Pulmonary Function Testing Case Questions and Answers

Answers / Correct Interpretations of the Cases

In the space that follows you will find the correct interpretations to pulmonary function test presented in each of the cases. These interpretations are based on American Thoracic Society criteria for interpreting pulmonary function tests and reflect the material covered in the Primer on Pulmonary Function Tests by Dr. Benditt that is part of the materials on this website. To go to this primer, click here.

These cases have been provided by Kenneth Steinberg, MD from the Division of Pulmonary and Critical Care Medicine.

Abbreviations:
FVC   Forced Vital Capacity
FEV_1 Forced Expiratory Volume in One Second
TLC   Total Lung Capacity
RV   Residual Volume
DLCO   Diffusion Capacity for Carbon Monoxide
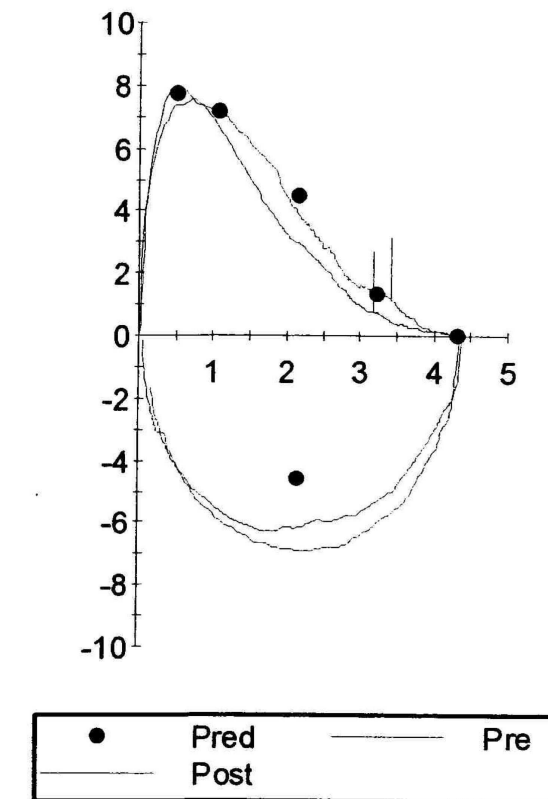BD   Bronchodilator

Case 1

A 65 year-old man undergoes pulmonary function testing as part of a routine health-screening test. He had no pulmonary complaints. He is a lifelong non-smoker and had a prior history of asbestos exposure while serving in the Navy. His pulmonary function test results are as follows:

Test	Pre-Bronchodilator (BD)			Post- BD
	Actual	Predicted	% Predicted	% Change
FVC (L)	4.39	4.32	102	-1
FEV$_1$ (L)	3.20	3.37	95	7
FEV$_1$/FVC (%)	73	78		8
FRC (L)	3.17	3.25	98	
ERV (L)	0.63	0.93	68	
RV (L)	2.54	2.32	109	
TLC (L)	6.86	6.09	113	
DLCO uncorr	25.69	31.28	82	
DLCO corr	26.14	31.28	84	

DLCO is measured in ml/min/mmHg

His flow volume loops is as follows:
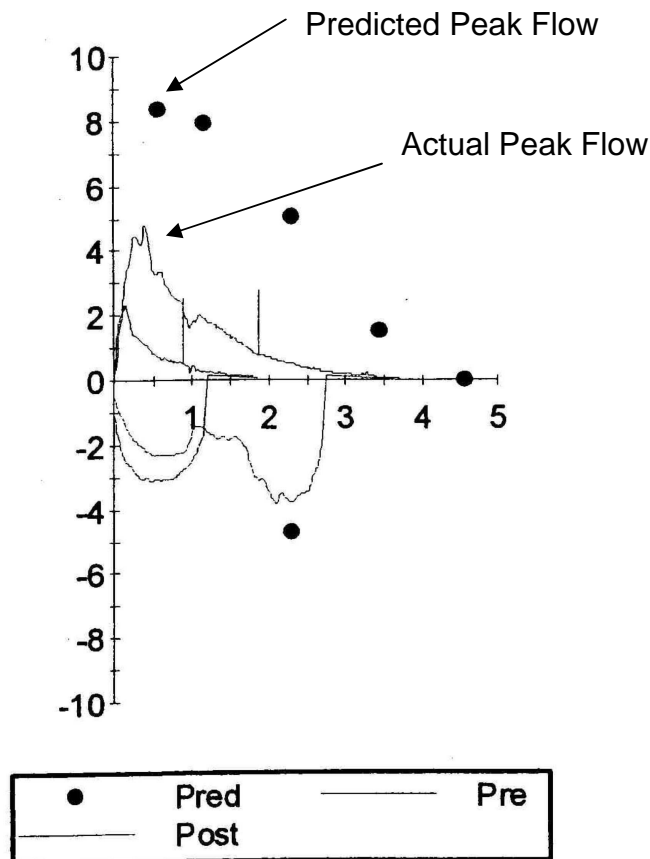
Case 1 Interpretation

This case demonstrates an example of normal pulmonary function tests. The FVC and the FEV_1 are 102% and 95% of predicted, respectively, values well above the lower limit of normal and the FEV_1/FVC ratio is greater than the predicted value minus 8. The flow-volume loop also corresponds quite nicely to the predicted values for this patient (darkened circles). Based on this normal spirometry pattern, you would conclude that there is no evidence of air-flow obstruction. The patient also has normal total lung capacity, indicating that there is no evidence of restriction, and a normal diffusing capacity for carbon monoxide, indicating that the alveolar-capillary surface area for gas exchange is normal. There is no bronchodilator response.

Case 2
A 54 year-old man presents to his primary care provider with dyspnea and a cough. He is a non-smoker with no relevant occupational exposures.

