Pulmonary Function Testing

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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**
- **6 Minute walk test:**
  - **Measures oxygenation during exercise**

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

Pulmonary Function Tests: Spirometry

- Measure of airflow
- Forced vital capacity (FVC) – amount of air that can be exhaled in one breath with maximum force
- Forced expiratory volume in 1 sec. ($FEV_{1.0}$)
- $FEV_{1.0}$/FVC ratio
- FEF25-75% - forced expiratory flow between the 25^{th} and 75^{th} percent of an exhaled breath
- Peak flow rate (PEF, PEFR) – highest flow rate achieved during expiration
- Reversible obstruction
  - 12% increase and 200 mL increase in FVC or $FEV_{1.0}$ with bronchodilator

A Spirometry Test Requires 3 Steps To Be Done Correctly

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

Computer interpretation of spirometry

- Reasonably good at identifying normal spirometry
- The computer cannot interpret flow volume loop patterns
- For patients with abnormal spirometry, the computer interpretation is frequently inaccurate and can give an incorrect interpretation in more than half of cases, depending on the population of patients being tested

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.

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

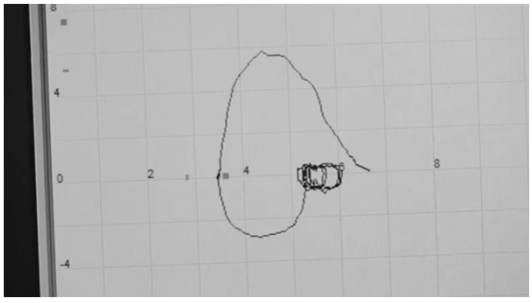
1. Place a nose clip on the patient
2. Have the patient take as deep of a breath as possible
3. When instructed by the spirometer, tell patients to "blast" their air out as hard and fast as they can
4. The patient should continue exhaling until they have exhaled at least 6 seconds and there is no further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



Defining Normal Values

- The FEV1 and FVC vary depending on:
  1. Age
  2. Gender
  3. Race
  4. 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

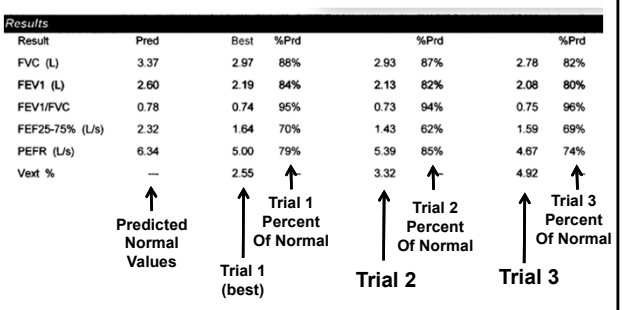
Defining obstruction

- 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: 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. 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	—

Spirometry Interpretation

Results

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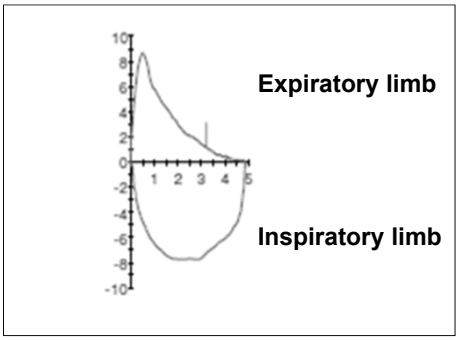
FVC (L)	3.37	2.97	88%
FEV1 (L)	2.60	2.19	84%
FEV1/FVC	0.78	0.74	95%
FEF25-75% (L/s)	2.32	1.64	70%
PEFR (L/s)	6.34	5.00	79%
Vext %	—	2.55	—

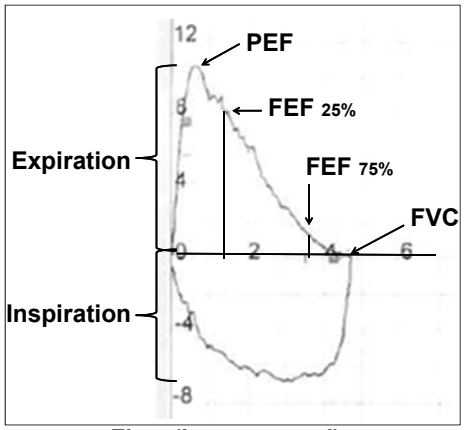
In this case, the FEV1/FVC is within a normal range (0.74 or 74%). Most office spirometers will not display the range of normal (in this case 68%-90%). The computer will flag an abnormally low value by putting an asterisk or square mark to the left of the values

Important Note:

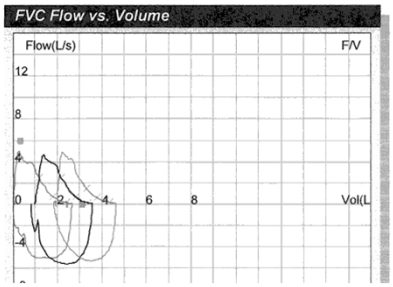
If the FEV1/FVC ratio is normal, then the patient is NOT obstructed. In this case, the FEV1 can be normal, elevated, <u>or reduced</u> but the patient is still not obstructed

Normal Flow Volume Loop (PFT lab spirometer)



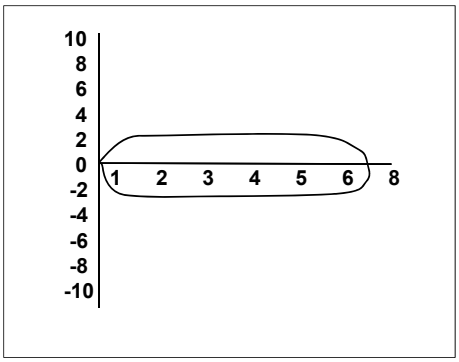


Normal Flow Volume Loop (office spirometer)

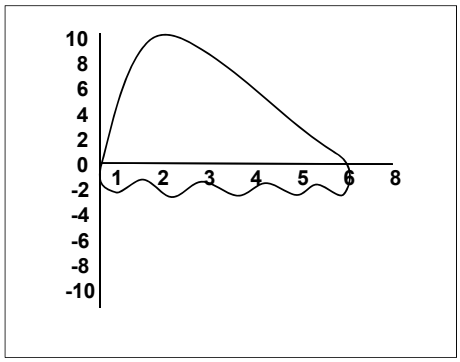


Note that there are 3 separate flow-volume loops all superimposed on one graph. This is typical for office spirometry

