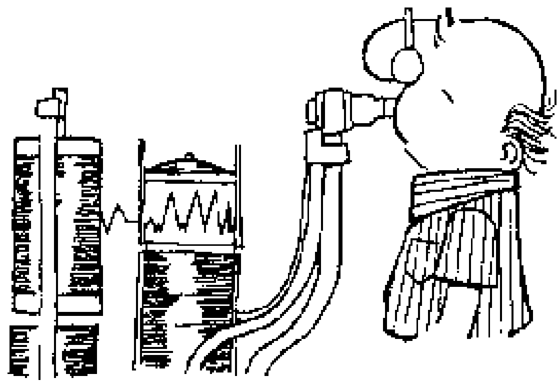
Pulmonary Function Tests



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

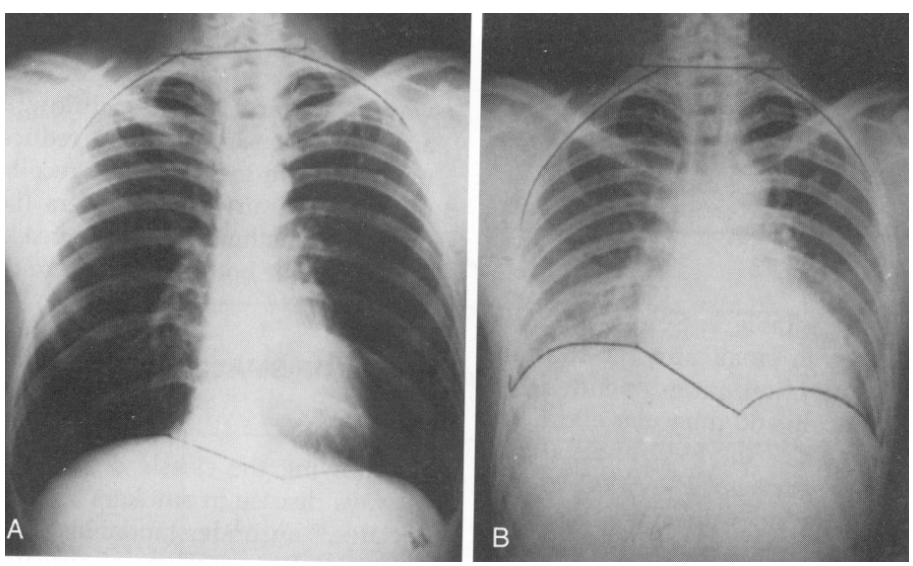
The interpretation of lung function tests involves two tasks:

1) the classification of the derived values with respect to a reference population and assessment of the reliability of the data; and
2) 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

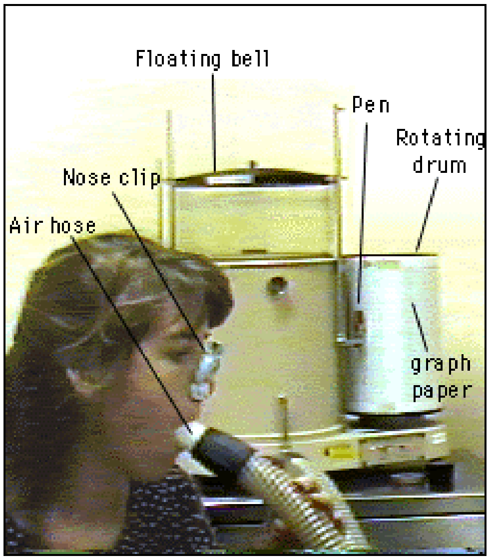
- “Dynamic function”: obstructive defects
- “Static function”: restrictive defects
- Diffusion abnormalities (gas exchange)