Test	Pre-Bronchodilator (BD)			Post- BD	
	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	3.19	4.22	76	4.00	25
FEV_1 (L)	2.18	3.39	64	2.83	30
FEV_1/FVC (%)	68	80		71	4

His flow volume loop is as follows:

Case 2 Interpretation
The FVC and FEV_1 are both below the lower limit of normal (defined as 80% of the predicted value for the patient). In addition, the FEV_1/FVC ratio is only 0.68, less than the lower limit of normal of the predicted value minus 8 (80-8 = 72) for this male patient. A low FEV_1 and FVC with a decreased FEV_1/FVC ratio is consistent with a diagnosis of air-flow obstruction. With an FEV_1 of 64% predicted this would be classified as "moderate" airflow obstruction. In addition, the FVC improves by 0.81 L (25% increase) and the FEV_1 improves by 0.65L (30% increase) following administration of a bronchodilator so this patient would qualify as having a bronchodilator response (defined as a 12% and 200 ml increase in

either the FEV_1 or FVC). The flow volume loop also shows several abnormalities consistent with obstructive lung disease. The peak expiratory flow rate is lower than the predicted peak expiratory flow and the curve has the characteristic scooped out appearance typically seen in airflow obstruction.
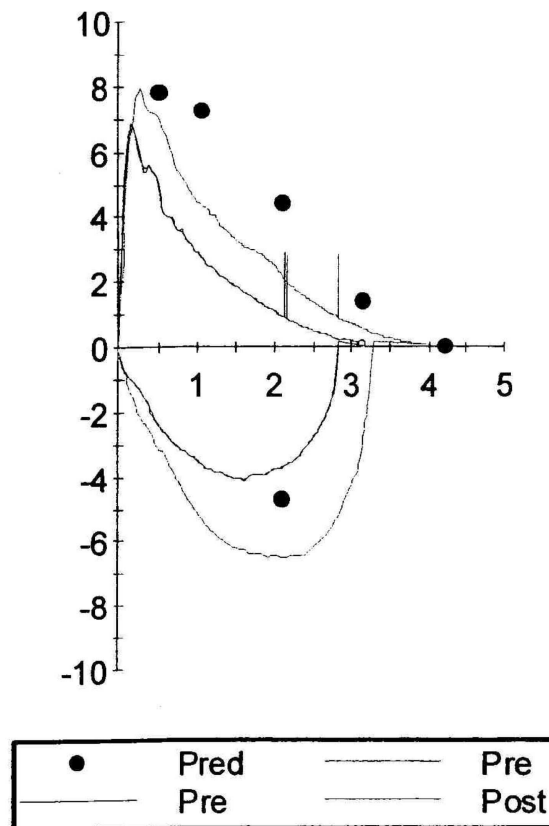
Case 3

A 60 year-old man presents to his primary care provider with complaints of increasing dyspnea on exertion. He has a 40 pack-year history of smoking and is retired following a career as a building contractor. His pulmonary function testing is as follows:

Test	Pre-Bronchodilator (BD)			Post- BD	
	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	1.89	4.58	41	3.69	96
FEV$_1$ (L)	0.89	3.60	25	1.89	112
FEV$_1$/FVC (%)	47	79			
RV (L)	5.72	2.31	248		
TLC (L)	7.51	6.41	117		
RV/TLC (%)	76	37			
DLCO corr	20.73	33.43	62		

The units for DLCO are ml/min/mmHg

His flow volume loop is as follows:

Case 3 Interpretation

This patient has markedly abnormal spirometry. The FVC is only 41% predicted while the FEV$_1$ is only 25% predicted, well below the lower limit of normal of 80%

predicted. In addition, the FEV_1/FVC ratio is markedly reduced. The combination of the low FEV_1, FVC and reduced FEV_1/FVC ratio is consistent with a diagnosis of airflow obstruction. With an FEV_1 of 25% predicted, this would be classified as "severe" airflow obstruction.

The patient also meets criteria for reversible airflow obstruction as both the FEV_1 and FVC improve by over 200 ml and 12% following administration of a bronchodilator.
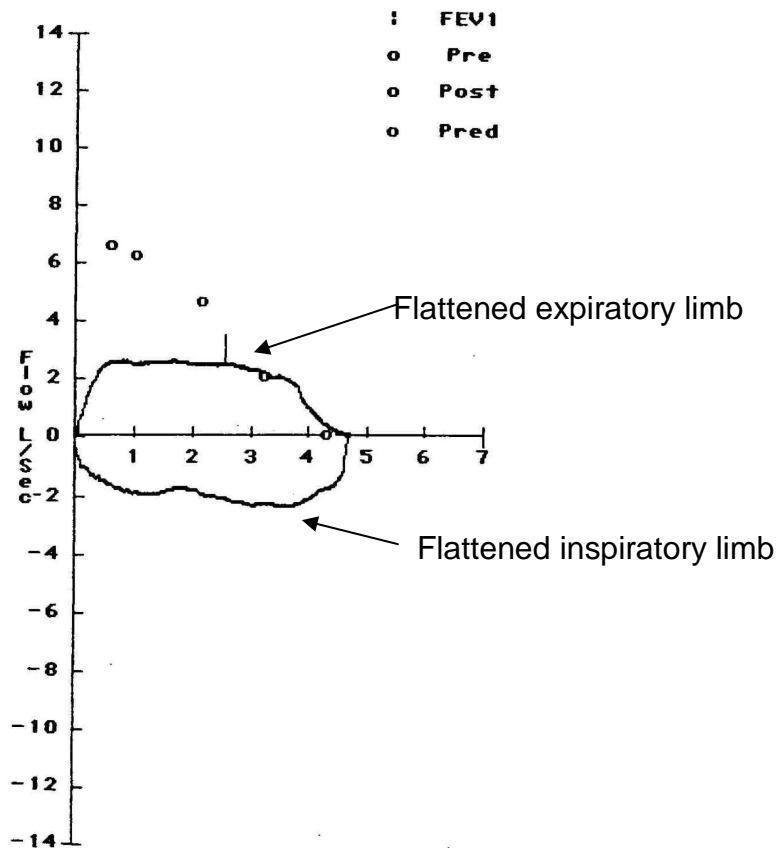
In addition to these abnormalities on spirometry, the patient has a markedly elevated residual volume (RV), a finding that is indicative of air-trapping. The total lung capacity (TLC) is somewhat elevated at 117% predicted but it is still shy of the 120% predicted level used to define hyperinflation.