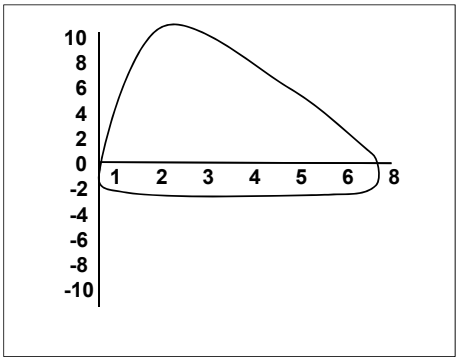
Tracheostenosis



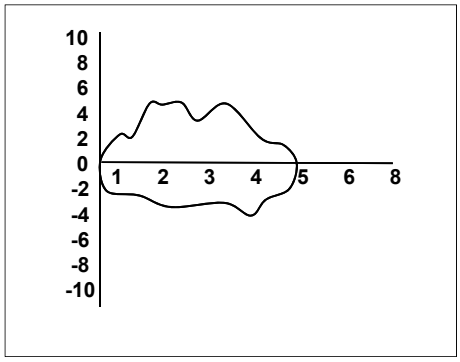
Vocal Cord Dysfunction



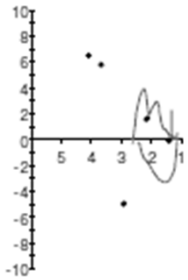
Vocal Cord Paralysis



Invalid Test

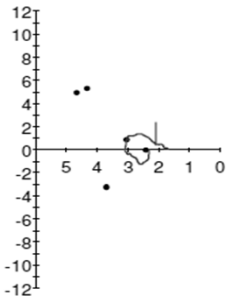


Invalid Test: Patient Coughed During Expiration



Note the "double-humped" pattern on the expiratory limb

Invalid Test: Poor Effort



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 (or Combivent), 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

A note about spirometry and children

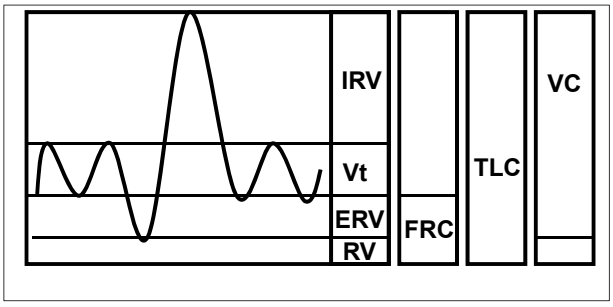
Children

- 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

Pulmonary Function Tests: Lung Volumes

- Total lung capacity (TLC)
  - Restriction defined as TLC < 80% predicted
  - Hyperinflation defined as TLC > 120% predicted
- Residual volume (RV)
- Functional residual capacity (FRC)
  - Air-trapping defined as FRC or RV > 120% predicted

Derivation of the lung volumes



Causes of Restriction

- Interstitial lung disease
- Alveolar filling processes
- Chest wall impairment
- Respiratory muscle weakness

Diagnosing Restriction Based On Spirometry

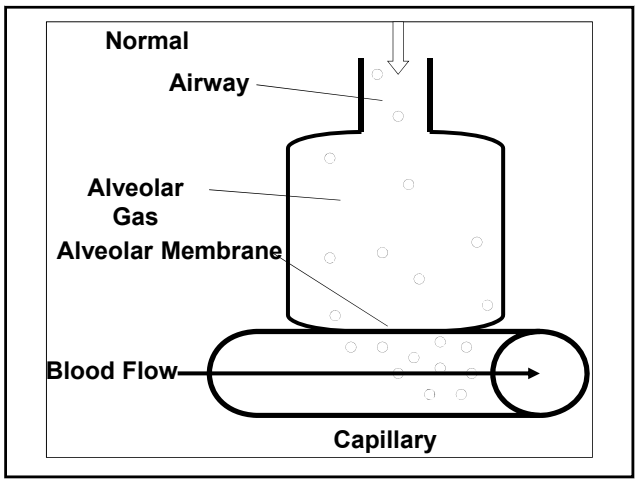
- The only confident way to diagnose restriction is by full lung volume measurements with measurement of the total lung capacity (TLC).
- You can suspect restriction if the FVC is low on spirometry but this can be fraught with error.
  - Many patients with COPD will have a low FVC
  - The FVC is often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

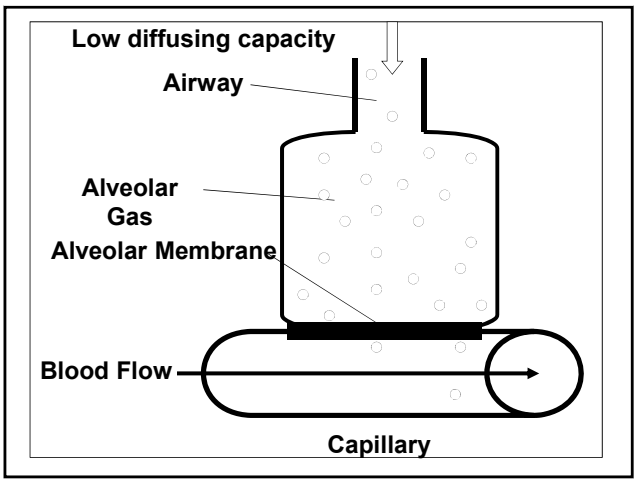
Diagnosing Restriction Based On Spirometry (continued)

- However, in some diseases, following the FVC serially can be a good marker of lung capacity and 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.

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





Decreased Diffusing Capacity

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

Correcting The Diffusing Capacity

- DLCO
- Hematocrit-adjusted DLCO
- DLCO/VA
- Hematocrit-adjusted DLCO/VA

4 Questions Of PFT Interpretation

1. Is the patient obstructed?
   - Is FEV1/FVC reduced?
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?
   - DL_{CO} vs. DL_{CO}/VA

PFT Patterns in Lung Disease

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

Obstructive Lung Disease: COPD

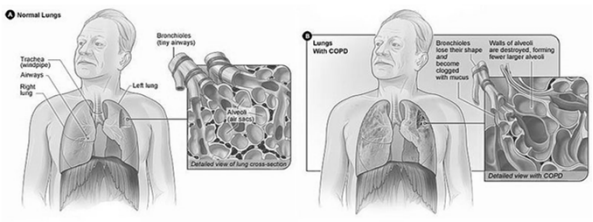


Image: National Institutes of Health

Obstructive Lung Disease: Asthma

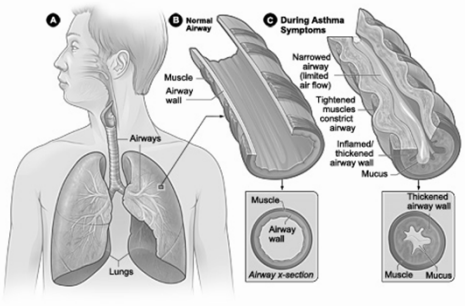
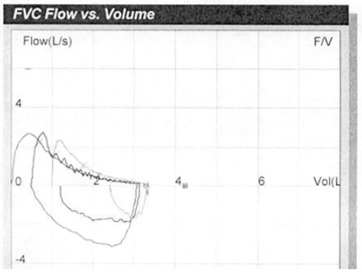


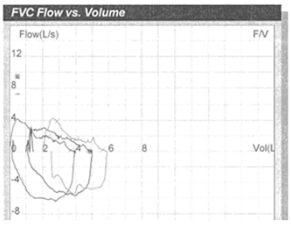
Image: National Institutes of Health

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

Causes Of Obstruction

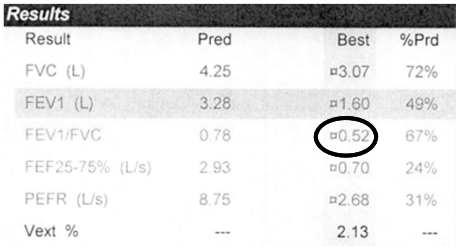
- **Chronic obstructive pulmonary disease**
  - **Emphysema**
  - **Chronic bronchitis**
- **Asthma**
- **Bronchiectasis**
- **Bronchiolitis & bronchiolitis obliterans**

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



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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/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.

