Office Spirometry and Pulmonary Function Testing

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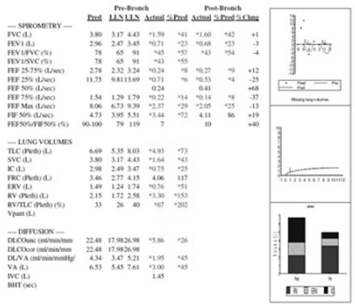
MedNet21
Center for Continuing Medical Education

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
5. Understand the clinical significance of restriction and low diffusing capacity



	Pre-Bronch				Post-Bronch		
	Pred	LLN	ULN	Actual	%Pred	Actual	%Pred	%Chng
— SPIROMETRY —								
FVC (L)	3.80	3.17	4.43	*1.59	*41	*1.60	*42	+1
FEV1 (L)	2.96	2.47	3.45	*0.71	*23	*0.68	*23	-3
FEV1/FVC (%)	78	65	91	*45	*57	*43	*54	-4
FEV1/SVC (%)	78	65	91	*43	*55			
FEF 25-75% (L/sec)	2.78	2.32	3.24	*0.24	*8	*0.27	*9	+12
FEF 25% (L/sec)	11.75	9.81	13.69	*0.71	*6	*0.53	*4	-25
FEF 50% (L/sec)				0.24		0.41		+68
FEF 75% (L/sec)	1.54	1.29	1.79	*0.22	*14	*0.14	*8	-37
FEF Max (L/sec)	8.06	6.73	9.39	*2.37	*29	*2.05	*25	-13
FIF 50% (L/sec)	4.73	3.95	5.51	*3.44	*72	4.11	86	+19
FEF50%/FIF50% (%)	90-100	79	119	7		10		+40
— LUNG VOLUMES								
TLC (Pleth) (L)	6.69	5.35	8.03	*4.93	*73			
SVC (L)	3.80	3.17	4.43	*1.64	*43			
IC (L)	2.98	2.49	3.47	*0.75	*25			
FRC (Pleth) (L)	3.46	2.77	4.15	4.06	117			
ERV (L)	1.49	1.24	1.74	*0.76	*51			
RV (Pleth) (L)	2.15	1.72	2.58	*3.30	*153			
RV/TLC (Pleth) (%)	33	26	40	*67	*202			
Vpeak (L)								
— DIFFUSION —								
DLCOunc (ml/min/mm	22.48	17.98	26.98	*5.86	*26			
DLCOcor (ml/min/mm	22.48	17.98	26.98					
DLVA (ml/min/mmHg/	4.34	3.47	5.21	*1.95	*45			
VA (L)	6.53	5.45	7.61	*3.00	*45			
IVC (L)				1.45				
BHT (sec)								

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

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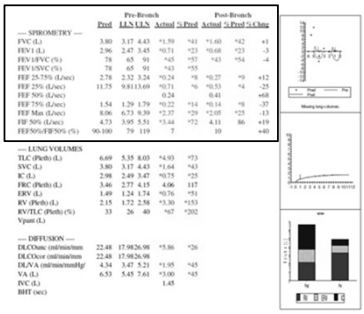

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BHT (sec)								

Pulmonary Function Tests: Spirometry

- Measure of airflow
- Forced vital capacity (FVC)
- Forced expiratory volume in 1 sec. ($FEV_{1.0}$)
- FEV1/FVC ratio
- Obstruction
  - ↓ $FEV_{1.0}$/FVC ratio
- Reversible obstruction
  - 12% & 200 ml increase in FVC or $FEV_{1.0}$ after a bronchodilator

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 forced vital capacity in patients with known neuromuscular disease
- Pre-operative assessment in patients with known or suspected lung disease

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 often not accurate and can give an incorrect interpretation in as many as half of cases

A Spirometry Test Requires 3 Steps To Be Done Correctly

1. Correct demographic information (age, height, gender, race/ethnicity)
2. Correct technique used by the nurse or other provider administering the test
3. Correct interpretation by the physician reading the test

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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

Results

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.

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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

A Spirometry Test Requires 3 Steps To Be Done Correctly

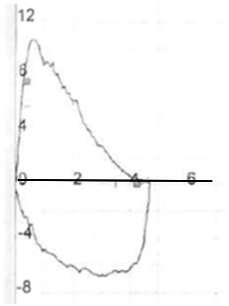
1. Correct demographic information (age, height, gender, race/ethnicity)
2. Correct technique used by the nurse or other provider administering the test
3. Correct interpretation by the physician reading the test

