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.

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?

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<th>Spirometry</th>
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Upper Airway Obstruction

![Pictograph of airflow and volume relationship with key markers: PEF, V_{max,25\%}, V_{max,50\%}, V_{max,75\%}, MIF_{50\%}.]
"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
- \( V_{\text{FRC}} = V_{\text{reservoir}} \times \frac{\text{Conc init} - \text{Conc final}}{\text{Conc final}} \)
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
• \( V_{FRC} = V_{EXP} \times \text{con}_{\text{EXP}} / .79 - \text{Conc ALV (final)} \)

Plethysmographic Lung Volumes

• \( P_1V_1 = P_2V_2 \) 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:

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

- \( V_{\text{FRC}} = \frac{\Delta V}{\Delta P} (P_{\text{FRC}} - \Delta P) \) where \( \Delta P \) is negligible c/w \( P_{\text{FRC}} \)
- \( V_{\text{FRC}} = \frac{\Delta V}{\Delta P} (P_{\text{FRC}}) \)

\( \Delta P \) 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

- \( P_{\text{FRC}} = \text{alveolar pressure} = \text{atmospheric pressure with zero flow against occluded airway} \)

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 ($V_A$)

$V_{A\text{ pleth}} > V_{A\text{ He rebreathe}} > V_{A\text{ He single breath}}$

$V_{A\text{ He rebreathe}} > V_{A\text{ single breath}}$ correlated with decreased FEV1/FVC, increased RV/TLC

Restrictive Ventilation

- A decrease in lung expansion
- FEV$_1$ decreased
- FVC decreased
- FEV$_1$/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 for CO (DL\textsubscript{CO})

- $DL_{CO} = \frac{CO \text{ rate of uptake (ml/min)}}{\Delta PCO (mmHg)}$
- O2 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 ($Dm$), and “reactive” conductance (molecular conformation/rate of reaction properties of Hgb binding x pulmonary capillary blood volume ($Vc$)).
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 \textit{kCO, the Krogh coefficient}) and alveolar volume, divided by effective gas pressure (PB-PH\textsubscript{20}), expressed as units of conductance (eg, ml CO/min/mmHg);  
- Thus, DLCO = (kcOxVA)/(Pb-PH\textsubscript{20}).  
- This assumes what the conductance would be if 100% of alveolar volume was filled with CO (that is the VA 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 DLCO (on the other hand, lower PO\textsubscript{2} gradient for transfer of oxygen)  
- \textit{Note that properties of CO uptake are different than those of oxygen (in fact, CO=diffusion limited, O\textsubscript{2} more perfusion limited)}

Diffusing Capacity for CO (DL\textsubscript{CO})

Determinants:  
Gas gradient, solubility,  
hemoglobin and rate of gas  
uptake by Hgb, membrane  
thickness, surface area, capillary  
blood volume
Single breath Diffusing Capacity for CO (DL_{CO\,SB})

- Inspirate 0.25% CO, 10% inert gas, 21%O2, balance N2
- 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

Measured Diffusing Capacity

- Increased in alveolar hemorrhage, erythrocytosis, obesity, asthma??, altitude?? (since CO and O2 in competition, altitude decreases PIO2 and increases DLCO; but less PO2 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
Diffusing Capacity

- Single breath (10 sec) vs steady state/rebreath techniques: SB may UNDERESTIMATE true diffusing capacity in emphysema if it underestimates gas dilution $V_A$ since $DLCO = \frac{(k_cO_xVA)}{(P_b-P_H20)}$

“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 PIO2+ increased circulatory time) so that insufficient transfer of alveolar PO2 occur
- Low alveolar volume, low Hgb, may result in low diffusing capacity as measured by transfer of CO, and low O2 content, but not low PaO2
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, orthopaedic and lower abdominal with lung disease, or smoking
- Age>60 years
Postoperative Pulmonary Risks

- Spirometry: FEV\textsubscript{1} or FVC <70%, FEV\textsubscript{1}/FVC<65%
- PaCO\textsubscript{2}>45 mmHg, DLCO<40% in COPD
- None contraindicate
- Lung resection: FEV\textsubscript{1} best for pulmonary reserve and post op complications; post op FEV\textsubscript{1} <30% predicted=increased long term mortality and immediate post op problems

PFT Summary

- Obstructive ventilatory defect: decreased FEV\textsubscript{1}/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)
Series “ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING” Edited by V. Brusasco, R. Crapo and G. Viegi. General considerations for lung function testing

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