and calibration.

Major Indications

- Help diagnose lung diseases.
- Monitor disease progression.
  - Cystic fibrosis disease progression.
- Quantify the level of lung dysfunction.
- Aid in pre-procedure screening & risk adjustment.
  - Pre surgical screening for patient being a high risk

Categories of Pulmonary Function Tests

- Tests are divided by the lung function they measure, and we'll focus on the first two categories today!
  - ***Airway Function***
  - ***Lung Volumes and Ventilation***
  - Diffusing Capacity Tests
  - Blood Gases and Gas Exchange tests
  - Cardiopulmonary Exercise tests
  - Metabolic Measurements

Categories of Airway Function Tests

1. Simple spirometry
    a. VC, expiratory reserve volume (ERV), inspiratory capacity (IC)
2. Forced vital capacity maneuver
    a. FVC, FEV_1, FEF_{timed}, PEF
        (1) Pre/post bronchodilator
        (2) Pre/post bronchial challenge
    b. MEFV curves, V_{max}
        (1) Pre/post bronchodilator
        (2) Pre/post bronchial challenge
3. Maximal voluntary ventilation (MVV)
4. Maximal inspiratory/expiratory pressures (MIP/MEP)
5. Airway resistance (R_{aw})-body box, and Compliance (C_L)-esophageal balloon

Lung Volume and Ventilation Tests

1. Functional residual capacity (FRC)
    a. Open circuit (N_2 washout)
    b. Closed-circuit/rebreathing (He dilution)
    c. Thoracic gas volume (V_{TG})
2. Total lung capacity (TLC), residual volume (RV), RV/TLC ratio
3. Minute ventilation (Ve), alveolar ventilation (Va), and dead space (V_D)
4. Distribution of ventilation
    a. Multiple-breath N_2
    b. He equilibration
    c. Single-breath techniques

Diffusing Capacity Tests

1. Single breath (breath holding) D_{LCO}
2. Steady state
3. Other techniques

Blood Gases and Gas Exchange Tests

1. Blood gas analysis and co-oximetry
    a. Shunt studies
2. Pulse Oximetry
3. Capnography

Patient Preparation

- Withholding
  - Medication
    - Bronchodilators
    - Methylxanthine
    - Leukotrienes
  - Smoking
    - Refrain from smoking 24 hrs before
- Avoid big meals before the test (2-4hrs fasting)
- Avoid caffeinated beverages
- Avoid alcohol or any other stimulants
- Avoid exercising before
- Wear lose, comfortable clothing
- Need of an interpreter if needed

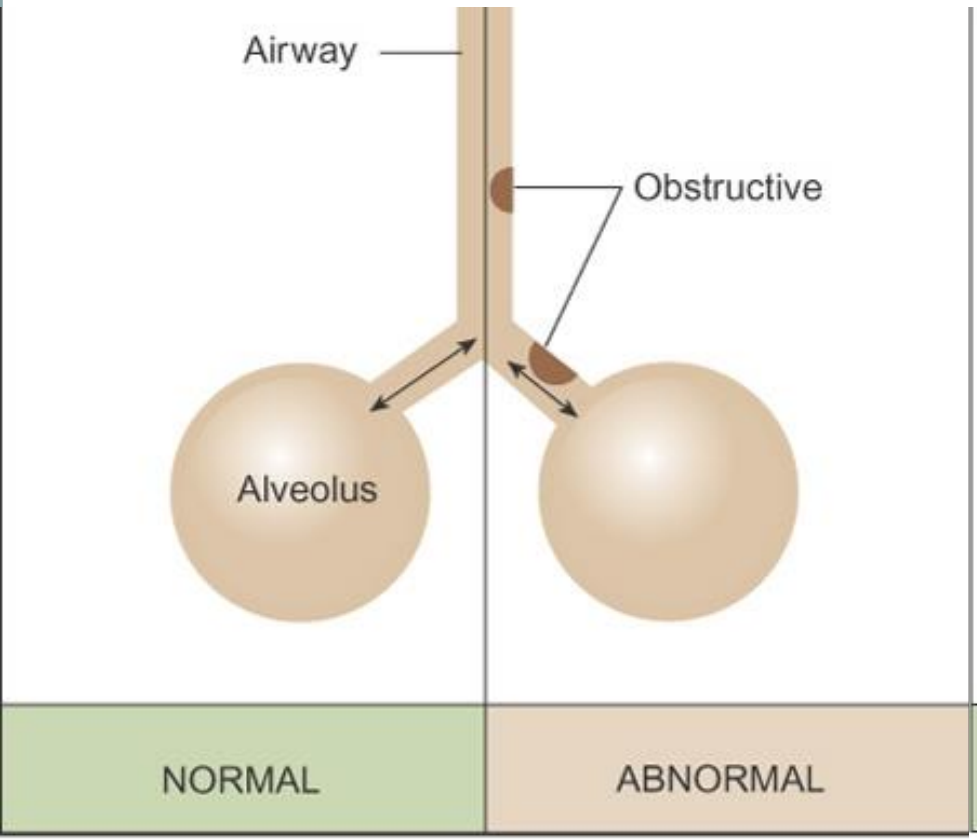
Preparations (cont.)

