Interpreting Office Spirometry

Jim Allen, MD
Medical Director, University Hospital East
Professor of Internal Medicine
Division of Pulmonary & Critical Care Medicine
The Ohio State University Wexner Medical Center

Objectives

1. Understand the indications for office spirometry
2. Understand the definitions of obstruction
3. Recognize common errors with data entry and performance of testing
4. Recognize common flow volume loop patterns

What do pulmonary function tests tell you?

- **Spirometry:**
  - **Identifies airflow obstruction**
- **Lung volumes**
  - **Identifies restriction and hyperinflation**
- **Diffusing capacity:**
  - **Measures how well gas exchanges from the air into the blood**

Pulmonary Function Test Lab


Office Spirometry
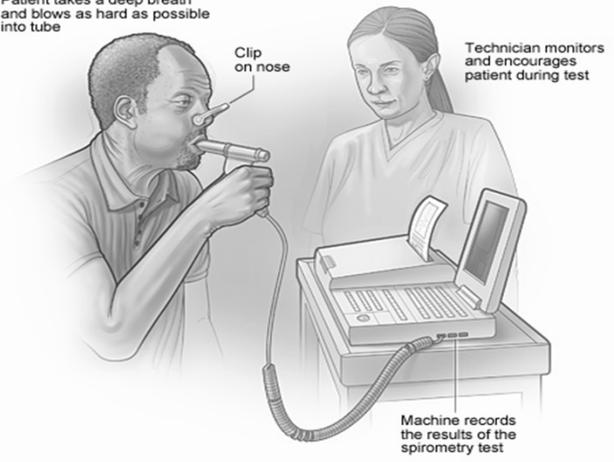
Indications For Spirometry

- Evaluation of unexplained dyspnea, cough, or wheezing
- Suspected COPD or asthma with no previous spirometry
- Known asthma or COPD with uncertain control
- Known asthma or COPD when assessing response to treatment
- Periodic assessment (every 1-2 years) of asthma to assess for changes in therapy
- Assessment of vital capacity in patients with known neuromuscular disease
- Pre-operative assessment in patients with known or suspected lung disease

Spirometry Abbreviations:

- FVC = forced vital capacity – amount of air that can be exhaled in one breath with maximum force
- FEV1 = forced expiratory volume in 1 second – amount of air that is exhaled in the first second with maximum force
- FEV1/FVC = ratio of the forced expiratory volume in 1 second to the forced vital capacity
- FEF25-75% = forced expiratory flow between the 25th and 75th percentile of an exhaled breath
- PF = peak flow rate – the highest flow rate achieved during expiration (also abbreviated PEF or PEFR)

Volume (L)

Flow (L per second)

Flow (L per second)

Flow (L per second)

FEF$_{25-75\%}$

Volume (L)

