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

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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60 yo with progressive SOB
- Asthma
- Interstitial Pulmonary Fibrosis
- Emphysema
- Primary pulmonary hypertension
- Amyotrophic lateral sclerosis

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:**

- Decrease in expiratory airflow (volume and/or rate of flow)
- FEV<sub>1</sub> decreased
- FVC normal or decreased
- FEV<sub>1</sub>/FVC decreased*
- FEF<sub>25-75</sub> 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

- FEV/FVC = obstructive ventilatory defect:
- Why is FEV itself NOT diagnostic of an obstructive defect?

Upper Airway Obstruction
**Upper Airway** Obstruction

**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
  - $V_{FRC} = V_{reservoir} \times \frac{\text{Conc INIT} - \text{Conc FINAL}}{\text{Conc FINAL}}$

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

**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
  - $V_{FRC} = V_{EXP} \times \text{conc EXP} \times 0.79 - \text{conc ALV (final)}$
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

Measurement of Alveolar Volume ($V_A$) in Emphysema

$V_A \text{ pleth} > V_A \text{ He rebreathe} > V_A \text{ He single breath}$

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

Plethysmographic Lung Volumes

So, in inspiration:

$P_{FRC}V_{FRC} = (P_{FRC} - \Delta P)(V_{FRC} \times \Delta V)$

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

$V_{FRC} = \frac{\Delta V}{\Delta P}$

$\Delta P$ 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

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 Question #2

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

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)

- DLCO = CO rate of uptake (ml/min)/ΔPCO (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 (DLCO) Determinants:
- Gas gradient, solubility, hemoglobin and rate of gas uptake by Hgb, membrane thickness, surface area, capillary blood volume

Diffusing Capacity for CO (DLCO)

| Parameter | Male | Female | Control | Test
|-----------|------|--------|---------|------
| DLCO (ml/min/mmHg) | 273 | 263 | 41 | 41
| DLCO/VA | 1.25 | 1.21 | 1.37 | 1.37
| DLCO/VA (predicted) | 5.40 | 5.34 | 5.00 | 5.00
| DLCO/VA (observed) | 1.30 | 1.26 | 1.40 | 1.40

New York Presbyterian Hospital
Cooperative Pulmonary Diagnostic Unit

Adult Pulmonary Diagnostic Unit

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Cooperative Pulmonary Diagnostic Unit

Adult Pulmonary Diagnostic Unit
Single breath Diffusing Capacity for CO (DLCO 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
- Expire; discard anatomic dead space gas; sample 500-1000 ml alveolar gas

“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 occurs
- Low alveolar volume, low Hgb, may result in low diffusion capacity as measured by transfer of CO, and low O2 content, but not low PaO2

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/rebreathe techniques: SB may UNDERESTIMATE true diffusing capacity in emphysema if it underestimates gas dilution $V_a$ since DLCO = ($kCoxVA$)/(PA-PH2O)
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 (e.g., anemia, carboxyHgb, methHgb)

PFT Summary

- Obstructive ventilatory defect: decreased FEV₁/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 (e.g., emphysema): single breath gas dilution will underestimate lung volumes (and DLCO)

Pre-operative Pulmonary Assessment: PFTs

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

Postoperative Pulmonary Risks

- Spirometry: FEV₁ or FVC < 70%, FEV₁/FVC < 65%
- PaCO₂ > 45 mmHg, DLCO < 40% in COPD
- None contraindicate
- Lung resection: FEV₁ best for pulmonary reserve and post op complications; post op FEV₁ < 30% predicted = increased long term mortality and immediate post op problems

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General considerations for lung function testing

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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{k}_\textit{CO}, 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 = \(\frac{\textit{k}_\textit{CO} \times \text{VA}}{\text{PB}-\text{PH}_{20}}\).
- 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).
- Note that properties of CO uptake are different than those of oxygen (in fact, CO=diffusion limited, O\textsubscript{2} more perfusion limited).