Pulmonary Diagnostics tests

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A comprehensive guide to essential diagnostic tools and techniques in respiratory medicine, from imaging to invasive procedures.

The Evolution of Chest Imaging

Historical Milestone

Wilhelm Conrad Röntgen accidentally discovered X-rays in 1895 during cathode ray tube experiments. Despite numerous advances since, chest radiography remains the first-line imaging modality for lung and airway symptoms.

Low Radiation

Minimal radiation exposure for patients

Heart size and mediastinal structures

Major Vessels

Aorta and pulmonary vasculature

Bones & Abdomen

Ribs, spine, and upper abdominal structures

Not routine but valuable for localizing abnormalities and visualizing retrosternal, retrocardiac spaces, and posterior costophrenic recesses.

Position Effects

Supine position causes cardiac silhouette enlargement, diaphragm elevation, and altered appearance of effusions and pneumothorax.

Technical Artifacts

Rotation, poor inspiration, skin folds, and shadows from medical devices compromise image q

Distance Factors

Smaller distances between X-ray tube, patient, and detector affect image magnification and quality.

General performance of Chest X-ray
•**Sensitivity:** low–moderate
•**Specificity:** moderate–high
➡️ Good as a **screening/initial test**, poor to **rule out disease**

Sensitivity & specificity by common lung diseases
1. Pneumonia
•**Sensitivity:** ~60–70%
•**Specificity:** ~70–85%
•Misses:
- Early disease
- Dehydration
- Immunocompromised patients

•**CT is far more sensitive**

2. Pulmonary Tuberculosis
•**Sensitivity:** ~70–80% (active TB)
•**Specificity:** ~60–70%
•Abnormal CXR ≠ TB (many mimics)
•Normal CXR **does NOT exclude TB**

3. Lung Cancer
•**Sensitivity:** ~70–75% (large/central lesions)
•**Specificity:** ~85–90%
•Misses:
- Small nodules (<1 cm)
- Early adenocarcinoma

  ➡️ **Low-dose CT is preferred for screening**

4. Interstitial Lung Disease (ILD)
•**Sensitivity:** ~60–70%
•**Specificity:** ~80%
•Early ILD often **normal on CXR**
➡️ **HRCT is mandatory**

5. COPD / Emphysema
•**Sensitivity:** ~40–60%
•**Specificity:** ~80–90%
•Structural changes appear **late**
➡️ Diagnosis is **spirometric**, not radiologic

6. Pulmonary Edema (Heart failure)
•**Sensitivity:** ~70–80%
•**Specificity:** ~80–90%
•Early interstitial edema may be missed

7. Pulmonary Embolism
•**Sensitivity:** ~30–40%
•**Specificity:** low
•Often **normal**
➡️ Used to rule out alternatives, **not PE**

Chest X-ray vs Chest CT (summary table)

Feature	Chest X-ray (CXR)	Chest CT
Imaging type	2-D projection	Cross-sectional (3-D)
Availability	Widely available	Less available
Cost	Low	High
Time	Minutes	Longer
Radiation dose	**Low** (~0.1 mSv)	**Higher** (5–7 mSv; LDCT ~1–2 mSv)
Contrast needed	No	Often yes (depending on indicatio
Sensitivity (lung disease)	**Low–moderate**	**High**
Specificity	Moderate–high	High
Early disease detection	Poor	**Excellent**
Spatial resolution	Limited	**Excellent**
Overlap of structures	Yes	No

Spirometry

The gold standard for measuring lung function through objective, noninvasive, and reproducible testing of expired and inspired air.

Key Spirometric Measures

maximum air exhaled

%

FEV1/FVC Ratio

Critical diagnostic ratio for obstruction

PEF

Peak expiratory flow - maximal flow rate

IVC

Inspiratory vital capacity after full expiration

Spirometry Contraindications

Important: Wait until patient fully recovers before testing if any of

- Hemoptysis of unknown origin
- Pneumothorax
- Unstable cardiovascular status
- Recent MI or pulmonary embolism
- Thoracic, abdominal, or cerebral aneurysms
- Recent eye surgery
- Acute nausea or vomiting
- Recent thoracic/abdominal surgery

Quality Criteria for Spirometry

1 Explosive Start

maneuver

Exhaling ≥6 seconds with <50 mL in last 2 seconds

5 Reproducibility

Best two values within 5% or 150 mL of each other

Achieving Quality Results

Three acceptable maneuvers required per ATS/ERS guidelines. If reproducibility criteria not met, continue testing up to eight maneuvers maximum.

