

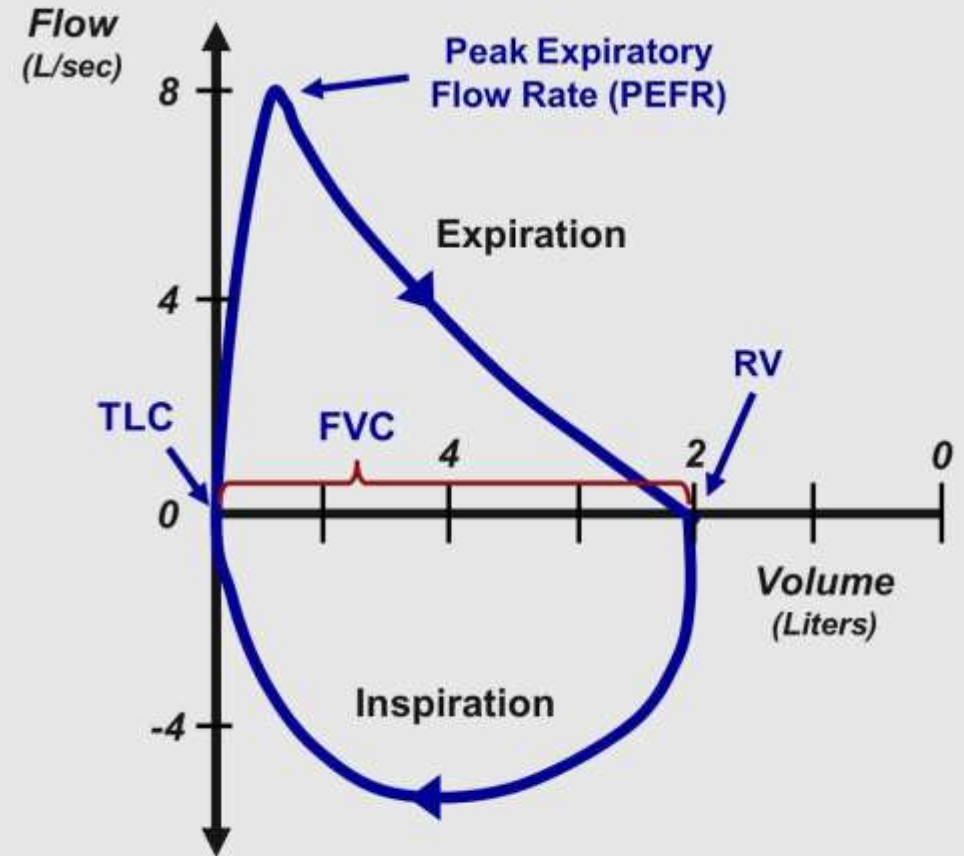
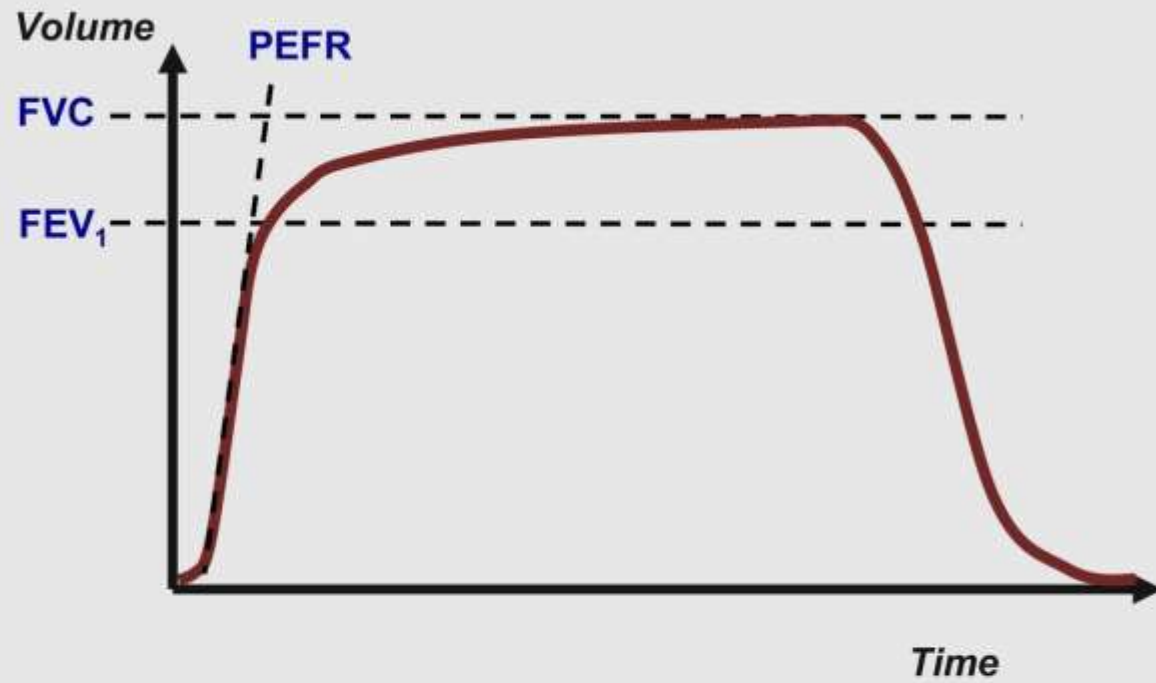
# Pulmonary Function Tests

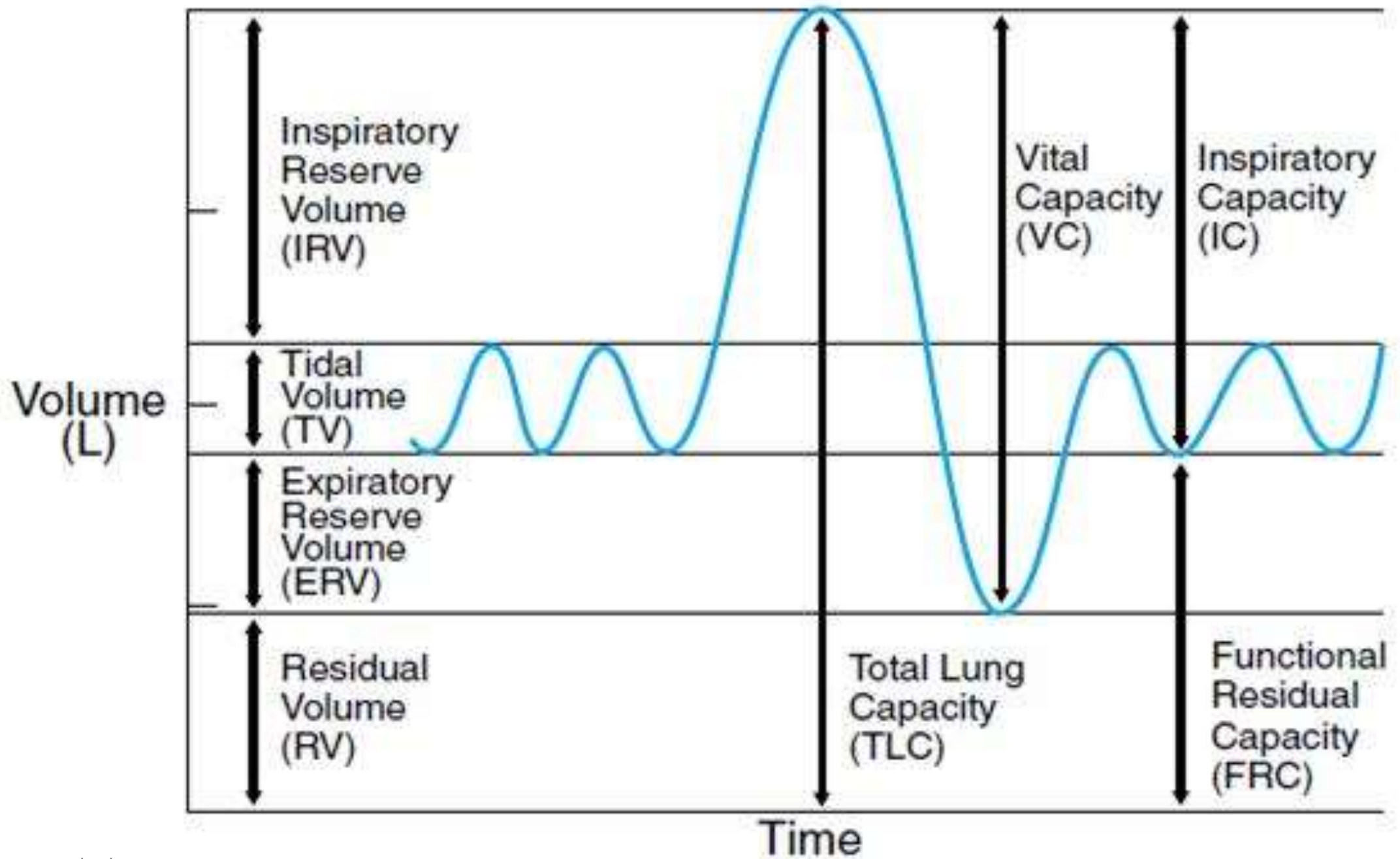
## **Interpretative Strategies**

# PFTS

- Spirometry
  - With Post - Bronchodilators
- Lung Volumes
  - Plethysmography
  - Gas Dilution
- DLCO
- Bronchoprovacation Testing
  - Methacholine
  - Other – e.g. Mannitol, Eucapnic Voluntary Hyperventilation
- Six Minute Walk

