

INTERPRETATION OF PULMONARY FUNCTION TESTS (PFTS)

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ACP

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What would you like to learn about Pulmonary Function Testing?

LEARNING OBJECTIVES

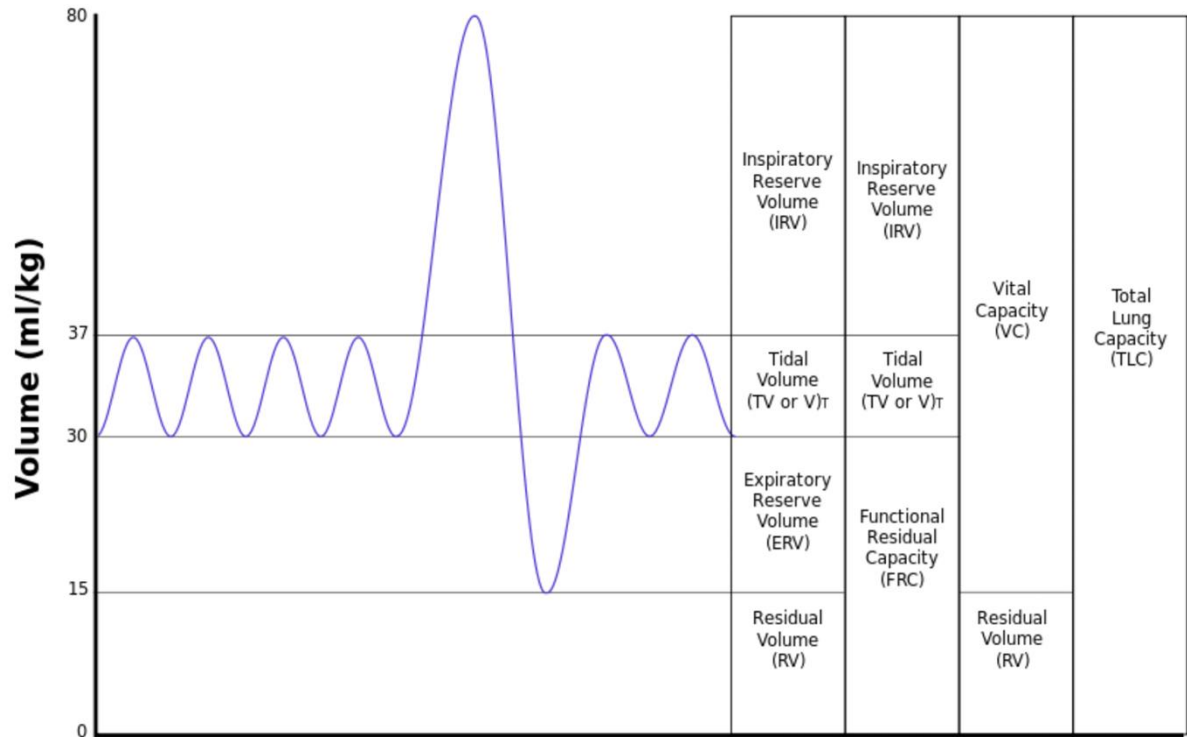
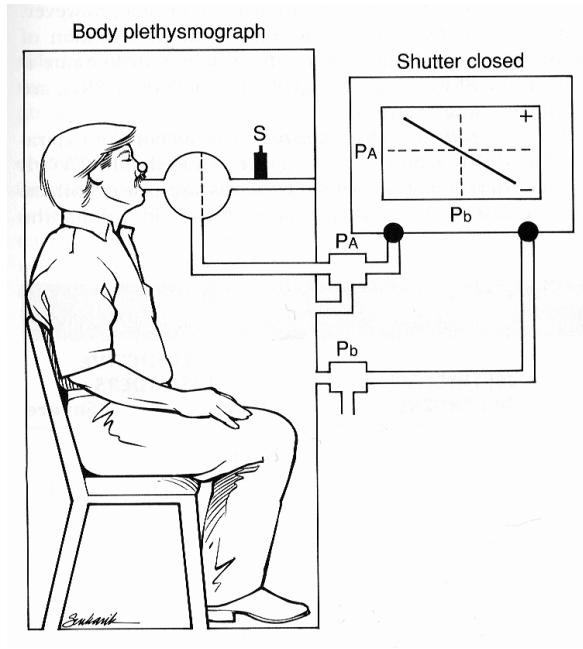
1. Describe the clinical indications for pulmonary function testing
2. Understand the physiology of the core pulmonary function tests: spirometry, lung volumes and DLCO
3. Apply an organized approach to interpreting pulmonary function tests
4. Identify obstructive, restrictive, mixed obstructive-restrictive and pulmonary vascular patterns of abnormalities on pulmonary function testing.

INDICATIONS FOR PFTS

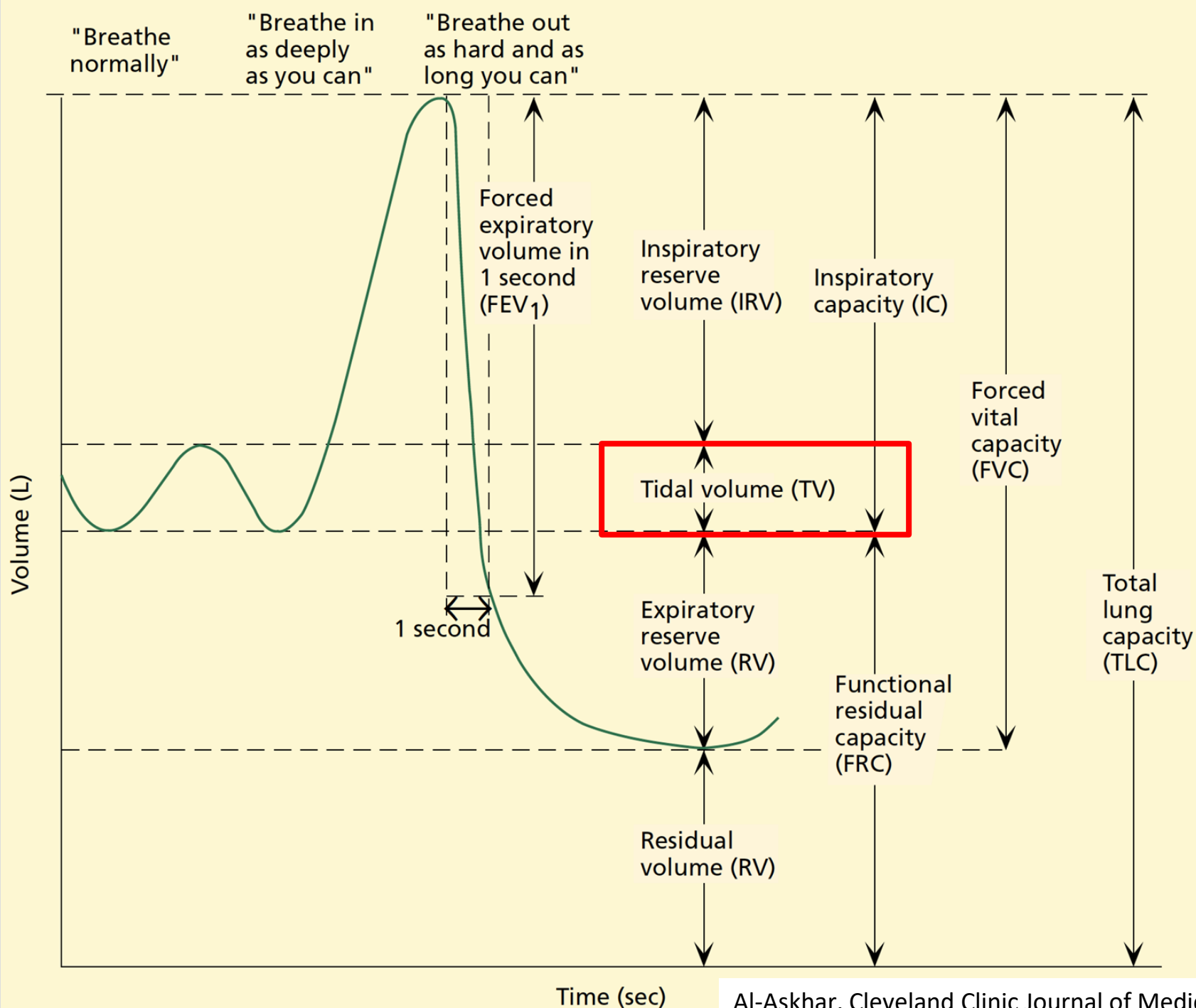
- Evaluation of patients presenting with dyspnea
- Evaluating disease severity and monitoring response to treatment
- Determine fitness for surgery
 - *thoracic surgery/lung resection