Critical timing: Allow ≥30 seconds between maneuvers to prevent bronchoconstriction. Asthmatic patients may need several minutes between attempts.

Full inspiration can cause bronchodilation, so continue until no further improvement occurs.

Initial measurements recorded

4×100 μg salbutamol via spacer OR 4×40 μg ipratropium

Wait Period

15 min for β-agonist, 30 min for anticholinergic

Retest

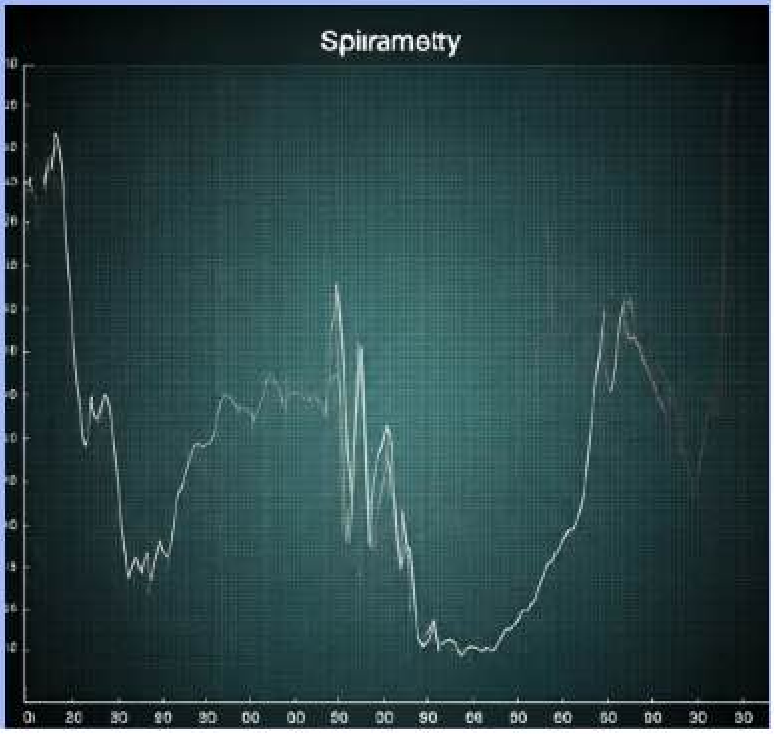
Repeat spirometry and compare

Key Point: Lack of reversibility does not exclude asthma diagnosis. Reversibility is the defining characteristic separating asthma from other obstructive diseases.

Japanese, Polynesian, Indian, Pakistani, and African patients: multiply reference by 0.90 factor.

- Reduced FEV1
- Normal or reduced VC
- Normal or reduced FVC
- Reduced FEV1/FVC ratio
- Concave flow-volume loop

Mechanism: Decreased airway calibre from smooth muscle contraction, inflammation, mucus plugging, or emphysematous airway collapse.



