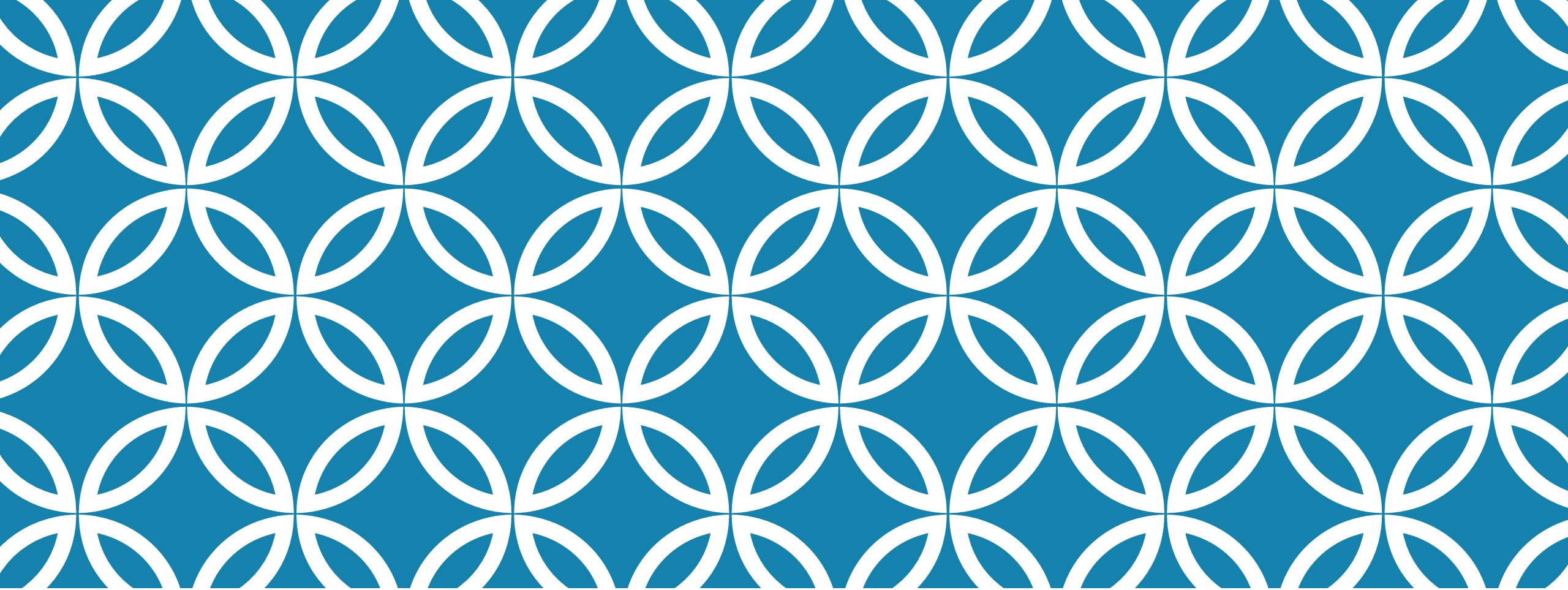

# INTRO TO PFTS

Lisa Jarnagin, MD
Pulmonary & Critical Care

# GOALS AND OBJECTIVES

1. List the 3 factors that must be confirmed before PFTs can be reliably interpreted
2. Describe steps of PFT interpretation & understand their values in order to make a diagnosis

# PULMONARY FUNCTION TESTS

- Indications
  - Diagnosis
  - Monitoring disease progression
  - Evaluating therapy effect
- Contraindications
  - Inability to understand or follow directions
  - Relative:
    - Increased myocardial demand/BP
    - Increased intracranial/intraocular pressure
    - Increases sinus/middle ear pressures
    - Increases intraabdominal/intrathoracic pressure

# PULMONARY FUNCTION TESTS

## Spirometry

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## Plethysmography

# SPIROMETRY

- Measures maximal expiration and inhalation
- Measuring lung function
- Four phases
  1. Maximal inspiration
  2. “Blast” of expiration (FEV1)
  3. Continued expiration (6 - 15 seconds)
  4. Return to maximal inspiration

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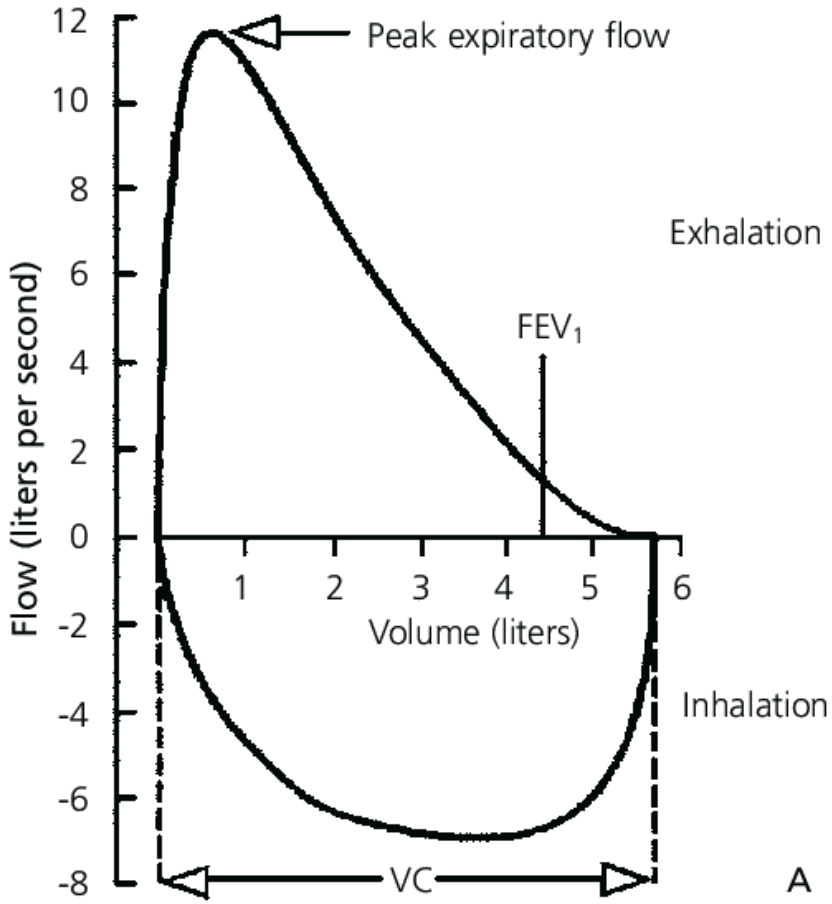
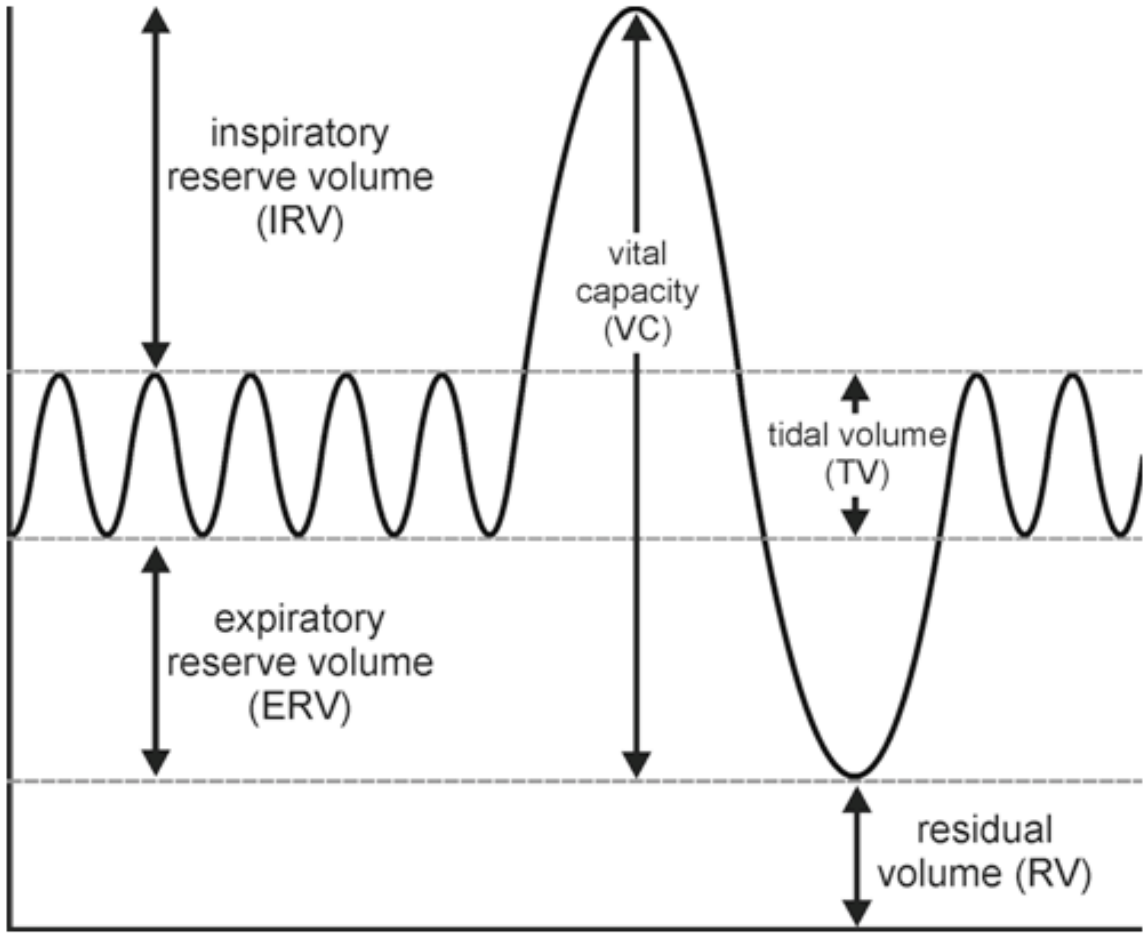
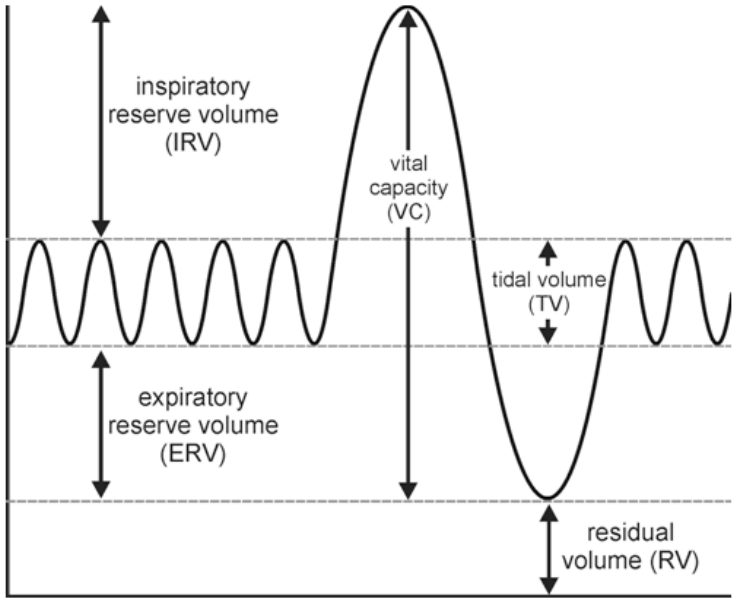
# FLOW VOLUME LOOP