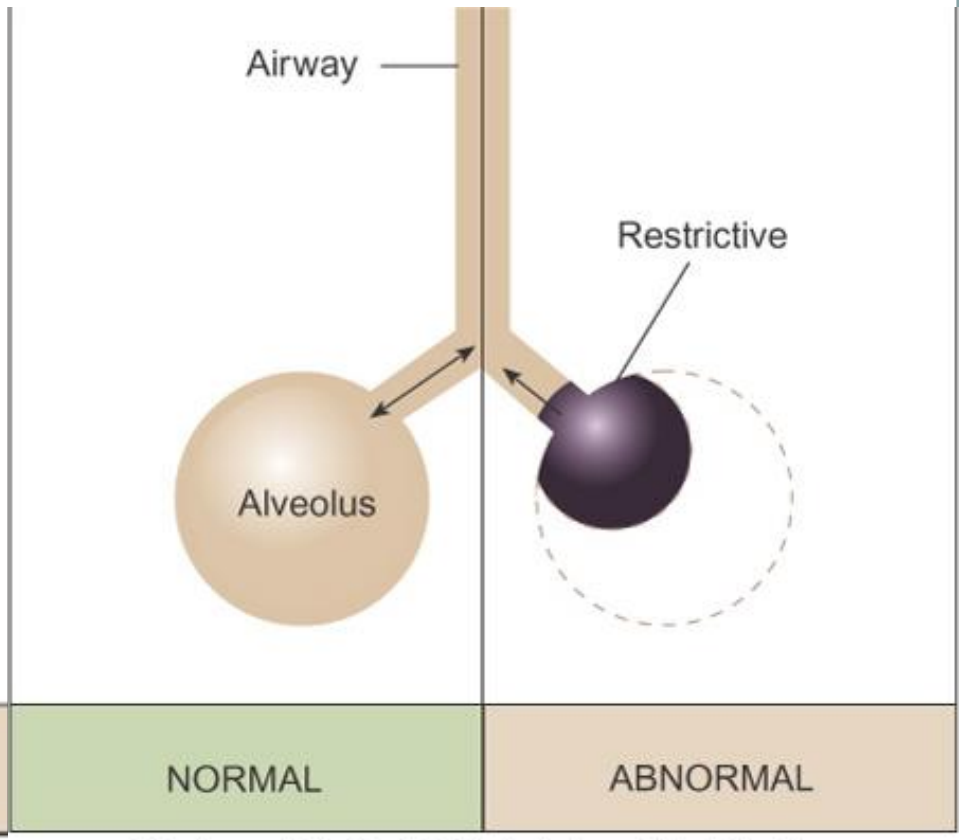
- Physical Measurements:
  - Age: as of last birthday
  - Height (standing). If pat. u/a to stand use the arm-span method
  - Weight
  - Sex
- Physical Assessment
  - Breathing Pattern
  - Breath Sounds
  - Respiratory Symptoms

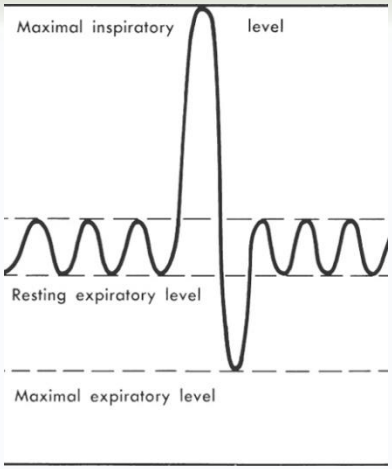
Pulmonary Hx

- Age, sex, height, weight and race
- Current dx or indications
- Family hx
- Personal Hx
- *Occupational/environmental exposure*
- Smoking habits
- Cough
- Dyspnea
- Current medications

Obstructive *vs.* Restrictive Patterns







Restrictive

TLC
IC
IRV
TV
ERV
RV
VC
FRC

Normal

TLC
IC
IRV
TV
ERV
RV
VC
FRC

Obstructive

TLC
IC
IRV
TV
ERV
RV
VC
FRC

Patterns of Impaired Pulmonary Function

Obstructive Airway Diseases

- COPD
  - Emphysema:
    - Centrilobular: Involves respiratory bronchioles
    - Panlobular: Involves bronchioles plus alveoli
    - Alfa-1 deficiency
  - Chronic Bronchitis
  - Bronchiectasis
- Hyperactive Airway Disease (Asthma)
- Cystic Fibrosis

Upper/Large AW Obstruction

- Neuromuscular disorders
- Obstructive Sleep Apnea
- Tracheal Stenosis
- Extrinsic Airway Compression

Patterns …(cont.)

- Restrictive Diseases of ***Chest*** Wall/Pleura
  - Kyphoscoliosis
  - Obesity
  - Pleurisy
  - Pleura Effusions
  - Pneumothorax
- Restrictive ***Lung*** Diseases
  - Pulm. Fibrosis and Idiopathic Pulmonary Fibrosis (IPF)
  - Pneumoconioses (dust inhalation)
  - Sarcoidosis (systemic inflammation)
- Congestive Heart Failure
  - Left Ventricular Failure

Patterns…(cont.)