There are two commonly used scales of obstruction severity:

American Thoracic Society (ATS)

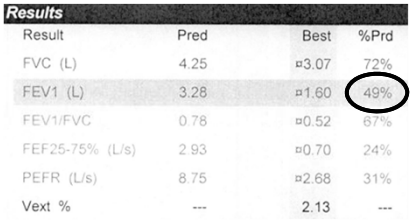
FEV1 (% predicted)	Obstruction
> 70%	Mild
60-69%	Moderate
50-59%	Moderately Severe
35-49%	Severe
< 35%	Very Severe

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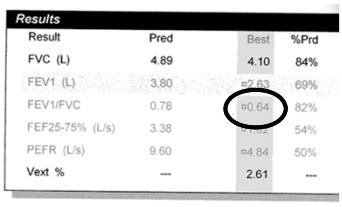
FEF25-75% (L/s)	2.93	¤0.70	24%
PEFR (L/s)	8.75	¤2.68	31%
Vext %	---	2.13	---

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

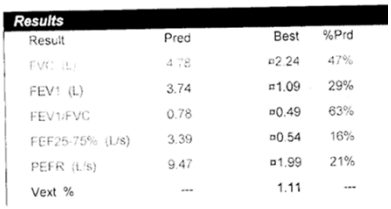


Results

Result	Pred	Best	%Prd
FVC (L)	4.89	4.10	84%
FEV1 (L)	3.80	¤2.63	69%
FEV1/FVC	0.78	¤0.64	82%
FEF25-75% (L/s)	3.38	¤1.82	54%
PEFR (L/s)	9.60	¤4.84	50%
Vext %	---	2.61	---

In this case, the FEV1 is 69% of predicted so the patient would be defined as having moderate obstruction by either the ATS or the GOLD criteria.

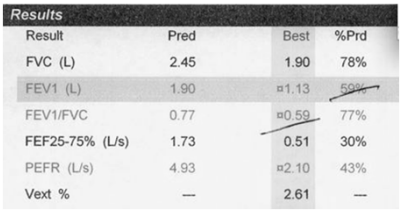
Obstructive Pattern



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 mark to the left of the value. 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.

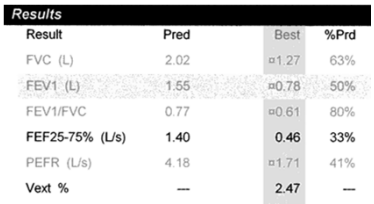
Obstructive Pattern



Results			
Result	Pred	Best	%Prd
FVC (L)	2.45	1.90	78%
FEV1 (L)	1.90	¤1.13	59%
FEV1/FVC	0.77	¤0.59	77%
FEF25-75% (L/s)	1.73	0.51	30%
PEFR (L/s)	4.93	¤2.10	43%
Vext %	---	2.61	---

In this case, the FEV1/FVC ratio is low at 0.59 (59% of predicted). It is marked as abnormal by the computer with the square mark to the left of the value. The FEV1 is 1.13 L (59% of predicted) which makes this moderate obstruction by GOLD criteria but moderately severe obstruction by ATS criteria. The computer interpreted this as mild obstruction.

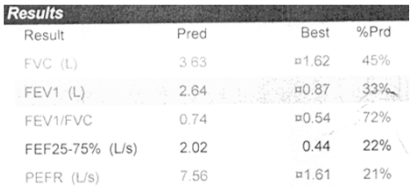
Obstructive Pattern



Results			
Result	Pred	Best	%Prd
FVC (L)	2.02	¤1.27	63%
FEV1 (L)	1.55	¤0.78	50%
FEV1/FVC	0.77	¤0.61	80%
FEF25-75% (L/s)	1.40	0.46	33%
PEFR (L/s)	4.18	¤1.71	41%
Vext %	---	2.47	---

In this case, the FEV1/FVC ratio is low at 0.61 (61% of predicted). It is marked as abnormal by the computer with the square mark to the left of the value. The FEV1 is 0.78 L (50% of predicted) which makes this moderate obstruction by GOLD criteria but moderately severe obstruction by ATS criteria.

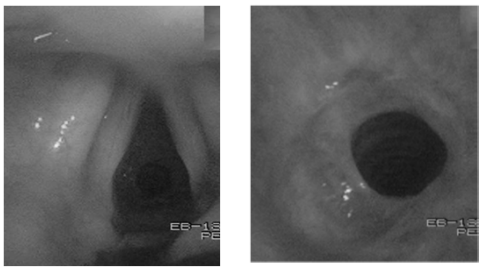
Obstructive Pattern



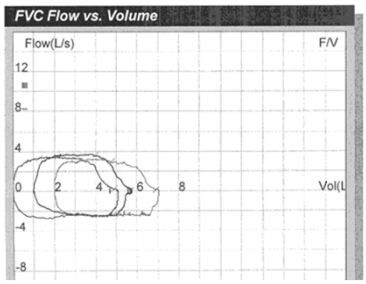
Results			
Result	Pred	Best	%Prd
FVC (L)	3.63	¤1.62	45%
FEV1 (L)	2.64	¤0.87	33%
FEV1/FVC	0.74	¤0.54	72%
FEF25-75% (L/s)	2.02	0.44	22%
PEFR (L/s)	7.56	¤1.61	21%

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

Tracheostenosis

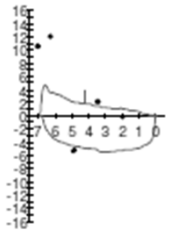


Tracheostenosis



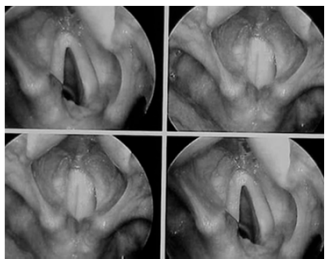
This patient has granulomatosis with angiitis (Wegener's granulomatosis) with subglottic stenosis. Note the flattening of both the inspiratory and expiratory limbs.

Tracheostenosis

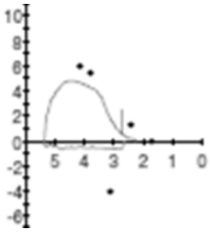


This patient also has granulomatosis with angiitis (Wegener's granulomatosis) with subglottic stenosis. The inspiratory and expiratory limbs are somewhat flattened but more subtle than the previous case.