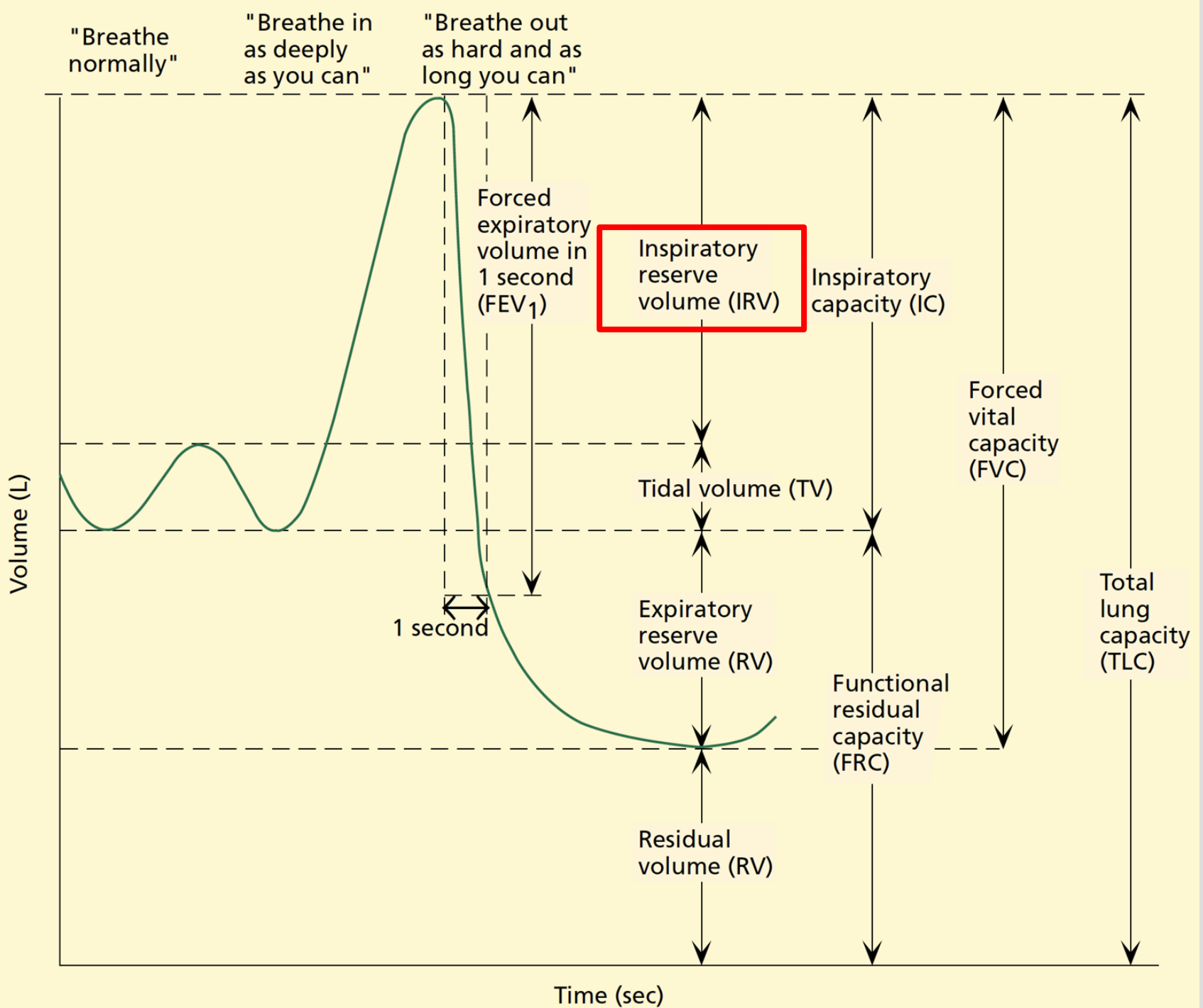
PFTS: AVAILABLE MEASURES

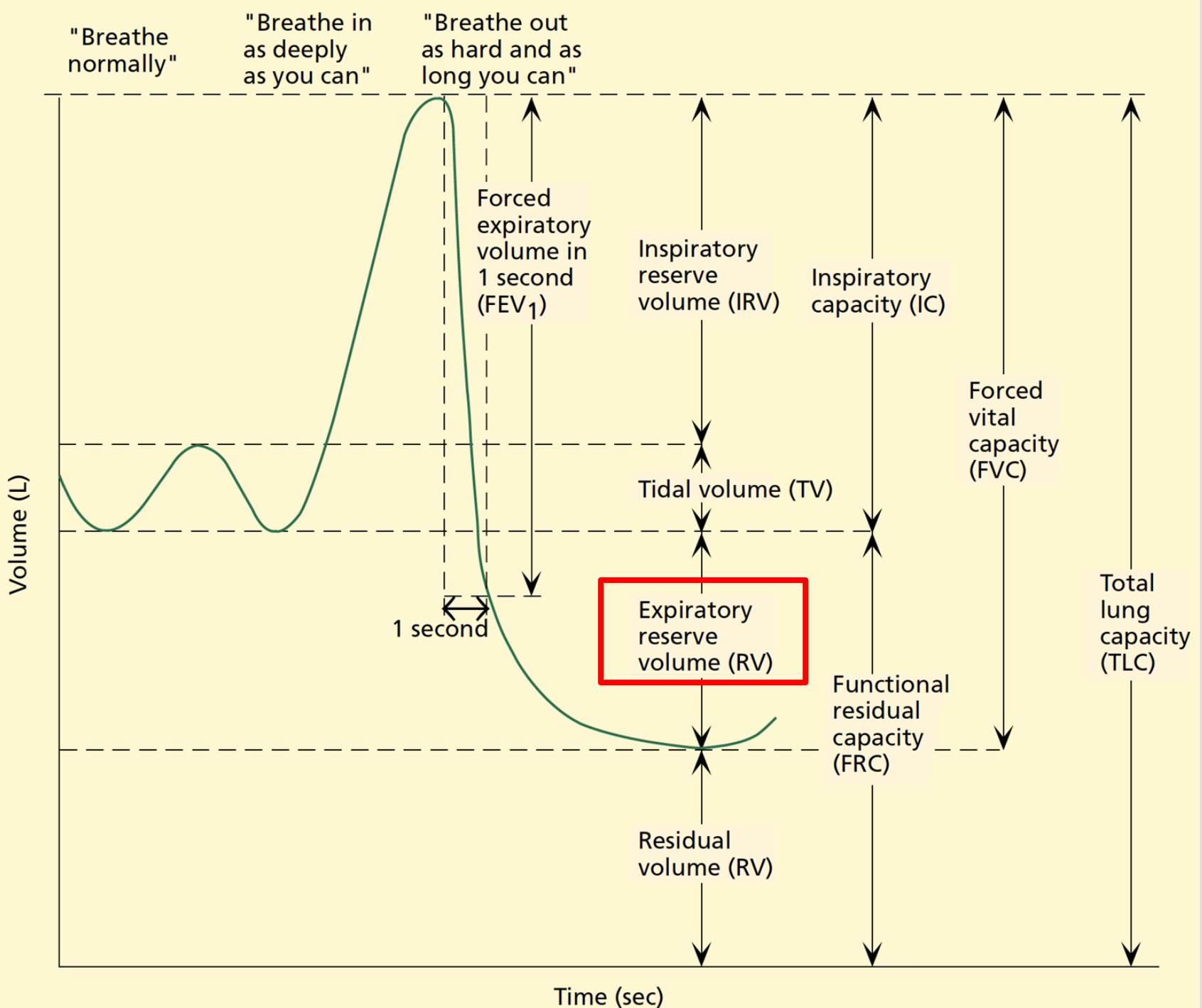
- Spirometry
 - Airflow (how much air, how fast)
- (Static) Lung volumes
 - Volume (how much air)
- Diffusing Capacity/DLCO
 - Gas exchange (how effective)
- Other testing:
 - Airway responsiveness
 - Respiratory muscle strength testing
 - Compliance of the lungs