Flow (L per second)
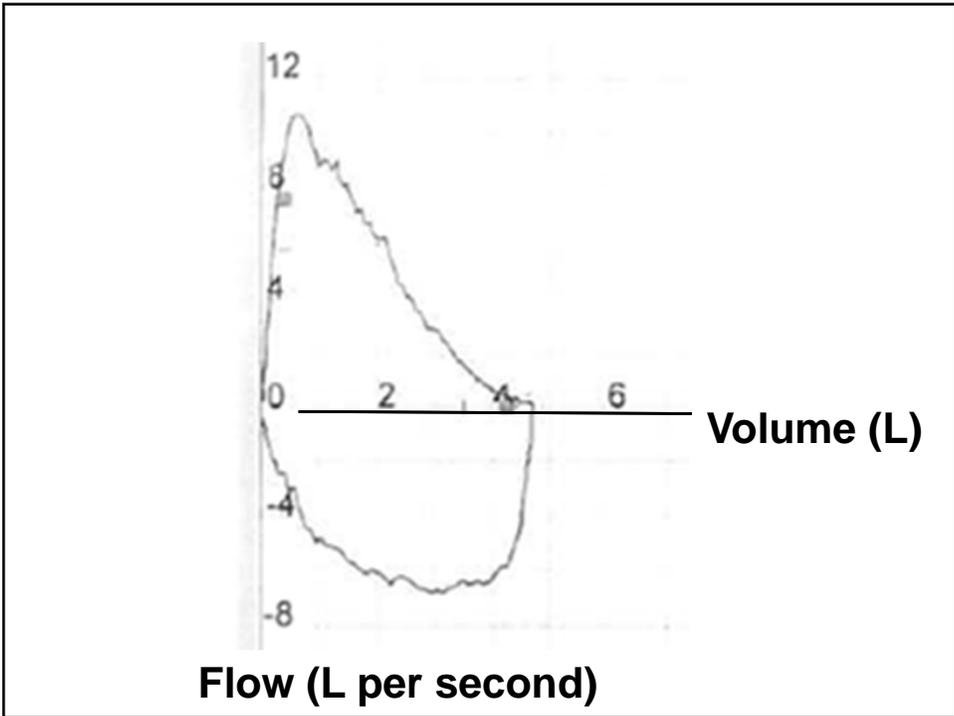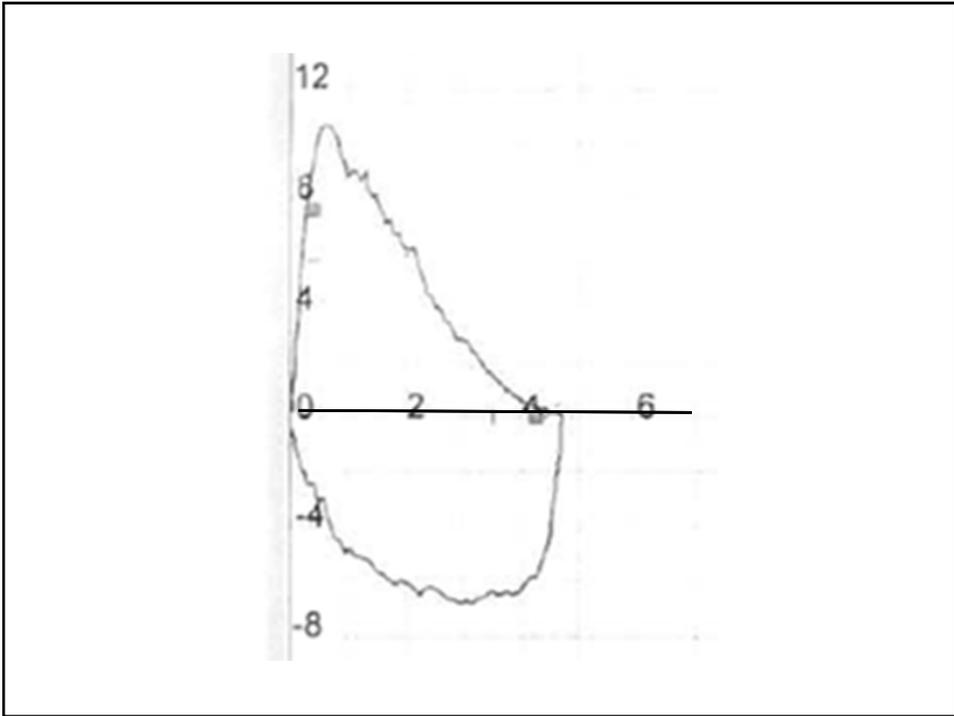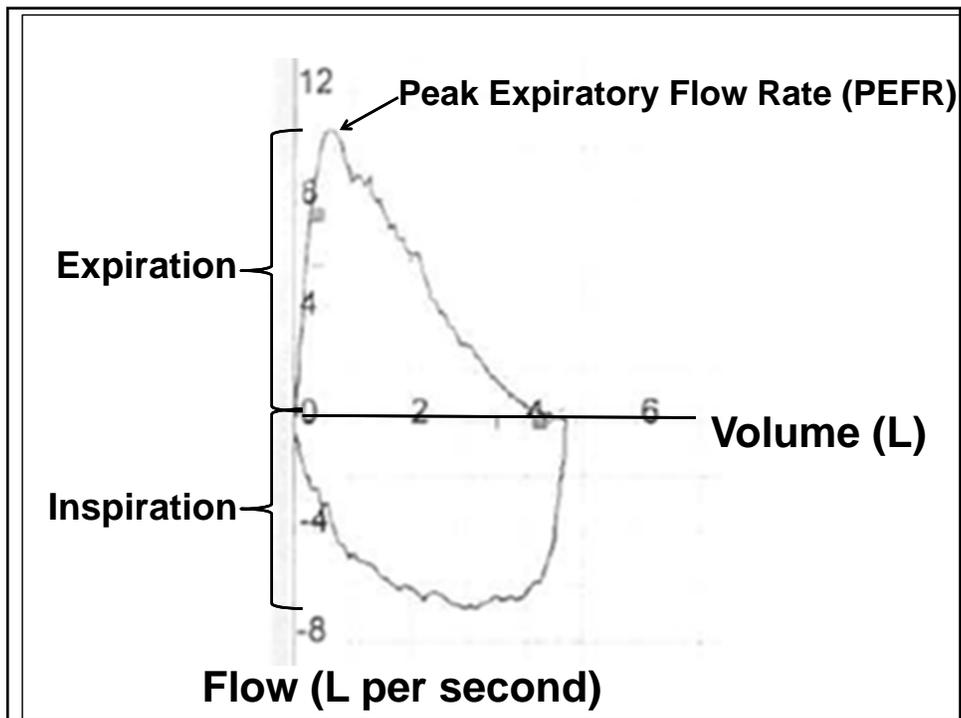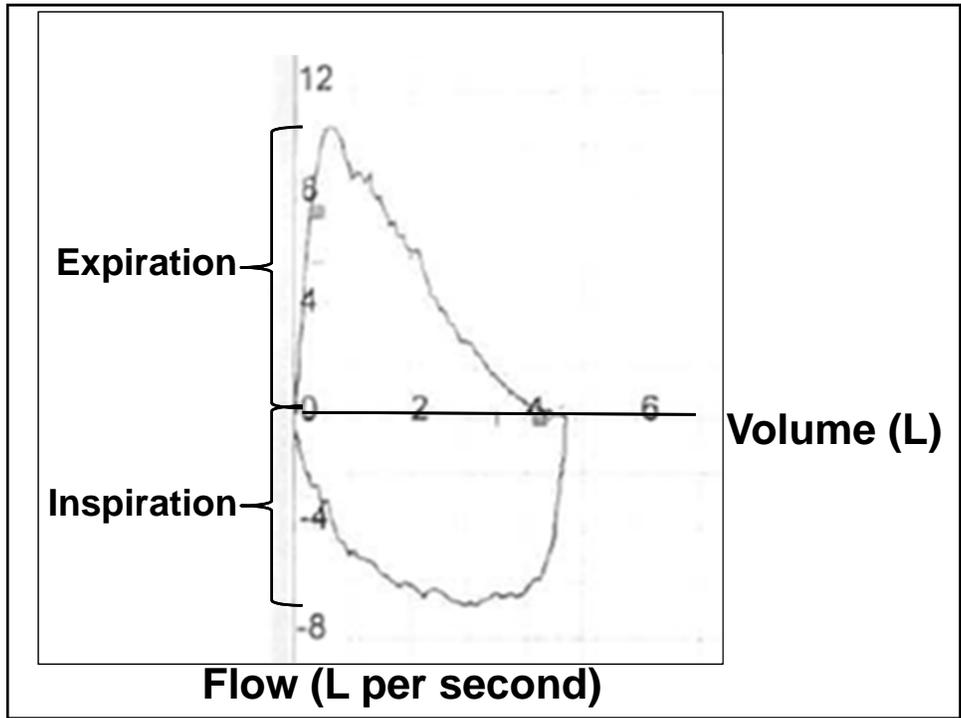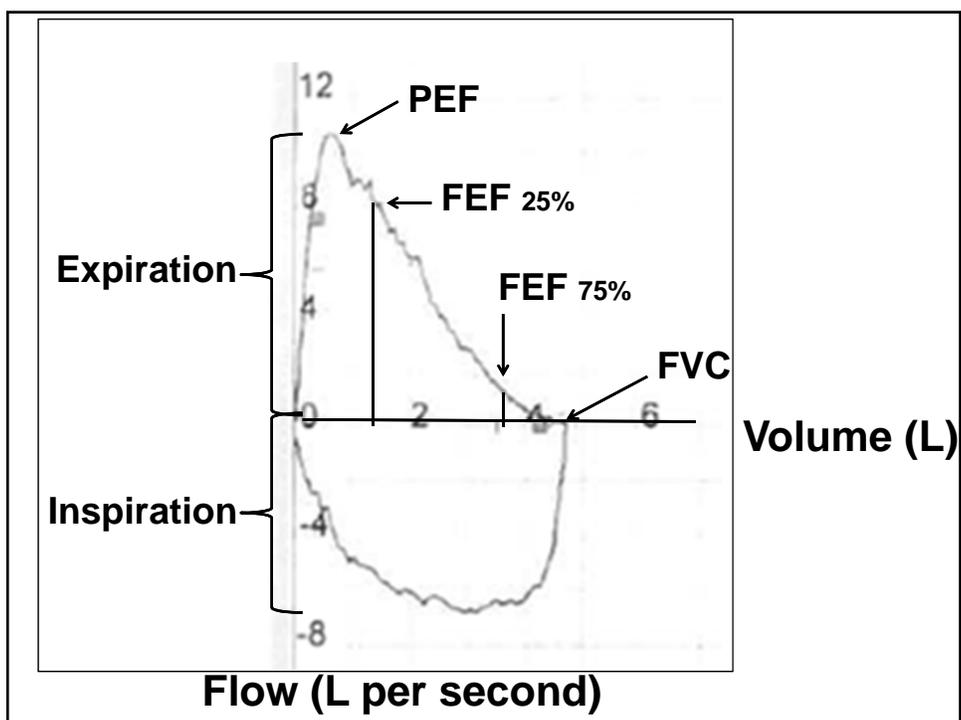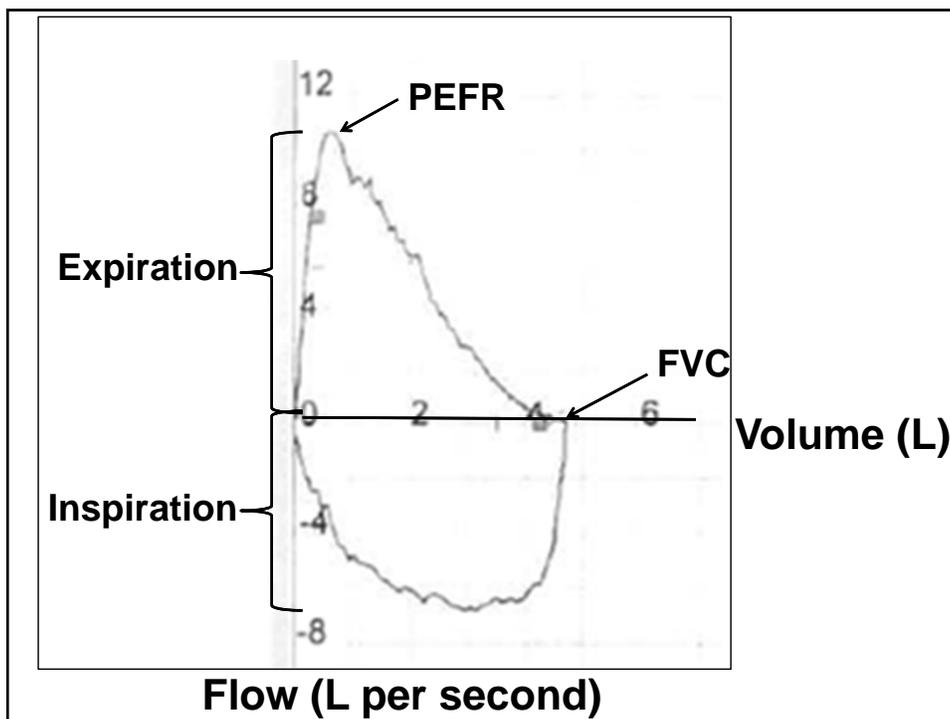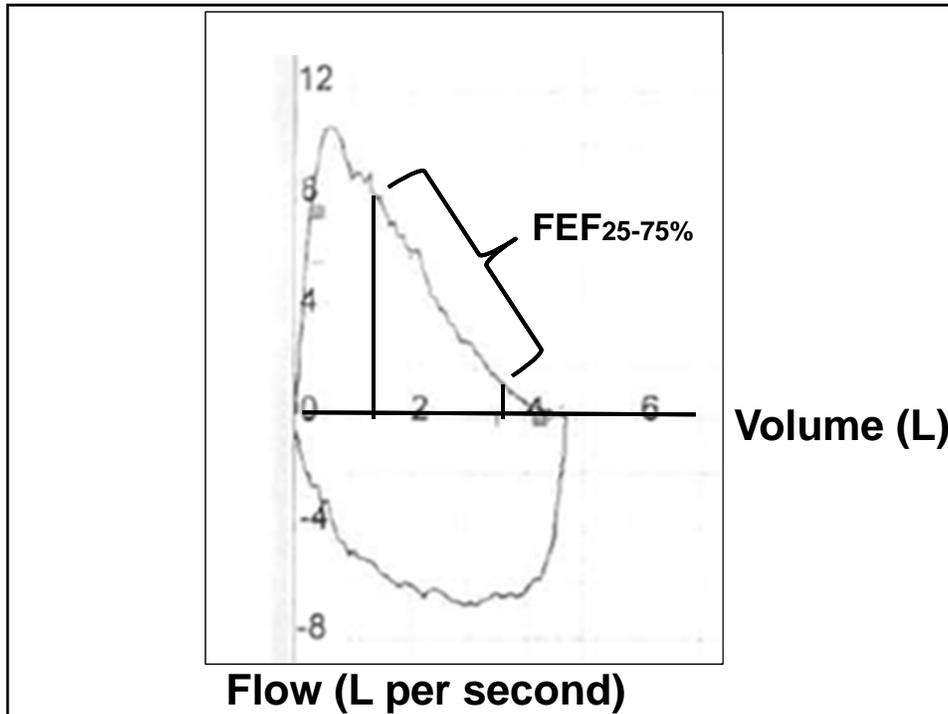
Defining Normal Values