Vocal Cord Paralysis

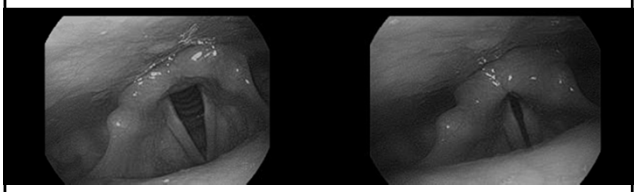


Paralyzed Vocal Cords



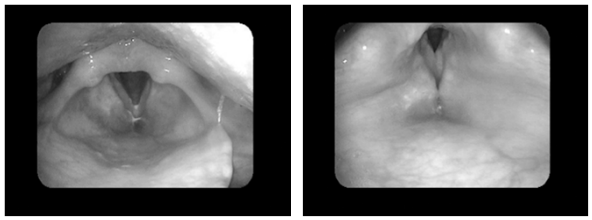
This patient has a history of recurrent laryngeal nerve damage during a mediastinoscopy. The computer interpretation was normal. The flow-volume loop shows severe inspiratory flattening indicating variable upper airway obstruction

Vocal Cord Dysfunction

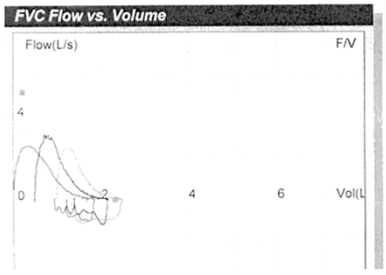


Fully Abducted **Constricted Respiration**

Vocal Cord Dysfunction



Vocal Cord Dysfunction



Note the "notching" on the inspiratory limb

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		
	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

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

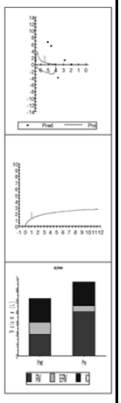
Irreversible obstruction

		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

Case #1

- 20-year-old college student
- Dyspnea and cough since classes started
- Moved from a dorm to an apartment this year

	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	3.53	2.95	4.11	*2.74	*77			
FEV1 (L)	2.75	2.30	3.20	*1.25	*45			
FEV1/FVC (%)	79	66	92	*46	*57			
FEV1/SVC (%)	78	65	91	*46	*58			
FEF 25-75% (L/sec)	2.57	2.15	2.99	*0.42	*16			
FEF 25% (L/sec)	5.55	4.63	6.47	*1.23	*22			
FEF 50% (L/sec)				0.50				
FEF 75% (L/sec)	1.29	1.08	1.50	*0.20	*15			
FEF Max (L/sec)	6.64	5.54	7.74	*3.85	*57			
FIF 50% (L/sec)	3.90	3.26	4.54	*2.39	*61			
FEF50%/FIF50% (%)	90-100	79	119	21				
---- LUNG VOLUMES								
TLC (Pleth) (L)	5.20	4.16	6.24	*6.71	*128			
SVC (L)	3.53	2.95	4.11	*2.74	*77			
IC (L)	2.18	1.82	2.54	2.14	98			
FRC (Pleth) (L)	2.94	2.35	3.53	*4.52	*153			
ERV (L)	1.09	0.91	1.27	*0.56	*51			
RV (Pleth) (L)	1.96	1.57	2.35	*3.96	*202			
RV/TLC (Pleth) (%)	38	30	46	*59	*155			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	22.46	17.97	26.95	22.93	102			
DLCOcor (ml/min/mm	22.46	17.97	26.95					
DL/VA (ml/min/mmHg/	4.46	3.57	5.35	5.09	114			
VA (L)	5.23	4.37	6.09	4.50	86			
IVC (L)				2.41				
BHT (sec)								

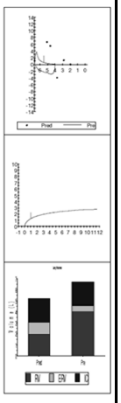


Case #1

- 20-year-old college student
- Dyspnea and cough since classes started
- Moved from a dorm to an apartment this year

	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	3.53	2.95	4.11	*2.74	*77			
FEV1 (L)	2.75	2.30	3.20	*1.25	*45			
FEV1/FVC (%)	79	66	92	*46	*57			
FEV1/SVC (%)	78	65	91	*46	*58			
FEF 25-75% (L/sec)	2.57	2.15	2.99	*0.42	*16			
FEF 25% (L/sec)	5.55	4.63	6.47	*1.23	*22			
FEF 50% (L/sec)				0.50				
FEF 75% (L/sec)	1.29	1.08	1.50	*0.20	*15			
FEF Max (L/sec)	6.64	5.54	7.74	*3.85	*57			
FIF 50% (L/sec)	3.90	3.26	4.54	*2.39	*61			
FEF50%/FIF50% (%)	90-100	79	119	21				
---- LUNG VOLUMES								
TLC (Pleth) (L)	5.20	4.16	6.24	*6.71	*128			
SVC (L)	3.53	2.95	4.11	*2.74	*77			
IC (L)	2.18	1.82	2.54	2.14	98			
FRC (Pleth) (L)	2.94	2.35	3.53	*4.52	*153			
ERV (L)	1.09	0.91	1.27	*0.56	*51			
RV (Pleth) (L)	1.96	1.57	2.35	*3.96	*202			
RV/TLC (Pleth) (%)	38	30	46	*59	*155			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	22.46	17.97	26.95	22.93	102			
DLCOcor (ml/min/mm	22.46	17.97	26.95					
DL/VA (ml/min/mmHg/	4.46	3.57	5.35	5.09	114			
VA (L)	5.23	4.37	6.09	4.50	86			
IVC (L)				2.41				
BHT (sec)								

*46

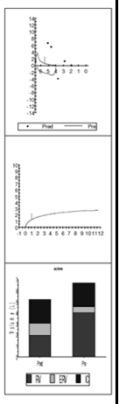


Case #1

- 20-year-old college student
- Dyspnea and cough since classes started
- Moved from a dorm to an apartment this year

	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	3.53	2.95	4.11	*2.74	*77			
FEV1 (L)	2.75	2.30	3.20	*1.25	*45			
FEV1/FVC (%)	79	66	92	*46	*57			
FEV1/SVC (%)	78	65	91	*46	*58			
FEF 25-75% (L/sec)	2.57	2.15	2.99	*0.42	*16			
FEF 25% (L/sec)	5.55	4.63	6.47	*1.23	*22			
FEF 50% (L/sec)				0.50				
FEF 75% (L/sec)	1.29	1.08	1.50	*0.20	*15			
FEF Max (L/sec)	6.64	5.54	7.74	*3.85	*57			
FIF 50% (L/sec)	3.90	3.26	4.54	*2.39	*61			
FEF50%/FIF50% (%)	90-100	79	119	21				
---- LUNG VOLUMES								
TLC (Pleth) (L)	5.20	4.16	6.24	*6.71	*128			
SVC (L)	3.53	2.95	4.11	*2.74	*77			
IC (L)	2.18	1.82	2.54	2.14	98			
FRC (Pleth) (L)	2.94	2.35	3.53	*4.52	*153			
ERV (L)	1.09	0.91	1.27	*0.56	*51			
RV (Pleth) (L)	1.96	1.57	2.35	*3.96	*202			
RV/TLC (Pleth) (%)	38	30	46	*59	*155			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	22.46	17.97	26.95	22.93	102			
DLCOcor (ml/min/mm	22.46	17.97	26.95					
DL/VA (ml/min/mmHg/	4.46	3.57	5.35	5.09	114			
VA (L)	5.23	4.37	6.09	4.50	86			
IVC (L)				2.41				
BHT (sec)								

