Pulmonary investigations

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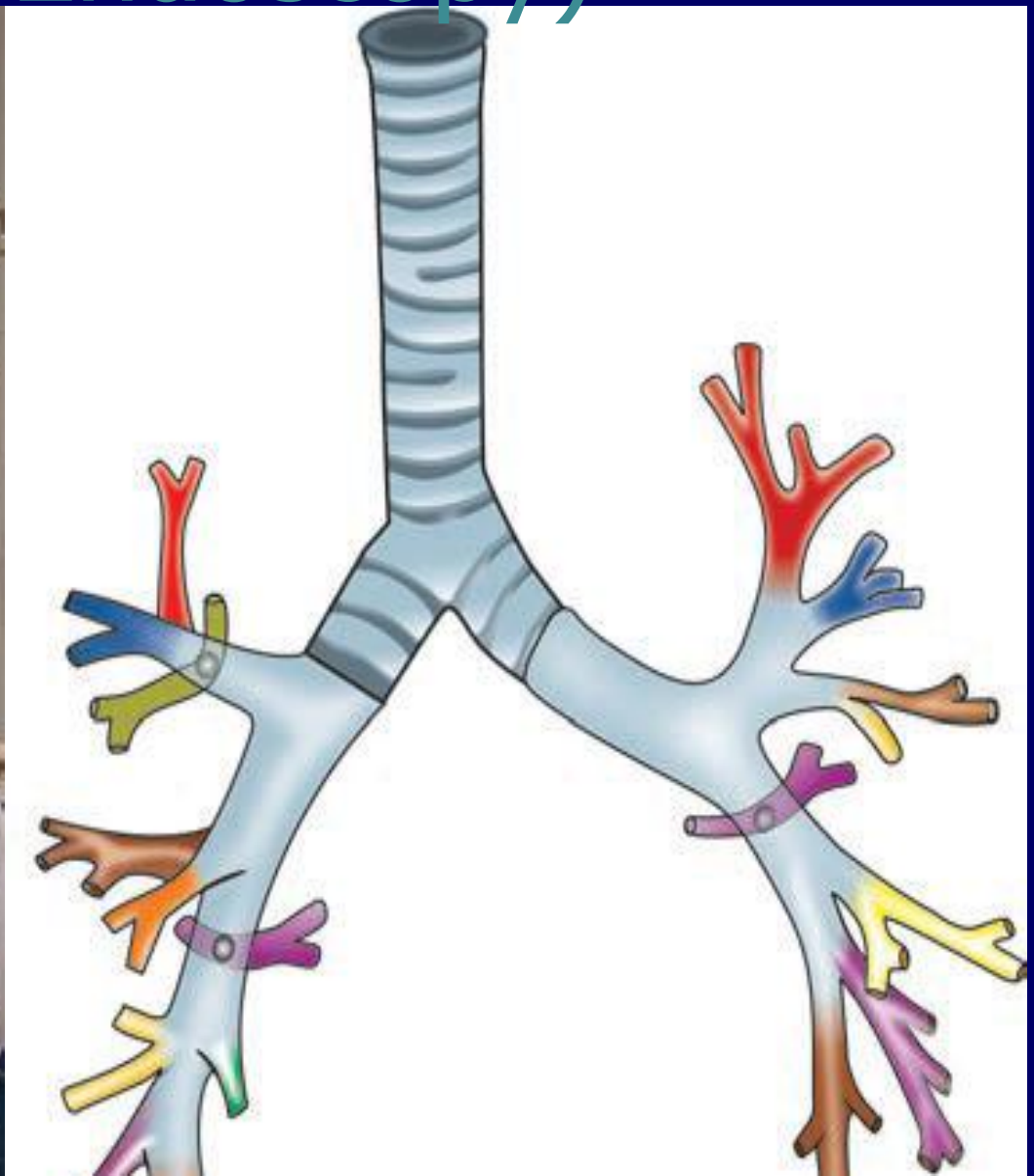
Flexible Bronchoscopy (Airway Endoscopy)



Prebronchoscopy Evaluation

• In an American College of Chest Physicians (ACCP) survey, a majority of operators obtain a preprocedure chest radiograph, coagulation studies, and complete blood count. Less than one-half obtain an EKG, arterial blood gas, electrolytes, or pulmonary function tests. Routine preprocedure labs are not absolutely indicated unless specific concerns exist.

• Cardiac evaluation in patients with known coronary disease undergoing elective

CONTRAINDICATIONS

Bronchoscopy has been generally shown to be a safe procedure, though the risk of complications are increased in the presence of several conditions such as follows:

Respiratory

1. Uncorrectable hypoxemia: If partial pressure of oxygen (PaO_2) remains less than 70 mm Hg despite maximal oxygen supplementation.
2. Hypoventilation with hypercapnia.
3. Unstable asthma or severe bronchospasm.
4. Tracheal stenosis.

Cardiovascular

1. Recent myocardial infarction within 6 weeks. However recent evidence suggest that bronchoscopy in the immediate postmyocardial infarction period is safe, provided there is no ongoing ischemia.
2. Unstable angina or uncontrolled left ventricular failure.
3. Unstable arrhythmias.
4. Severe hypertension.
5. Severe carotid or cerebrovascular disease.

Neurological

1. Active seizures.
2. Raised intracranial pressure.
3. Severe agitation.

Other Medical Conditions

1. Uncooperative patients.
2. Bleeding diathesis: if bleeding time is more than 15 minutes.
3. Platelet dysfunction or thrombocytopenia. If platelet count is less than 50,000/mm3, at least 6 to 12 units of platelet should be transfused before or during bronchoscopy.
4. Severe anemia.
5. Cirrhosis with portal hypertension.
6. Uremia: if serum creatinine is more than 3 mg/dL.

Procedural Medications

• Medications are commonly used before and during bronchoscopy to facilitate a safe, comfortable, and successful procedure.

• Antisialogogues are used with the intent of drying secretions and reducing the vasovagal response.

Atropine 0.4 mg IM is the antisialogogue most commonly used. There are no convincing data that antisialogogues are efficacious, and because of the side effects , they are not recommended on a routine basis.

• Benzodiazepines play a central role in providing amnesia and anxiolysis.
Midazolam given parenterally is often used for its fast onset of action and short half-life.
Lorazepam has been used as a preprocedure medication with improved patient satisfaction at 24 hours versus placebo.

Opiates decrease the laryngeal reflexes and cough response, and provide some anxiolysis.
Fentanyl given parenterally is commonly used, again because of its short onset of action.
Meperidine has been used pre- and intraprocedurally, but its use is increasingly discouraged because of its active metabolites, long half-life, and increased risk of seizures.

Naloxone reverses opiate sedation through direct competitive inhibition. It should only be used in cases of a significant narcotic overdose.
Repeated doses or a continuous infusion may be required.

• Topical anesthesia to the upper aerodigestive tract, glottic area, and bronchial tree can be accomplished by the application of lidocaine, benzocaine, tetracaine, or historically, cocaine.

Lidocaine is the most commonly used topical anesthetic for FB because of its fast onset of action and wide therapeutic window. It is applied in the glottic area, as well as directly on the tracheobronchial tree.

Safety for lidocaine is well established at doses <7 mg/kg.
Operators must be aware of the risk of methemoglobinemia when using topical anesthetics, even in small amounts.
When it occurs, it can be reversed by administration of methylene blue.

- **Propofol** is a sedative-hypnotic drug with rapid onset and very short duration of action.

Recovery time after an infusion is only minutes.
Titration of propofol takes experience to avoid the most common side effect, hypotension.
Many institutions require anesthesia support for administration during procedures, and therefore it is often not used during routine bronchoscopies.

Technique

• The most common patient position is supine, in bed, with the operator standing at the patient's head.

• A transoral approach is often used, sometimes with insertion of a laryngeal mask airway or endotracheal tube, and sometimes with no artificial airway
A transnasal or transtracheostomy approach may also be utilized

• During insertion of the bronchoscope, the operator should note abnormalities of the upper airway, false and true vocal cords, and glottic area
After passage through the cords, the trachea and tracheobronchial tree are examined to at least the first subsegmental level.

• After examination of the airways, diagnostic or therapeutic procedures may be attempted.

DIAGNOSIS

• Airway inspection is the mainstay of FB and is generally performed with each procedure.
• Tumors, cysts, source of hemoptysis, signs of infection, foreign bodies, and altered airway

• Bronchoalveolar lavage (BAL) consists of wedging the end of the FB in a distal airway, followed by instillation of sterile saline through the bronchoscope with subsequent aspiration back through the bronchoscope, in 50-mL aliquots.

BAL is most useful for obtaining microbiologic cultures in diagnosing typical and atypical infections.

Cytology can be sent to aid in diagnosis of infection, malignancy, and occasionally diffuse lung disease.

Successively bloodier BAL return aliquot is characteristic of diffuse alveolar hemorrhage.

- Transbronchial lung biopsy is performed by passing biopsy forceps through the bronchoscope and into the lung, with the goal of sampling the distal airways parenchyma.

Transbronchial biopsies are generally performed using fluoroscopic guidance as the area being sampled is too distal for direct visualization, though this is not absolutely necessary.

- Endobronchial biopsy is performed by passing biopsy forceps through the bronchoscope and sampling airways lesions in the larger airways under direct visualization.

- Transbronchial needle aspirations (TBNA) are used to take cytologic samples from enlarged mediastinal lymph nodes and mediastinal masses.

• **Endobronchial ultrasound** has led to a marked increase in the range of diagnostic uses of FB.

• Along with ***radial endobronchial ultrasound, 3D*** navigational systems have been developed that are being increasingly used to sample pulmonary nodules .

TREATMENT

• Advances in the field of interventional pulmonology have led to a large increase in the therapeutic uses of FB

Tracheobronchial narrowing from malignancy, strictures, or other pathology can be alleviated by **stent** placement or **balloon** dilatation, though the latter's effects are much less permanent.

Cryotherapy can remove malignancies or other airway obstructions. During cryotherapy, a probe is placed on the obstruction at extremely low temperatures, in essence freezing the obstruction to the probe and allowing for extrication.

Argon plasma coagulation can be used to stop focal bleeding or obliterate obstructive airway lesions,
neodymium:yttrium aluminium garnet (Nd:YAG) lasers may also do the latter.

Foreign body removals are usually performed using biopsy forceps and sometimes occur under fluoroscopic guidance depending on the density of the foreign body.

Therapeutic aspiration of secretions is sometimes performed in the presence of atelectasis with respiratory failure .