# Flow-Volume Loop

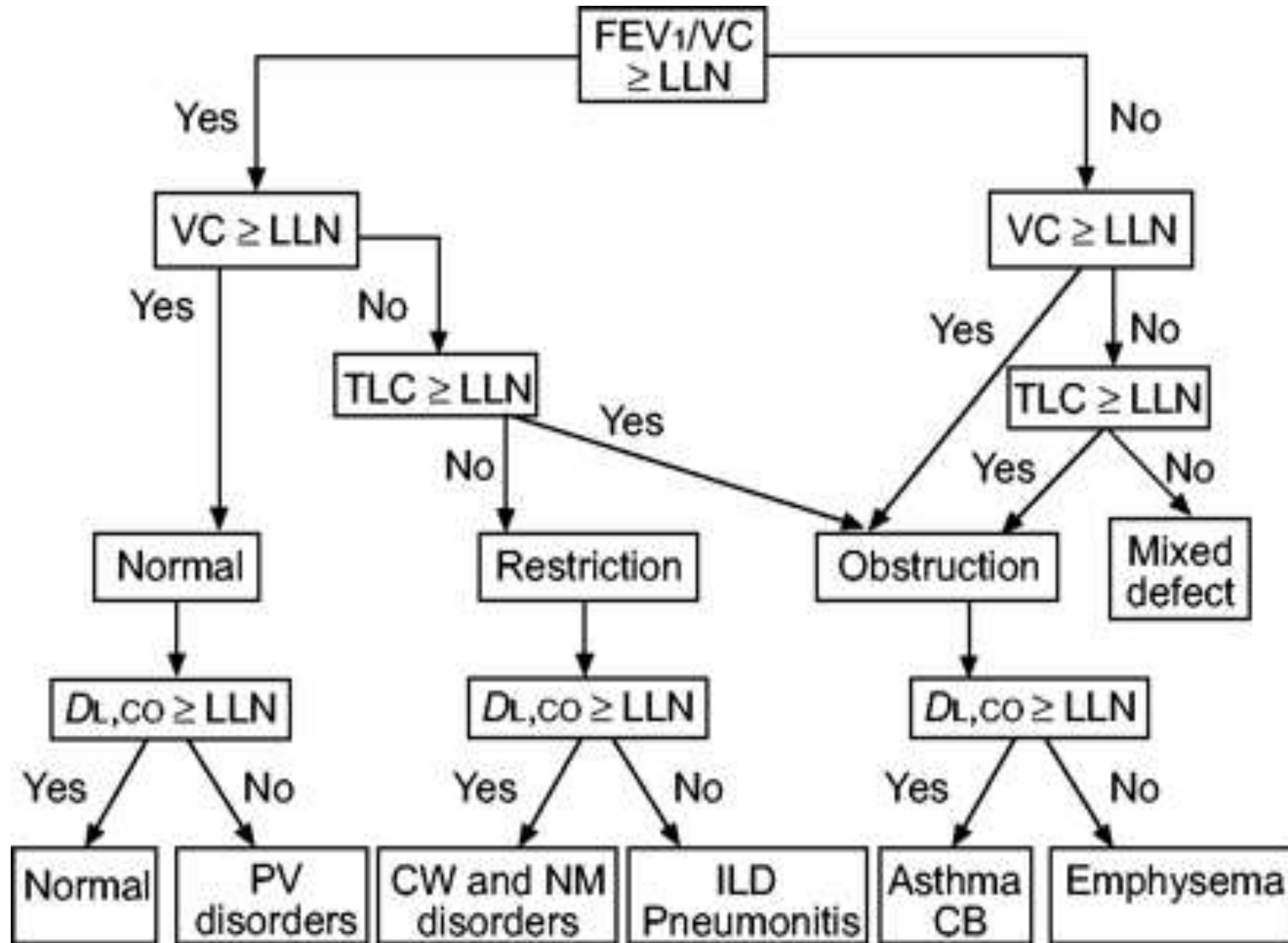




# PFT Interpretation

- The VC, FEV1, FEV1/VC ratio, TLC and DLCO are the basic parameters used to properly interpret lung function

