Comprehensive Pulmonary Function Testing

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- Data from testing helps to classify lung disease into 3 categories.
  - Obstructive disorders that typically reduce airflow
    - Examples: asthma, COPD (chronic bronchitis, emphysema), cystic fibrosis
  - Restrictive disorders that typically reduce total lung volumes
    - Examples: pulmonary fibrosis, sarcoidosis, scoliosis, obesity, and neuromuscular diseases
  - Pulmonary vascular diseases
    - Example: primary pulmonary hypertension

Use of Comprehensive Pulmonary Function Testing

- Comprehensive PFT – addition of lung volume measurements (LVM) and diffusing lung capacity (DLCO) to routine spirometry/PFT.
- Current comprehensive PFTs measure how much and how fast air can be moved into and out of the lungs; as well as the amount of air that remains in the lungs after forced exhalation.
- Measurements used to:
  - Evaluate signs and symptoms of lung disease.
  - Quantify the severity of lung disease.
  - Follow the course of a specific disease; quantify changes in pulmonary function over time.
  - Monitor therapeutic intervention.
  - Exclude certain disease processes from diagnostic consideration (upper airway obstruction).

Comprehensive Pulmonary Function Testing

- Age*
- Gender*
- Height*
- Weight
- Race*
- Disease
- Patient Technique

*Predicted normal values are adjusted for age, gender, height, and race. Values built into the software for the spirometer.

Factors That Affect Testing Results
Patient testing – current testing process

- **Routine Spirometry/PFT**
  - Begin test with 2-3 tidal breathing cycles.
  - Inhale rapidly and completely and immediately "blow" the air out fully – exhaling completely for at least 6 seconds, until plateau reached in volume-time graph.
  - Upon complete exhalation, patient to inhale rapidly and completely.
  - Repeat for 3 acceptable results.
  - Results reported: FVC, FEV1, FEV1/FVC, FEF25-75, PEFR

- **Lung Volume Measurements**
  - Begin relaxed tidal breathing, approximately 15-25 breathes per min.
  - Minibox will start the valve closure upon detection of minimal consistent tidal breaths necessary.
  - Continue tidal breathing until 6 successful measurements obtained with chamber system.
  - Instructed to take deep and complete inhalation, exhale small amount of air, then inhale again as deeply as possible.
  - Exhale slowly and completely
  - Results reported: TLC, RV, RV/TLC

- **Reactive Airway Assessment**
  - Administration SABA via valved spacer
  - Repeat basic PFT
  - Reactivity demonstrated: FEV1 or FVC >12% change and 250mL
  - Results reported: FVC, FEV1, FEV1/FVC, FEF25-75, PEFR and % change from Pre-BD testing

Key measurements reported:

- FVC: Forced Vital Capacity
- FEV1: Forced Expiratory Volume in 1 second
- FEV1/FVC: Ratio of FEV1 to FVC
- FEF25-75: Forced Expiratory Flow
- Flow Volume Loop
  - RV: Residual Volume
  - TLC: Total Lung Capacity
  - RV/TLC

(DLCO: Diffusing capacity of the lungs for carbon monoxide)

Terms used in result reporting

- **FVC**
  - Measures volume of air which can be exhaled with maximum force after maximal inspiration.
  - Exhalation must be at least six seconds long.
    - Normal lungs generally empty ≥ 80% of their volume within 6 seconds.
  - Is usually reduced in diseases that cause the lungs to be smaller.
  - Decrease in FVC can occur if lungs hyper-inflated due to air trapping, and increased residual volume.
  - Interpretation of results based upon % predicted
    - Normal: >79%
    - Mild restriction: 60-79%
    - Moderate restriction: 40-69%
    - Severe restriction: <40%

- **FEV1; FEV1/FVC**
  - Measures volume of air exhaled in first second under force after maximal inhalation.
  - Most widely used parameter to measure the mechanical properties of the lungs.
  - Reflects mechanical properties of the large and medium-sized airways.
  - FEV1 is reduced in obstructive and restrictive disorders.
  - Interpretation of results based upon % predicted
    - Normal: >79%
    - Mild: >70%
    - Moderate: 60-69%
    - Moderately severe: 50-59%
    - Severe: 35-49%
    - Very severe: <35%
  - In obstructive diseases, FEV1 is reduced while FVC is normal; reducing the FEV1/FVC ratio.
  - In restrictive disorders, the FEV1, FVC, and total lung capacity are all reduced, therefore FEV1/FVC ratio is normal or even elevated.
• Forced Expiratory Flow 25–75% (FEF\textsubscript{25–75})
  – The slope of the spirogram between the 25\textsuperscript{th} and the 75\textsuperscript{th} percentiles of an FVC maneuver
  – Reflects the status of the small airways
  – Highly dependent on FVC measurement and expiratory effort

**FEF 25–75**

• Residual Volume. The volume of air still remaining in the lungs after the most forcible expiration possible.
• Tidal Lung Capacity. The volume of gas contained in the lung after a full inhalation; total amount of air lungs can hold.
• Interpretation of results based upon % predicted.
  – Normal: 80–120%
  – Obstruction >120%
  – Restriction <80%
    • TLC:
      – <80 but >70 = mild restriction
      – <70 but >60 = moderate restriction
      – <60 = severe restriction
  – RV/TLC%. Normal = 20–35%

