Pulmonary Function Test Interpretation

March 2024

Is Spirometry different to a ‘PFT’?

Spirometry

- Airflow (how much air, how fast)

(Static) Lung volumes

- Volume (how much air)

Diffusing Capacity/DLCO

- Gas exchange (how effective)

Other testing:

- Airway responsiveness
- Respiratory muscle strength testing
- Compliance of the lungs

Why do a spirometry?

- To evaluation patients with dyspnea.
- To evaluate disease severity and monitoring treatment response.
- Determine fitness for surgery.

Before you begin…

Before the numbers / Quality control

- Review age, gender, smoking status, BMI, indication, flow-volume curves
- Quality control
  - Three acceptable maneuvers with repeatable values: Two highest values of FVC and FEV_1 should be within 150mL (100mL if FVC ≤ 1L)
  - Good start (back extrapolation < 5% of FVC or 150 mL)
  - No cough or artifact in initial expiratory loop
  - Post-expiratory flow should be ≥ 6 seconds or 1 second plateau

Te Whatu Ora Health New Zealand

Lung Function Tests Results

Testing Site: Southland Hospital Respiratory Lab
Contact details: (03) 2145775

NHI:
Dr. / Referrer: Hafetz, Dr M
GP Practice/Dept: Resp OP

NHI:

Date and time of tests: 26/02/2024 10:19:10

D.O.B 27/09/1934 **Age:** 89
Birth sex: Female **Ethnicity:** Caucasian
Height (cm): 150.5 **or, arm span (cm):** **Weight (kg):** 60.0 **BMI:** 26.5
Smoking history: Never Smoked **Pack years:** **Years quit:**
Medications taken with possible implications on lung function:
Nil inhaler usage

Physician's Report: Respiratory clinic patient, please refer to clinic letter for further details.

Clinical details: Right hilar mass.
Report: Spirometry is within normal limits with no evidence of airflow obstruction, and the flow volume loop has normal contours. Pulmonary gas transfer factor appears low (there is no predicted range for ages greater than 85 yrs for DLco). There are no previous results available for comparison.

Carla Hancock, Respiratory Physiologist and Team Leader Southland site.
Dr Colin Wong, Respiratory Physician
26/02/2024

Comments relating to testing session below: Respiratory Physiologist: Johnston, Ethan

Interpreter to note: There is no predicted range for ages greater than 85 yrs for pulmonary gas transfer factor. Spirometry - Only maximal expiratory manoeuvres were performed for the flow volume loop. Tests were performed using the Medgraphics 2022 Platinum Elite body plethysmograph; software - Breeze Suite version 8.6.

Note: Unless otherwise stated: 1. All tests meet the latest ATS/ERS grading standards - Grade A (spirometry A-C)
2. The inspiratory effort(s) printed on the graph(s) is maximal. 3. Predicted equations used: GLI for spirometry (2012) diffusion capacity (2017) and subdivisions of lung volumes (2021). 4. An * highlights measured value is outside the lower (LLN) or upper limit of normal. 5. Results are reported in BTPS.
Barometric pressure mmHg: 759 Temperature °C:22 Humidity %: 41

	Pre-Broncho						Post-Bronchod		
	Actual	Pred	Pred	LLN	ULN	Z Score	Actual	%Chng	Z Score (Post)
--- Spirometry ---									
FEV1 (L)	1.53	1.47	104	0.99	1.92	+0.24			
FVC (L)	1.83	1.94	94	1.31	2.61	-0.29			
FEV1/FVC (%)	84	77	109	61	91	+0.82			
FEV1/SVC (%)	85	76	112	60	89	+1.12			
PEF (L/min)	256.8								
Expiratory Time (sec)	6.36								
FIVC (L)	1.67								
--- Lung Volumes ---									
SVC (L)	1.80	1.94	92	1.31	2.61	-0.35			
--Diffusion/Transfer Factor--									
DLCOunadjusted (ml/min/mmHg	10.0								
DLCOadjusted (ml/min/mmHg)									
Kco (ml/min/mmHg/L)	3.4								
VA (L)	2.94								

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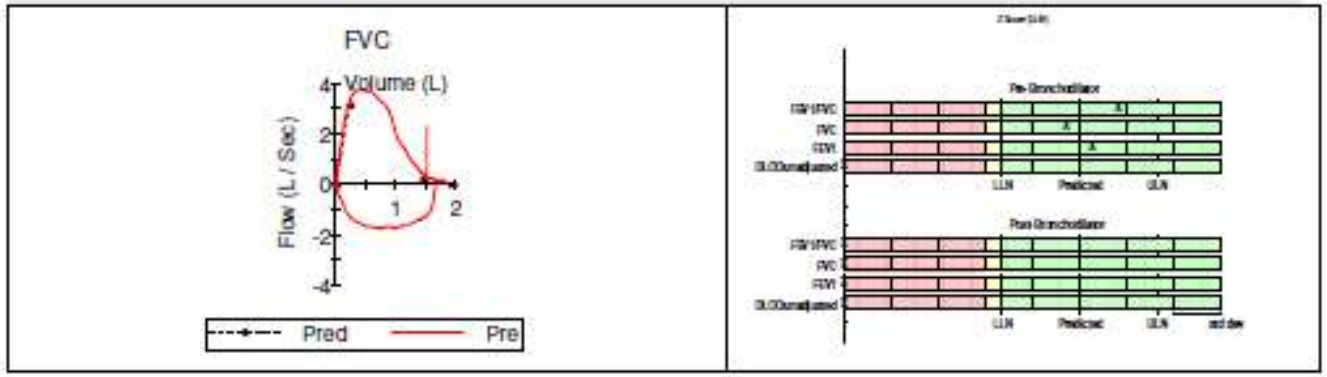
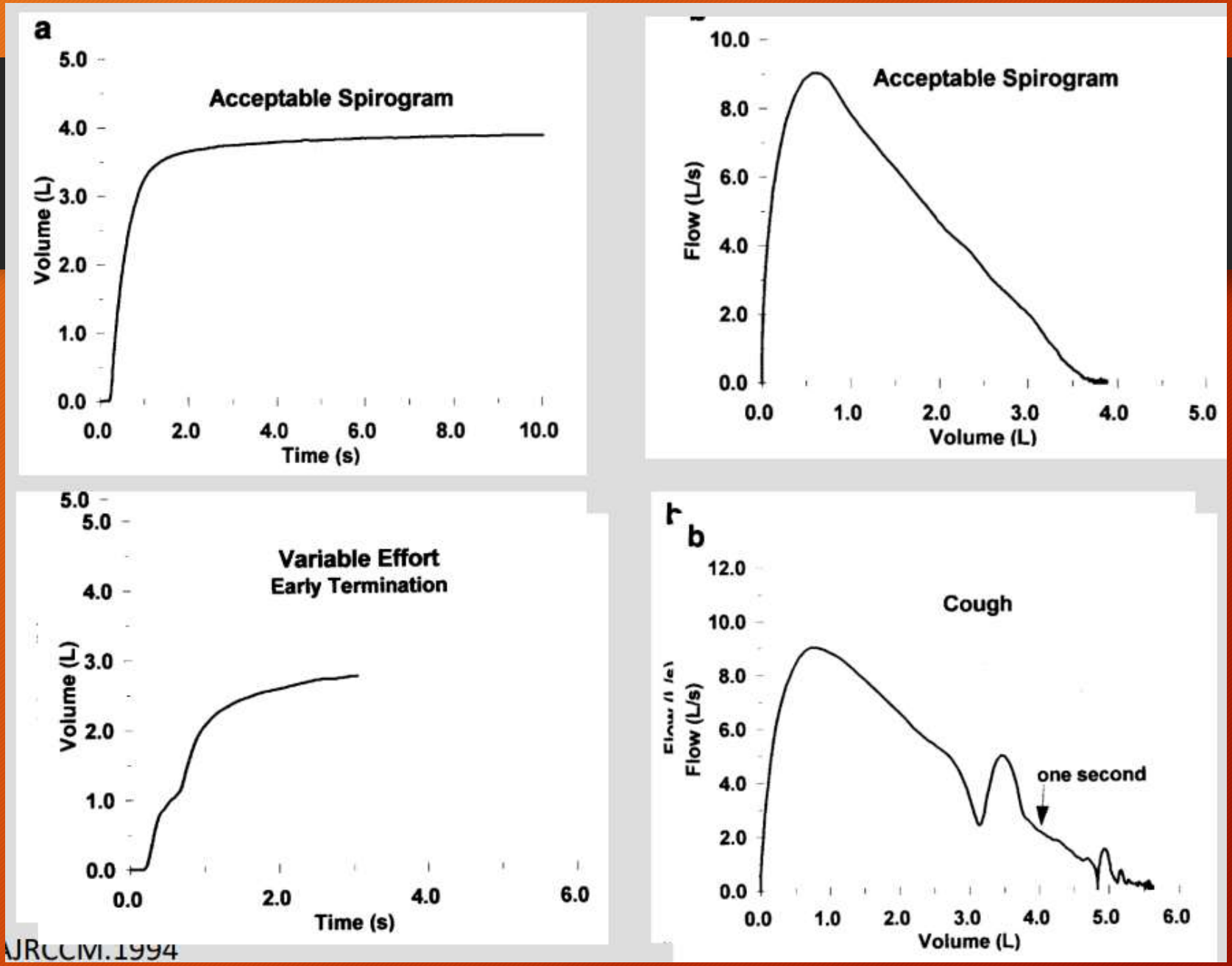
	Pre-Broncho						Post-Bronchod		
	Actual	Pred	Pred	LLN	ULN	Z Score	Actual	%Chng	Z Score (Post)
IVC (L)	1.66								
BHT (sec)	11.22								




a
Acceptable Spirogram
Volume (L)
Time (s)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10.0
Acceptable Spirogram
Flow (L/s)
Volume (L)
Variable Effort
Early Termination
Volume (L)
Time (s)
b
Cough
Flow (L/s)
one second
Volume (L)

AJRCCM.1994

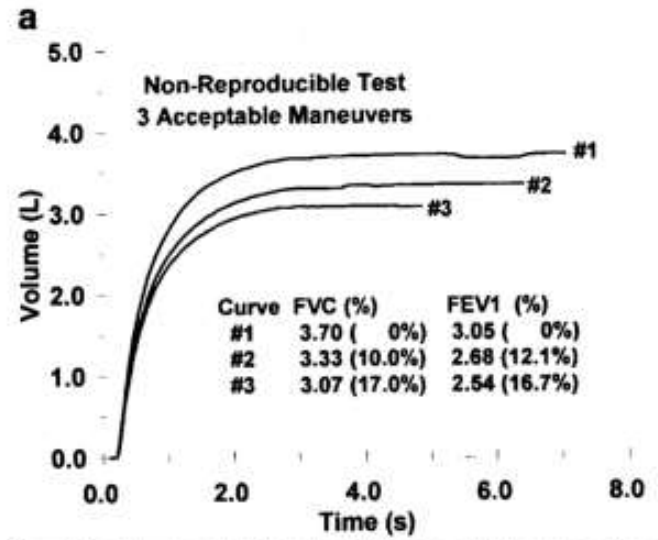


Figure A7a. Nonreproducible test with three acceptable volume–time curves. Percents are difference from largest value.