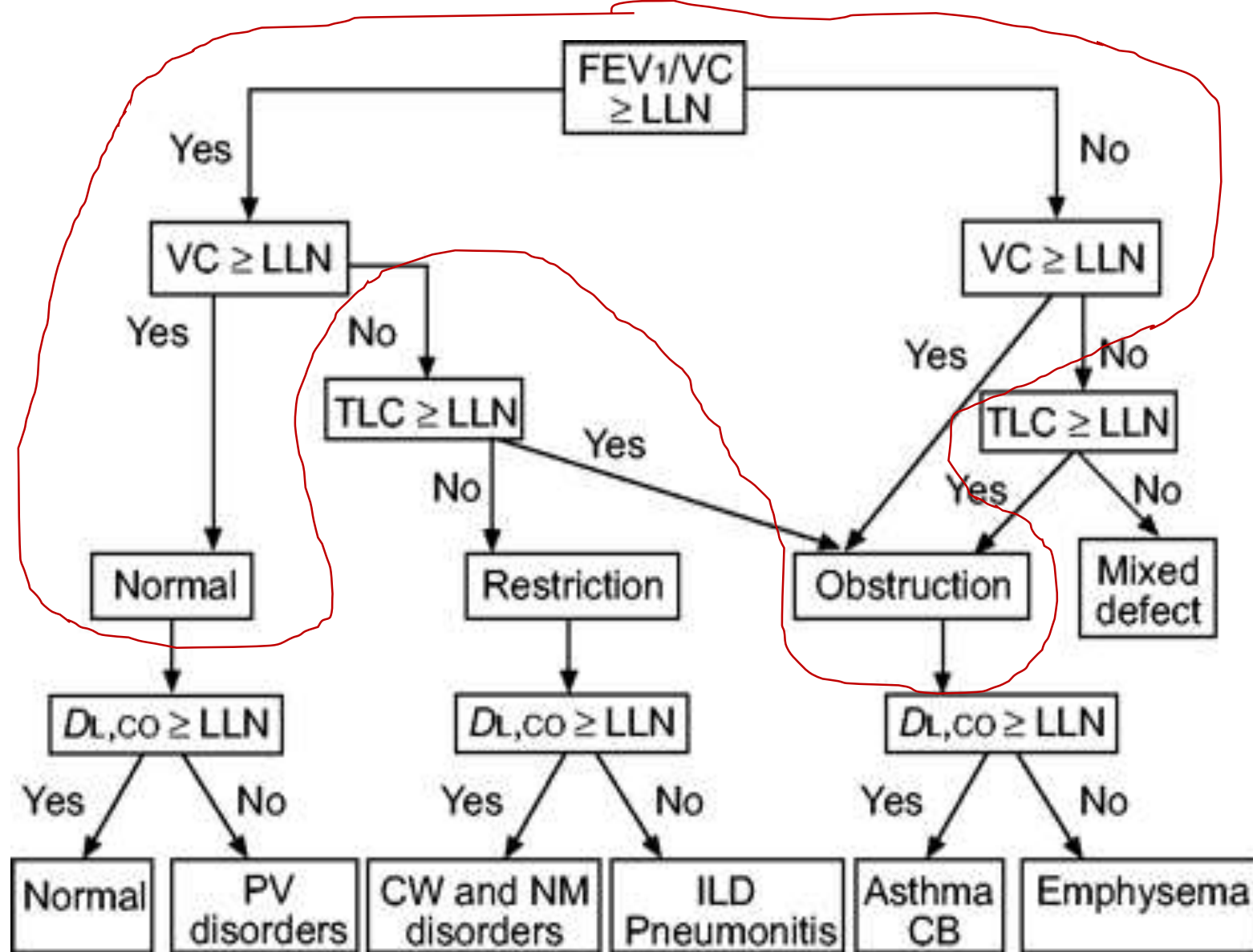
# PFT Interpretive Strategy



# Spirometry



# PFT Interpretive Strategy

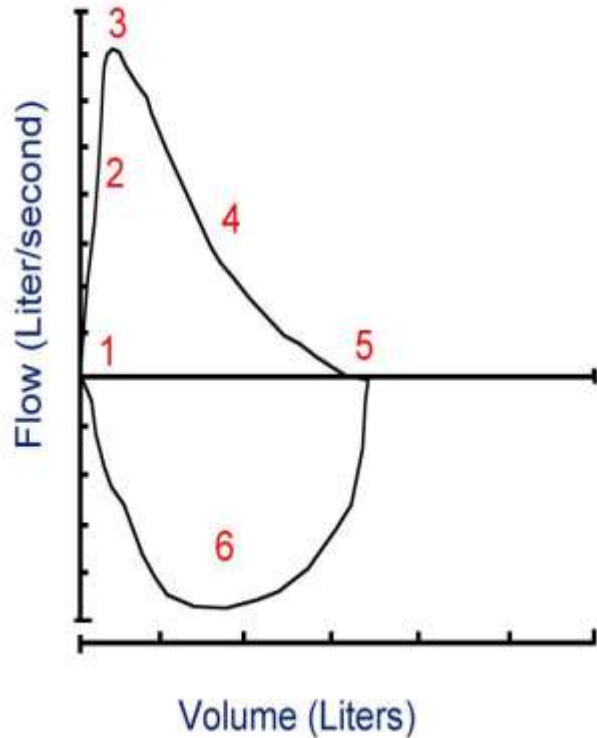




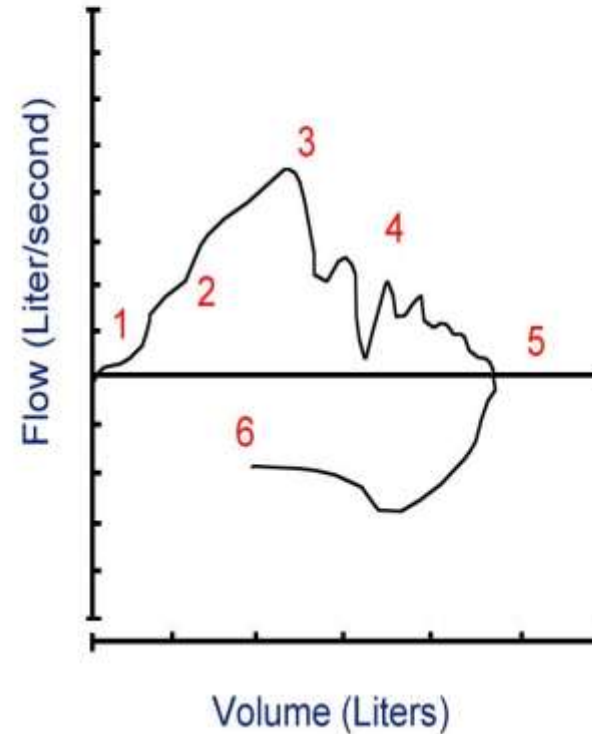
# Characteristics of Acceptable Spirometry Efforts

- Starts from full inflation
- Shows minimal hesitation at the start of the forced expiration (extrapolated volume (EV) <5% of FVC or 0.15 L, whichever is larger)
- Shows an explosive start of the forced exhalation (time to peak flow no greater than 0.12 s)
- Shows no evidence of cough in the first second of forced exhalation
- Meets one of three criteria that define a valid end-of-test:
  - Smooth curvilinear rise of the volume-time tracing to a plateau of at least 1 second's duration;
  - If a test fails to exhibit an expiratory plateau, a forced expiratory time (FET) of 15 seconds; or
  - When the patient cannot or should not continue forced exhalation for valid medical reason

## Flow-volume Characteristics of Acceptable and Unacceptable Spirometry

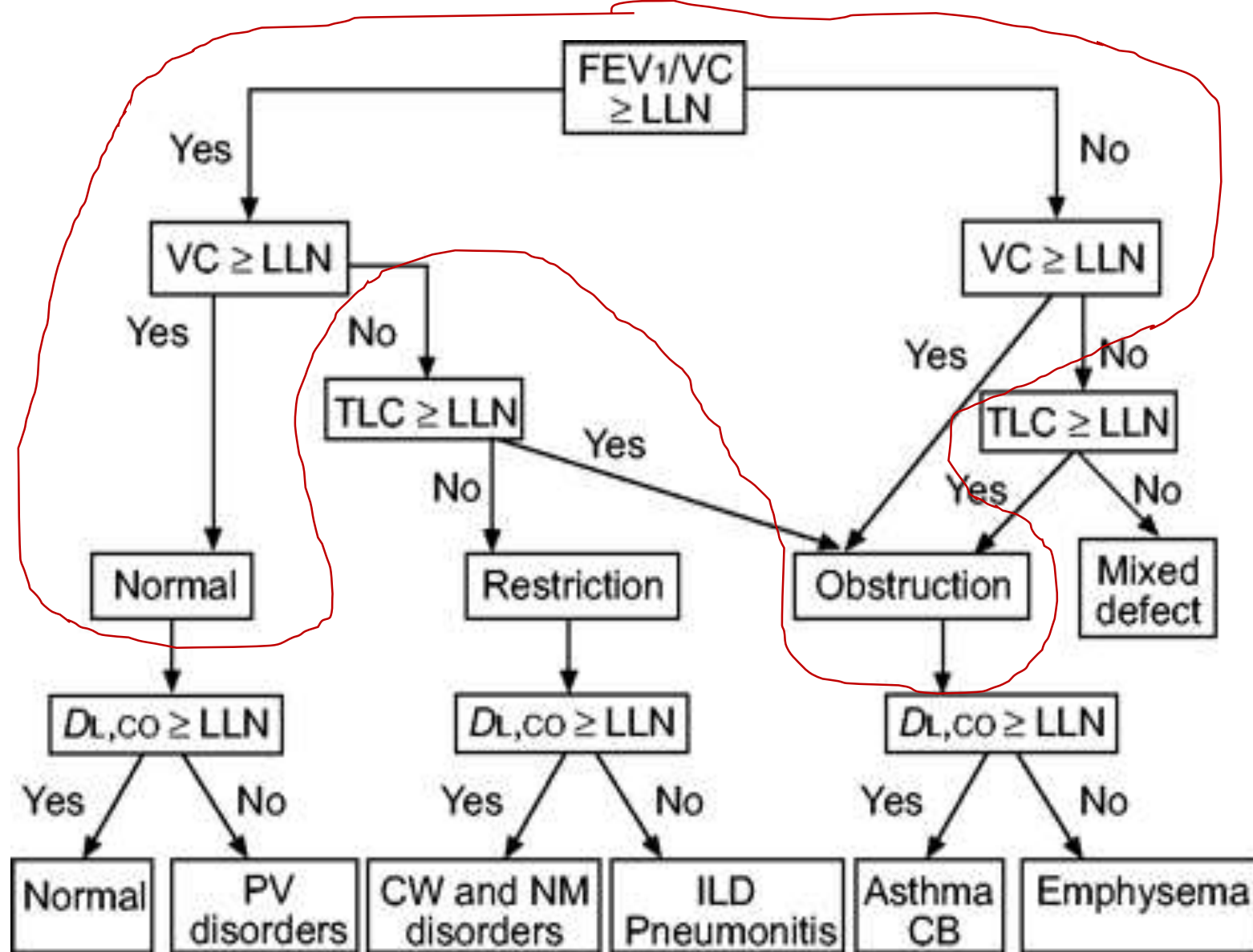


1. Instantaneous start of exhalation
2. Rapid rise in flow to peak flow
3. Sharp peak occurring early in exhalation
4. Smooth continuous fall in flow without interruptions
5. Gradual fall in low flow to IV
6. Smooth continuous inhalation to TLC
7. Reproducible shape



1. Slow start
2. Slow rise in flow
3. Broad late peak
4. Erratic flow (cough or vocal cord) dysfunction
5. Abrupt return to zero flow
6. Incomplete inhalation
7. Non-reproducible