Management of anastomotic stricture or dehiscence after lung transplantation can generally be managed by debridement or stenting.

Placement of one-way endobronchial valves will lead to collapse of selective subsegments of the lung and is being increasingly used in management of refractory, localized bronchopleural fistulas .

COMPLICATIONS

• FB is overall very safe, with a reported mortality of 0–0.013%.
• Major complications (pneumothorax, pulmonary hemorrhage, or respiratory failure) occur in <1% of procedures.

• After bronchoscopy, the patient may experience low-grade fever, cough, hypoxemia, sore throat, hoarseness, or low-grade hemoptysis .

• Pneumothorax occurs in ~4% of patients after transbronchial lung biopsy, and is usually detected by postprocedure chest radiograph.

Indications for pleural biopsy :

- Undiagnosed exudative lymphocytic pleural effusions
- Pleural mass, thickening, or nodularity
- Recurrent pleural effusion of unknown etiology

Diagnostic yield

Needle biopsy of the pleura is useful for establishing the diagnosis of malignant or tuberculous pleural effusion.

Multiple pleural biopsies are taken to increase the diagnostic yield. Pleural biopsy in combination with pleural fluid cytology improves the yield.

Needle biopsy of parietal pleural is more valuable in patients with suspected tuberculous effusion than in those with malignant effusion. The initial biopsy may demonstrate granuloma in 50%-80% of patients.

Historically, the sensitivity of Abrams biopsies for malignancy ranged between 27% and 60%, and, in the largest review of 2,893 Abrams samples, the diagnostic yield for malignancy was 57%.
The reported sensitivity is higher for diagnosing tuberculosis with Abrams biopsies, ranging from 67%-92%, in part owing to the diffuse pleural involvement with tuberculous pleuritis

Complications and precautions

Injury to adjacent organs during pleural biopsy, including liver, kidney, and spleen, is rare. Chest radiography is recommended to exclude immediate postprocedural complications, including **pneumothorax.**

The incidence of pneumothorax with closed needle biopsy is approximately 8%-18%.

Hemorrhagic states are considered a relative contraindication to pleural biopsy. The coagulation profile should be corrected prior to any biopsy procedure to minimize the risk of bleeding, including chest wall **hematoma** and **hemothorax**.

Medical Thoracoscopy (Pleuroscopy)

Thoracoscopy has been used for over 100 years, and pleuroscopy has gained increased acceptance as one version of the criterion standard for diagnosis of pleural effusions, with a diagnostic yield of up to 95% in malignant pleural disease.
Compared with previous biopsy techniques, pleuroscopy can be both ***diagnostic and therapeutic***, allowing direct visualization of pleural pathology, adhesiolysis, pleurodesis, and chest tube placement. Pleuroscopy is performed by a pulmonologist in the endoscopy suite or in the operating room with local anesthesia or under moderate sedation with appropriate cardiopulmonary monitoring.

Video-Assisted Thoracic Surgery

Video-assisted thoracic surgery (VATS) allows additional access to lung tissue and operative interventions, including lung biopsies, lobectomy, pericardial window placement, and empyema drainage. VATS is carried out by surgeons in an operating room under general anesthesia using single-lung ventilation with double-lumen endotracheal intubation.

Lung Function Tests

GENERAL PRINCIPLES

- **Pulmonary function tests (PFTs) are an integral part of a pulmonary evaluation and management.**
- **PFTscan be divided into spirometry (measurement of air movement in and out of the lungs), diffusing capacity (measure of gas exchange within the lungs), and plethysmography (measurement of lung volumes).**

- **It is important to remember that PFTs do not make pathologic diagnoses such as emphysema or pulmonary fibrosis.**

They provide physiologic measurements identifying ventilatory defects and, in doing so, support the existence of the relevant disease process and aid in the evaluation of its treatment.

PATIENT CONSIDERATIONS

Contraindications

Performing lung function tests can be physically demanding for a minority of patients. It is recommended that patients should not be tested within 1 month of a myocardial infarction.

Chest or abdominal pain of any cause
Oral or facial pain exacerbated by a mouthpiece
Stress incontinence
Dementia or confusional state

Therapy

The operator should record the type and dosage of any (inhaled or oral) medication that may alter lung function and when the drugs were last administered.

Activities that should preferably be avoided prior to lung function testing:

Smoking within at least 1 h of testing
Consuming alcohol within 4 h of testing
Performing vigorous exercise within 30 min of testing
Wearing clothing that substantially restricts full chest and abdominal expansion
Eating a large meal within 2 h of testing

What is Spirometry?

Spirometry is a method of assessing lung function by measuring the volume of air the patient can expel from the lungs after a maximal expiration.

Spirometry

KEY POINTS

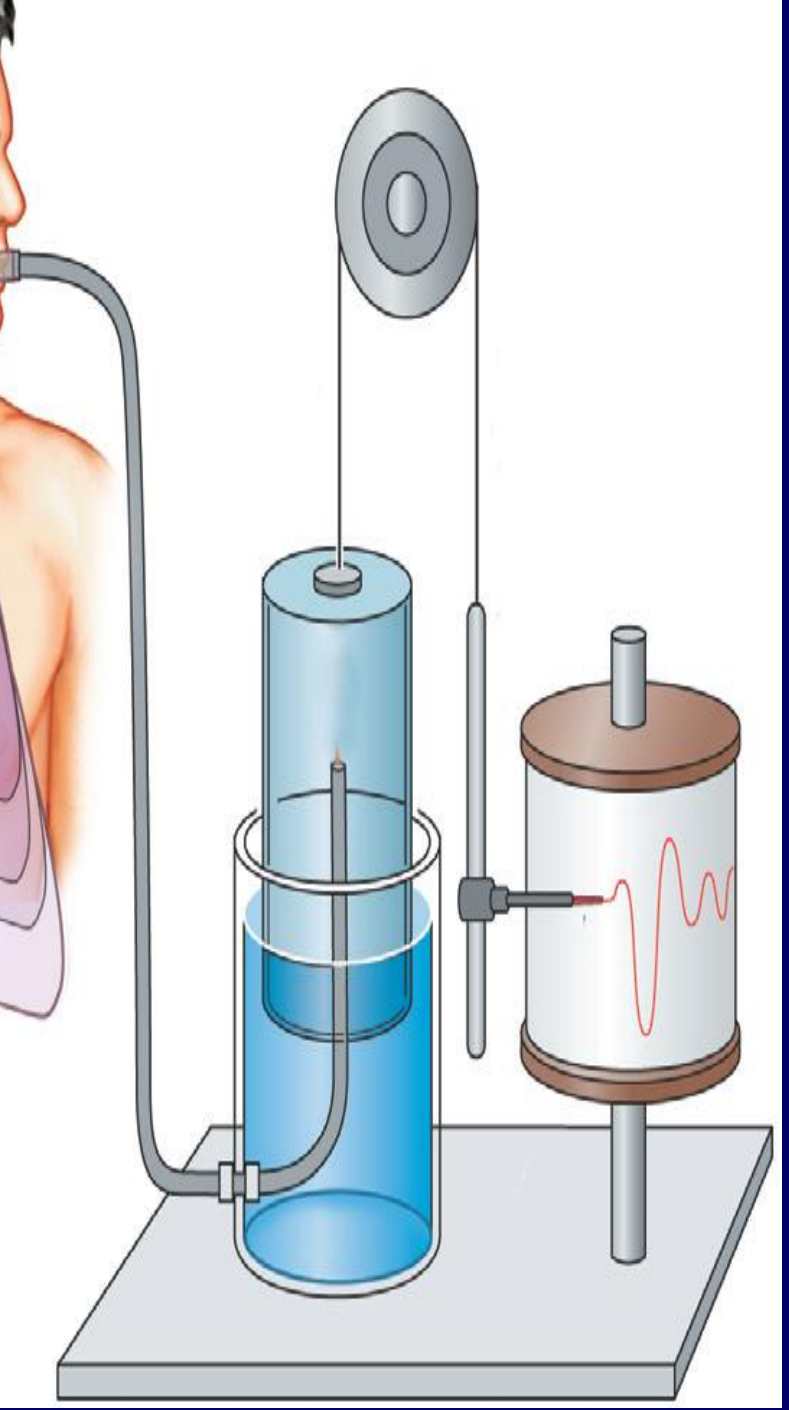
Peak flow measurement and spirometry are basic and easily available tests of lung function.

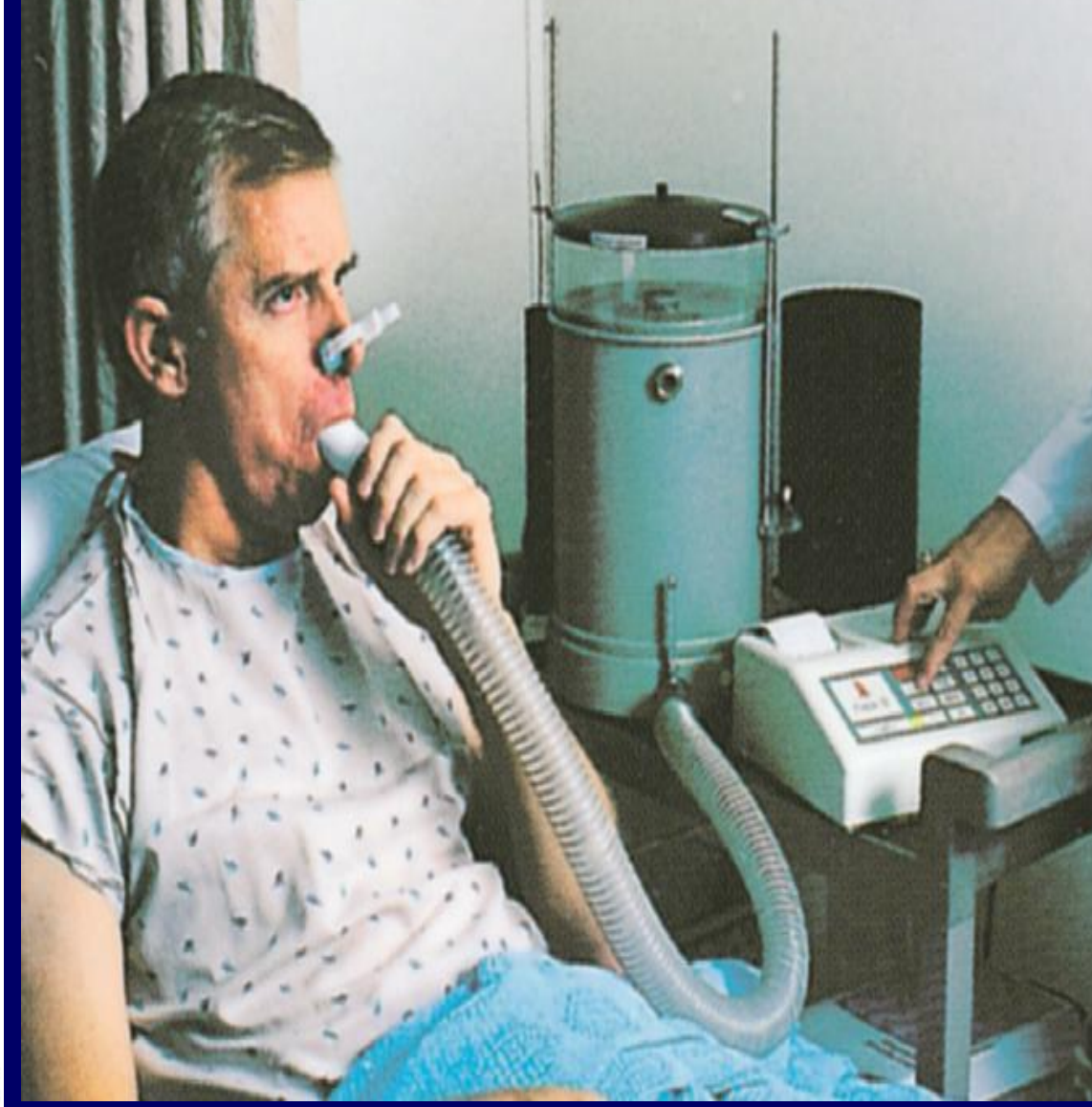
- Spirometry measures static (volume) and dynamic (flow) parameters.