Case 4

A 25 year-old man presents to his physician with complaints of dyspnea and wheezing. He is a non-smoker. Two years ago, he was in a major motor vehicle accident and was hospitalized for 3 months. He had a tracheostomy placed because he remained on the ventilator for a total of 7 weeks. His tracheostomy was removed 2 months after his discharge from the hospital. His pulmonary tests are as follows:

Test	Pre-Bronchodilator (BD)		
	Actual	Predicted	% Predicted
FVC (L)	4.73	4.35	109
FEV_1 (L)	2.56	3.69	69
FEV_1/FVC (%)	54	85	

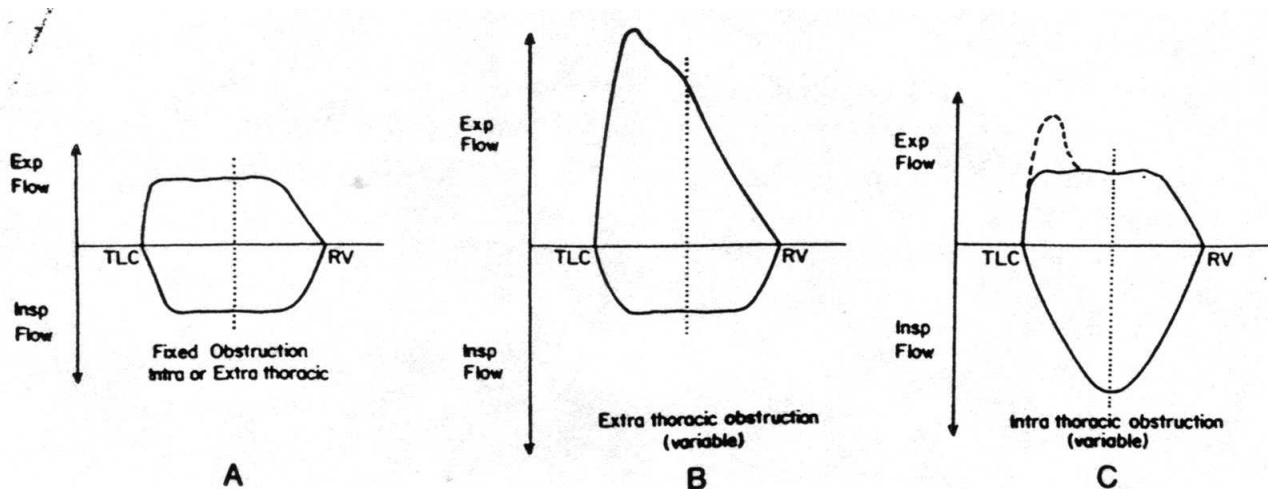His flow volume loops is as follows:

Case 4 Interpretation

This patient has evidence of airflow obstruction on spirometry as he has a low FEV_1 and a reduced FEV_1/FVC ratio of 0.54. Given that the FEV1 is 69% of predicted this patient would be labeled as having "mild airflow obstruction.

In order to make a correct diagnosis in this patient, however, you cannot look simply at the numbers from his spirometry testing but must also look at the flow volume loops. A noteworthy feature of his flow volume loop is that there is flattening of both the inspiratory and expiratory limbs. This pattern is seen in patients who have a fixed upper airway obstruction. In a patient with a prior history of tracheostomy, you would be very suspicious that this patient has developed tracheal stenosis, a known long-term complication of tracheostomy tubes.

Other forms of airway obstruction will also demonstrate characteristic patterns on the flow-volume loops. Patients with a variable intrathoracic obstruction (eg. a carcinoid tumor in a mainstem bronchus) have flattening of the expiratory limb of the flow-volume loop while patients with variable extrathoracic obstruction (eg. a thyroid tumor) have flattening of the inspiratory limb of the flow-volume loop. All three of these patterns are demonstrated in the figure below.
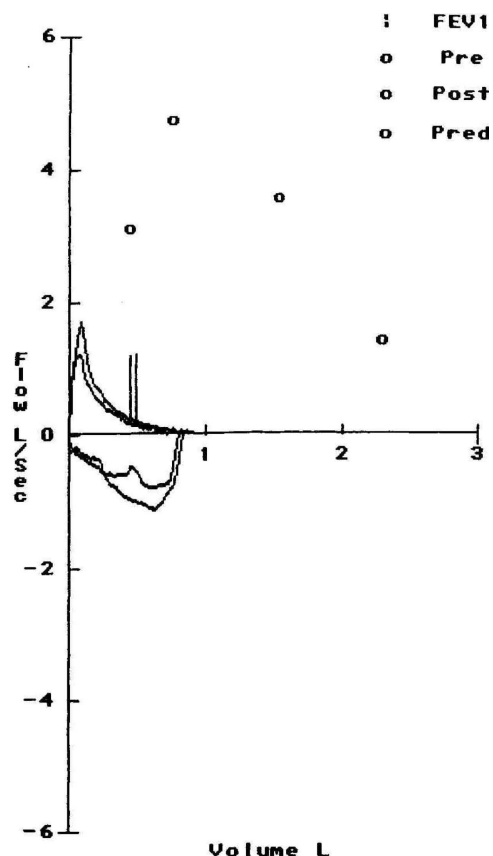
Case 5

A 41 year-old woman presents to the General Internal Medicine Clinic at Harborview Medical Center complaining of dyspnea with mild exertion. She has a 10 pack-year history of smoking and a history of using intravenous drugs including heroin and ritalin. Her pulmonary function tests are as follows:

Test	Pre-Bronchodilator (BD)			Post- BD	
	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	0.90	3.09	29	0.74	- 17
FEV_1 (L)	0.49	2.57	19	0.44	-10
FEV_1/FVC (%)	54	83		59	8
RV (L)	3.83	1.49	257		
TLC (L)	4.78	4.44	108		
RV/TLC (%)	80	33			
DLCO corr	0.75	24.85	3		

