Pulmonary Function Testing – A Case Based Approach

Nitin Bhatt MD
Karen Wood MD
Pulmonary/Critical Care Medicine

Interpretation

• Is test acceptable and reproducible?
• Look at flow volume loop
• Examine FEV₁/FVC ratio
• Look at FVC
• If obstruction – is there a post-bronchodilator response
• Classify severity
• Look at lung volumes (specifically TLC)
• Examine DLCO

Patterns of Disease

• Obstructive Pattern
  • Decreased FEV₁/FVC ratio
  • Asthma, COPD/Emphysema, CF, Bronchiectasis

Respirology (2005) 10, S1-S19
**Patterns of Disease**

- **Restrictive Pattern**
  - FEV<sub>1</sub>/FVC ratio preserved but values decreased
  - Parenchymal disease
    - Idiopathic pulmonary fibrosis (IPF),
    - Pneumoconiosis
    - Interstitial lung diseases
  - Restrictive bellows
    - Neuromuscular disease (ALS, MD)
    - Chest wall abnormalities (obesity, kyphoscoliosis)

**Bronchodiilator Challenge**

- Assess lung function at baseline
- Administer bronchodilator through a spacer
- Re-assess lung function after 15 min
- Positive bronchodilator response
  - An increase in FEV<sub>1</sub> and/or FVC by 12% of control and by > 200 mL
  - In the lack of a bronchodilator response in the laboratory does not preclude a clinical response to bronchodilator therapy

**Flow Volume Loop**

- Early glottic closure
- Variable effort Cough
- Normal
- Obstructive
- Restrictive

**Bronchodilator Challenge Diagram**

- Examine FEV<sub>1</sub>/FVC ratio
- Obstruction or LLN
- Examine FVC nl
- Possible restriction - perform lung volumes
- TLC nl
- Restriction
- Post bronchodilator
  - FEV<sub>1</sub> and FVC nl
  - Asthma
  - COPD
  - Emphysema
  - Chronic bronchitis

**Flow Volume Loop Diagram**

- Normal
- Obstructive
- Restrictive
Case 1

- 31 y/o female with 3 ½ month history of cough usually non-productive. Associated wheezing and mild dyspnea. Started after a viral illness.
- No PMH, ROS negative.
- Lungs – scattered bilateral expiratory wheezes.
- CXR - negative

Obstruction with bronchodilator response

- Started on inhaled corticosteroid, as needed B2 agonist, and given peak flow meter.
- Return in 3 weeks revealed cough has almost totally resolved, peak flow has increased from 460 to 600.
- Dx – asthma

Case 2

59 yr old male

Obstruction with bronchodilator response

- Started on inhaled corticosteroid, as needed B2 agonist, and given peak flow meter.
- Return in 3 weeks revealed cough has almost totally resolved, peak flow has increased from 460 to 600.
- Dx – asthma
Interpretative strategies for lung function tests. SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING" Eur Respir J 2005

**TABLE 6** Severity of any spirometric abnormality based on the forced expiratory volume in one second (FEV1)

<table>
<thead>
<tr>
<th>Degree of severity</th>
<th>FEV1 % pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>&gt;70</td>
</tr>
<tr>
<td>Moderate</td>
<td>60-69</td>
</tr>
<tr>
<td>Moderately severe</td>
<td>50-69</td>
</tr>
<tr>
<td>Severe</td>
<td>40-49</td>
</tr>
<tr>
<td>Very severe</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>

% pred: % predicted

Interpretative strategies for lung function tests. SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING" Eur Respir J 2005
Dx - Severe oxygen-dependent chronic obstructive pulmonary disease

• Reduced FEV1 and FVC suggest restriction by spirometry
• No evidence of restriction by lung volumes.
• Low FVC – pseudorestriction
• If use SVC then the FEV1/VC ratio is 48%.

Case 4

What’s normal?

- Reference Populations
  - Comparable to the patient population with regards to:
    - Age
    - Height
    - Gender
    - Ethnicity
  - Spirometric reference values
    - Developed from National Health and Nutrition Examination Survey (NHANES III)
    - 7,429 asymptomatic, lifelong nonsmoking subjects
    - Included Caucasians, African-Americans, and Hispanic-Americans

- FEV1/FVC is inversely proportional to age and height.
Case 5

- 58 yo AAM smoker with cough
- 40PY tob history
- Yearly history and physical exam—c/o mild dyspnea

Lung Age

Lung Age calculation formula developed by Morris and Temple 

Men
- Long age=2.67+height (in inches)-[1.25×(systolic BP in mm Hg)] - 10.2

Women
- Long age=2.67+height (in inches)-[1.25×(systolic BP in mm Hg)] - 77.68

54 yo WM with cough
- Ht 71in, wt, 215 lbs
- BMI=30
- Hgb=14.3
- No tobacco hx
- Works as a welder, machinist in auto parts assembly
• No evidence of obstruction by spirometry
• Restriction by lung volumes
• Low diffusing capacity
• Some desaturation with 6 minute walk
• Chest CT: pulmonary fibrosis

Lung transplant in 2004.

