Pulmonary Function Testing

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Lecture Overview

- General Introduction
- Indications and Uses
- Technical aspects
- Interpretation
- Patterns of Abnormalities
When to perform a PFT

1. Evaluation of a pulmonary complaint or sign to assess for any impairment in function
2. Quantification of a known impairment (whether part of initial eval. or follow up/assessing dz. progression)
3. Preoperative assessment
4. Disability evaluation
5. Screen people exposed to inhalational/toxic agents or drug effects
Caution

- Myocardial infarction within the last month
- Unstable Angina
- Recent Thoraco-abdominal surgery
- Recent ophthalmic surgery
- Thoracic or abdominal Aneurysm
- Current Pneumothorax

Wilde M, Nair S, Madden B. Pulmonary Function tests- a review. Care of the Crit Ill. 2007; Dec23(6): 173-7
PFT - Components

- Spirometry
- Bronchodilator challenge
- Lung Volumes
- DLCO
- Maximal Respiratory Pressures
- Maximal Voluntary Ventilation
- Bronchoprovocation
Lung Volumes
Volume -Time Spirogram

- Tidal volume respirations
- At end expiration pt. performs a maximal inspiration followed by
- Exhalation as hard and fast as possible
- Exhaling the FVC
- Volumes within ±5% or 50 ml; flows within ±5% or 200 ml/s
- Check accuracy & linearity daily with 3 L syringe
- Explain and demonstrate maneuver; proper patient position; repeat tests until 3 acceptable tests or patient has made 8 attempts
- Good quick start with vigorous effort; no cough or pause in first sec; 6 sec minimum or good plateau without glottic closure
- For 3 acceptable tests, difference between largest two FVC’s and largest two FEV1’s should be within 150 ml of each other
- Analyze largest FVC and FEV1 from acceptable tests & select appropriate reference values
- Use established guidelines for interpretation
General Approach to Interpreting a PFT

• Confirm demographic data
• Is the test Acceptable/Reproducible
• Are the results normal
• What is the pattern of abnormality
• What is the severity of abnormality
• What does this mean for the patient - comparison to previous tests
Pitfalls and Errors in Flow Volume Loops

- Flow Volume loop is useful in assessing acceptability of the maneuvers:
  1. Lack of early peak suggest poor effort.
  2. Sudden tailing off of expiratory limb / stopped blowing too early / early glottic closure.
  3. Cough

Source: emedicine.com
Variable Effort  Cough
Normal Values

- Appropriate Reference Standards must be used for comparison
- Based on Age, Height, Sex and Race
- In the US: NHANES III standard for adults
- Different adjustment factors for different values for Caucasian, African American, Asian, eastern Indian
- Should be updated at least every 10 years
Percent Predicted as Normal Range

• Results are expressed as % Predicted of a predicted normal value of a person the same age, sex, race and height

• Normal Ranges:
  - FVC >80%
  - FEV₁ >80%
  - FEV₁/FVC less than 5th percentile (LLN), >0.70
  - FEF 25-75: 65%; 50%
  - DLCO 80-120%
  - TLC 80-120%
  - RV 80-120%

• Use of LLN below 5th percentile of the normal distribution instead of %predicted
Patterns of Abnormality

- Obstructive pattern
- Restrictive pattern
- Mixed pattern
- Vascular pattern
- Neuromuscular pattern
- Poor effort pattern
- Non Specific Pattern
Obstructive Ventilatory Defect

- Limitation of expiratory flow
- The hallmark is a reduced FEV1/FVC ratio < 0.7
- FEF 25-75 < 50%

- Asthma
- COPD
- Cystic Fibrosis
- Bronchiectasis
The Flow Volume Loop

- The usual linear descent of the flow-volume curve is disrupted by an exaggerated upward concavity of the descending limb of the curve.
Bronchodilator Response

- Physiologic response involving airway epithelium, nerves, mediators and smooth muscle
- Bronchodilator to be held prior to testing
- Increase in either FEV1 or FVC from baseline
  - By at least 12% and 200 mL
- The correlation between bronchoconstriction and BD response is imperfect
### Spirometry