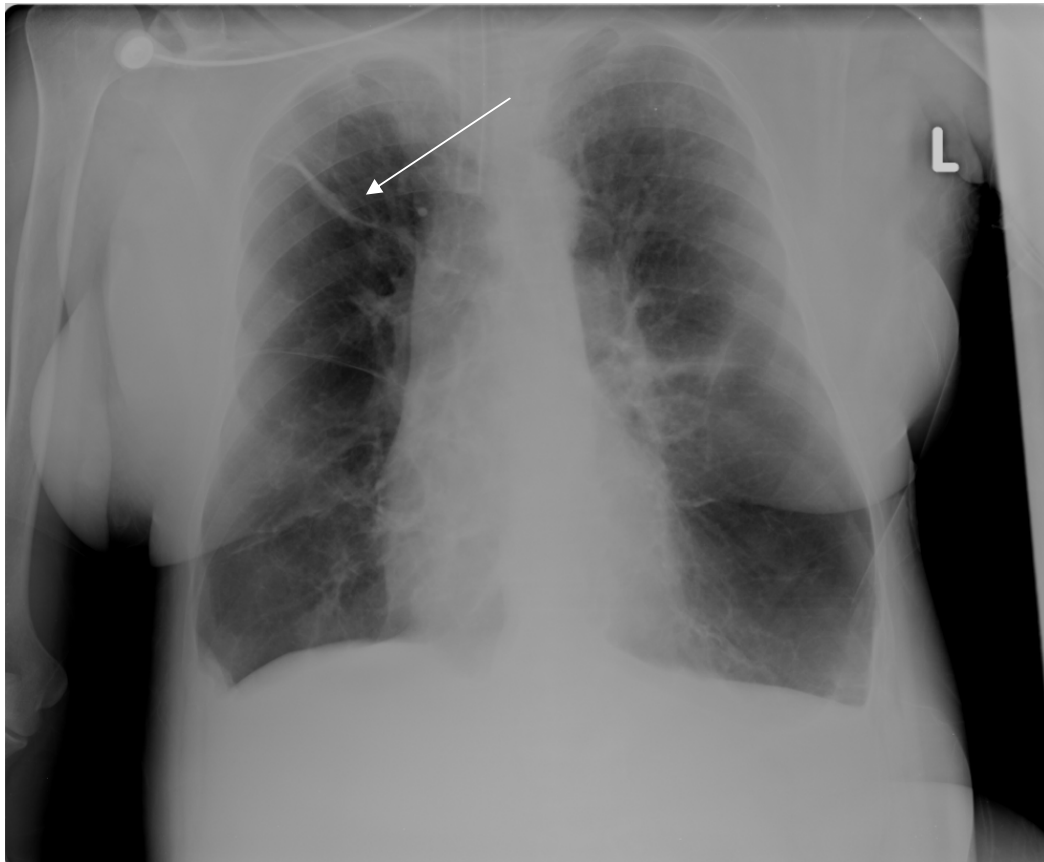Her flow volume loop is as follows:

Case 5 Interpretation

This patient has evidence of air-flow obstruction, as her FEV_1, FVC and her FEV_1/FVC are all decreased. Her flow volume demonstrates the characteristic scooped-out appearance seen in obstructive lung disease and also demonstrates markedly reduced peak expiratory flows. Based on her FEV_1 of 19% predicted

this would be classified as "very severe" obstructive lung disease. The patient also has evidence of air-trapping, as her RV is 257% predicted. She would not be classified as being hyper-inflated because her TLC is only 108% predicted. There is no evidence of a bronchodilator response as her FVC and FEV_1 both decline following bronchodilator administration. Her DLCO is also decreased, indicating a loss of alveolar-capillary surface area for gas exchange.

It is highly unlikely for a 41 year-old person to have obstructive lung disease with only a 10-pack year history of smoking. Asthma is an unlikely diagnosis given the absence of reversibility with bronchodilator administration. Her chest x-ray provides some clues to the diagnosis, however. There is marked hyper-lucency at the bases, suggesting that this is a basilar-predominant form of emphysema. The minor fissure (arrow) is also shifted upward on the right side, indicating that the lower lobes are over-inflated. Two disorders can give you early-onset emphysema with a basilar predominance: alpha-one anti-trypsin deficiency (it is usually only seen this early if the person also smokes) and ritalin lung. The latter is an uncommon form of the severe basilar-predominant emphysema seen in people who previously used intravenous injections of ritalin (methylphenidate).
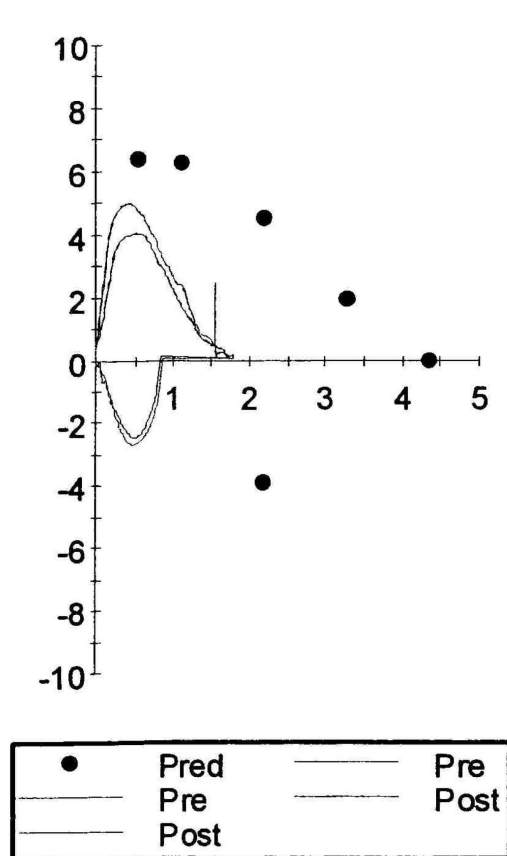
Case 6

A 30 year-old woman presents for evaluation of dyspnea on exertion, which has been present for 2 months. She is a life-long non-smoker with no prior history of asthma or other pulmonary problems. She works as a receptionist at a publishing company. She has two cats and several parakeets at home. Her pulmonary function testing is as follows:

Test	Pre-Bronchodilator (BD)			Post- BD	
	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	1.73	4.37	40	1.79	4
FEV$_1$ (L)	1.57	3.65	43	1.58	0
FEV$_1$/FVC (%)	91	84		88	-3
RV (L)	1.01	1.98	51		
TLC (L)	2.68	6.12	44		
RV/TLC (%)	38	30			
DLCO corr	5.13	32.19	16		

Her flow volume loop is as follows:

●	Pred	———	Pre
———	Pre	– – –	Post
———	Post		

Case 6 Interpretation

This patient has a markedly reduced FEV$_1$ and FVC. However, the FEV$_1$/FVC ratio is normal (91%) and, therefore, she cannot be classified as having
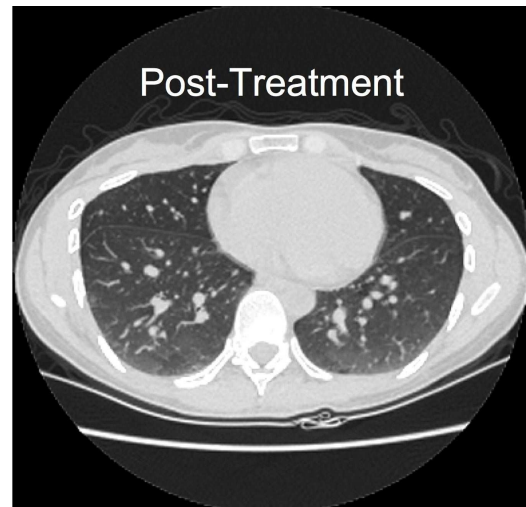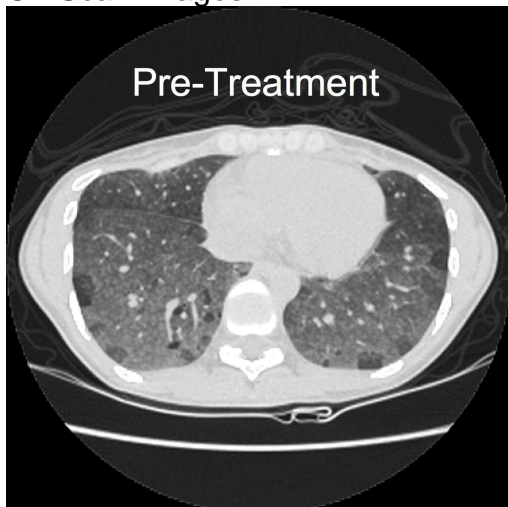
obstructive lung disease. The pattern of reduced FEV_1 and FVC with preserved FEV_1/FVC ratio is often seen in restrictive processes but in order to confirm the diagnosis of restriction, you must examine the total lung capacity. For this patient, the TLC is markedly reduced at 41% of predicted and confirms that she has a restrictive process. Based on her TLC of < 50% predicted, she would be classified as having a "severe" restrictive defect. Her DLCO is also reduced suggesting she has a loss of alveolar-capillary surface area for gas exchange and also suggesting that the cause of her restriction is intrinsic to the lungs (i.e. due to a problem in the pulmonary parenchyma).

Further evaluation revealed that this patient had hypersensitivity pneumonitis, likely secondary to her exposure to parakeets. The parakeets were removed from her home and she was given a course of oral corticosteroids. Following treatment, her repeat pulmonary function tests were improved, as was the CT scan of her chest. The pulmonary function tests and CT images are shown below:

Pulmonary Function Tests Pre- and Post-Treatment

Test	Pre-Treatment			Post-Treatment		
	Actual	Predicted	% Pred.	Actual	Predicted	% Pred.
FVC (L)	1.73	4.37	40	3.00	4.35	69
FEV_1 (L)	1.57	3.65	43	2.40	3.63	66
FEV_1/FVC (%)	91	84		80	83	
RV (L)	1.01	1.98	51	0.70	1.99	35
TLC (L)	2.68	6.12	44	3.70	6.11	61
RV/TLC (%)	38	30		19	30	
DLCO corr	5.13	32.19	16	13.61	32.04	42

CT Scan Images
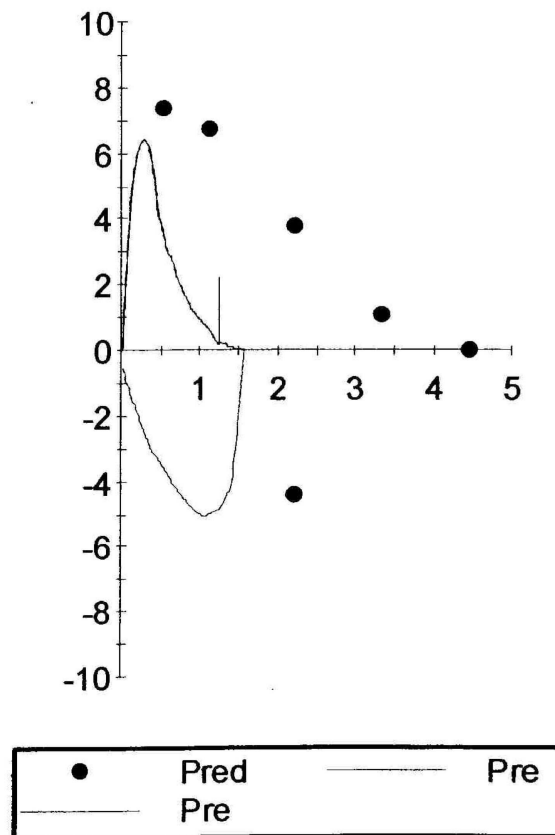

Pre-Treatment

Post-Treatment

Case 7

A 73 year-old man presents with progressive dyspnea on exertion over the past one year. He reports a dry cough but no wheezes, sputum production, fevers or hemoptysis. He is a life-long non-smoker and worked as a lawyer until retiring 3 years ago. He likes to hunt and fish in his leisure time. His pulmonary function testing is as follows:

Test	Pre-Bronchodilator (BD)		
	Actual	Predicted	% Predicted
FVC (L)	1.57	4.46	35
FEV_1 (L)	1.28	3.39	38
FEV_1/FVC (%)	82	76	
FRC	1.73	3.80	45
RV (L)	1.12	2.59	43
TLC (L)	2.70	6.45	42
RV/TLC (%)	41	42	
DLCO corr	5.06	31.64	16