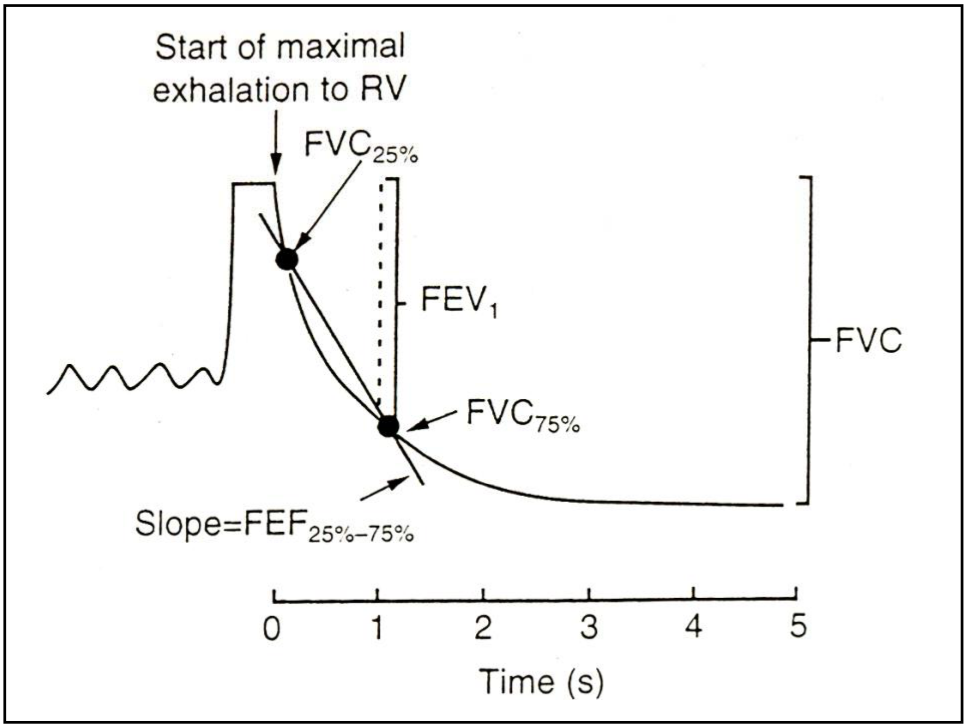


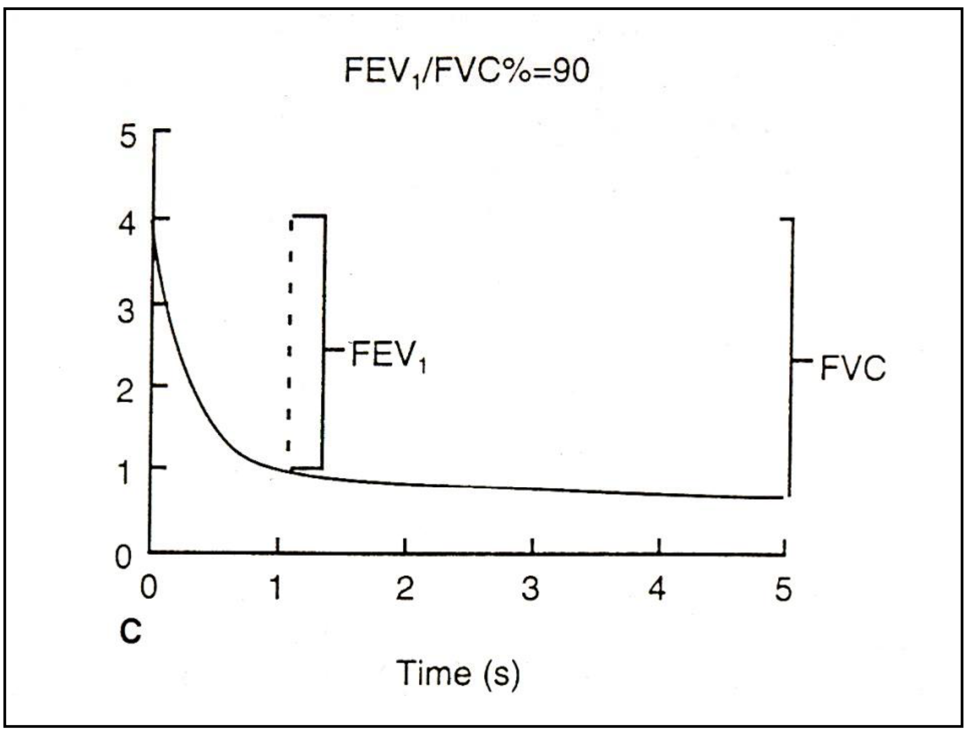
Spirometry and Maximal Expiratory and Inspiratory Flow Volume Curves