*45
*46

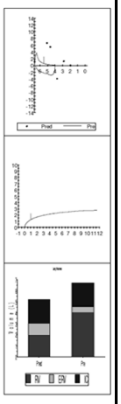


Case #1

- 20-year-old college student
- Dyspnea and cough since classes started
- Moved from a dorm to an apartment this year

	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	3.53	2.95	4.11	*2.74	*77			
FEV1 (L)	2.75	2.30	3.20	*1.25	*45			
FEV1/FVC (%)	79	66	92	*46	*57			
FEV1/SVC (%)	78	65	91	*46	*58			
FEF 25-75% (L/sec)	2.57	2.15	2.99	*0.42	*16			
FEF 25% (L/sec)	5.55	4.63	6.47	*1.23	*22			
FEF 50% (L/sec)				0.50				
FEF 75% (L/sec)	1.29	1.08	1.50	*0.20	*15			
FEF Max (L/sec)	6.64	5.54	7.74	*3.85	*57			
FIF 50% (L/sec)	3.90	3.26	4.54	*2.39	*61			
FEF50%/FIF50% (%)	90-100	79	119	21				
---- LUNG VOLUMES								
TLC (Pleth) (L)	5.20	4.16	6.24	*6.71	*128			
SVC (L)	3.53	2.95	4.11	*2.74	*77			
IC (L)	2.18	1.82	2.54	2.14	98			
FRC (Pleth) (L)	2.94	2.35	3.53	*4.52	*153			
ERV (L)	1.09	0.91	1.27	*0.56	*51			
RV (Pleth) (L)	1.96	1.57	2.35	*3.96	*202			
RV/TLC (Pleth) (%)	38	30	46	*59	*155			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	22.46	17.97	26.95	22.93	102			
DLCOcor (ml/min/mm	22.46	17.97	26.95					
DL/VA (ml/min/mmHg/	4.46	3.57	5.35	5.09	114			
VA (L)	5.23	4.37	6.09	4.50	86			
IVC (L)				2.41				
BHT (sec)								

*45
*46
*128
*202



Case #1

- 20-year-old college student
- Dyspnea and cough since classes started
- Moved from a dorm to an apartment this year

	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	3.53	2.95	4.11	*2.74	*77			
FEV1 (L)	2.75	2.30	3.20	*1.26	*45			
FEV1/FVC (%)	79	66	92	*46	*58			
FEV1/SVC (%)	78	65	91	*46	*58			
FEF 25-75% (L/sec)	2.57	2.15	2.99	*0.42	*16			
FEF 25% (L/sec)	5.55	4.63	6.47	*1.23	*22			
FEF 50% (L/sec)				0.50				
FEF 75% (L/sec)	1.29	1.08	1.50	*0.20	*15			
FEF Max (L/sec)	6.64	5.54	7.74	*3.85	*57			
FIF 50% (L/sec)	3.90	3.26	4.54	*2.39	*61			
FEF50%/FIF50% (%)	90-100	79	119	21				
---- LUNG VOLUMES								
TLC (Pleth) (L)	5.20	4.16	6.24	*6.71	*129			
SVC (L)	3.53	2.95	4.11	*2.74	*77			
IC (L)	2.18	1.82	2.54	2.14	98			
FRC (Pleth) (L)	2.94	2.35	3.53	*4.52	*153			
ERV (L)	1.09	0.91	1.27	*0.56	*51			
RV (Pleth) (L)	1.96	1.57	2.35	*3.96	*202			
RV/TLC (Pleth) (%)	38	30	46	*59	*155			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	22.46	17.97	26.95	22.93	102			
DLCOcor (ml/min/mm	22.46	17.97	26.95					
DL/VA (ml/min/mmHg/	4.46	3.57	5.35	5.09	114			
VA (L)	5.23	4.37	6.09	4.50	86			
IVC (L)				2.41				
BHT (sec)								

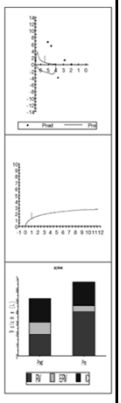
*45

*46

*128

*202

102



Case #1

- 20-year-old college student
- Dyspnea and cough since classes started
- Moved from a dorm to an apartment this year
- **Asthma**

	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	3.53	2.95	4.11	*2.74	*77			
FEV1 (L)	2.75	2.30	3.20	*1.26	*45			
FEV1/FVC (%)	79	66	92	*46	*58			
FEV1/SVC (%)	78	65	91	*46	*58			
FEF 25-75% (L/sec)	2.57	2.15	2.99	*0.42	*16			
FEF 25% (L/sec)	5.55	4.63	6.47	*1.23	*22			
FEF 50% (L/sec)				0.50				
FEF 75% (L/sec)	1.29	1.08	1.50	*0.20	*15			
FEF Max (L/sec)	6.64	5.54	7.74	*3.85	*57			
FIF 50% (L/sec)	3.90	3.26	4.54	*2.39	*61			
FEF50%/FIF50% (%)	90-100	79	119	21				
---- LUNG VOLUMES								
TLC (Pleth) (L)	5.20	4.16	6.24	*6.71	*129			
SVC (L)	3.53	2.95	4.11	*2.74	*77			
IC (L)	2.18	1.82	2.54	2.14	98			
FRC (Pleth) (L)	2.94	2.35	3.53	*4.52	*153			
ERV (L)	1.09	0.91	1.27	*0.56	*51			
RV (Pleth) (L)	1.96	1.57	2.35	*3.96	*202			
RV/TLC (Pleth) (%)	38	30	46	*59	*155			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	22.46	17.97	26.95	22.93	102			
DLCOcor (ml/min/mm	22.46	17.97	26.95					
DL/VA (ml/min/mmHg/	4.46	3.57	5.35	5.09	114			
VA (L)	5.23	4.37	6.09	4.50	86			
IVC (L)				2.41				
BHT (sec)								