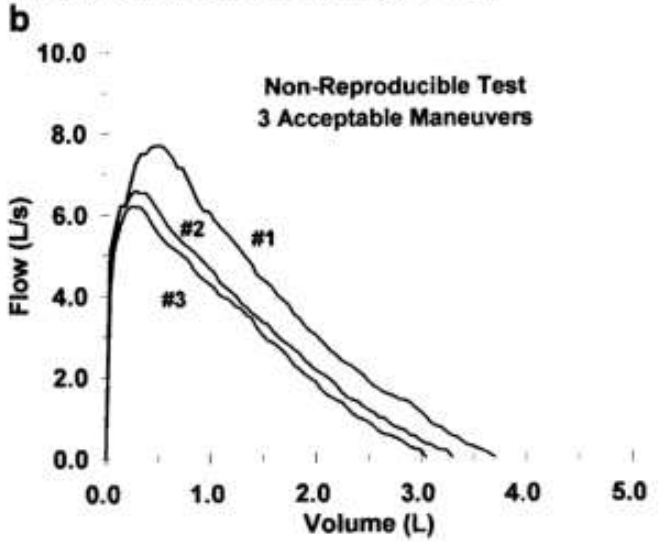


Figure A7b. Nonreproducible test with three acceptable flow–volume curves.

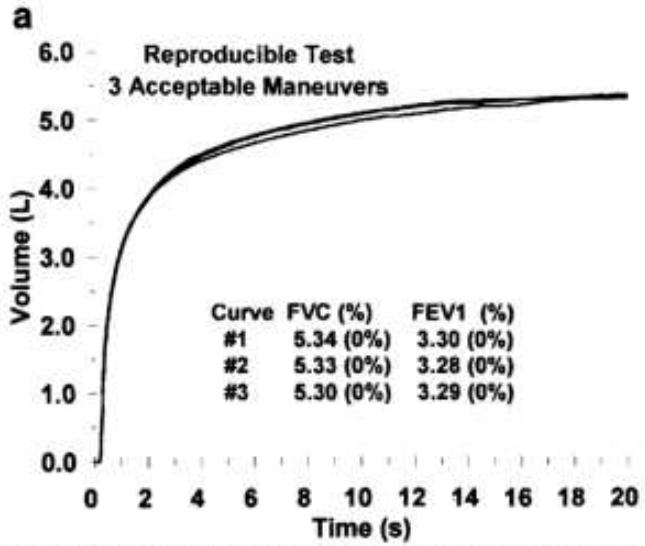


Figure A8a. Reproducible test with three acceptable volume–time curves. Percents are difference from largest value.

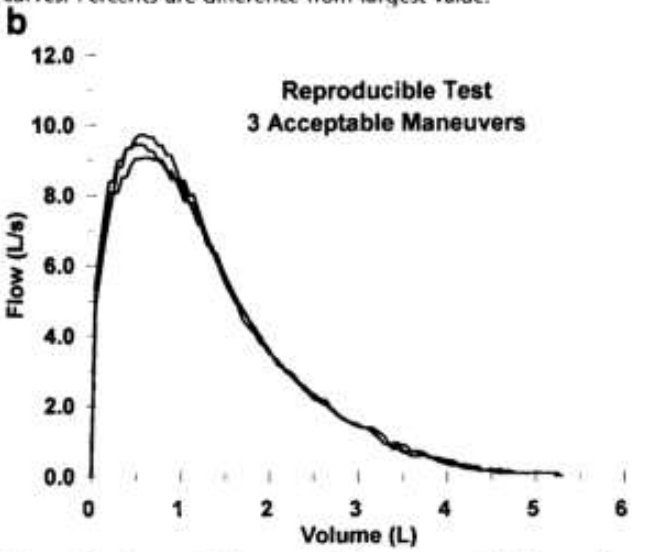
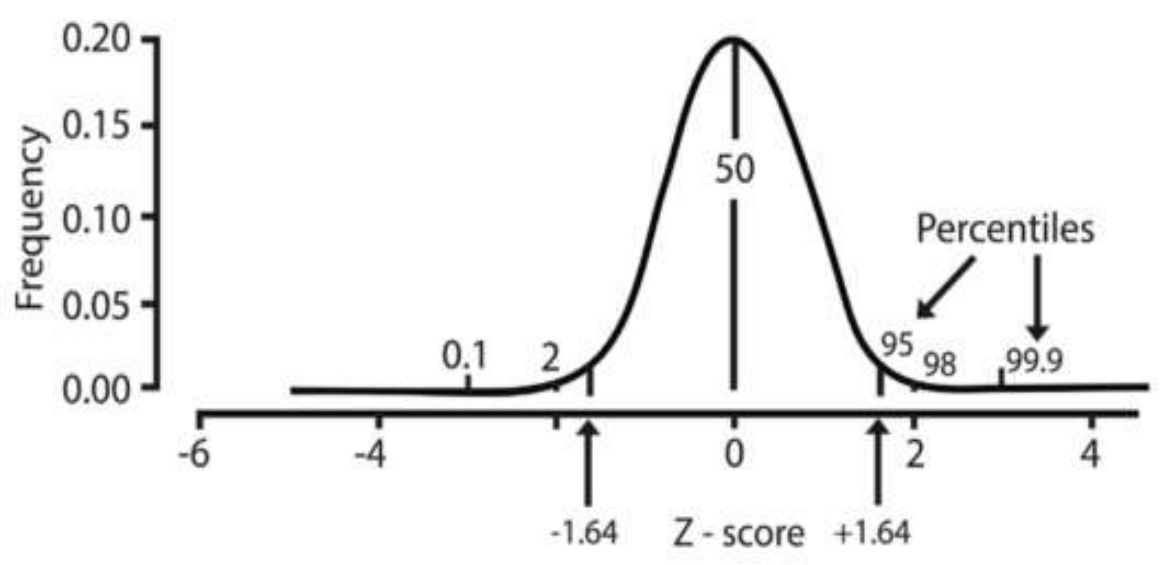
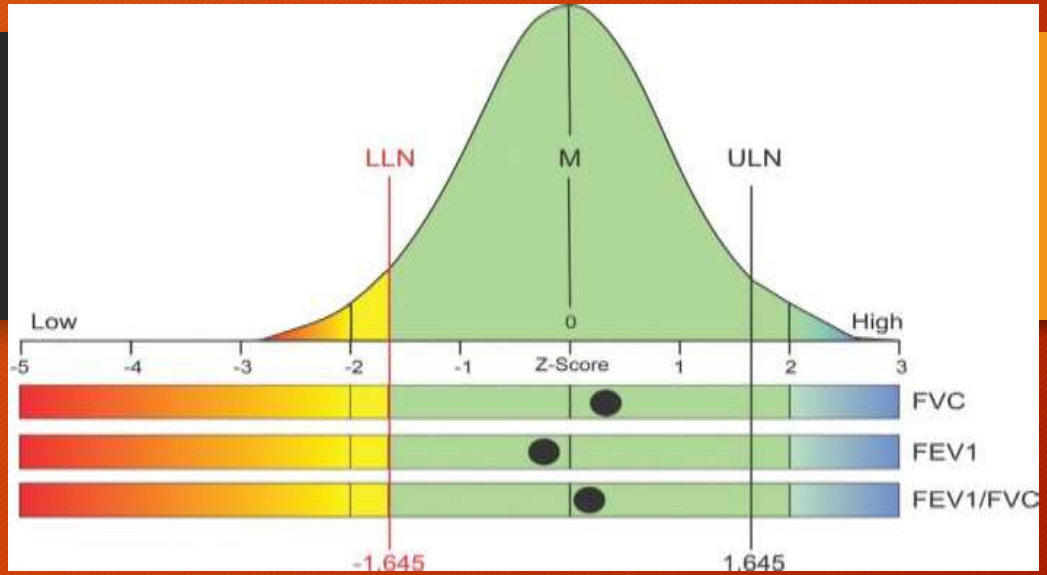