PEF, FEV1, FVC and VC are the most important spirometric parameters that indicate obstructive or restrictive disease.

Spirometry is an important tool in the diagnosis, management and follow-up of both obstructive and restrictive disorders.

Tests of airway hyperresponsiveness and bronchodilatation using spirometric monitoring are a useful diagnostic tool for asthma






JAEGER

Flow Measuring Spirometers

FEV1and FVC

- **Normal pulmonary function is also defined by the measured values for the FVC and the FEV1.**

- **FVC is defined as the maximum volume of air that is forcefully exhaled after a maximum inspiration.**

- **FEV1 is defined as the maximum volume of air exhaled during the first second of the FVC.**

- **The measured values for FEV1 and FVC are compared to the predicted values for FEV1 and FVC as a percent of predicted.**
  Values of 80–120% are considered normal.

Standard Spirometric Indices

- FEV_1 - *Forced expiratory volume in one second:*

  The volume of air expired in the first second of the blow

- FVC - *Forced vital capacity:*

  The total volume of air that can be forcibly exhaled in one breath

- FEV_1/FVC *ratio:*

  The fraction of air exhaled in the first second relative to the total volume exhaled

TLC is defined as the volume of air in the lung after complete maximal inspiration and a value of 80–120% of predicted is normal.

RV is defined as the volume of air left in the lungs after complete maximal expiration and a value of 80–120% of predicted is normal.

SVC is defined as the maximal volume of air that can be exhaled with normal effort after a maximum inspiration. (It is similar to the FVC except performed without full force.) A value of 80–120% of predicted is normal.

Acceptability Criteria

PFTs should initially be assessed for acceptability that is best determined by studying the flow-volume loops.

Acceptability criteria for PFTs include the following:

- Freedom from artifacts (coughing, glottic closure,early termination leak, variable effort)
- Good starts (i.e., the initial portion of the curve that is most dependent on patient effort is free from artifact)
- Satisfactory expiratory time (at least 6 seconds of expiration on the volume–time curve, or at least 1-second plateau in the volume–time curve)

Reproducibility Criteria

Once the minimum of three acceptable flow-volume loops has been obtained, the reproducibility of the PFTs should be assessed.

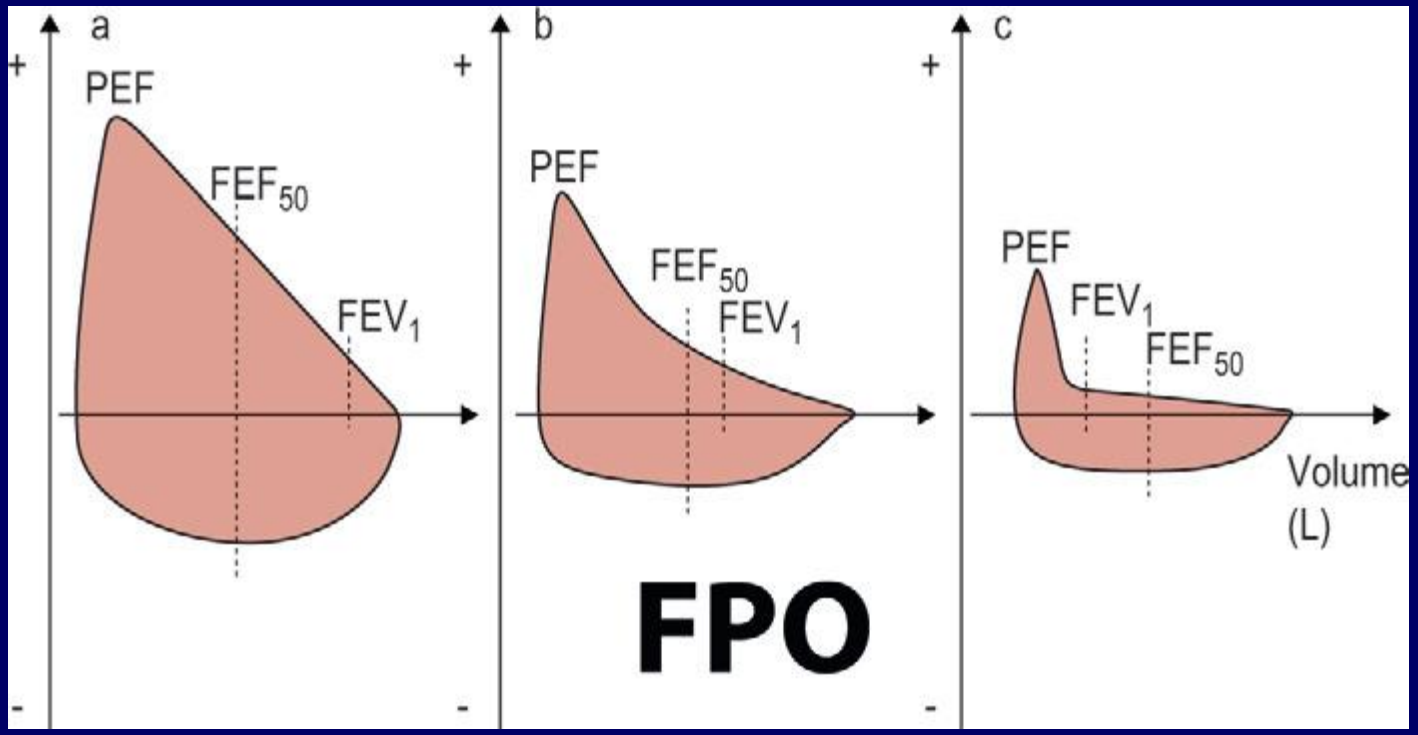
Reproducibility criteria for PFTs include the following:

- **The two largest forced vital capacity (FVC) measurements should be within 0.2 L of each other.**
- **The two largest forced expiratory volumes in 1 second (FEV1) measurements should be within 0.2L of each other.**

Predicted Normal Values

Affected by:

- ✓ Age
- ✓ Height
- ✓ Sex
- ✓ Ethnic Origin


a
+
PEF
FEF50
FEV1
-
b
+
PEF
FEF50
FEV1
-
c
+
PEF
FEV1
FEF50
Volume
(L)
-
FPO

Spirometry

Predicted Normal Values

NORMAL VALUES AND REFERENCE RANGES

The results of PFTs are interpreted by comparing them to reference values representing normal healthy subjects.

- These normal or predicted values take into account many variables, most importantly age, height, gender, race/ethnicity, and to a lesser extent, weight.

- The lower and upper limits of normal for each predicted value are set as 80% and 120% of the predicted value, respectively.
- The measured values for each pulmonary function variable are compared with the Predicted values of each variable and expressed as "percent of predicted."

- Up to eight patient efforts may be performed; after this, patient fatigue affects the data obtained.
- The best results are always used for interpretation

PRACTICAL SESSION

Performing Spirometry

Performing Spirometry

- Breath in until the lungs are full
- Hold the breath and seal the lips tightly around a clean mouthpiece
- Blast the air out as forcibly and fast as possible. Provide lots of encouragement!
- Continue blowing until the lungs feel empty