- The FEV1 and FVC vary depending on age, gender, race, and height.
- Therefore (for example), the normal FEV1 for a 64 inch tall, 50-year old Caucasian woman will be very different than a 72 inch, 40-year old African American man
- Normal values are determined by doing spirometry on large numbers of people and grouping them by age, gender, race, and height and then creating large databases of normals

Databases of Normal Subjects

- **There are more than 50 different databases of normal subjects' spirometry values (most are for very specific racial or ethnic groups)**
- **A patient may be normal by comparison to one database but be mildly or even severely obstructed using a different database.**
- **Most office spirometers will allow you to choose among several databases pre-loaded into the spirometer's computer program**

Databases of Normal Subjects (continued)

- **The most common database of normal subjects used for spirometry in the United States is the NHANES III (National Health And Nutrition Examination Survey) published in 1999. This is sometimes listed under "Hankinson" for the name of the first author of the publication.**
- **The NHANES III (Hankinson) database is most commonly used for office spirometry**

9

Computer interpretation of spirometry

- Reasonably good at identifying normal
- The computer cannot interpret flow volume loop patterns
- For patients who are not normal, the computer interpretation is not always accurate and can give an incorrect interpretation in more than half of cases, depending on the population of patients being tested

A Spirometry Test Requires 3 Steps To Be Done Correctly

- Correct demographic information (age, height, gender, race)
- Correct technique used by the nurse or other provider administering the test
- Correct interpretation by the physician reading the test

A Spirometry Test Requires 3 Steps To Be Done Correctly

- Correct demographic information (age, height, gender, race)
- Correct technique used by the nurse or other provider administering the test
- Correct interpretation by the physician reading the test

Entering Demographics

- If demographic values are not entered, the computer cannot calculate the percent predicted values and only the raw numeric results will appear
- If the demographics are entered incorrectly, then the percent predicted values will be incorrect. Always check at the top of a spirometry result to be sure that the age, gender, and height look correct. Decimal point errors or incorrectly entering cm rather than inches are common sources of error

Incorrect Demographics

Result	Pred	Best	%Prd
FVC (L)	***	0.74	---
FEV1 (L)	***	0.28	---
FEV1/FVC	0.80	¤0.38	47%
FEF25-75% (L/s)	0.23	0.10	43%
PEFR (L/s)	1.29	1.36	106%

In this case, the height was incorrectly entered as 23 inches rather than the correct value of 60 inches for this 57-year old patient. Because there are no normal data sets for 23 inch women who are 57 years old, the predicted values for FVC and FEV1 are left blank. The predicted value for FEV1/FVC ratio is based off of age only and not height, so it is not affected.

A Spirometry Test Requires 3 Steps To Be Done Correctly

- **Correct demographic information (age, height, gender, race)**
- **Correct technique used by the nurse or other provider administering the test**
- **Correct interpretation by the physician reading the test**

Spirometry Administration

- Each spirometer will have slightly different instructions for preparing the equipment and performing the test. Be sure that your office staff are following the manufacturer's instructions for test performance
- In common to all spirometers, the patient will be required to inhale as deeply as possible and then exhale as hard and fast as they can until they have forced all air out of their lungs
- If the patient does not inhale as deeply as possible or exhale as forcefully or completely as possible, the results will not be valid

Spirometry Administration

1. Place a nose clip on the patient
2. Have the patient take as deep of a breath as possible
3. When instructed by the spirometer, tell the patient to "blast" their air out as hard and fast as they can
4. The patient should continue exhaling until they have exhaled at least 6 seconds and there is no further flow for at least 1 second. Nearly all patients will complete the exhalation maneuver in less than 15 seconds.

Spirometry Administration

- **Be sure there is no air leak around the mouthpiece**
- **If the patient coughs (especially in the first second), the trial is not valid**
- **At least 3 trials should be performed**
- **Trials are considered reliable if the FEV1 and FVC vary by less than 0.15 L between trials**
- **The computer will generally pick the trial with the largest FVC and FEV1 as the "best" trial and report it first**

Spirometry Demonstration

Spirometry Demonstration

A Spirometry Test Requires 3 Steps To Be Done Correctly

- Correct demographic information (age, height, gender, race)
- Correct technique used by the nurse or other provider administering the test
- Correct interpretation by the physician reading the test

Spirometry Interpretation

1. Determine if the flow-volume loop appears acceptable
2. Determine if the patient is obstructed by whether the FEV1/FVC ratio is below normal
3. If the patient is obstructed, determine how severe the obstruction is by how far below normal the FEV1 is

Flow Volume Loop Quality Killers

- **Cough**
- **Inserting tongue in the mouthpiece**
- **Air leak around the mouth**
- **Poor effort**
- **Stopping exhalation before the lungs are empty**
- **Glottic closure or hesitation during exhalation**

Normal Flow Volume Loop (PFT lab spirometer)

Expiratory limb
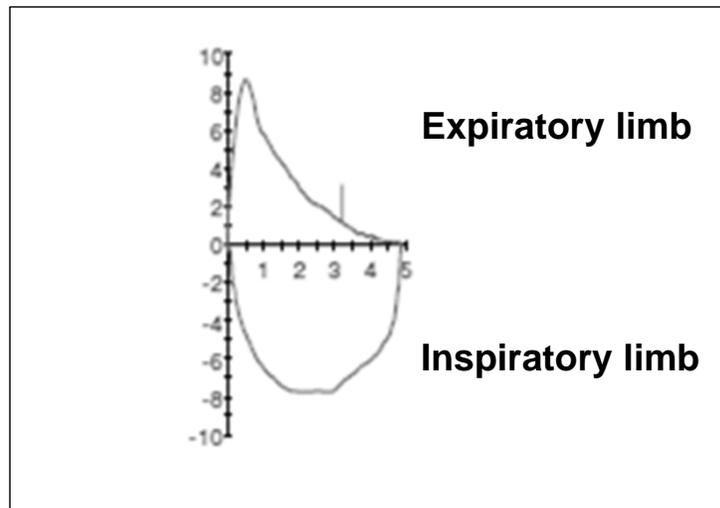
Inspiratory limb
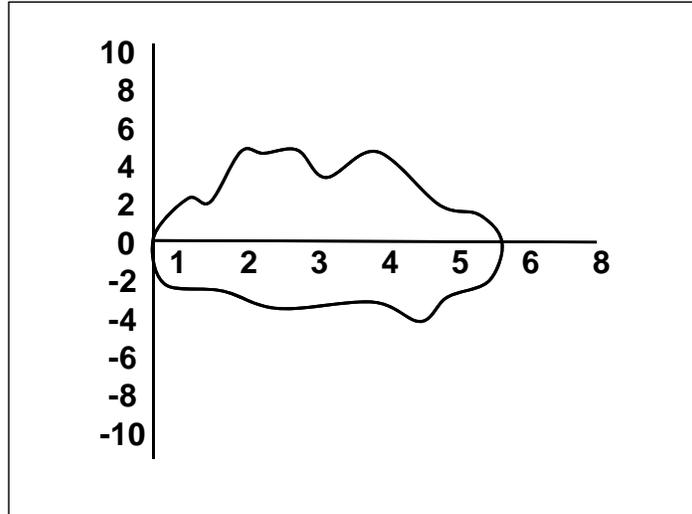
Invalid Test