# PFT Interpretive Strategy



# Spirometry and Obstructive Physiology

- **Obstructive Physiology = FEV1/FVC Ratio < Predicted LLN**
- In the past a fixed ratio of <70% was used to define obstructive physiology
- Currently the WHO Gold Criteria for COPD uses a fixed ratio of 70%

# ATS Defined Severity of Obstruction is Based on FEV<sub>1</sub> % pred

Degree of severity	FEV <sub>1</sub> % pred
Mild	>70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

## Severity of airflow limitation in COPD (based on postbronchodilator FEV<sub>1</sub>)

In patients with FEV <sub>1</sub> /FVC <0.7:		
GOLD 1	Mild	FEV <sub>1</sub> ≥80 percent predicted
GOLD 2	Moderate	50 percent ≤ FEV <sub>1</sub> <80 percent predicted
GOLD 3	Severe	30 percent ≤ FEV <sub>1</sub> <50 percent predicted
GOLD 4	Very severe	FEV <sub>1</sub> <30 percent predicted

FEV<sub>1</sub>: forced expiratory volume in one second; FVC: forced vital capacity; respiratory failure: arterial partial pressure of oxygen (PaO<sub>2</sub>) less than 60 mmHg (8 kPa) with or without arterial partial pressure of CO<sub>2</sub> (PaCO<sub>2</sub>) greater than 50 mmHg (6.7 kPa) while breathing ambient air at sea level.

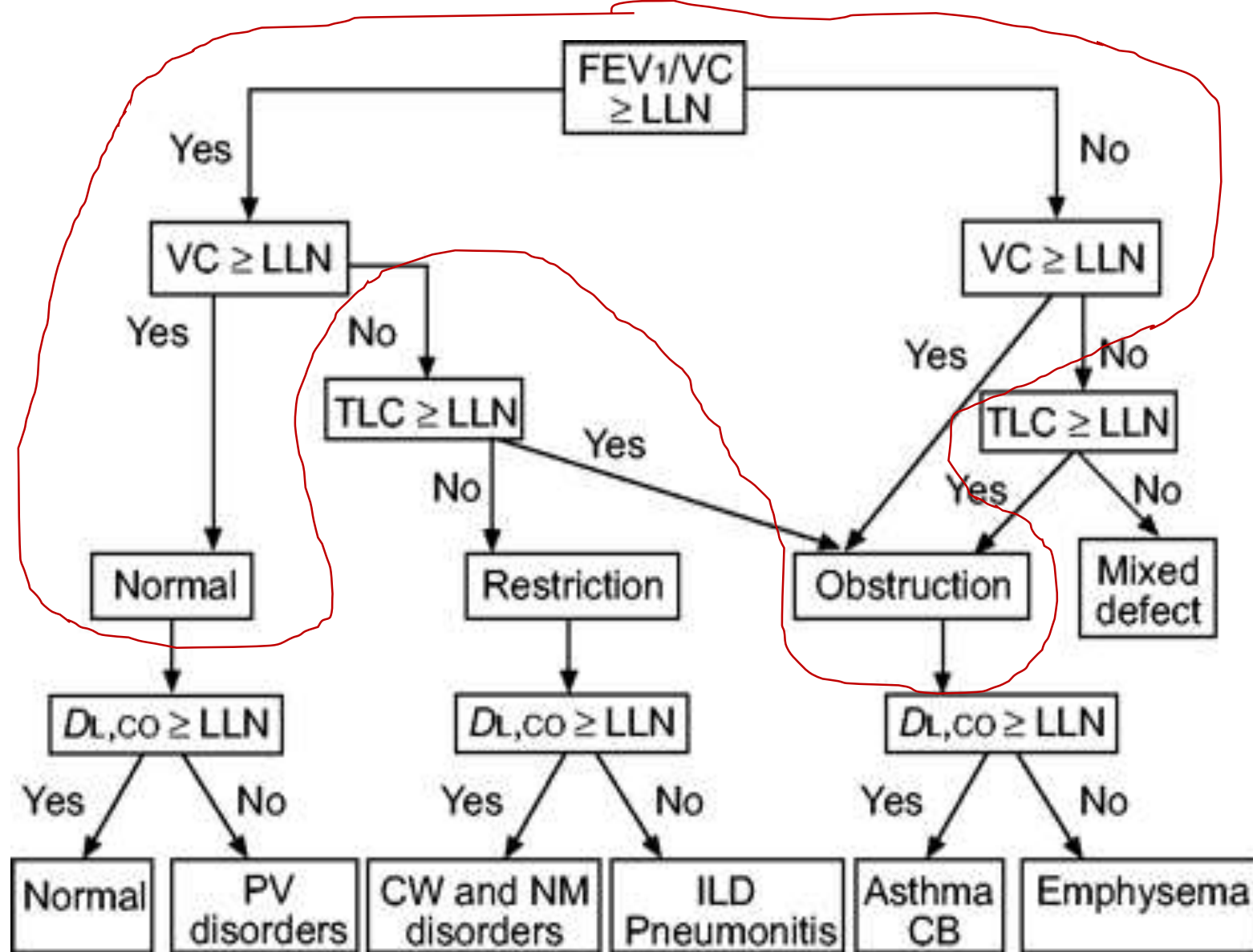
*From the Global Strategy for the Diagnosis, Management and Prevention of COPD 2013, Global Initiative for Chronic Obstructive Lung Disease (GOLD), [www.goldcopd.org](http://www.goldcopd.org).*

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# Spirometry and Post-Bronchodilator Response

- Compare pre- and post- FEV<sub>1</sub> and FVC.
- The currently recommended criteria in adults for a significant response to a bronchodilator are that FEV<sub>1</sub> and/or FVC should increase by 12 percent or more AND by at least 200 mL.