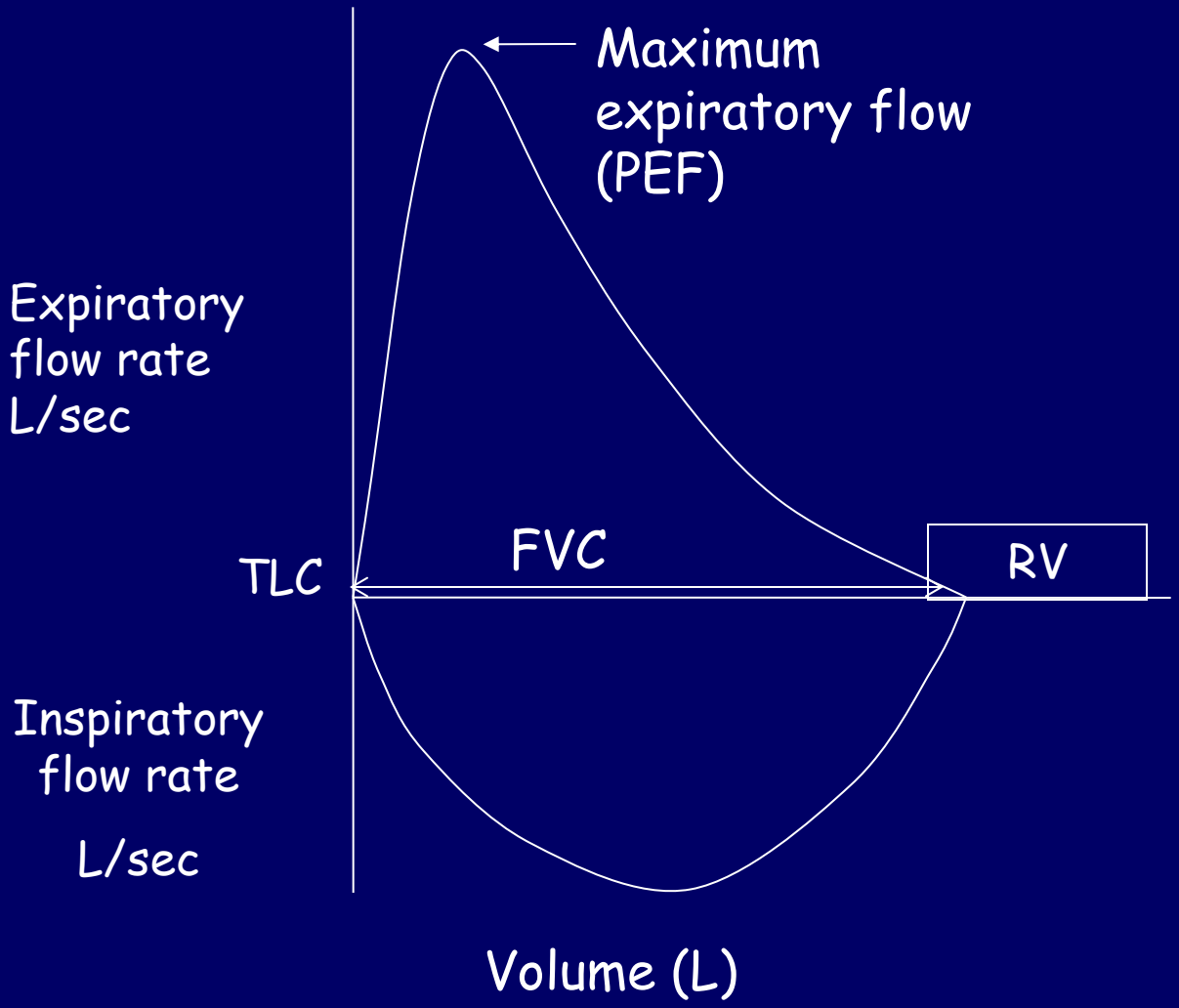
Performing Spirometry

- Watch the patient during the blow to assure the lips are sealed around the mouthpiece
- Check to determine if an adequate trace has been achieved

SPIROMETRY

Flow Volume

Flow Volume Curve



Spirogram Patterns

- Normal
- Obstructive
- Restrictive
- Mixed Obstructive and Restrictive

SPIROMETRY

OBSTRUCTIVE DISEASE

Criteria for Normal Post-bronchodilator Spirometry

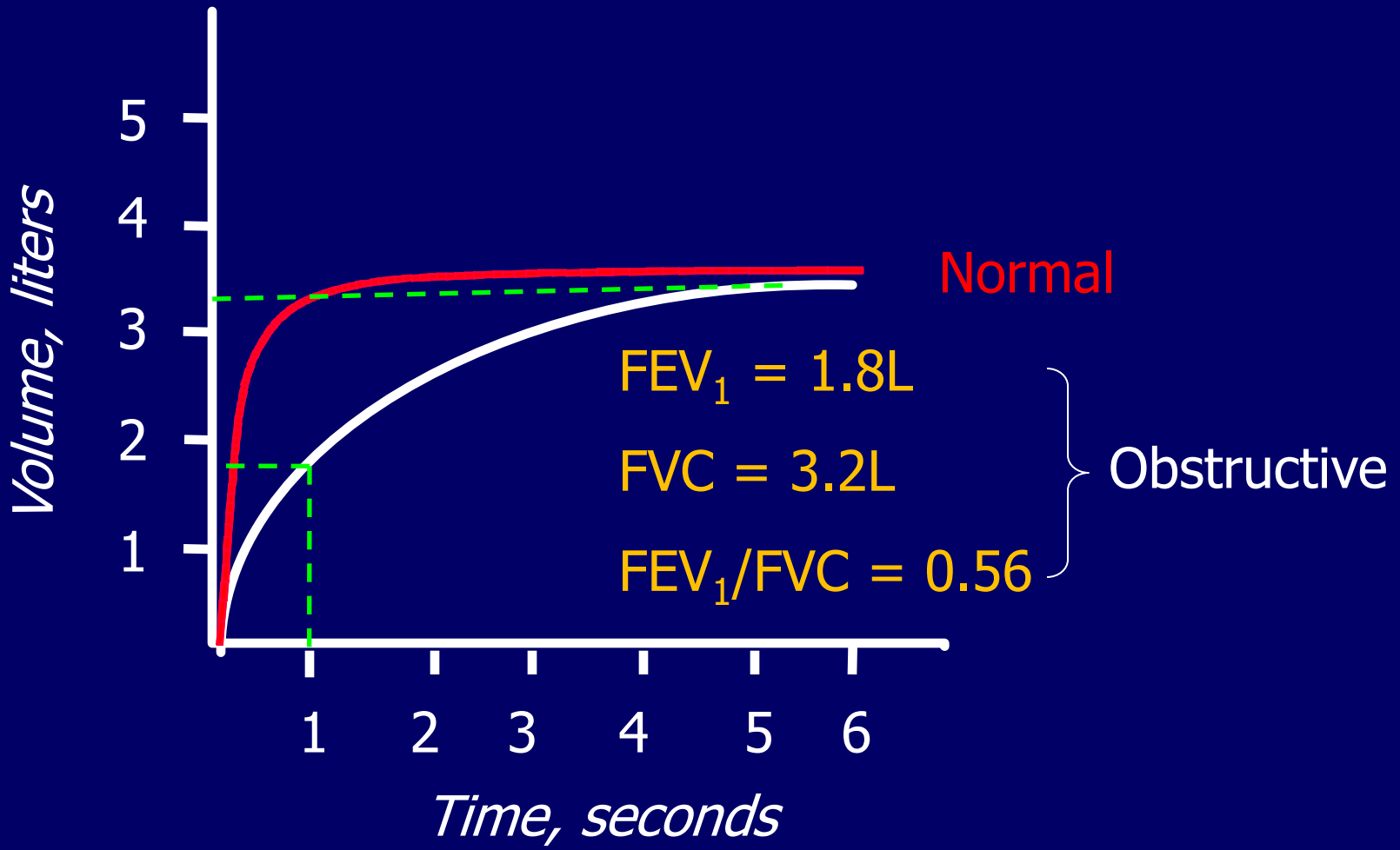
- FEV_1: % predicted $\geq$ 80%
- FVC: % predicted $\geq$ 80%
- FEV_1/FVC: > 0.7

Additional Spirometric Indicies

- MEFR – *Mid-expiratory flow rates:*
  Derived from the mid portion of the flow volume curve but is not useful for COPD diagnosis
- Peak Expiratory flow : PEF , the quantity of air you expel in one minute

These two indices are effort dependant

Spirometry : Obstructive Disease
After bronchodilatation



Spirometric Diagnosis of COPD

- COPD is confirmed by post–bronchodilator $FEV_1/FVC < 0.7$

- Post-bronchodilator FEV_1/FVC measured 10-15 minutes after 400µg salbutamol or equivalent

Bronchodilator -Reversibility Testing

Results

- An increase in FEV_1 that is both greater than 200 ml and 12% above the pre-bronchodilator FEV_1 (baseline value) is considered significant

- It is usually helpful to report the absolute change (in ml) as well as the % change from baseline to set the improvement in a clinical context

- The lack of reversibility during a PFT does not prohibit a clinical response to bronchodilator therapy.
- Although asthma is typically a reversible OVD, bronchodilator responsiveness during a PFT is not pathognomonic for asthma