Invalid Test: Patient Coughed During Expiration
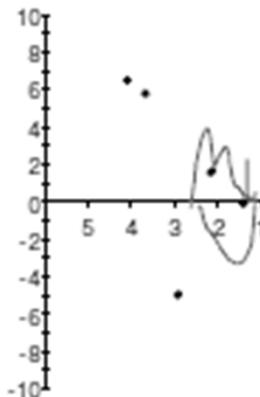
Note the "double-humped" pattern on the expiratory limb

Invalid Test: Poor Effort
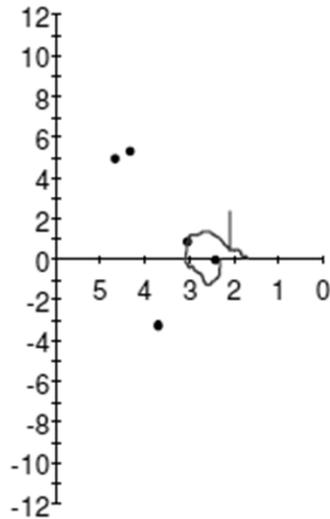
Invalid Test: Poor Effort
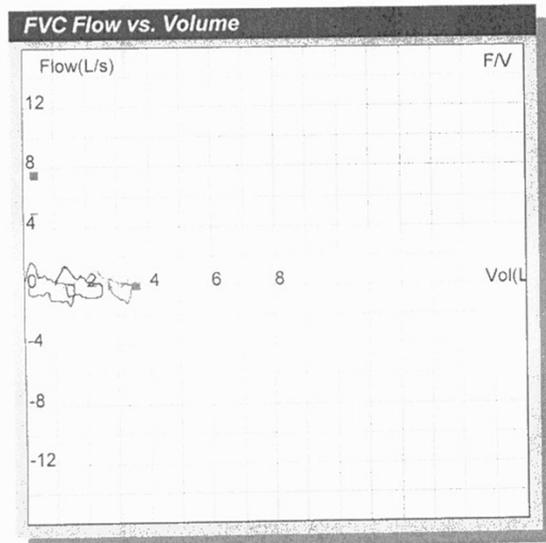
Normal Flow Volume Loop (office spirometer)
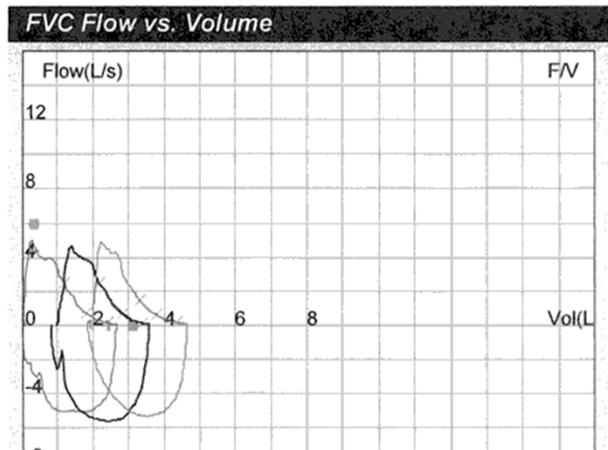
Note that there are 3 separate flow-volume loops all superimposed on one graph. This is typical for office spirometry

Normal Flow Volume Loop (office spirometer)
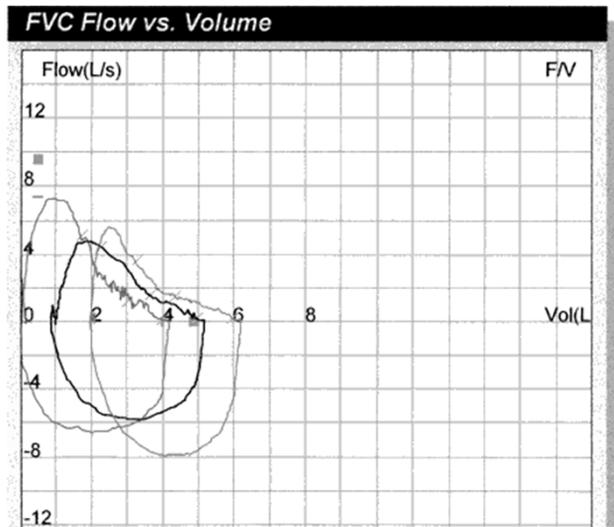
**Another example of normal flow volume loops (3 trials)**

Spirometry Interpretation

1. Determine if the flow-volume loop appears acceptable

2. Determine if the patient is obstructed by whether the FEV1/FVC ratio is below normal

3. If the patient is obstructed, determine how severe the obstruction is by how far below normal the FEV1 is

# Defining obstruction

- Obstruction is present if the FEV1/FVC ratio is reduced

- There are several different ways of defining a low FEV1/FVC ratio. The two most common are:

1. <u>American Thoracic Society</u>: defines a low FEV1/FVC by comparison to large databases of normal subjects. A low FEV1/FVC is then defined as less than the 5th percentile of normal subjects stratified by age

2. <u>Global Initiative for Obstructive Lung Disease (GOLD)</u>: uses a fixed number for all people regardless of age and defines a low FEV1/FVC as less than 70% for everyone

The FEV1/FVC Ratio Changes With Age

- **The FEV1/FVC ratio declines in normal people as they get older**
  - An <u>average</u> FEV1/FVC in a 20 year old is 87%
  - An <u>average</u> FEV1/FVC in an 80 year old is 71%
- **The ATS definition of obstruction takes this age variation into account**
- **The GOLD definition of obstruction does not**
  - Some normal older patients may be mis-classified as being obstructed when using the GOLD criteria

Causes Of Obstruction

- **Chronic obstructive pulmonary disease**
  - Emphysema
  - Chronic bronchitis
- **Asthma**
- **Bronchiectasis**
- **Bronchiolitis & bronchiolitis obliterans**