**Case 7**

**Lung Volumes: Gas Dilution**

- Helium Dilution
  - Inert tracer gas (He) of known initial concentration contained in a circuit of known volume (C1V1)
  - Diluted by an unknown volume of gas from an additional source (patient)
  - Produced CO2 removed from system and absorbed oxygen replaced
  - Measure the new steady-state helium concentration (C2)
  - \( C_2 V_1 = C_1 V_2 \)

**2/23/06**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FRED</th>
<th>ACTUAL</th>
<th>FRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced Vital Capacity (FVC)</td>
<td>3.30</td>
<td>2.50</td>
<td>71*</td>
</tr>
<tr>
<td>Forced Exp. Vol. 1 (FEV1)</td>
<td>2.52</td>
<td>1.43</td>
<td>57*</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>59.04</td>
<td>39.8</td>
<td>15*</td>
</tr>
<tr>
<td>Peak Flow (FIF)</td>
<td>2.50</td>
<td>.42</td>
<td>15*</td>
</tr>
</tbody>
</table>

**5/03/06**

<table>
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<tbody>
<tr>
<td>Forced Vital Capacity (FVC)</td>
<td>3.30</td>
<td>2.41</td>
<td>71*</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>59.04</td>
<td>44.0</td>
<td>71*</td>
</tr>
<tr>
<td>Peak Flow (FIF)</td>
<td>3.58</td>
<td>.83</td>
<td>27*</td>
</tr>
<tr>
<td>Total Lung Capacity (TLC)</td>
<td>5.99</td>
<td>47*</td>
<td></td>
</tr>
</tbody>
</table>

**PULMONARY REFERENCE: Levitsky, 2007**
Lung Volumes

- Limitation of gas dilution
- Assumes all areas of lung equally ventilated
- Underestimates lung volumes in obstructive disease
- Communicating gas volumes
- Leaks

Lung Volumes: Body Plethysmography

- Based on Boyle’s Law: $P_1V_1 = P_2V_2$
- Patient seated within a body box and breathes through a mouthpiece to outside atmosphere via a shutter
- Body box is a closed system and with inspiratory and expiratory efforts
- Pressure changes within the lung, measured at the mouth
- Resulting changes in the lung volume (thoracic gas volume)
- Changes in the lung volume result in opposite changes in the body box system pressure

Case 8

<table>
<thead>
<tr>
<th>Test Date: 08-01-2009</th>
<th>Sex: F</th>
<th>Age: 63.5 yrs</th>
<th>BMI: 30.1</th>
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<tbody>
<tr>
<td>Height: 5’11”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight: 190.5 lbs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary Function:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forced Vital Capacity (FVC):</td>
<td>3.46</td>
<td>0.44</td>
<td>1L</td>
</tr>
<tr>
<td>Forced Exp. Vol. 1 (FEV1):</td>
<td>2.36</td>
<td>0.45</td>
<td>1L</td>
</tr>
<tr>
<td>Residual volume (RV):</td>
<td>3.46</td>
<td>0.44</td>
<td>1L</td>
</tr>
<tr>
<td>Total Lung Capacity (TLC):</td>
<td>5.70</td>
<td>0.53</td>
<td>1L</td>
</tr>
<tr>
<td>Vital Capacity (VC):</td>
<td>2.36</td>
<td>0.45</td>
<td>1L</td>
</tr>
<tr>
<td>DLCO:</td>
<td>34.8</td>
<td>40.1</td>
<td></td>
</tr>
<tr>
<td>PFTS:</td>
<td>Severe restriction</td>
<td>Reduced DLCO</td>
<td></td>
</tr>
<tr>
<td>Dx:</td>
<td>Kyphoscoliosis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case 9

- 76yo WM with progressive SOB and cough
- 50PY tob hx
- Mild obstruction by spirometry
- Mild restriction by lung volumes
- Severely reduced DLCO
- Increased ERV

Case 10

- Mixed obstruction and restriction pattern
- Decreased DLCO
- Dx: emphysema + pulmonary fibrosis

Case 11

- 24yo WM admitted with SOB/DOE, wheezing, inspiratory stridor
- No PMHx, medications
- PSHx sig for exp lap 6 months prior after MVA
- 2 PY Tob hx, occ EtOH
- Dx with asthma but no improvement with meds
- Normal spirometry
- Decreased peak flow
- Consistent with asthma
- No obstruction
- Tech notes: Patient with stridor during spirometry

Case 12:

Fixed airway obstruction
Post-intubation tracheal stenosis/stricture

46 F with recent dx of asthma
Calibrate Machine

- Frequent checks with 3 liter syringe
- Biological control – no more than 5% variation in FVC and FEV1 per week.