His flow-volume loop is as follows:
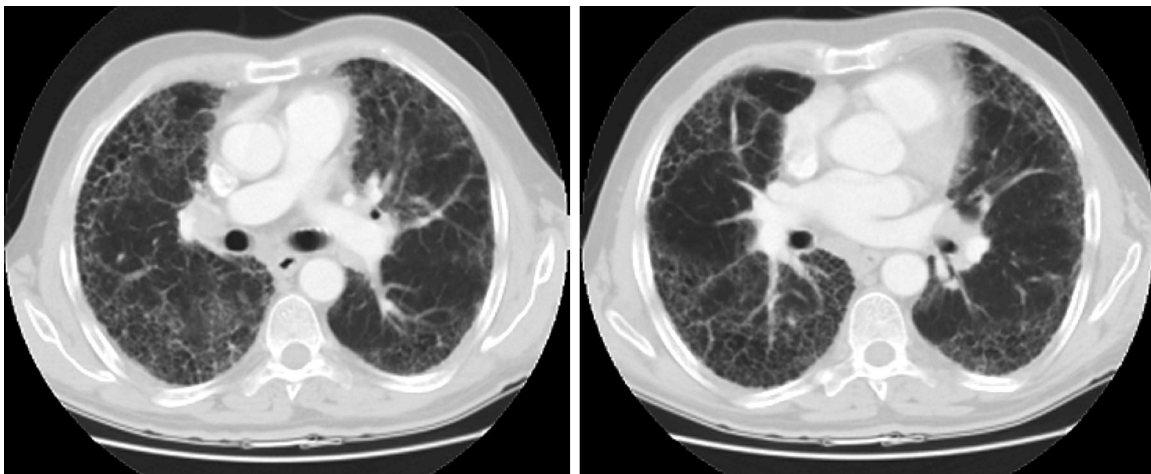

Case 7 Interpretation

This patient has a reduced FEV_1 and FVC with a preserved FEV_1/FVC ratio. The total lung capacity is reduced and the patient, therefore, has a restrictive defect. The flow-volume loop also has the characteristic appearance of a restrictive process – tall, narrow and a short expiratory phase. Based on the fact that his TLC is below 50% predicted, this would be classified as a "severe" restrictive defect. His DLCO is also markedly reduced indicating he has a reduced alveolar-capillary interface for gas exchange and suggesting that the cause of his restrictive process lies within the lung parenchyma.

This patient was subsequent found to have idiopathic pulmonary fibrosis. His chest x-ray and CT images are shown below.
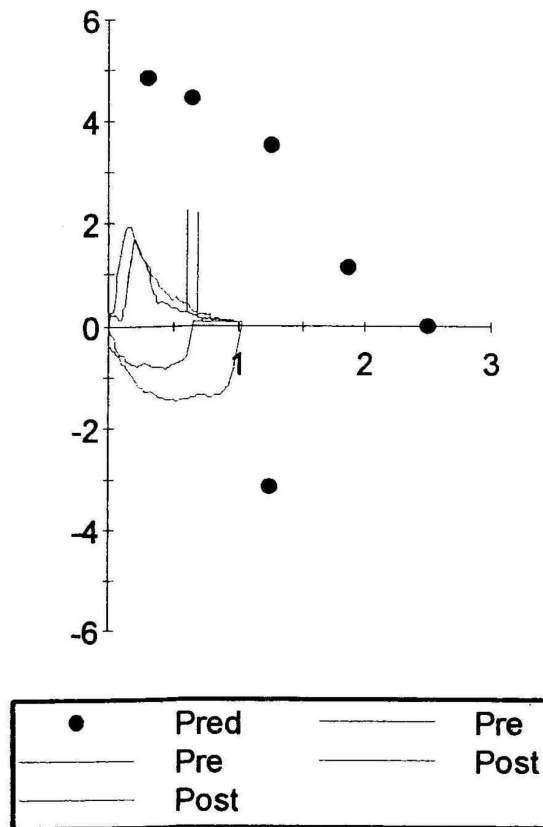
PA and Lateral Chest X-Ray

Chest CT Images

Case 8

A 64 year-old woman presents with complaints of dyspnea and orthopnea. She is a life-long non-smoker. Her pulmonary function testing is as follows:

Test	Pre-Bronchodilator (BD)			Post- BD	
	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	1.00	2.51	40	1.02	3
FEV_1 (L)	0.61	2.00	30	0.69	13
FEV_1/FVC (%)	61	80		67	10
RV (L)	1.15	1.55	74		
TLC (L)	2.08	4.04	52		
RV/TLC (%)	55	39			

Her spirometry is repeated with her in the upright and supine positions:

Test	Upright	Supine
FVC (L)	0.49	0.37
FEV_1 (L)	0.82	0.68
FEV_1/FVC (%)	0.60	0.54

Her flow volume loop is as follows:

Case 8 Interpretation

This patient has a reduced FEV_1 and FVC with a reduced FEV_1/FVC ratio. She would, therefore, be classified as having an obstructive defect. However, she also has a low TLC (52% predicted). This is evidence of a restrictive defect and, therefore, this patient would be labeled as having a combined obstructive-restrictive defect. A DLCO is not provided which makes it difficult to determine if the cause of her restriction is due to a pulmonary parenchymal process or an extra-pulmonary process.
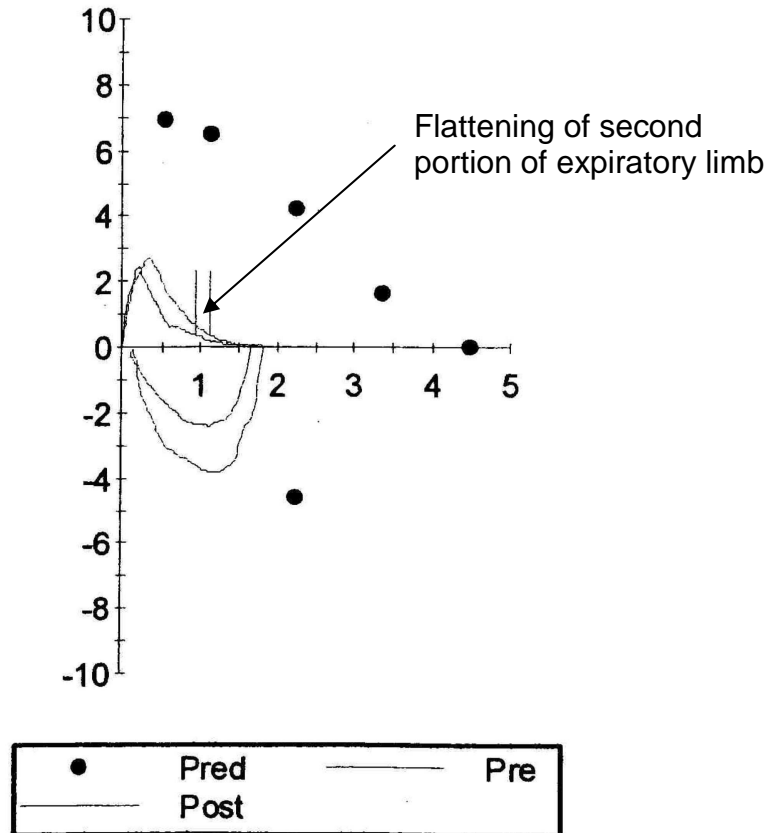
An important clue comes from her history. The patient reports orthopnea. Although this is classically seen in patients with heart failure, it is not specific for this disease. Patients with diaphragmatic weakness can also present with this symptom. When they lie supine, gravity no longer exerts an effect on the diaphragm and abdominal contents and the patients have trouble getting their diaphragm to descend against the abdominal contents on inspiration. The presence of diaphragmatic weakness is confirmed by repeating her pulmonary function tests with her in the upright and supine positions. When she is supine, her FVC and FEV_1 both fall by greater than 20%, thus providing evidence that she may, in fact, have diaphragmatic weakness as the cause of her lung restriction.

A 35 year-old previously healthy man presents with dyspnea, fevers, chills and night sweats for the past 2 months. He is a non-smoker with no concerning habits or occupational exposures. His pulmonary function tests are as follows:

Test	Pre-Bronchodilator (BD)		
	Actual	Predicted	% Predicted
FVC (L)	1.66	4.48	37
FEV_1 (L)	0.94	3.67	26
FEV_1/FVC (%)	57	82	
RV (L)	1.39	1.66	84
TLC (L)	3.06	5.96	51
RV/TLC (%)	45	29	

His flow volume loop is as follows:

Flattening of second portion of expiratory limb

Case 9 Interpretation

This patient has reduced FEV_1 and FVC with a low FEV_1/FVC ratio, consistent with an obstructive process. He also has a low TLC indicating he has a restrictive process as well. He would, therefore, be labeled as having a combined obstructive-restrictive defect. His obstructive defect would be classified as "very

severe" based on his FEV_1 of only 26% predicted while his restrictive process would be labeled as moderate given his TLC of 51% predicted.
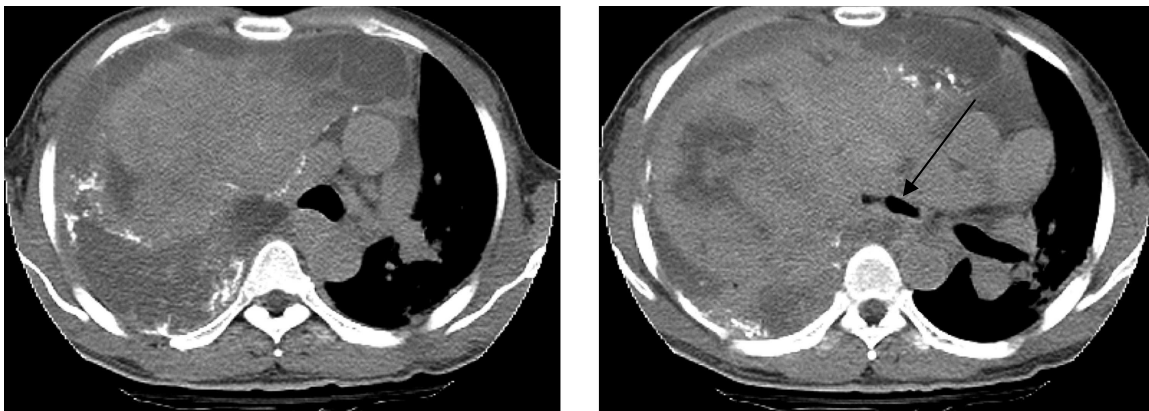
There is an interesting finding in his flow-volume loop as well. The expiratory limb appears to have two components. There is a steep component and then a second, flatter component over the latter half of exhalation. This pattern suggests that one lung may be emptying faster than the other and, therefore, that the slowly emptying lung might have an obstructing airway lesion.

In fact, when the patient underwent chest x-ray imaging, he was found to have a dense opacity in the right chest. CT scanning revealed the presence of a large mass. This mass was so large it not only collapsed the right lung but also compressed the left lung causing lung restriction. It also compresses the airways (arrow in CT scan) on the right side leading to the obstruction to air-flow out of the viable right lung. These images are shown below.
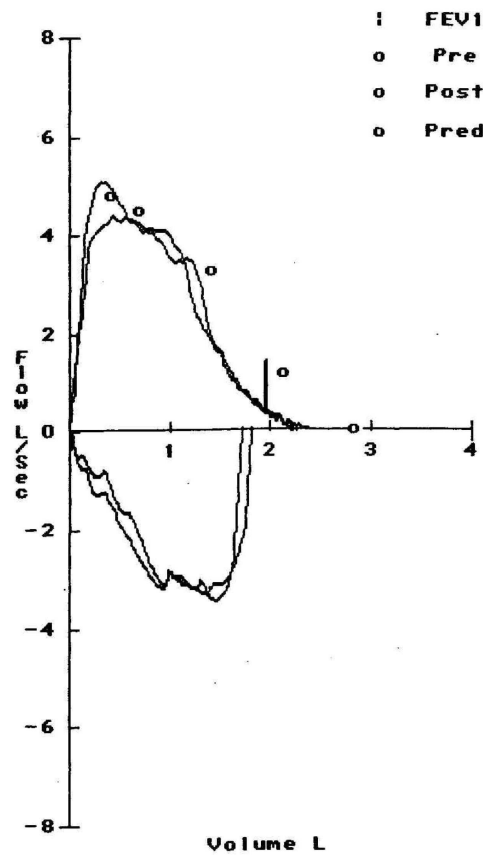
Chest X—Ray