# PFT Interpretive Strategy





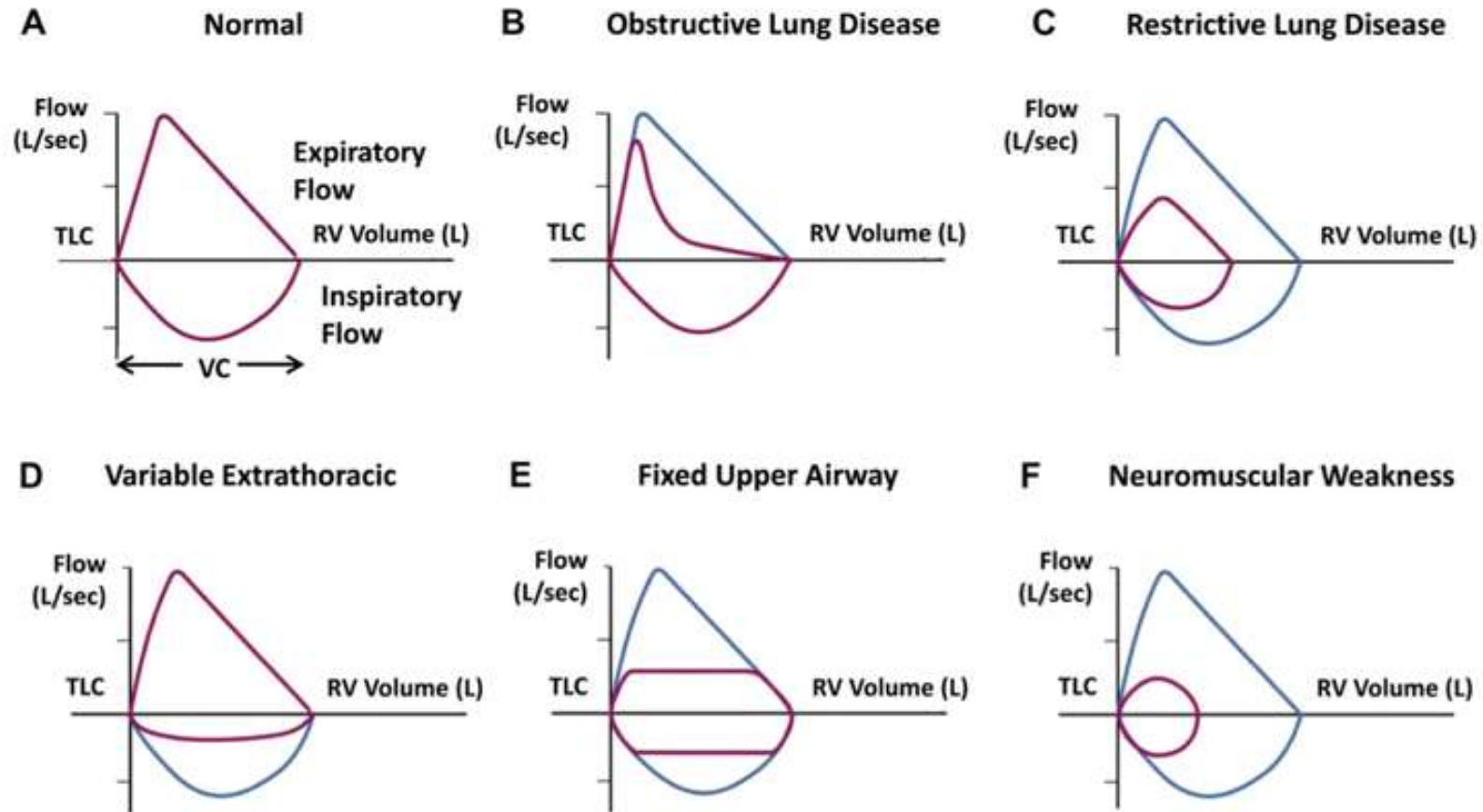
# Spirometry and Restrictive Physiology

- FEV<sub>1</sub>/FVC Ratio > LLN pred – No evidence of obstruction
- However if FVC actual value (in liters) less than LLN predicted – consistent with restrictive physiology
- Severity of restriction from spirometry alone is based on the FEV<sub>1</sub> %pred

Degree of severity	FEV <sub>1</sub> % pred
Mild	>70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

- Gold standard for restrictive physiology is Lung Volumes

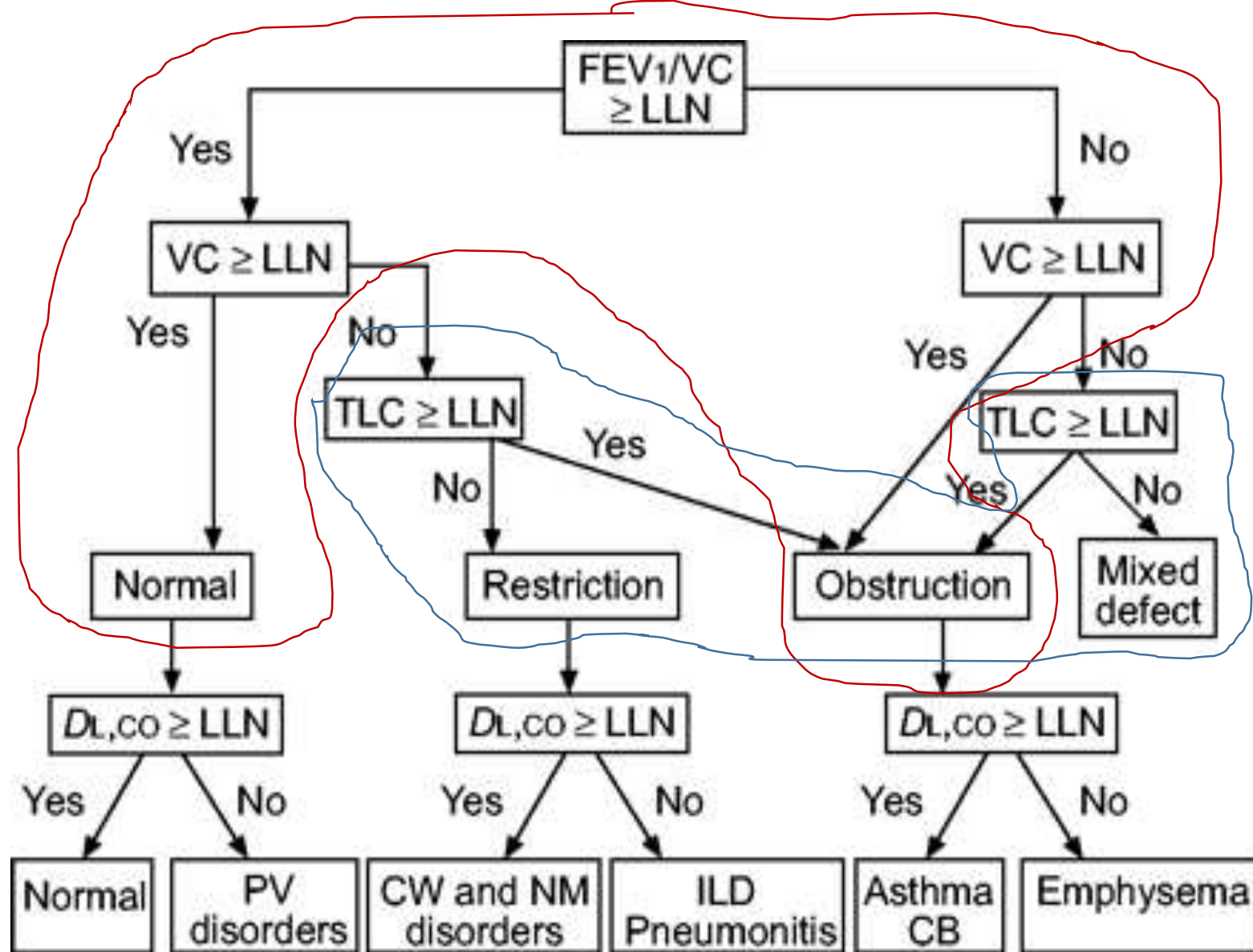
# Spirometry and Flow Volume Loop



# Lung Volumes



# PFT Interpretive Strategy

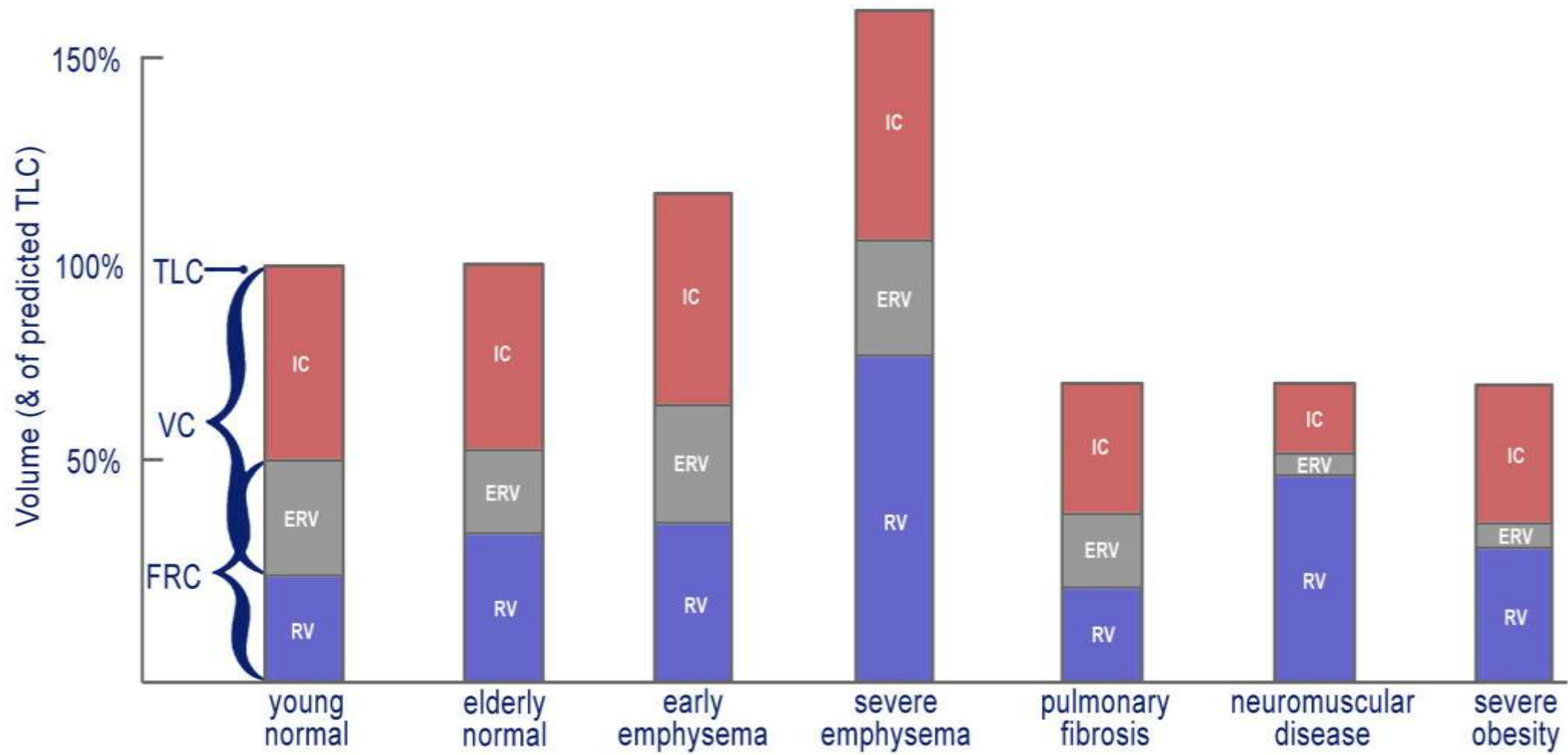


# Lung Volumes and Restriction

- The test is most reliably interpreted as showing restrictive abnormality on the basis of total lung capacity.
- The presence of Restrictive Physiology is based on  $TLC < LLN \text{ pred}$
- The severity of the abnormality is based on
  - FEV<sub>1</sub>

