Basic Interpretation of Pulmonary Function Tests and Implications for Pulmonary Rehab

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I have no disclosures.

Any opinions expressed are my own.

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Objectives

1. Attendees will be knowledgeable of basic pulmonary function tests, and implications for participation in pulmonary rehabilitation/respiratory services.
2. Attendees will review case examples of lung pathologies and pulmonary function values, determine if PR should be considered, and identify appropriate billing codes.

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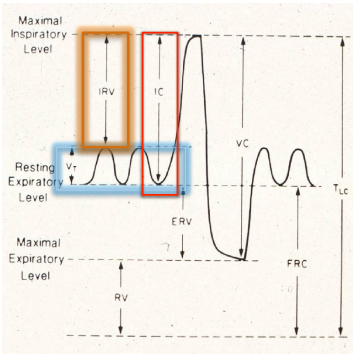
Tidal Volume (V_T)
Amount of air inspired & expired during normal resting ventilation = ~500 mL*

Inspiratory Reserve Volume (IRV)
The IRV is the volume of air that can be inspired when needed
~3000 mL
The "room to breathe"

Inspiratory Capacity – IC
V_T + IRV



*Volumes are estimates for a healthy, young male

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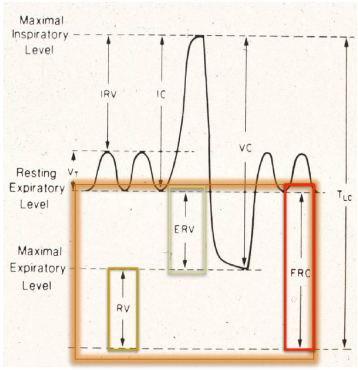
Expiratory Reserve Volume - ERV
Amt of air that can potentially be exhaled beyond the end of a tidal exhalation (~1000 mL)

Residual Volume – RV
Air remaining in lungs when ERV has been exhaled (~1500 mL)

Functional Residual Capacity – FRC
Sum of RV & ERV



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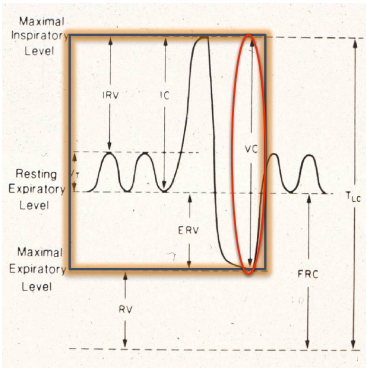
Vital Capacity - VC
The sum of the 3 volumes that are under voluntary control
V_T + IRV + ERV
500 + 3000 + 1000 =
4500 mL



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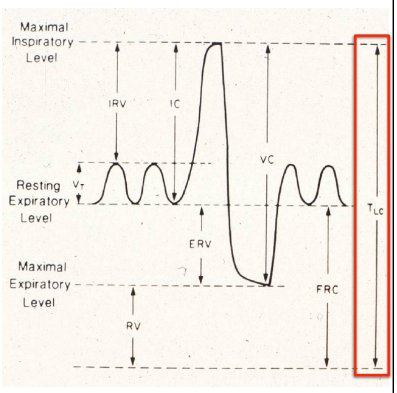
Total Lung Capacity - TLC

The sum of the 4 lung volumes

V_T + IRV + ERV + RV

500 + 3000 + 1000 + 1500 =

6000 mL



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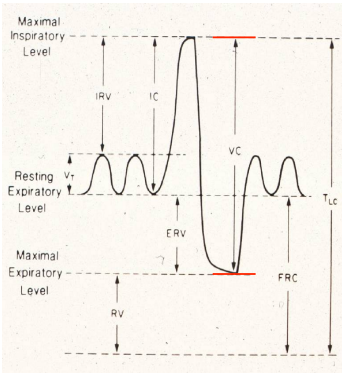
Forced Vital Capacity – FVC

Maximal volume of air a person can forcefully exhale after a maximal inspiration

Exhalation includes:

- Resting tidal volume
- Inspiratory reserve volume
- Expiratory reserve volume



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Forced Expiratory Volume in One Second (FEV_1)

- Definition: the volume of air that can be forcefully exhaled during the 1st second of the forced vital capacity maneuver
- FEV_1 = > 75% of the FVC
  Example: healthy, young man
  FVC = 4500 X 0.75 = > 3.4 liters

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FEV_1/FVC

- FEV_1/FVC: 3500L/4500L = 0.78
  - COPD definition according to GOLD: Post-bronchodilator ratio of < 0.70
  - Asthma: Post-bronchodilator FEV_1/FVC should normalize with good asthma control
  - FEV_1/FVC is used to determine whether airflow obstruction is present. The FEV_1 is used to estimate the severity of obstruction.
- Normals:
  - Age 8-19 yrs = .85
  - Age 20-39 yrs = .80

  } Potential for *under diagnosis* of COPD
  - Age 40-59 yrs = .75
  - Age 60-80 yrs = .70

  } Potential for *over diagnosis* of COPD

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Diffusing Capacity for Carbon Monoxide (DLCO)

- Measures diffusion of carbon monoxide across the alveolar-capillary membrane
- Indicates damage to the alveolar-capillary membrane
- Predicts the potential for oxygen desaturation

In COPD, a DLCO of <50 %
commonly predicts oxygen desaturation

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Predicted or Reference Values

- Values that indicate how the patient's measured values compare to the value the patient should have based on specific characteristics
- PFT Report shows:

Spirometry	Measured	Predicted (Reference)	% Predicted
FVC (L)	3.00	5.26	57%

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Predicted Values

- Depend on 4 characteristics:
  1. Age
  2. Height
  3. Gender
  4. Ethnicity
- ATS recommendations in the US: NHANES III reference equations for ages 8–80 years.
- Normal predicted values: 80–120%, i.e., excludes ratios

Pellegrino R, Viegi G, Brusasco V, Crapo RO, et al. Interpretative strategies for lung function tests. *Eur Respir J* 2005; 26:948-968.

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Predicted Values

1. **Age:** lung function plateaus b/w ages 20 & 30 with decline in FEV_1 of ~25–30 ml/year thereafter (in healthy nonsmokers without exposure to air pollution)
   - Smoking beginning in early teens may result in earlier peak in lung function and earlier onset of decline
   - Also see an accelerated decline in FEV_1 in susceptible cigarette smokers
2. **Height:** differences in trunk length relative to standing height

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Predicted Value Variables

3. **Gender:** women have smaller lungs than men
4. **Ethnicity:** African Americans, East Asians & East Indians typically have smaller lung volumes explained in part by differences in:
   a. Trunk length relative to standing height
   b. Fat-free mass
   c. Chest dimensions
   d. Respiratory muscle strength

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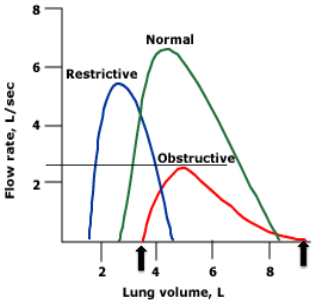
Expiratory Flow Volume Loop



Normal: rapid rise to peak flow rate, followed by a nearly linear fall in flow during exhalation to RV

Obstructive: maximal expiration begins & ends at higher lung volumes & lower flow rates than normal

Restrictive: lung volumes & flow rates are reduced but the flow in relation to lung volume is higher than normal

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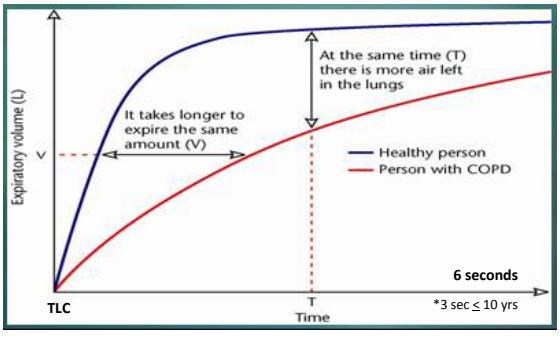
Prolonged Expiratory Time