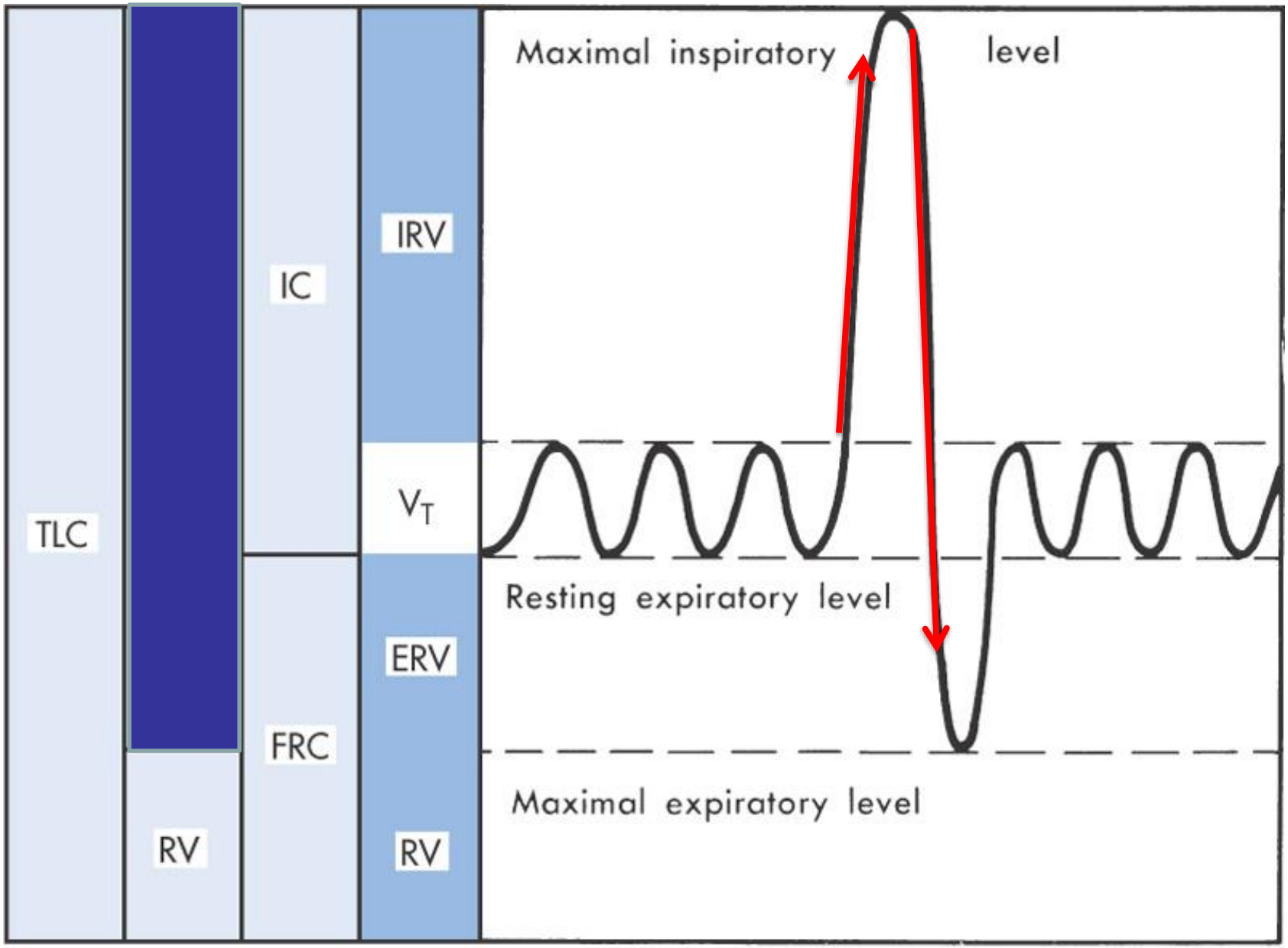
- Neuromuscular Disorders…Also Restrictive
  - Diaphragmatic Paralysis
  - Amyotrophic lateral Sclerosis (ALS)
  - Guillain- Barre syndrome
  - Myasthenia Gravis
- Lung transplant
  - Single
  - Double
  - Heart-Lung
  - LVRS

Terms and Definitions

- Vital Capacity (VC): the maximum volume of air exhaled after a maximum inspiration
- Forced Vital Capacity (FVC): the maximum volume of air exhaled with maximum force from a maximum inspiration
- Forced Expiratory Volume in 1 second (FEV_1): the volume of air exhaled in first second of an FVC maneuver
- Forced Expiratory Flow between 25% and 75% ($FEF_{25-75\%}$): the average flow during the middle half of an FVC maneuver

Terms and Definitions

- Peak Expiratory Flow Rate (PEFR): the maximum flow attained during an FVC maneuver
- Maximum Voluntary Ventilation (MVV): the volume of air a patient can breathe rapidly and forcefully over a specified period of time (e.g., 12 seconds)



(Modified from Comroe JH Jr, Forster RE, Dubois AB, et al: The lung: clinical physiology and pulmonary function tests, *ed 2, St Louis, 1962, Mosby.)*