Normal Lungs
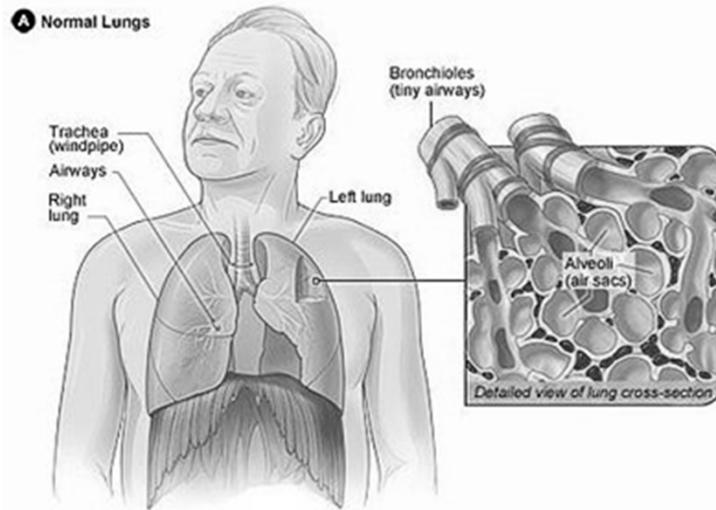
Obstructive Lung Disease: COPD
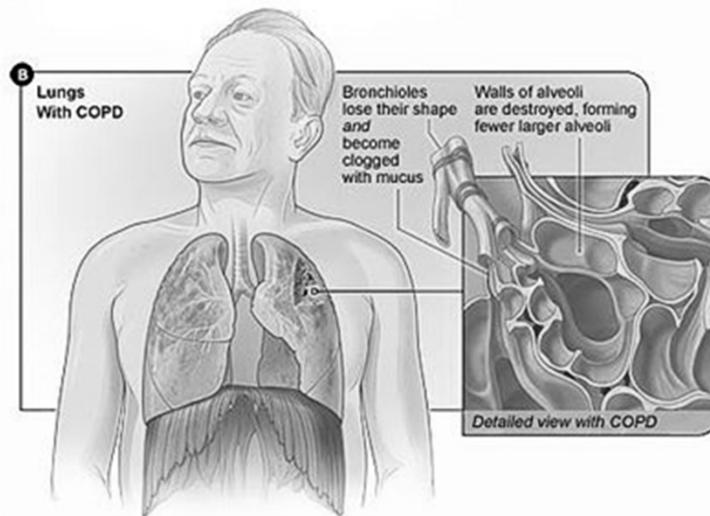
Obstructive Lung Disease: Asthma
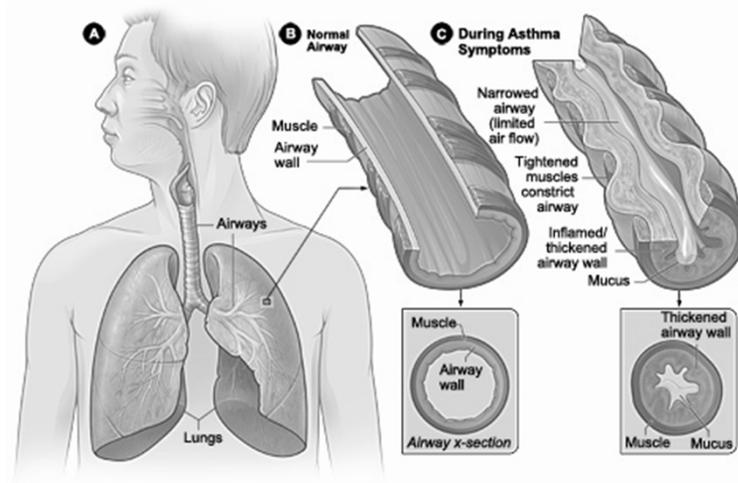
Flow volume loop in obstruction

Normal   **Obstructed**
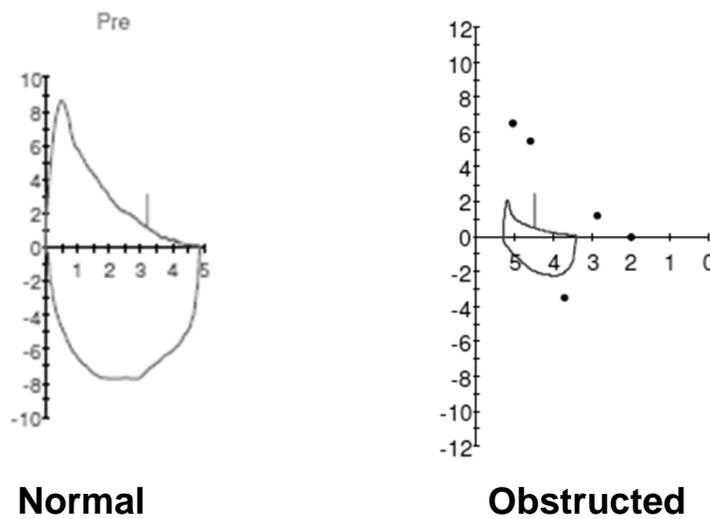
Obstructive Lung Disease
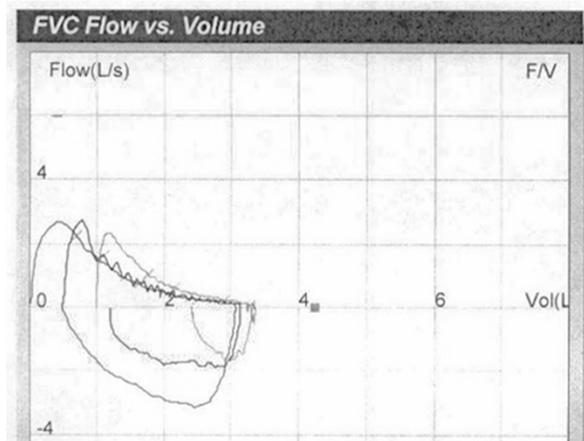
This patient has COPD. Note the concave ("scooped out") nature to the expiratory limb of the flow-volume loop

Obstructive Lung Disease
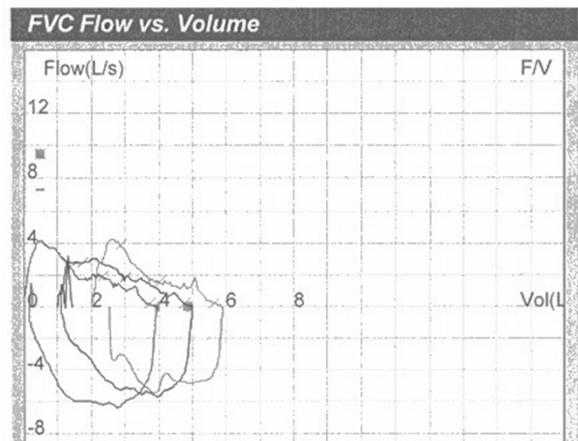
This patient has asthma. Note the less steep slope of the expiratory limb of the flow-volume loop. The expiratory limb Is irregular indicating he had difficulty exhaling with force

Spirometry Interpretation

Result	Pred	Best	%Prd		%Prd		%Prd
FVC (L)	3.37	2.97	88%	2.93	87%	2.78	82%
FEV1 (L)	2.60	2.19	84%	2.13	82%	2.08	80%
FEV1/FVC	0.78	0.74	95%	0.73	94%	0.75	96%
FEF25-75% (L/s)	2.32	1.64	70%	1.43	62%	1.59	69%
PEFR (L/s)	6.34	5.00	79%	5.39	85%	4.67	74%
Vext %	---	2.55	—	3.32	---	4.92	—

Spirometry Interpretation

Results

Result	Pred	Best	%Prd		%Prd		%Prd
FVC (L)	3.37	2.97	88%	2.93	87%	2.78	82%
FEV1 (L)	2.60	2.19	84%	2.13	82%	2.08	80%
FEV1/FVC	0.78	0.74	95%	0.73	94%	0.75	96%
FEF25-75% (L/s)	2.32	1.64	70%	1.43	62%	1.59	69%
PEFR (L/s)	6.34	5.00	79%	5.39	85%	4.67	74%
Vext %	---	2.55	—	3.32	---	4.92	—

↑
**Predicted
Normal
Values**

Spirometry Interpretation

Results							
Result	Pred	Best	%Prd		%Prd		%Prd
FVC (L)	3.37	2.97	88%	2.93	87%	2.78	82%
FEV1 (L)	2.60	2.19	84%	2.13	82%	2.08	80%
FEV1/FVC	0.78	0.74	95%	0.73	94%	0.75	96%
FEF25-75% (L/s)	2.32	1.64	70%	1.43	62%	1.59	69%
PEFR (L/s)	6.34	5.00	79%	5.39	85%	4.67	74%
Vext %	—	2.55	—	3.32	—	4.92	—

Trial 1 (best)   **Trial 2**   **Trial 3**

Spirometry Interpretation

Results							
Result	Pred	Best	%Prd		%Prd		%Prd
FVC (L)	3.37	2.97	88%	2.93	87%	2.78	82%
FEV1 (L)	2.60	2.19	84%	2.13	82%	2.08	80%
FEV1/FVC	0.78	0.74	95%	0.73	94%	0.75	96%
FEF25-75% (L/s)	2.32	1.64	70%	1.43	62%	1.59	69%
PEFR (L/s)	6.34	5.00	79%	5.39	85%	4.67	74%
Vext %	—	2.55	—	3.32	—	4.92	—

Trial 1 Percent Of Normal   **Trial 2 Percent Of Normal**   **Trial 3 Percent Of Normal**

27

Spirometry Interpretation

Results

Result	Pred	Best	%Prd		%Prd		%Prd
FVC (L)	3.37	2.97	88%	2.93	87%	2.78	82%
FEV1 (L)	2.60	2.19	84%	2.13	82%	2.08	80%
FEV1/FVC	0.78	0.74	95%	0.73	94%	0.75	96%
FEF25-75% (L/s)	2.32	1.64	70%	1.43	62%	1.59	69%
PEFR (L/s)	6.34	5.00	79%	5.39	85%	4.67	74%
Vext %	---	2.55		3.32		4.92	