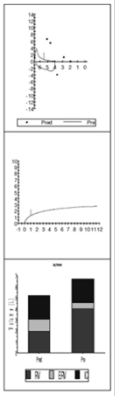
*45

*46

*128

*202

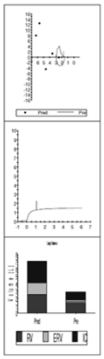
102



Case #2

- 50-year-old man
- History of ALS
- Dyspnea for 2 years

	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	4.33	3.62	5.04	*1.48	*34			
FEV1 (L)	3.15	2.63	3.67	*1.29	*41			
FEV1/FVC (%)	73	61	85	*87	*119			
FEV1/SVC (%)	73	61	85	*94	*129			
FEF 25-75% (L/sec)	2.32	1.94	2.70	*1.69	*72			
FEF 25% (L/sec)	12.62	10.54	14.70	*3.23	*25			
FEF 50% (L/sec)				2.42				
FEF 75% (L/sec)	1.36	1.14	1.58	*0.57	*42			
FEF Max (L/sec)	8.04	6.71	9.37	*4.05	*50			
FIF 50% (L/sec)	4.37	3.65	5.09	*3.13	*71			
FEF50%/FIF50% (%)	90-100	79	119	77				
---- LUNG VOLUMES								
TLC (Pleth) (L)	7.09	5.67	8.51	*2.91	*40			
SVC (L)	4.33	3.62	5.04	*1.37	*31			
IC (L)	2.96	2.47	3.45	*1.12	*37			
FRC (Pleth) (L)	3.79	3.03	4.55	*1.73	*45			
ERV (L)	1.48	1.24	1.72	*0.19	*13			
RV (Pleth) (L)	2.54	2.03	3.05	*1.53	*60			
RV/TLC (Pleth) (%)	37	30	44	*53	*142			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	25.42	20.34	30.50	*16.04	*63			
DLCOcor (ml/min/mm	25.42	20.34	30.50					
DL/VA (ml/min/mmHg/	3.81	3.05	4.57	*6.42	*168			
VA (L)	6.87	5.74	8.00	*2.50	*36			
IVC (L)				1.42				
BHT (sec)								

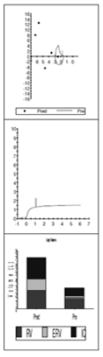


Case #2

- 50-year-old man
- History of ALS
- Dyspnea for 2 years

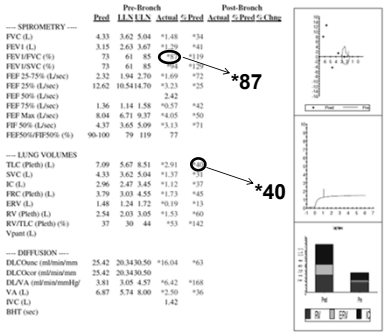
	Pred	Pre-Bronch LLN	ULN	Actual	%Pred	Post-Bronch Actual	%Pred	%Chng
---- SPIROMETRY ----								
FVC (L)	4.33	3.62	5.04	*1.48	*34			
FEV1 (L)	3.15	2.63	3.67	*1.29	*41			
FEV1/FVC (%)	73	61	85	*87	*119			
FEV1/SVC (%)	73	61	85	*94	*129			
FEF 25-75% (L/sec)	2.32	1.94	2.70	*1.69	*72			
FEF 25% (L/sec)	12.62	10.54	14.70	*3.23	*25			
FEF 50% (L/sec)				2.42				
FEF 75% (L/sec)	1.36	1.14	1.58	*0.57	*42			
FEF Max (L/sec)	8.04	6.71	9.37	*4.05	*50			
FIF 50% (L/sec)	4.37	3.65	5.09	*3.13	*71			
FEF50%/FIF50% (%)	90-100	79	119	77				
---- LUNG VOLUMES								
TLC (Pleth) (L)	7.09	5.67	8.51	*2.91	*40			
SVC (L)	4.33	3.62	5.04	*1.37	*31			
IC (L)	2.96	2.47	3.45	*1.12	*37			
FRC (Pleth) (L)	3.79	3.03	4.55	*1.73	*45			
ERV (L)	1.48	1.24	1.72	*0.19	*13			
RV (Pleth) (L)	2.54	2.03	3.05	*1.53	*60			
RV/TLC (Pleth) (%)	37	30	44	*53	*142			
Vpant (L)								
---- DIFFUSION ----								
DLCOunc (ml/min/mm	25.42	20.34	30.50	*16.04	*63			
DLCOcor (ml/min/mm	25.42	20.34	30.50					
DL/VA (ml/min/mmHg/	3.81	3.05	4.57	*6.42	*168			
VA (L)	6.87	5.74	8.00	*2.50	*36			
IVC (L)				1.42				
BHT (sec)								

*87



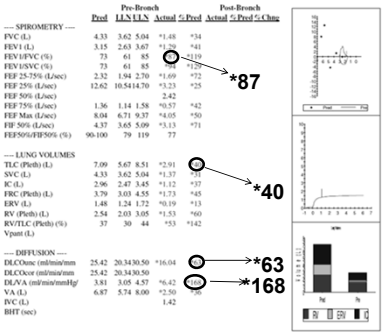
Case #2

- 50-year-old man
- History of ALS
- Dyspnea for 2 years



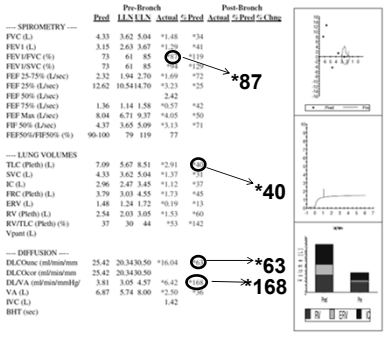
Case #2

- 50-year-old man
- History of ALS
- Dyspnea for 2 years



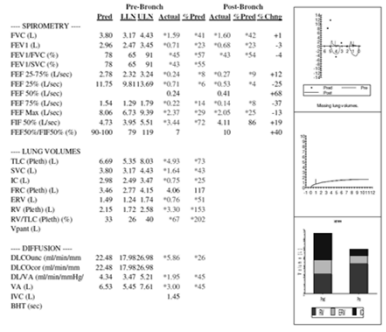
Case #2

- 50-year-old man
- History of ALS
- Dyspnea for 2 years
- Neuromuscular weakness



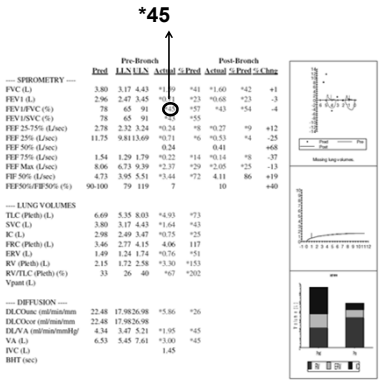
Case #3

- 65-year-old woman
- Dyspnea for 3 years
- Frequent bronchitis
- Daily sputum production
- Non-smoker
- Moist crackles on exam



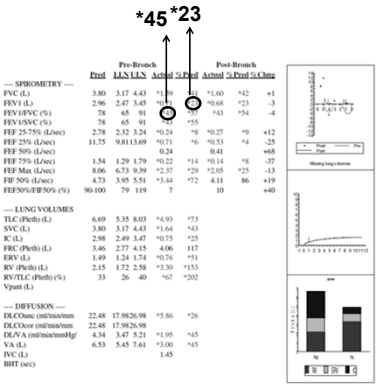
Case #3

- 65-year-old woman
- Dyspnea for 3 years
- Frequent bronchitis
- Daily sputum production
- Non-smoker
- Moist crackles on exam