Restriction

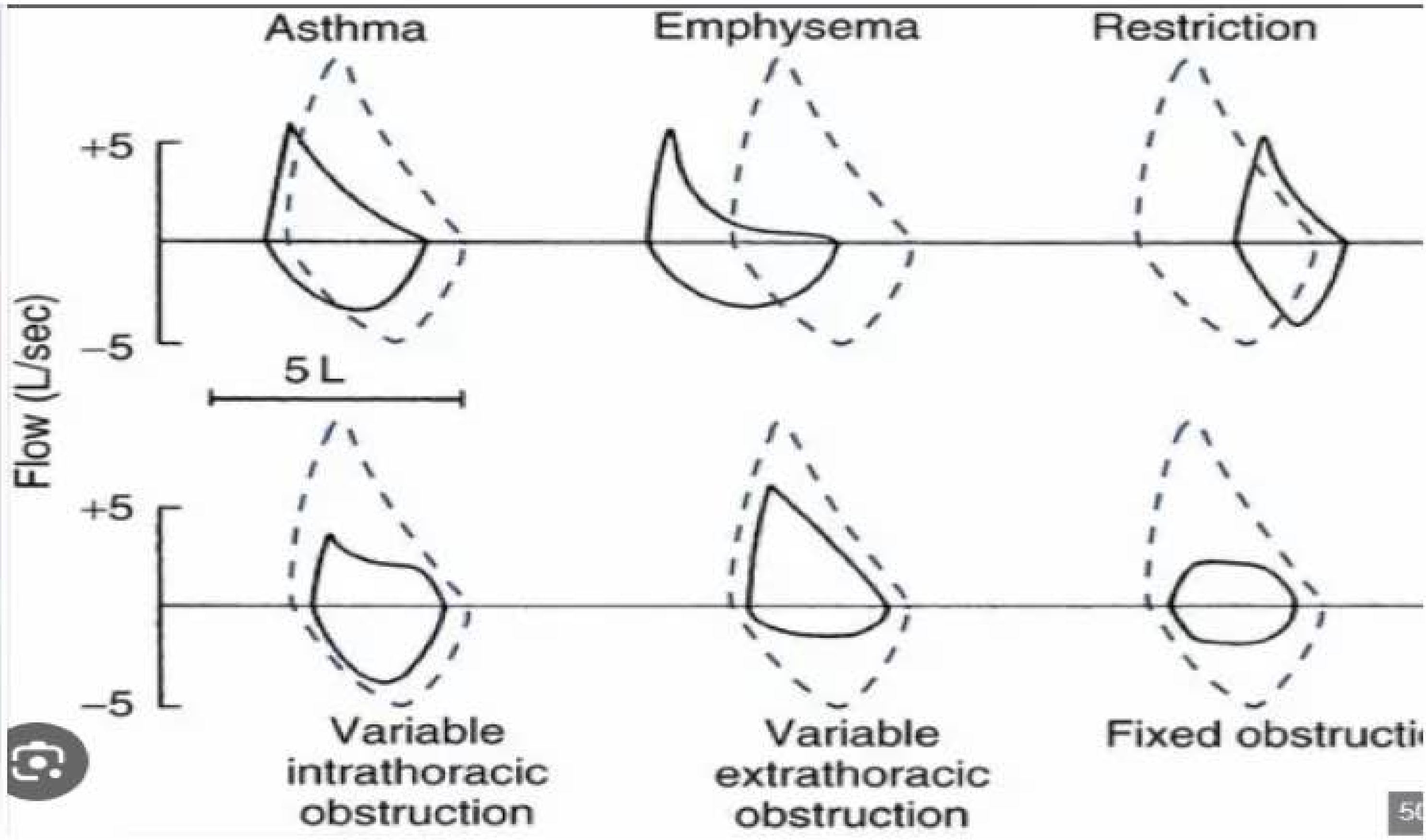
Characteristic Pattern

- Reduced FVC
-
-
- Possibly relatively high PEF

Common Causes

- Pulmonary fibrosis
- Neuromuscular disorders
- Pneumonectomy
- Pulmonary edema
- Obesity

Caution: Many "restrictive" patterns result from failure to reach end of expiration, falsely reducing FVC. Further testing may be needed.


Asthma
Emphysema
Restriction
+5
−5
Flow (L/sec)
5 L
+5
−5
Variable intrathoracic obstruction
Variable extrathoracic obstruction
Fixed obstructi