Predicted Normal Values

Trial 1 (best)

Trial 1 Percent Of Normal

Trial 2

Trial 2 Percent Of Normal

Trial 3

Trial 3 Percent Of Normal

Spirometry Interpretation

Results

Result	Pred	Best	%Prd
FVC (L)	3.37	2.97	88%
FEV1 (L)	2.60	2.19	84%
FEV1/FVC	0.78	0.74	95%
FEF25-75% (L/s)	2.32	1.64	70%
PEFR (L/s)	6.34	5.00	79%
Vext %	---	2.55	---

Spirometry Interpretation

Results			
Result	Pred	Best	%Prd
FVC (L)	3.37	2.97	88%
FEV1 (L)	2.60	2.19	84%
FEV1/FVC	0.78	(0.74)	95%
FEF25-75% (L/s)	2.32	1.64	70%
PEFR (L/s)	6.34	5.00	79%
Vext %	---	2.55	---

In this case, the FEV1/FVC (0.74 or 74%) is within a normal range. The computer will flag an abnormally low value by putting an asterisk or square mark to the left of the values

Spirometry Interpretation

Results			
Result	Pred	Best	%Prd
FVC (L)	3.37	2.97	88%
FEV1 (L)	2.60	2.19	84%
FEV1/FVC	(0.78)	0.74	95%
FEF25-75% (L/s)	2.32	1.64	70%
PEFR (L/s)	6.34	5.00	79%
Vext %	---	2.55	---

The FEV1/FVC Predicted value is the mean FEV1/FVC for a large number of normal people of this particular age. In this particular case, the range of normal is 0.68 – 0.90. The computer interpretation frequently does not print the range of normal.

Spirometry Interpretation

Results			
Result	Pred	Best	%Prd
FVC (L)	3.37	2.97	88%
FEV1 (L)	2.60	2.19	84%
FEV1/FVC	0.78	0.74	(95%)
FEF25-75% (L/s)	2.32	1.64	70%
PEFR (L/s)	6.34	5.00	79%
Vext %	---	2.55	—

The FEV1/FVC %Predicted is often a source of confusion. For interpretation purposes, the FEV1/FVC is either normal or low. For practical purposes, if the FEV1/FVC does not have an asterisk, consider it normal and ignore the FEV1/FVC %Predicted value

Spirometry Interpretation

Results			
Result	Pred	Best	%Prd
FVC (L)	3.37	2.97	88%
FEV1 (L)	2.60	2.19	84%
FEV1/FVC	0.78	0.74	95%
FEF25-75% (L/s)	2.32	1.64	70%
PEFR (L/s)	6.34	5.00	79%
Vext %	---	2.55	—

Therefore, the value to use when interpreting spirometry is the patient's FEV1/FVC value only.

Important Note:
If the FEV1/FVC ratio is normal, then the patient is NOT obstructed. In this case, the FEV1 can be normal, elevated, <u>or reduced</u> but the patient is still not obstructed

Spirometry Showing Obstruction
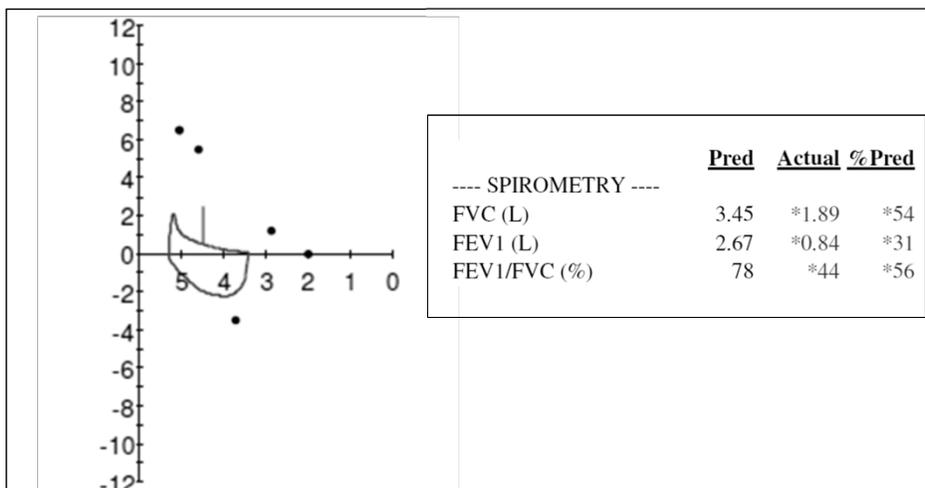
	Pred	Actual	%Pred
---- SPIROMETRY ----			
FVC (L)	3.45	*1.89	*54
FEV1 (L)	2.67	*0.84	*31
FEV1/FVC (%)	78	*44	*56

Obstructive Pattern

Results			
Result	Pred	Best	%Prd
FVC (L)	4.25	¤3.07	72%
FEV1 (L)	3.28	¤1.60	49%
FEV1/FVC	0.78	¤0.52	67%
FEF25-75% (L/s)	2.93	¤0.70	24%
PEFR (L/s)	8.75	¤2.68	31%
Vext %	---	2.13	---

Obstructive Pattern

Results			
Result	Pred	Best	%Prd
FVC (L)	4.25	¤3.07	72%
FEV1 (L)	3.28	¤1.60	49%
FEV1/FVC	0.78	¤0.52	67%
FEF25-75% (L/s)	2.93	¤0.70	24%
PEFR (L/s)	8.75	¤2.68	31%
Vext %	---	2.13	---

In this case, the FEV1/FVC is low (0.52 or 52%) and the computer has identified it as low by the square asterisk to the left of the value. Therefore, this patient is obstructed. To determine how obstructed, we next look at the FEV1.

Spirometry Interpretation

1. Determine if the flow-volume loop appears acceptable
2. Determine if the patient is obstructed by whether the FEV1/FVC ratio is below normal
3. If the patient is obstructed, determine how severe the obstruction is by how far below normal the FEV1 is

There are two commonly used scales of obstruction severity:

American Thoracic Society (ATS)		Global Initiative on Obstructive Lung Disease (GOLD)	
FEV1 (% predicted)	**Obstruction**	**FEV1 (% predicted)**	**Obstruction**
> 70%	Mild	> 80%	Mild
60-69%	Moderate	50-79%	Moderate
50-59%	Moderately Severe	30-49%	Severe
		< 30%	Very Severe
35-49%	Severe		
< 35%	Very Severe		

Remember, the ATS defines obstruction as an FEV1/FVC ratio of less than the 5th percentile of predicted for that patient's age and this number will vary from patient to patient. The GOLD defines obstruction as anyone with an FEV1/FVC ratio of less than 70% for all patients, regardless of age

Obstructive Pattern

Results

Result	Pred	Best	%Prd
FVC (L)	4.25	¤3.07	72%
FEV1 (L)	3.28	¤1.60	49%
FEV1/FVC	0.78	¤0.52	67%
FEF25-75% (L/s)	2.93	¤0.70	24%
PEFR (L/s)	8.75	¤2.68	31%
Vext %	---	2.13	---

American Thoracic Society (ATS)		Global Initiative on Obstructive Lung Disease (GOLD)	
FEV1 (% predicted)	**Obstruction**	**FEV1 (% predicted)**	**Obstruction**
> 70%	Mild	> 80%	Mild
60-69%	Moderate	50-79%	Moderate
50-59%	Moderately Severe	30-49%	Severe
35-49%	Severe	< 30%	Very Severe
< 35%	Very Severe		

Obstructive Pattern

Results			
Result	Pred	Best	%Prd
FVC (L)	4.25	¤3.07	72%
FEV1 (L)	3.28	¤1.60	49%
FEV1/FVC	0.78	¤0.52	67%
FEF25-75% (L/s)	2.93	¤0.70	24%
PEFR (L/s)	8.75	¤2.68	31%
Vext %	---	2.13	---

In this case, the FEV1 is 49% of predicted so the patient would be defined as having severe obstruction by either the ATS or the GOLD criteria.

Obstructive Pattern

Results			
Result	Pred	Best	%Prd
FVC (L)	4.78	¤2.24	47%
FEV1 (L)	3.74	¤1.09	29%
FEV1/FVC	0.78	¤0.49	63%
FEF25-75% (L/s)	3.39	¤0.54	16%
PEFR (L/s)	9.47	¤1.99	21%
Vext %	---	1.11	---

In this case, the FEV1/FVC ratio is low at 0.49 (49% of predicted). It is marked as abnormal by the computer with the square asterisk to the left of the value.