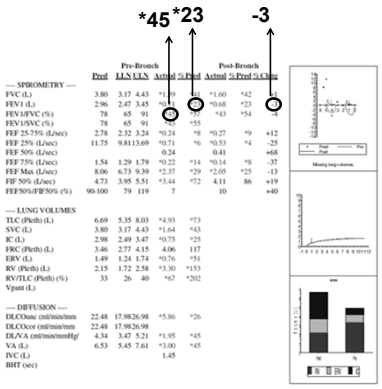
Case #3

- 65-year-old woman
- Dyspnea for 3 years
- Frequent bronchitis
- Daily sputum production
- Non-smoker
- Moist crackles on exam



Case #3

- 65-year-old woman
- Dyspnea for 3 years
- Frequent bronchitis
- Daily sputum production
- Non-smoker
- Moist crackles on exam



Case #3

- 65-year-old woman
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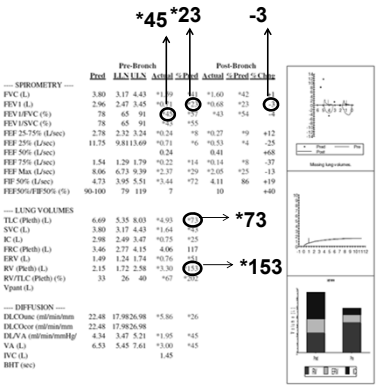
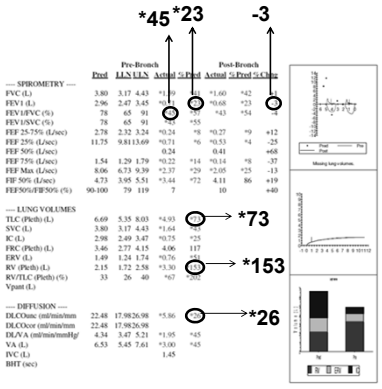
- Frequent bronchitis
- Daily sputum production
- Non-smoker
- Moist crackles on exam



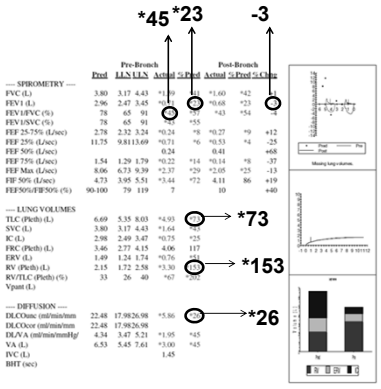
Case #3

- 65-year-old woman
- Dyspnea for 3 years
- Frequent bronchitis
- Daily sputum production
- Non-smoker
- Moist crackles on exam



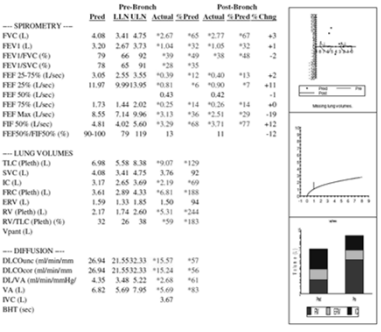
Case #3

- 65-year-old woman
- Dyspnea for 3 years
- Frequent bronchitis
- Daily sputum production
- Non-smoker
- Moist crackles on exam
- **Bronchiectasis**



