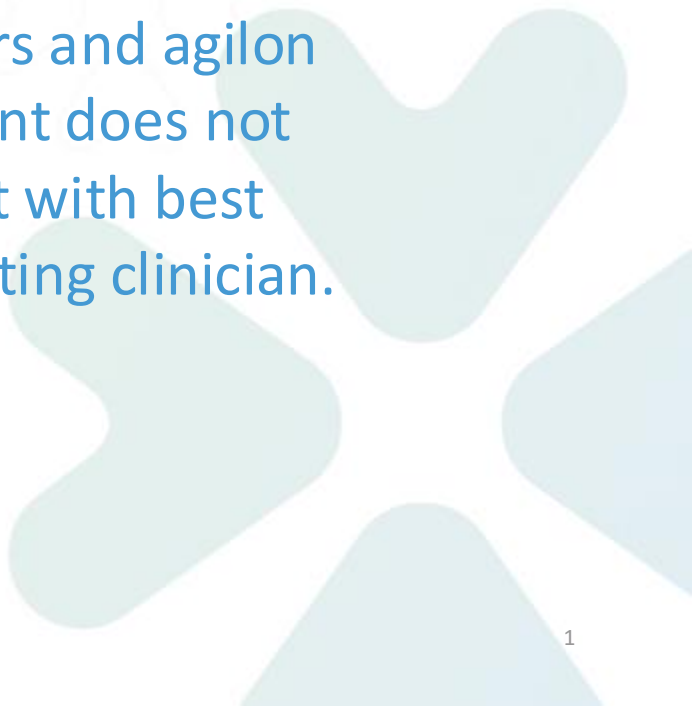


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# Making Sense of the Curves:

## Practical Interpretation of Spirometry for Clinicians

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## Disclosures or Conflicts of Interest: None

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# Agenda/Learning Objectives

-  Review the key components of spirometry, including flow-volume loops, FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC ratio.
-  Differentiate obstructive, restrictive, and mixed ventilatory patterns based on spirometric criteria.
-  Recognize common pitfalls and sources of error in spirometry testing and interpretation.

# Agenda



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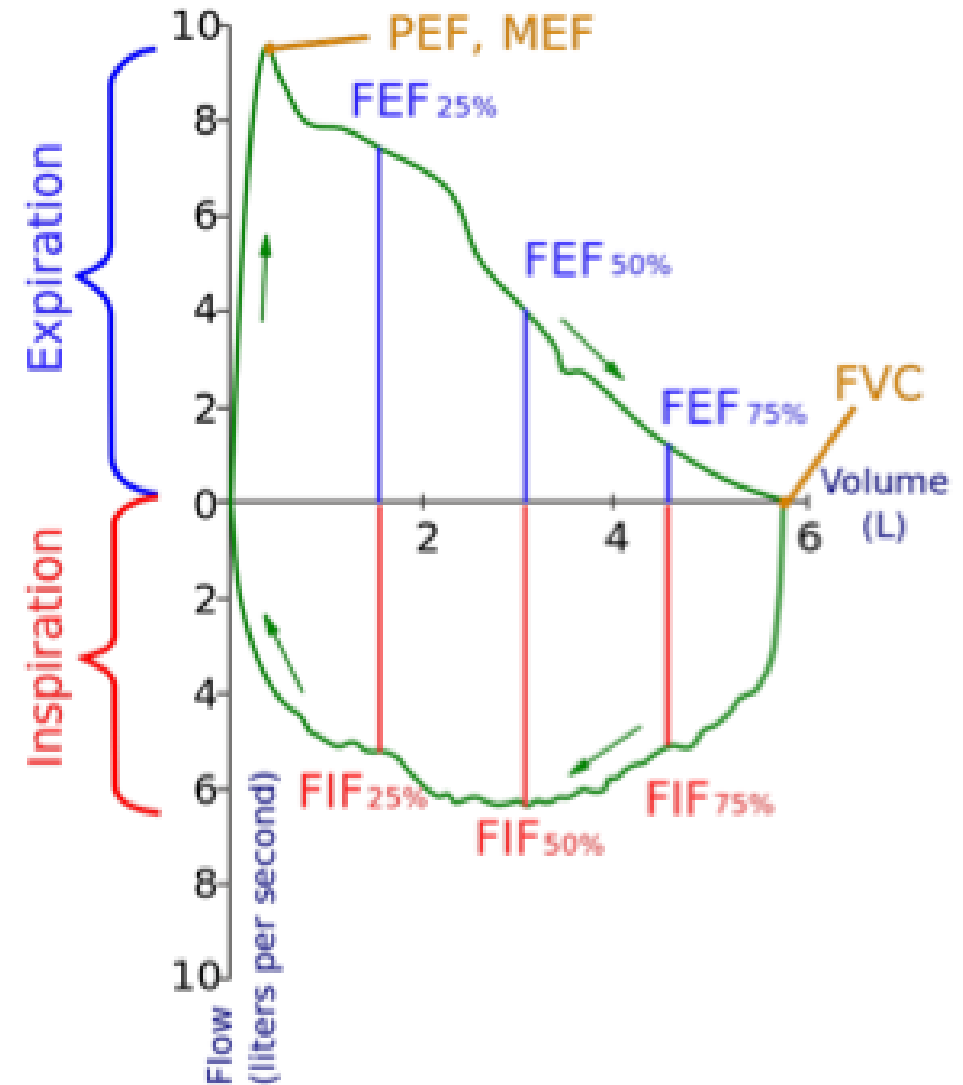
Recognize common pitfalls and sources of error in spirometry testing and interpretation.