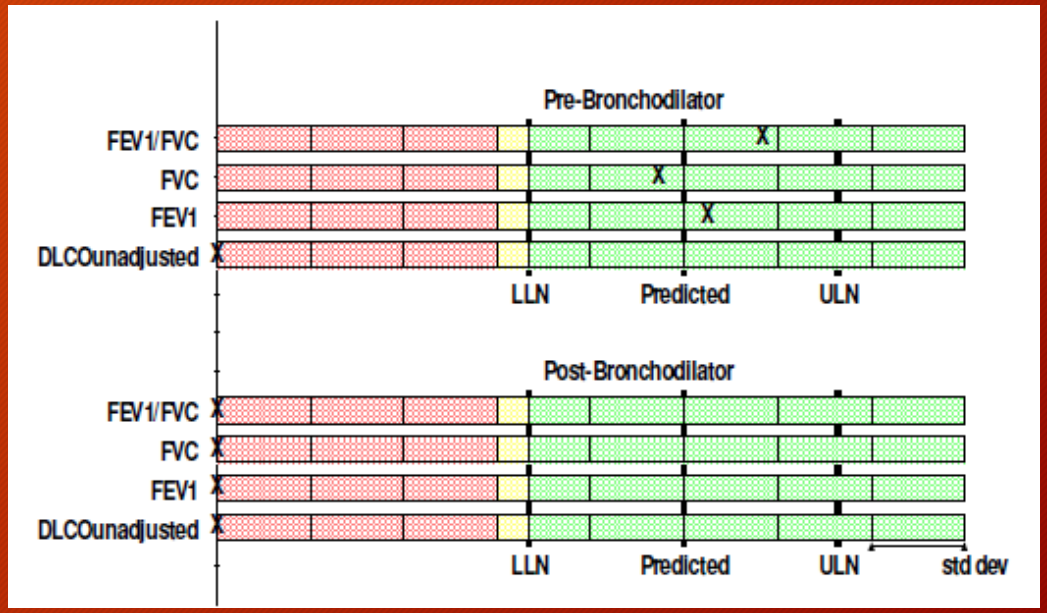
Figure A8b. Reproducible test with three acceptable flow–volume curves.

3 acceptable maneuvers with at least 2 that are repeatable within 0.15L of each other (0.1L if FVC<1L)

Z-score (LLN)


0.20
0.15
0.10
0.05
0.00
Frequency
50
Percentiles
0.1
2
95
98
99.9
-6
-4
0
2
4
-1.64
Z - score
+1.64


LLN
M
ULN
Low
0
High
-5
-4
-3
-2
-1
Z-Score
1
2
3
FVC
FEV1
FEV1/FVC
-1.645
1.645


Pre-Bronchodilator
FEV1/FVC
FVC
FEV1
DLCOunadjusted
LLN
Predicted
ULN
Post-Bronchodilator
FEV1/FVC
FVC
FEV1
DLCOunadjusted
LLN
Predicted
ULN
std dev

Spirometry

- Normal FEV_1 and FVC 80-120% predicted
- FEV_1/**VC** increased: suggests restriction
- FEV_1/**VC** < LLN (ATS) or < 70% (GOLD): airflow obstruction present
  - Severity* FEV_1 (% pred)

Severity*	FEV_1 (% pred)
Mild	≥80%
Moderate	50-79%
Severe	30-50%
Very severe	<30%

Either forced (F**VC**) or slow (S**VC**) vital capacity can be used to determine FEV_1/VC ratio

*No universally agreed upon severity measures. These are GOLD

Bronchodilator response

- Positive response: ↑ FEV_1 or FCV by ≥ 12% and ≥ 200ml
- Lack of bronchodilator response does not preclude bronchodilator therapy

PATTERNS OF DISEASE WITH PFTS

Obstructive

FEV1/FVC <0.7 (or <LLN)

- Asthma
- COPD (emphysema, chronic bronchitis)
- Bronchiolitis/Bronchiectasis

Restrictive

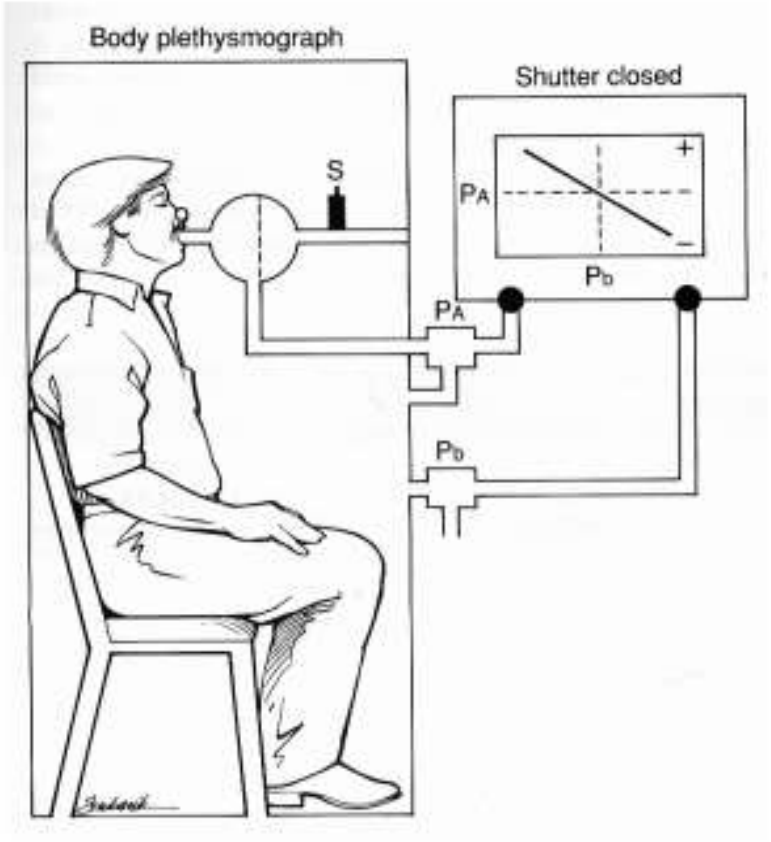
FEV1/FVC reduced with low lung volumes*

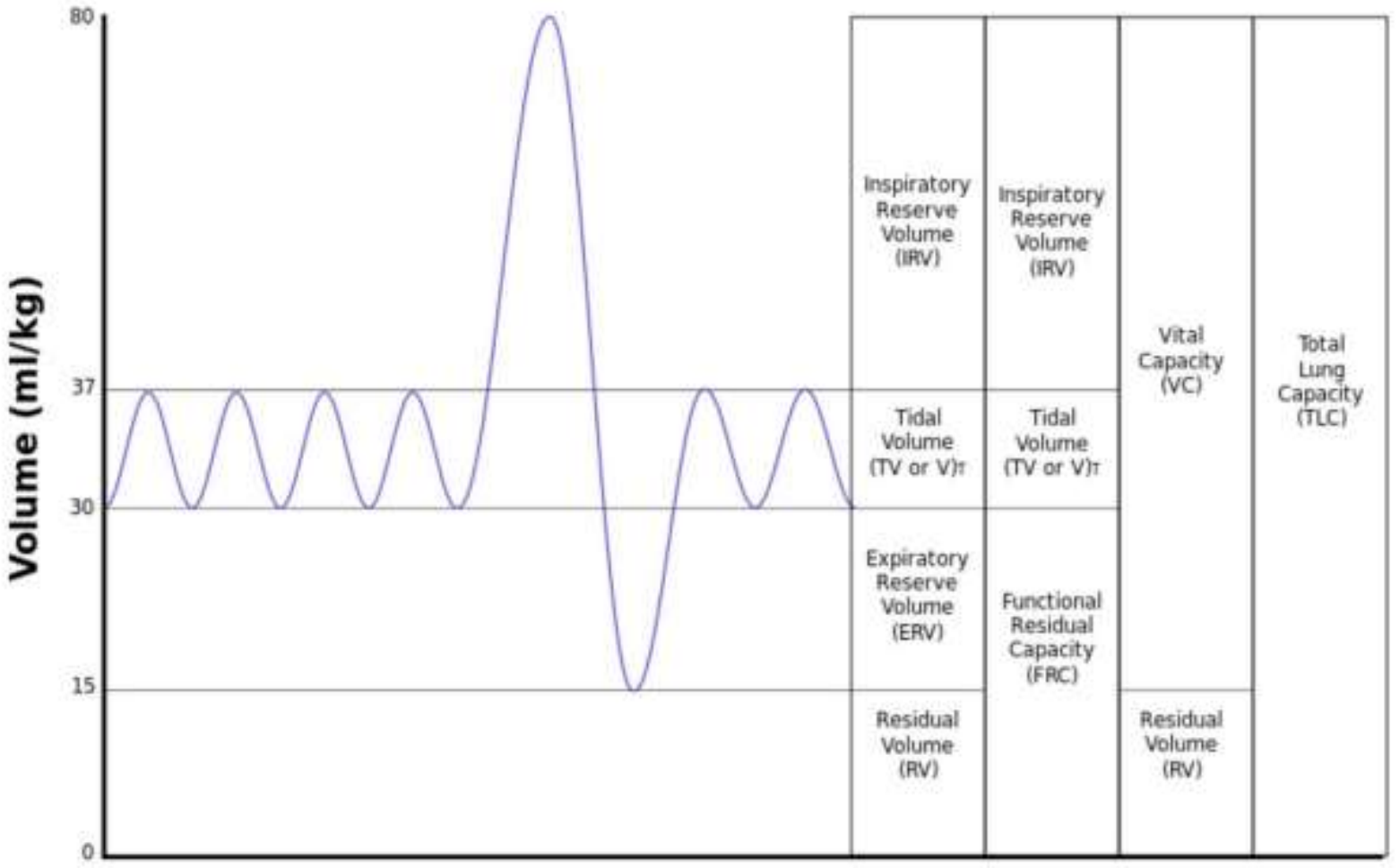
- Interstitial lung disease
- Neuromuscular weakness
- Pleural disease
- Chest wall deformities
- Obesity