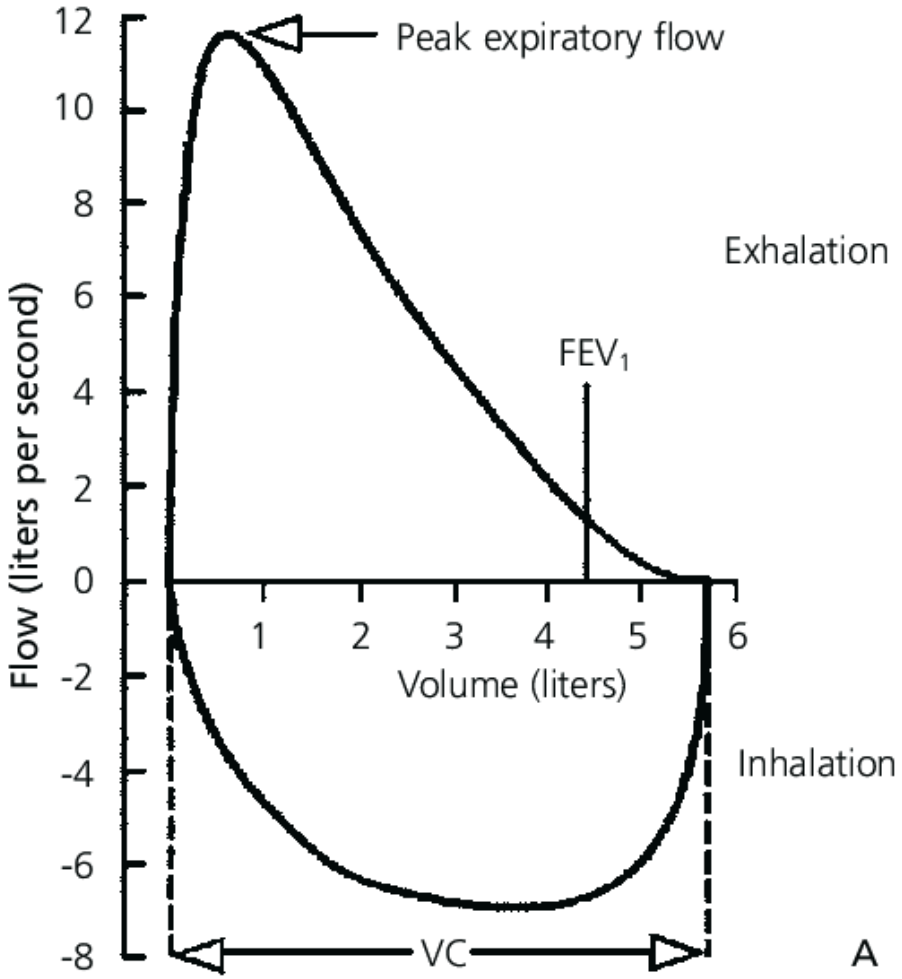


# LUNG VOLUMES

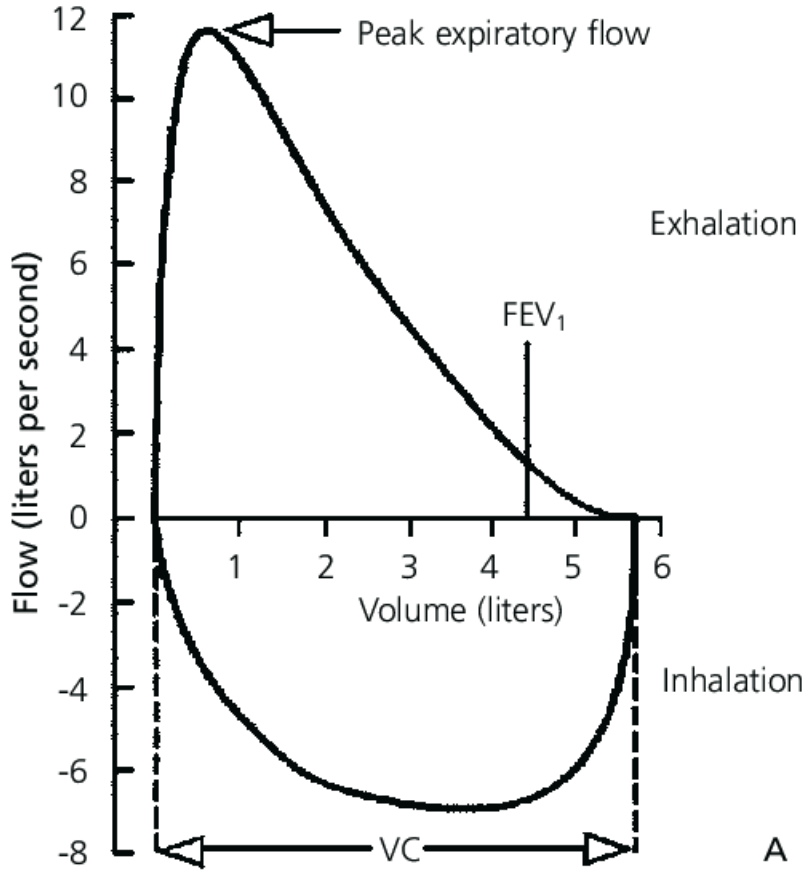


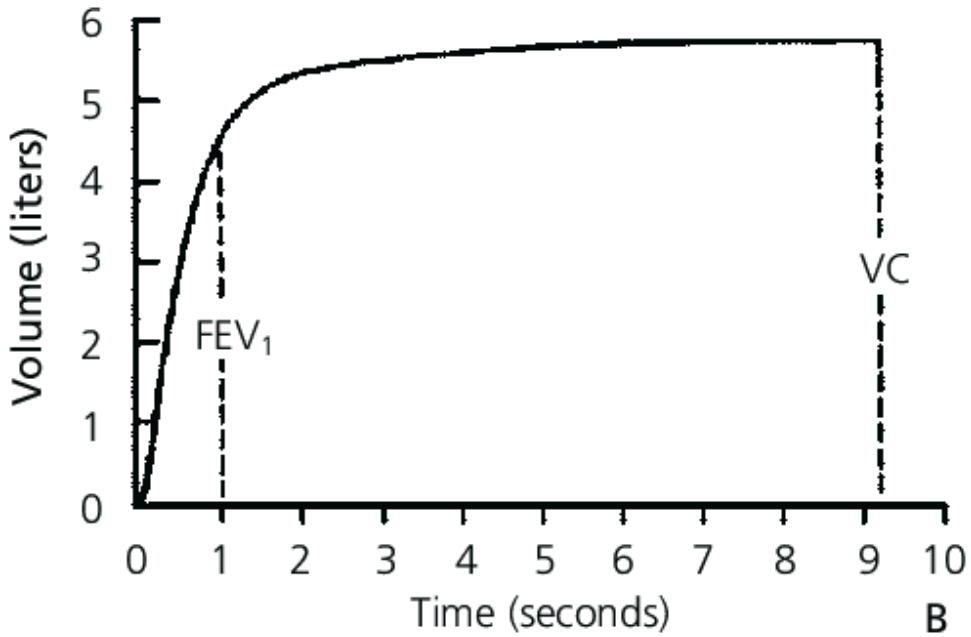
# FLOW VOLUME LOOPS



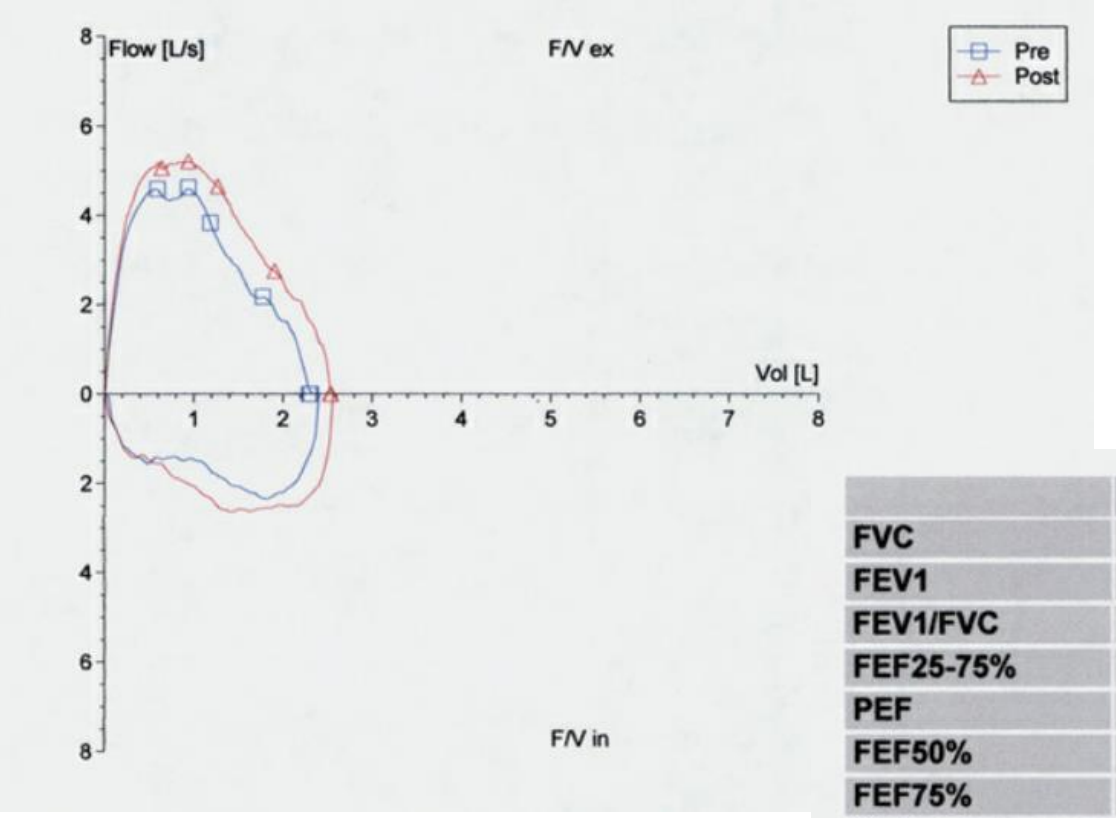



# FLOW VOLUME LOOPS



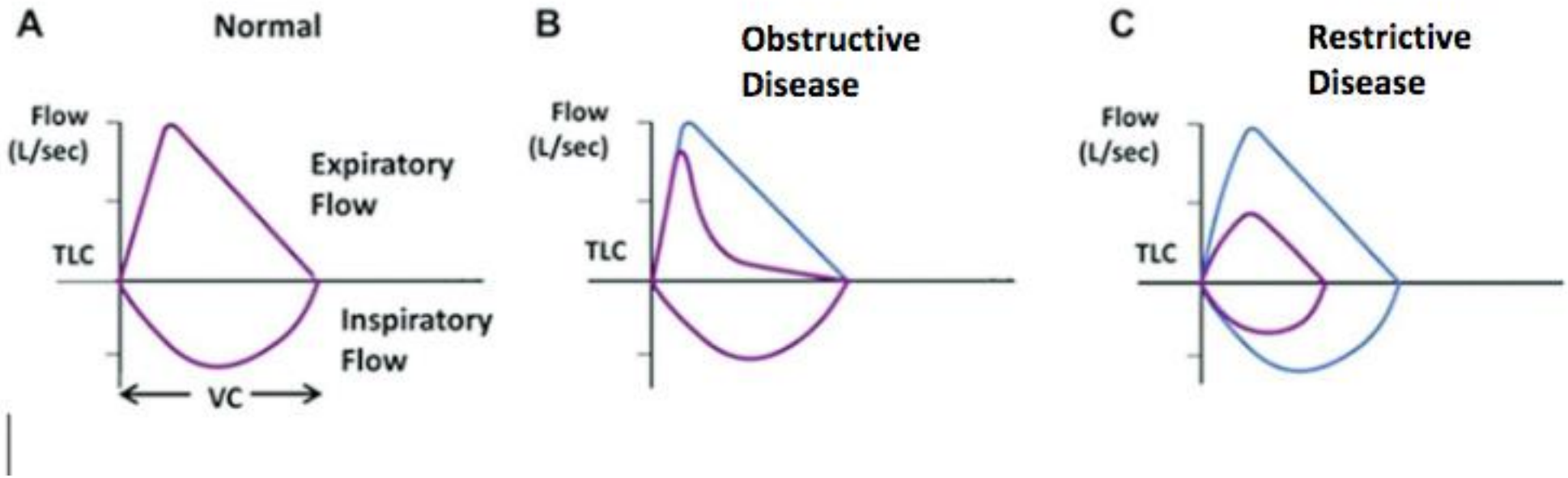
# SPIROMETRY




1. Flow volume loops
2. Forced vital capacity (FVC)
3. Forced expiratory volume 1 sec (FEV1)

| | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|
| FVC | 3.28 | 2.31 | 70 | 2.54 | 77 |
| FEV1 | 2.85 | 2.29 | 80 | 2.52 | 88 |