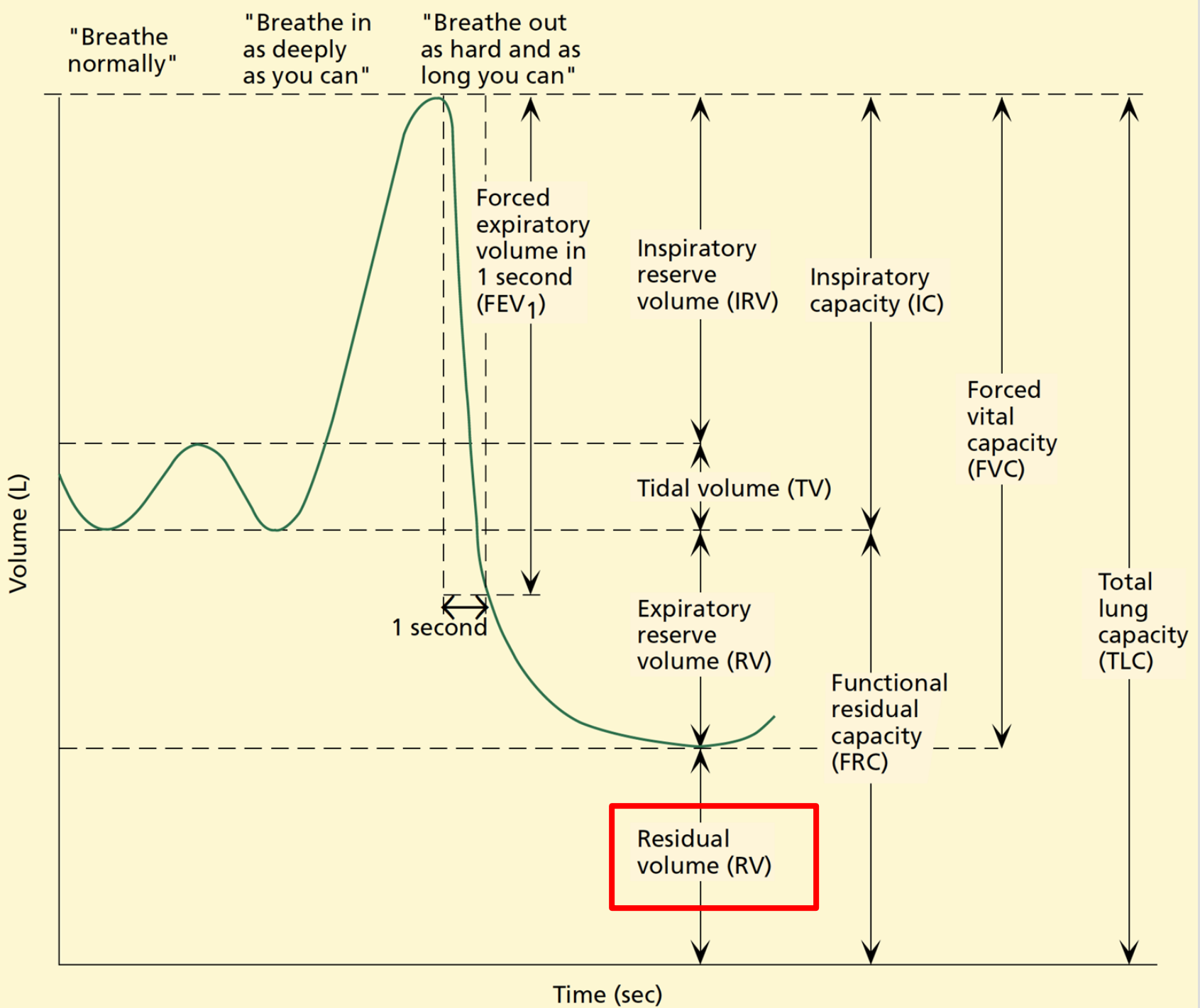


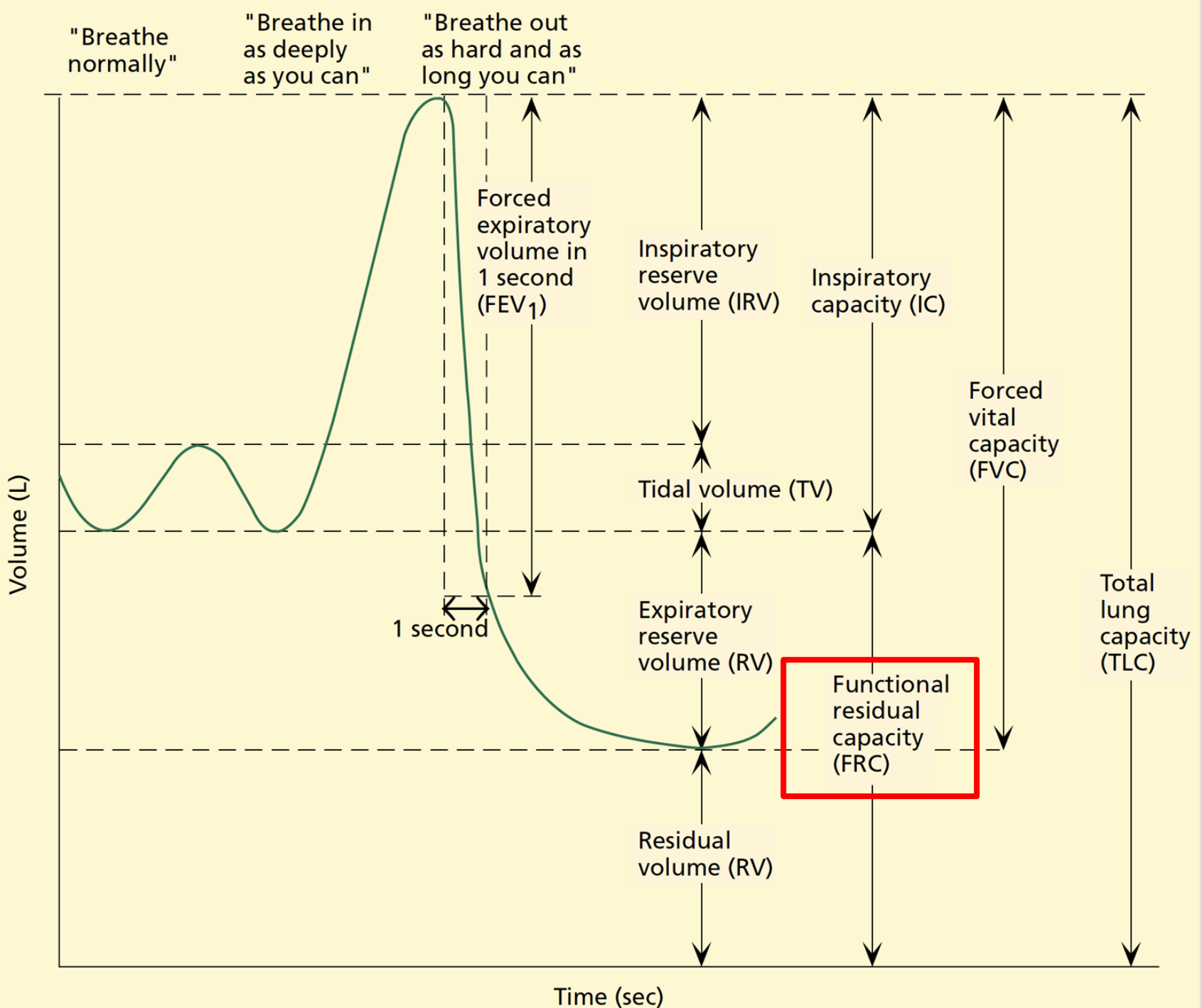
A PHYSIOLOGY REFRESHER: LUNG VOLUMES AND CAPACITIES

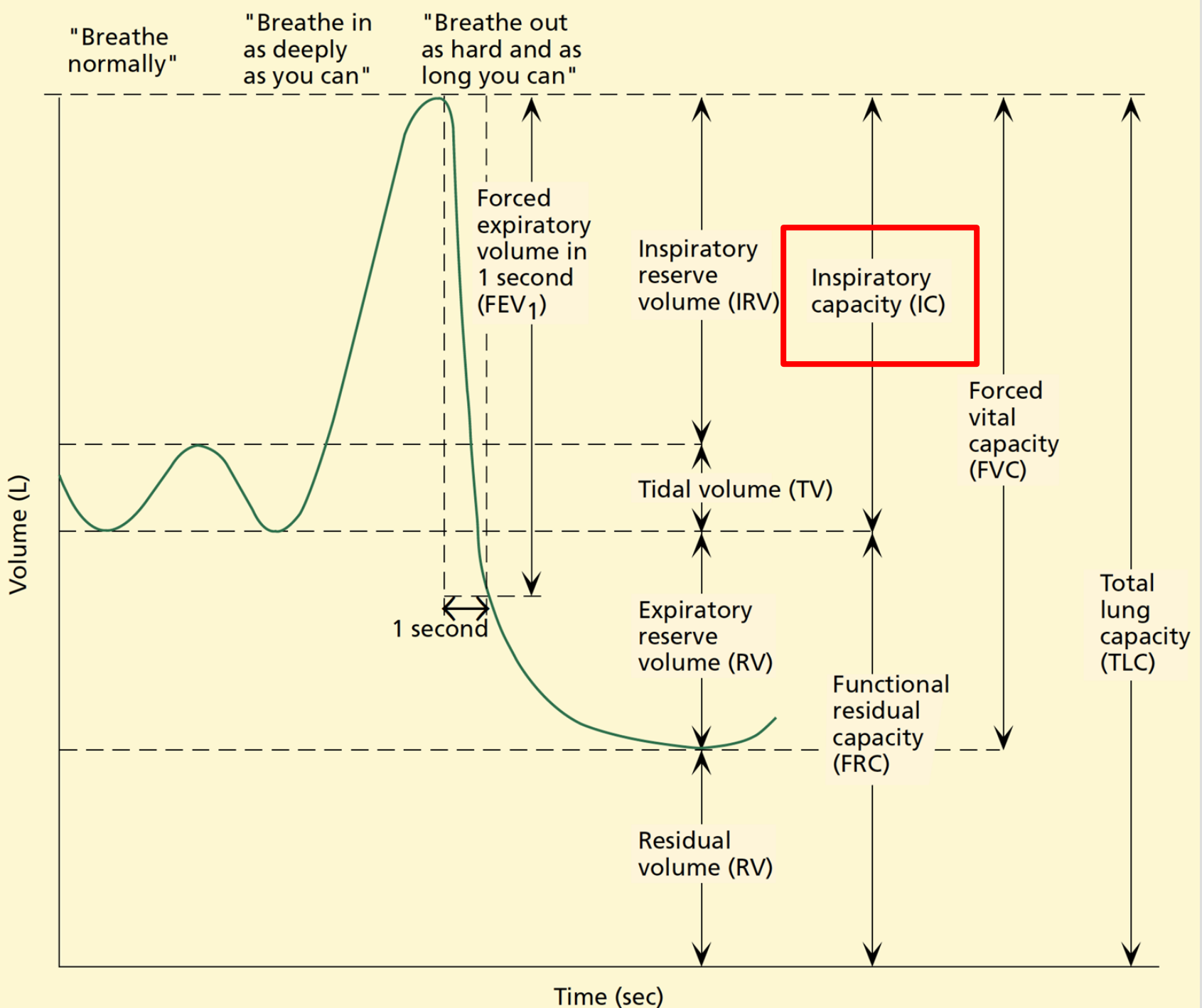


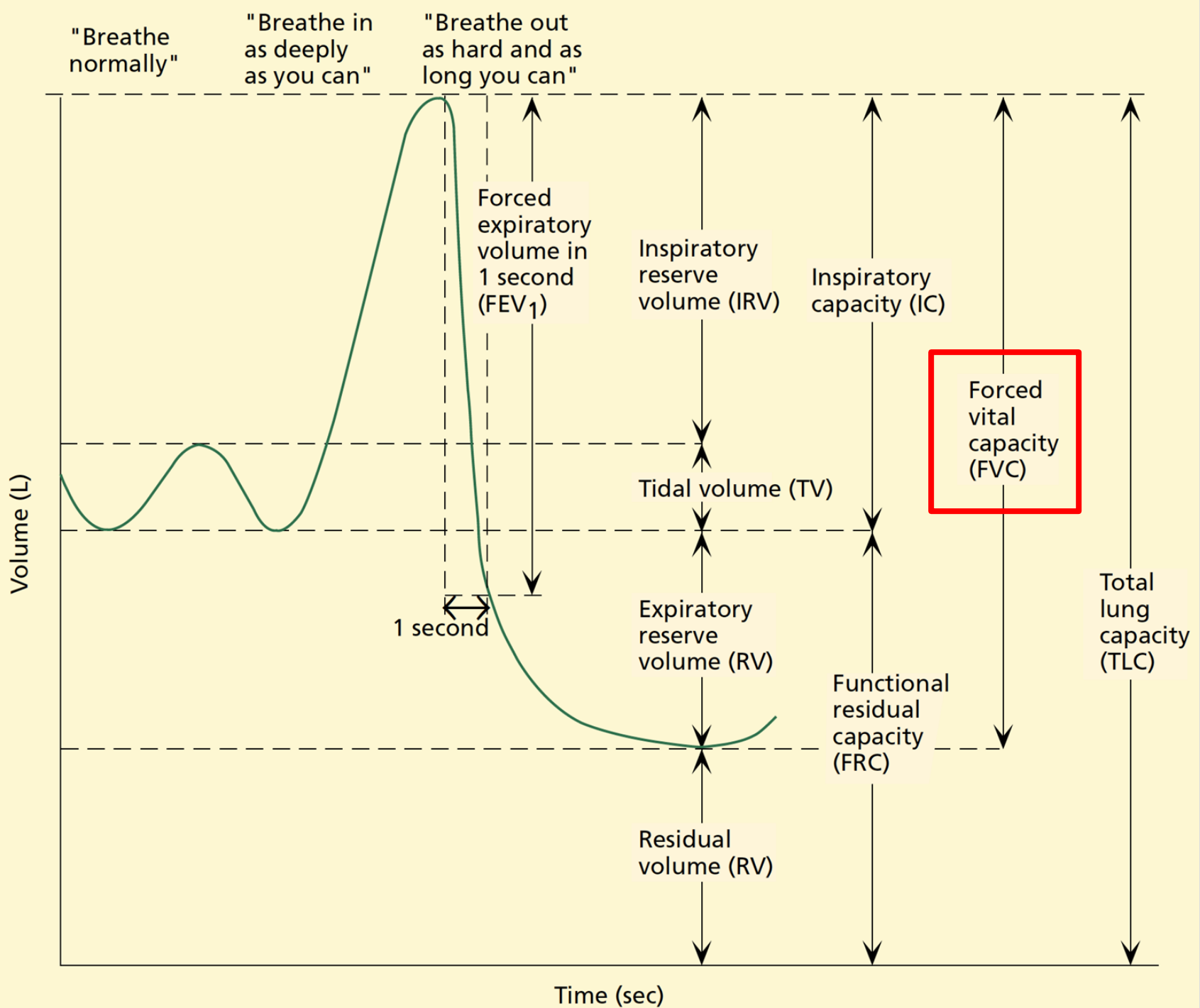


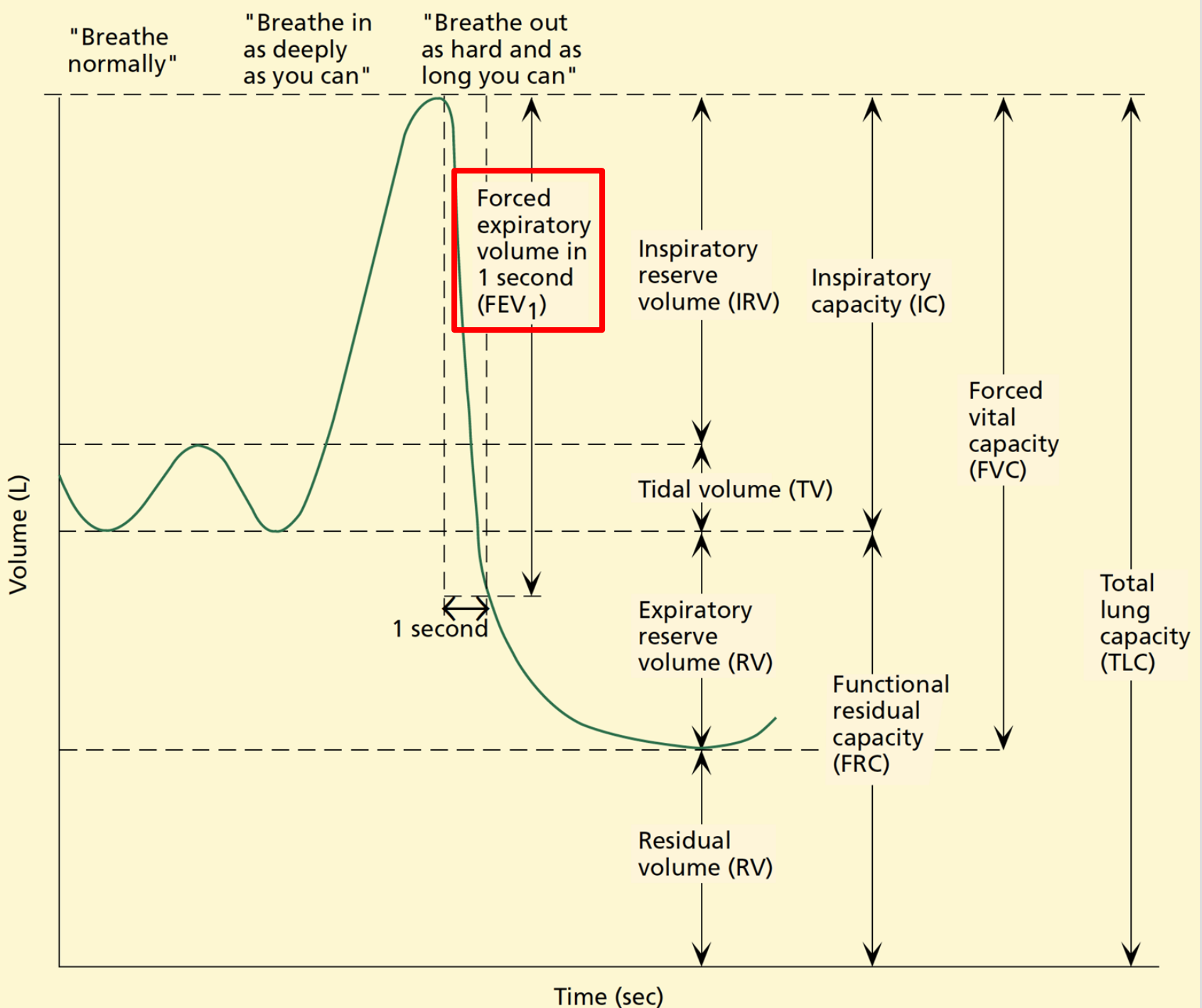


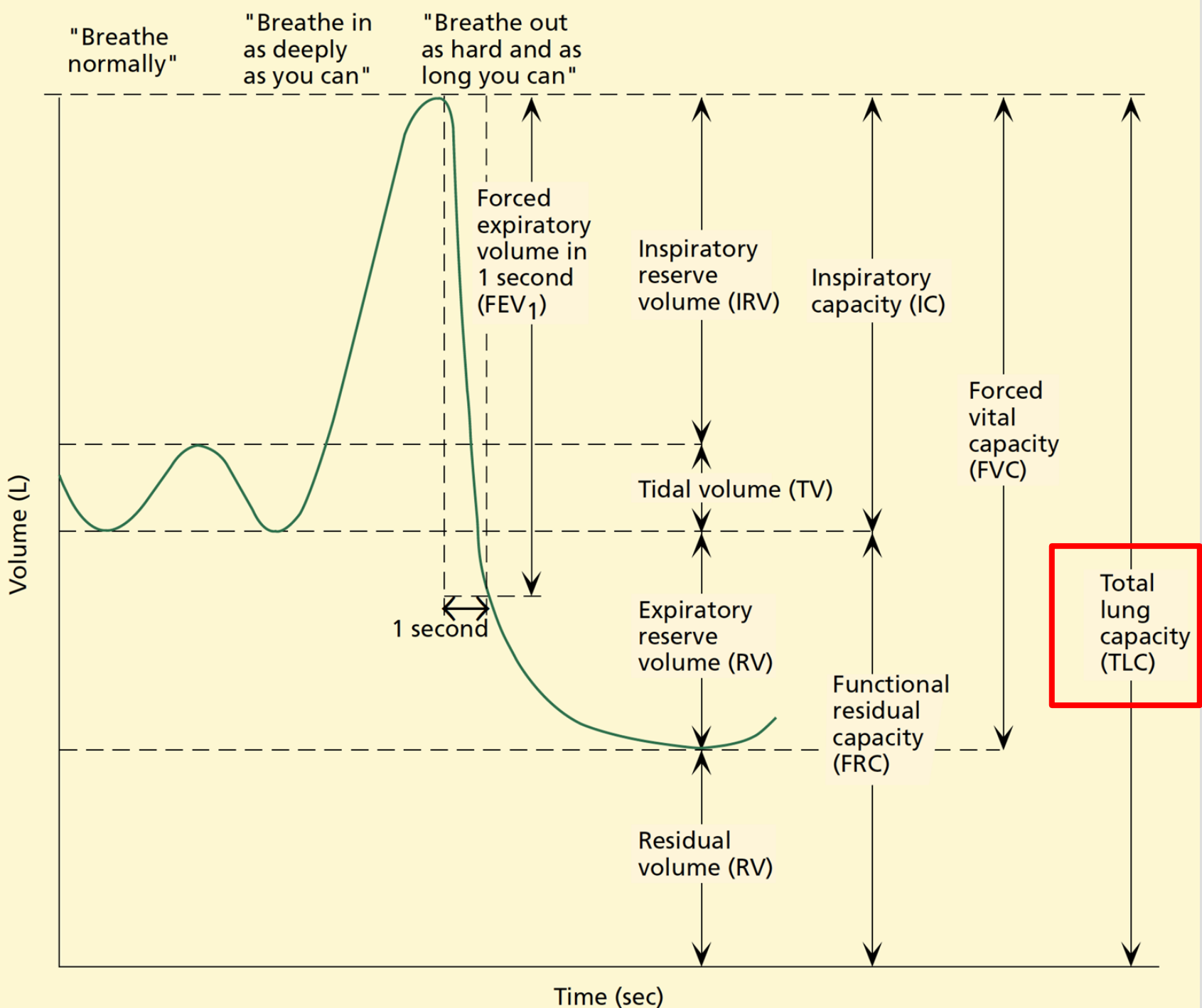


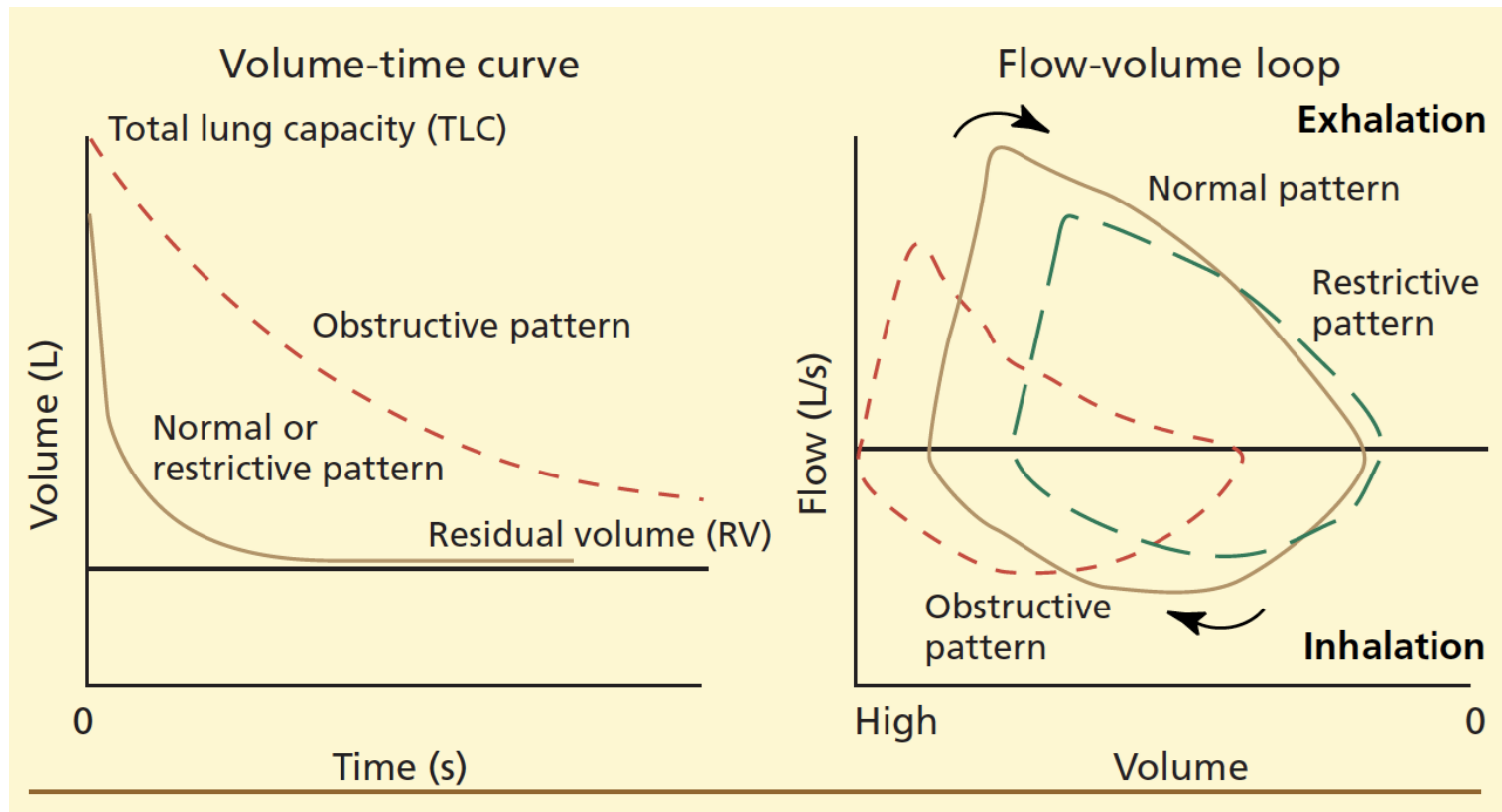