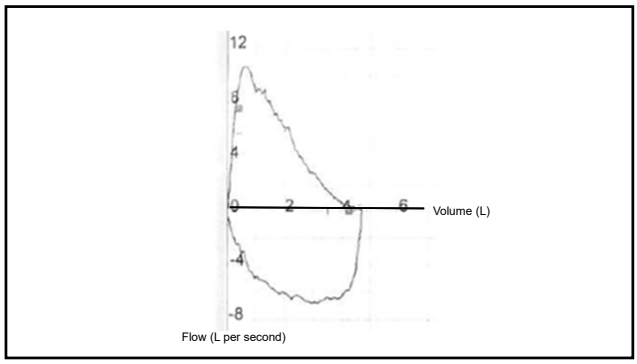
Spirometry Interpretation

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

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




12
8
4
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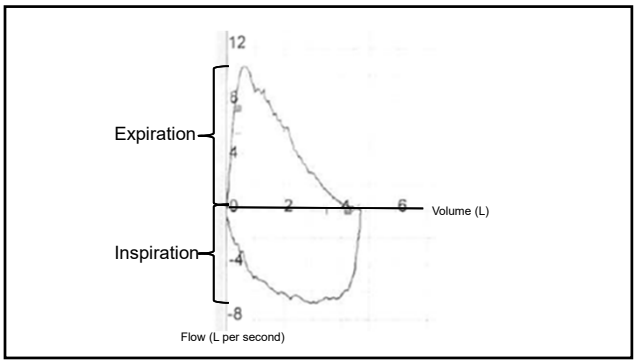
2
4
6
Volume (L)
-4
-8
Flow (L per second)


Expiration
Inspiration
12
8
4
0
2
4
6
Volume (L)
-4
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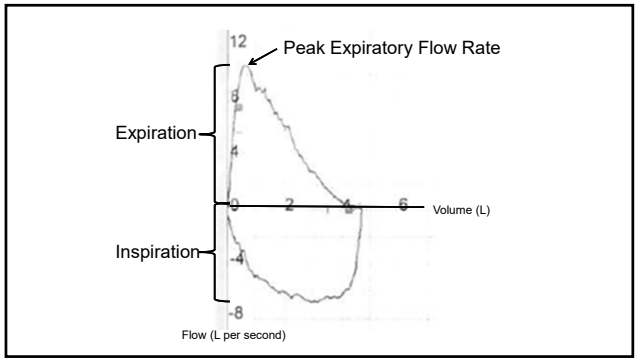
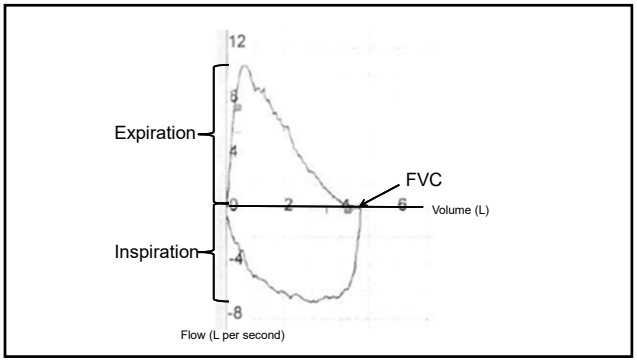

Peak Expiratory Flow Rate
Expiration
Inspiration
12
8
4
0
2
4
6
Volume (L)
-4
-8
Flow (L per second)


Expiration
Inspiration
FVC
12
8
4
0
2
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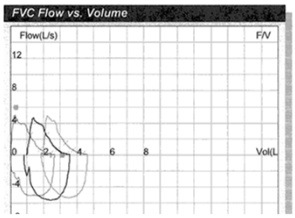
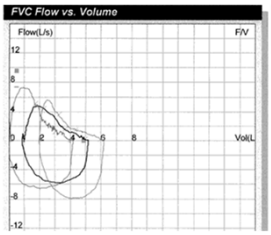
Normal Flow Volume Loop (office spirometer)



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)

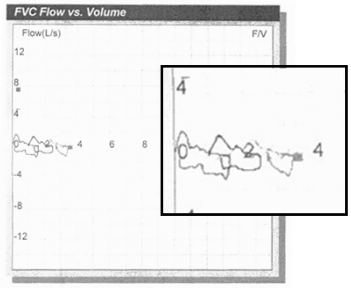


Another example of normal flow volume loops (3 trials)

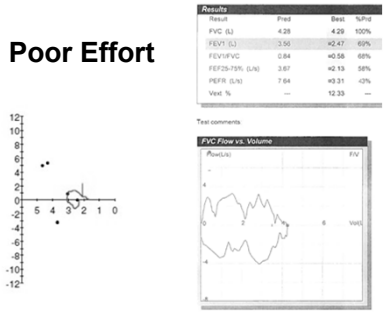
Flow Volume Loop Quality Killers

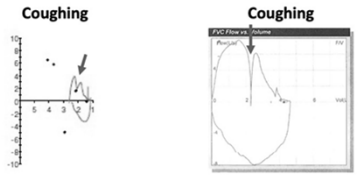
- Cough
- Inserting tongue in the mouthpiece
- Air leak around the mouth
- Poor effort
- Stopping exhalation before the lungs are empty
- Glottic closure or hesitation during exhalation

Invalid Test: Poor Effort



Poor Effort





Defining Normal Values

- The FEV1 and FVC vary depending on:
  1. Age
  2. Gender
  3. Race/ethnicity
  4. Height
- Therefore (for example), the normal FEV1 for a 64 inch tall, 70-year-old Caucasian American 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/ethnicity, and height and then creating large databases of normal people