| FEV1/FVC | 87 | 99 | 113 | 100 | 114 |
| FEF25-75% | 3.46 | 3.52 | 102 | 4.22 | 122 |
| PEF | | 4.62 | | 5.21 | |
| FEF50% | | 3.99 | | 4.65 | |
| FEF75% | 1.57 | 2.14 | 136 | 2.76 | 176 |
| PIF | | 2.35 | | 2.64 | |
| FIF50% | | 1.78 | | 2.55 | |
| FET100% | | 2.51 | | 3.81 | |

# FLOW VOLUME LOOPS

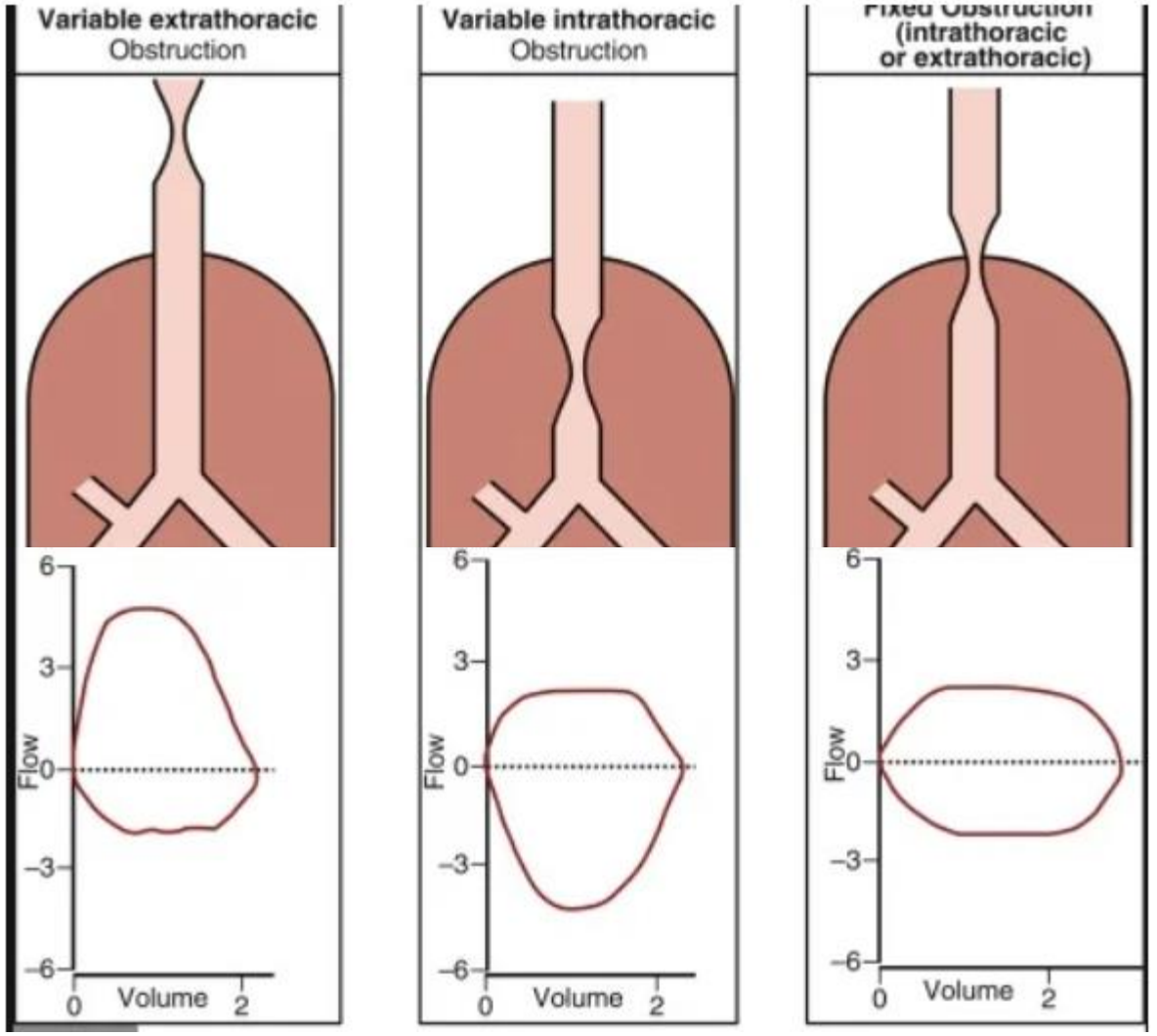


# FLOW VOLUME LOOPS

Tracheomalacia

Vocal Cord Dysfunction

Tracheal stenosis



# PLETHYSMOGRAPHY

- Measures total lung volume
- Boyle's law: pressure and volume of a gas are inversely proportional