American Thoracic Society (ATS)			Global Initiative on Obstructive Lung Disease (GOLD)	
FEV1 (% predicted)	**Obstruction**		**FEV1 (% predicted)**	**Obstruction**
> 70%	Mild		> 80%	Mild
60-69%	Moderate		50-79%	Moderate
50-59%	Moderately Severe		30-49%	Severe
35-49%	Severe		< 30%	Very Severe
< 35%	Very Severe			

Obstructive Pattern

Results

Result	Pred	Best	%Prd
FVC (L)	4.78	¤2.24	47%
FEV1 (L)	3.74	¤1.09	29%
FEV1/FVC	0.78	¤0.49	63%
FEF25-75% (L/s)	3.39	¤0.54	16%
PEFR (L/s)	9.47	¤1.99	21%
Vext %	---	1.11	---

The FEV1 is 29% of predicted which makes this very severe obstruction by either the ATS or GOLD criteria. The computer interpreted this as mild obstruction, however.

Obstructive Pattern

Results			
Result	Pred	Best	%Prd
FVC (L)	3.63	¤1.62	45%
FEV1 (L)	2.64	¤0.87	33%
FEV1/FVC	0.74	¤0.54	72%
FEF25-75% (L/s)	2.02	0.44	22%
PEFR (L/s)	7.56	¤1.61	21%

In this case, the FEV1/FVC ratio is low at 0.54 (54% of predicted). It is marked as abnormal by the computer with the square asterisk to the left of the value.

American Thoracic Society (ATS)		Global Initiative on Obstructive Lung Disease (GOLD)	
FEV1 (% predicted)	**Obstruction**	**FEV1 (% predicted)**	**Obstruction**
> 70%	Mild	> 80%	Mild
60-69%	Moderate	50-79%	Moderate
50-59%	Moderately Severe	30-49%	Severe
35-49%	Severe	< 30%	Very Severe
< 35%	Very Severe		

Obstructive Pattern

Results			
Result	Pred	Best	%Prd
FVC (L)	3.63	¤1.62	45%
FEV1 (L)	2.64	¤0.87	33%
FEV1/FVC	0.74	¤0.54	72%
FEF25-75% (L/s)	2.02	0.44	22%
PEFR (L/s)	7.56	¤1.61	21%

The FEV1 is 0.87 L (33% of predicted) which makes this severe obstruction by GOLD criteria but very severe obstruction by ATS criteria. The computer interpretation was mild obstruction.

Reversible obstruction

- **Although more commonly performed in the PFT lab than with office spirometry, a "bronchodilator study" can be performed to determine if there is an improvement in obstruction 15 minutes after a bronchodilator, such as albuterol is given.**

- **Reversible obstruction can also be established by repeating spirometry after a 2-3 week treatment trial**

Reversible obstruction (continued)

- The most accurate definition of reversible obstruction is an increase in the FEV1 by > 12% <u>and</u> at least 200 ml.

- An increase in the FVC by > 12% <u>and</u> at least 200 ml is also frequently used as a definition of reversibility but it is not as accurate as the FEV1

Diagnosing Restriction Based On Spirometry

- The only confident way to diagnose restriction is by full lung volume measurements with measurement of the total lung capacity (TLC).
- You can <u>suspect</u> restriction if the FVC is low on spirometry but this is fraught with error.
  - Many patients with COPD will have a low FVC
  - The FVC is often low even when the TLC is normal
- If the FVC is low and you suspect restriction, you should order lung volumes in the PFT lab to confirm restriction

Monitoring Restriction By Spirometry

- **In some diseases, following the FVC serially can be a good marker of lung capacity and/or respiratory muscle strength**
  - **Patients with interstitial lung disease**
  - **Patients with neuromuscular weakness**
- **When using the FVC to follow these patients for disease progression, it is important that the test be done with consistent technique, preferably by the same individual(s). Often, this is best accomplished in the PFT lab or in clinics that regularly care for neuromuscular patients.**

A Note About The FEF25-75%...

FEF$_{25\text{-}75\%}$

Volume (L)

Flow (L per second)
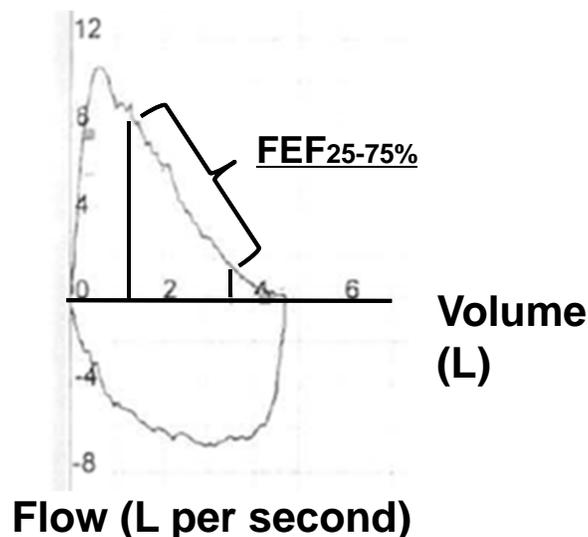
A Note About The FEF$_{25-75\%}$...

- **Some physicians will interpret a low FEF25-75% as a sign of possible "early obstructive disease" or "small airways obstructive disease" when the FEV1/FVC ratio is normal.**

- **It is far less specific than the FEV1/FVC definition of obstruction and many normal people will have an isolated low FEF25-75% value**

- **This interpretation should be done with caution and only when the spirometry maneuver is performed exceptionally well by the patient**

A Note About The Peak Flow Rate...

Peak Expiratory Flow Rate (PEFR)

Volume (L)

Flow (L per second)
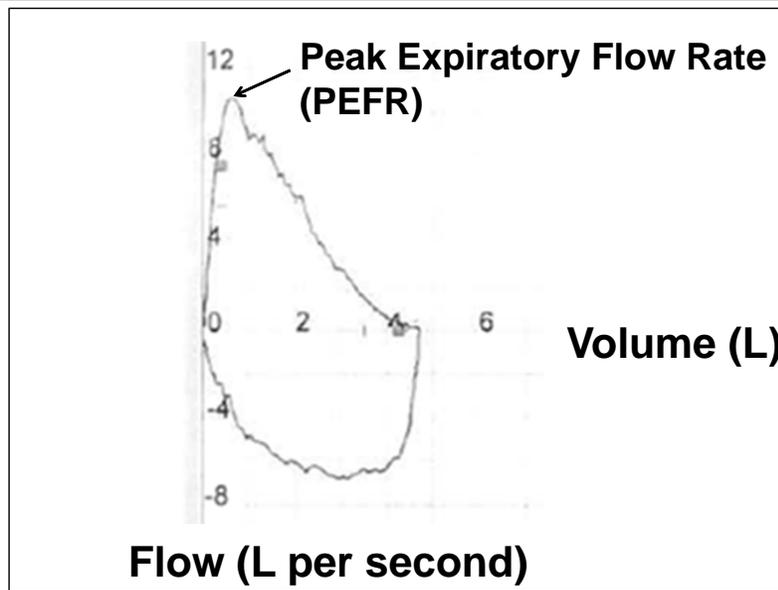
A Note About The Peak Flow Rate...