Degree of severity	FEV <sub>1</sub> % pred
Mild	>70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

- TLC (much less validated) – use if there is no spirometry
  - Mild: Predicted TLC < LLN but  $\geq 70\%$
  - Moderate: Predicted TLC < 70% and  $\geq 60\%$
  - Moderately severe: Predicted TLC < 60%



# Non-Specific Pattern

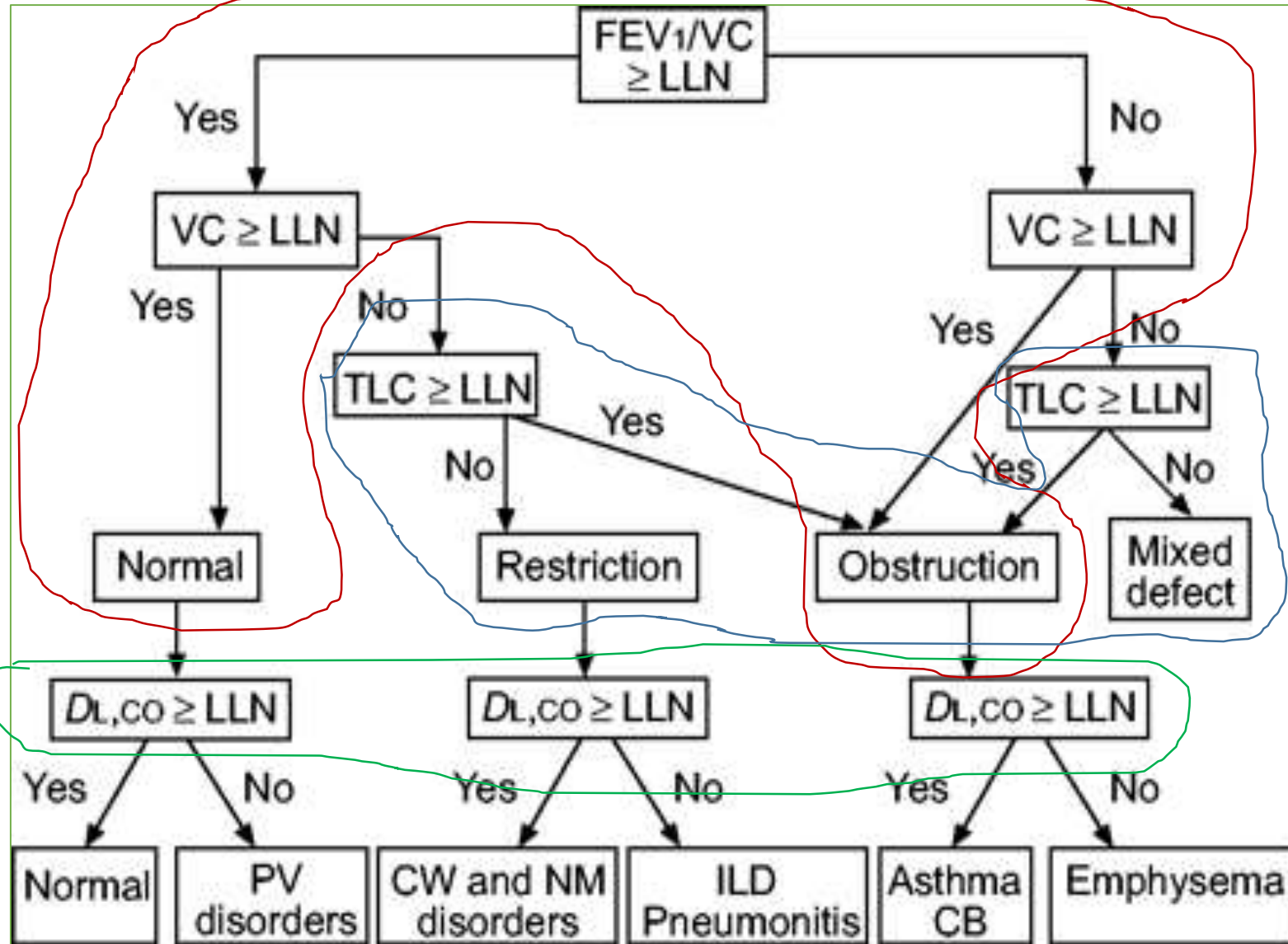
- Actually a thing
- Reduced FEV1 and FVC *with a* Normal FEV1/FVC *and* Normal TLC
- Stable pattern 2/3 of the time
  - Of the other 1/3
    - ½ progress to restriction
    - ½ progress to restriction

# Diffusing Capacity

- A high DL,CO is associated with asthma, obesity and intrapulmonary hemorrhage.
- Adjustments of DL,CO for changes in hemoglobin and carboxyhemoglobin are important.



# PFT Interpretive Strategy



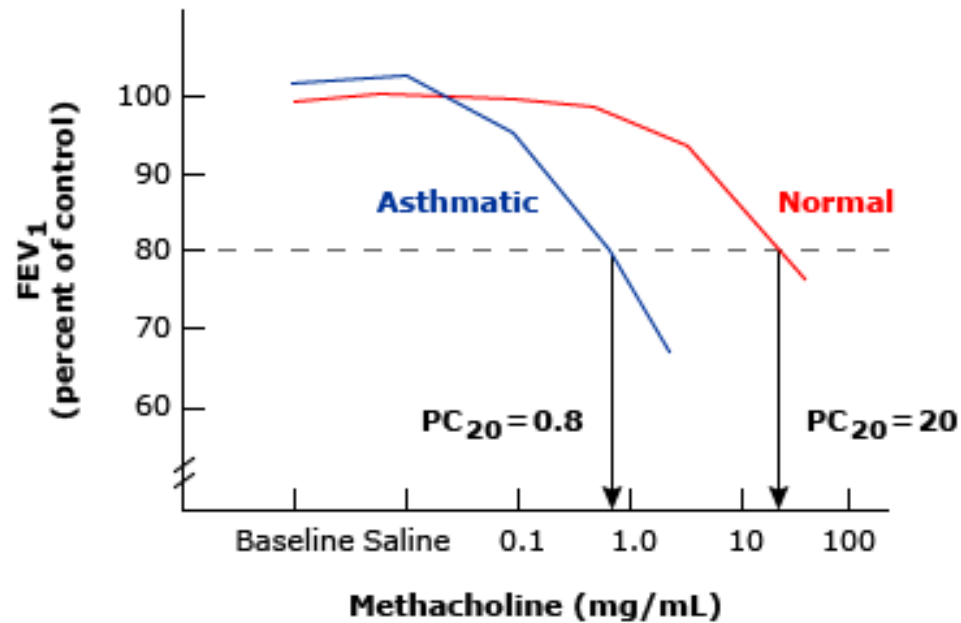
Adjust for Hb

# Diffusion Capacity – Severity

Degree of severity	$D_{L,CO}$ % pred
Mild	>60% and <LLN
Moderate	40–60%
Severe	<40