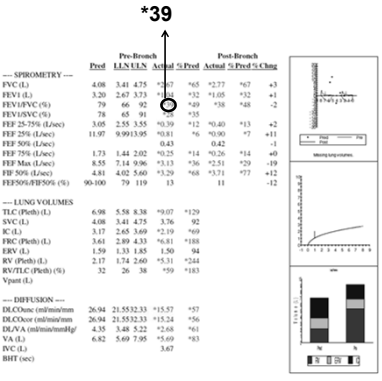
Case #4

- 55-year-old man
- Dyspnea for 5 years
- Smokes 1 pack a day



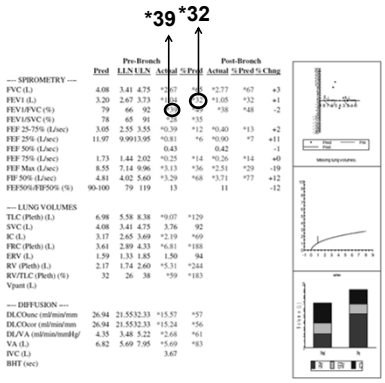
Case #4

- 55-year-old man
- Dyspnea for 5 years
- Smokes 1 pack a day



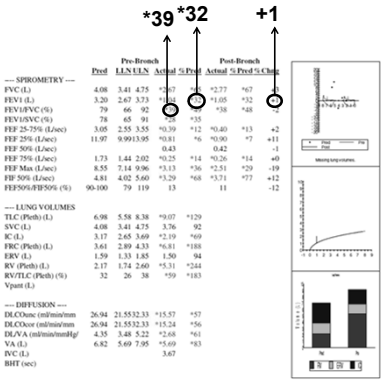
Case #4

- 55-year-old man
- Dyspnea for 5 years
- Smokes 1 pack a day



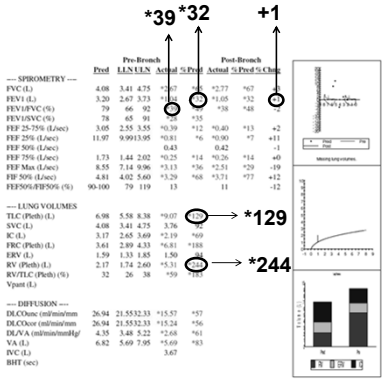
Case #4

- 55-year-old man
- Dyspnea for 5 years
- Smokes 1 pack a day



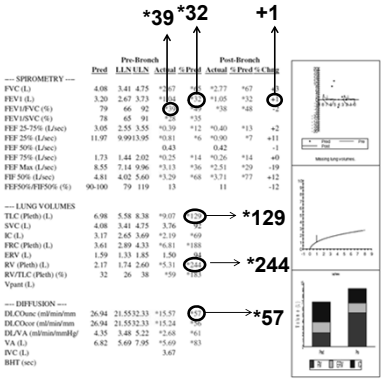
Case #4

- 55-year-old man
- Dyspnea for 5 years
- Smokes 1 pack a day



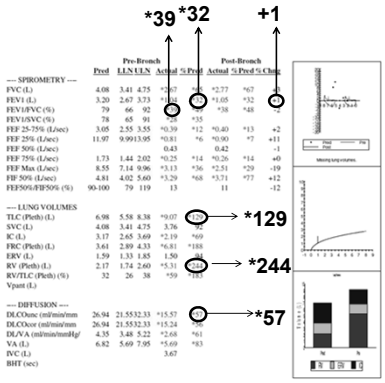
Case #4

- 55-year-old man
- Dyspnea for 5 years
- Smokes 1 pack a day



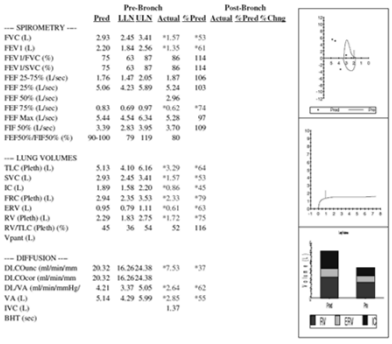
Case #4

- 55-year-old man
- Dyspnea for 5 years
- Smokes 1 pack a day
- **Emphysema**



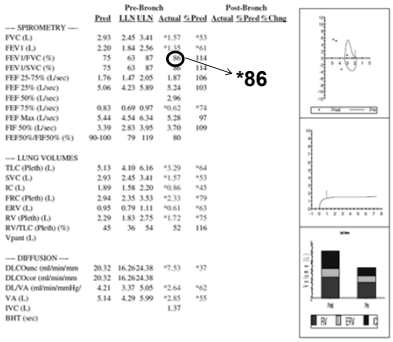
Case #5

- 70-year-old woman
- Dyspnea for 6 months
- Non-smoker
- Dry crackles on exam



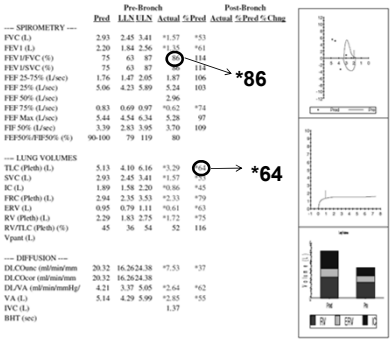
Case #5

- 70-year-old woman
- Dyspnea for 6 months
- Non-smoker
- Dry crackles on exam



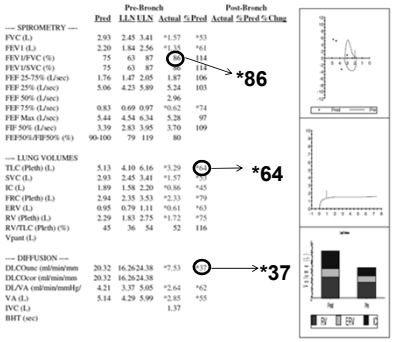
Case #5

- 70-year-old woman
- Dyspnea for 6 months
- Non-smoker
- Dry crackles on exam



Case #5

- 70-year-old woman
- Dyspnea for 6 months
- Non-smoker
- Dry crackles on exam



	Pre-Bronch				Post-Bronch	
	Pred	LLN ULN	Actual	%Pred	Actual	%Pred %Chng
--- SPIROMETRY ---						
FVC (L)	2.93	2.45 3.41	*1.57	*53		
FEV1 (L)	2.20	1.84 2.56	*1.61	*61		
FEV1/FVC (%)	75	63 87	86	114		
FEV1/SVC (%)	75	63 87		114		
FEF 25-75% (L/sec)	1.76	1.47 2.05	1.87	106		
FEF 25% (L/sec)	5.06	4.23 5.89	5.24	103		
FEF 50% (L/sec)			2.96			
FEF 75% (L/sec)	0.83	0.69 0.97	*0.62	*74		
FEF Max (L/sec)	5.44	4.54 6.34	5.28	97		
FIF 50% (L/sec)	3.39	2.83 3.95	3.70	109		
FEF50%/FIF50% (%)	90-100	79 119	80			
--- LUNG VOLUMES						
TLC (Pleth) (L)	5.13	4.10 6.16	*3.29	64		
SVC (L)	2.93	2.45 3.41	*1.57			
IC (L)	1.89	1.58 2.20	*0.86	*45		
FRC (Pleth) (L)	2.94	2.35 3.53	*2.33	*79		
ERV (L)	0.95	0.79 1.11	*0.61	*63		
RV (Pleth) (L)	2.29	1.83 2.75	*1.72	*75		
RV/TLC (Pleth) (%)	45	36 54	52	116		
Vpatt (L)						
--- DIFFUSION ---						
DLCOunc (ml/min/mm	20.32	16.26 24.38	*7.53	37		
DLCOcor (ml/min/mm	20.32	16.26 24.38				
DL/VA (ml/min/mmHg/	4.21	3.37 5.05	*2.64	*62		
VA (L)	5.14	4.29 5.99	*2.85	*55		
IVC (L)			1.37			
BHT (sec)						

*86

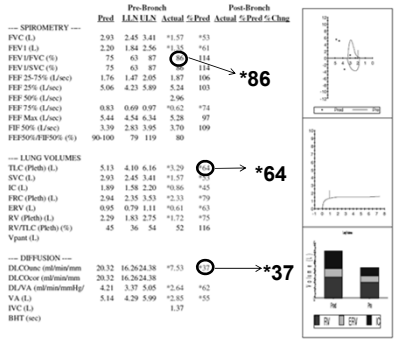
*64

*37

Case #5

- 70-year-old woman
- Dyspnea for 6 months
- Non-smoker
- Dry crackles on exam

- **Idiopathic pulmonary fibrosis**



	Pre-Bronch				Post-Bronch	
	Pred	LLN ULN	Actual	%Pred	Actual	%Pred %Chng
--- SPIROMETRY ---						
FVC (L)	2.93	2.45 3.41	*1.57	*53		
FEV1 (L)	2.20	1.84 2.56	*1.61	*61		
FEV1/FVC (%)	75	63 87	86	114		
FEV1/SVC (%)	75	63 87		114		
FEF 25-75% (L/sec)	1.76	1.47 2.05	1.87	106		
FEF 25% (L/sec)	5.06	4.23 5.89	5.24	103		
FEF 50% (L/sec)			2.96			
FEF 75% (L/sec)	0.83	0.69 0.97	*0.62	*74		
FEF Max (L/sec)	5.44	4.54 6.34	5.28	97		
FIF 50% (L/sec)	3.39	2.83 3.95	3.70	109		
FEF50%/FIF50% (%)	90-100	79 119	80			
--- LUNG VOLUMES						
TLC (Pleth) (L)	5.13	4.10 6.16	*3.29	64		
SVC (L)	2.93	2.45 3.41	*1.57			
IC (L)	1.89	1.58 2.20	*0.86	*45		
FRC (Pleth) (L)	2.94	2.35 3.53	*2.33	*79		
ERV (L)	0.95	0.79 1.11	*0.61	*63		
RV (Pleth) (L)	2.29	1.83 2.75	*1.72	*75		
RV/TLC (Pleth) (%)	45	36 54	52	116		
Vpatt (L)						
--- DIFFUSION ---						
DLCOunc (ml/min/mm	20.32	16.26 24.38	*7.53	37		
DLCOcor (ml/min/mm	20.32	16.26 24.38				
DL/VA (ml/min/mmHg/	4.21	3.37 5.05	*2.64	*62		
VA (L)	5.14	4.29 5.99	*2.85	*55		
IVC (L)			1.37			
BHT (sec)						

*86

*64

*37