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)

1. **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.
   - U.S. normal subjects
   - Age 8 - 80
2. **GLI** (Global Lung Function Initiative) published in 2012.
   - Normal subjects from 26 countries
   - Age 3 - 95
   - Reference values for more racial/ethnic groups

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. American Thoracic Society (ATS): defines a low FEV1/FVC by comparison to large databases of normal people. A low FEV1/FVC is then defined as less than the 5th percentile of normal people stratified by age
  2. Global Initiative for Obstructive Lung Disease (GOLD): 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 average FEV1/FVC in a 20 year old is 87%
  - An average FEV1/FVC in an 84 year old is 71%
    - The lower limit of normal in an 84 year old is 59%!
- 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

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	—

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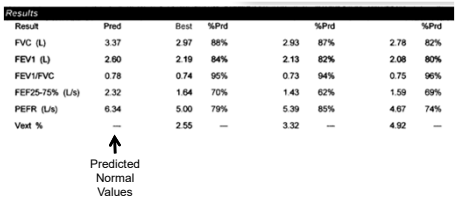

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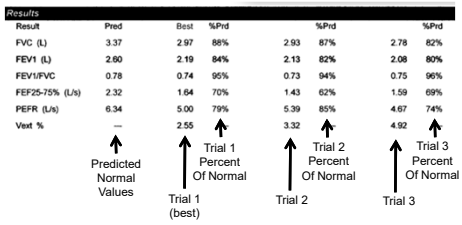

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Vext %	—	2.55	—

In this case, the FEV1/FVC is within a normal range (0.74 or 74%). Most office spirometers will not display the range of normal (in this case 68%-90%). The computer will flag an abnormally low value by putting an asterisk or square mark to the left of the values

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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

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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, or reduced but the patient is still not obstructed

Causes Of Obstruction

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

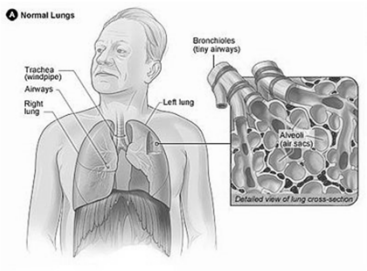
Reversible obstruction

- 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

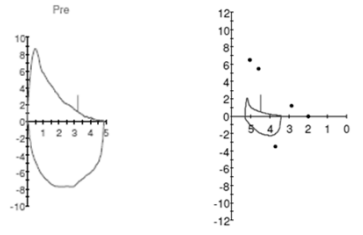
Reversible obstruction (continued)

- The most accurate definition of reversible obstruction is an increase in the **FEV1** by > 12% and at least 200 ml.
- An increase in the **FVC** by > 12% and at least 200 ml is also frequently used as a definition of reversibility but it is not as accurate as the FEV1

Normal Lungs

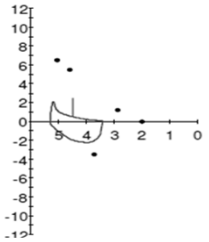


Flow volume loop in obstruction



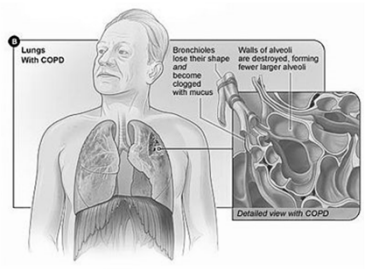
Normal Obstructed

Spirometry Showing Obstruction

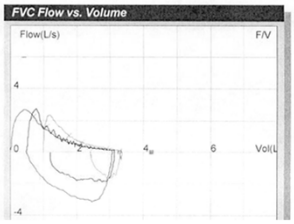


	Pred	Actual	%Pred
---- SPIROMETRY ----			
FVC (L)	3.45	*1.89	*54
FEV1 (L)	2.67	*0.84	*31
FEV1/FVC (%)	78	44	*56

Obstructive Lung Disease: COPD



Obstructive Lung Disease



This patient has COPD. Note the concave (“scooped out”) nature to the expiratory limb of the flow-volume loop

Irreversible obstruction

		Pre-Bronch				Post-Bronch		
	Pred	LLN	ULN	Actual	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	2.77	2.31	3.23	2.38	85	2.45	88	+2
FEV1 (L)	2.19	1.83	2.55	*1.12	*51	*1.24	*56	+10
FEV1/FVC (%)	80	67	93	*47	*59	*51	*63	+7
FEV1/SVC (%)	80	67	93					
FEF 25-75% (L/sec)	2.23	1.86	2.60	*0.41	*18	*0.56	*25	+36
FEF 25% (L/sec)	5.45	4.55	6.35	*1.24	*22	*1.47	*27	+18
FEF 50% (L/sec)				0.48		0.70		+46
FEF 75% (L/sec)	1.25	1.04	1.46	*0.18	*14	*0.27	*21	+47
FEF Max (L/sec)	5.87	4.90	6.84	*2.25	*38	*2.36	*40	+4
FIF 50% (L/sec)	3.23	2.70	3.76	*1.61	*49	*1.45	*44	-9
FEF50%/FIF50% (%)	90-100	79	119	30		48		+62