Chest CT

Case 10

A 53 year-old woman presents with increasing dyspnea on exertion. She denies cough, fevers, hemoptysis, weight loss or sweats. She was previously an active runner but has had to cut back significantly because of her symptoms with exercise. She does note occasional chest pain with exercise but has not had any syncope or palpitations. Her pulmonary function tests are as follows:

Test	Pre-Bronchodilator (BD)			Post- BD	
	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	2.38	2.87	83	2.23	-6
FEV$_1$ (L)	1.95	2.31	84	1.93	-1
FEV$_1$/FVC (%)	82	81		87	
RV (L)	1.69	1.58	107		
TLC (L)	4.26	4.36	98		
RV/TLC (%)	40	36			
DLCO corr	9.96	23.25	43		

DLCO is measured in ml/min/mmHg

Her flow volume loop is as follows:

Case 10 Interpretation

This patient has normal FEV_1 and FVC and a preserved FEV_1/FVC ratio. She also has a normal total lung capacity. As a result, there is no evidence of either obstructive or restrictive lung disease. The patient does have a reduced DLCO, however, indicating that she has a reduced alveolar-capillary interface for gas exchange. Based on her DLCO of 43% predicted, she would be labeled as having a "moderate" gas exchange abnormality.

The finding of an isolated decreased in the DLCO (i.e. normal spirometry and lung volumes) is highly suggestive of a pulmonary vascular process such as pulmonary hypertension. This patient was, in fact, found to have pulmonary hypertension due to chronic thromboembolic disease.

Case 11

A 36 year-old woman presents with a several month history of worsening dyspnea on exertion and exercise limitation. She is a life-long non-smoker and has no history of asthma or other known pulmonary diseases. She has had to stop going out with her weekly running group because she can no longer keep up with her friends. Her pulmonary function testing is as follows:

Test	Pre-Bronchodilator (BD)		
	Actual	Predicted	% Predicted
FVC (L)	0.88	3.34	26
FEV$_1$ (L)	0.87	2.87	30
FEV$_1$/FVC (%)	99	86	
RV (L)	1.61	1.40	115
TLC (L)	2.49	4.73	53
RV/TLC (%)	65	29	
DLCO corr	21	26.6	78

A flow-volume loop is not available for this case.

Case 11 Interpretation

This patient has reduced FEV$_1$ and FVC with a preserved FEV$_1$/FVC ratio, a finding that is suggestive, but not diagnostic of a restrictive process. The presence of a reduced TLC confirms the presence of a restrictive defect. Based on the fact that her TLC is 53% of predicted, this would be labeled as a "moderate" restrictive defect. The patient has an essentially normal DLCO. Although the value is technically less than 80% of predicted, due to the inherent variability in this test, values in this range are considered normal. This suggests that her alveolar-capillary interface for gas exchange for normal and further suggests that her restrictive process is due to a process extrinsic to the pulmonary parenchyma.

This patient was sent for further pulmonary function testing. She had a 17% drop in her FVC from the sitting to supine position. Her maximum inspiratory pressures (– 35 cm H$_2$0), maximum expiratory pressure (- 50 cm H$_2$0) and peak cough flow (180 L/min) were all markedly reduced relative to normal values, findings that are indicative of muscle weakness. Upon further evaluation by a neurologist, the patient was found to have Limb Girdle Muscular Dystrophy.

Case 12

A 44 year-old woman with cirrhosis secondary to chronic alcohol abuse and Hepatitis C presents with complaints of increasing dyspnea. She reports that her dyspnea is worse when she is sitting upright or walking but improves when she is lying flat. She is an active cigarette smoker. On exam, she has a room air oxygen saturation of 88% in the sitting position and a room air oxygen saturation of 96% in the supine position. Her pulmonary function testing is as follows.

Test	Pre-Bronchodilator (BD)			Post- BD	
	Actual	Predicted	% Predicted	Actual	% Change
FVC (L)	3.94	3.69	107%	3.86	-2
FEV$_1$ (L)	2.76	3.03	91%	2.85	3
FEV$_1$/FVC (%)	70	82			
RV (L)	1.89	1.86	102		
TLC (L)	5.67	5.40	105		
RV/TLC (%)	33	33			
DLCO corr	10.22	28.22	36		

DLCO is measured in ml/min/mmHg

A flow-volume loop is not available for this case.

Case 12 Interpretation

The patient has normal FVC and FEV$_1$ but a reduced FEV$_1$/FVC ratio. Even though the FEV$_1$ is within the normal range, she would, therefore, be classified as having mild obstructive lung disease because of the reduced FEV$_1$/FVC ratio. There is no evidence of a bronchodilator response and the lung volumes are normal. Her DLCO, however, is markedly reduced and the reduction is far out of proportion to the abnormalities seen in her spirometry. This suggests that she may, in fact, have a pulmonary vascular problem.

Patients with chronic liver disease are predisposed to several pulmonary vascular problems including portopulmonary hypertension and hepatopulmonary syndrome. The latter disorder is marked by the presence of intrapulmonary shunts, which occur predominantly at the bases of the lungs. Both of these problems can cause an isolated reduction in the DLCO on pulmonary function testing. In her case, she has a symptom (platypnea – dyspnea that is worse in the upright position compared to the supine position) and a sign (orthodeoxia – oxygen saturation or PaO$_2$ is worse in the upright position compared to the supine position) that are both highly suggestive of the presence of intrapulmonary shunts and, therefore, a diagnosis of hepatopulmonary syndrome.