Air trapping ⟶ Dynamic Hyperinflation

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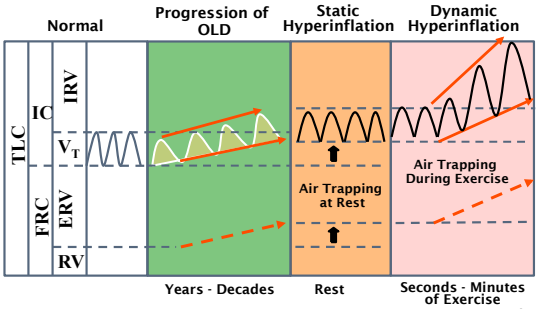
Exercise & Dynamic Hyperinflation



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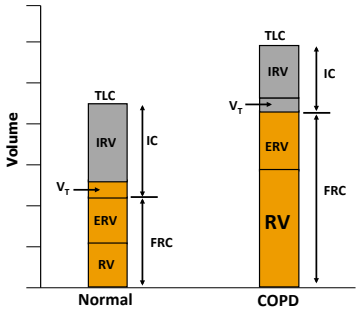
Obstruction to Airflow

- Loss of elastic recoil allows unrestrained expansion of the lung
- ↑ Residual Volume and Total Lung Capacity



Reduced IC (inspiratory capacity) → Less "room for breathing"

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GOLD Classification of COPD

Stage	FEV_1/FVC	FEV_1
I - Mild COPD	< 0.70	FEV_1 ≥80% predicted
II - Moderate COPD	< 0.70	FEV_1 50% -79% predicted
III - Severe COPD	< 0.70	FEV_1 30% - 49%
IV - Very Severe COPD	< 0.70	FEV_1 <30% OR <50% with signs of chronic respiratory failure

GOLD = Global Strategy for the Diagnosis, Management, and Prevention of COPD - GOLD Update, 2017

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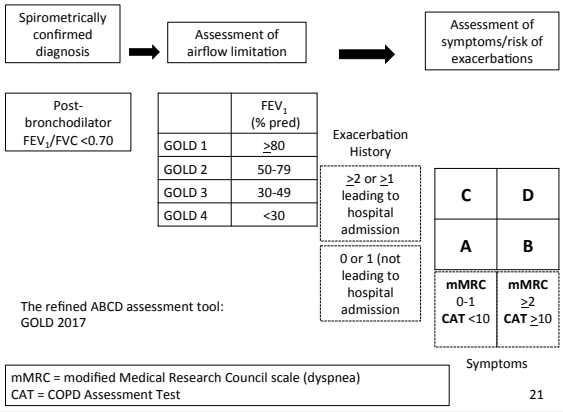

mMRC = modified Medical Research Council scale (dyspnea)
CAT = COPD Assessment Test

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Example from GOLD 2017

- 2 patients with FEV_1 <30% of predicted and CAT scores of 18 (<10 is desired)
  - **Patient A** had no exacerbations in the past year
    - GOLD grade 4, group B
    - Consider LAMA + LABA if persistent sx despite LAMA
  - **Patient B** had 3 exacerbations in the past year
    - GOLD grade 4, group D
    - Consider LAMA/LABA combination + ICS, or LABA/ICS + LAMA for persistent symptoms. Add roflumilast if patient has chronic bronchitis

LAMA: Long-acting muscarinic antagonist
LABA: Long-acting beta-agonist
ICS: Inhaled corticosteroid

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Respiratory Therapeutic Services for non-COPD Patients

- Lack of Local Coverage Decision (LCD) for Respiratory Services in J5 MAC
  - NO rules for Respiratory Services
  - NO approved diagnosis list
  - NO PFT value guidelines

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Respiratory Therapeutic Services for non-COPD Patients