Irreversible obstruction

	Pred	Pre-Bronch LLN	Pre-Bronch ULN	Pre-Bronch Actual	Pre-Bronch %Pred	Post-Bronch Actual	Post-Bronch %Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	2.77	2.31	3.23	2.38	85	2.45	88	+2
FEV1 (L)	2.19	1.83	2.55	*1.12	*51	*1.24	*56	+10
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Irreversible obstruction

	Pred	Pre-Bronch LLN	Pre-Bronch ULN	Pre-Bronch Actual	Pre-Bronch %Pred	Post-Bronch Actual	Post-Bronch %Pred	%Chng
---- SPIROMETRY ----								
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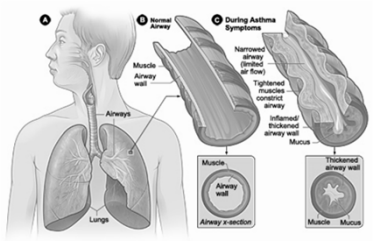
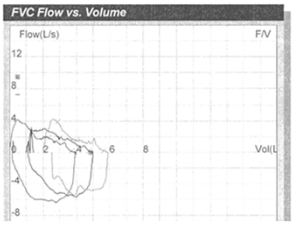
FEF50%/FIF50% (%)	90-100	79	119	30		48		+62

Obstructive Lung Disease: Asthma



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

Reversible obstruction

				Pre-Bronch		Post-Bronch		
	Pred	LLN	ULN	Actual	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	3.55	2.96	4.14	*2.12	*59	*2.20	*62	+3
FEV1 (L)	2.78	2.32	3.24	*1.01	*36	*1.26	*45	+24
FEV1/FVC (%)	79	66	92	*48	*60	*57	*72	+19
FEV1/SVC (%)	79	66	92					
FEF 25-75% (L/sec)	2.69	2.25	3.13	*0.33	*12	*0.60	*22	+81
FEF 25% (L/sec)	11.23	9.38	13.08	*1.06	*9	*1.72	*15	+61
FEF 50% (L/sec)				0.43		0.73		+71
FEF 75% (L/sec)	1.43	1.19	1.67	*0.14	*9	*0.25	*17	+77
FEF Max (L/sec)	7.67	6.40	8.94	*2.53	*33	*2.82	*36	+11
FIF 50% (L/sec)	4.78	3.99	5.57	*1.61	*33	*2.40	*50	+49
FEF50%/FIF50% (%)	90-100	79	119	26		30		+14

Reversible obstruction

				Pre-Bronch		Post-Bronch		
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Reversible obstruction

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FVC (L)	3.55	2.96	4.14	*2.12	*59	*2.20	*62	+3
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FIF 50% (L/sec)	4.78	3.99	5.57	*1.61	*33	*2.40	*50	+49
FEF50%/FIF50% (%)	90-100	79	119	26		30		+14

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

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 mark to the left of the value. Therefore, this patient is obstructed. To determine how obstructed, we next look at the FEV1.

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	---

The FEV1 is reduced at 49% of the predicted value.

There are two commonly used scales of obstruction severity:

American Thoracic Society (ATS)

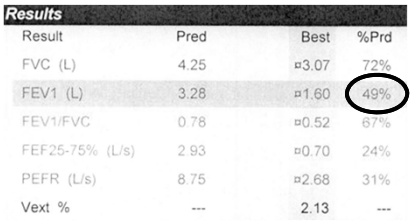
FEV1 (% predicted)	Obstruction
> 70%	Mild
60-69%	Moderate
50-59%	Moderately Severe
35-49%	Severe
< 35%	Very Severe

Global Initiative on Obstructive Lung Disease (GOLD)

FEV1 (% predicted)	Obstruction
> 80%	Mild
50-79%	Moderate
30-49%	Severe
< 30%	Very Severe

Remember, the ATS defines obstruction as an FEV1/FVC ratio of less than the 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% regardless of age

Obstructive Pattern



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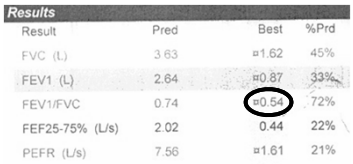
FEF25-75% (L/s)	2.93	¤0.70	24%
PEFR (L/s)	8.75	¤2.68	31%
Vext %	---	2.13	---

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

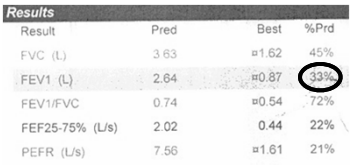


Results

Result	Pred	Best	%Prd
FVC (L)	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 54%. It is marked as abnormal by the computer with the square asterisk to the left of the value.