# Indications for Spirometry/PFTs

- Chronic dyspnea at rest or with exertion
- Chronic cough
- Suspicion for pulmonary disease
  - Asthma
  - COPD
  - Bronchiectasis
  - Bronchiolitis
  - Upper airway obstruction
  - ILD
- Suspicion for neuromuscular, chest wall disease, diaphragmatic weakness
- Pre-operative evaluation
- Screen for those at risk of lung disease (occupational exposures, drug toxicity)
- Disability assessment

# Key Measures of Spirometry

- Measures the volume of air exhaled at specific time points during a forceful and complete exhalation after a maximal inhalation
  - FVC = Forced vital capacity (total exhaled volume after max inspiration)
  - FEV<sub>1</sub> = forced expiratory volume in one second
  - FEV<sub>1</sub>/FVC ratio
  - For validity, typically patient must exhale for at least 6 seconds to ensure a effective full exhalation
  - SVC = slow vital capacity
    - Data collected over 30 seconds, useful when FVC is reduced and airway obstruction patient



# Spirometry vs Full Pulmonary Function Testing

## Spirometry

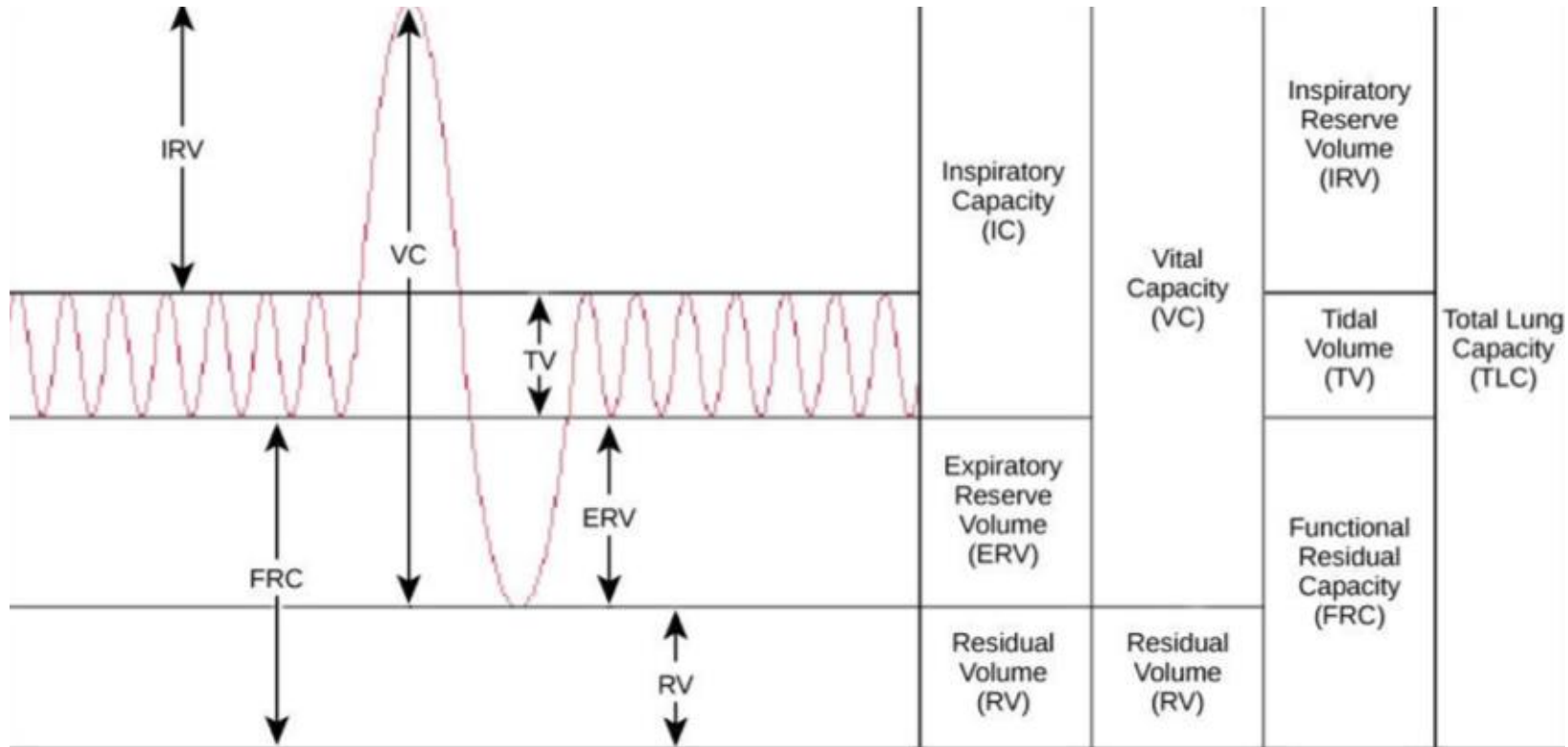
- Flow-volume loops (which can suggest lung disease categories via pattern recognition)
- Spirometry (pre and post bronchodilator) can suggest airway obstruction (both fixed and reversible) and small airways disease
- More accessible/potentially more feasible to deploy in primary care offices

## Pulmonary Function Testing

- Gives all data of Spirometry plus:
  - Lung Volumes
  - Diffusion capacity for carbon monoxide
  - Can additionally perform
    - supine spirometry
    - maximal inspiratory/maximal expiratory pressure (MIP/MEP), helpful for suggesting neuromuscular weakness
    - Bronchoprovocative testing (i.e. methacholine challenge) to elucidate asthma that lacks obstruction on baseline PFTs