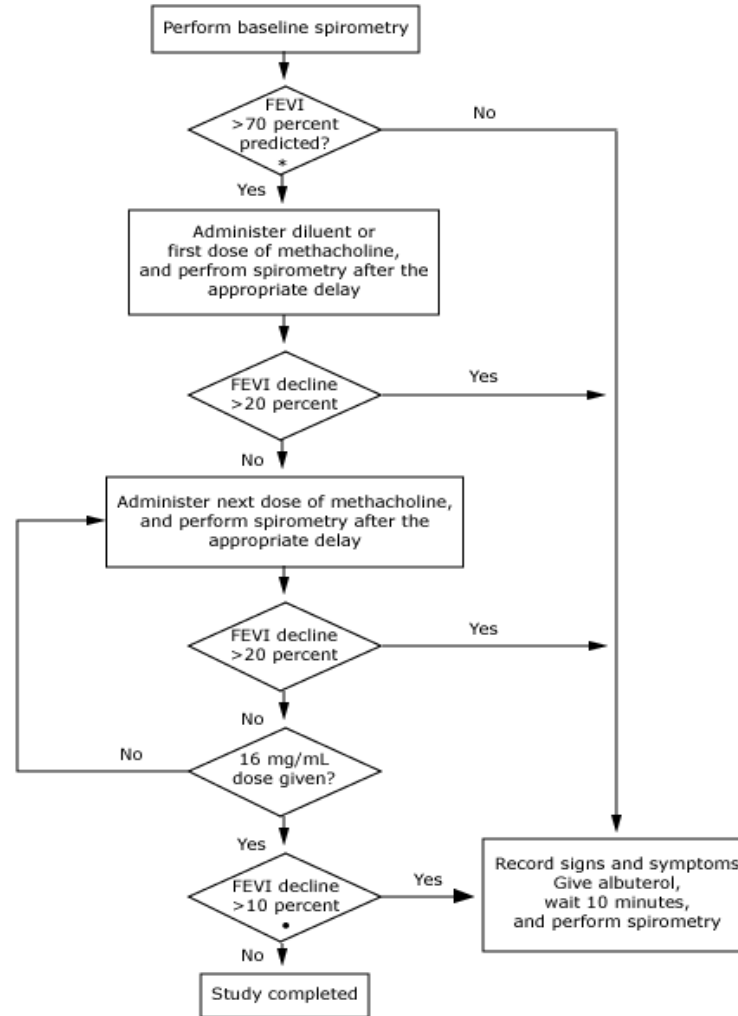
# Bronchprovocation Testing

## Bronchoprovocation testing



The effect of increasing the inhaled dose of methacholine in a healthy subject (red) and an asthmatic patient (blue). The provocative concentration is the amount of inhaled agonist required to drop the FEV<sub>1</sub> by 20 percent from the baseline (PC<sub>20</sub> FEV<sub>1</sub>) and is much less in the asthmatic than in the normal subject: 0.8 mg/mL versus 20 mg/mL. In general, a PC<sub>20</sub> ≤ 8 mg/mL is consistent with asthma; and a PC<sub>20</sub> > 16 mg/mL is considered a negative test. Thus, an increase in airway responsiveness is characterized by a decrease in the PC<sub>20</sub>.

## Methacholine challenge testing sequence



\* The choice of the FEV1 value considered a contraindication may vary from 60 to 70 percent of predicted.

• The final dose may vary depending on the dosing schedule used. Final doses discussed in this statement are 16, 25 and 32 mg/mL.

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# Methacholine Challenge Testing

- A 20% decrease in FEV1 is considered a positive test.
- Severity based on the dose of methacholine at which the PD20 (PC20) occurred.

Methacholine Dose (mg/ml)	Result
> 16	Normal Bronchial Responsiveness
4-16	Borderline Bronchial Hyper-responsiveness
1-4	Mild Bronchial Hyper-responsiveness
<1	Moderate-Severe Bronchial Hyper-responsiveness

# Eucapnic Voluntary Hyperventilation

- Stimulus is hyperventilation
  - Reported as % of MVV
  - $MVV = 35 \times FEV1$
  - Target Ventilation for adequate test = 60% MVV (21 x FEV1)
- A 10% decrease in FEV1 consistent with exercised induced bronchial hyper-responsiveness

- Severity:

% Decrease in FEV1	Result
<10	Normal Bronchial responsiveness
10.0 – 19.9	Mild Bronchial Hyper-responsiveness
20.0 – 29.9	Moderate Bronchial Hyper-responsiveness
>30	Severe Bronchial Hyper-responsiveness

## Medications that may affect bronchoprovocation challenge test

Medication	Minimum time to omit medication before challenge tests
<b>Inhaled bronchodilators</b>	
Albuterol	8 hours
Metaproterenol	8 hours
Terbutaline	8 hours
Ipratropium	24 hours
Salmeterol	48 hours
Formoterol	48 hours
Tiotropium	1 week
<b>Oral bronchodilators</b>	
Liquid theophylline	12 hours
Intermediate-acting theophylline	24 hours
Long-acting theophylline	48 hours
Albuterol tablet	12 hours
Long-acting albuterol tablet	24 hours
<b>Inhaled glucocorticoid*</b>	2-3 weeks
<b>Oral glucocorticoid*</b>	2-3 weeks
<b>Mast cell stabilizers</b>	
Cromolyn sodium	8 hours
<b>Antihistamines<sup>†</sup></b>	
Diphenhydramine	72 hours
Chlorpheniramine	72 hours
Hydroxyzine	72 hours
Cetirizine	72 hours
<b>Leukotriene modifiers</b>	
Montelukast	24 hours
Zafirlukast	24 hours

\* The authors do not recommend routinely withholding inhaled or oral glucocorticoids, but their antiinflammatory effect may decrease bronchial responsiveness. A negative test while the patient is using glucocorticoids implies that the patient's current symptoms are not due to asthma.

<sup>†</sup> Antihistamines are discontinued because of their anticholinergic effect.