**TABLE 2** Activities that should preferably be avoided prior to lung function testing

<table>
<thead>
<tr>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking within at least 1 h of testing</td>
</tr>
<tr>
<td>Consuming alcohol within 4 h of testing</td>
</tr>
<tr>
<td>Performing vigorous exercise within 30 min of testing</td>
</tr>
<tr>
<td>Wearing clothing that substantially restricts full chest and abdominal expansion</td>
</tr>
<tr>
<td>Eating a large meal within 2 h of testing</td>
</tr>
</tbody>
</table>

- No use of short acting bronchodilators for 4 hours prior to testing.
- Long acting β agonists or aminophylline should be held for 12 hours.
Case 13

- 26yo AAF with progressive SOB/DOE
- Ht 61 in, wt 100 lbs
- BMI=19
- Hgb=11.3
- 7 PY tob hx

Echocardiogram:
- The right ventricular systolic pressure is calculated at 49 mmHg. There is evidence of moderate pulmonary
- Right Ventricle: The right ventricle is slightly dilated. The right ventricular global systolic function is mildly reduced.

Diffusing Capacity

- Normal spirometry
- Normal lung volumes
- Low diffusing capacity
- Significant desaturation with normal walk distance
- DDx:
  - Pulm HTN
  - Early ILD

- Capacity of the lungs to exchange gas across the alveolar-capillary interface
- Most common technique based on CO uptake
- Function of
  - Flow delivery of CO to alveoli
  - Mixing and diffusion of CO to airways and alveoli
  - Transfer of CO across gas/liquid interface
  - Mixing and diffusion of CO in the lung parenchyma/capillary plasma
  - Diffusion across RBC membrane
  - Chemical reaction with Hgb
### Case 15

- **Age:** 26 yrs
- **Gender:** WF
- **PMHx:** Cystinosis

<table>
<thead>
<tr>
<th>Test Date: 10-30-2009</th>
<th>Age (yrs): 26</th>
<th>Height: 5'10&quot;</th>
<th>Weight: 175 lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Weights: 35 lbs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI: 25.3 kg/m²</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PFTs:**
- **Restriction**
- **Reduced DLCO but normal when adjusted for lung volumes**
- **No desaturation when walking**
- **Reduced maximum inspiratory pressure**

**DIAGNOSIS:** Dyspnea secondary to muscle weakness

### Case 16

- **Age:** 26 yrs
- **Gender:** WF
- **PMHx:** Cystinosis

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**PFTs:**
- **Restriction**
- **Reduced DLCO but normal when adjusted for lung volumes**
- **No desaturation when walking**
- **Reduced maximum inspiratory pressure**

**DIAGNOSIS:** Dyspnea secondary to muscle weakness
Case 17

55yo WM with long standing asthma

- PFTS:
  - Obstruction by spirometry
  - Increased RV c/w air trapping
  - Increased DLCO
- Asthma
- Obesity
- Polycythemia, cardiac shunts, alveolar hemorrhage

**PFTS:**

<table>
<thead>
<tr>
<th>Test Date: 02-23-2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left: 72,40,60</td>
</tr>
<tr>
<td>Right: 72,40,60</td>
</tr>
<tr>
<td>Age: 55</td>
</tr>
<tr>
<td>Height: 170</td>
</tr>
<tr>
<td>Weight: 170</td>
</tr>
<tr>
<td>FEV1: 130</td>
</tr>
<tr>
<td>FVC: 100</td>
</tr>
<tr>
<td>FEV1/FVC: 1.25</td>
</tr>
<tr>
<td>FEV1%: 90</td>
</tr>
<tr>
<td>FVC%: 75</td>
</tr>
<tr>
<td>DLCO: 47</td>
</tr>
</tbody>
</table>

**Hematology:**

- RBC: 4.8
- Hgb: 12.6
- WBC: 5.2
- Platelets: 150,000

**Chemistry:**

- Na: 138
- K: 4.5
- Ca: 9.5
- Mg: 2.2
- Cl: 99.5
- BUN: 20
- Creatinine: 1.2
- SGOT: 39
- SGPT: 30
- Alkaline Phosphatase: 45

**Hx:**

- 55yo WM with long standing asthma
- Obesity
- Polycythemia, cardiac shunts, alveolar hemorrhage

**Comorbidities:**

- Asthma
- Obesity
- Polycythemia, cardiac shunts, alveolar hemorrhage