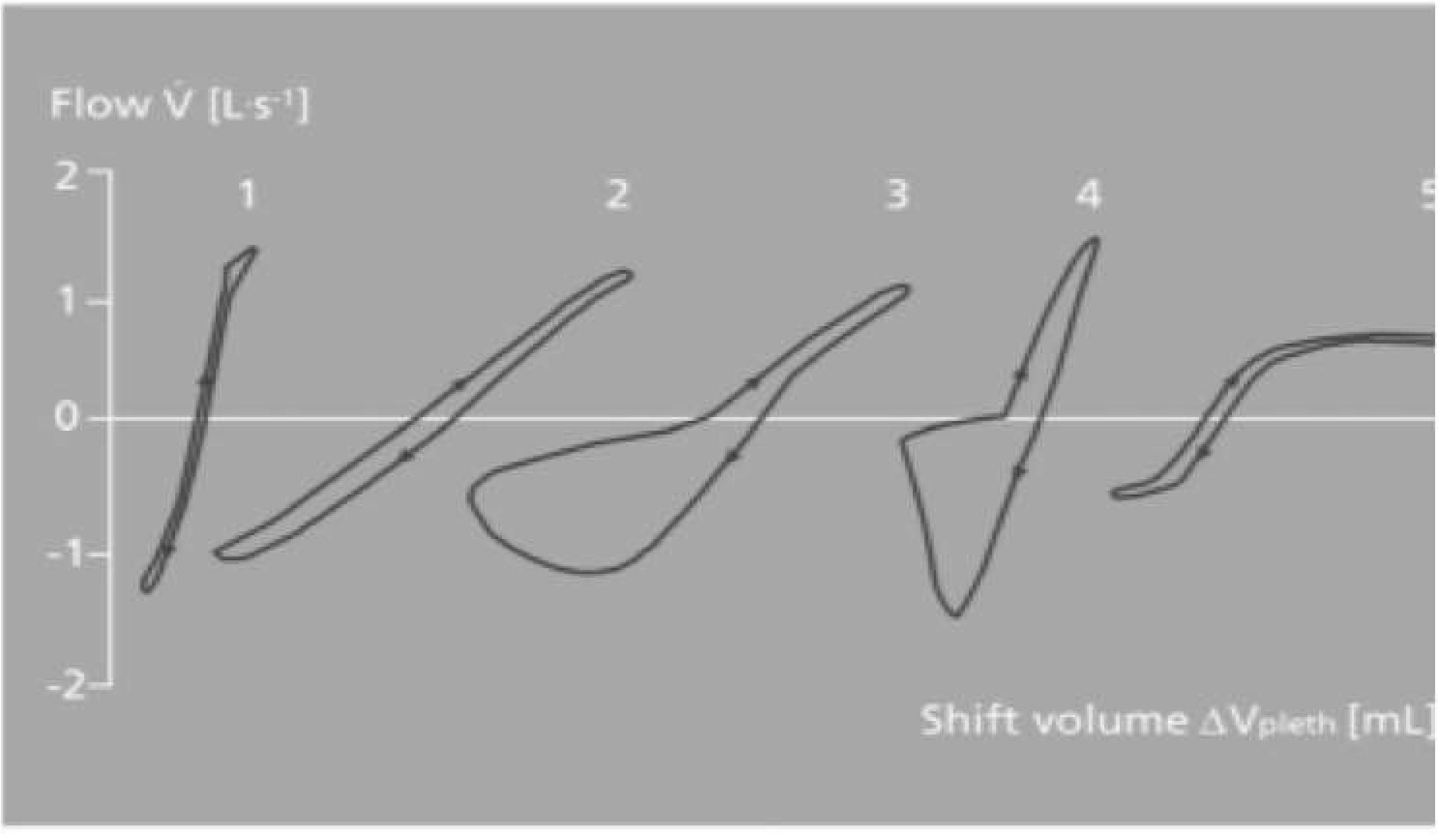

Flow V̇ [L·s⁻¹]
2
1
0
-1
-2
1
2
3
4
Shift volume ΔVpleth [mL]

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	Elevat
Hyperinflation	Elevated	Elevated	Normal or elevated	Normal	Elevat
Restrictive disorders	Reduced	Reduced or normal	Reduced	Normal	Norma

DLCO Testing

Diffusing capacity of the lung for carbon monoxide measures gas exchange efficiency when adjusted for lung volume.

KCO Pattern

Normal diffusing capacity when adjusted for volume. Occurs with normal lungs or low VA from non-pulmonary causes.

KCO = DLCO in emphysema/vascular disease. KCO > DLCO in ILD. May be low, normal, or elevated in ILD.

Clinical Applications of DLCO

Adjustment of DLCO and KCO for lung volume in patients with low lung volume yields better indication of gas exchange ability.

Similar to hemoglobin adjustment in anemia, volume adjustment accounts for non-pulmonary causes of reduced lung capacity.

Note: Neuromuscular disease or chest wall deformity may cause atelectasis, potentially reducing DACO.

Methacholine Challenge

Bronchial challenge testing to assess airway responsiveness and aid in asthma diagnosis.

Indications for Bronchial Cha

Asthma Diagnosis

Confirm or exclude suspected asthma when spirometry is normal or inconclusive, especially with atypical symptoms.