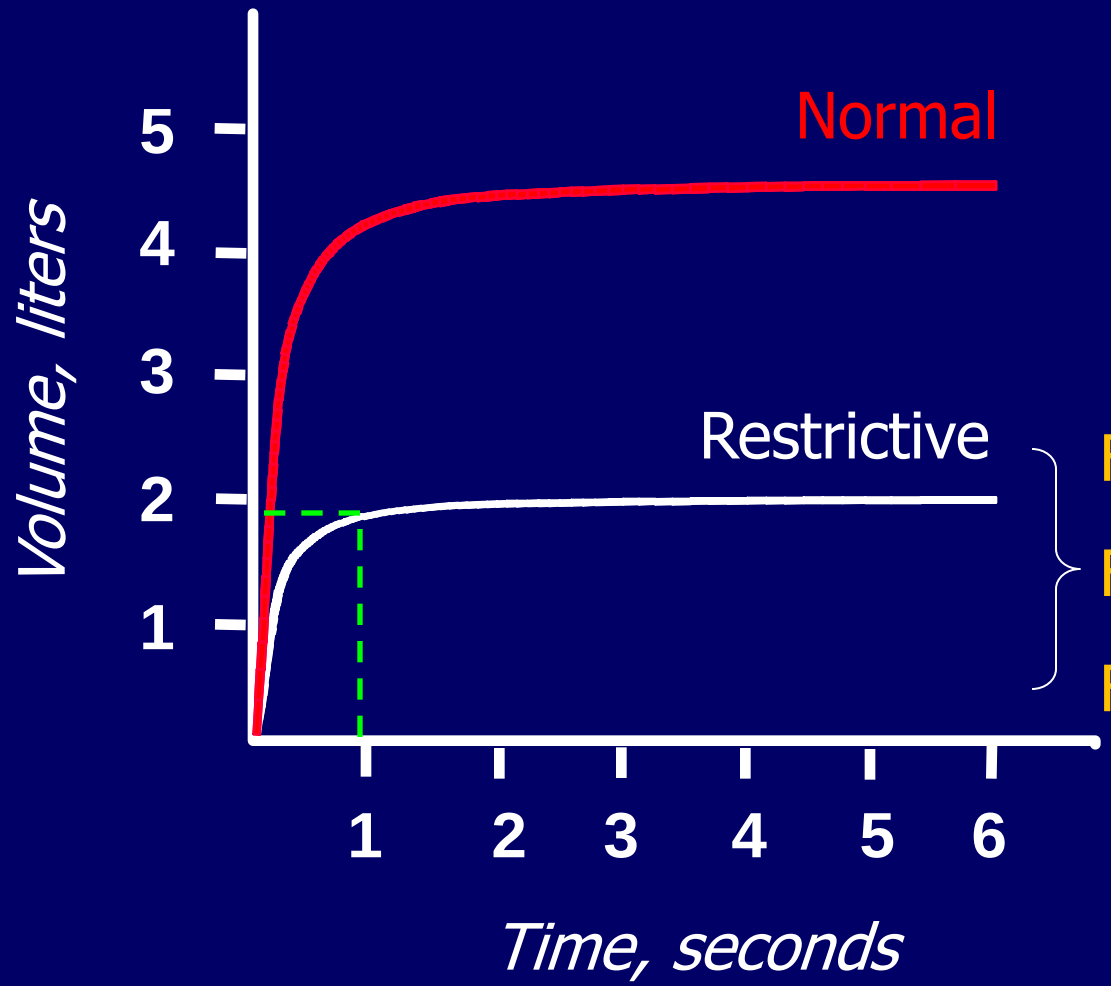
SPIROMETRY

RESTRICTIVE DISEASE

Criteria: Restrictive Disease

- $FEV_{1:}$ % predicted < 80%
- FVC: % predicted < 80%
- FEV_1/FVC: > 0.7

Spirometry: Restrictive Disease

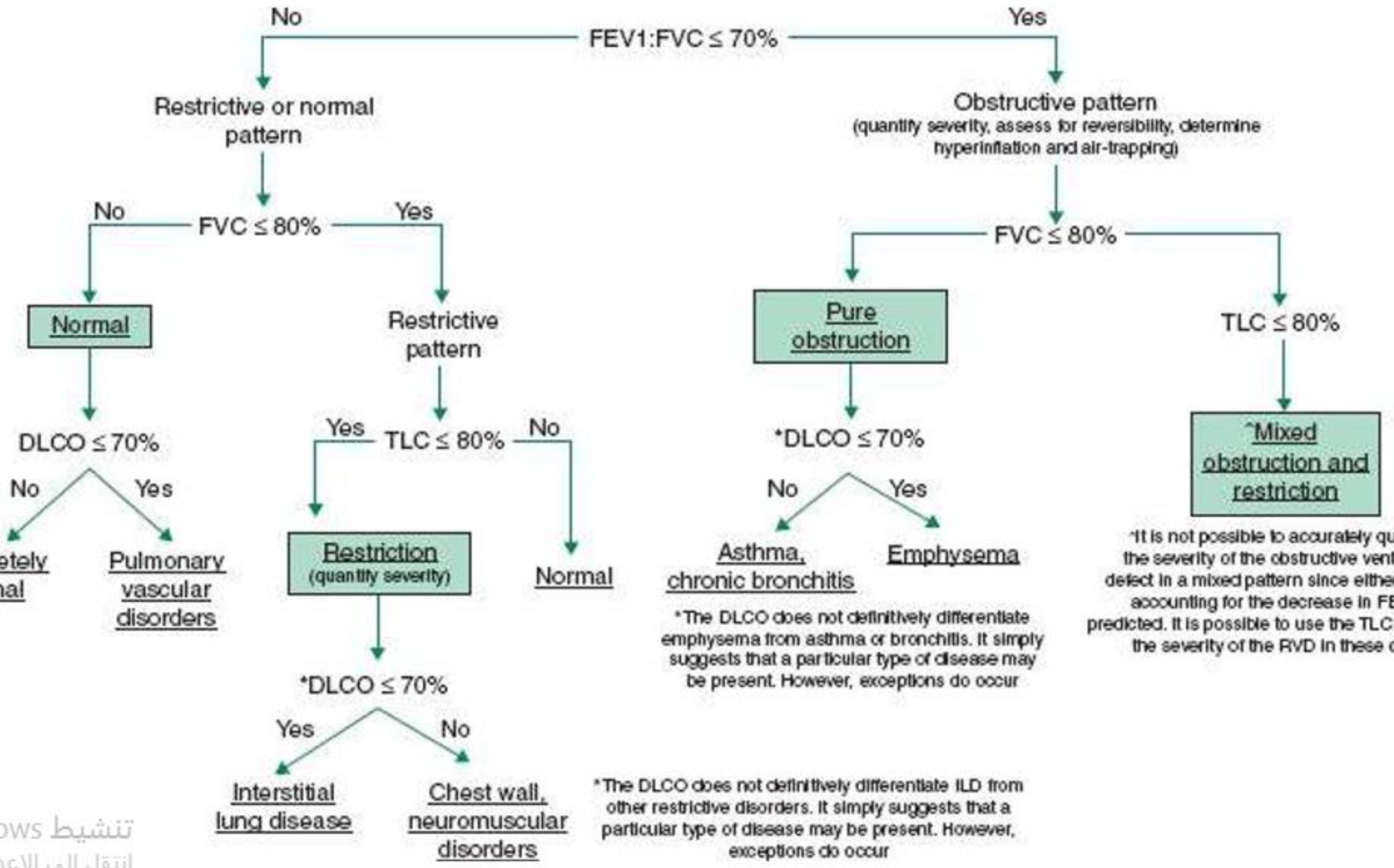


FEV_1 = 1.9L

FVC = 2.0L

FEV_1/FVC = 0.95

thognomonic for asthma.

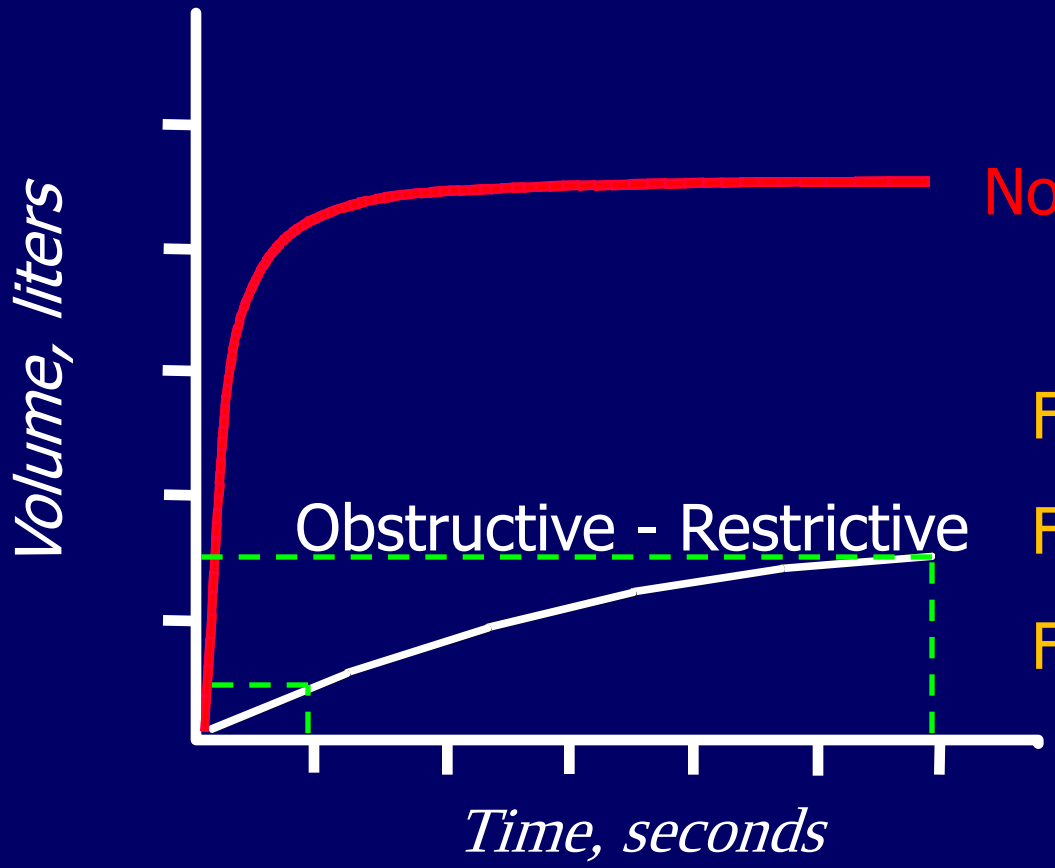


Evaluation of pulmonary function tests. DLCO, diffusing capacity for carbon monoxide; FVC, forced vit

Mixed Obstructive/Restrictive

- FEV_1: % predicted < 80%
- FVC: % predicted < 80%
- FEV_1 /FVC: < 0.7

Mixed Obstructive and Restrictive



FEV_1 = 0.5L

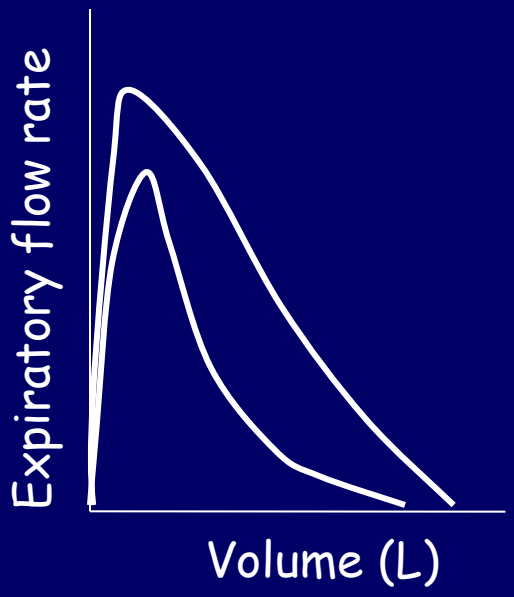
FVC = 1.5L

FEV_1/FVC = 0.30

Restrictive and mixed obstructive-restrictive are difficult to diagnose by spirometry alone; full respiratory function tests are usually required (e.g., body plethysmography, etc)

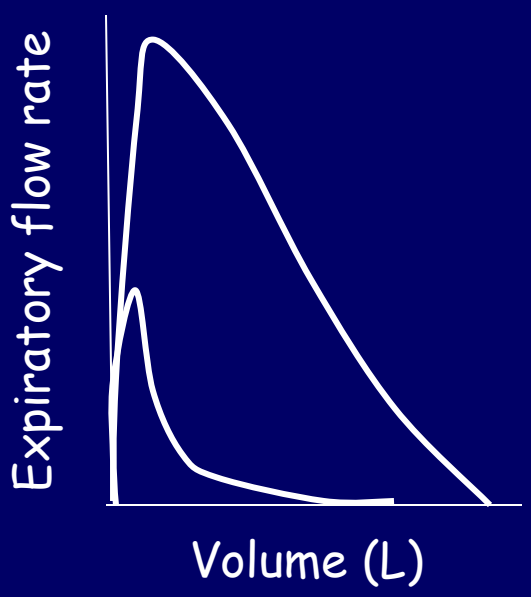
Flow Volume Curve Patterns Obstructive and Restrictive