<table>
<thead>
<tr>
<th></th>
<th>PRED (BTPS)</th>
<th>PRE-RX</th>
<th>POST-RX</th>
<th>% CHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>3.83</td>
<td>2.98</td>
<td>3.21</td>
<td>8</td>
</tr>
<tr>
<td>FEV1</td>
<td>2.99</td>
<td>1.84</td>
<td>2.22</td>
<td>21</td>
</tr>
<tr>
<td>FEV1/FVC %</td>
<td>62</td>
<td>69</td>
<td>69</td>
<td>12</td>
</tr>
<tr>
<td>FEV6</td>
<td>3.77</td>
<td>2.67</td>
<td>3.06</td>
<td>15</td>
</tr>
<tr>
<td>FEV1/FEV6 %</td>
<td>79</td>
<td>89</td>
<td>89</td>
<td>5</td>
</tr>
<tr>
<td>FEF25-75% L/sec</td>
<td>2.25</td>
<td>0.76</td>
<td>1.27</td>
<td>68</td>
</tr>
<tr>
<td>FEF75-85% L/sec</td>
<td>0.15</td>
<td>0.26</td>
<td>0.26</td>
<td>76</td>
</tr>
<tr>
<td>FEF25% L/sec</td>
<td>5.67</td>
<td>5.32</td>
<td>6.59</td>
<td>116</td>
</tr>
<tr>
<td>FEF50% L/sec</td>
<td>3.82</td>
<td>1.20</td>
<td>1.82</td>
<td>48</td>
</tr>
<tr>
<td>FEF75% L/sec</td>
<td>1.21</td>
<td>0.21</td>
<td>0.42</td>
<td>35</td>
</tr>
</tbody>
</table>
Restrictive Ventilatory Defect

• The hallmark is reduced Lung volumes

• Reduced TLC by definition

• The flow volume loop often maintains a nearly normal shape though miniaturized.
### Spirometry

<table>
<thead>
<tr>
<th>Measurement</th>
<th>PRED</th>
<th>PRE-RX</th>
<th>POST-RX</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>3.04</td>
<td>2.19</td>
<td>72</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>2.35</td>
<td>1.84</td>
<td>78</td>
</tr>
<tr>
<td>FEV1/FVC %</td>
<td></td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>FEV6 (L)</td>
<td>2.93</td>
<td>2.19</td>
<td>75</td>
</tr>
<tr>
<td>FEV1/FEV6 %</td>
<td>81</td>
<td>84</td>
<td>104</td>
</tr>
<tr>
<td>FEF25-75% L/sec</td>
<td>2.23</td>
<td>3.83</td>
<td>172</td>
</tr>
<tr>
<td>FEF75-85% L/sec</td>
<td>0.27</td>
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<td></td>
</tr>
<tr>
<td>FEF25% L/sec</td>
<td>5.16</td>
<td>7.29</td>
<td>141</td>
</tr>
<tr>
<td>FEF50% L/sec</td>
<td>3.51</td>
<td>5.29</td>
<td>151</td>
</tr>
<tr>
<td>FEF75% L/sec</td>
<td>1.26</td>
<td>1.56</td>
<td>124</td>
</tr>
<tr>
<td>PEF (L/sec)</td>
<td>5.96</td>
<td>7.29</td>
<td>122</td>
</tr>
<tr>
<td>PFT100% Sec</td>
<td></td>
<td>6.40</td>
<td></td>
</tr>
<tr>
<td>FVC (L)</td>
<td></td>
<td>2.08</td>
<td></td>
</tr>
<tr>
<td>MVV (L/min)</td>
<td>94</td>
<td>92</td>
<td>98</td>
</tr>
<tr>
<td>PI max (cmH2O)</td>
<td>73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE max (cmH2O)</td>
<td>138</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Diffusion

<table>
<thead>
<tr>
<th>Measurement</th>
<th>PRED</th>
<th>PRE-RX</th>
<th>POST-RX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb: 11.7 g/dL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO Hb: 1.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLCO mL/mmHg/min</td>
<td>21.4</td>
<td>8.8</td>
<td>41</td>
</tr>
<tr>
<td>DL Adj mL/mmHg/min</td>
<td>21.4</td>
<td>9.5</td>
<td>44</td>
</tr>
<tr>
<td>DLCO/VA mL/mmHg/min</td>
<td>4.68</td>
<td>3.25</td>
<td>69</td>
</tr>
<tr>
<td>DLVA Adj mL/mmHg/min</td>
<td>4.68</td>
<td>3.51</td>
<td>75</td>
</tr>
<tr>
<td>VA (L)</td>
<td>4.57</td>
<td>2.72</td>
<td>59</td>
</tr>
<tr>
<td>IVC (L)</td>
<td>2.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Plethysmography