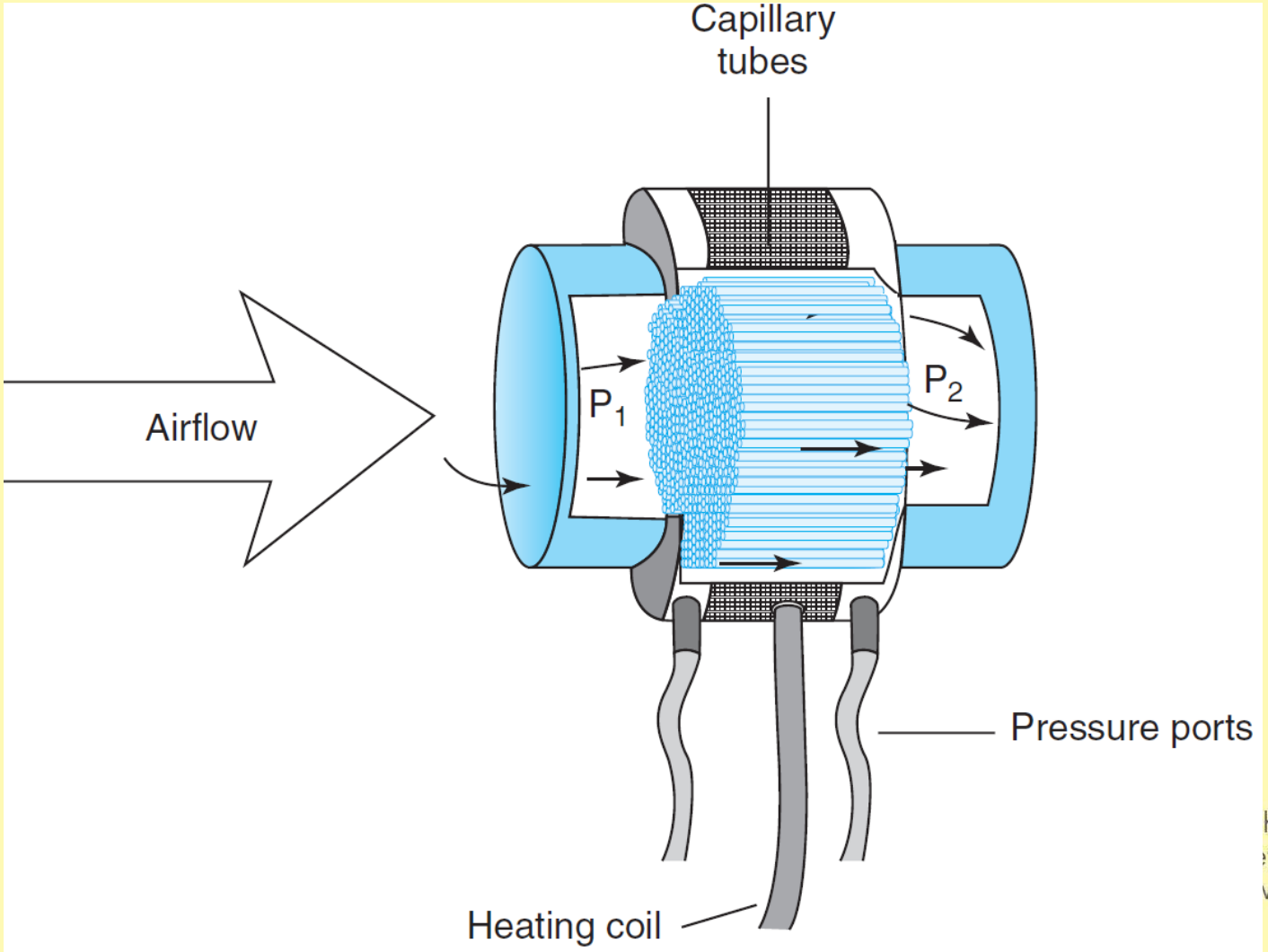
Forced Vital Capacity-FVC

- FVC maneuver consists of a maximal inspiration and then a rapid, forceful, and complete expiration
- Physiologic factors that influence the gas flow during this maneuver:
  - Mechanical properties of the lungs
    - Compliance (CL) and elastic recoil
  - Resistive elements
    - The smaller the diameter of the conducting airways → more resistance
    - 2 Main Factors that affect the airways
      - Lung Volumes
      - Bronchial Smooth Muscles
  - Airway collapsibility
    - Pressure-flow relationship
    - Single equal-pressure point

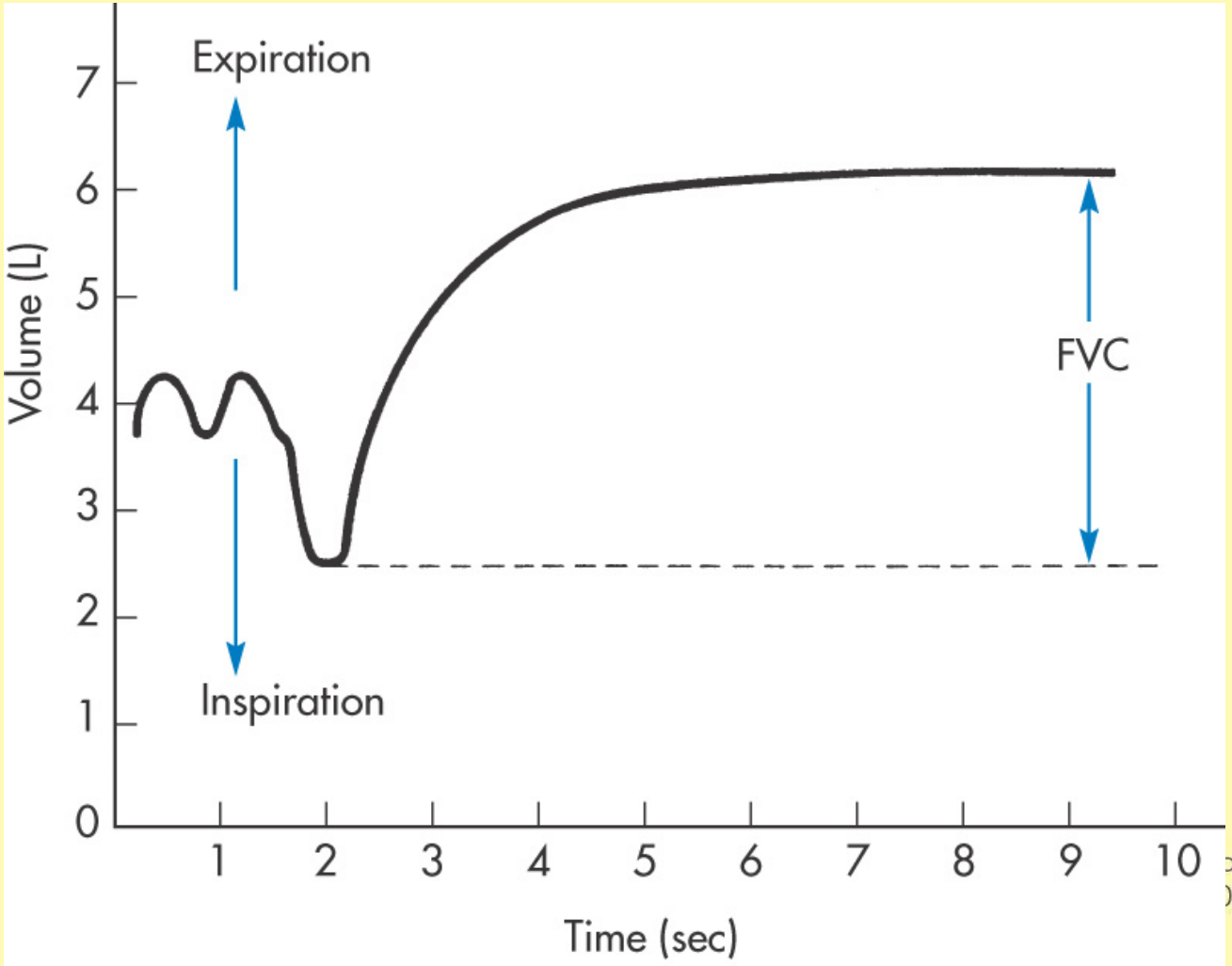
FVC- How Do I Know the Test is Accurate?