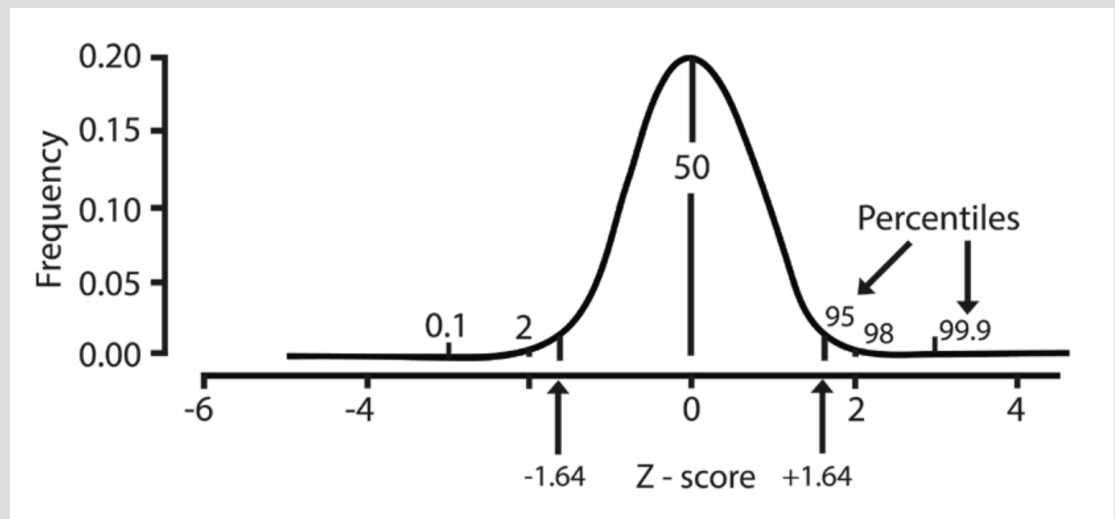


AN APPROACH TO PFT INTERPRETATION

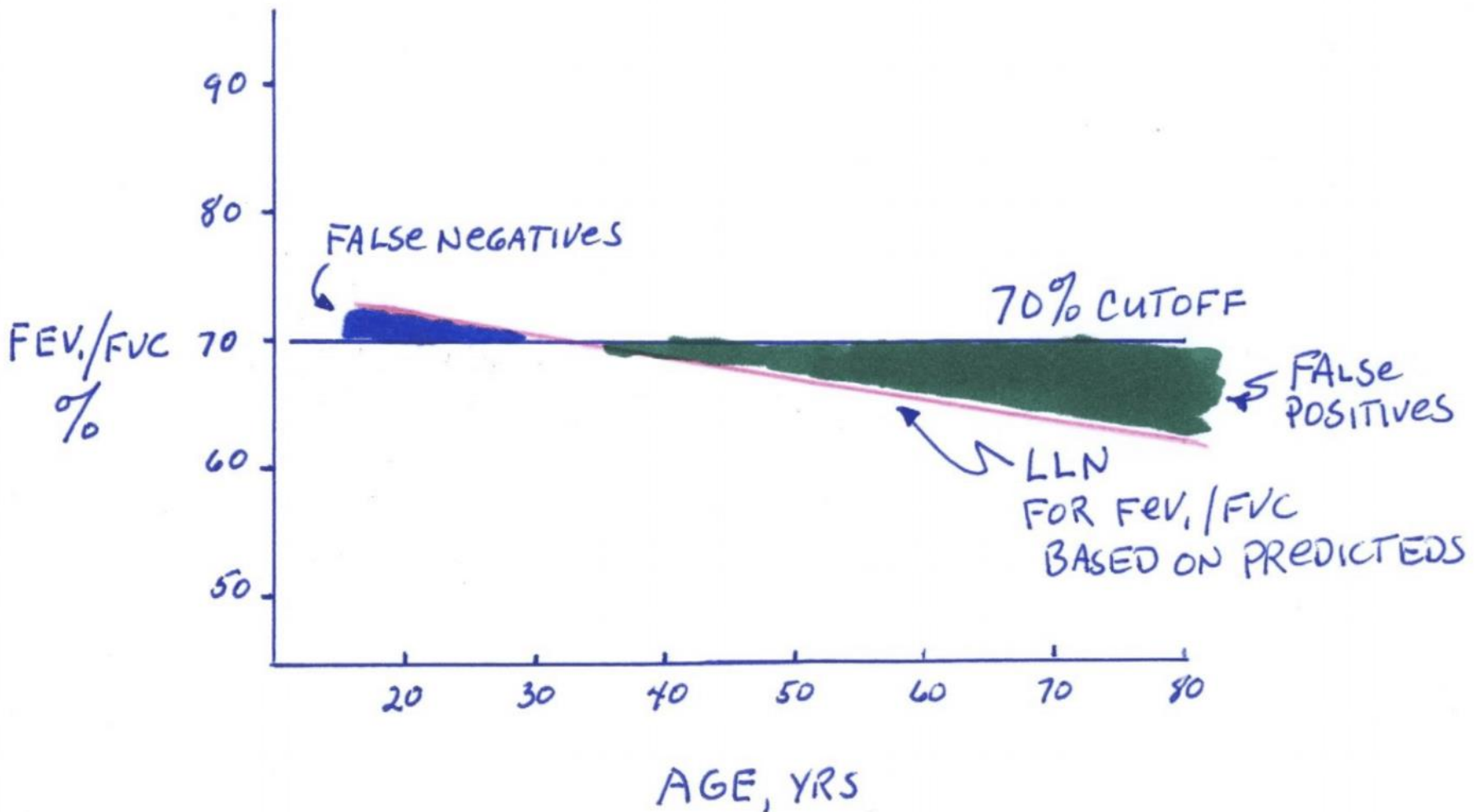
**STEP 1: CONFIRM PATIENT
DEMOGRAPHIC DATA**

DEFINING NORMAL AND ABNORMAL VALUES

- Interpretation involves comparison of the patient's values with reference values (Crapo Hsu, NHANES III, GLI)
 - Dependent on age, sex, race and ethnicity, height
 - African Americans have values that are 12% lower than Caucasians
- **Threshold for Normal**
 - 80-120% predicted
 - age-adjusted LLN
(lower limits of normal)



DEFINING OBSTRUCTION WITH FEV₁/FVC RATIO: FIXED 0.7 CUT-OFF VS. AGE-ADJUSTED LLN



STEP II: IS THE TEST OF ADEQUATE
QUALITY?