Obstructive Pattern



Results

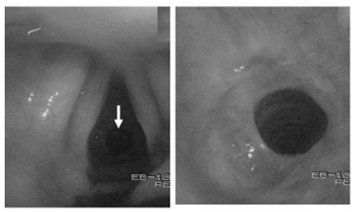
Result	Pred	Best	%Prd
FVC (L)	3.63	¤1.62	45%
FEV1 (L)	2.64	¤0.87	33%
FEV1/FVC	0.74	¤0.54	72%
FEF25-75% (L/s)	2.02	0.44	22%
PEFR (L/s)	7.56	¤1.61	21%

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.

The Flow-Volume Loop In Other Conditions

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

Tracheostenosis



Tracheostenosis

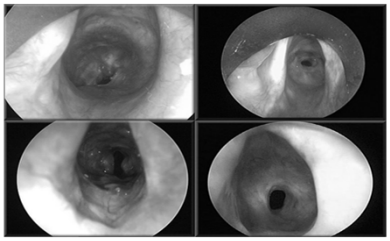
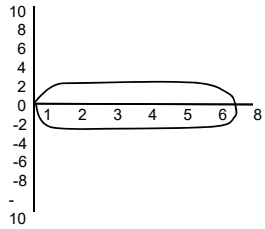
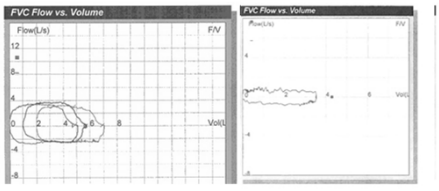


Photo: Rn cantab

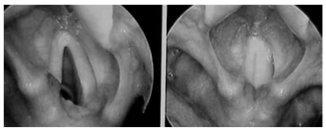
Tracheostenosis



Tracheostenosis

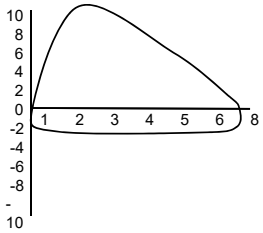


Vocal Cord Paralysis

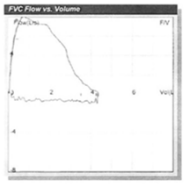


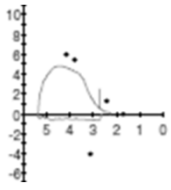
Exhalation Inhalation

Vocal Cord Paralysis

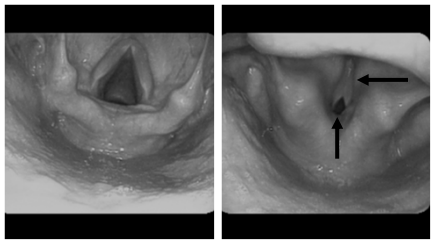


Vocal Cord Paralysis



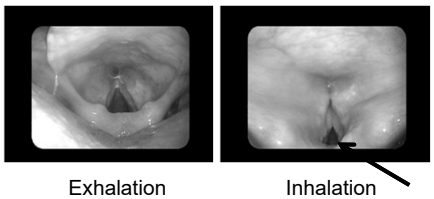


Vocal Cord Dysfunction



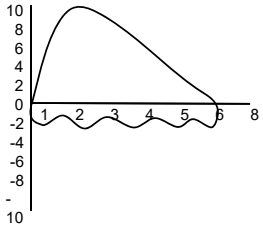
Fully Abducted Constricted Respiration

Vocal Cord Dysfunction

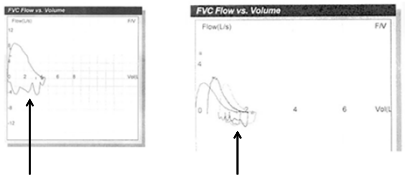


Exhalation Inhalation

Vocal Cord Dysfunction

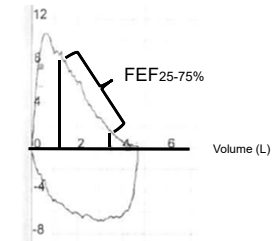


Vocal Cord Dysfunction



Note the “notching” on the inspiratory limb

A Note About The FEF25-75%...

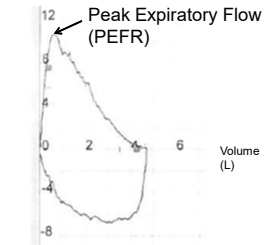


Flow (L per second)

A Note About The FEF25-75%...

- 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
- **It is best to not use the FEF25-75% to diagnose obstruction**

A Note About The Peak Flow Rate...



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 FEF25-75%, it is not very specific.
- **The peak flow rate should not be used to define obstruction by itself**

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?