- Step 1 – Assess the start of test
  - Best Effort Vol difference < 150 mL among top three
  - PEFT is < 120 ms
- Step 2 – Assess the end of test
  - the maneuver must last at least 6 sec
  - there must also be an obvious plateau for ≥ 1 sec
- Step 3 – Inspect FVC graphic/rule out problems
- Step 4 – Assess reproducibility
  - The two best/acceptable FVC must be within 200 mL
  - The two best/acceptable FEV1 must be within 200 mL

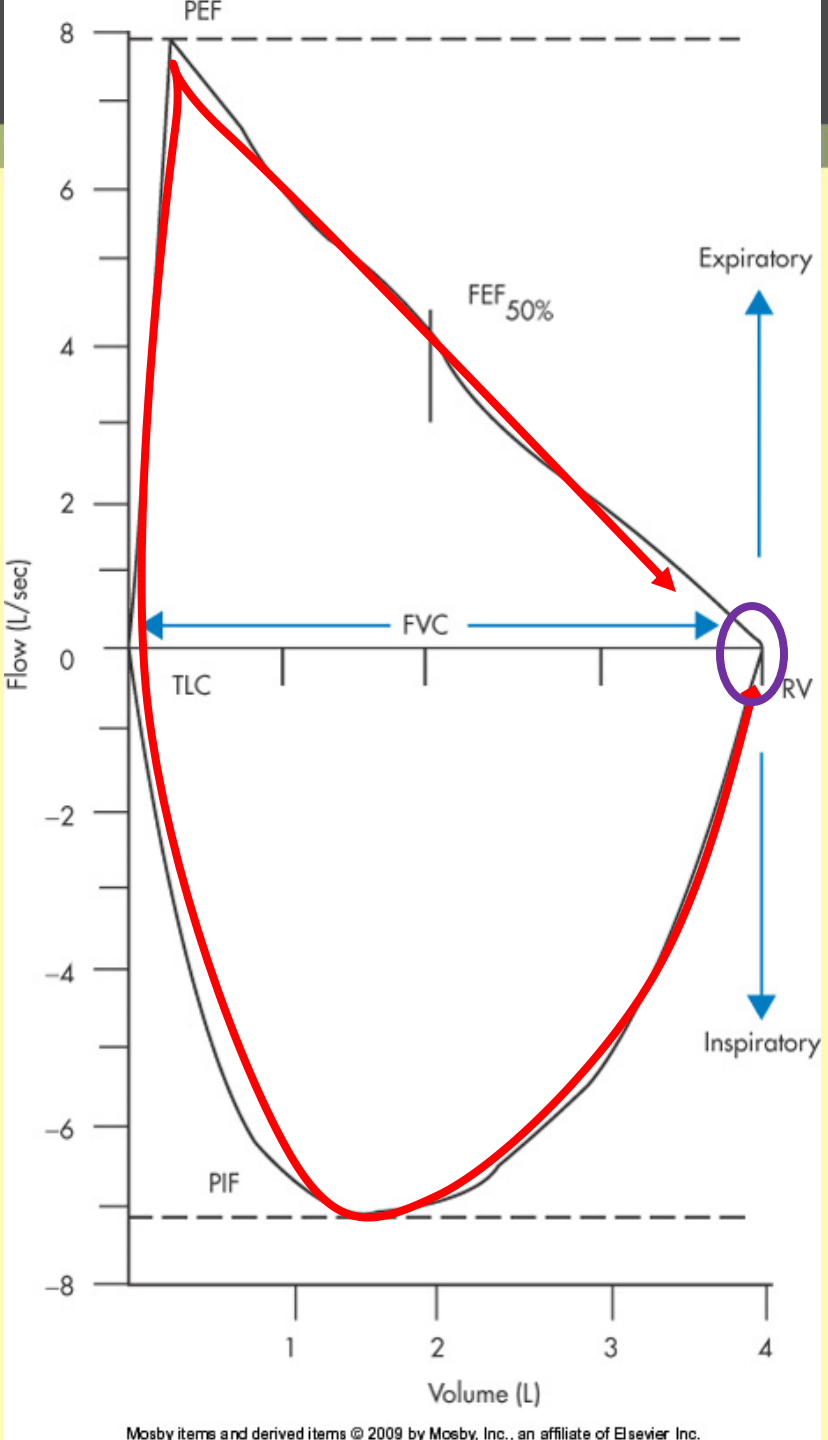
Spirometers



FVC –Vol-Time Curve



The volume –time curve as might be seen during an FVC maneuver. The advantage of this display is the ability to view small changes in volume as the maneuver ends, thus helping the operator better detect the end of the test.



FVC- Flow-Vol Loop

The flow–volume curve as might be seen during an FVC maneuver. The advantage of this display is the ability to see peak flow (which provides information on patient effort and technique at the start of the test).

Preparation & Testing

- Patient Prep—As previously noted
- Instructions on maneuver
  - Use simple terms the patient can understand
- Demonstrate maneuver
- Coaching and encouragement
  - Use enthusiastic, active, and forceful coaching to help the patient perform the maneuver
  - You may need to raise your voice with some urgency, using such phrases as “BLAST your air out,” “blow, blow, blow,” “keep blowing, keep blowing,” or “don’t stop blowing.”