Occupational Screening

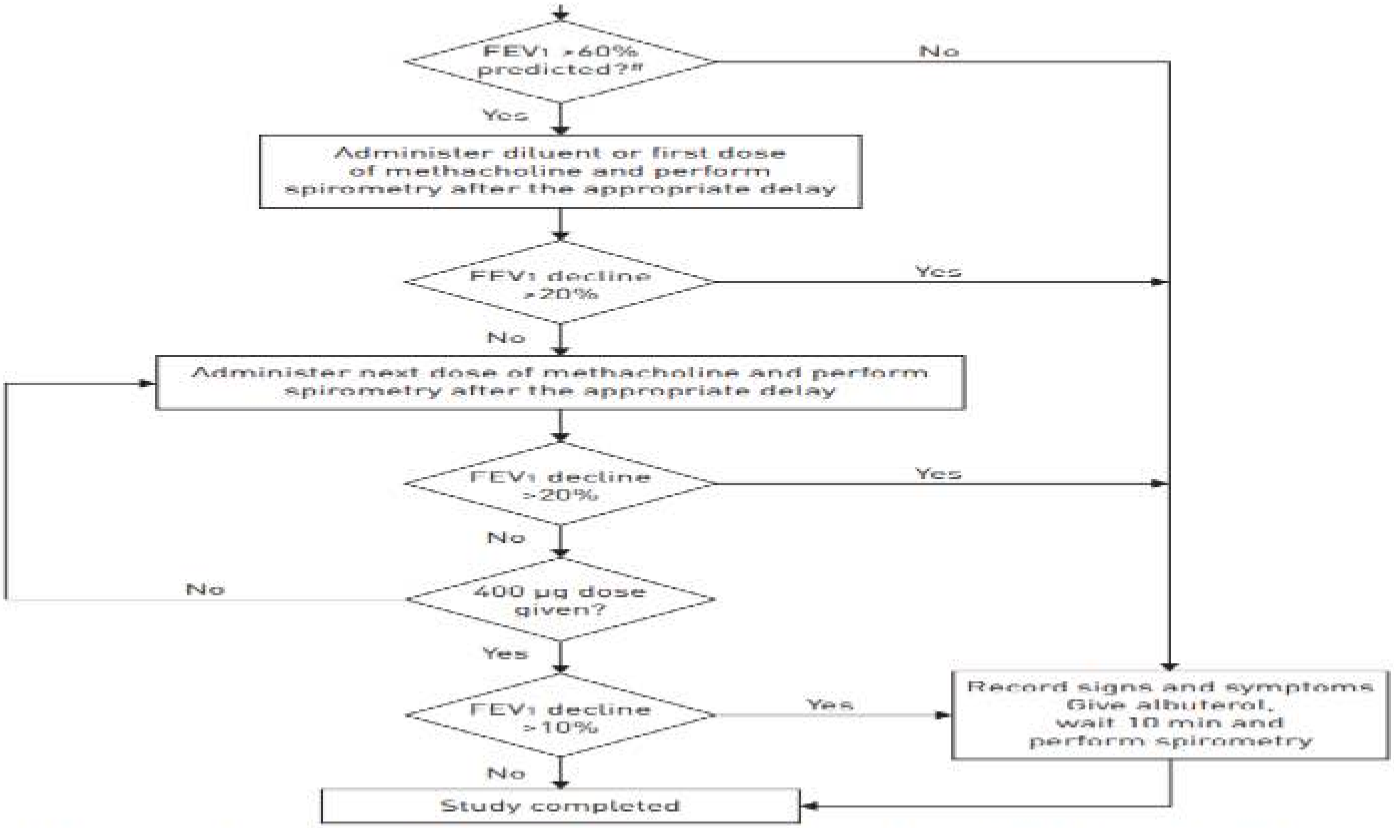
Screen applicants for high-risk situations: commercial diving, submarine service, certain occupational exposures.

Monitoring Therapy

Indirect tests correlate with airway inflammation and may monitor anti-inflammatory treatment response.