- Often requires more specialized equipment/facilities, more frequent calibration, and may require referral to a dedicated pulmonary function testing facility or pulmonology.
- However, can better elucidate defects in lung gas exchange and lung restriction

# Lung Volumes

- Body plethysmography (AKA body box) gold standard, and may not be included in standard spirometry
- Vital Capacity (VC): Maximum volume exhaled after maximum inspiration; can be forced (FVC) or slow (SVC) exhalation
- Functional Residual Capacity (FRC): Volume of air remaining in chest at end of a tidal volume of breath
- Residual Volume (RV): volume of air remaining in chest after maximal expiration
- Expiratory Reserve Volume (ERV): volume of air exhaled from end-tidal volume (FRC) to point of maximal exhalation (RV); so  $RV + ERV = FRC$
- Inspiratory Capacity (IC): maximum inspiration from end-tidal volume (FRC) to lung capacity
- Total Lung Capacity (TLC): volume of air in lung at end of maximal inspiration ( $RV + VC$  or  $FRC + IC$ )



# Lung Volumes

- In obstruction
  - TLC may be increased (TLC > 120% = hyperinflation)
  - RV may be increased (RV > 140% = air trapping)
  - RV/TLC ratio may be increased
- Decrease in FVC and FEV<sub>1</sub> with ratio > 70 suggests restriction (need lung volumes to confirm)
  - If FVC is < 80% and TLC < 80%, this confirms restriction
  - Severity of restriction is based on FVC
    - Mild 60-<80% (or LLN)
    - Moderate 51-59%
    - Severe ≤ 50%
- Restriction can be due to several etiologies
  - Normal DLCO typically extra-thoracic restriction, can be chest wall issues, abdominal issues (including obesity, pregnancy, ascites), neuromuscular weakness, or diaphragmatic weakness
  - Low DLCO suggests an intra-thoracic restriction, can be due to pulmonary fibrosis or interstitial lung disease