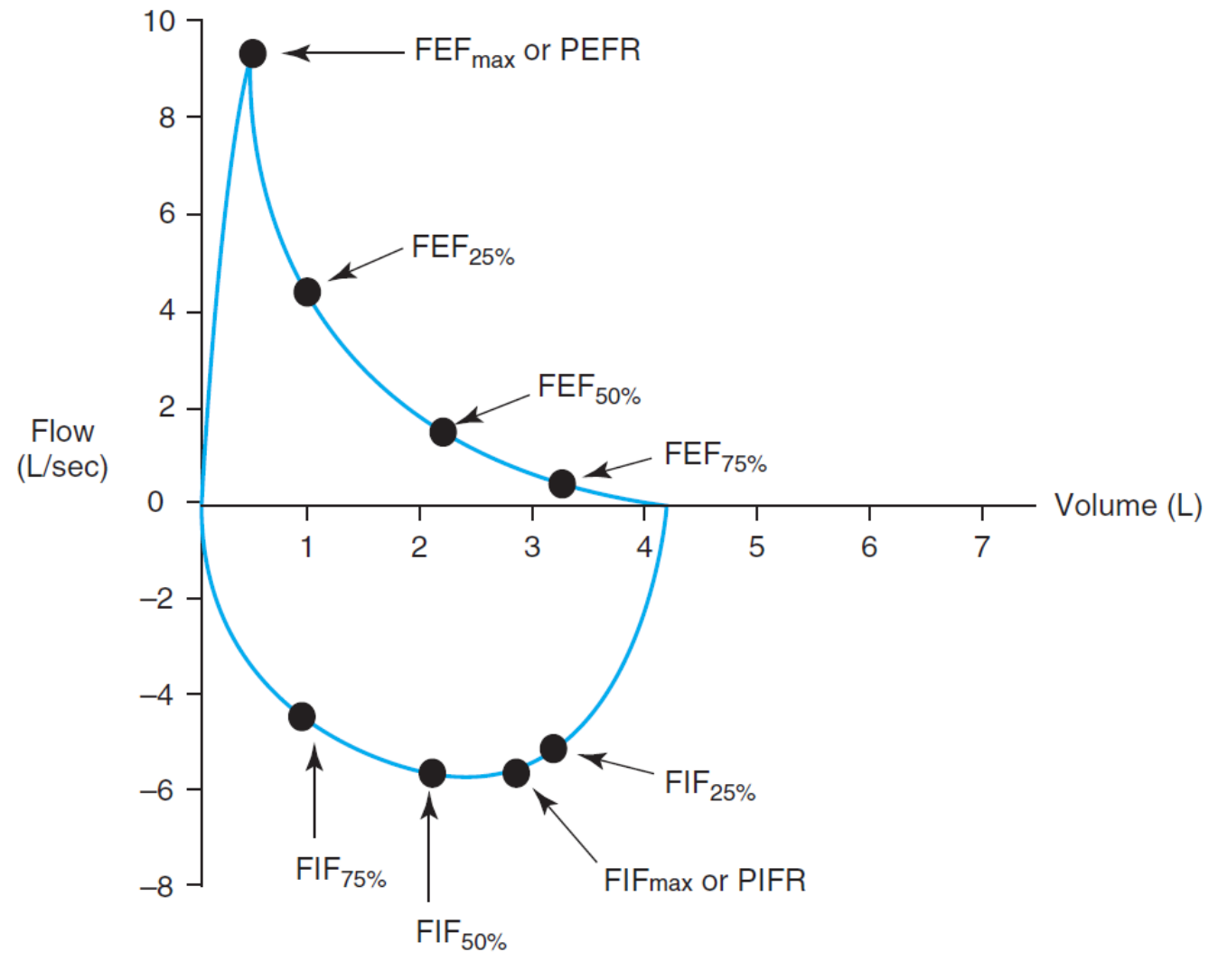
Testing Techniques (cont.)

- Maneuver should have:
  - Rapid and maximal inspiration
    - Submaximal inspirations will result in reduced FVC, FEV_1, and PEFR values
  - Blast out hard and fast
    - Patient should be prompted to blow the air out as hard and fast as possible with minimal hesitation
  - Continued and complete exhalation
    - Incomplete expirations will lead to reduced FVC values