- Detecting changes in box pressure as a result of changes in lung volume

# PLETHYSMOGRAPHY

***LUNG VOLUME STUDY***

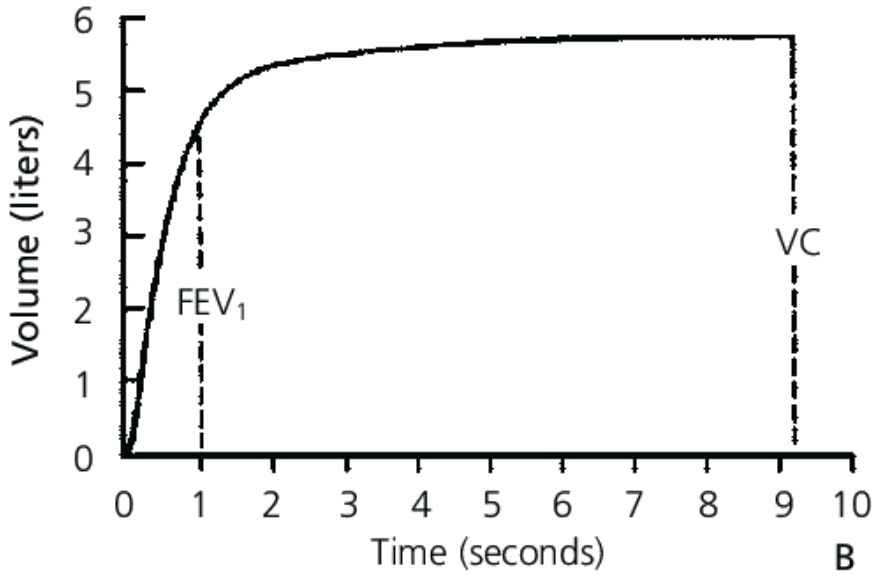
| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 6.05 | 1.00 | 5.60 | 93 |
| RV | Liters | 2.39 | 0.79 | 1.95 | 82 |
| RV/TLC | % | 40 | 12 | 35 | |
| FRC PL | Liters | 3.51 | 1.21 | 3.11 | 89 |
| VC | Liters | | | 3.65 | |
| IC | Liters | | | 2.49 | |
| ERV | Liters | | | 1.15 | |
| Raw | cmH2O/L/sec | 1.28 | | 2.45 | 191 |
| sGaw | L/s/cmH2O/L | | | 0.091 | |