*Acceptability and
Reproducibility*

ACCEPTABILITY

1

Free from artifacts (cough, glottic closure)

2

Free from leaks

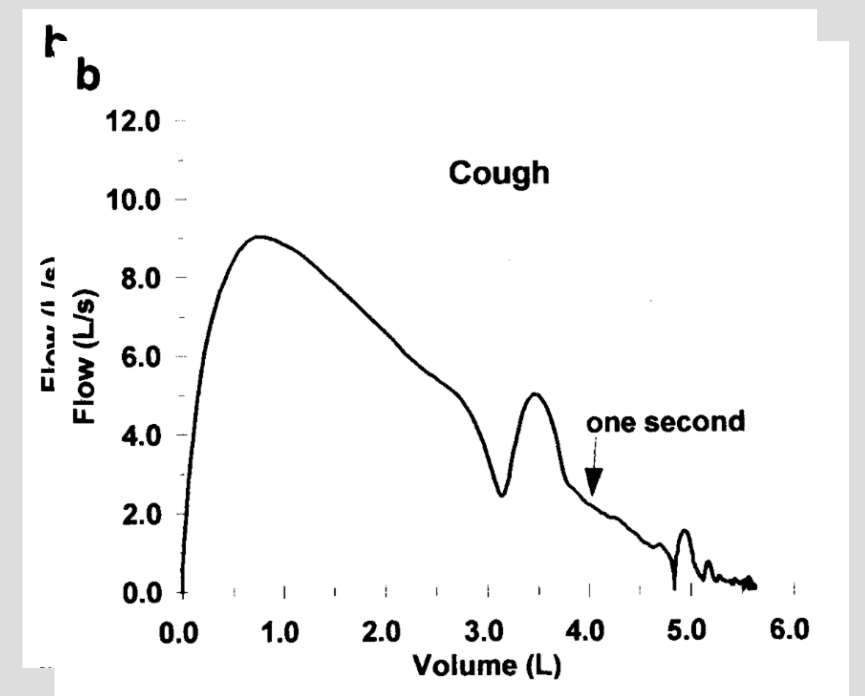
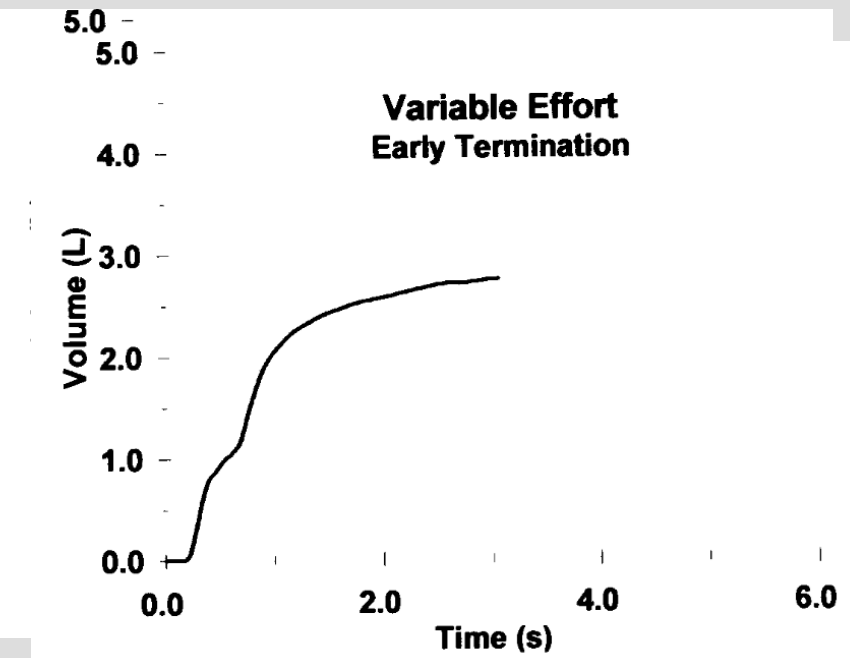
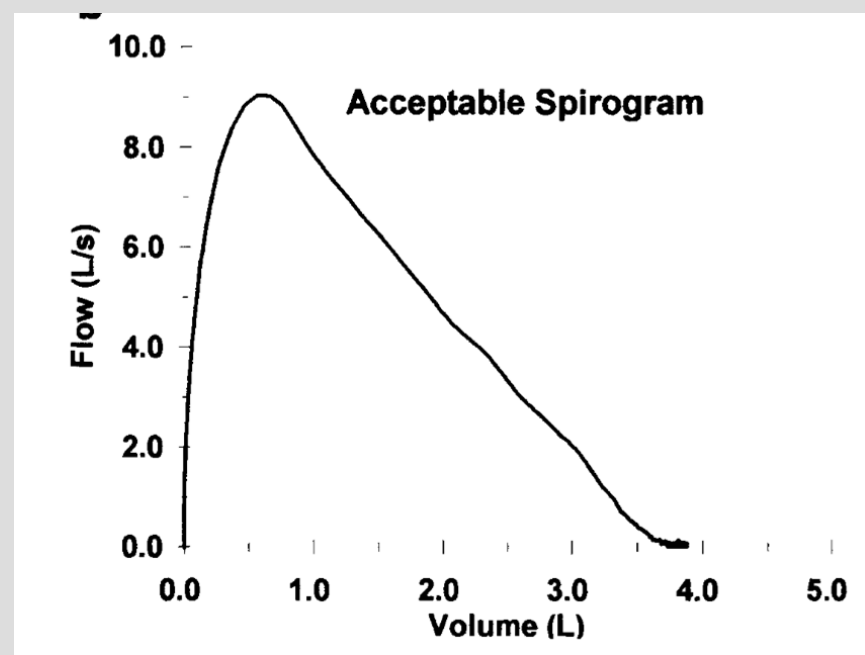
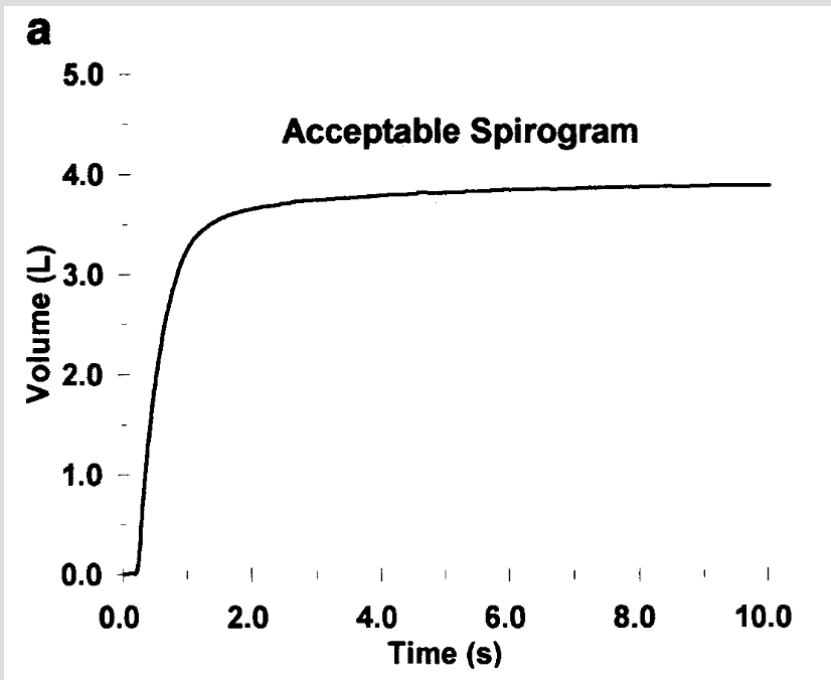
3

Good start

4

Good Effort

Examine the flow volume loop and the flow time curve



REPRODUCIBILITY

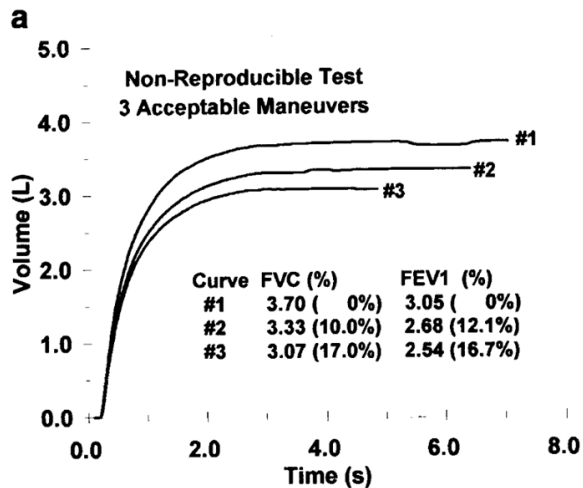


Figure A7a. Nonreproducible test with three acceptable volume-time curves. Percents are difference from largest value.

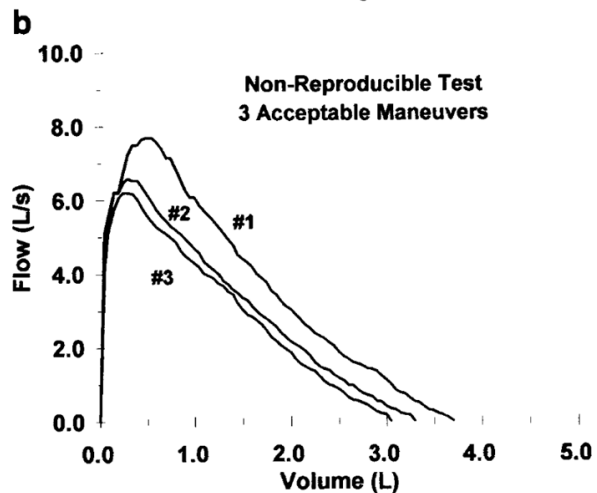


Figure A7b. Nonreproducible test with three acceptable flow-volume curves.

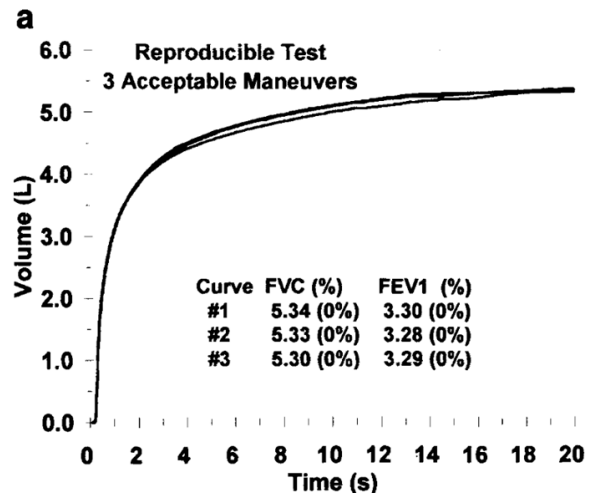


Figure A8a. Reproducible test with three acceptable volume-time curves. Percents are difference from largest value.