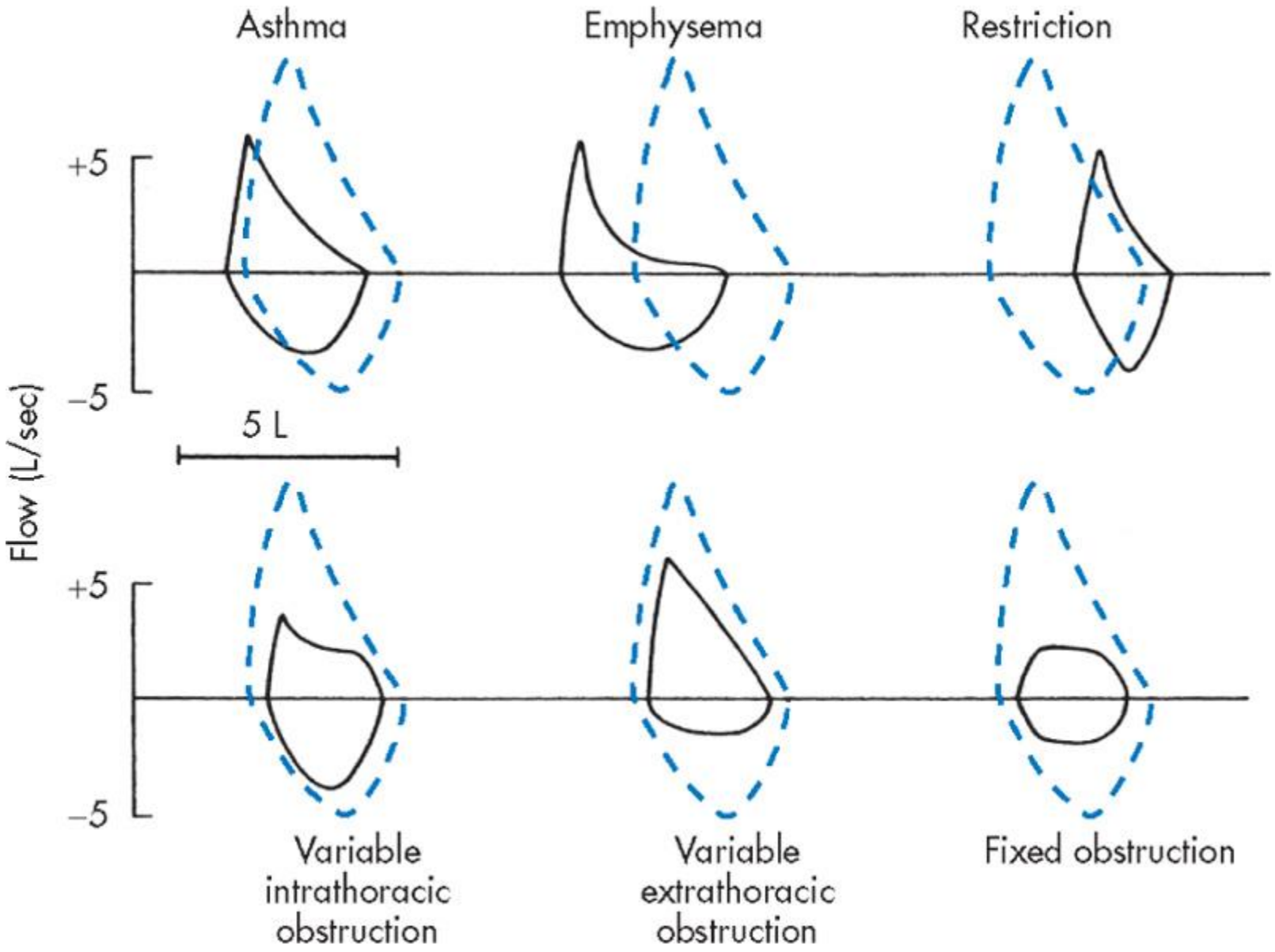
Testing Techniques (cont.)

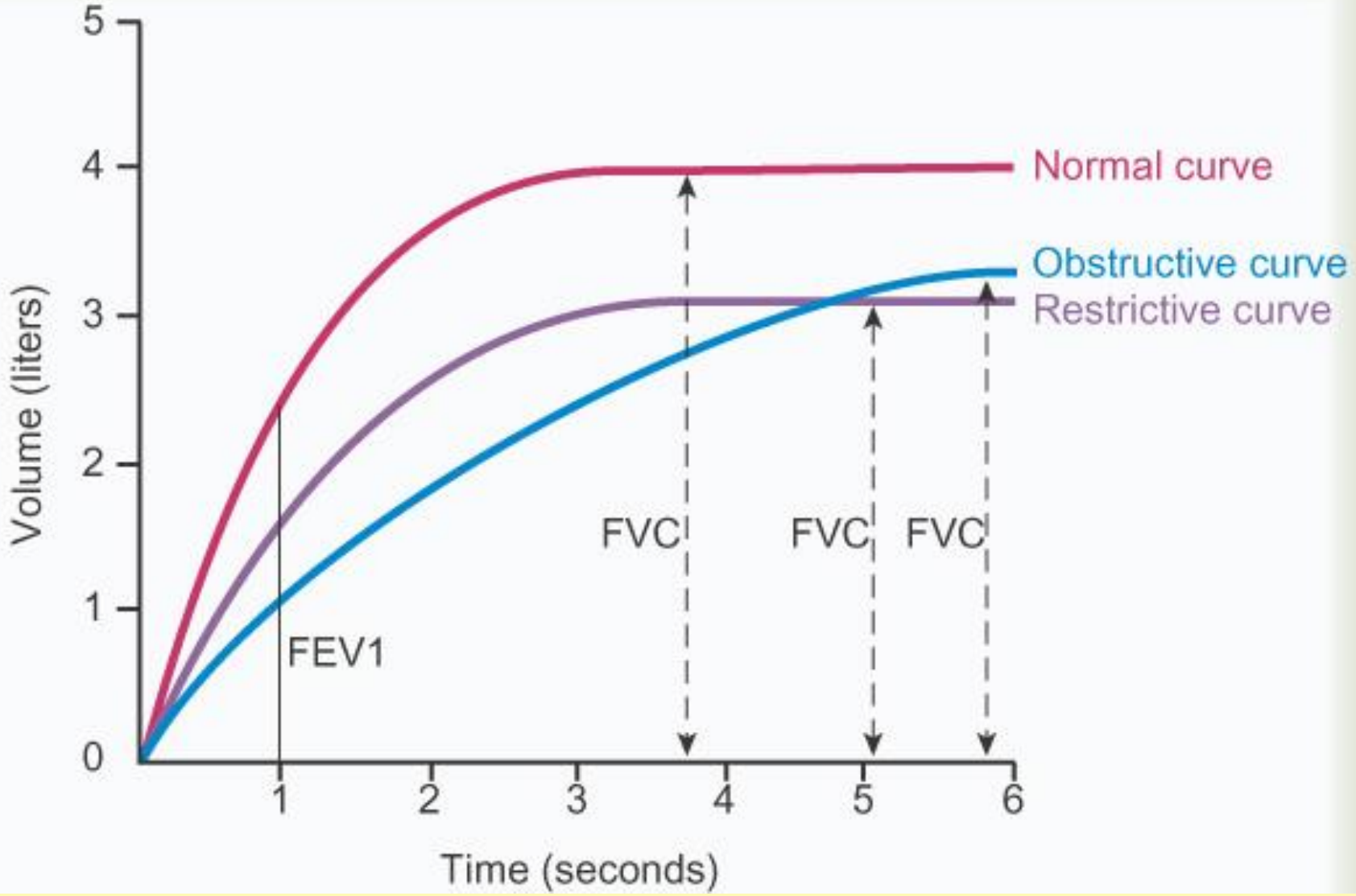
- Within maneuver acceptability
  - Good start of test
    - No excessive hesitation
    - Back-extrapolation volume < 5% of FVC, or 0.150 L, whichever is greater
  - No cough in first second
  - No variable flow
  - No early termination of exhalation
    - At least 6 sec or plateau has been achieved
  - No evidence of glottis closure or extra breaths
- Obtain AT LEAST 3 acceptable maneuvers