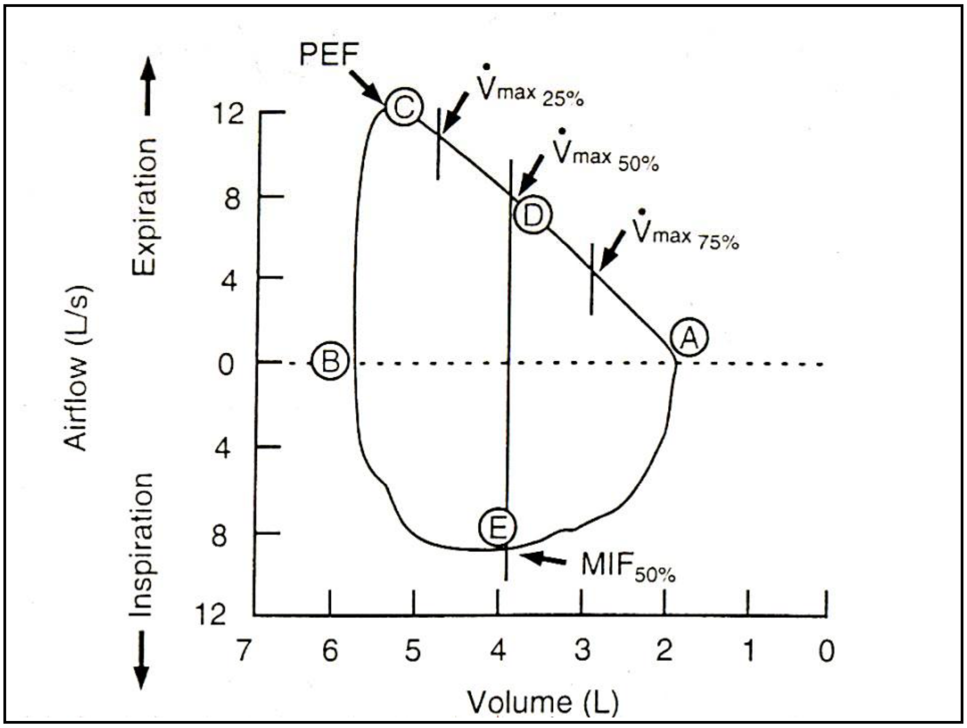
- "Dynamic function"

Spirometry




Start of maximal
exhalation to RV
FVC25%
FEV1
FVC
FVC75%
Slope=FEF25%–75%
0
1
2
3
4
5
Time (s)


FEV1/FVC%=90
5
4
3
2
1
0
FEV1
FVC
0
1
2
3
4
5
C
Time (s)