# Agenda

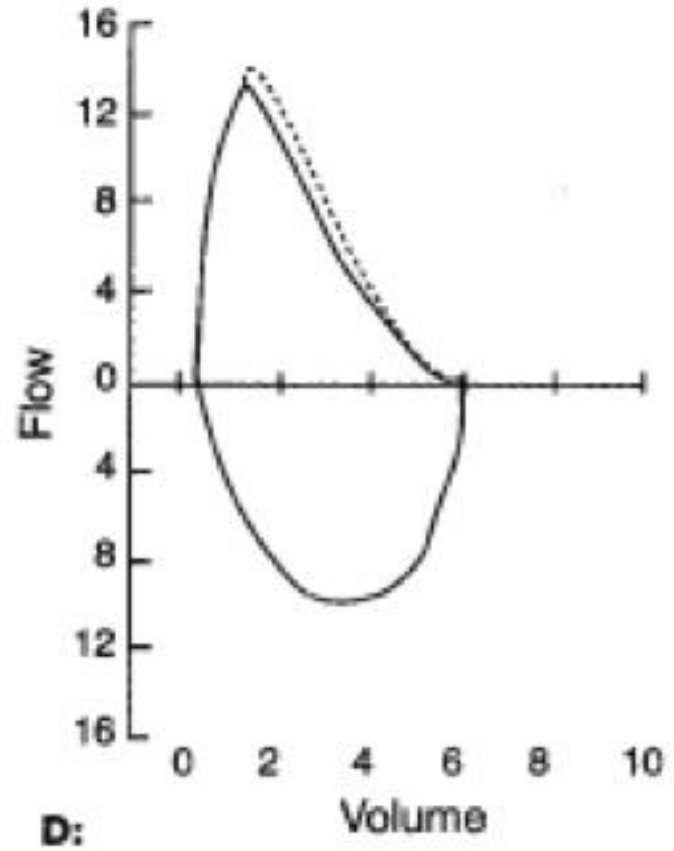
Review the key components of spirometry, including flow-volume loops, FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC ratio.



**Differentiate obstructive, restrictive, and mixed ventilatory patterns based on spirometric criteria.**

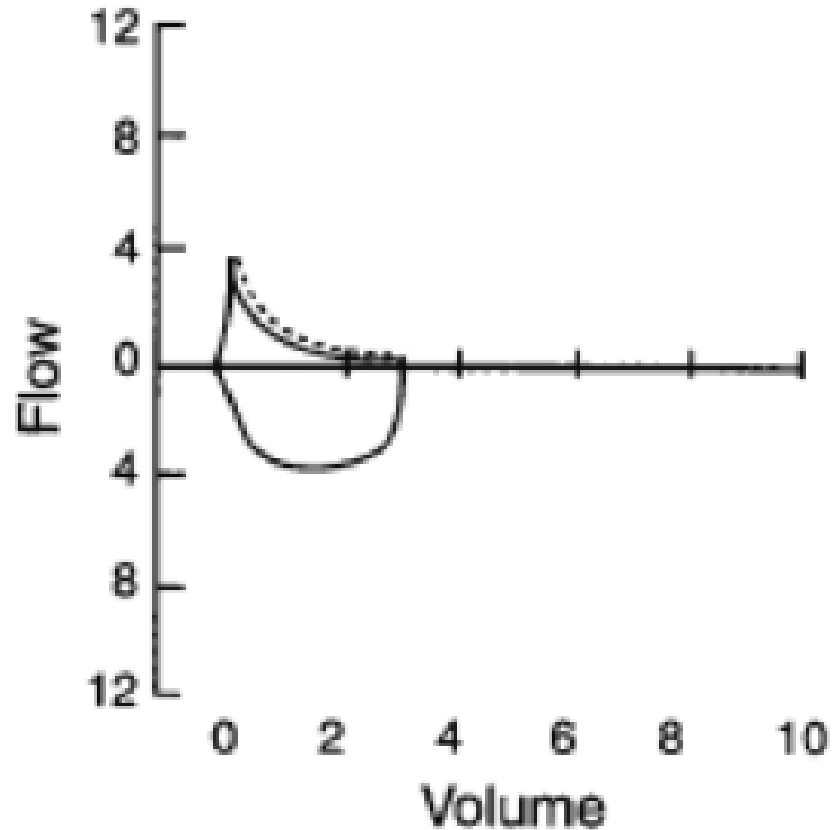
Recognize common pitfalls and sources of error in spirometry testing and interpretation.