Obstructive



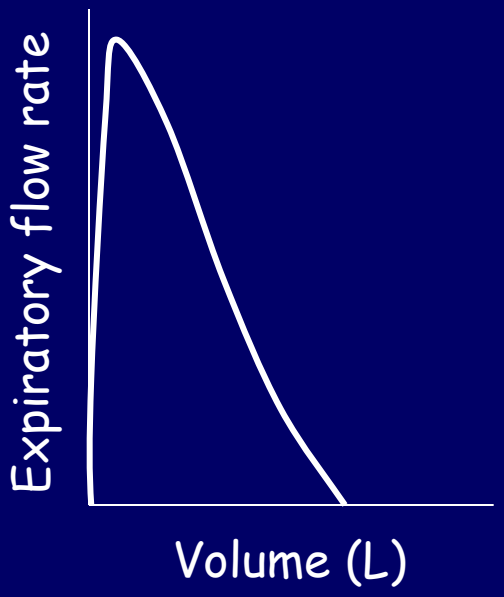
Reduced peak flow, scooped out mid-curve

Severe obstructive



Steeple pattern, reduced peak flow, rapid fall off

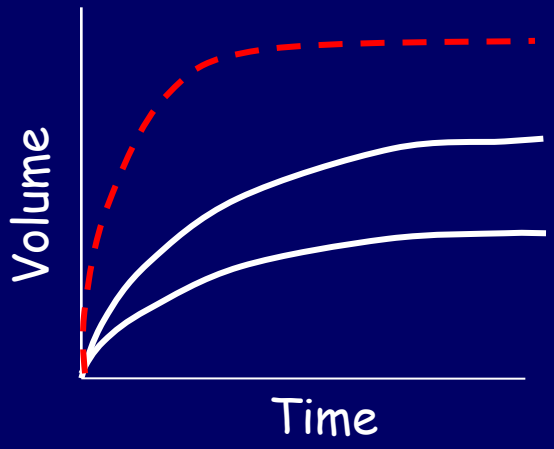
Restrictive



Normal shape, normal peak flow, reduced volume

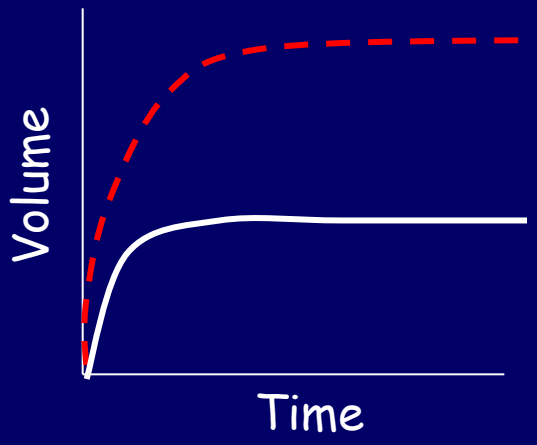
Spirometry: Abnormal Patterns

Obstructive



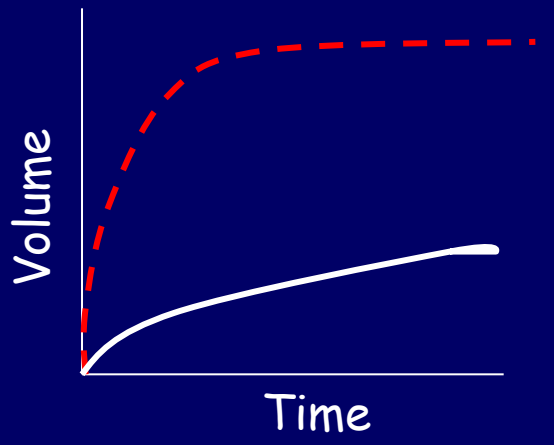
Slow rise, reduced volume expired; prolonged time to full expiration

Restrictive



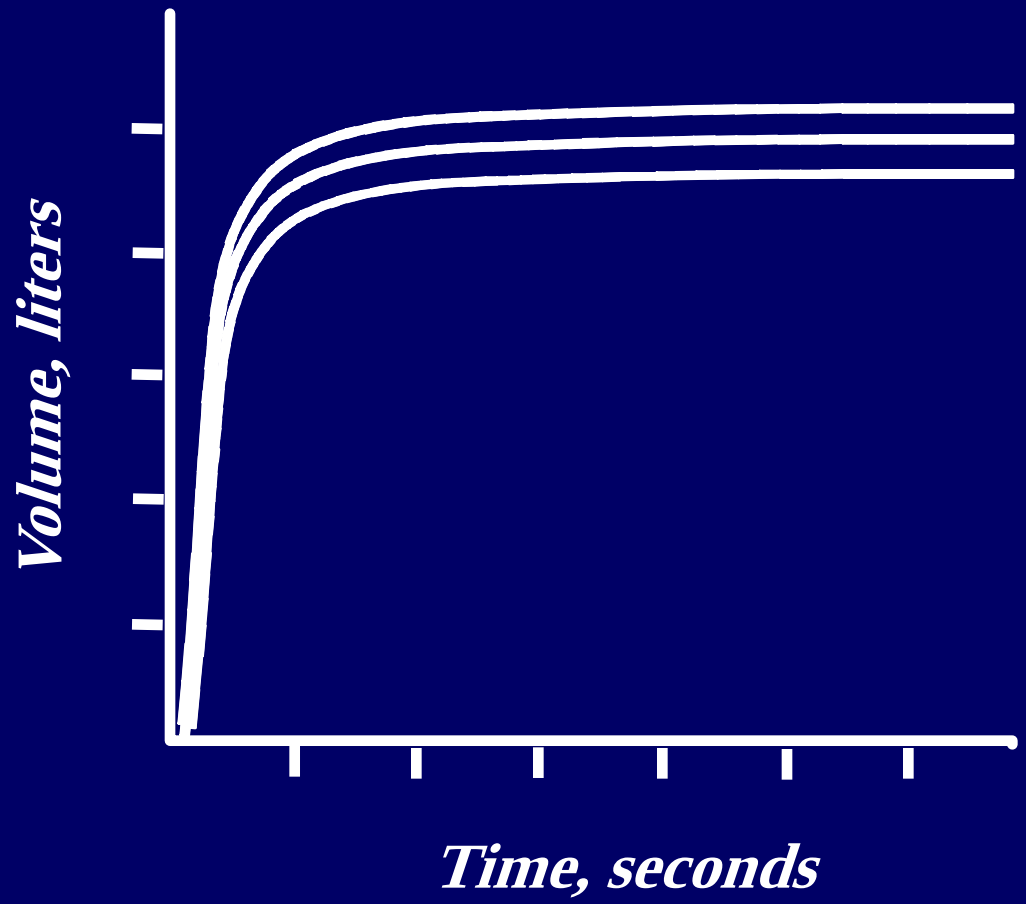
Fast rise to plateau at reduced maximum volume

Mixed



Slow rise to reduced maximum volume; measure static lung volumes and full PFT's to confirm

Reproducibility - Quality of Results

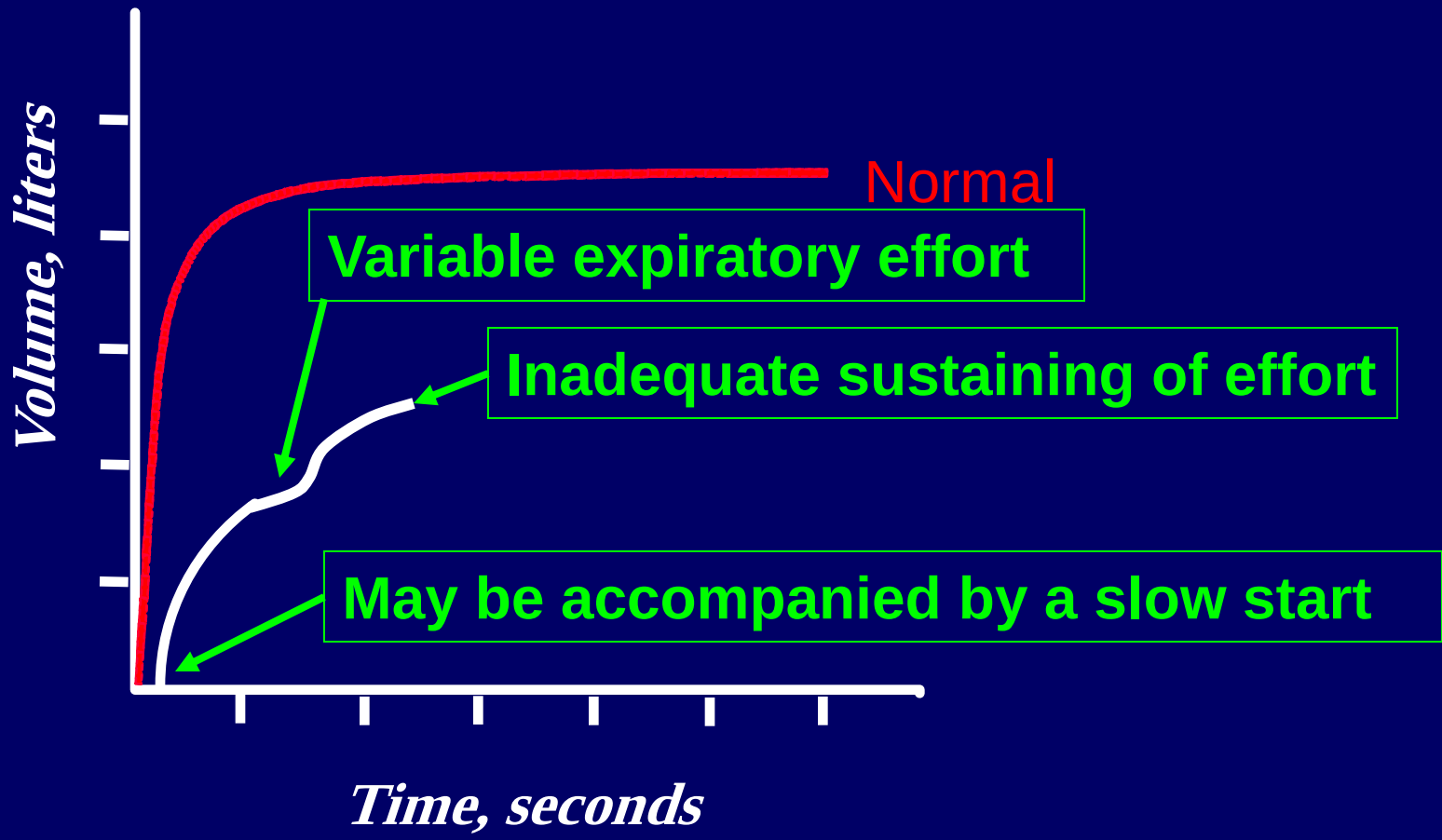


Three times FVC within 5% or 0.1 litre (100 ml)

