Pulmonary Function Tests

60 yo with progressive SOB

• FVC: 1.39 L (37%)
• FEV1: 0.54 L (19%)
• FEV1/FVC: 39%
• VC: 1.82 L (49%)
• TLC (PL): 7.42 L (122%)
• VA (He): 2.34 L
• DLCO: 40% of predicted

60 yo with progressive SOB

• Asthma
• Interstitial Pulmonary Fibrosis
• Emphysema
• Primary pulmonary hypertension
• Amyotrophic lateral sclerosis

PFT Interpretation

The interpretation of lung function tests involves two tasks:

1) the classification of the derived values with respect to a reference population and assessment of the reliability of the data; and

2) the integration of the obtained values into the diagnosis, therapy and prognosis for an individual patient.

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Pulmonary Function: Tests

• “Dynamic function”: obstructive defects
• “Static function”: restrictive defects
• Diffusion abnormalities (gas exchange)
Spirometry and Maximal Expiratory and Inspiratory Flow Volume Curves

- “Dynamic function”

Obstructive Ventilation: Expiratory

- Decrease in expiratory airflow (volume and/or rate of flow)
- FEV₁ decreased
- FVC normal or decreased
- FEV₁/FVC decreased*
- FEF₂₅-₇₅ decreased

*definition of obstructive defect
Types of Airflow Obstruction

- Bronchoconstriction
- Dynamic airway compression (FVC vs SVC). Emphysema: FVC < slow or inspiratory VC, and plethysmographic volumes greater than gas dilution volumes
- Upper Airway
- Small Airways
- "Mixed"

PFT Question #1

- FEV₁/FVC=obstructive ventilatory defect:
- Why is FEV₁ itself NOT diagnostic of an obstructive defect?
Upper Airway Obstruction

"Upper Airway" Obstruction

Lung Volumes

- "Static function"
- Gas Equilibration ("wash in" and "wash out")
- Body plethysmography

Gas Equilibration Lung Volumes

- "Wash in:" Helium (insoluble gas) breathed from a reservoir of known VOLUME and CONCENTRATION, thus diluting its concentration by the volume of the lungs
- $V_{FRC} = V_{Reservoir} \times \frac{Conc_{init} - Conc_{final}}{Conc_{final}}$
Gas Equilibration Lung Volumes

- "Wash out:” Lung gas (N2) washed out during breathing of 100% O2
- Initial N2 concentration known (atmospheric); volume and N2 concentration of expired gas measured
- \( V_{FRC} = V_{EXP} \times \text{conc}_{EXP} / 0.79 - \text{conc}_{ALV} \) (final)

Plethysmographic Lung Volumes

- \( P_1 V_1 = P_2 V_2 \) in a closed system at same temperature
- Lungs and airway closed system when occluded
- Panting at FRC: inhalation=decreased intrathoracic pressure, increased volume

Plethysmographic Lung Volumes

So, in inspiration:

\[ P_{FRC} V_{FRC} = (P_{FRC} - \Delta P) (V_{FRC} + \Delta V) \]

- \( V_{FRC} = \frac{V}{\Delta P} (P_{FRC} - \Delta P) \) where \( \Delta P \) is negligible c/w \( P_{FRC} \)
- \( V_{FRC} = \frac{\Delta V}{\Delta P} (P_{FRC}) \)
- \( \Delta P \) obtained from change in mouth pressure against occluded valve
- \( \Delta V \) obtained from change in pressure in the plethysmograph as air in the box is compressed by increase in lung volume
- \( P_{FRC} = \) alveolar pressure=atmospheric pressure with zero flow against occluded airway

PFT Question #2

- With airways disease/dysfunction (e.g., emphysema), if gas dilution is not complete, how will lung volume measurement be affected?

Measurement of Alveolar Volume (\( V_A \))

- \( V_{A_{pleth}} > V_{A_{He rebreathe}} > V_{A_{He single breath}} \)
- \( V_{A_{He rebreathe}} > V_{A_{single breath}} \) correlated with decreased FEV1/FVC, increased RV/TLC

Restrictive Ventilation

- A decrease in lung expansion
- FEV1 decreased
- FVC decreased
- FEV1/FVC normal or increased
- Total Lung Capacity (TLC) decreased*

* Definition of restrictive ventilatory defect
PFT Questions #3 and #4

Why is FVC itself NOT diagnostic of a restrictive ventilatory defect?
Why is VC itself not diagnostic of a restrictive ventilatory defect?