Label strength	Take	Add NaCl (0.9%)	Obtain dilution
Example of a dilution schedule for quadrupling concentrations			
100 mg	100 mg	6.25 mL	A: 16 $mg \cdot mL^{-1}$
	3 mL of dilution A	9 mL	B: 4 $mg \cdot mL^{-1}$
	3 mL of dilution B	9 mL	C: 1 $mg \cdot mL^{-1}$
	3 mL of dilution C	9 mL	D: 0.25 $mg \cdot mL^{-1}$
	3 mL of dilution D	9 mL	E: 0.0625 $mg \cdot mL^{-1}$
	3 mL of dilution E	9 mL	F: 0.015625 $mg \cdot mL^{-1}$
Example of a dilution schedule for doubling doses			
100 mg	100 mg	6.25 mL	A: 16 $mg \cdot mL^{-1}$
	3 mL of dilution A	3 mL	B: 8 $mg \cdot mL^{-1}$
	3 mL of dilution B	3 mL	C: 4 $mg \cdot mL^{-1}$
	3 mL of dilution C	3 mL	D: 2 $mg \cdot mL^{-1}$
	3 mL of dilution D	3 mL	E: 1 $mg \cdot mL^{-1}$
	3 mL of dilution E	3 mL	F: 0.5 $mg \cdot mL^{-1}$
	3 mL of dilution F	3 mL	G: 0.25 $mg \cdot mL^{-1}$
	3 mL of dilution G	3 mL	H: 0.125 $mg \cdot mL^{-1}$
	3 mL of dilution H	3 mL	I: 0.0625 $mg \cdot mL^{-1}$
	3 mL of dilution I	3 mL	J: 0.03125 $mg \cdot mL^{-1}$

Using a 100-mg vial of methacholine and NaCl (0.9%) for diluent, the table shows the range of concentrations available to produce appropriate dose steps using examples of dilutions with quadrupling and doubling increases. If necessary, alternative concentrations can be produced from a different initial dilution step. For example, adding 5 mL of diluent to 100 mg methacholine would produce dilution A of 20 $mg \cdot mL^{-1}$ and adding 8.3 mL of diluent to 100 mg methacholine would produce dilution A of 12 $mg \cdot mL^{-1}$.



1 Testing sequence flow chart. FEV1: forced expiratory volume in 1 s. #: FEV1 <1.5 L in adults is an al contraindication. Reproduced and modified from [3] with permission.

Interpreting Methacholine Results

>16

PC20 mg·mL

Normal (negative) result effectively excludes current asthma if symptoms present within previous few days.

High

Negative Predictive Value

Test is highly sensitive - more useful for excluding asthma than establishing diagnosis.

Variable

Positive Predictive Value

Positive results consistent with but not diagnostic of asthma. Must interpret with clinical context.

False-positives occur in significant proportion of individuals without asthma symptoms. False-negatives rare but can occur in elite athletes.

Six-Minute Walk Test

Standardization Requirements

Perform twice at PR commencement to account for learning effect. Best distance in metres recorded.

Rest period: ≥30 minutes between same-day tests. Debilitated patients may need separate days (within one week).

6MWT Track Requirements

Track Layout

Continuous (oval/rectangular) or point-to-point track. Same layout for all patient tests.

Specifications

Flat surface, minimal blind turns or obstacles. Minimum 25m length, marked in metre increments.

Environment

Comfortable ambient temperature and humidity maintained for all tests.

Note: Shorter tracks (<25m) may result in reduced distance due to increased turning frequency.

6MWT Predictive Equations

Males

6MWD(m) = 867 – (5.71 × age, yrs) + (1.03 × height, cm)

Females

6MWD(m) = 525 – (2.86 × age, yrs) + (2.71 × height, cm) – (6.22 × BMI)

Minimum Important Difference: 30 meters improvement (95% CI: 25-33 meters) indicates clinically significant change after pulmonary rehabilitation.

Bronchoscopy

Essential diagnostic and therapeutic tool for direct airway visualization and tissue sampling.

