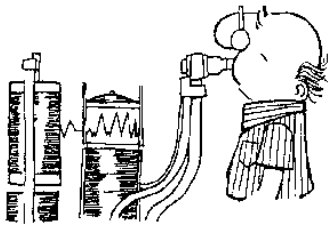
## Pulmonary Function Tests

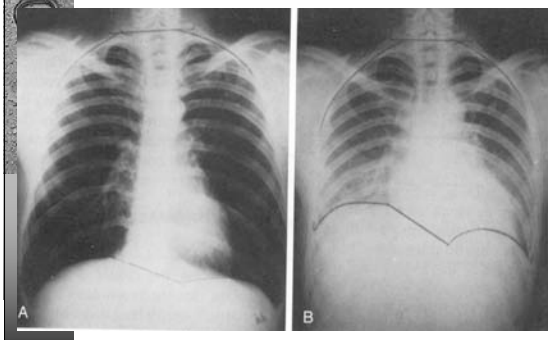


## PFT Interpretation

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. ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING'' Eur Respir J 2005; 26: 153–161

## Pulmonary Function: Tests

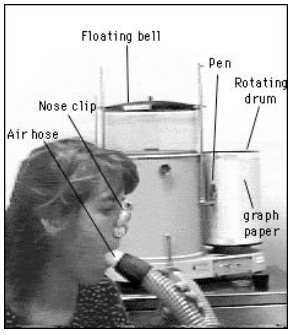
- "Dynamic function": obstructive defects
- "Static function": restrictive defects
- Diffusion abnormalities (gas exchange)

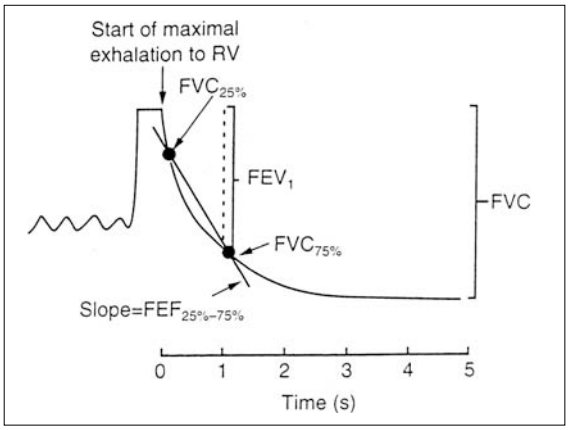


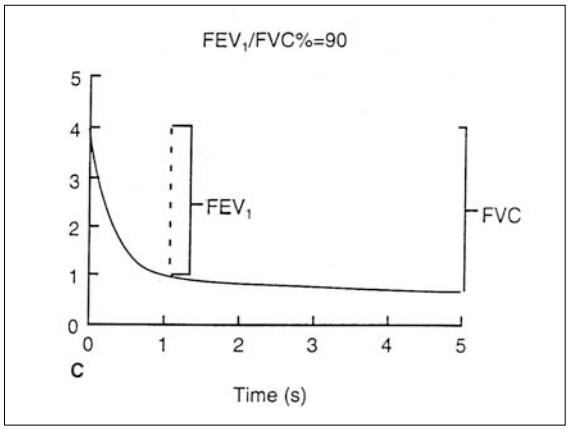

## Spirometry and Maximal Expiratory and Inspiratory Flow Volume Curves

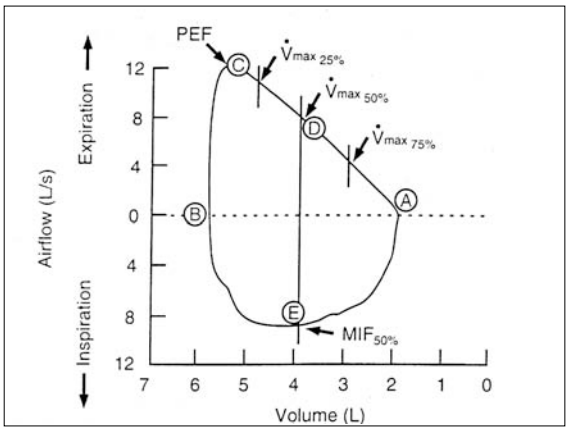
- "Dynamic function"