<table>
<thead>
<tr>
<th>Measurement</th>
<th>PRED</th>
<th>PRE-RX</th>
<th>POST-RX</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC (L)</td>
<td>4.57</td>
<td>3.23</td>
<td>71</td>
</tr>
<tr>
<td>VC (L)</td>
<td>3.04</td>
<td>2.25</td>
<td>74</td>
</tr>
<tr>
<td>IC (L)</td>
<td></td>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td>FRC PL (L)</td>
<td>2.58</td>
<td>1.83</td>
<td>71</td>
</tr>
<tr>
<td>Vi (L)</td>
<td>1.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERV (L)</td>
<td>0.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RV (L)</td>
<td>1.80</td>
<td>0.98</td>
<td>55</td>
</tr>
<tr>
<td>RV/TLC %</td>
<td>39</td>
<td>30</td>
<td>77</td>
</tr>
<tr>
<td>Raw (cmH2O/L/sec)</td>
<td>2.24</td>
<td>2.35</td>
<td>105</td>
</tr>
<tr>
<td>Raw f (BPM)</td>
<td></td>
<td>79</td>
<td></td>
</tr>
</tbody>
</table>
Normal vs. Obstructive vs. Restrictive
Mixed Obstructive and Restrictive Pattern

• Reduced FEV1/FVC ratio with a reduced TLC
• Could be two disease processes: Amiodarone Drug Toxicity in a patient with COPD...
• Sarcoidosis, Lymphangiomleiomatosis, cryptogenic organizing pneumonia, langerhans cell histiocytsis, respiratory bronchiolitis
Rating of Severity

• Based on statement/guidelines from the American Thoracic Society (ATS)- FEV1
• Obstructive Pattern - FEV1
• Restrictive Pattern – TLC (lung volumes)
  ✓ If lung volumes not obtained – FVC
<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>50–59</td>
</tr>
<tr>
<td>Severe</td>
<td>35–49</td>
</tr>
<tr>
<td>Very severe</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>

% pred: % predicted.
Isolated Reduction in Diffusion Capacity

- Single-breath DLCO measures the capacity of the lung to transfer gas

- Patient exhales to RV then rapidly inhales gas mixture with a minute amount of CO. After, 10 second breath-hold at TLC, the patient rapidly exhales & the exhaled gas is analyzed to measure the amount of CO transferred into the capillary blood during the maneuver
Causes of Decreased $D_L^\text{CO}$

- Anemia, high CO levels
- Obstructive Lung Disease
  - Emphysema
  - Cystic Fibrosis
- Parenchymal Lung Disease
  - Interstitial Lung Disease
  - Sarcoidosis
- Pulmonary Vascular Disease
  - Primary Pulmonary Hypertension
  - Acute and Chronic Pulmonary Thromboembolism
Neuromuscular Pattern

• Restrictive pattern with normal $D_LCO$
  
  Lung compliance (microatelectasis) greater loss of VC with chronic Muscle weakness

  Chest wall compliance (stiff ligaments, ankylosed joints, kyphoscoliosis)

• Change in FVC between upright and supine
  
  ✓ Normal fall - average 8%; upper limit 19%
  ✓ >20% fall suggests diaphragmatic paralysis

Measurement of MIP and MEP
Maximum Airway Pressures

- % predicted values are available, decreases with age, lower values in females
- Variability of around 24 cm H2O pressures in same day measurements
- Normal MIP good –ve predictive value
- MIP < 1/3 NL predicts hypercarbia
- MEP < 60 cmH2O predicts weak cough
- correlates poorly with severity of limb muscle weakness
Grippi MA et al Pulmonary function testing. In Fishman AP, ed Pulmonary Diseases and Disorders, 1988; 2nd ed, pp 2469-2521

**Maximum Voluntary Ventilation**
Maximal Voluntary Ventilation

• Originally called maximal breathing capacity
• The maximal volume of air that can be moved by voluntary effort in 1 minute
• Technique: breathe rapidly and deeply for 15 to 30 seconds, ventilatory volumes are recorded
MVV

• Heavily dependent on patient cooperation and effort
• Non specific: Loss of coordination of respiratory muscles, musculoskeletal disease of the chest wall, neurologic disease, and deconditioning from any chronic illness, as well as ventilatory defects decrease MVV
• It correlates well with subjective dyspnea
• Useful in evaluating exercise tolerance
• Has a prognostic value in preoperative evaluation
• It provides a measure of respiratory muscle endurance and ventilatory reserve
• MVV=FEV1 * 35-40
Non specific Airway Disease Pattern
Central and Upper Airway Obstruction

- Flow volume loops can provide information on upper airway obstruction
- Characteristics of the lesion
  - Location of the lesion: intrathoracic vs extrathoracic
  - Behavior of the lesion in rapid inspiration and rapid exhalation: fixed vs variable
Fixed Obstruction

- Tracheal stenosis/stricture
- Bilateral vocal cord paralysis
- Extrinsic compression

- Inspiration
- Expiration
- Fixed (intra- or extrathoracic)
Variable Extrathoracic Obstruction

- Vocal cord paralysis
- Goiter
- Tumor
Variable Intrathoracic Obstruction

- **Intrathoracic Obstruction**
- **Tracheomalacia**
- **Intratracheal tumor**

Thank You!

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