Diagnostic Indications

Lung Malignancy

[illegible]

Pulmonary Infections

Non-resolving pneumonia, immunocompromised patients, TB, fungal infections

Hemoptysis

Unknown origin, bleeding localization, malignancy exclusion

Interstitial Disease

BAL for cellular analysis, transbronchial biopsy

Airway Abnormalities

Stenosis, tracheomalacia, unexplained stridor

Therapeutic Applications

Airway Obstruction Relief

Mucus plug removal, tumor debulking, laser/cryotherapy

Stent Placement

Management of benign or malignant airway stenosis

Absolute Contraindications

Severe Hypoxemia

Refractory hypoxemia despite supplemental oxygen - inability to maintain adequate oxygenation

Cardiovascular Instability

Recent MI, unstable angina, life-threatening arrhythmias, hemodynamic instability or shock

Severe Coagulopathy

Uncorrectable bleeding disorder: platelets <20,000/μL (especially for biopsy), markedly elevated INR

Consent Issues

Patient refusal, inability to obtain informed consent, lack of airway control

Bronchoscopy Complications

Medication-Related

- Local anesthetic overdose: CNS toxicity, seizures, coma
- Methemoglobinemia
- Sedation effects: hypotension, bradycardia
- Malignant hyperthermia (general anesthesia)

Procedure-Related

- [illegible]
- [illegible]
- [illegible]
- Vocal cord trauma
- Pneumomediastinum, hypoxia

Critical: Most pneumothoraces develop within first hour but can be delayed up to 24 hours. Appropriate follow-up essential.

Types of Pulmonary Biopsies

1. **Endobronchial Biopsy (EBB)**
   Visible lesions within bronchial lumen. Best for central airway lesions and endobronchial tumors.

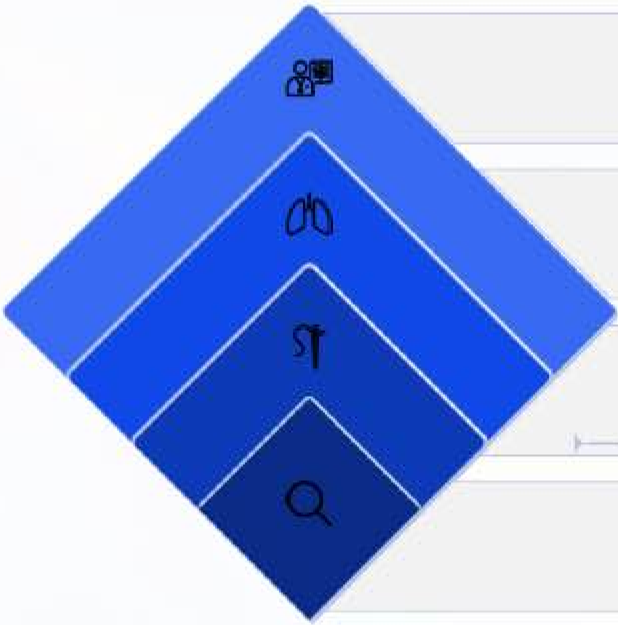
2. **Transbronchial Lung Biopsy (TBLB)**
   Small tissue samples via forceps. Best for diffuse or peribronchial parenchymal disease, ILD, infections.

3. **EBUS-TBNA**
   Ultrasound-guided needle aspiration. Best for mediastinal lymph nodes with high diagnostic yield.

4. **CT-Guided Biopsy**
   Transthoracic needle biopsy. Best for peripheral lesions not reachable by bronchoscopy.

5. **Cryobiopsy**
   Freezing technique for larger samples. Alternative to surgical biopsy for ILD in high-risk patients.

Biopsy Selection Algorithm



Peripheral Nodule

CT-guided biopsy

Diffuse Parenchymal

→ TBLB/cryobiopsy → surgical

Mediastinal Nodes

Use EBUS-TBNA

Central Airway

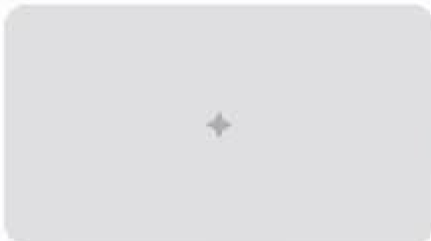
Choose EBB

Central Airway Lesions

First Choice: Endobronchial biopsy (EBB) ± Brushings/Washings

Typical Diagnoses:

- Squamous cell carcinoma
- Endobronchial tuberculosis
- Carcinoid tumor



Mediastinal Lymphadenopathy

Imaging

Enlarged lymph nodes on CT/PET scan

EBUS-TBNA

First choice for tissue diagnosis

Applications

Lung cancer N staging, sarcoidosis, lymphoma screening

If EBUS unavailable, conventional TBNA is alternative approach.