## Spirometry





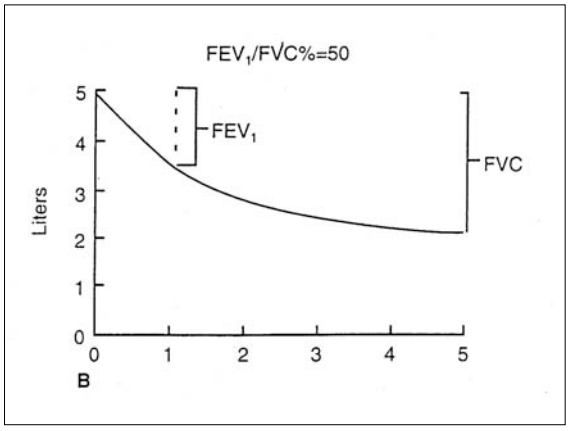

## Obstructive Ventilation: Expiratory

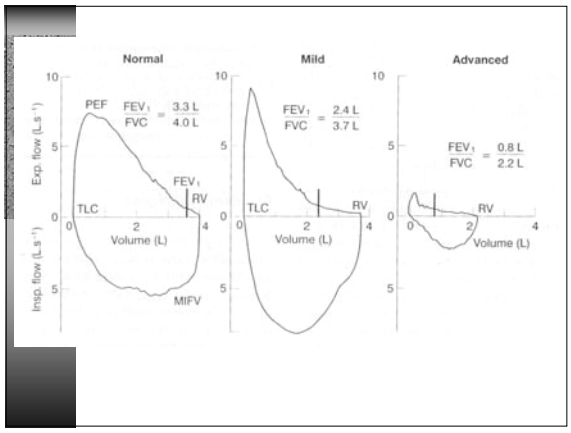
- Decrease in expiratory airflow (volume and/or rate of flow)
- $FEV_1$ decreased
- FVC normal or decreased
- $FEV_1/FVC$ decreased*
- $FEF_{25-75}$ decreased

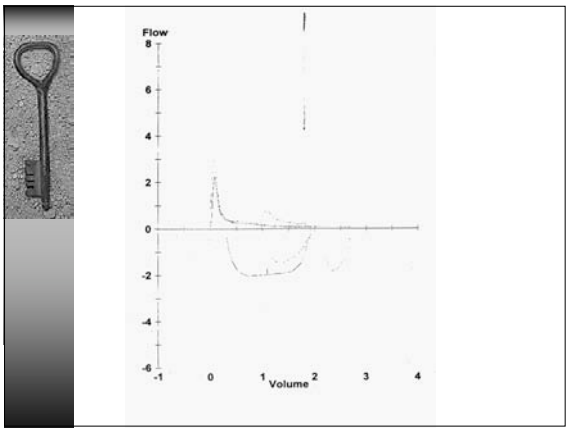
*definition of obstructive defect

## 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

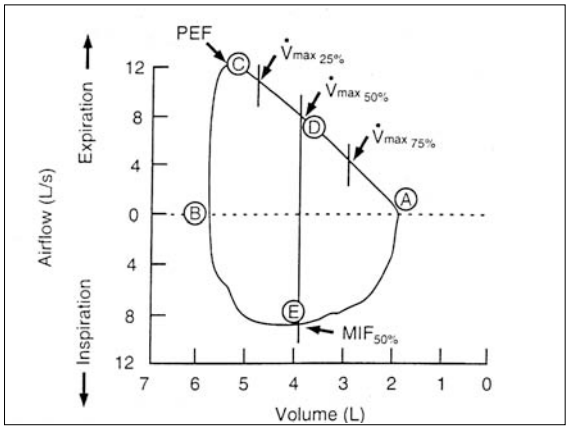
- FEV1/FVC=obstructive ventilatory defect:
- Why is FEV1 itself NOT diagnostic of an obstructive defect?

Patient: [redacted]
Age: 65 Gender: Male
Height(in): 70 (cm): 179
Weight(lb): 204 (kg): 92.5