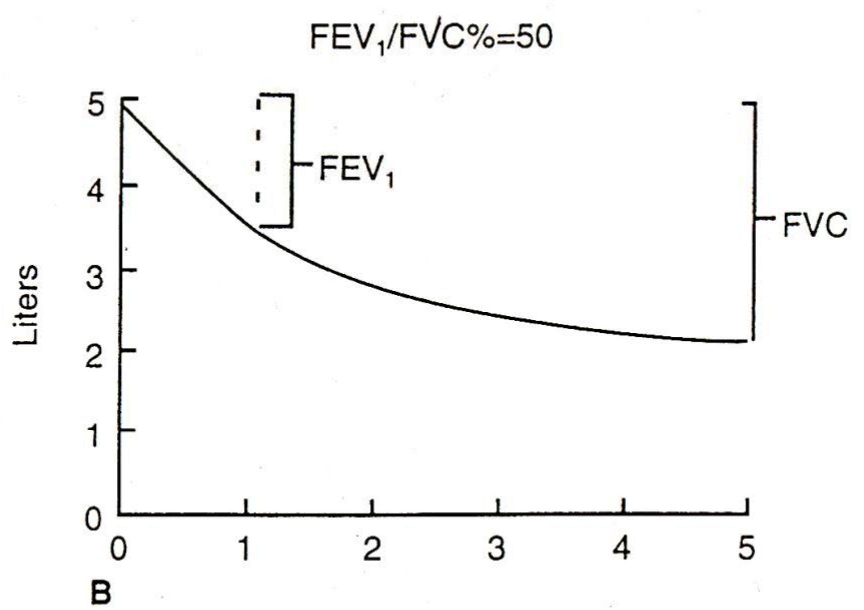
Obstructive Ventilation: Expiratory

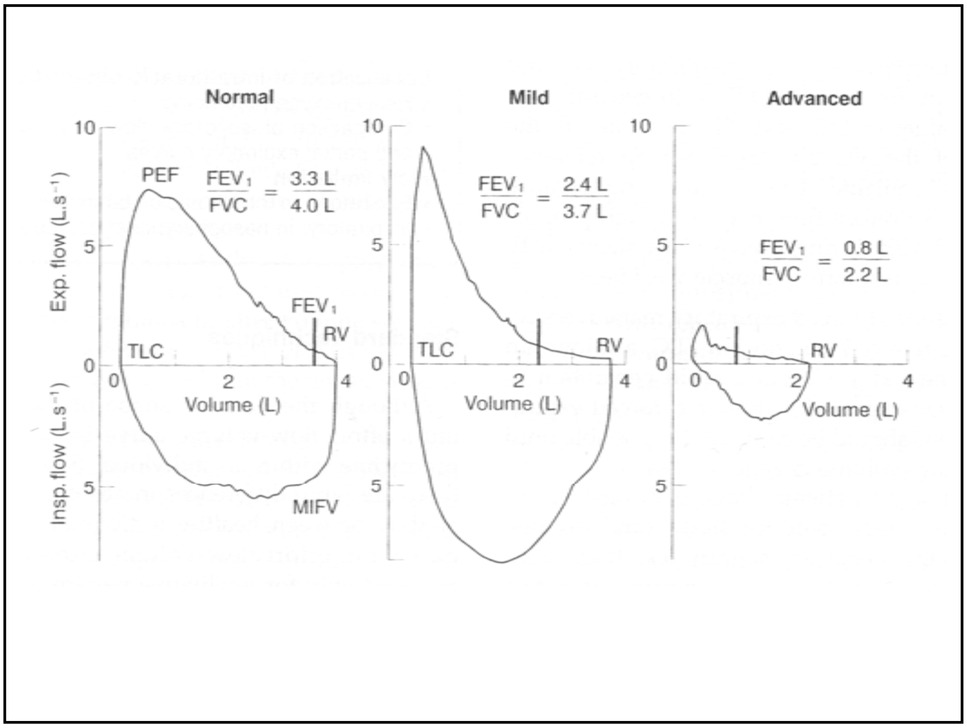
- Decrease in expiratory airflow (volume and/or rate of flow)
- FEV_1 decreased
- FVC normal or decreased
- FEV_1/FVC decreased*
- FEF_{25-75} decreased

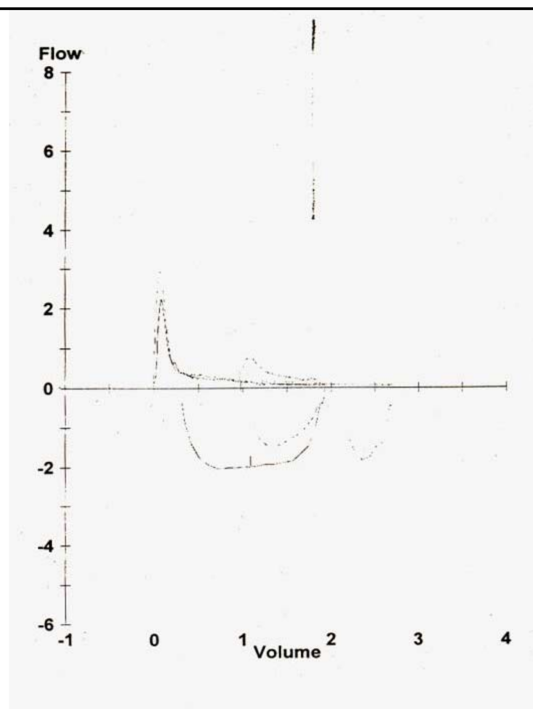
*definition of obstructive defect

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”




Normal
Mild
Advanced
PEF
FEV₁ / FVC = 3.3 L / 4.0 L
FEV₁ / FVC = 2.4 L / 3.7 L
FEV₁ / FVC = 0.8 L / 2.2 L
FEV₁
TLC
RV
MIFV
Exp. flow (L.s⁻¹)
Insp. flow (L.s⁻¹)
Volume (L)