Interstitial Lung Disease Approach

Step 1: BAL

Bronchoalveolar lavage for infection, hemorrhage, cellular pattern analysis

Step 2: Tissue Sampling

TBLB or Cryobiopsy if tissue diagnosis needed and expertise available

Step 3: Surgical Biopsy

VATS if previous steps nondiagnostic - gold standard but higher morbidity

Peripheral Lung Nodules

Not Reachable by Bronchoscopy

Approach: CT-guided percutaneous needle biopsy

Advantages:

- Direct access to peripheral lesions
- High diagnostic yield
- Outpatient procedure

Main Complication

Pneumothorax - most common complication requiring monitoring and potential intervention

Exam High-Yield Points

First-line for mediastinal lymph nodes?

EBUS-TBNA

Best for peripheral nodules?

CT-guided transthoracic needle biopsy

Largest bronchoscopic tissue sample?

Cryobiopsy

Highest pneumothorax risk?

CT-guided transthoracic biopsy

Lung Cancer Staging & Sarcoidosis

N

Lung Cancer N Staging

Best test: EBUS-TBNA for mediastinal lymph node assessment

1st

Sarcoidosis Diagnosis

Preferred: EBUS-TBNA if lymphadenopathy present, otherwise TBLB

BAL Clinical Utility

Most Useful For:

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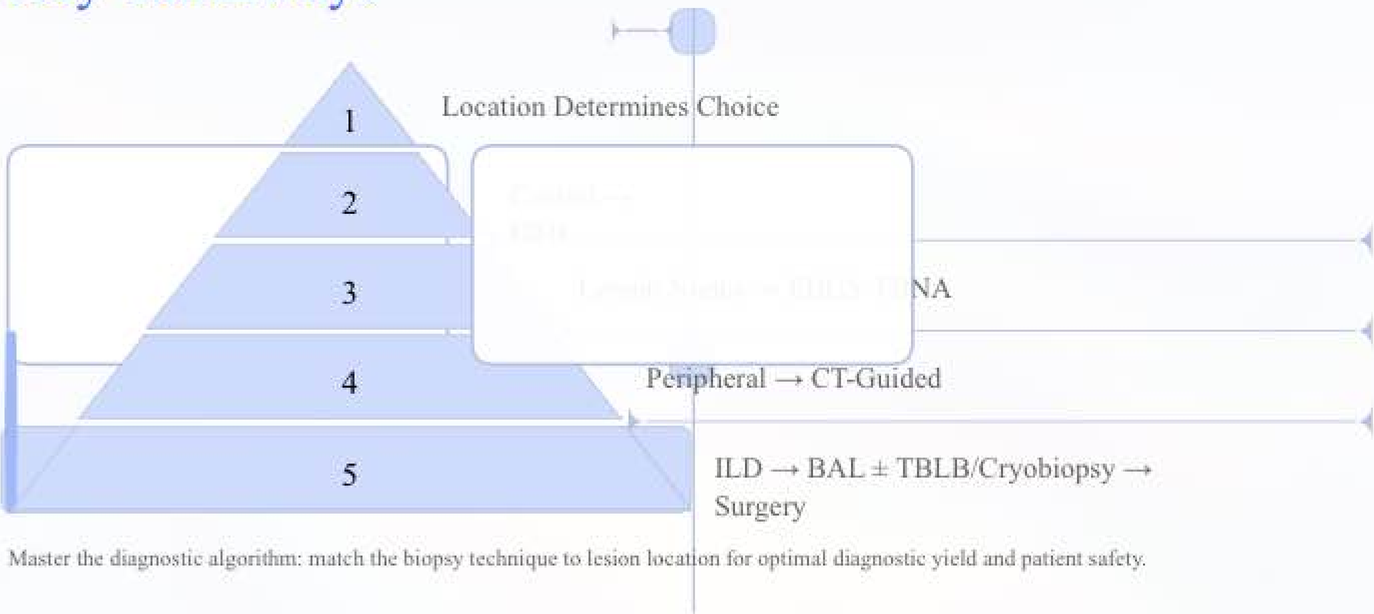
- Alveolar hemorrhage
- Pulmonary alveolar proteinosis (PAP)
- Cellular analysis in ILD

Not Useful For:

Solid tumor diagnosis - tissue biopsy required for malignancy assessment

Key Takeaways



Master the diagnostic algorithm: match the biopsy technique to lesion location for optimal diagnostic yield and patient safety.