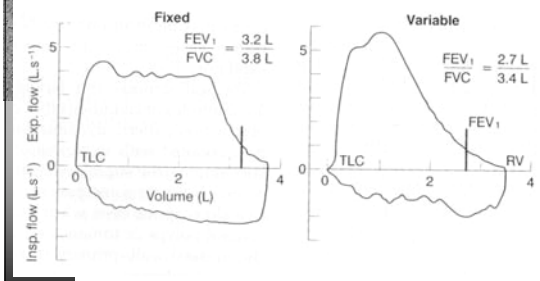
Id: [redacted]
Location: Out-Pt Date: [redacted]
Temp: 29 PBar: 7[redacted]
Physician: [redacted]
Technician: GD

| *Spirometry* | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 4.70 | 1.93 | 41 | 2.71 | 58 |
| FEV1 | Liters | 3.63 | 0.54 | 15 | 0.60 | 17 |
| FEV1/FVC | % | 77 | 28 | | 22 | |
| FEF25-75% | L/sec | 2.88 | 0.25 | 9 | 0.24 | 8 |
| FEF25% | L/sec | 7.80 | 0.27 | 3 | 0.29 | 4 |
| FEF50% | L/sec | 4.32 | 0.18 | 4 | 0.19 | 4 |
| FEF75% | L/sec | 1.57 | 0.10 | 6 | 0.09 | 6 |
| PEF | L/sec | 8.44 | 2.27 | 27 | 2.96 | 35 |
| MVV | L/min | 134 | | | 26 | 19 |
| PIF | L/sec | 3.67 | | | | |
| FIF50% | L/sec | 4.59 | | | | |
| FET100% | Sec | | 13.02 | | 19.70 | |
| *Lung Volumes* | | | | | | |
| VC | Liters | 4.49 | | | 2.85 | 63 |
| TLC | Liters | 6.59 | | | 8.66 | 132 |
| RV | Liters | 2.46 | | | 5.81 | 236 |
| RV/TLC | % | 39 | | | 67 | |
| FRC PL | Liters | 3.52 | | | 7.02 | 199 |
| FRC He | Liters | 3.52 | | | | |
| Vtg | Liters | | | | 6.94 | |

## Upper Airway Obstruction

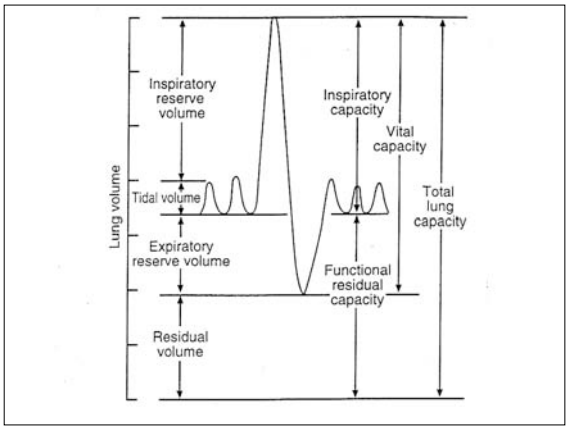


## "Upper Airway" Obstruction




## 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
- $V_{FRC} = V_{reservoir} \times$ Conc $_{INIT}$ – Conc $_{FINAL}$/ Conc $_{FINAL}$

## Gas Equilibration Lung Volumes

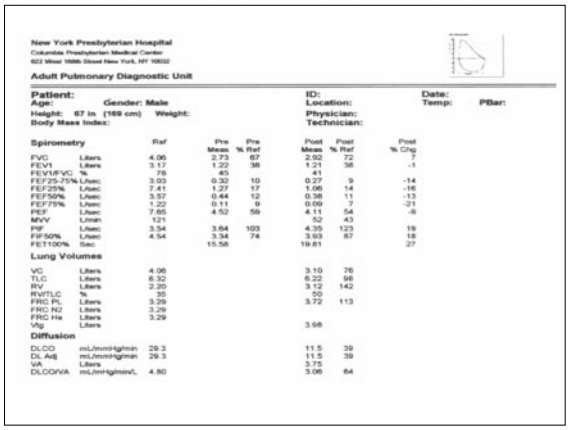
- "Wash out:" Lung gas (N2) washed out during breathing of 100% O2
- Initial N2 concentration known (atmospheric); volume and N2 concentration of expired gas measured
- $V_{FRC}=V_{EXP} \times$ conc $_{EXP}$/ .79- Conc ALV (final)

## 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

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



New York Presbyterian Hospital
Columbia Presbyterian Medical Center
622 West 168th Street New York, NY 10032

Adult Pulmonary Diagnostic Unit

Patient:
Age: Gender: Male
Height: 67 in (169 cm) Weight:
Body Mass Index:

ID:
Location:
Physician:
Technician:

Date:
Temp: PBar:

| Spirometry | | Ref | Pre Meas. | Pre % Ref | Post Meas. | Post % Ref | Post % Chg |
|---|---|---|---|---|---|---|---|
| FVC | Liters | 4.06 | 2.73 | 67 | 2.92 | 72 | 7 |
| FEV1 | Liters | 3.17 | 1.22 | 38 | 1.21 | 38 | -1 |
| FEV1/FVC | % | 78 | 45 | | 41 | | |
| FEF25-75% | L/sec | 3.03 | 0.32 | 10 | 0.27 | 9 | -14 |
| FEF25% | L/sec | 7.41 | 1.27 | 17 | 1.06 | 14 | -16 |
| FEF50% | L/sec | 3.57 | 0.44 | 12 | 0.38 | 11 | -13 |
| FEF75% | L/sec | 1.22 | 0.11 | 9 | 0.09 | 7 | -21 |
| PEF | L/sec | 7.65 | 4.52 | 59 | 4.11 | 54 | -9 |
| MVV | L/min | 121 | | | 52 | 43 | |
| PIF | L/sec | 3.54 | 3.64 | 103 | 4.35 | 123 | 19 |
| FIF50% | L/sec | 4.54 | 3.34 | 74 | 3.93 | 87 | 18 |
| FET100% | Sec | | 15.58 | | 19.81 | | 27 |
| **Lung Volumes** | | | | | | | |
| VC | Liters | 4.06 | | | 3.10 | 76 | |
| TLC | Liters | 6.32 | | | 6.22 | 98 | |
| RV | Liters | 2.20 | | | 3.12 | 142 | |
| RV/TLC | % | 35 | | | 50 | | |
| FRC PL | Liters | 3.29 | | | 3.72 | 113 | |
| FRC N2 | Liters | 3.29 | | | | | |
| FRC He | Liters | 3.29 | | | | | |
| Vtg | Liters | | | | 3.66 | | |
| **Diffusion** | | | | | | | |
| DLCO | mL/mmHg/min | 29.3 | | | 11.5 | 39 | |
| DL Adj | mL/mmHg/min | 29.3 | | | 11.5 | 39 | |
| VA | Liters | | | | 3.75 | | |
| DLCO/VA | mL/mmHg/mmVL | 4.80 | | | 3.06 | 64 | |

## PFT Question #2

- In airways disease (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?

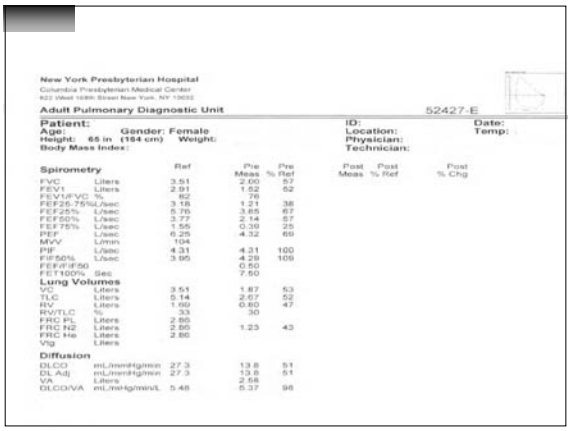
Why is VC itself not diagnostic of a restrictive ventilatory defect?

## 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



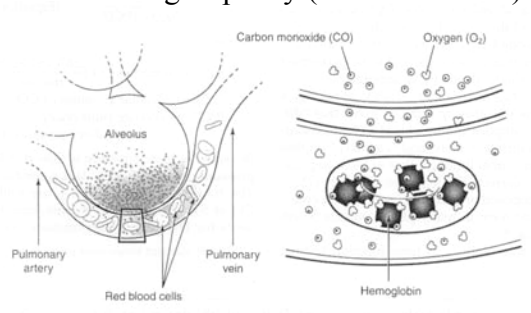
New York Presbyterian Hospital
Columbia Presbyterian Medical Center
622 West 168th Street New York, NY 10032