# Flow Volume Loops: Normal



- Flow rate declines linearly and proportionally to volume
- Straight slope

# Flow Volume Loops: COPD



**A:** - - - - = After bronchodilator

- "Scooped-out" pattern or golf club lying flat pattern
- Decreased slope on expiratory curve
- No/minimal improvement with bronchodilators

# Spirometry: Obstruction

- $FEV_1/FVC < 0.70$  = obstruction
  - May lead to over-diagnosis in the elderly and under-diagnosis in the adults <45
  - Alternatively can use  $FEV_1/FVC < LLN$  with increasing use of Z-score based diagnosis (based on TORCH trial and GLI reclassification of spirometry)
  - COPD Z -score  $FEV_1/FVC < -1.64$ , severity stratified by Z score of  $FEV_1$ ,  $FEV_1$  Z-scores:  $\geq -1.64$  for mild;  $< -1.64$  but  $\geq -2.55$  for moderate; and  $< -2.55$  for severe
- Obstruction = COPD, asthma, bronchiectasis, bronchiolitis obliterans
- $FEV_1$  is used to grade the severity of obstruction

## GOLD

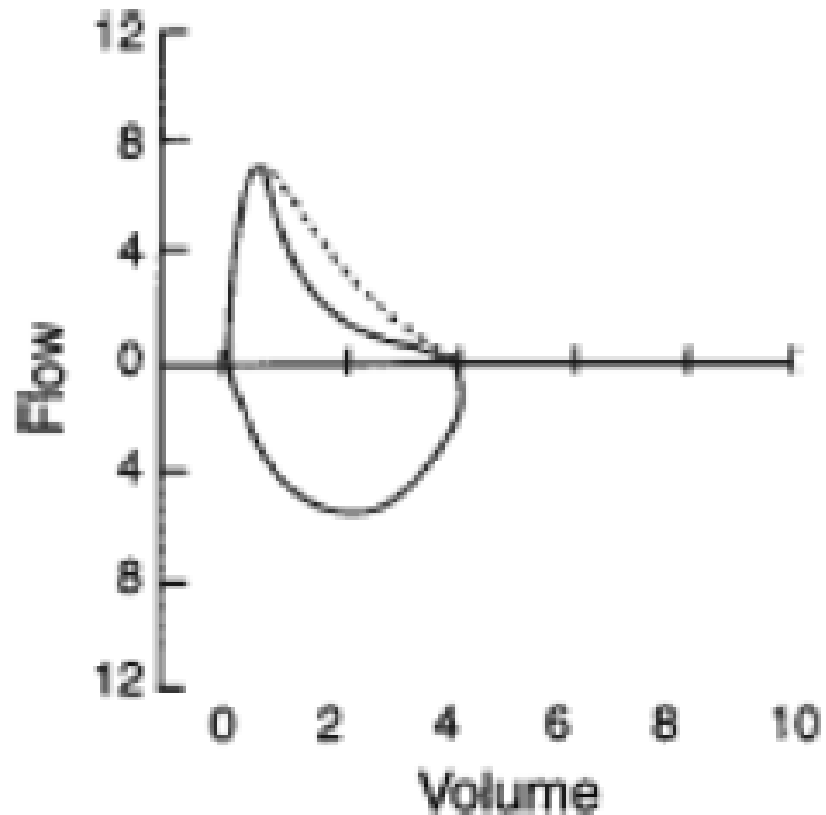
Severity of COPD	FEV1/FVC	FEV1 percent of Normal
Mild	$FEV_1/FVC < 0.70$	$FEV_1 > 80\%$ normal
Moderate	$FEV_1/FVC < 0.70$	$FEV_1 50\%-79\%$ normal
Severe	$FEV_1/FVC < 0.70$	$FEV_1 30\%-49\%$ normal
Very severe	$FEV_1/FVC < 0.70$	$FEV_1 < 30\%$ normal

## ATS

TABLE 6 Severity of any spirometric abnormality based on the forced expiratory volume in one second ( $FEV_1$ )	
Degree of severity	$FEV_1$ % pred
Mild	>70
Moderate	60-69
Moderately severe	50-59
Severe	35-49
Very severe	<35

% pred: % predicted.