Flow
Volume

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
Physician: [redacted]
Technician: GD

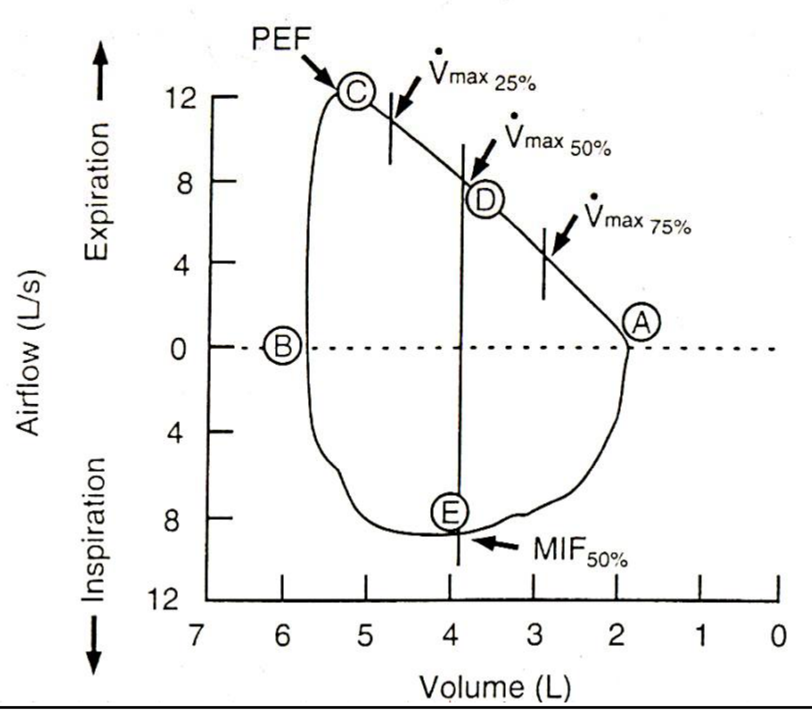
Spirometry

		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	

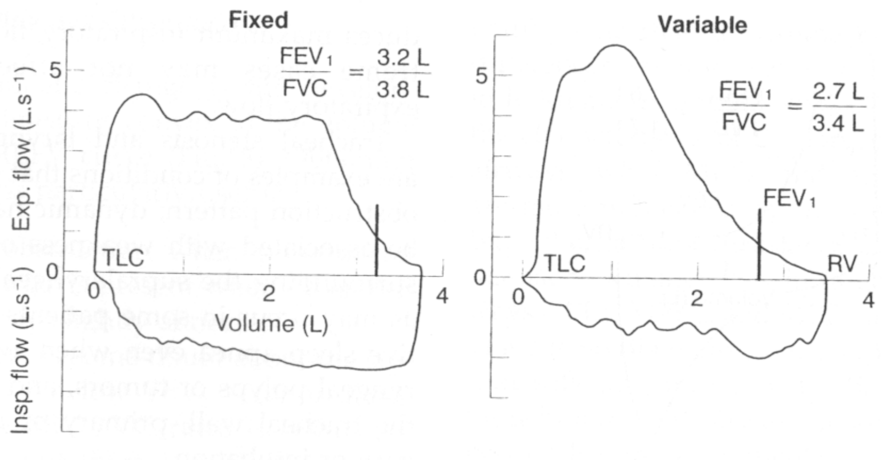
Lung Volumes

		Ref	Pre Meas	Pre % Ref	Post Meas	Post % Ref
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