**Adult Pulmonary Diagnostic Unit** 52427-E

**Patient:** **ID:** **Date:**
**Age:** **Gender: Female** **Location:** **Temp:**
**Height: 65 in (164 cm)** **Weight:** **Physician:**
**Body Mass Index:** **Technician:**

| Spirometry | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref | Post % Chg |
|---|---|---|---|---|---|---|---|
| FVC | Liters | 3.51 | 2.00 | 57 | | | |
| FEV1 | Liters | 2.91 | 1.52 | 52 | | | |
| FEV1/FVC | % | 82 | 76 | | | | |
| FEF25-75% | L/sec | 3.18 | 1.21 | 38 | | | |
| FEF25% | L/sec | 5.76 | 3.85 | 67 | | | |
| FEF50% | L/sec | 3.77 | 2.14 | 57 | | | |
| FEF75% | L/sec | 1.55 | 0.39 | 25 | | | |
| PEF | L/sec | 6.25 | 4.32 | 69 | | | |
| MVV | L/min | 104 | | | | | |
| PIF | L/sec | 4.31 | 4.31 | 100 | | | |
| FIF50% | L/sec | 3.95 | 4.29 | 109 | | | |
| FEF/FIF50 | | | 0.50 | | | | |
| FET100% | Sec | | 7.50 | | | | |
| **Lung Volumes** | | | | | | | |
| VC | Liters | 3.51 | 1.87 | 53 | | | |
| TLC | Liters | 5.14 | 2.67 | 52 | | | |
| RV | Liters | 1.69 | 0.80 | 47 | | | |
| RV/TLC | % | 33 | 30 | | | | |
| FRC PL | Liters | 2.86 | | | | | |
| FRC N2 | Liters | 2.86 | 1.23 | 43 | | | |
| FRC He | Liters | 2.86 | | | | | |
| Vtg | Liters | | | | | | |
| **Diffusion** | | | | | | | |
| DLCO | mL/mmHg/min | 27.3 | 13.8 | 51 | | | |
| DL Adj | mL/mmHg/min | 27.3 | 13.8 | 51 | | | |
| VA | Liters | | 2.58 | | | | |
| DLCO/VA | mL/mHg/min/L | 5.48 | 5.37 | 98 | | | |

## Diffusing Capacity (Transfer Factor)




## Diffusing Capacity for CO ($DL_{CO}$)

- *$DL_{CO}$ = 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 (*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 ($DL_{CO}$)

- $DL_{CO}$ (if transfer factor, TLCO) calculated as the product of the rate constant for CO uptake (called **kCO, the Krogh coefficient)** and alveolar volume, divided by effective gas pressure (**PB-PH20)**, expressed as units of conductance (eg, ml CO/min/mmHg);
- Thus, DLCO **=(kc0xVA)/(Pb-PH20).**
- 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)

## Diffusing Capacity for CO ($DL_{CO}$)

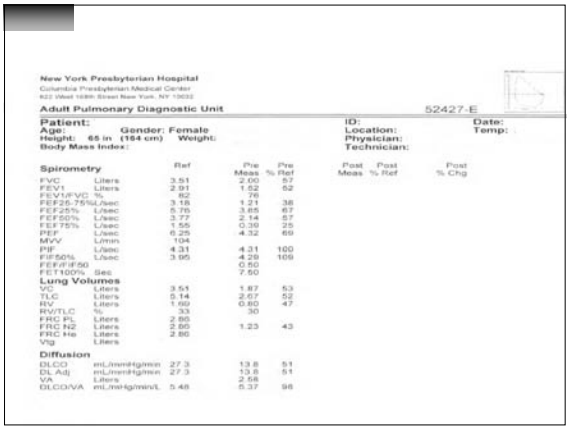
Diffusion determinants: Gas gradient, solubility, hemoglobin, membrane thickness, surface area

## SB Diffusing Capacity for CO ($DL_{CO}$)

- 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

## Diffusing Capacity

- Increased in alveolar hemorrhage, obesity, asthma??, altitude (since CO and O2 in competition, altitude decreases PIO2 and increases DLCO)
- Decreased in emphysema (destruction and/or non-equilibration), restrictive disorders (all:why??), pulmonary vascular disorders, anemia, abnormal Hgb
- 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)/(Pb-PH20



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Adult Pulmonary Diagnostic Unit 52427-E

Patient:
Age: Gender: Female
Height: 65 in (164 cm) Weight:
Body Mass Index:

ID:
Location:
Physician:
Technician:

Date:
Temp:

| Spirometry | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref | Post % Chg |
|---|---|---|---|---|---|---|---|
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| FEF25-75% | L/sec | 3.18 | 1.21 | 38 | | | |
| FEF25% | L/sec | 5.76 | 3.85 | 67 | | | |
| FEF50% | L/sec | 3.77 | 2.14 | 57 | | | |
| FEF75% | L/sec | 1.55 | 0.39 | 25 | | | |
| PEF | L/sec | 6.25 | 4.32 | 69 | | | |
| MVV | L/min | 104 | | | | | |
| PIF | L/sec | 4.31 | 4.31 | 100 | | | |
| FIF50% | L/sec | 3.95 | 4.29 | 109 | | | |
| FEF/FIF50 | | | 0.50 | | | | |
| FET100% | Sec | | 7.50 | | | | |
| **Lung Volumes** | | | | | | | |
| VC | Liters | 3.51 | 1.87 | 53 | | | |
| TLC | Liters | 5.14 | 2.67 | 52 | | | |
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| RV/TLC | % | 33 | 30 | | | | |
| FRC PL | Liters | 2.86 | | | | | |
| FRC N2 | Liters | 2.86 | 1.23 | 43 | | | |
| FRC He | Liters | 2.86 | | | | | |
| Vtg | Liters | | | | | | |
| **Diffusion** | | | | | | | |
| DLCO | mL/mmHg/min | 27.3 | 13.8 | 51 | | | |
| DL Adj | mL/mmHg/min | 27.3 | 13.8 | 51 | | | |
| VA | Liters | | 2.58 | | | | |
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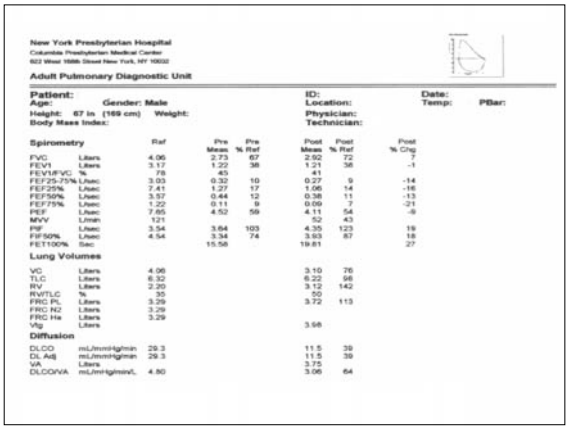

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Adult Pulmonary Diagnostic Unit

Patient:
Age: Gender: Male
Height: 67 in (169 cm) Weight:
Body Mass Index:

ID:
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Physician:
Technician:

Date:
Temp:
PBar:

| Spirometry | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref | Post % Chg |
|---|---|---|---|---|---|---|---|
| FVC | Liters | 4.06 | 2.73 | 67 | 2.92 | 72 | 7 |
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| FEF50% | L/sec | 3.57 | 0.44 | 12 | 0.38 | 11 | -13 |
| FEF75% | L/sec | 1.22 | 0.11 | 9 | 0.09 | 7 | -21 |
| PEF | L/sec | 7.85 | 4.52 | 58 | 4.11 | 54 | -9 |
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| FET100% | Sec | | 15.58 | | 19.81 | | 27 |
| **Lung Volumes** | | | | | | | |
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| TLC | Liters | 6.32 | | | 6.22 | 98 | |
| RV | Liters | 2.20 | | | 3.12 | 142 | |
| RV/TLC | % | 35 | | | 50 | | |
| FRC PL | Liters | 3.29 | | | 3.72 | 113 | |
| FRC N2 | Liters | 3.29 | | | | | |
| FRC He | Liters | 3.29 | | | | | |
| Vtg | Liters | | | | 3.98 | | |
| **Diffusion** | | | | | | | |
| DLCO | mL/mmHg/min | 29.3 | | | 11.5 | 39 | |
| DL Adj | mL/mmHg/min | 29.3 | | | 11.5 | 39 | |
| VA | Liters | | | | 3.75 | | |
| DLCO/VA | mL/mHg/min/L | 4.80 | | | 3.06 | 64 | |

## DLCO Pearl

- Isolated DLCO decrease: 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, orthopoedic and lower abdominal with lung disease, or smoking
- Age>60 years

## Pre-operative Pulmonary Assessment: PFTs

- Spirometry: $FEV_1$ or FVC <70%, $FEV_1$/FVC<65%
- PaCO2>45 mmHg, DLCO<40% in COPD
- None contraindicate
- Lung resection: $FEV_1$ best for pulmonary reserve and post op complications; post op $FEV_1$ <30% predicted=increased long term mortality and immediate post op problems

## PFT Summary

- Obstructive ventilatory defect: decreased $FEV_1$/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
- Disorders with airway dysequilibration (emphysema): 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

Eur Respir J 2005; 26: 153–161

“When you can’t breathe, nothing else matters.”