# Flow Volume Loops: Asthma

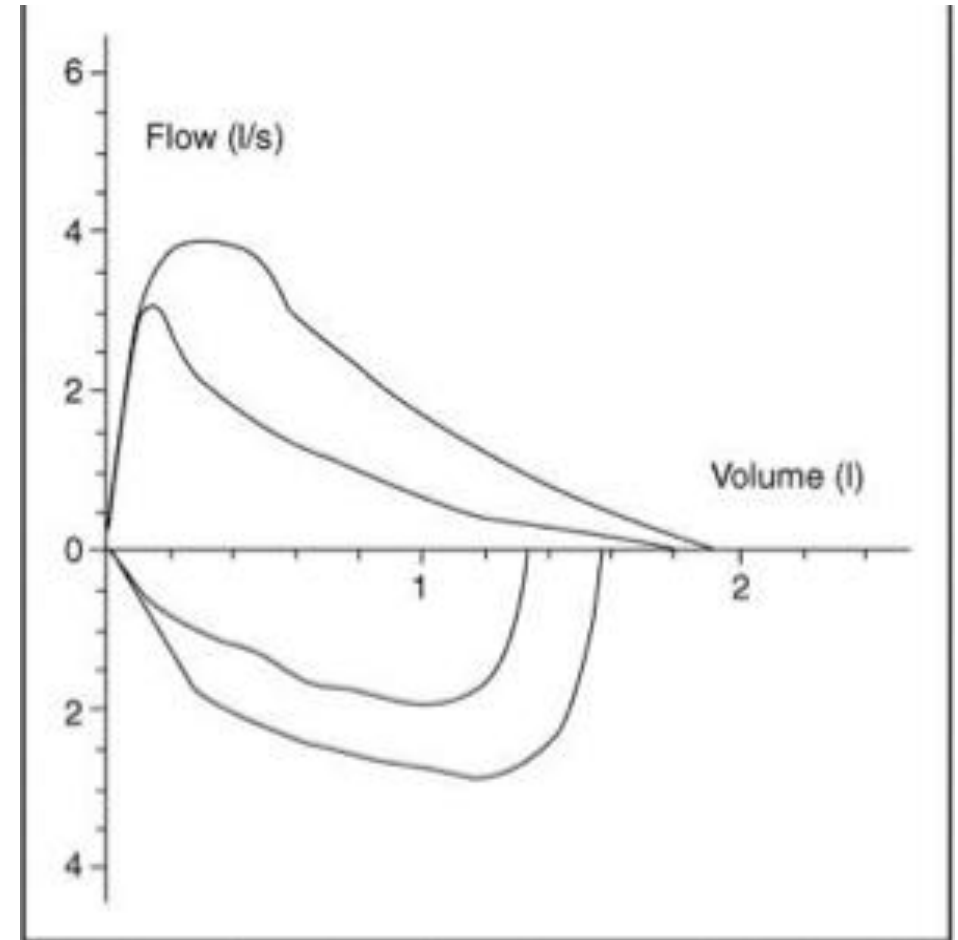


**B:** - - - - = After bronchodilator

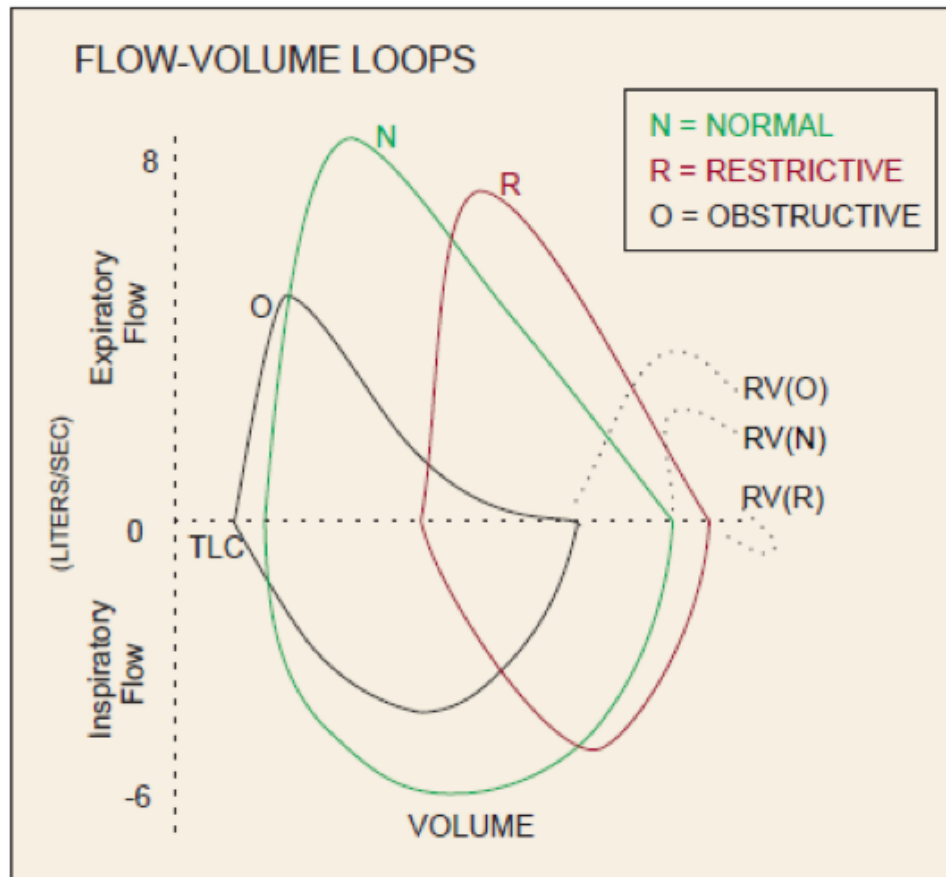
- “Scooped-out” pattern again, characteristic of obstruction
- Decreased slope on expiratory curve
- Improvement with bronchodilators

# Post-Bronchodilator Spirometry

- Assess degree of reversibility of airflow obstruction
- Order if baseline obstruction or if worry about asthma or COPD
- Typically administer albuterol 2-4 puffs followed by repeat spirometry 10-15 minutes later
- An increase of **200 ml** & **12% increase** in FEV<sub>1</sub> or FVC is consistent with a positive bronchodilator response, suggestive of reversible airway obstruction (more commonly seen in Asthma)
- Notably, a lack of bronchodilator response should not preclude clinical use of bronchodilators (i.e. fixed obstruction commonly seen in COPD doesn't mean the patient won't respond to bronchodilators )



# Flow-Volume Loops: Restriction



- Can be suggested by flow volume loops, but easier to grade severity with addition of lung volumes
- Marked by steeper slope on exhalation and overall smaller lung volumes

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# Common pitfalls

- Spirometry and Pulmonary Function Testing can be highly effort dependent, and require a motivated and cooperative patient. Coaching and encouragement from clinic staff can significantly improve performance!
- Note expiration must be at least 6 seconds to aid validity
- Coughing, hiccups, and pain/discomfort can lead to falsely foreshortened performance
- Language barriers, claustrophobia, white coat syndrome, or inattention/difficulty following commands can all impact performance as well
- Poor mouthpiece seals (from difficulty holding lips/jaw closed, dentures, etc) can also lead to leaks in the system/false studies
- Equipment also require regular inspection, and always confirm correct patient information (age, height, etc), are used to set normal ranges for interpretation

# Summary

1. Spirometry is likely underutilized in assessing common pulmonary complaints
2. In office spirometry can be a powerful tool for suggesting airway obstruction that can be indicative of asthma or COPD
3. Consider ordering/referring for full pulmonary function testing including lung volumes and DLCO for patients with concerns for restriction, or for patients with advanced COPD that may have significant reductions in DLCO that may suggest severity of disease and determine which interventions may be indicated/feasible
4. Obstruction is marked by a scooped-out appearance and decreased curve on expiration. The severity is graded by the reduction in the FEV<sub>1</sub>

Questions?

Answers.



CME Survey



**Thank You.**