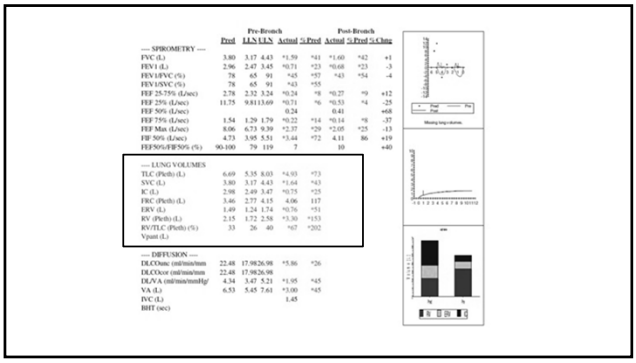
- 2022 Medicare reimbursement: $25.60
- Assume equipment cost of $2,500
  - Number of tests to break even: 98
- Assume equipment cost of $800
  - Number of tests to break even: 32

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.

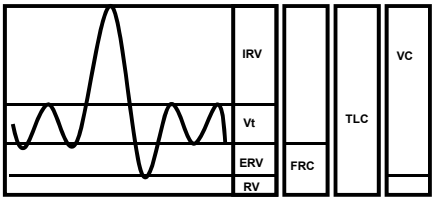
What do pulmonary function tests tell you?

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



	Pre-Bronch				Post-Bronch		
--- SPIROMETRY ---	Pred	LLN	ULN	Actual	%Pred	Actual	%Pred	%Chng
FVC (L)	3.80	3.17	4.43	*1.59	*41	*1.60	*42	+1
FEV1 (L)	2.96	2.47	3.45	*0.71	*23	*0.68	*23	-3
FEV1/FVC (%)	78	65	91	*45	*57	*43	*54	-4
FEV1/SVC (%)	78	65	91	*43	*55			
FEF 25-75% (L/sec)	2.78	2.32	3.24	*0.24	*8	*0.27	*9	+12
FEF 25% (L/sec)	11.75	9.81	13.69	*0.71	*6	*0.53	*4	-25
FEF 50% (L/sec)				0.24		0.41		+68
FEF 75% (L/sec)	1.54	1.29	1.79	*0.22	*14	*0.14	*8	-37
FEF Max (L/sec)	8.06	6.73	9.39	*2.37	*29	*2.05	*25	-13
FIF 50% (L/sec)	4.73	3.95	5.51	*3.44	*72	4.11	86	+19
FEF50%/FIF50% (%)	90-100	79	119	7		10		+40
--- LUNG VOLUMES								
TLC (Pleth) (L)	6.69	5.35	8.03	*4.93	*73			
SVC (L)	3.80	3.17	4.43	*1.64	*43			
IC (L)	2.98	2.49	3.47	*0.75	*25			
FRC (Pleth) (L)	3.46	2.77	4.15	4.06	117			
ERV (L)	1.49	1.24	1.74	*0.76	*51			
RV (Pleth) (L)	2.15	1.72	2.58	*3.30	*153			
RV/TLC (Pleth) (%)	33	26	40	*67	*202			
Vpast (L)								
--- DIFFUSION ---								
DLCOunc (ml/min/mm	22.48	17.98	26.98	*5.86	*26			
DLCOcor (ml/min/mm	22.48	17.98	26.98					
DLVA (ml/min/mmHg/	4.34	3.47	5.21	*1.95	*45			
VA (L)	6.53	5.45	7.61	*3.00	*45			
IVC (L)				1.45				
BHT (sec)								

Derivation of the lung volumes



Pulmonary Function Tests: Lung Volumes

- **Restriction**:
  - Total lung capacity (TLC) < 5th percentile of normal
- **Hyperinflation**:
  - Total lung capacity (TLC) > 95th percentile of normal
- **Air-trapping** defined as *either*:
  - Residual volume (RV) > 95th percentile of normal
  - Functional residual capacity (FRC) > 95th percentile of normal

Severity of Restriction

TLC (% predicted)	Restriction
70% - LLN*	Mild
60-70%	Moderate
50-60%	Moderately Severe
<50%	Severe

*LLN = lower limit of normal

Common Causes Of Restriction

- Interstitial lung disease
- Chest wall impairment
- Respiratory muscle weakness
- Previous lung resection

Diagnosing Restriction Based On Spirometry

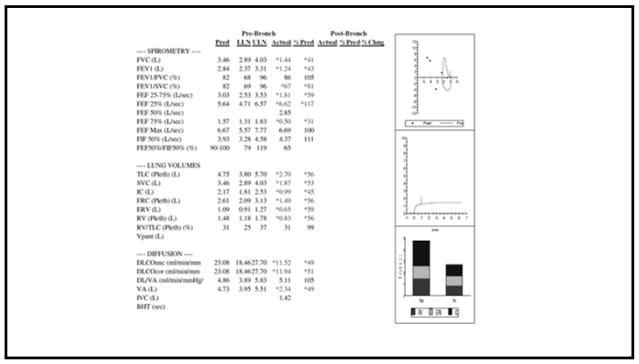
- The only confident way to diagnose restriction is by full lung volume measurements with measurement of the total lung capacity (TLC).
- You can suspect restriction if the FVC is low on spirometry but this is fraught with error.
  - Many patients with COPD will have a low FVC
  - The FVC is often low 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