Flow Volume loop



Abnormal Flow Volume Loops Patterns




5
4
3
2
1
0
Volume (liters)
1
2
3
4
5
6
Time (seconds)
Normal curve
Obstructive curve
Restrictive curve
FEV1
FVC
FVC
FVC

Comparison of Spirometry Efforts

Test	Trial 1	Trial 2	Trial 3	Best Test Reported
FVC (L)	5.20	5.30	5.35*	5.35
FEV_1 (L)	4.41*	4.35	4.36*	4.41
FEV_1/FVC (%)	85	82	82	82
$FEF_{25\%-75\%}$ (L/sec)	3.87	3.92	3.94	3.94
$FEF_{50\%}$ (L/sec)	3.99	3.95	3.41	3.41
$FEF_{25\%}$ (L/sec)	1.97	1.95	1.89	1.89
PEF (L/sec)	8.39	9.44	9.89	9.89

Classification of Severity*

- Mild Obstruction: FEV_1 > 70% Predicted
- Moderate Obstruction: FEV_1 = 60%-69% Predicted
- Moderately Severe: FEV_1 = 50%-59% Predicted
- Severe Obstruction: FEV_1 = 35% - 49% Predicted
- Very Severe Obstruction: FEV_1 < 35% Predicted

*When the VC is in the normal range

Reversibility Testing-Pre/Post

- Inhaled bronchodilators are administered routinely in the PF laboratory to determine whether airflow obstruction is reversible.
- Aerosolized bronchodilators administered using:
  - Metered dose inhaler (MDI)
  - Jet nebulizer
  - Ultrasonic nebulizer

$$\%\ \text{change} = \frac{\text{Post value} - \text{Pre value}}{\text{Pre value}} \times 100$$

Reversibility Testing (cont.)

- If using MDI, administer or supervise patient administer correct amount
- Typical waiting time for repeating postbronchodilator testing is 10 to 15 min
- Make comment on report on what drug was used, how much and method of administration, and any responses (e.g., shakiness and increased heart rate).

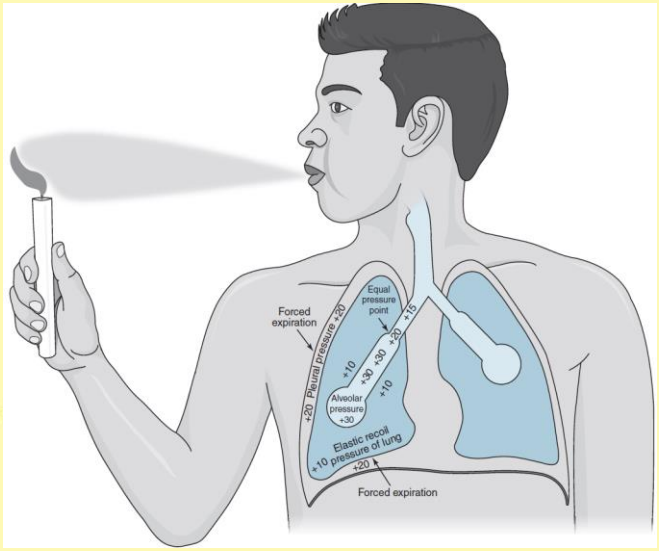
Test	Pre	Post	Change
FVC (L)	2.80	3.25	+0.45 (16%)
FEV_1 (L)	1.82	2.07	+0.25 (14%)

Basic Elements of Interpretation

- Reference (predicted) values
  - Race-specific NHANES III reference values recommended
- Airflow limitation
  - Reduced FVC and FEV_1, and FEV_1/FVC ratio
- Restriction
  - Reduced FVC and FEV_1, but FEV_1/FVC ratio is normal or elevated
- Bronchodilator response
  - % change from pre to postbronchodilator
  - 12% and 0.200 L increase in FEV_1 or FVC is considered meaningful
  - FEV_1/FVC ratio should not be used to measure response to a bronchodilator.

Peak Expiratory Flow Rate

- PEFR can be measured by spirometer or peak flow meter
  - When measured by spirometer it is usually reported in L/sec
  - When measured by peak flow meter it is usually reported in L/min
- PEFR greatly depends on patient effort and cooperation, and lung volume
  - Green: 80%-100% of personal best
  - Yellow: 50%-80% of personal best
  - Red: < 50% of personal best



Take Home Points

- PFTs can be a valuable diagnostic & monitoring tool, especially for chronic lung disease.
- They can also help screen patient who are high-risk or unsuitable for certain procedures (e.g., surgery)
- However, specialized equipment and training are required to obtain and interpret results.

Selected Sources & References

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Questions?