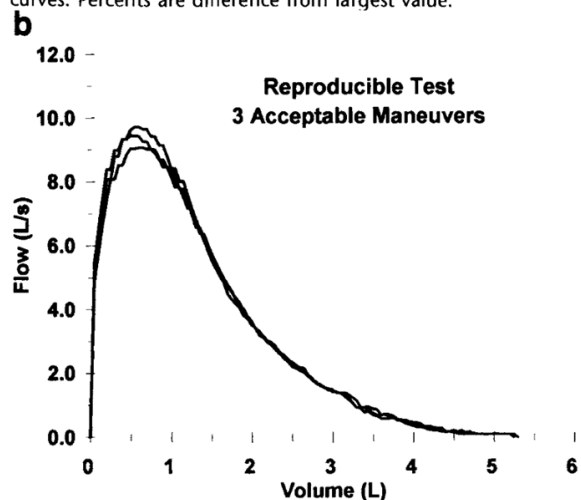
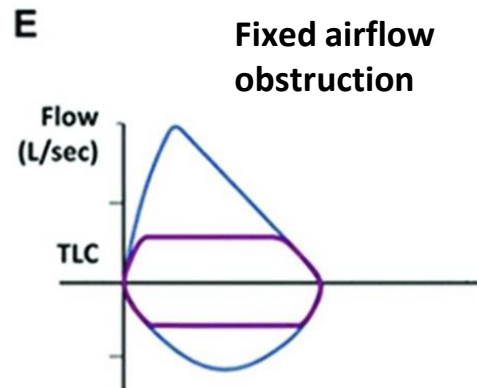
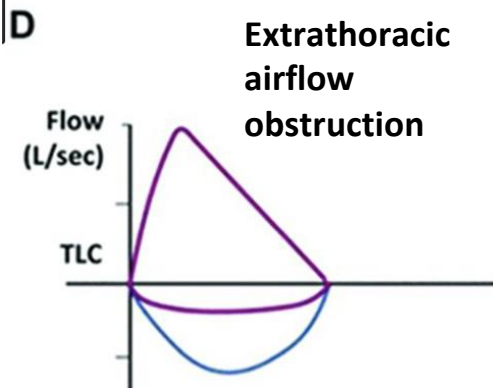
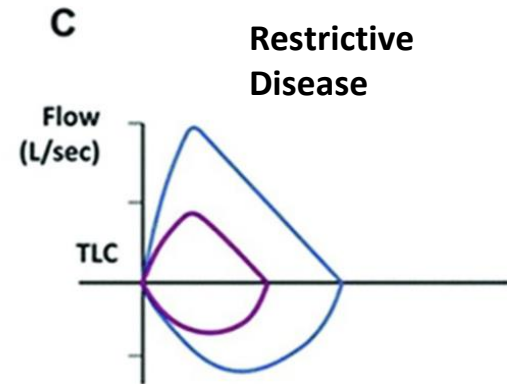
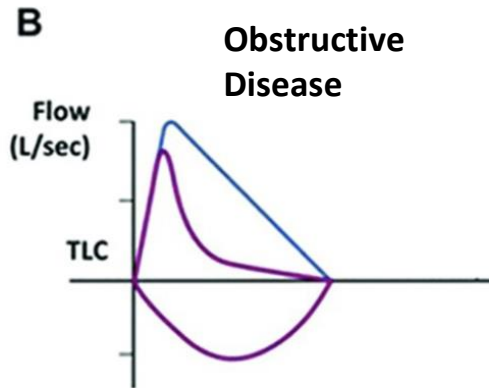
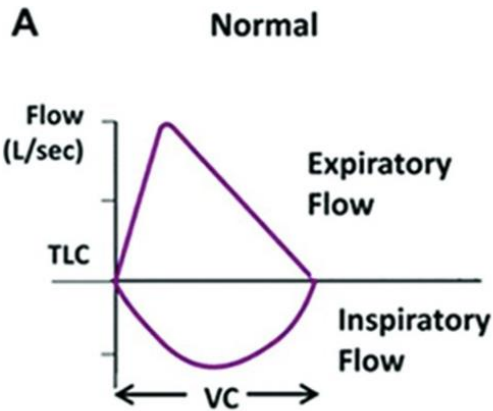


Figure A8b. Reproducible test with three acceptable flow-volume curves.

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

STEP III: FLOW VOLUME LOOPS



STEP IV: INTERPRET THE PFTS WITH A SYSTEMATIC APPROACH

*Recognize the pattern and classify
the severity of abnormality*

PATTERNS OF DISEASE WITH PFTS

Obstructive
FEV1/FVC <0.7
(or <LLN)

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

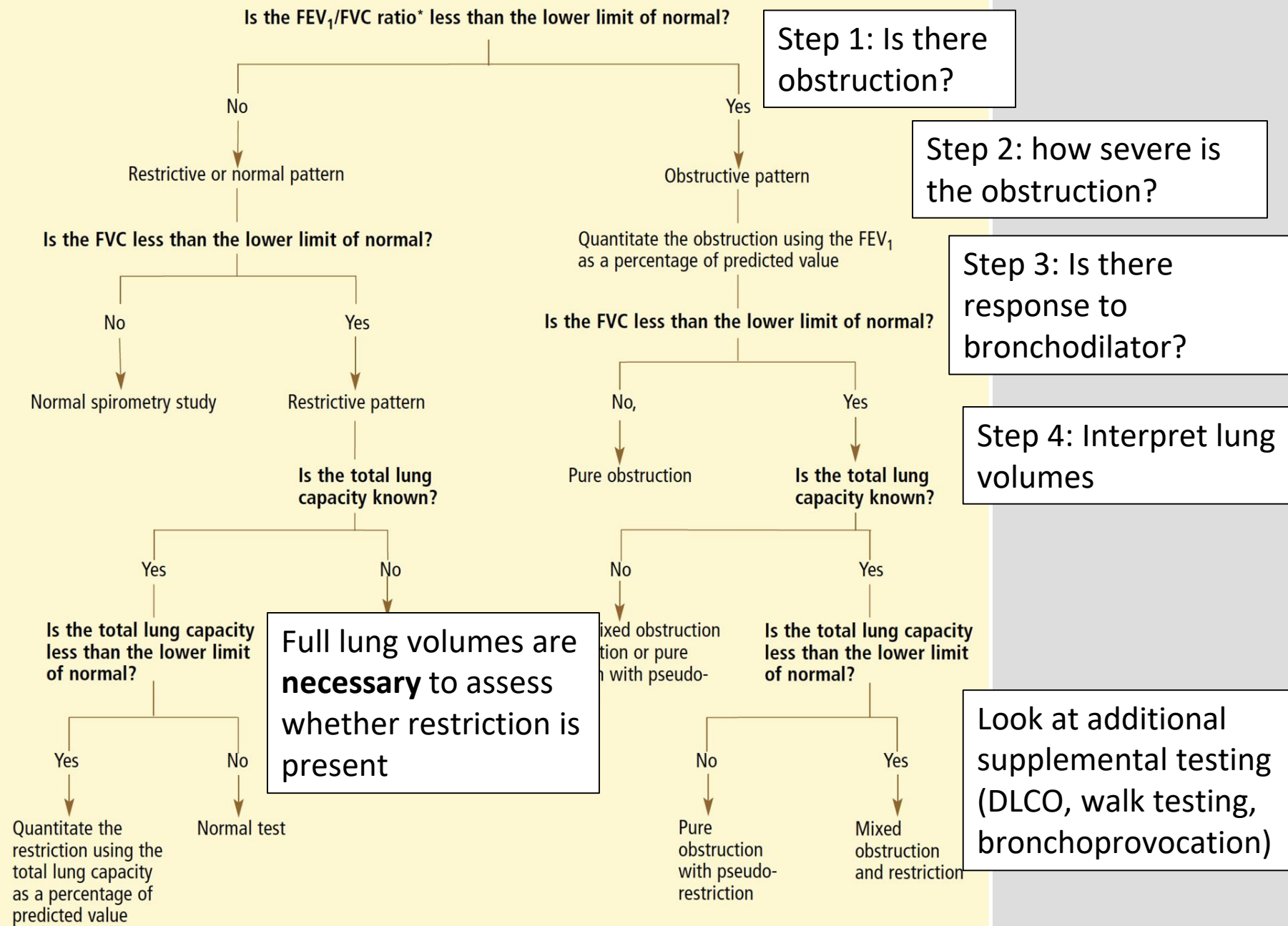
Restrictive
FEV1/FVC
reduced with low
lung volumes*