Mixed

- Both obstructive and restrictive elements

Body Plethysmograph

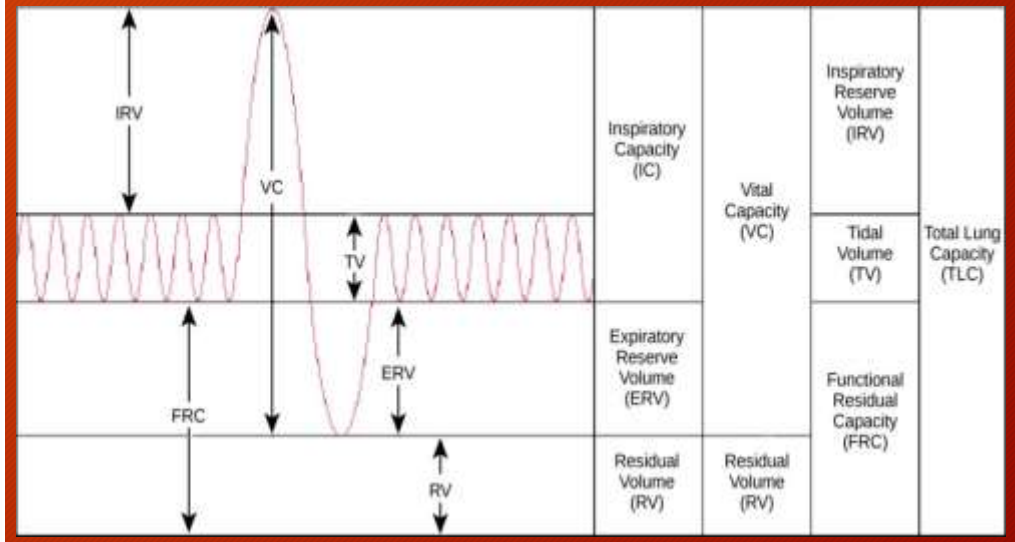




Lung Volumes and Capacities

Table 1. Lung Volumes and Capacities (Avg Adult Male)

Volume/Capacity	Definition	Volume (liters)	Equations
Tidal volume (TV)	Amount of air inhaled during a normal breath	0.5	–
Expiratory reserve volume (ERV)	Amount of air that can be exhaled after a normal exhalation	1.2	–
Inspiratory reserve volume (IRV)	Amount of air that can be further inhaled after a normal inhalation	3.1	–
Residual volume (RV)	Air left in the lungs after a forced exhalation	1.2	–
Vital capacity (VC)	Maximum amount of air that can be moved in or out of the lungs in a single respiratory cycle	4.8	ERV+TV+IRV
Inspiratory capacity (IC)	Volume of air that can be inhaled in addition to a normal exhalation	3.6	TV+IRV
Functional residual capacity (FRC)	Volume of air remaining after a normal exhalation	2.4	ERV+RV
Total lung capacity (TLC)	Total volume of air in the lungs after a maximal inspiration	6.0	RV+ERV+TV+IRV
Forced expiratory volume (FEV1)	How much air can be forced out of the lungs over a specific time period, usually one second	~4.1 to 5.5	–



Interpreting Lung Volumes

Lung volumes

- TLC < LLN (ATS) or < 80% (GOLD): restriction present
  - Severity — TLC (% pred)

Severity	TLC (% pred)
Mild	>70%
Moderate	50-69%
Severe	<50%

- TLC > 120%: hyperinflation (if obstruction present)

Other Lung Volumes:
VC: ↓ in restriction or air trapping
RV & FRC: ↑ with air trapping
RV & FRC: ↓ with restriction
ERV: ↓ in obesity, look at BMI

'Grocery Bag'
- High compliance

'Thick balloon'
- low compliance

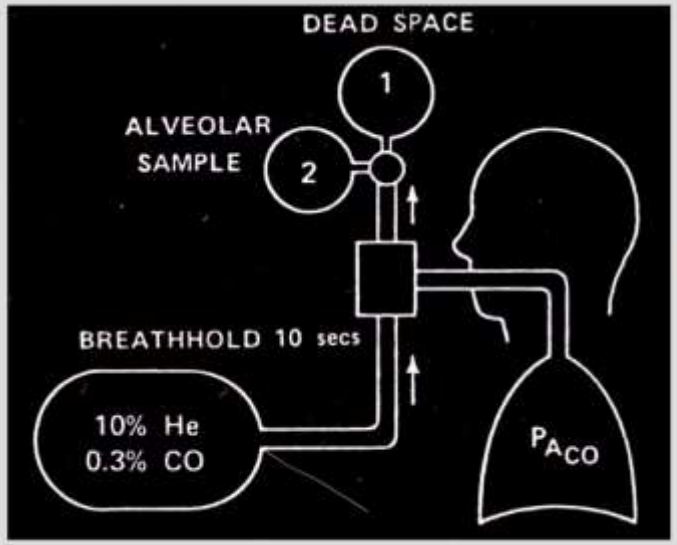
DLCO

Diffusion capacity

- DL_{CO} >120%: L → R shunt, alveolar hemorrhage, polycythemia
- DL_{CO} < LLN (ATS) or < 80% (GOLD): low; context to interpret
  - Severity — DL_{CO} (% pred)
    - Mild — >60%
    - Moderate — 40-60%
    - Severe — <40%

Context:

- Obstruction present: emphysema
- Restriction present: parenchymal disease, lung resection
- Normal spirometry & lung volumes: anemia, early interstitial lung disease, pulmonary vascular disease

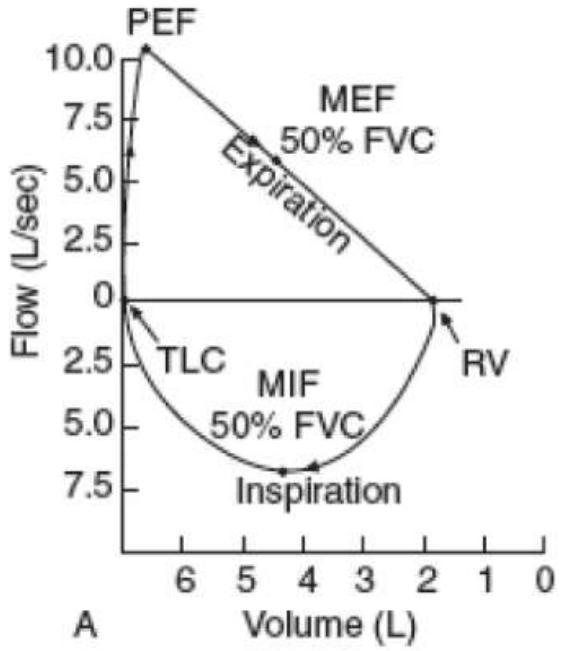


Transfer of CO from alveoli to blood is diffusion limited:

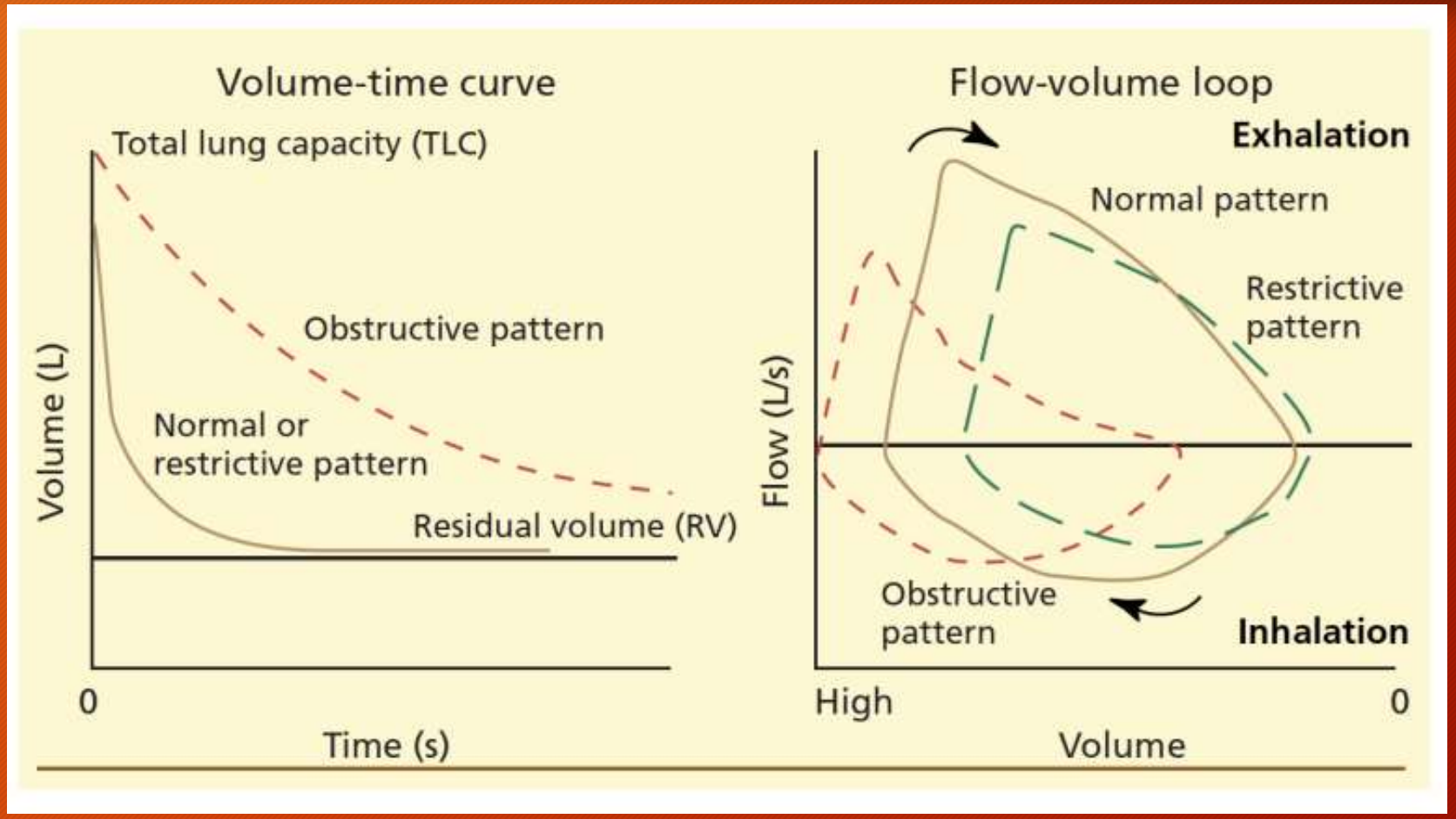
CO binds hemoglobin 210 times more efficiently than O2 and normally very low concentration in blood