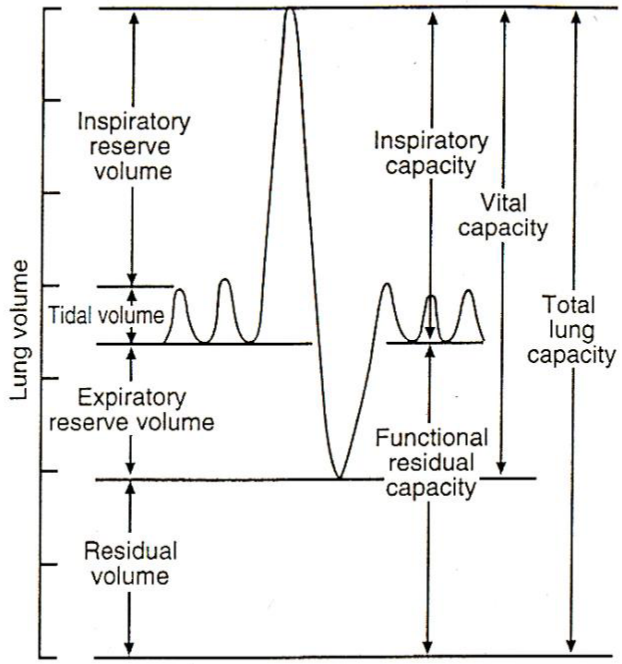


"Upper Airway" Obstruction



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
- $V_{FRC} = V_{reservoir}$ x

  Conc $_{INIT}$ – Conc $_{FINAL}$/ Conc $_{FINAL}$

Gas Equilibration Lung Volumes

- "Wash out:" Lung gas (N_2) washed out during breathing of 100% O_2
- Initial N_2 concentration known (atmospheric); volume and N_2 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

So, in inspiration:

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

- $V_{FRC} = V / \Delta P$ ($P_{FRC} - \Delta P$) where ΔP is negligible c/w P_{FRC}
- $V_{FRC} = \Delta V / \Delta P$ (P_{FRC})
- ΔP obtained from change in mouth pressure against occluded valve
- ΔV 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
- 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

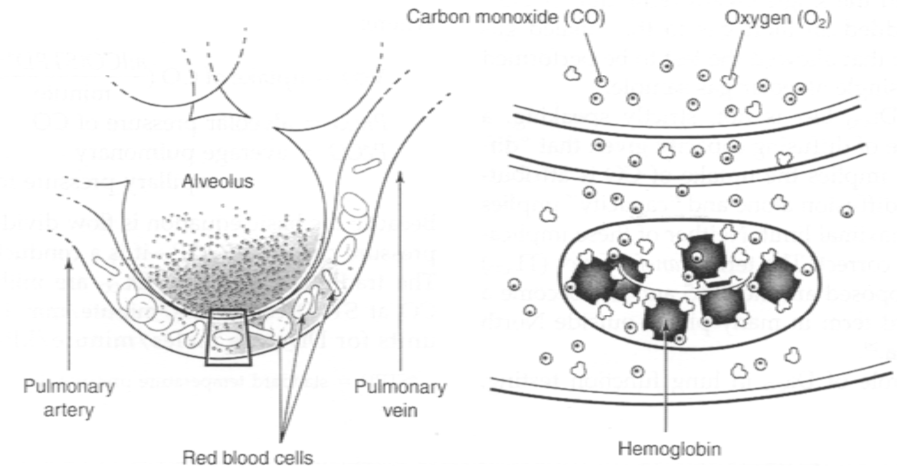
New York Presbyterian Hospital
Columbia Presbyterian Medical Center
622 West 168th Street New York, NY 10032

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 (also known as "permeability factor" and 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 **=(kcOxVA)/(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)
- Influenced by altitude since CO and O_2 in competition for Hgb; thus high altitude decreases PIO_2 and therefore increases DLCO (on the other hand, lower PO_2 gradient for transfer of oxygen
- **Note that properties of CO uptake are different than those of oxygen (in fact, CO=diffusion limited, O_2 more perfusion limited)**

Diffusing Capacity for CO (DL_{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/rebreathe techniques: SB may UNDERESTIMATE true diffusing capacity in emphysema if it underestimates gas dilution V_A since DLCO **=(kcOxVA)/(Pb-PH20)**

“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 PO_2 occur
- Low alveolar volume, low Hgb, may result in low diffusing capacity as measured by transfer of CO, and low O_2 content, but not low PaO_2

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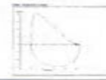

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Vtg	Liters						
Diffusion							
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Patient:			**ID:**	**Date:**
Age:	**Gender: Male**		**Location:**	**Temp:** **PBar:**
Height: 67 in (169 cm)	**Weight:**		**Physician:**	
Body Mass Index:			**Technician:**	

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				3.98		
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 (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, orthopoedic and lower abdominal with lung disease, or smoking
- Age>60 years

Postoperative Pulmonary Risks

- 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, 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

Eur Respir J 2005; 26: 153–161