- What do we do?
  - Look at PFTs for evidence of chronic lung disease
  - Clinical assessment:
    - Symptoms persist despite medical treatment
    - Decrease in functional capacity, i.e. inability to complete ADLs independently due to symptoms of lung disease?
    - Increased use of health care resources, i.e. increased # of unscheduled doctor visits, ED visits, hospitalizations related to the respiratory diagnosis?
    - Decreased quality of life?
  - Confer with your Compliance Office

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PFTs in Obstructive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	3.00	5.27	57%
FEV1 (L)	1.23	4.09	30%
FEV1/FVC	0.41	0.78	
Lung Volumes:			
TLC (L)	8.85	7.05	126%
RV (L)	5.85	1.93	303%
DLCO Adj. (ml/min/mmHg)	5.6	20.0	34%

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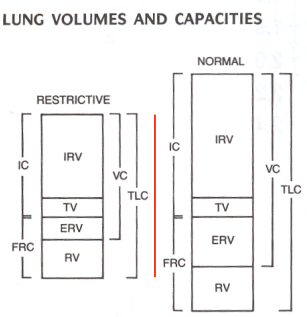
Restriction to lung expansion

- A restriction prevents normal expansion of the lung
- ↓ Total Lung Capacity defines restriction



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PFTs in Restrictive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.74	4.25	41%
FEV1 (L)	1.66	3.37	49%
FEV1/FVC	0.95	0.79	
Lung Volumes:			
TLC (L)	3.47	5.94	58%
RV (L)	1.73	1.90	91%
DLCO Adj. (ml/min/mmHg)	20.6	21.2	98%

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PFTs in Obstructive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.85	4.30	43%
FEV_1 (L)	0.53	3.12	17%
FEV_1/FVC	0.29	0.73	
Lung Volumes:			
TLC (L)	9.37	6.21	151%
RV (L)	7.52	2.26	333%
DLCO mL/mmHg/min	6.5	27.1	24%

62 year old Caucasian male with GOLD Stage IV – Very severe COPD; height = 5 ft 8 in

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PFTs in Obstructive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.37	3.70	37%
FEV_1 (L)	0.53	2.94	18%
FEV_1/FVC	0.39	0.79	
Lung Volumes:			
TLC (L)	7.71	5.11	151%
RV (L)	5.74	1.65	347%
DLCO mL/mmHg/min	13.9	24	58%

38 year old Caucasian female with cystic fibrosis; 5 ft 3 ½ in

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PFTs Post-Lung Transplant

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	3.69	3.69	100% (37%)
FEV_1 (L)	3.49	3.04	115% (18%)
FEV_1/FVC	0.94 (0.39)	0.82	
Lung Volumes:			
TLC (L)	4.56	5.01	91% (151%)
RV (L)	0.57	1.63	35% (347%)
DLCO mL/mmHg/min	21.3	23.9	89% (58%)

38 year old Caucasian female one year post lung-transplant for CF

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PFTs in Obstructive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	3.02	3.21	94%
FEV_1 (L)	0.74	2.47	30%
FEV_1/FVC	0.25	0.77	
Lung Volumes:			
TLC (L)	6.96	4.64	150%
RV (L)	3.69	1.70	217%
DLCO mL/mmHg/min	4.2	21	20%

63 year old Caucasian female with $alpha_1$ antitrypsin deficiency and severe COPD; 5 ft 1 ½ in

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PFTs in Obstructive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	3.74		89%
FEV_1 (L)	2.38		73%
FEV_1/FVC	0.64	0.77	
Lung Volumes:			
TLC (L)			
RV (L)			
DLCO mL/mmHg/min	11.0	27.8	40%

55 year old Caucasian male with lung adenocarcinoma; 5 ft 6 in

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PFTs emailed to me for help with interpretation – Dx: COPD

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	3.42	5.46	63%
FEV_1 (L)	1.84	3.99	46%
FEV_1/FVC	0.54	0.73	
Lung Volumes:			
TLC (L)			
RV (L)			
DLCO mL/mmHg/min			64%