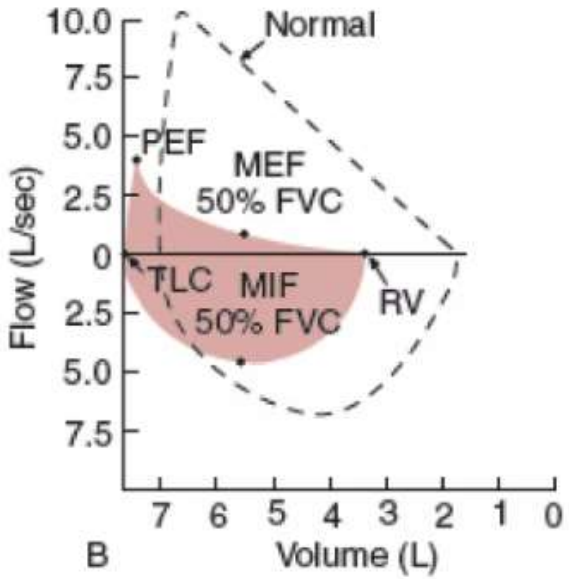
Thus, limited by **surface area, membrane thickness & blood flow/Hb**

The Flow Volume Loop

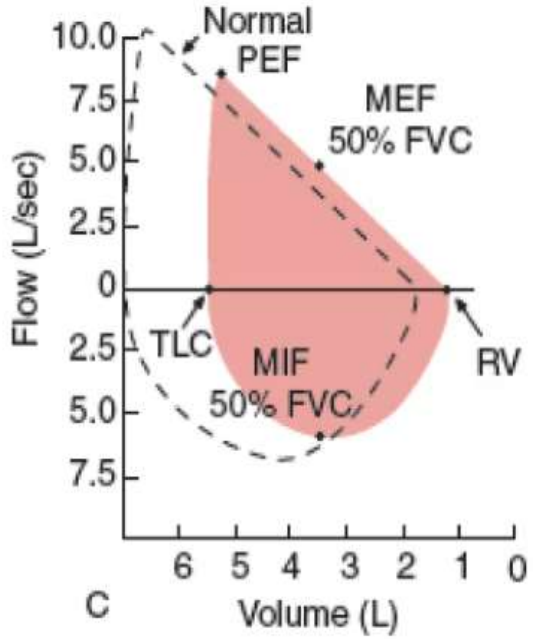


(A) Normal. Inspiratory limb of loop is symmetric and convex. Expiratory limb is linear. Flow rates at the midpoint of the inspiratory and expiratory capacity are often measured. Maximal inspiratory flow at 50% of forced vital capacity (MIF 50%FVC) is greater than maximal expiratory flow at 50% FVC (MEF 50%FVC) because dynamic compression of the airways occurs during exhalation.

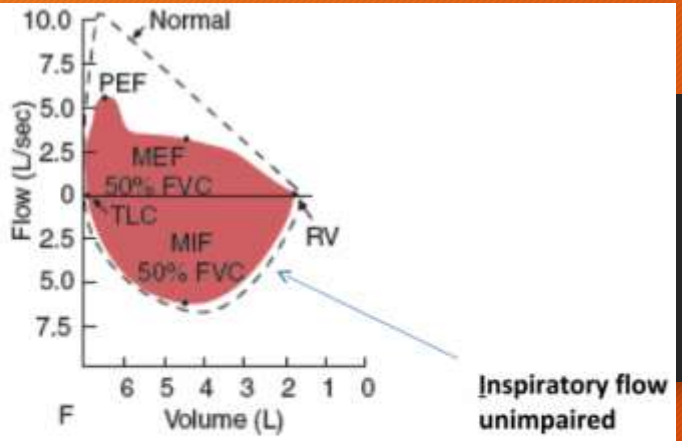

Volume-time curve
Total lung capacity (TLC)
Obstructive pattern
Normal or
restrictive pattern
Residual volume (RV)
Volume (L)
0
Time (s)
Flow-volume loop
Exhalation
Normal pattern
Restrictive
pattern
Obstructive
pattern
Inhalation
Flow (L/s)
High
0
Volume



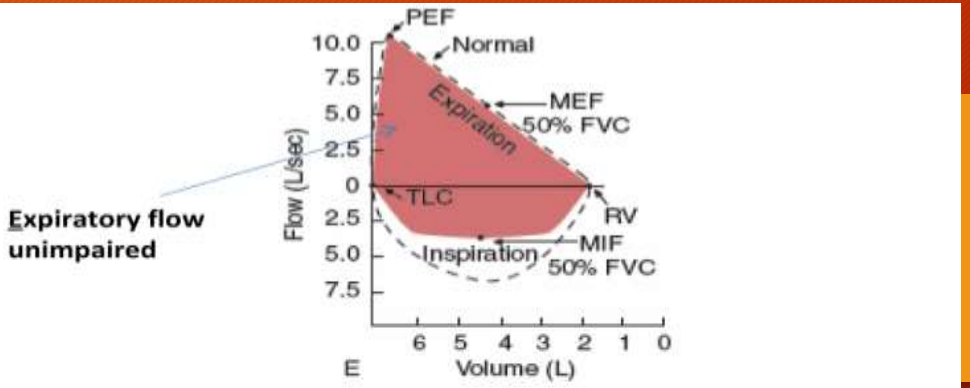
(B) Obstructive disease (eg, emphysema, asthma). Although all flow rates are diminished, expiratory prolongation predominates, and MEF < MIF. Peak expiratory flow is sometimes used to estimate degree of airway obstruction but is dependent on patient effort.



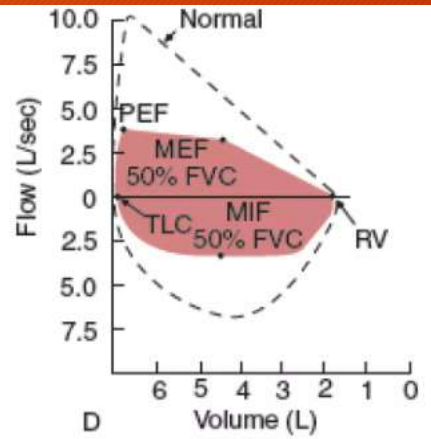
(C) Restrictive disease (eg, interstitial lung disease, kyphoscoliosis). The loop is narrowed because of diminished lung volumes, but the shape is generally the same as in normal volume. Flow rates are greater than normal at comparable lung volumes because the increased elastic recoil of lungs holds the airways open.



(F) Variable intrathoracic obstruction (eg, tracheomalacia). During a forced inspiration, negative pleural pressure holds the "floppy" trachea open. With forced expiration, loss of structural support results in tracheal narrowing of the trachea and a plateau of diminished flow. Flow is maintained briefly before airway compression occurs.

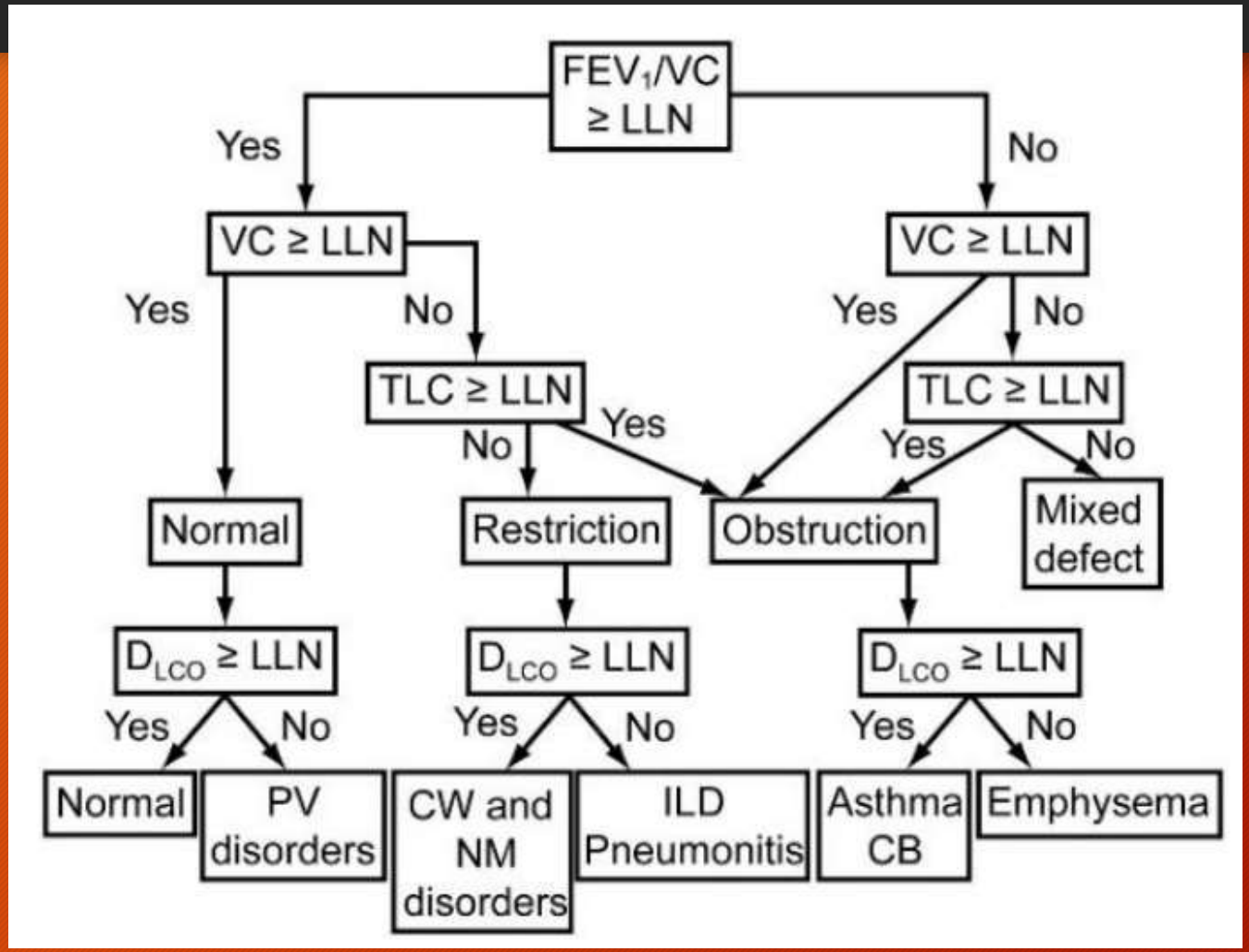


(E) Variable extrathoracic obstruction (eg, unilateral vocal cord paralysis, vocal cord dysfunction).
When a single vocal cord is paralyzed, it moves passively with pressure gradients across the glottis. During forced inspiration, it is drawn inward, resulting in a plateau of decreased inspiratory flow. During forced expiration, it is passively blown aside, and expiratory flow is unimpaired. Therefore, **MIF 50%FVC < MEF 50%FVC**.