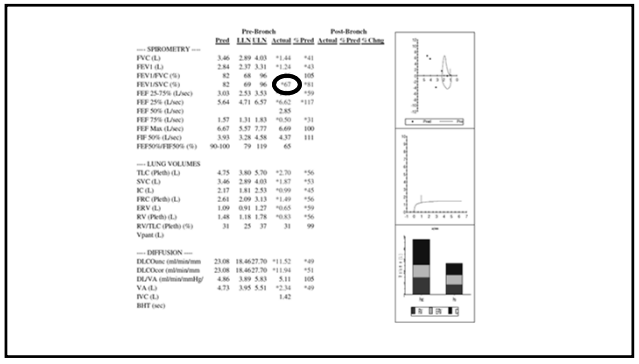
- In some diseases, following the FVC serially can be a good marker of lung capacity and/or respiratory muscle strength
  - Patients with interstitial lung disease
  - Patients with neuromuscular weakness
- When using the FVC to follow these patients for disease progression, it is important that the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

A word about the SVC

- There are 2 ways to measure vital capacity:
  - FVC (**F**orced **V**ital **C**apacity) – measured during spirometry
  - SVC (**S**low **V**ital **C**apacity) – measured during lung volumes
- *Either* the FVC or the SVC can be used to diagnose obstruction:
  - FEV1/**F**VC
  - FEV1/**S**VC



	Pre-Bronch				Post-Bronch	
	Pred	LLN	ULN	Actual	%Pred	Actual	%Pred	%Chng
--- SPIROMETRY ---								
FVC (L)	3.46	2.89	4.03	*1.44	*41			
FEV1 (L)	2.84	2.37	3.31	*1.24	*43			
FEV1/FVC (%)	82	68	96	86	105			
FEV1/SVC (%)	82	69	96	*67	*81			
FEF 25-75% (L/sec)	3.03	2.53	3.53	*1.81	*59			
FEF 25% (L/sec)	5.64	4.71	6.57	*6.62	*117			
FEF 50% (L/sec)				2.85				
FEF 75% (L/sec)	1.57	1.31	1.83	*0.50	*31			
FEF Max (L/sec)	6.67	5.57	7.77	6.69	100			
FIF 50% (L/sec)	3.93	3.28	4.58	4.37	111			
FEF50%/FIF50% (%)	90-100	79	119	65				
--- LUNG VOLUMES								
TLC (Pleth) (L)	4.75	3.80	5.70	*2.70	*56			
SVC (L)	3.46	2.89	4.03	*1.87	*53			
IC (L)	2.17	1.81	2.53	*0.99	*45			
FRC (Pleth) (L)	2.61	2.09	3.13	*1.49	*56			
ERV (L)	1.09	0.91	1.27	*0.65	*59			
RV (Pleth) (L)	1.48	1.18	1.78	*0.83	*56			
RV/TLC (Pleth) (%)	31	25	37	31	99			
Vpast (L)								
--- DIFFUSION ---								
DLCOunc (ml/min/mm	23.08	18.46	27.70	*11.52	*49			
DLCOcor (ml/min/mm	23.08	18.46	27.70	*11.94	*51			
DL/VA (ml/min/mmHg/	4.86	3.89	5.83	5.11	105			
VA (L)	4.73	3.95	5.51	*2.34	*49			
IVC (L)				1.42				
BHT (sec)								



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	Pred	LLN	ULN	Actual	%Pred	Actual	%Pred	%Chng
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FEF 25-75% (L/sec)	3.03	2.53	3.53		*59			
FEF 25% (L/sec)	5.64	4.71	6.57	*6.62	*117			
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FEF 75% (L/sec)	1.57	1.31	1.83	*0.50	*31			
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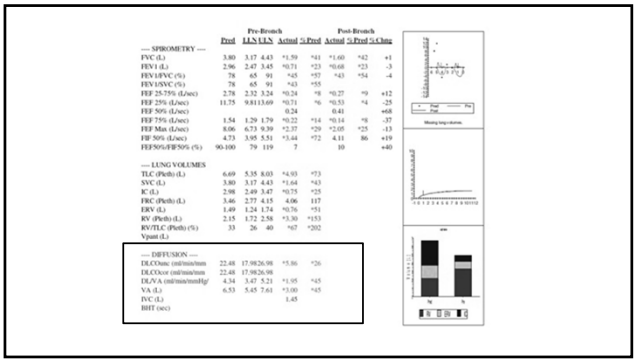
VA (L)	4.73	3.95	5.51	*2.34	*49			
IVC (L)				1.42				
BHT (sec)								