Types of Restrictive Defects

- Parenchymal removal/destruction
- Parenchymal infiltration
- Extrapulmonary deformity
- Reduced force generation

Restrictive patterns

- Diffuse parenchymal disease, thoracic cage restriction: symmetric decrease in TLC, VC, FRC, RV
- Neuromuscular weakness: IC mainly decreased; TLC and VC decreased and FRC and RV spared

Diffusing Capacity (Transfer Factor)

\[ DL_{CO} = \frac{CO \text{ rate of uptake (ml/min)}}{\Delta PCO (mmHg)} \]

- \( O_2 \) and CO combine with Hgb; therefore reflect properties of alveolar-capillary membrane, and its uptake therefore limited by resistance across this interface
- Soluble gases limited by pulmonary blood flow
- 2 major resistances therefore: membrane properties \((D_m)\), and "reactive" conductance (molecular conformation/rate of reaction properties of Hgb binding x pulmonary capillary blood volume \((V_c)\)).
**Diffusing Capacity for CO (DL\textsubscript{CO}):**

- DL\textsubscript{CO} (if “transfer factor”, TLCO) calculated as the product of the rate constant for CO uptake (also known as “permeability factor” and called \(k_{CO}\), the Krogh coefficient) and alveolar volume, divided by effective gas pressure (\(P_B-PH_20\)), expressed as units of conductance (eg, ml CO/min/mmHg);

- Thus, DL\textsubscript{CO} = \(\frac{k_{CO} \times VA}{P_B-PH_20}\).

- This assumes what the conductance would be if 100% of alveolar volume was filled with CO (that is the \(V_A\) component is the volume of distribution)

- Influenced by altitude since CO and O\textsubscript{2} in competition for Hgb; thus high altitude decreases PIO\textsubscript{2} and therefore increases DL\textsubscript{CO} (on the other hand, lower PO\textsubscript{2} gradient for transfer of oxygen

- Note that properties of CO uptake are different than those of oxygen (in fact, CO=diffusion limited, O\textsubscript{2} more perfusion limited)

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**Single breath Diffusing Capacity for CO (DL\textsubscript{CO} SB)**

- Inspirate 0.25% CO, 10% inert gas, 21%O\textsubscript{2}, balance N\textsubscript{2}

- Expire to RV; inhale rapidly to TLC; hold for remainder of 10 seconds of breath hold time (BHT)

- Expire; discard anatomic dead space gas; sample 500-1000 ml alveolar gas

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**Measured Diffusing Capacity**

- Increased in alveolar hemorrhage, erythrocytosis, obesity, asthma??, altitude?? (since CO and O\textsubscript{2} in competition, altitude decreases PIO\textsubscript{2} and increases DL\textsubscript{CO}; but less PO\textsubscript{2} gradient as well) supine, L-R shunt

- Decreased in emphysema (destruction and/or non-equilibration), ? restrictive disorders (all:why??), pulmonary vascular disorders, anemia, abnormal Hgb

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**Diffusing Capacity**

- Single breath (10 sec) vs steady state/rebreathe techniques: SB may UNDERESTIMATE true diffusing capacity in emphysema if it underestimates gas dilution \(V_A\) since DL\textsubscript{CO} = \(\frac{k_{CO} \times VA}{P_B-PH_20}\)

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**“Diffusion Capacity” vs Diffusion**

- Note that: decreased diffusing capacity/gas transfer abnormality can result from numerous abnormalities not having anything to do with diffusion block itself

- So when we say diffusion abnormality=cause of hypoxemia, we mean those abnormalities which involve some form of diffusion block, or other inability to transfer gas completely (eg, low PIO\textsubscript{2}+ increased circulatory time) so that insufficient transfer of alveolar PO\textsubscript{2} occur

- Low alveolar volume, low Hgb, may result in low diffusing capacity as measured by transfer of CO, and low O\textsubscript{2} content, but not low PaO\textsubscript{2}
DLCO Pearl

- Isolated DLCO decrease (normal spirometry and volumes): suspect pulmonary vascular disorder
- Or, interstitial disorder not yet, or no longer, affecting parenchymal volume
- Or, abnormality of Hgb (eg, anemia, carboxyHgb, methHgb)

Pre-operative Pulmonary Assessment: PFTs

- Complications: highest for thoracic and upper abdominal (ie, near the diaphragm)
- All having lung resection, orthopedic and lower abdominal with lung disease, or smoking
- Age>60 years

Postoperative Pulmonary Risks

- Spirometry: FEV, or FVC <70%, FEV/FVC<65%
- PaCO2>45 mmHg, DLCO<40% in COPD
- None contraindicate
- Lung resection: FEV, best for pulmonary reserve and post op complications; post op FEV, <30% predicted=increased long term mortality and immediate post op problems

PFT Summary

- Obstructive ventilatory defect: decreased FEV/FVC
- Restrictive ventilatory defect: decreased TLC
- Low DLCO: abnormal uptake of gas by Hgb across alveolar capillary membrane: Diffusion determinants= Gas gradient, solubility, hemoglobin, membrane thickness, surface area, alveolar volume, rate of circulatory flow
- Disorders with airway dysequilibrium (eg emphysema): single breath gas dilution will underestimate lung volumes (and ? DLCO)
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