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PFTs in Restrictive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	2.89	5.07	57%
FEV_1 (L)	2.24	3.61	62%
FEV_1/FVC	0.78	0.71	
Lung Volumes:			
TLC (L)	3.71	7.27	51%
RV (L)	0.82	2.41	34%
DLCO mL/mmHg/min	6.1	30.5	20%

55 year old Caucasian male with Idiopathic Pulmonary Fibrosis (IPF); 5 ft 11 in

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PFTs in Restrictive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.81	5.17	35%
FEV_1 (L)	1.50	3.95	38%
FEV_1/FVC	0.83	0.76	
Lung Volumes:			
TLC (L)	3.25	7.22	45%
RV (L)	1.35	2.55	53%
DLCO mL/mmHg/min	8.3	29.6	28%

61 year old Caucasian male IPF; 6 ft 0 in

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PFTs in Restrictive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.29	4.61	28%
FEV_1 (L)	1.14	3.26	35%
FEV_1/FVC	0.88	0.71	
Lung Volumes:			
TLC (L)	2.18	6.61	33%
RV (L)	0.89	2.34	38%
DLCO mL/mmHg/min	3.1	28.2	11%

61 year old Caucasian male with IPF; 5 ft 9 ½ in

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PFTs in Restrictive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.89	4.20	45%
FEV_1 (L)	1.65	3.17	52%
FEV_1/FVC	0.87	0.75	
Lung Volumes:			
TLC (L)	2.75	6.55	42%
RV (L)	0.86	1.59	54%
DLCO mL/mmHg/min	7.6	33	23%

40 year old African-American male with IPF; 5 ft 6 in

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PFTs in Restrictive Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	3.72	5.55	67%
FEV_1 (L)	2.65	4.27	62%
FEV_1/FVC	0.71	0.75	
Lung Volumes:			
TLC (L)	5.28	7.65	69%
RV (L)	1.56	2.56	61%
DLCO mL/mmHg/min	21	30.9	68%

56 year old Caucasian with Parkinson's Disease & increasing dyspnea; ht = 6 ft 2 in.

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How would you interpret this?

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.65	3.59	46%
FEV_1 (L)	1.43	2.55	56%
FEV_1/FVC	0.87	0.71	
Lung Volumes:			
TLC (L)	3.87	5.78	67%
RV (L)	2.27	2.58	88%
DLCO mL/mmHg/min	6.1	22.59	27%

81 year old male Caucasian; 5 ft 8 inches

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Recent referral to Pulmonary Rehab

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	3.01	5.67	53%
FEV_1 (L)	2.57	4.31	60%
FEV_1/FVC	0.85	0.71	
Lung Volumes:			
TLC (L)			
RV (L)			
DLCO mL/mmHg/min	17.2	30.7	56%

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Recent referral to Pulmonary Rehab

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	4.64	4.64	100%
FEV_1 (L)	4.33	3.57	121%
FEV_1/FVC	0.93	0.77	
Lung Volumes:			
TLC (L)			
RV (L)			
DLCO mL/mmHg/min	10.5	29.0	36%

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PFTs in Mixed Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	4.72	3.45	137%
FEV_1 (L)	3.15	2.56	123%
FEV_1/FVC	0.67	0.74	
Lung Volumes:			
TLC (L)	7.02	5.90	119%
RV (L)	2.30	2.45	94%
DLCO mL/mmHg/min	5.0	25	20%

73 year old African-American male referred with COPD

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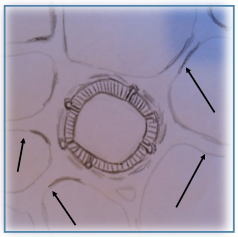
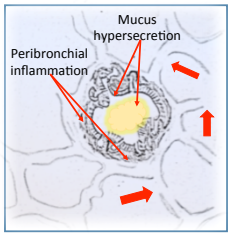
Normal lung tissue



Alveolar walls/attachments create traction pulling bronchiole open

COPD



Alveolar attachments weaken and break down

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- If this patient was diagnosed solely with spirometry and lung volumes, his significant disease would not have been diagnosed!
- Diffusing capacity was a critical piece to the puzzle, as were his symptoms which lead to further evaluation with CT scan.