- The peak flow rate is very good for home monitoring of asthma when patients are trained in the use of a peak flow meter and do serial testing over time
- However, the peak flow rate on an isolated spirometry test is less meaningful. Like the $FEF_{25-75\%}$, it is not very specific and it should not be used to define obstruction by itself

The Flow-Volume Loop In Other Conditions

1. Tracheostenosis
2. Vocal cord paralysis
3. Vocal cord dysfunction

# Tracheostenosis
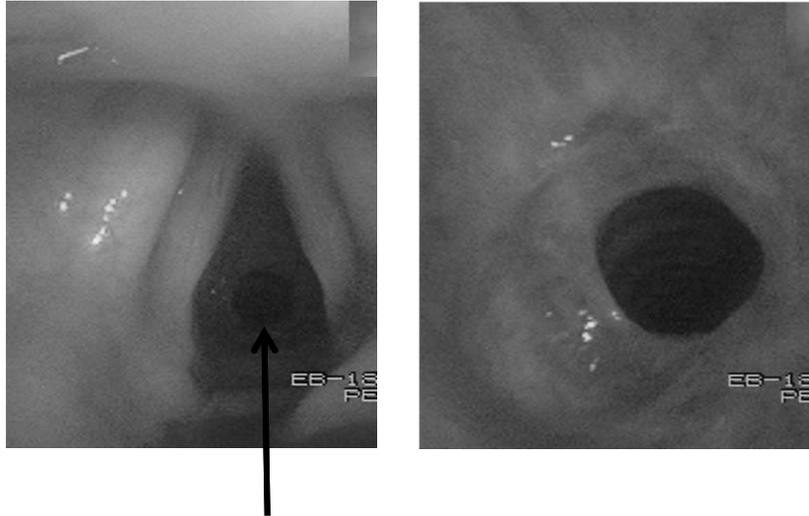
Tracheostenosis
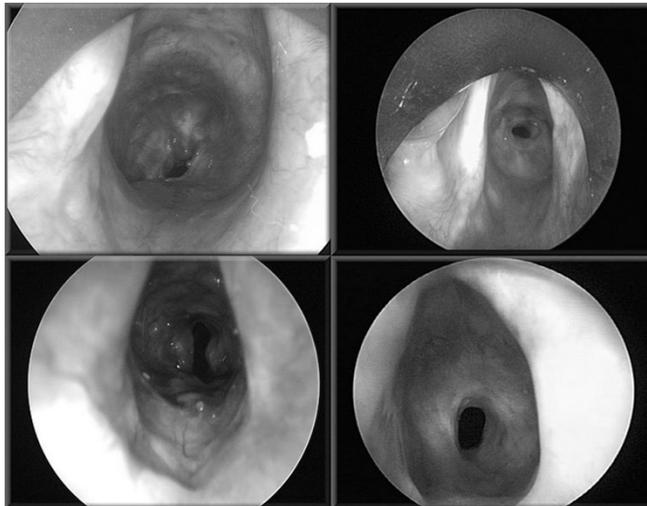
Photo: Rn cantab

Tracheostenosis
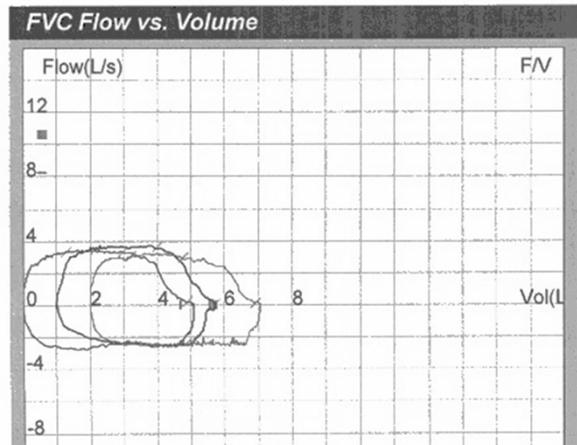
This patient has granulomatosis with angitis (Wegener's granulomatosis) with subglottic stenosis. Note the flattening of both the inspiratory and expiratory limbs.

Vocal Cord Paralysis
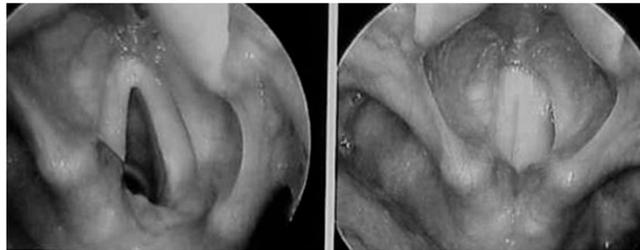
**Exhalation**   **Inhalation**

Paralyzed Vocal Cords
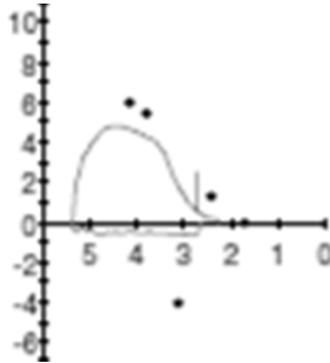
This patient has a history of recurrent laryngeal nerve damage during a mediastinoscopy. The computer interpretation was normal. The flow-volume loop shows severe inspiratory flattening indicating variable upper airway obstruction

# Vocal Cord Dysfunction
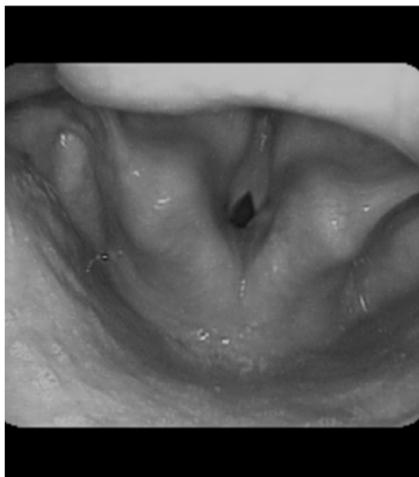
**Fully Abducted**   **Constricted Respiration**

Vocal Cord Dysfunction

Exhalation   **Inhalation**
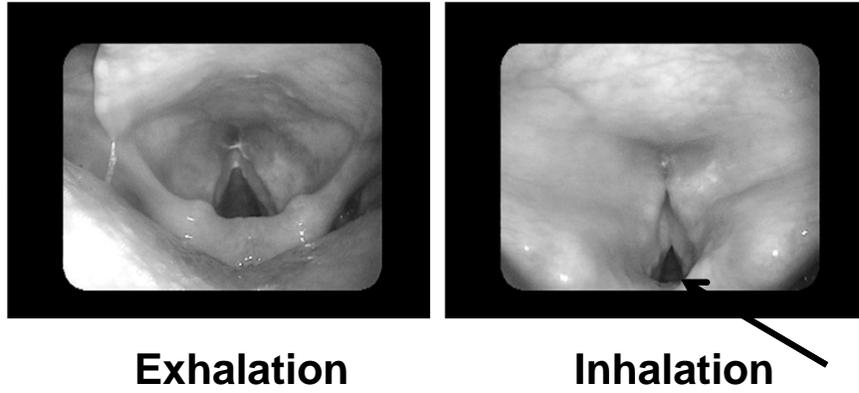
Vocal Cord Dysfunction
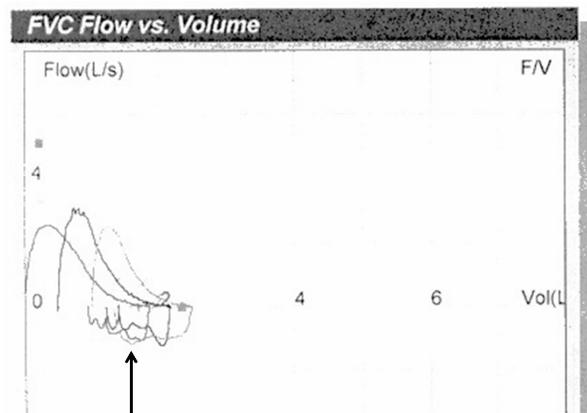
Note the "notching" on the inspiratory limb

A note about spirometry and children

Children

- **Office spirometry generally is not possible in children under age 6 years**
- **A shorter minimal FVC exhalation time of 3 seconds (rather than 6 seconds) is appropriate for children under age 10 years**
- **Children require more detailed coaching to perform the test**
- **There must be extra attention to quality measures and reproducibility of trials**

Should you buy an office spirometer?

- **2015 Medicare reimbursement: $34**
- **Assume equipment cost of $2,500**
  - **Number of tests to break even: 74**
- **Assume equipment cost of $800**
  - **Number of tests to break even: 24**

When to get help?

- **Remember, office spirometry is sometimes called "screening spirometry" for a reason. If you are uncertain of the results, if the flow volume curves look wrong, or if the results from different trials have significant variation, then consider getting formal spirometry in the pulmonary function lab.**

References

- **American Thoracic Society Guideline: Standardization of Spirometry: http://www.thoracic.org/statements/resources/pft/PFT2.pdf**
- **American Thoracic Society Guideline: Interpretative Strategies for Lung Function Tests: http://www.thoracic.org/statements/resources/pft/pft5.pdf**
- **GOLD Spirometry Guide: http://www.goldcopd.org/other-resources-gold-spirometry-guide.html**