# INTERPRETING PFTS

1. Confirm validity
2. FEV1/FVC Ratio
3. FVC (forced vital capacity) and Total Lung Volumes
4. Grade the severity
5. Determine Reversibility of Obstructive Defect
6. DLCO

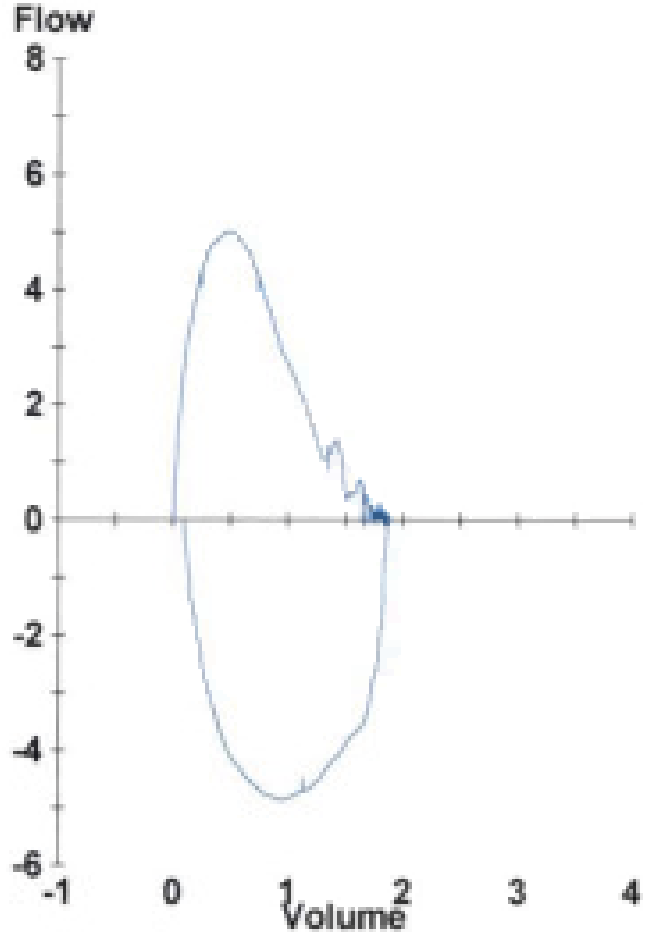
# INTERPRETING PFTS: CONFIRM VALIDITY

1. Volume-time curve
   - Reaches plateau
   - Expiration $\geq$ 6 seconds



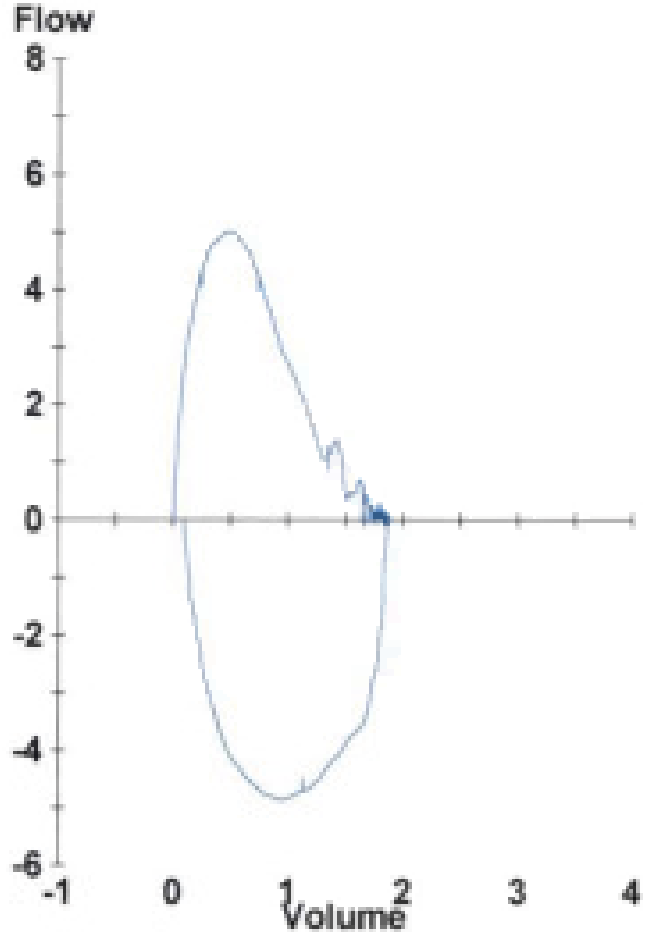
# INTERPRETING PFTS: CONFIRM VALIDITY

1. Volume-time curve
   - Reaches plateau
   - Expiration $\geq$ 6 seconds
2. Flow-volume loops are free of artifacts



# INTERPRETING PFTS: CONFIRM VALIDITY

1. Volume-time curve
   - Reaches plateau
   - Expiration $\geq$ 6 seconds
2. Flow-volume loops are free of artifacts
3. Results of 2 best efforts within 0.2L



# INTERPRETING PFTS

1. Confirm validity
2. FEV1/FVC Ratio
3. FVC (forced vital capacity) and Total Lung Volumes
4. Grade the severity: FEV1
5. Determine Reversibility of Obstructive Defect
6. DLCO

# FEV1/FVC

## GOLD Criteria

- Ratio < 70% then obstructive
- More sensitive for > 65 years old

## ATS Criteria

- < lower limit of normal then obstructive
- More sensitive < 65 years old

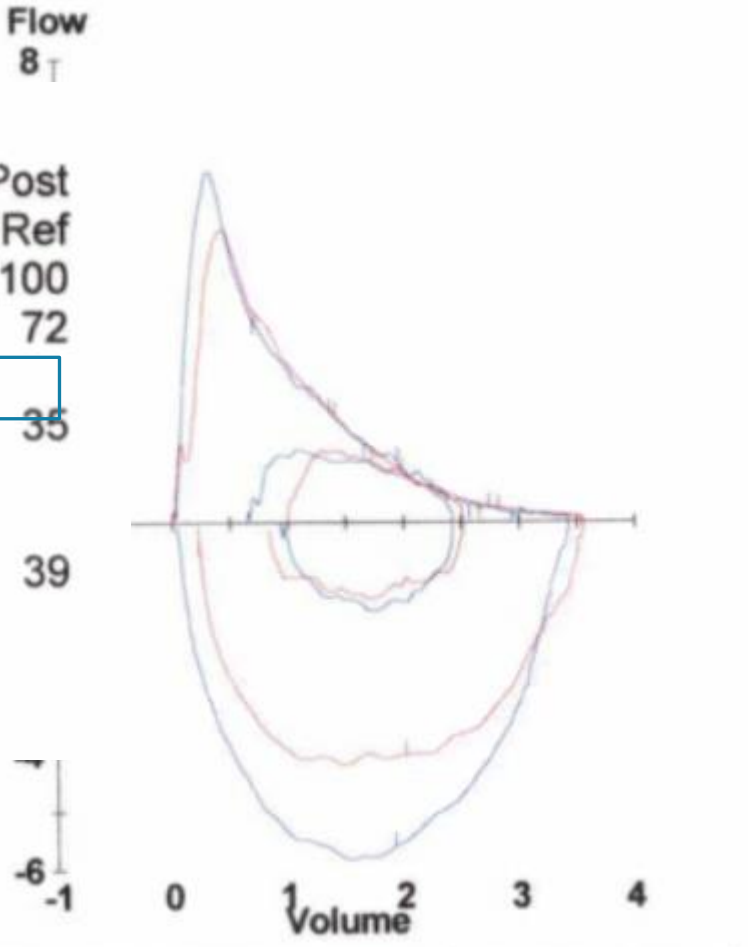
**Low** FEV1/FVC ratio ➔ obstructive lung disease