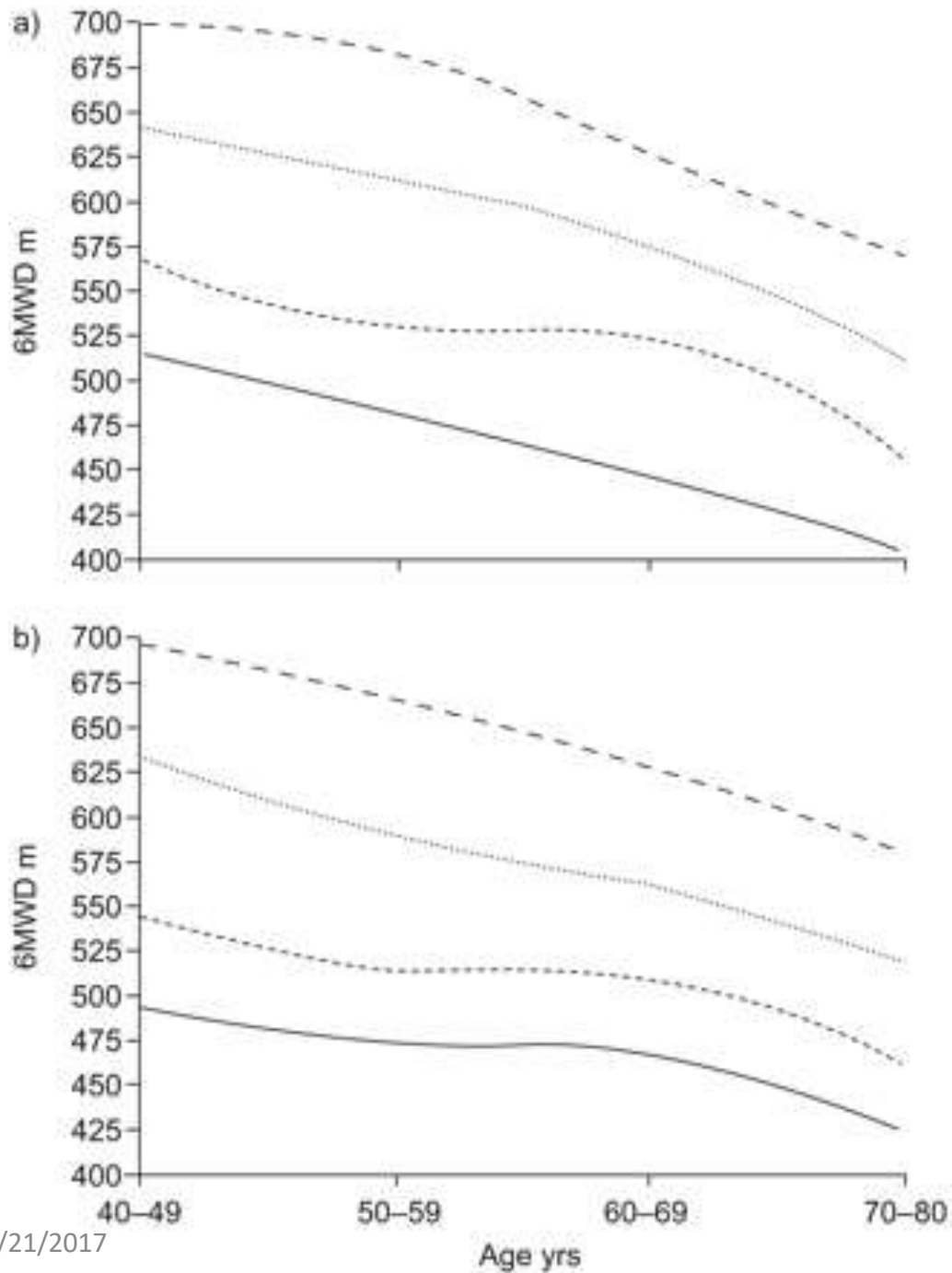
# Six Minute Walk

- Good index of physical function and therapeutic response in patients with chronic lung disease, such as COPD, pulmonary fibrosis, or PAH
  - Correlates well with important outcomes including death.
  - Is it different from a previous test?
- Interpretation
  - How far can the patient walk in 6 minutes?
    - Healthy subjects can typically walk 400 to 700 m (Males walked 30 m more than females )
    - Available evidence suggests an improvement of about 30 m in distance walked is the minimally important difference
  - What is the reason for stopping?
    - Borg Scale, others
  - Did the patient maintain their oxygen saturation during the walk?
    - Greater than 4% drop from resting saturation = “Desaturation”
    - Oxygen saturation < 88% is an indication for oxygen

# REFERENCE EQUATIONS FOR 6-MIN WALK DISTANCE IN HEALTHY ADULTS

- Men
  - $6\text{MWD} = (7.57 \times \text{height}_{\text{cm}}) - (5.02 \times \text{age}) - (1.76 \times \text{weight}_{\text{kg}}) - 309 \text{ m.}$
  - Alternate equation using BMI\*:  $6\text{MWD} = 1,140 \text{ m} - (5.61 \times \text{BMI}) - (6.94 \times \text{age})$ 
    - When using either equation, subtract 153 m for the LLN
- Women:
  - $6\text{MWD} = (2.11 \times \text{height}_{\text{cm}}) - (2.29 \times \text{weight}_{\text{kg}}) - (5.78 \times \text{age}) + 667 \text{ m.}$
  - Alternate equation using BMI:  $6\text{MWD} = 1,017 \text{ m} - (6.24 \times \text{BMI}) - (5.83 \times \text{age})$ 
    - When using either equation, subtract 139 m for the LLN

Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. *Am J Respir Crit Care Med* 1998;158:1384–1387



- Predicted 6MWD =  $361 - (\text{age in yrs} \times 4) + (\text{height in cm} \times 2) + (\text{HR}_{\text{max}}/\text{HR}_{\text{max}} \% \text{ pred} \times 3) - (\text{weight in kg} \times 1.5) - 30$  (if females).

## The modified Borg Scale for assessing the intensity of of dyspnea or fatigue

0	Nothing at all
0.5	Very, very slight (just noticeable)
1	Very slight
2	Slight (light)
3	Moderate
4	Somewhat severe
5	Severe (heavy)
6	
7	Very severe
8	
9	
10	Very, very severe (maximal)

This Borg scale should be printed on heavy paper (11 inches high and perhaps laminated) in 20-point type size. At the beginning of the 6-minute exercise, show the scale to the patient and ask the patient this: "Please grade your level of shortness of breath using this scale." Then ask this: "Please grade your level of fatigue using this scale." At the end of the exercise, remind the patient of the breathing number that they chose before the exercise and ask the patient to grade their breathing level again. Then ask the patient to grade their level of fatigue, after reminding them of their grade before the exercise.

### Sources:

1. Reproduced with permission from: Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982; 14:377. Copyright © 1982 Lippincott Williams & Wilkins.
2. Reproduced with permission from: the American Thoracic Society. ATS statement: Guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002; 166:111.

# Reporting

# My Phrases - Spirometry

- **Spirometry is normal.** (FEV1/FVC Ratio > LLN and FVC > LLN)
- **Spirometry shows mild obstruction.** (FEV1/FVC Ratio <LLN and FEV1 >70% pred)
- **Spirometry shows moderate obstruction.** (FEV1/FVC Ratio <LLN and FEV1 60-69% pred)
- **Spirometry shows moderately severe obstruction.** (FEV1/FVC Ratio <LLN and FEV1 50-59% pred)
- **Spirometry shows severe obstruction.** (FEV1/FVC Ratio <LLN and FEV1 35-49% pred)
- **Spirometry shows very severe obstruction.** (FEV1/FVC Ratio <LLN and FEV1 <35% pred)
- **Spirometry shows no evidence of obstruction.** (FEV1/FVC Ratio > LLN)
- **Spirometry consistent with restrictive physiology, consider lung volumes to confirm.** (FEV1/FVC Ratio > LLN and FVC < LLN)

# My Phrases – Post Bronchodilators

- **Significant bronchodilator response is seen.** (FEV<sub>1</sub> and/or FVC increase by at least 12% and by at least 200 mL)
- **No significant bronchodilator response is seen, however, lack of response does not predict lack of therapeutic response.** (FEV<sub>1</sub> and/or FVC did not increase by at least 12% and by at least 200 mL)

# My Phrases – Lung Volumes

- **Normal lung volumes.** (TLC > LLN)
- **Lung Volumes show mild restriction.** (TLC < LLN and FEV1 >70% pred)
- **Lung Volumes show moderate restriction.** (TLC < LLN and FEV1 60-69% pred)
- **Lung Volumes show moderately severe restriction.** (TLC < LLN and FEV1 50-59% pred)
- **Lung Volumes show severe restriction.** (TLC < LLN and FEV1 35-49% pred)
- **Lung Volumes show very severe restriction.** (TLC < LLN and FEV1 <35% pred)
- **Lung volumes show hyperinflation** (TLC > 140% pred)
- **Lung Volumes show air trapping** (RV > 140% pred)



# My Phrases – Diffusing Capacity

- **Normal diffusion capacity.** (DLCO > LLN pred)
- **Diffusion capacity is high.** (DLCO >120% pred)
- **Diffusion capacity is mildly decreased.** (DLCO >60% and < LLN pred)
- **Diffusion capacity is moderately decreased.** (DLCO 40-60% pred)
- **Diffusion capacity is severely decreased.** (DLCO < 40% pred)

# My Phrases – Six Minute Walk

- **This study was performed on supplemental oxygen.**
- **This study was performed on Room Air.**
- **The patient walked greater than the predicted distance indicating no potential exercise intolerance. (Distance > LLN pred)**
- **The patient walked less than the predicted distance indicating potential exercise intolerance. (Distance < LLN pred)**
- **There was no evidence of desaturation on room air. (Change in O2 saturation  $\leq$  4%)**
- **There was no evidence of desaturation on supplemental oxygen. (Change in O2 saturation  $\leq$  4%)**
- **There was a significant desaturation during this study on room air. (Change in O2 saturation  $\geq$  4%)**
- **There was a significant desaturation during this study on supplemental oxygen. (Change in O2 saturation  $\geq$  4%)**
- **The level of desaturation met the criteria for supplemental oxygen. (Saturation < 88%)**

# My Phrases – Bronchoprovocation

- **The methacholine study show normal bronchial responsiveness. (PC20 >16)**
- **The methacholine study shows borderline bronchial hyper-responsiveness. (PC20 4-16)**
- **The methacholine study shows mild bronchial hyper-responsiveness. (PC20 1-4)**
- **The methacholine study shows moderate-severe bronchial hyper-responsiveness. (PC20 <1)**
- **The eucapnic voluntary hyperventilation study shows normal bronchial responsiveness. (FEV1 decrease < 10%)**
- **The eucapnic voluntary hyperventilation study shows mild bronchial hyper-responsiveness. (FEV1 decrease 10.0-19.9%)**
- **The eucapnic voluntary hyperventilation study shows moderate bronchial hyper-responsiveness. (FEV1 decrease 20.0-29.9%)**
- **The eucapnic voluntary hyperventilation study shows severe bronchial hyper-responsiveness. (FEV1 decrease  $\geq$  30%)**

# My Phrases - Other

- **There is flattening of the inspiratory limb.**
- **There is flattening of the expiratory limb.**
- **There is flattening of both the inspiratory and expiratory limb.**
- **The MIP is decreased consistent with inspiratory muscle weakness.**  
(MIP < LLN pred)
- **The MEP is decreased consistent with expiratory muscle weakness.**  
(MEP < LLN pred)