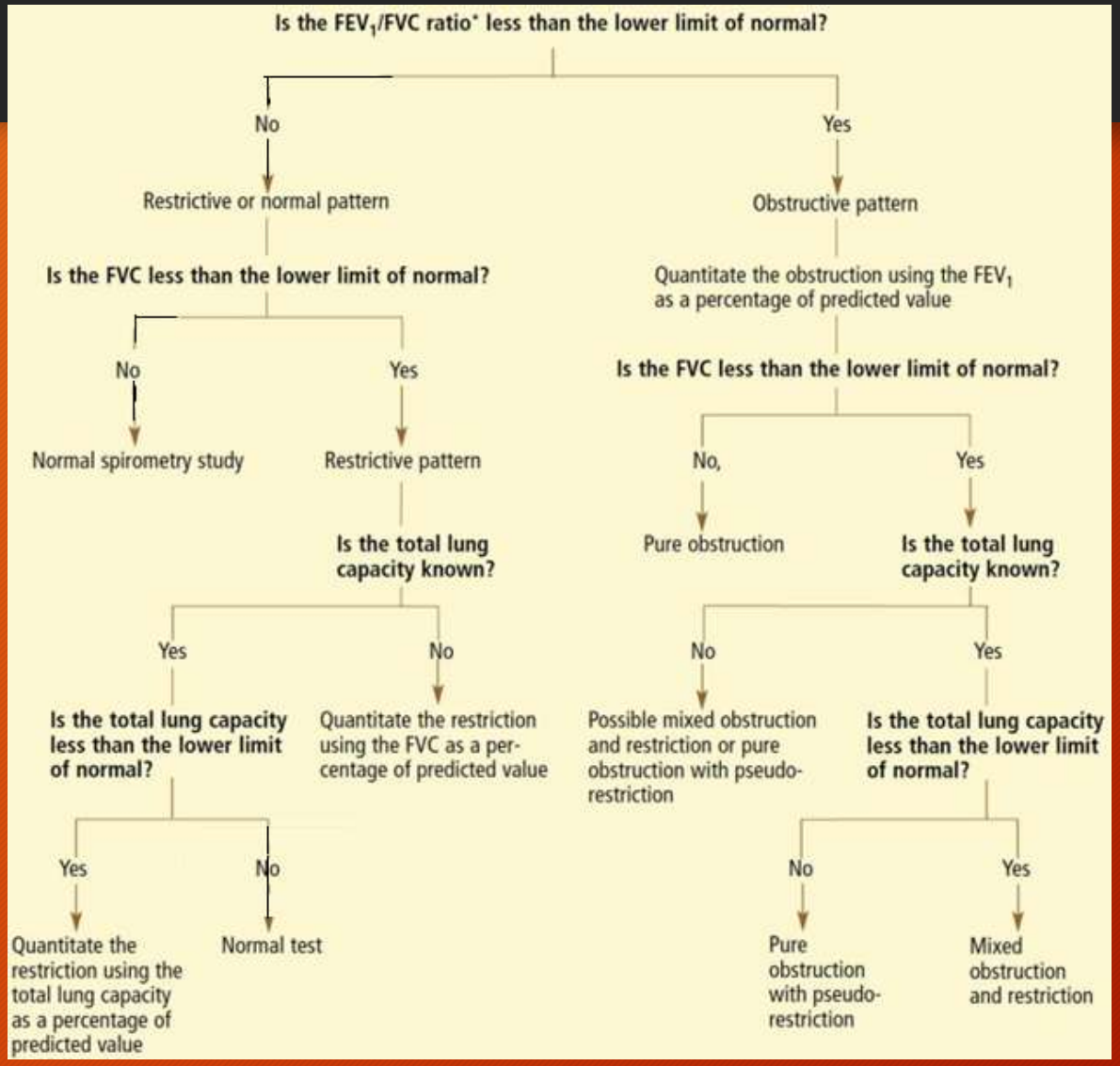


(D) Fixed obstruction of the upper airway (eg,
tracheal stenosis, goiter). The top and bottom of the loops are flattened so that the configuration approaches that of a rectangle. Fixed obstruction limits flow equally during inspiration and expiration, and **MEF = MIF**.

The ATS guideline on Interpreting Lung Function



Take a step-by-step approach



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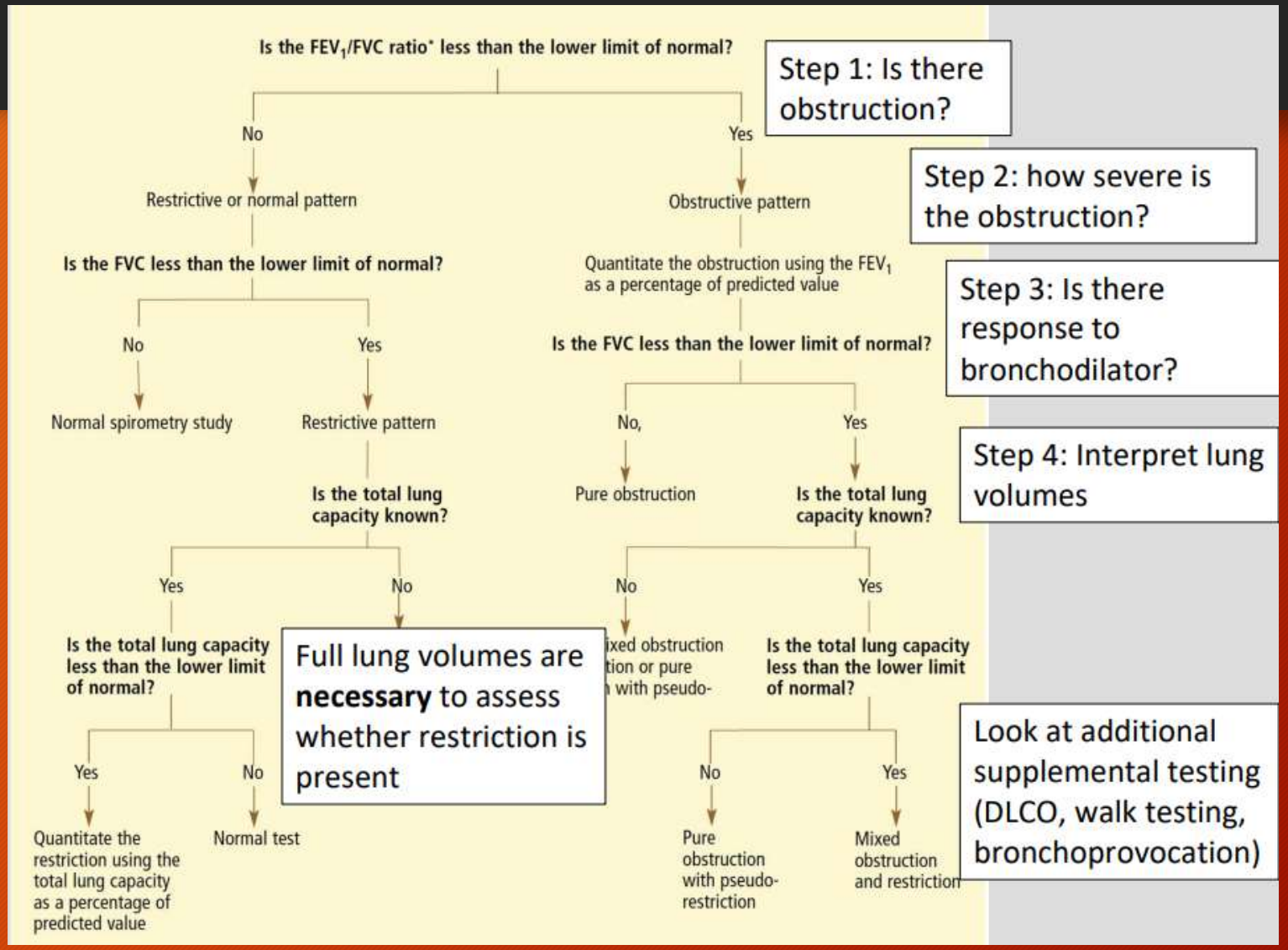
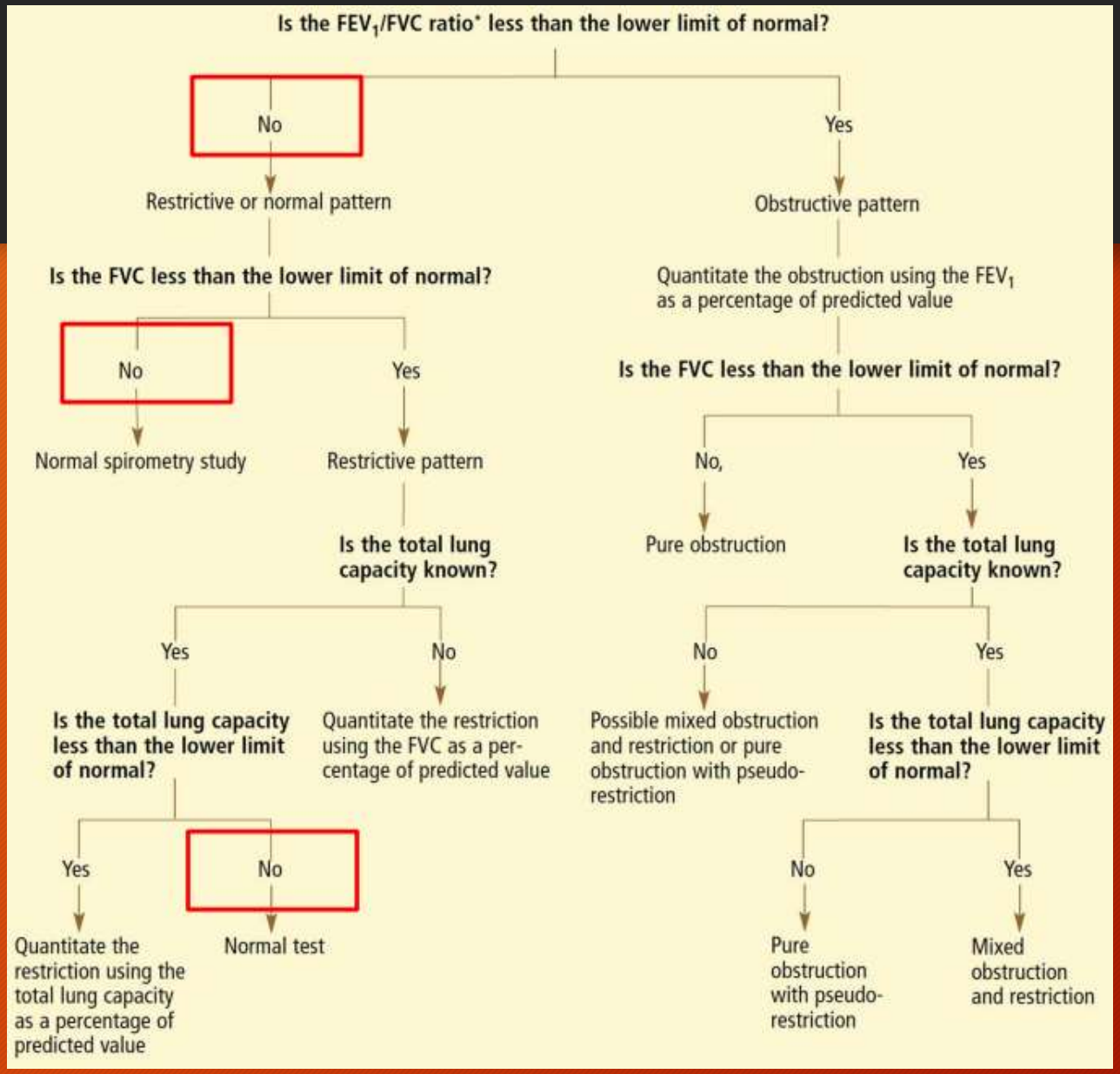