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



	Pre-Bronch				Post-Bronch			
	Pred	LLN	ULN	Actual	%Pred	Actual	%Pred	%Chng
--- SPIROMETRY ---								
FVC (L)	3.80	3.17	4.43	*1.59	*41	*1.60	*42	+1
FEV1 (L)	2.96	2.47	3.45	*0.71	*23	*0.68	*23	-3
FEV1/FVC (%)	78	65	91	*45	*57	*43	*54	-4
FEV1/SVC (%)	78	65	91	*43	*55			
FEF 25-75% (L/sec)	2.78	2.32	3.24	*0.24	*8	*0.27	*9	+12
FEF 25% (L/sec)	11.75	9.81	13.69	*0.71	*6	*0.53	*4	-25
FEF 50% (L/sec)				0.24		0.41		+68
FEF 75% (L/sec)	1.54	1.29	1.79	*0.22	*14	*0.14	*8	-37
FEF Max (L/sec)	8.06	6.73	9.39	*2.37	*29	*2.05	*25	-13
FIF 50% (L/sec)	4.73	3.95	5.51	*3.44	*72	4.11	86	+19
FEF50%/FIF50% (%)	90-100	79	119	7		10		+40
--- LUNG VOLUMES								
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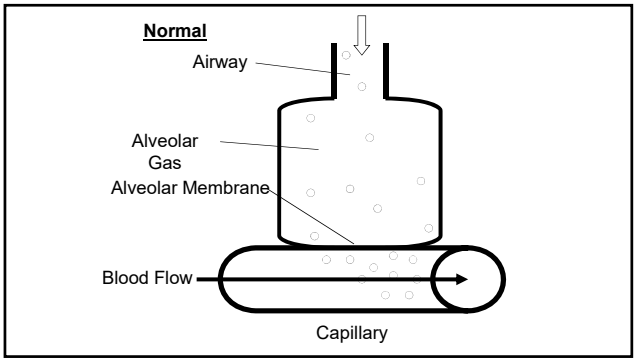
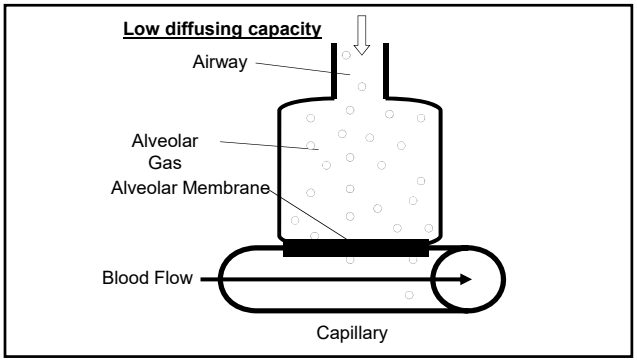
VA (L)	6.53	5.45	7.61	*3.00	*45			
IVC (L)				1.45				
BHT (sec)								

Pulmonary Function Tests: Diffusing Capacity

- Measure of gas exchange across the alveolar/capillary membrane
- Dependent on surface area, gas solubility, membrane thickness, and transit time
- Affected by age, body size, gender, hemoglobin, and lung volume
- Measured by carbon monoxide uptake





Diffusing Capacity Interpretation

DLCO (% predicted)	Severity
60% - LLN*	Mild
40-60%	Moderate
<40%	Severe

*LLN = lower limit of normal

Common Causes of a Decreased Diffusing Capacity

- Anemia
- Right-left intracardiac shunt
- Poor inspiration
- Interstitial lung disease
- Emphysema
- Pulmonary vascular disease

A word about correcting the DLCO

- **DLCO** – uncorrected diffusing capacity
- **DLCOcor** – diffusing capacity corrected for the hemoglobin level
- **DLCO/VA** – diffusing capacity corrected for the alveolar volume
  - VA = alveolar volume ≈ total lung capacity

4 Questions Of PFT Interpretation

1. Is the patient obstructed?
   - Is FEV1/FVC reduced?
   - Obstruction severity defined by the FEV1 % predicted
2. If obstructed, is obstruction reversible?
   - Use 12% improvement in FEV1 OR FVC
3. Is the patient restricted?
   - Is the TLC reduced?
4. Is the diffusing capacity reduced?
   - Is the DLCO reduced?

Respiratory Patterns in Common Diseases

	Asthma	Emphysema	Interstitial Lung Disease	Muscle Weakness
FVC	Normal or ↓	↓	↓	↓
$FEV_{1.0}$	↓	↓	↓	↓
$FEV_{1.0}$/FVC	↓	↓	Normal	Normal
TLC	Normal or ↑	↑	↓	↓
DLCO	Normal	↓	↓	Normal

Following Serial PFTs Over Time

Visit Date	FVC L	FEV1 L	FEV1/FVC %	FEV1/SVC %	TLC (Pleth) L	DLCOunc ml/min/mm	DLCOunc ml/min/m
Pre							
1/9/2014 10:35:14 AM	1.71	1.57	92	88	2.78	11.51	11.51
5/20/2014 2:00:05 PM	1.71	1.54	90	64	3.17	10.70	10.70
10/7/2014 2:49:45 PM	1.72	1.55	90	82	3.12	13.46	13.46
4/24/2015 3:05:27 PM	1.68	1.47	88	87	2.53	11.32	11.32
8/25/2015 1:03:04 PM	1.22	1.12	91	91	2.21	9.71	9.71
11/10/2015 2:51:33 PM	1.37	1.26	92	73	2.56	10.04	10.04
3/22/2016 1:22:08 PM	1.44	1.24	86	67	2.70	11.52	11.52