**Normal** FEV1/FVC ratio ➔ normal OR restrictive lung disease

# FEV1/FVC

***SPIROMETRY PRE AND POST BRONCHODILATOR***

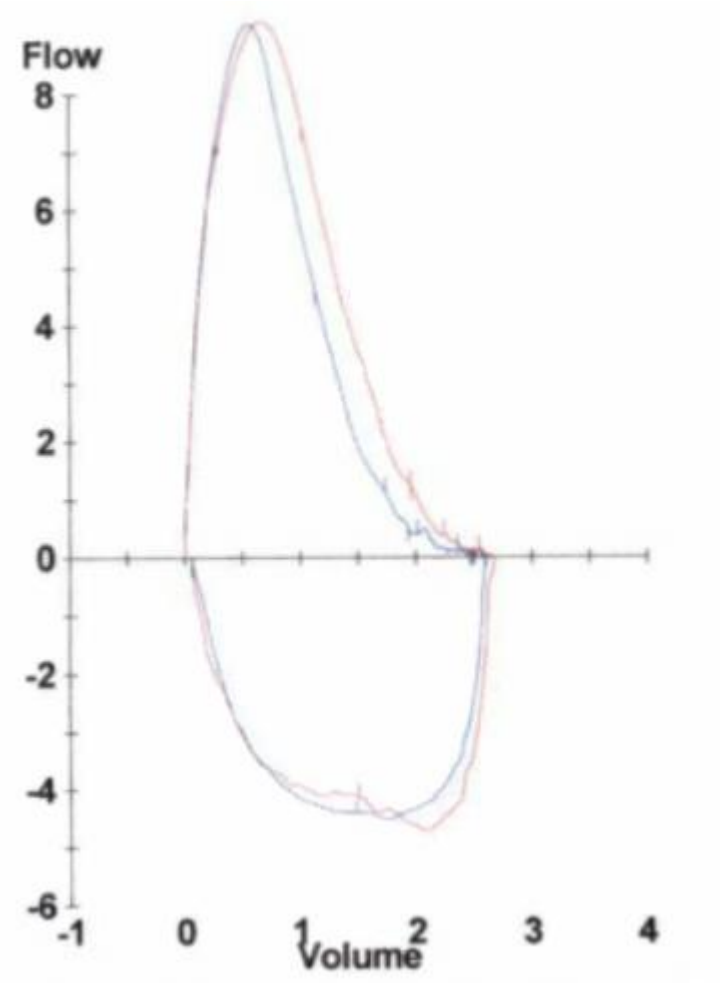
| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 3.57 | 3.45 | 97 | 3.56 | 100 |
| FEV1 | Liters | 2.80 | 1.99 | 71 | 2.03 | 72 |
| FEV1/FVC | % | 79 | 58 | | 57 | |
| FEF25-75% | L/sec | 2.36 | 0.83 | 35 | 0.82 | 35 |
| PEF | L/sec | | 6.06 | | 5.27 | |
| FEF50% | L/sec | | 1.16 | | 1.20 | |
| FEF75% | L/sec | 0.74 | 0.27 | 36 | 0.29 | 39 |
| PIF | L/sec | | 5.82 | | 4.19 | |
| FIF50% | L/sec | | 5.62 | | 3.98 | |
| FET100% | Sec | | 9.16 | | 9.25 | |



# FEV1/FVC

***SPIROMETRY PRE AND POST BRONCHODILATOR***

| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 2.86 | 2.61 | 91 | 2.67 | 93 |
| FEV1 | Liters | 2.25 | 2.03 | 90 | 2.26 | 101 |
| FEV1/FVC | % | 79 | 78 | | 85 | |
| FEF25-75% | L/sec | 2.00 | 1.88 | 94 | 3.20 | 160 |
| PEF | L/sec | | 9.19 | | 9.25 | |
| FEF50% | L/sec | | 3.99 | | 6.14 | |
| FEF75% | L/sec | 0.52 | 0.47 | 89 | 1.16 | 223 |
| PIF | L/sec | | 4.51 | | 4.70 | |
| FIF50% | L/sec | | 4.38 | | 3.89 | |
| FET100% | Sec | | 8.69 | | 7.18 | |



# INTERPRETING PFTS

1. Confirm validity
2. FEV1/FVC Ratio
3. FVC (forced vital capacity) and Total Lung Volumes
4. Grade the severity
5. Determine Reversibility of Obstructive Defect
6. DLCO

# FVC/ LUNG VOLUMES

## Forced Vital Capacity

- FVC < lower limit of normal suggests restriction
- Confirm w/ plethysmography and DLCO

## Total Lung Volumes

- < lower limit normal (80%) confirms restriction
  - Interstitial lung disease
  - Neuromuscular weakness
  - Chest wall limitation
- > upper limit normal suggests hyperinflation
  - Emphysema/COPD

# FVC/ LUNG VOLUMES

***SPIROMETRY PRE AND POST BRONCHODILATOR***

| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 3.86 | 2.47 | 64 | 2.56 | 66 |
| FEV1 | Liters | 3.16 | 1.86 | 59 | 2.07 | 65 |
| FEV1/FVC | % | 83 | 76 | | 81 | |
| FEF25-75% | L/sec | 3.25 | 1.57 | 48 | 2.14 | 66 |
| PEF | L/sec | | 4.31 | | 5.41 | |
| FEF50% | L/sec | | 2.42 | | 2.93 | |
| FEF75% | L/sec | 1.13 | 0.59 | 52 | 0.83 | 74 |
| PIF | L/sec | | 2.91 | | 4.51 | |
| FIF50% | L/sec | | 2.48 | | | |
| FET100% | Sec | | 8.40 | | | |

Restrictive lung disease

***LUNG VOLUME STUDY***

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 6.18 | 0.77 | 3.47 | 56 |
| RV | Liters | 2.09 | 0.70 | 1.01 | 48 |
| RV/TLC | % | 32 | 12 | 29 | |
| FRC PL | Liters | 3.34 | 0.95 | 1.82 | 55 |
| VC | Liters | | | 2.47 | |
| IC | Liters | | | 1.65 | |
| ERV | Liters | | | 0.51 | |
| Raw | cmH2O/L/sec | 1.12 | | 3.54 | 315 |
| sGaw | L/s/cmH2O/L | 0.266 | | 0.121 | 45 |

# FVC/ LUNG VOLUMES

***SPIROMETRY PRE AND POST BRONCHODILATOR***

| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 5.45 | 4.10 | 75 | 4.42 | 81 |
| FEV1 | Liters | 4.22 | 1.45 | 34 | 1.56 | 37 |
| FEV1/FVC | % | 78 | 35 | | 35 | |
| FEF25-75% | L/sec | 3.59 | 0.41 | 11 | 0.39 | 11 |
| PEF | L/sec | 10.40 | 6.80 | 65 | 7.18 | 69 |
| FEF50% | L/sec | | 0.41 | | 0.42 | |
| FEF75% | L/sec | 1.20 | 0.25 | 21 | 0.25 | 21 |
| PIF | L/sec | | 8.54 | | 8.23 | |
| FIF50% | L/sec | | 7.96 | | 7.93 | |
| FET100% | Sec | | 10.91 | | 11 | |

Obstructive lung disease with hyperinflation and air trapping

***LUNG VOLUME STUDY***

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 7.57 | 1.00 | 9.81 | 130 |
| RV | Liters | 2.53 | 0.79 | 4.56 | 180 |
| RV/TLC | % | 36 | 12 | 46 | |
| FRC PL | Liters | 3.81 | 1.21 | 5.93 | 156 |
| VC | Liters | | | 5.25 | |
| IC | Liters | | | 3.88 | |
| ERV | Liters | | | 1.33 | |
| Raw | cmH2O/L/sec | 1.16 | | 3.35 | 289 |
| sGaw | L/s/cmH2O/L | 0.226 | | 0.039 | 17 |