Residual Volume, Total Lung Capacity, RV/TLC

• The shape of the flow-volume loop can indicate the location of airflow limitation, such as the large upper airways or smaller distal airways.
• Normal vs. Obstructive vs. Restrictive

**Flow Volume Loop**

• Illustration of airflow while performing spirometry

**Lung Volumes/Capacities**

• 4 Volumes
  – TV: Tidal Volume
  – IRV: Inspiratory Reserve Volume
  – ERV: Expiratory Reserve Volume
  – RV: Residual Volume

• 4 Capacities
  – Sum of 2 or more lung volumes
    • IC: Inspiratory Capacity
    • FRC: Functional Residual Capacity
    • VC: Vital Capacity
    • TLC: Total Lung Capacity
• Illustration of air flow while performing LVMs

Performing Lung Volume Measurement. Volume/Time Curve

• DLCO — Diffusing capacity of the lungs for carbon monoxide; measures ability of lungs to transfer oxygen across alveolar-capillary membrane
  - Influenced by three key components:
    - The surface area of the lung with contact to diffusing alveoli
    - The thickness of the alveolar-capillary membrane
    - The volume of blood available in the capillary bed of the lung

• Causes of Low Diffusing Capacity
  - Lung diseases causing thickening of the alveolar-capillary membrane
    - Pulmonary fibrosis, Sarcoidosis
  - Lung diseases causing decreased surface area in the lungs
    - Emphysema, Lung cancer, Lung surgery
  - Pulmonary Vascular Disease
  - Anemia

• Causes of High Diffusing Capacity
  - Exercise
  - Asthma

  • Anticipate ability to perform the DLCO by summer 2017.

DLCO

• Obstructive
  - Spirometry
    - FVC decreased or nl
    - FEV1 decreased
    - FEV1/FVC decreased

  - Lung Volume Measurements
    - RV increased
    - TLC increased

• Restrictive
  - Spirometry
    - FVC decreased
    - FEV1 decreased
    - FEV1/FVC nl or increased

  - Lung Volume Measurements
    - All volumes/capacities reduced

Obstructive vs. Restrictive Respiratory Disorders
• 19YO with dx mild persistent asthma
• CompPFT ordered to assess for air trapping
• Plan: to d/c maintenance medication if LV NL

CompPFT 1

Interpretation of PFT 1

Due to significant air trapping and moderate hyperinflation, daily ICS/LABA continued.

• Newer patient – did not have access to prior PFTs
• 69 YO; dx mild intermittent asthma
• Reported use ICS/LABA – short courses for asthma exacerbations
• CompPFT ordered to assess for air trapping
  – To determine if AAP required change – for maintenance therapy

CompPFT 2

Interpretation of CompPFT 2

Mild obstruction with reversibility post BD. LVM – NL.
• No change made in AAP.
- 10 YO w/dx mild persistent asthma

- Reported improvement in symptoms after a maintenance ICS taken x 2mo.

- CompPFT ordered as routine spirometry was WNL in office – but results were slightly lower than prior tests
  - Assess for any significant air trapping
  - Possible change in AAP

CompPFT 3

- Hyperinflation noted. Patients AAP adjusted: daily maintenance therapy changed. ICS dose increased and patient advised to return in 3 months.

Interpretation of CompPFT 3

- 8 YO with moderate persistent asthma

- Reported improvement in overall symptom control at visit.

- CompPFT ordered to determine if daily ICS dosage could be decreased
  - Plan to decrease if LVM NL

CompPFT 4

- Hyperinflation noted from testing. Current AAP continued. ICS dose not reduced.

Interpretation of CompPFT 4
• 43 YO with mild intermittent asthma
• Office PFT NL but slight decline from previous studies
• CompPFT ordered to determine if maintenance therapy needed.

CompPFT 5

Test WNL.
• No evidence of obstruction or air trapping.
• No change in AAP; continued PRN use of SABA.

Interpretation of CompPFT 5

• 12YO with mild asthma
• PFT at office appt NL but slightly lower than previous studies
• AAP: Course of ICS/LABA for asthma exacerbations
• Plan to determine if AAP required change
  – If air trapping – routine maintenance ICS therapy

CompPFT 6

Small airway obstruction and significant air trapping. FEV1 reversibility demonstrated.
• AAP adjusted: ICS/LABA maintenance started.

Interpretation of CompPFT 6
• Comprehensive PFTs allow the assessment of values not obtainable through routine spirometry.
• Testing aids in determining normal airway functioning from obstructive, restrictive, and pulmonary vascular disorders.
• Results allow treatment plans to be tailored to each patient's needs.
• Testing is conveniently performed in the office setting.
• Results are available upon completion of testing. Patients are notified of their results by their physician.
• Video to follow with demonstration of Comprehensive PFT (pre-BD measurements).

Summary …