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PFTs in Mixed Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	1.41	2.71	52%
FEV_1 (L)	0.68	2.06	33%
FEV_1/FVC	0.48	0.76	
Lung Volumes:			
TLC (L)	2.93	4.19	70%
RV (L)	1.37	1.63	84%
DL_{CO} mL/mmHg/min	7.8	19.02	41%

71 y.o. female Caucasian with sarcoidosis

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PFTs in Mixed Lung Disease

Spirometry:	Measured	Predicted	% Predicted
FVC (L)	4.36	4.40	99%
FEV_1 (L)	2.73	3.29	83%
FEV_1/FVC	0.62	0.75	
Lung Volumes:			
TLC (L)	5.95	6.40	93%
RV (L)	1.59	2.45	65%
DL_{CO} mL/mmHg/min	14.9	27.1	55%

67 year old Caucasian male with emphysema; 5 ft 9 in. but with BMI of 41.4 kg/m² and waist circumference 110.5 cm

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Clinical Assessment

- Cough productive of thick, brown, sticky mucus
- Reports his activity is limited by dyspnea; breathing impacts his ability to participate in sexual activity
- Describes his dyspnea as Class 3 on the Medical Research Council Dyspnea Scale:
- Has to stop for breath after walking about 100 yards or after a few minutes on the level
- Tobacco use: currently smoking 1.5 to 2 ppd and has done so for approximately 50 years

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Clinical Assessment

- CT Scan:
  - Moderate severity emphysema (despite PFT's indicating Stage I COPD)
  - Sub-pleural scarring in the apices of both upper lobes
  - Lower lobe predominant sub-pleural fibrotic changes with associated honeycombing
- Graded exercise test: walked for 15 minutes at 1.4-2.2 mph
  - SpO_2 decreased to 84% despite supplemental oxygen @ 5 lpm (DLCO=55% predicted) – patient refused home O_2
  - He experienced a hypertensive response to exercise
- Physician interpretation of GXT indicated he was not safe to begin a home exercise program

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Clinical Decision Making

- **My opinion:** It is a disservice to our patients when we don't look beyond the PFTs.
  - Medicare is reasonable – would likely not deny the patient PR/Respiratory Services if documentation provides accurate of the patient's disease
- Use your Medical Director: He/She is supposed to be experienced in the diagnosis and management of chronic respiratory disease
  - Elicit help from the MD in interpreting the patient's diagnosis using all of the available data

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Summary: Obstructive Lung Disease

- Characterized by:
  - FEV_1 decreased out of proportion to the FVC
  - Decreased FEV_1/FVC
  - Would see reversibility with asthma; *may* see some with COPD
  - Increased RV due to air trapping
  - Eventual increase in TLC
  - Possible decrease in DLCO depending on degree of damage to the alveolar-capillary membrane

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Summary: Restrictive Lung Disease

- Characterized by:
  - Proportionate decrease in FEV_1 and FVC
  - Normal to high FEV_1/FVC
  - May have a decreased RV
  - Verify restriction by low TLC
  - Decrease in DLCO if alveolar-capillary damage

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Summary: Mixed OLD and RLD

- Characterized by:
  - Generally see a decreased FEV_1/FVC
  - Other spirometry and lung volumes *MAY* be normal
  - DLCO will likely be decreased
  - Need further clinical evaluation to diagnose
    - Medical Director involvement for interpretation
    - Chest CT/ Chest X-ray results
    - Clinical presentation

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References

1. Pellegrino R, Viegi G, Brusasco V, Crapo RO, et al. Interpretative strategies for lung function tests. *Eur Respir J* 2005; 26:948-968.
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