# INTERPRETING PFTS

1. Confirm validity
2. FEV1/FVC Ratio
3. FVC (forced vital capacity) and Total Lung Volumes
4. Grade the severity
5. Determine Reversibility of Obstructive Defect
6. DLCO

# INTERPRETING PFTS

**Table 3. American Thoracic Society Grades for Severity of a Pulmonary Function Test Abnormality**

| *Severity* | *$FEV_1$, percentage of predicted* |
|---|---|
| Mild | > 70 |
| Moderate | 60 to 69 |
| Moderately severe | 50 to 59 |
| Severe | 35 to 49 |
| Very severe | < 35 |

*$FEV_1$ = forced expiratory volume in one second.*

*Adapted with permission from Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests.* Eur Respir J. *2005; 26(5):957.*

**TABLE 3. Grading Restriction Severity[a,b]**

| Restriction grading[c] | TLC | FVC[d] |
|---|---|---|
| Mild | <80% | <80% |
| Moderate | <60% | <60% |
| Severe | <50% | <50% |
| Very severe | <35% | NA |

[a]ATS = American Thoracic Society; $FEV_1$ = forced expiratory volume in the first second; FVC = forced vital capacity; LLN = lower limit of normal; NA = not available; TLC = total lung capacity.

[b]Severity grading for restrictive diseases in our laboratory is loosely based on the 1986 ATS guidelines.[13] Of note, the cutoff points for grading the severity of decrease in diffusing capacity of lung for carbon monoxide are the same as the values provided in this table and based on the 2005 ATS guidelines.[7]

[c]The $FEV_1$/FVC ratio must be normal.

[d]If lung volumes are not measured and a previous TLC value is below the LLN.

# FVC/ LUNG VOLUMES

***SPIROMETRY PRE AND POST BRONCHODILATOR***

| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 3.57 | 3.45 | 97 | 3.56 | 100 |
| FEV1 | Liters | 2.80 | 1.99 | 71 | 2.03 | 72 |
| FEV1/FVC | % | 79 | 58 | | 57 | |
| FEF25-75% | L/sec | 2.36 | 0.83 | 35 | 0.82 | 35 |
| PEF | L/sec | | 6.06 | | 5.27 | |
| FEF50% | L/sec | | 1.16 | | 1.20 | |
| FEF75% | L/sec | 0.74 | 0.27 | 36 | 0.29 | 39 |
| PIF | L/sec | | 5.82 | | 4.19 | |
| FIF50% | L/sec | | 5.62 | | 3.98 | |
| FET100% | Sec | | 9.16 | | 9 | |

Moderate obstructive lung disease with normal lung volumes

***LUNG VOLUME STUDY***

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 6.05 | 1.00 | 5.60 | 93 |
| RV | Liters | 2.39 | 0.79 | 1.95 | 82 |
| RV/TLC | % | 40 | 12 | 35 | |
| FRC PL | Liters | 3.51 | 1.21 | 3.11 | 89 |
| VC | Liters | | | 3.65 | |
| IC | Liters | | | 2.49 | |
| ERV | Liters | | | 1.15 | |
| Raw | cmH2O/L/sec | 1.28 | | 2.45 | 191 |
| sGaw | L/s/cmH2O/L | | | 0.091 | |

# FVC/ LUNG VOLUMES

| SPIROMETRIC TESTS | | Ref | Pre Meas | Pre % Ref |
|---|---|---|---|---|
| FVC | Liters | 4.44 | 2.47 | 56 |
| FEV1 | Liters | 3.31 | 2.01 | 61 |
| FEV1/FVC | % | 75 | 82 | |
| FEF25-75% | L/sec | 2.42 | 2.11 | 87 |
| PEF | L/sec | 8.52 | 7.00 | 82 |
| FEF50% | L/sec | | 3.04 | |
| FEF75% | L/sec | 0.65 | 0.70 | 108 |
| PIF | L/sec | | 3.89 | |
| FIF50% | L/sec | | 2.68 | |
| FET100% | Sec | | 6.40 | |

Moderate pulmonary restriction

| LUNG VOLUME STUDY | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 6.94 | 1.00 | 4.08 | 59 |
| RV | Liters | 2.73 | 0.79 | 1.62 | 59 |
| RV/TLC | % | 42 | 12 | 40 | |
| FRC PL | Liters | 4.28 | 1.21 | 2.31 | 54 |
| VC | Liters | | | 2.47 | |
| IC | Liters | | | 1.77 | |
| ERV | Liters | | | 0.59 | |
| Raw | cmH2O/L/sec | 1.01 | | 2.29 | 227 |
| sGaw | L/s/cmH2O/L | 0.232 | | 0.155 | 67 |

# INTERPRETING PFTS

1. Confirm validity
2. FEV1/FVC Ratio
3. FVC (forced vital capacity) and Total Lung Volumes
4. Grade the severity
5. Determine Reversibility of Obstructive Defect
6. DLCO

# REVERSIBILITY

Increase in FEV1 or FVC of > 12% AND > 200mL of tidal volume

# REVERSIBILITY

***SPIROMETRY PRE AND POST BRONCHODILATOR***

| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 2.78 | 2.18 | 78 | 2.51 | 90 |
| FEV1 | Liters | 2.16 | 1.20 | 55 | 1.43 | 66 |
| FEV1/FVC | % | 78 | 55 | | 57 | |
| FEF25-75% | L/sec | 1.87 | 0.47 | 25 | 0.54 | 29 |
| PEF | L/sec | | 3.53 | | 3.27 | |
| FEF50% | L/sec | | 0.63 | | 0.84 | |
| FEF75% | L/sec | 0.46 | 0.18 | 40 | 0.19 | 41 |
| PIF | L/sec | | 2.52 | | 2.96 | |
| FIF50% | L/sec | | 2.41 | | 2.94 | |
| FET100% | Sec | | 9.92 | | 10.25 | |

***LUNG VOLUME STUDY***

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 4.62 | 0.77 | 5.41 | 117 |
| RV | Liters | 1.84 | 0.70 | 3.23 | 175 |
| RV/TLC | % | 40 | 12 | 60 | |
| FRC PL | Liters | 2.85 | 0.95 | 3.76 | 132 |
| VC | Liters | | | 2.18 | |
| IC | Liters | | | 1.65 | |
| ERV | Liters | | | 0.54 | |
| Raw | cmH2O/L/sec | 1.34 | | 4.05 | 303 |
| sGaw | L/s/cmH2O/L | | | 0.055 | |

# REVERSIBILITY

***SPIROMETRY PRE AND POST BRONCHODILATOR***

| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 2.78 | 2.18 | 78 | 2.51 | 90 |
| FEV1 | Liters | 2.16 | 1.20 | 55 | 1.43 | 66 |
| FEV1/FVC | % | 78 | 55 | | 57 | |
| FEF25-75% | L/sec | 1.87 | 0.47 | 25 | 0.54 | 29 |
| PEF | L/sec | | 3.53 | | 3.27 | |
| FEF50% | L/sec | | 0.63 | | 0.84 | |
| FEF75% | L/sec | 0.46 | 0.18 | 40 | 0.19 | 41 |
| PIF | L/sec | | 2.52 | | 2.96 | |
| FIF50% | L/sec | | 2.41 | | 2.94 | |
| FET100% | Sec | | 9.92 | | 10.25 | |

Moderate obstructive lung disease with significant bronchodilator response and notable air trapping

***LUNG VOLUME STUDY***

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 4.62 | 0.77 | 5.41 | 117 |
| RV | Liters | 1.84 | 0.70 | 3.23 | 175 |
| RV/TLC | % | 40 | 12 | 60 | |
| FRC PL | Liters | 2.85 | 0.95 | 3.76 | 132 |
| VC | Liters | | | 2.18 | |
| IC | Liters | | | 1.65 | |
| ERV | Liters | | | 0.54 | |
| Raw | cmH2O/L/sec | 1.34 | | 4.05 | 303 |
| sGaw | L/s/cmH2O/L | | | 0.055 | |