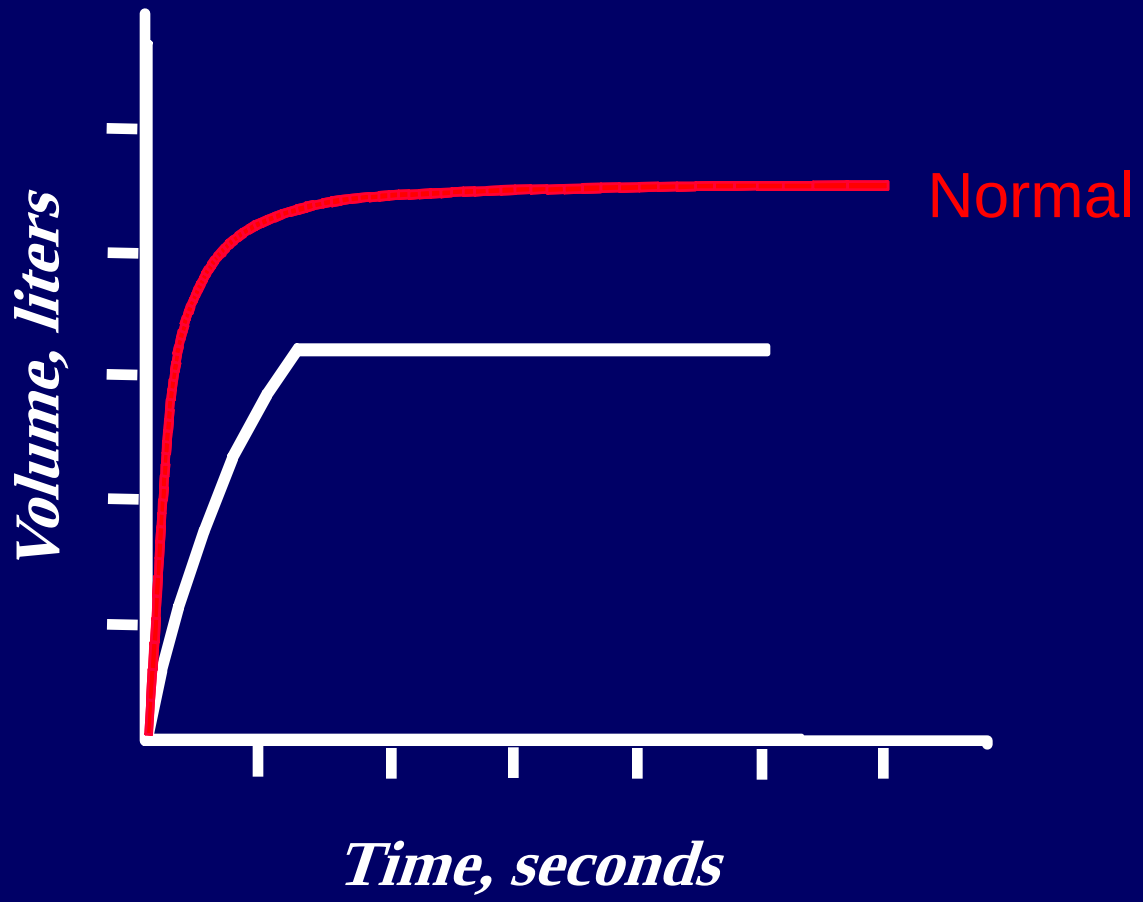
Troubleshooting

Examples - Unacceptable Traces

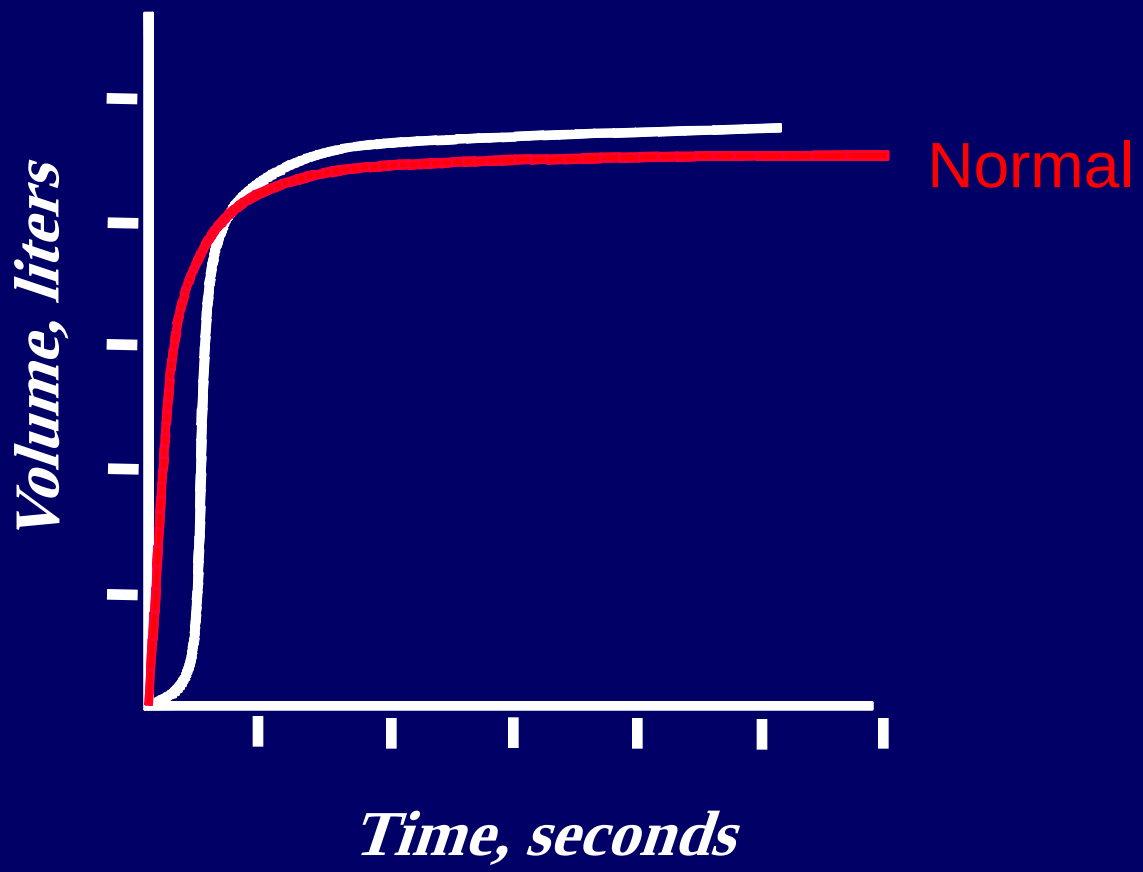
Unacceptable Trace - Poor Effort



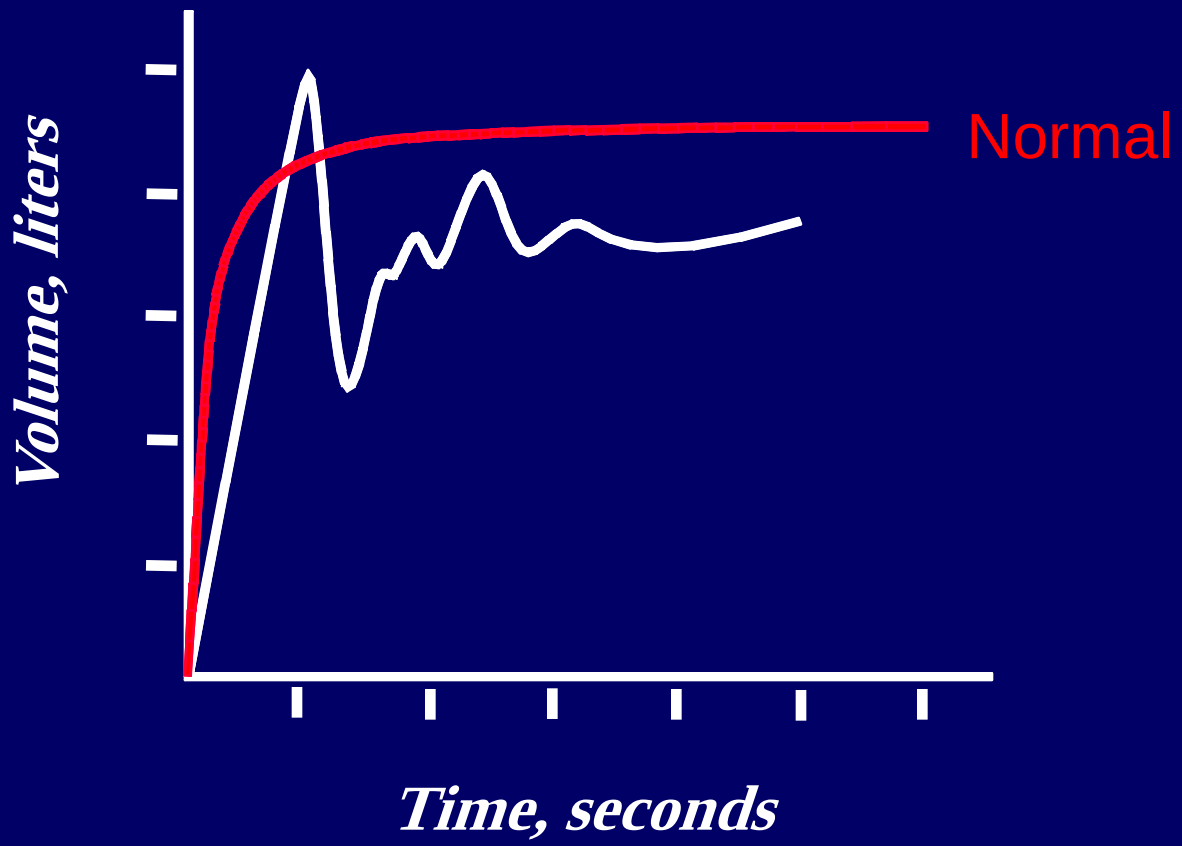
Unacceptable Trace – Stop Early



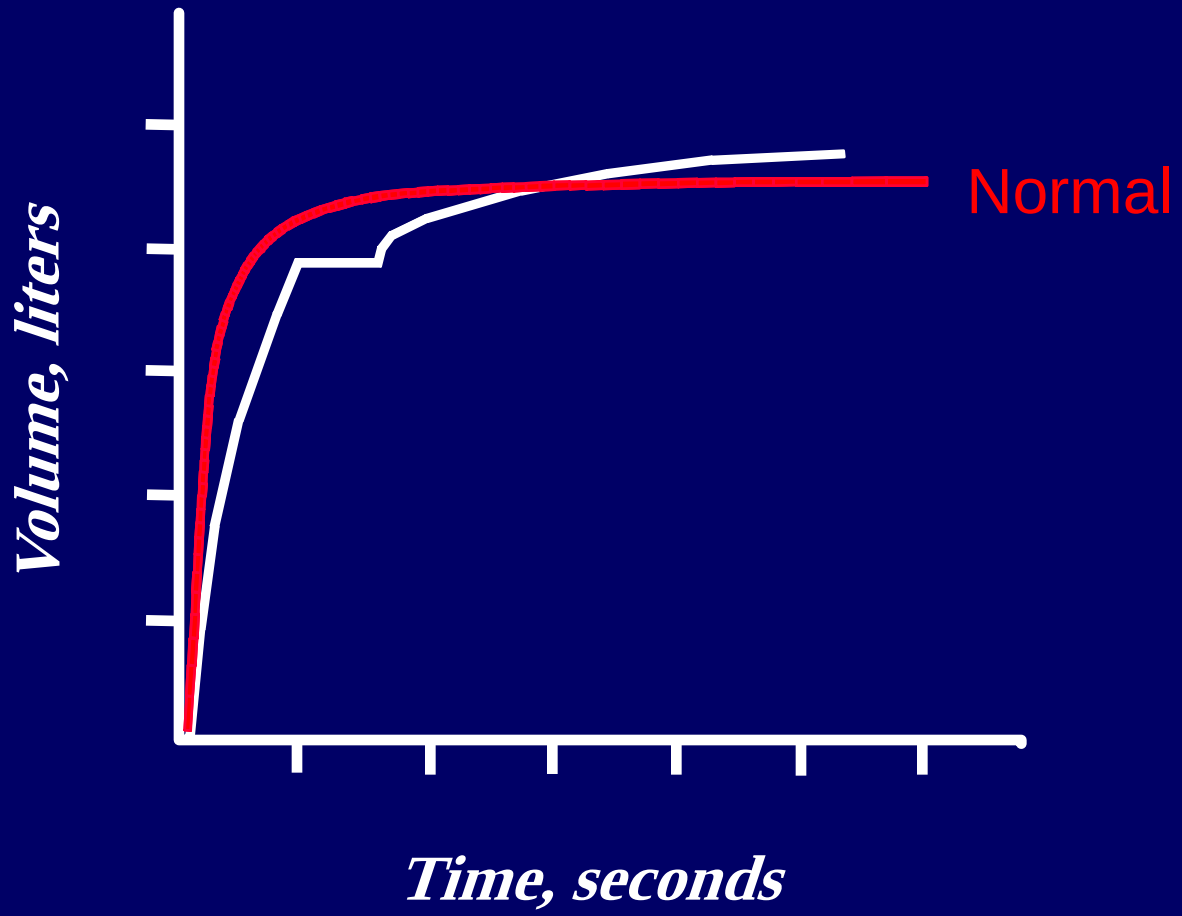
Unacceptable Trace – Slow Start



Unacceptable Trace – Coughing



Unacceptable Trace – Extra Breath



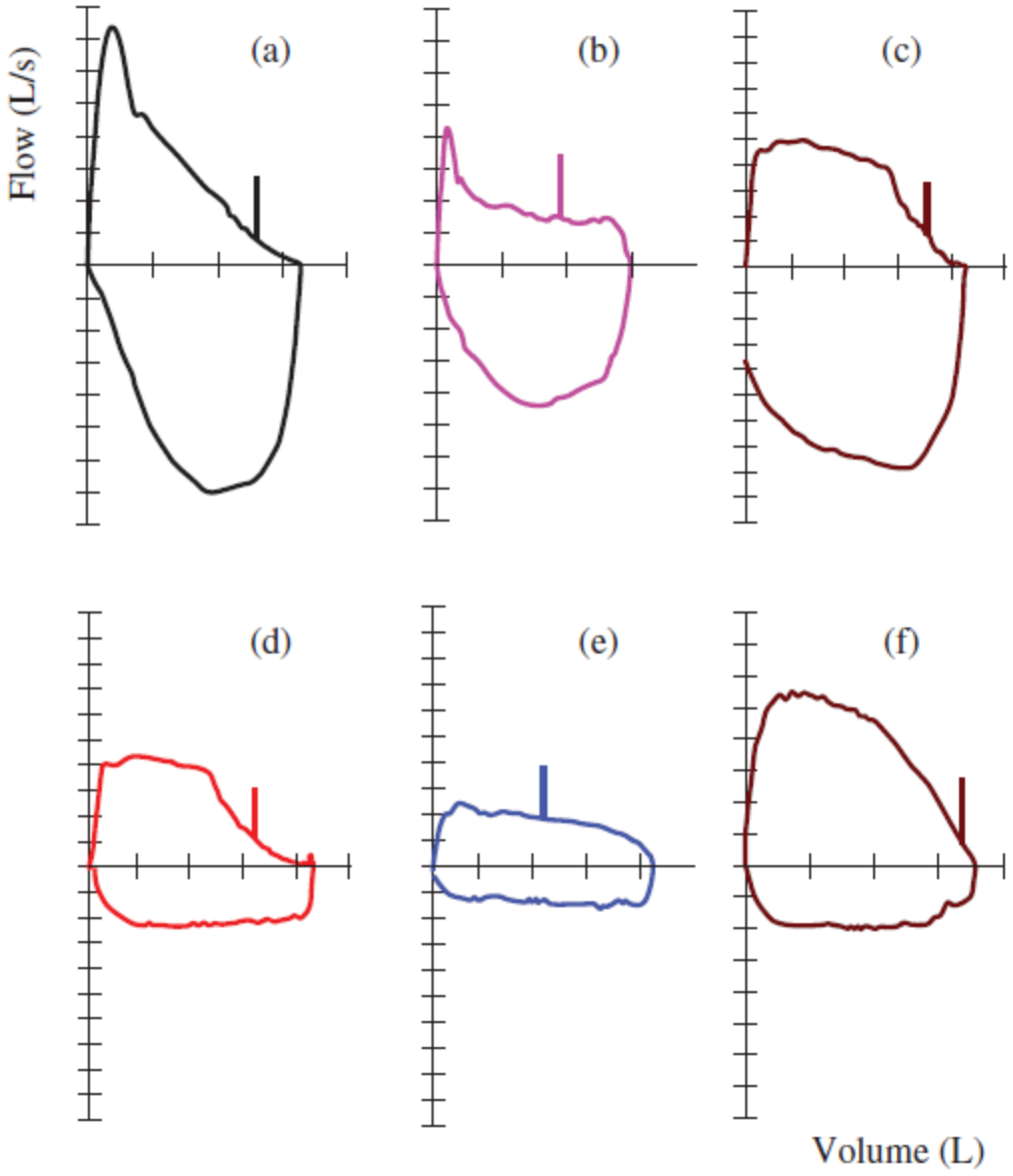


Figure 2.6 Flow–volume curve (a) depicts a normal curve shape; curves (

DIFFUSING CAPACITY

- Diffusing capacity is often measured as part of a PFT. It is performed separately from spirometry and lung volume measurement.
- It is a measure of the integrity of the alveolar-capillary membrane across which gas exchange takes place.

- The diffusing capacity is a nonspecific measurement and provides only a physiologic assessment of the efficiency of gas exchange.
- Any disease affecting the pulmonary parenchyma or circulation can alter the diffusing capacity.

- **The gas used to measure diffusing capacity is carbon monoxide, and the diffusing capacity is expressed as diffusing capacity of the lung for carbon monoxide (DLCO).**

- **The measured value is often adjusted to eliminate the effects of the hemoglobin concentration, which may artificially increase (high hemoglobin concentration) or reduce (low hemoglobin concentration) the DLCO. The adjusted value is expressed as the adjusted DLCO ($DLCO_{ADJ}$). The adjusted value for DLCO is sometimes called the corrected DLCO (DLCOc).**

- Percent predicted values for DLCO between 70% and 120% are considered normal.
  Also percent predicted values for $DLCO_{ADJ}$ between 70% and 120% are considered normal.
- The reason for the wide range in normal DLCO and $DLCO_{ADJ}$ is the large amount of variability between different measurements in the same individual at any given time.
  Of note the finding of normal PFTs with an isolated decrease in DLCO should raise a high index of suspicion for pulmonary vascular disease.

Methacholine Challenge Testing