CASE 1:

TEST	ACTUAL	PREDICTED	% PREDICTED
FVC (L)	4.39	4.32	102
FEV_1 (L)	3.20	3.37	95
FEV_1/FVC	0.73	0.78	N/A
FRC (L)	3.17	3.25	98
RV (L)	2.54	2.32	109
TLC (L)	6.86	6.09	113

A 29 y/o woman presents to your clinic with episodes of shortness of breath, chest tightness and wheezing during the springtime. You interpret her PFTs as:

a. Normal spirometry and lung volumes
b. Obstructive pattern
c. Restrictive pattern
d. Mixed obstructive restrictive pattern


Is the FEV1/FVC ratio* less than the lower limit of normal?
No
Yes
Restrictive or normal pattern
Obstructive pattern
Is the FVC less than the lower limit of normal?
Quantitate the obstruction using the FEV1 as a percentage of predicted value
No
Yes
Is the FVC less than the lower limit of normal?
Normal spirometry study
Restrictive pattern
No,
Yes
Pure obstruction
Is the total lung capacity known?
Is the total lung capacity known?
Yes
No
No
Yes
Is the total lung capacity less than the lower limit of normal?
Quantitate the restriction using the FVC as a percentage of predicted value
Possible mixed obstruction and restriction or pure obstruction with pseudo-restriction
Is the total lung capacity less than the lower limit of normal?
Yes
No
No
Yes
Quantitate the restriction using the total lung capacity as a percentage of predicted value
Normal test
Pure obstruction with pseudo-restriction
Mixed obstruction and restriction

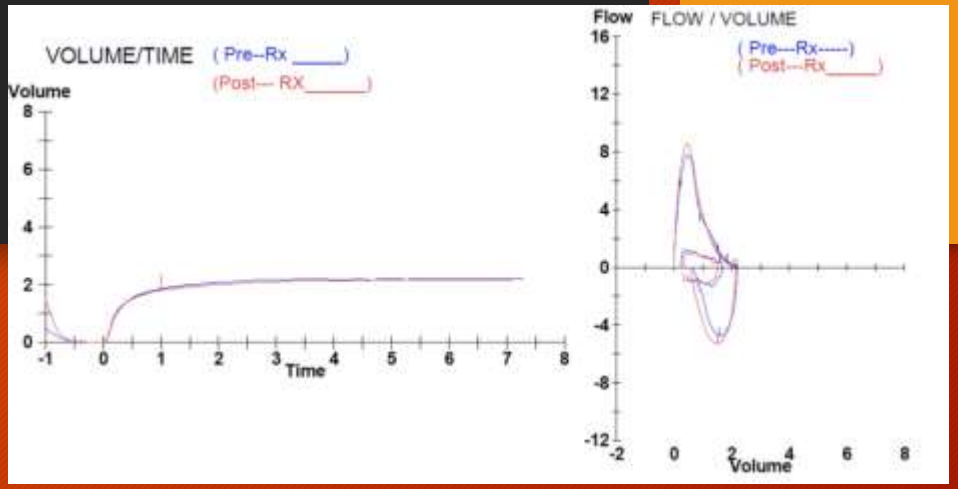
CASE 2: A 67 Y/O MAN WITH COUGH

Sex: Male
Age: 56 Race: Black
Height(in): 67 169 cm
Weight(lb): 118 53.6 kg

ID#: 1218299 Room: Out-Pt
Temp: 22 PBar: 641 FIN: 1029728145
Physician: GOEL
Technician: KIMBERLEY RAY RT

(BTPS)

		PRE-RX			POST-RX		
		PRED	BEST	%PRED	BEST	%PRED	% Chg
Spirometry		*Values in Parentheses or Asterisks are outside the normal range*					
FVC	Liters	3.96	(2.21)	(56)	(2.16)	(55)	-2
FEV1	Liters	3.16	(1.86)	(59)	(1.82)	(57)	-2
FEV1/FVC	%	80	84		84		
FEF25-75%	L/sec	3.45	2.23	65	2.18	63	-2
FEF25%	L/sec		7.11		7.09		-0
FEF50%	L/sec		3.11		3.65		17
FEF75%	L/sec		0.82		0.72		-13
PEF	L/sec	8.73	7.75	89	8.60	98	11
FEF/FIF50			0.68		0.69		2
Lung Volumes							
VC	Liters	4.29	(2.26)	(53)			
TLC	Liters	6.28	(3.71)	(59)			
RV	Liters	1.97	1.45	74			
RV/TLC	%	31	39				
FRC PL	Liters	3.19	2.76	86			
FRC N2	Liters	3.19					
ERV	Liters	1.42	1.20	85			



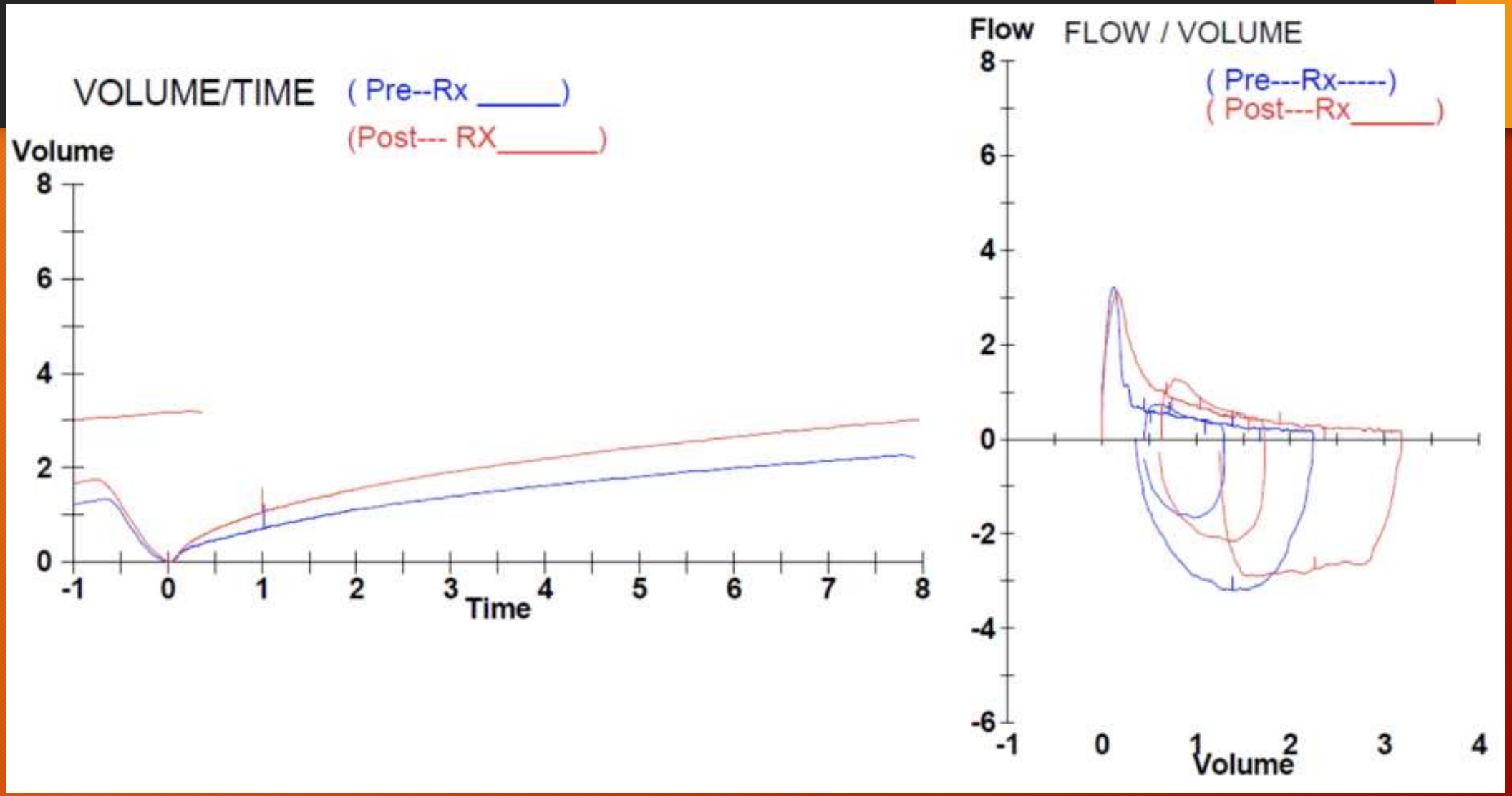
All of the following conditions could be causes of his restrictive lung disease except:

a. Interstitial lung disease
b. Pleural effusions
c. Kyphoscoliosis
d. Neuromuscular weakness
e. Obesity

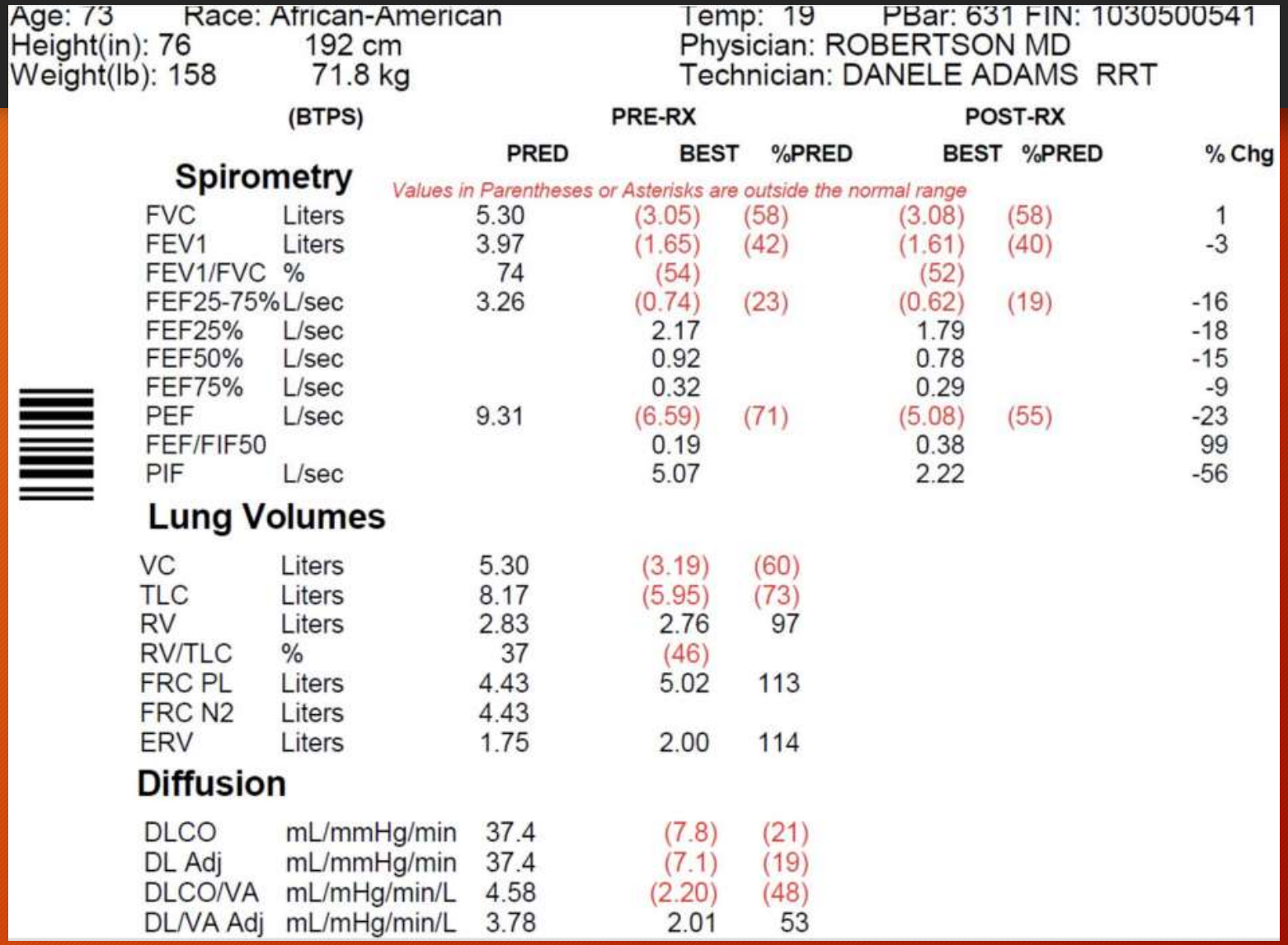
Cause of Restriction	Pattern of lung volume abnormality
Intrinsic Lung Disease (interstitial lung disease, pulmonary fibrosis)	Low VC and low RV
Neuromuscular Disease	Low VC and high RV
Chest wall restriction (kyphoscoliosis)	Low VC and low RV
Obesity	Low FRC and low ERV

CASE 3: A 77 Y/O MAN WITH DYSPNEA AND HYPOXEMIA

		PRED	BEST	%PRED	BEST	%PRED	% Chg
Spirometry		*Values in Parentheses or Asterisks are outside the normal range*					
FVC	Liters	3.88	(2.25)	(58)	3.19	82	42
FEV1	Liters	2.95	(0.73)	(25)	(1.08)	(37)	47
FEV1/FVC	%	77	(33)		(34)		
FEF25-75%	L/sec	2.64	(0.31)	(12)	(0.38)	(15)	25
FEF25%	L/sec		0.53		0.80		50
FEF50%	L/sec		0.32		0.39		23
FEF75%	L/sec		0.19		0.24		28
PEF	L/sec		3.22		3.10		-4
FEF/FIF50			0.10		0.14		43
Lung Volumes							
VC	Liters	3.88	(2.70)	(70)			
TLC	Liters	6.43	(8.74)	(136)			
RV	Liters	2.44	(6.04)	(247)			
RV/TLC	%	38	(69)				
FRC PL	Liters	3.44	(7.51)	(219)			
FRC N2	Liters	3.44					
ERV	Liters	1.28	1.63	127			
Diffusion							
DLCO	mL/mmHg/min	27.3	(6.1)	(22)			
DL Adj	mL/mmHg/min	27.3	(6.1)	(22)			
DLCO/VA	mL/mHg/min/L	4.43	(1.34)	(30)			
DL/VA Adj	mL/mHg/min/L		1.34				


VOLUME/TIME
(Pre--Rx _____)
(Post--- RX_____)
Volume
8
6
4
2
0
-1
0
1
2
3
4
5
6
7
8
Time
Flow
FLOW / VOLUME
(Pre---Rx-----)
(Post---Rx_____)
8
6
4
2
0
-2
-4
-6
-1
0
1
2
3
4
Volume

Case 4- A 76 y/o man presents with hypoxemia



Age: 73 Race: African-American Temp: 19 PBar: 631 FIN: 1030500541
Height(in): 76 192 cm Physician: ROBERTSON MD
Weight(lb): 158 71.8 kg Technician: DANELE ADAMS RRT

		(BTPS)	PRE-RX		POST-RX		
		PRED	BEST	%PRED	BEST	%PRED	% Chg
Spirometry		*Values in Parentheses or Asterisks are outside the normal range*					
FVC	Liters	5.30	(3.05)	(58)	(3.08)	(58)	1
FEV1	Liters	3.97	(1.65)	(42)	(1.61)	(40)	-3
FEV1/FVC	%	74	(54)		(52)		
FEF25-75%	L/sec	3.26	(0.74)	(23)	(0.62)	(19)	-16
FEF25%	L/sec		2.17		1.79		-18
FEF50%	L/sec		0.92		0.78		-15
FEF75%	L/sec		0.32		0.29		-9
PEF	L/sec	9.31	(6.59)	(71)	(5.08)	(55)	-23
FEF/FIF50			0.19		0.38		99
PIF	L/sec		5.07		2.22		-56
Lung Volumes							
VC	Liters	5.30	(3.19)	(60)			
TLC	Liters	8.17	(5.95)	(73)			
RV	Liters	2.83	2.76	97			
RV/TLC	%	37	(46)				
FRC PL	Liters	4.43	5.02	113			
FRC N2	Liters	4.43					
ERV	Liters	1.75	2.00	114			
Diffusion							
DLCO	mL/mmHg/min	37.4	(7.8)	(21)			
DL Adj	mL/mmHg/min	37.4	(7.1)	(19)			
DLCO/VA	mL/mHg/min/L	4.58	(2.20)	(48)			
DL/VA Adj	mL/mHg/min/L	3.78	2.01	53			