# REVERSIBILITY

Increase in FEV1 or FVC of > 12% AND > 200mL of tidal volume

Additional Bronchoprovocation testing (Asthma)

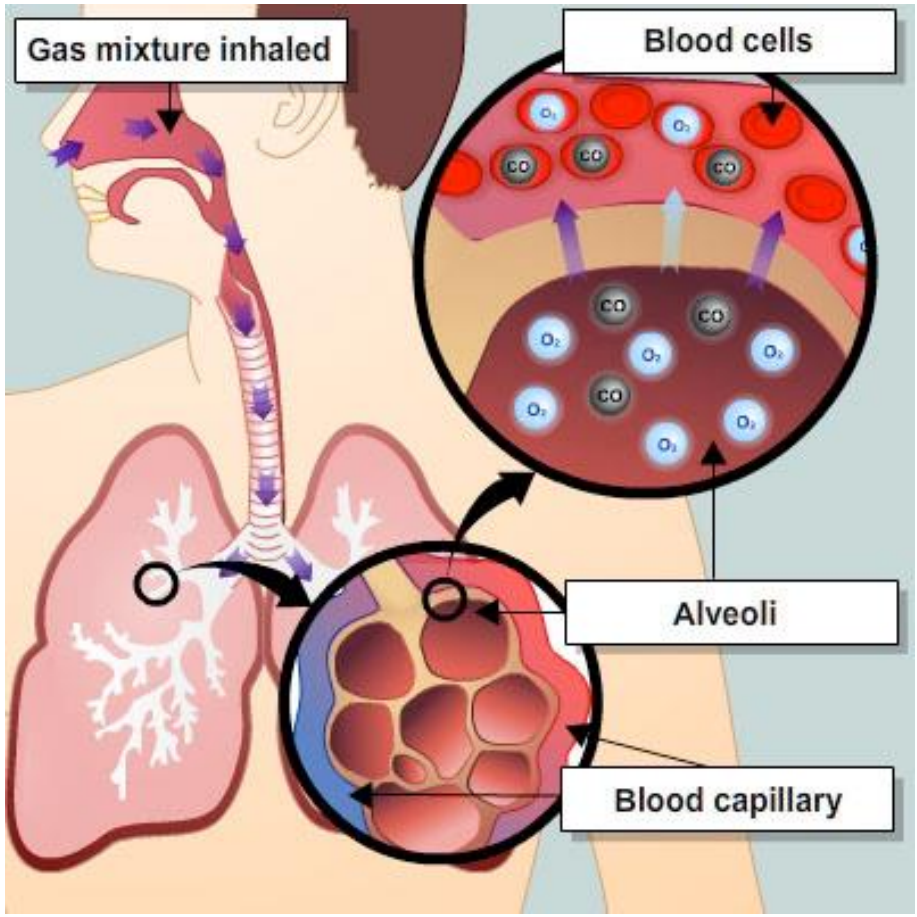
- Methacholine challenge
- Mannitol Inhalation challenge
- Exercise testing
- Eucapnic voluntary hyperpnea testing

# INTERPRETING PFTS

1. Confirm validity
2. FEV1/FVC Ratio
3. FVC (forced vital capacity) and Total Lung Volumes
4. Grade the severity
5. Determine Reversibility of Obstructive Defect
6. DLCO

# DLCO: DIFFUSION CAPACITY OF LUNG CARBON MONOXIDE

- Diffusion capacity of the alveoli
- The test:
  - Inhaled mixture of He, CO, O2, N
  - 10 second breath hold
  - Exhaled CO and N used to calculate DLCO
- Normal = LLN to 120%



# DLCO: DIFFUSION CAPACITY OF LUNG CARBON MONOXIDE

## Low DLCO

- Interstitial lung disease
- Emphysema
- Pulmonary hypertension
- Pulmonary embolism
- Anemia
- Amiodarone

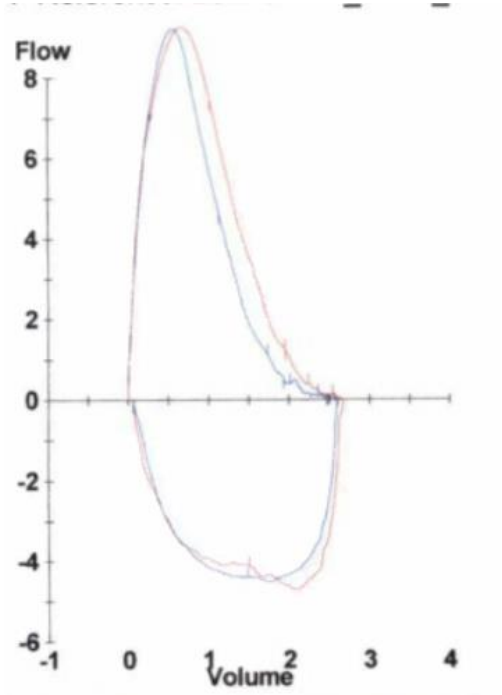
## High DLCO

- Asthma
- Congestive heart failure
- Intracardiac shunts
- Pulmonary hemorrhage
- Polycythemia

# DLCO: DIFFUSION CAPACITY OF LUNG CARBON MONOXIDE

***SINGLE BREATH DLCO***

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| DLCO | mL/min/mmHg | 26.3 | 6.5 | 9.7 | 37 |
| VA | Liters | 5.80 | 1.16 | 3.18 | 55 |
| DLCO/VA | mL/min/mHg/L | 4.54 | 1.32 | 3.06 | 67 |
| DL Adj | mL/min/mmHg | 26.3 | 6.5 | 14.4 | 55 |
| DL/VA Adj | mL/min/mHg/L | | | 4.52 | |




## SPIROMETRY PRE AND POST BRONCHODILATOR

| | | Ref | Pre Meas | Pre % Ref | Post Meas | Post % Ref |
|---|---|---|---|---|---|---|
| FVC | Liters | 2.86 | 2.61 | 91 | 2.67 | 93 |
| FEV1 | Liters | 2.25 | 2.03 | 90 | 2.26 | 101 |
| FEV1/FVC | % | 79 | 78 | | 85 | |
| FEF25-75% | L/sec | 2.00 | 1.88 | 94 | 3.20 | 160 |
| PEF | L/sec | | 9.19 | | 9.25 | |
| FEF50% | L/sec | | 3.99 | | 6.14 | |
| FEF75% | L/sec | 0.52 | 0.47 | 89 | 1.16 | 223 |
| PIF | L/sec | | 4.51 | | 4.70 | |
| FIF50% | L/sec | | 4.38 | | 3.89 | |
| FET100% | Sec | | 8.69 | | 7.18 | |

## LUNG VOLUME STUDY

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| TLC | Liters | 4.55 | 0.77 | 4.53 | 99 |
| RV | Liters | 1.77 | 0.70 | 1.91 | 108 |
| RV/TLC | % | 39 | 12 | 42 | |
| FRC PL | Liters | 1.72 | 0.95 | 2.46 | 143 |
| VC | Liters | | | 2.62 | |
| IC | Liters | | | 2.07 | |
| ERV | Liters | | | 0.55 | |
| Raw | cmH2O/L/sec | 2.38 | | 2.01 | 85 |
| sGaw | L/s/cmH2O/L | | | 0.158 | |

## SINGLE BREATH DLCO

| | | Ref | CI | Pre Meas | Pre % Ref |
|---|---|---|---|---|---|
| DLCO | mL/min/mmHg | 20.4 | 6.5 | 14.7 | 72 |
| VA | Liters | 4.61 | 0.92 | 4.40 | 95 |
| DLCO/VA | mL/min/mHg/L | 4.43 | 1.32 | 3.34 | 75 |

Spirometry and lung volumes are within normal limits. No significant bronchodilator response noted. DLCO is slightly reduced.