- **Asthma is defined as a reversible obstructive airway disease. Therefore, in individuals suspected of having asthma, PFTs may appear normal, without evidence of obstruction.**
- **In individuals where PFTs are normal but asthma is strongly suspected, bronchial provocation testing is indicated to induce airway constriction and allow for the diagnosis (and further management) of asthma.**

Other individuals who should be considered for bronchial provocation testing include those with:

- **Chronic cough**
- **Wheezing**
- **Intermittent dyspnea**
- **Work place-related cough / wheezing /dyspnea**
- **Exercise-associated cough / wheezing**

- The test begins with the administration of a sterile saline aerosol followed by the measurement of the FEV1 after 3–5 minutes (as a baseline).

- Increasing concentrations of methacholine diluted in sterile saline are then administered to the patient at 5-minute intervals, and the FEV1 is measured 3–5 minutes after each increase in concentration.
- The concentrations range from 0.003 to16 mg/mL of methacholine in sterile saline and are roughly doubled each time until either a positive response is obtained or a maximum concentration is achieved.
- A positive methacholine challenge is defined as a decrease in FEV1 from baseline of >20% at a methacholine concentration of ≤8 mg/mL .

- The methacholine concentration resulting in a positive challenge is reported as the PC20 (provocative concentration causing a 20% fall in FEV1), for example, a decrease in FEV1 from baseline occurring at a methacholine concentration of 0.5 mg/mL is reported as a PC20 = 0.5 mg/mL .
- A negative methacholine challenge occurs if there is no change from baseline, or any decrease in FEV1 from baseline is <20% and a concentration of >8 mg/mL has been reached.
- When patients undergoing bronchial provocation testing are on inhaled corticosteroids, a decrease in FEV1 from baseline of >20% at a methacholine concentration of16 mg/mL may be considered a positive methacholine challenge test .

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