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

Mixed

- Both obstructive and restrictive elements

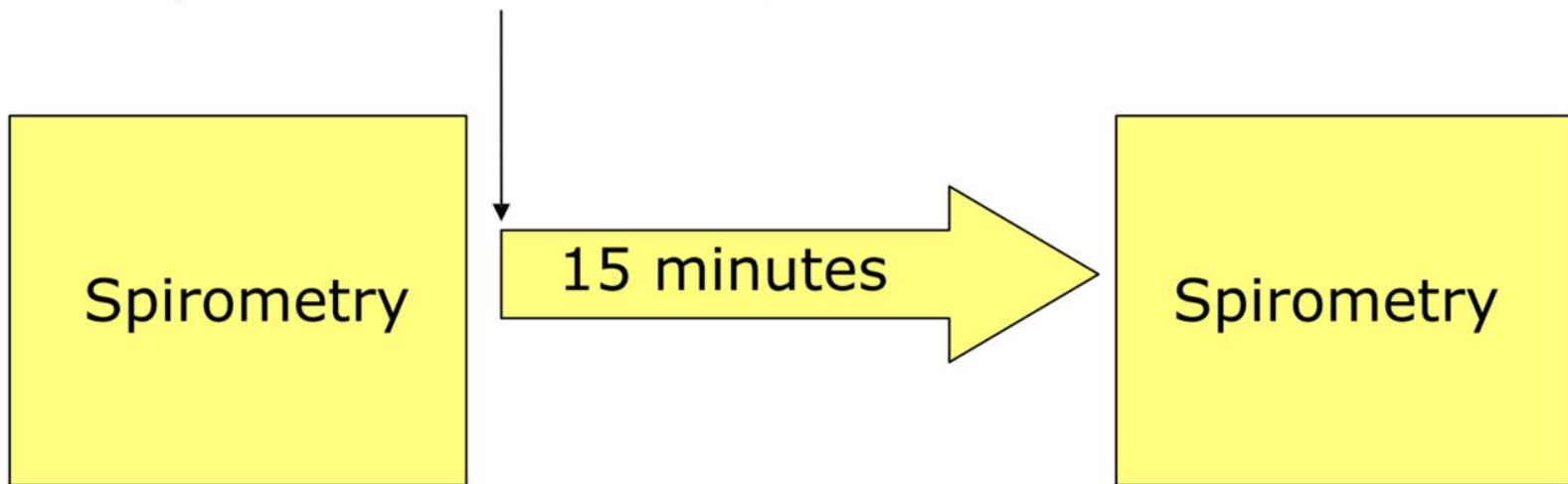
	Obstructive Pattern	Restrictive Pattern
Forced Vital Capacity (FVC)	Decreased or normal	Decreased
Forced Expiratory Volume in 1 second (FEV1)	Decreased	Decreased or normal
FEV1/FVC ratio	Decreased	Normal
Total Lung Capacity	Normal or Increased	Decreased



*FEV₁ = forced expiratory volume in 1 second, FVC = forced vital capacity

BRONCHODILATOR RESPONSE

4 puffs of albuterol via spacer



- Improvement in FEV1 or FVC by 12% and 200cc
- Normalization of spirometry after bronchodilator supports the diagnosis of asthma
- The lack of BD response does not preclude a clinical response to bronchodilator therapy

CASES

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:

- Normal spirometry and lung volumes
- Obstructive pattern
- Restrictive pattern
- Mixed obstructive restrictive pattern

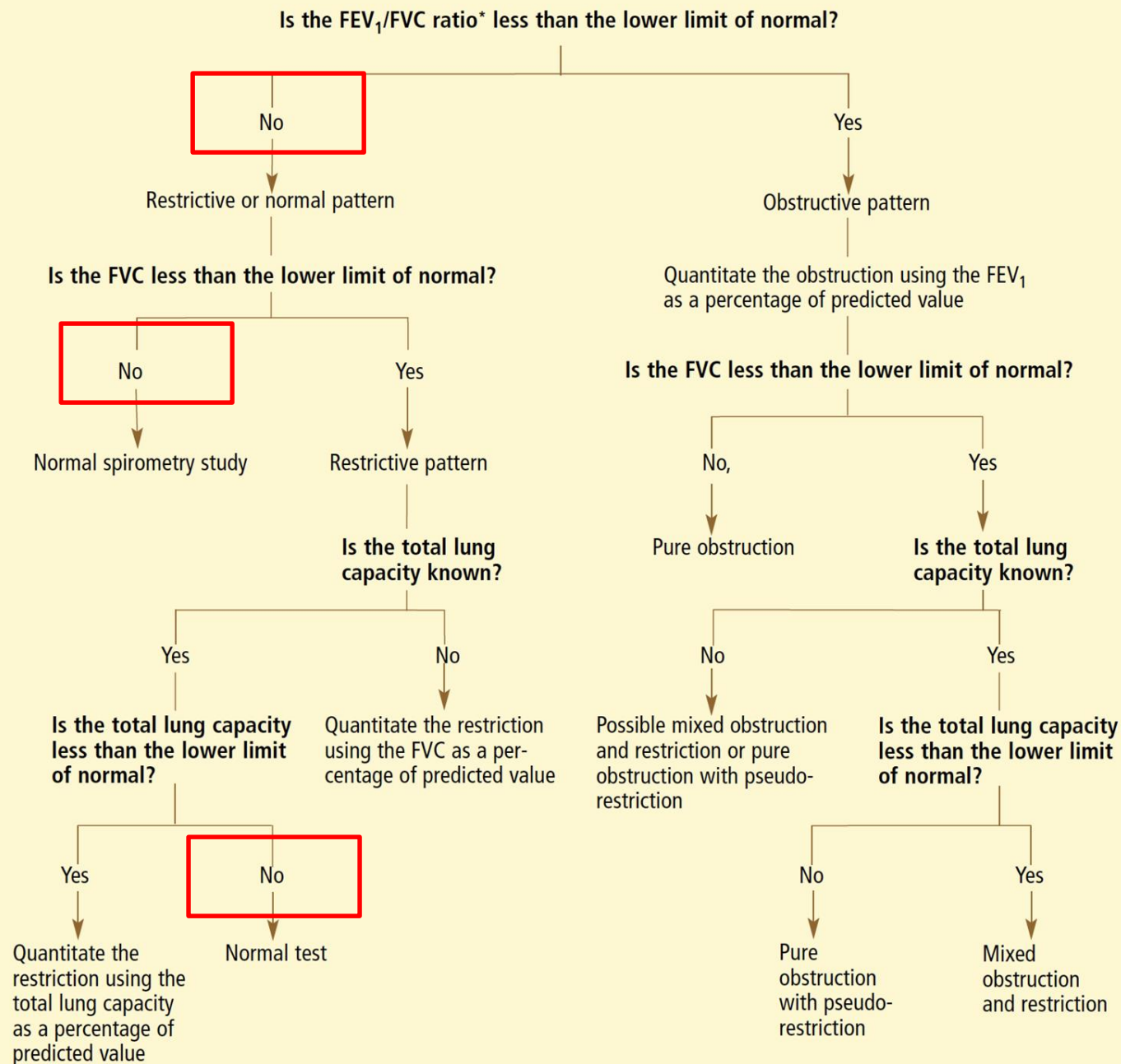
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Normal spirometry
and lung volumes

Obstructive
pattern

Restrictive pattern

Mixed obstructive
restrictive pattern



*FEV₁ = forced expiratory volume in 1 second, FVC = forced vital capacity

CASE 1:

TEST	ACTUAL	PREDICTED		% PREDICTED
FVC (L)	4.39	4.32	Normal	102
FEV ₁ (L)	3.20	3.37		95
FEV ₁ /FVC	0.73	0.78	Normal- no obstruction	
FRC (L)	3.17	3.25		98
RV (L)	2.54	2.32		109
TLC (L)	6.86	6.09	Normal	113

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Based on these lung function tests, your suspicion that this patient has asthma is:

- Decreased, normal lung function test rules out asthma
- Unchanged, her clinical history is suggestive and many patients with asthma have normal spirometry
- I can't tell as a bronchodilator response was not assessed

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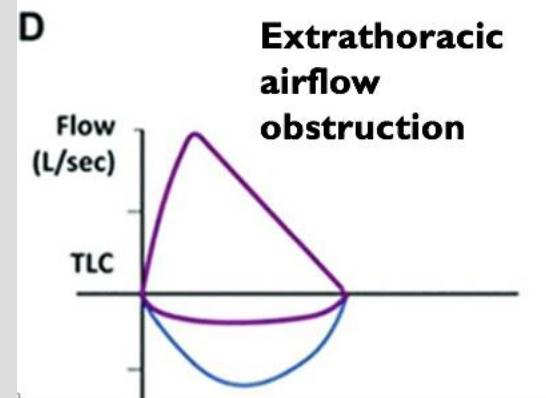
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unchanged, her clinical history is suggestive and many patients with asthma have normal spirometry

I can't tell as a bronchodilator response was not assessed

PFTS TO EVALUATE FOR ASTHMA

- Spirometry both pre- and post-bronchodilator
 - Bronchodilator response supports diagnosis
- Normal spirometry **does not exclude** a diagnosis of asthma
- Additional steps to assess for asthma:
 - Bronchoprovocation testing (methacholine challenge)
 - High-negative predictive value
 - Empiric therapy
 - Evaluation for asthma mimickers and look at flow volume loop



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

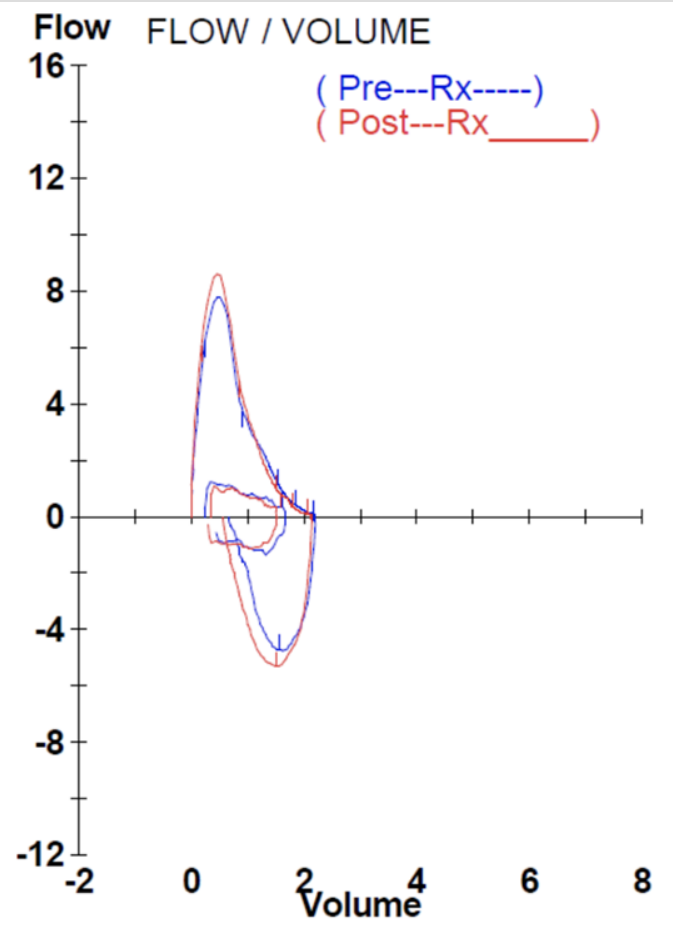
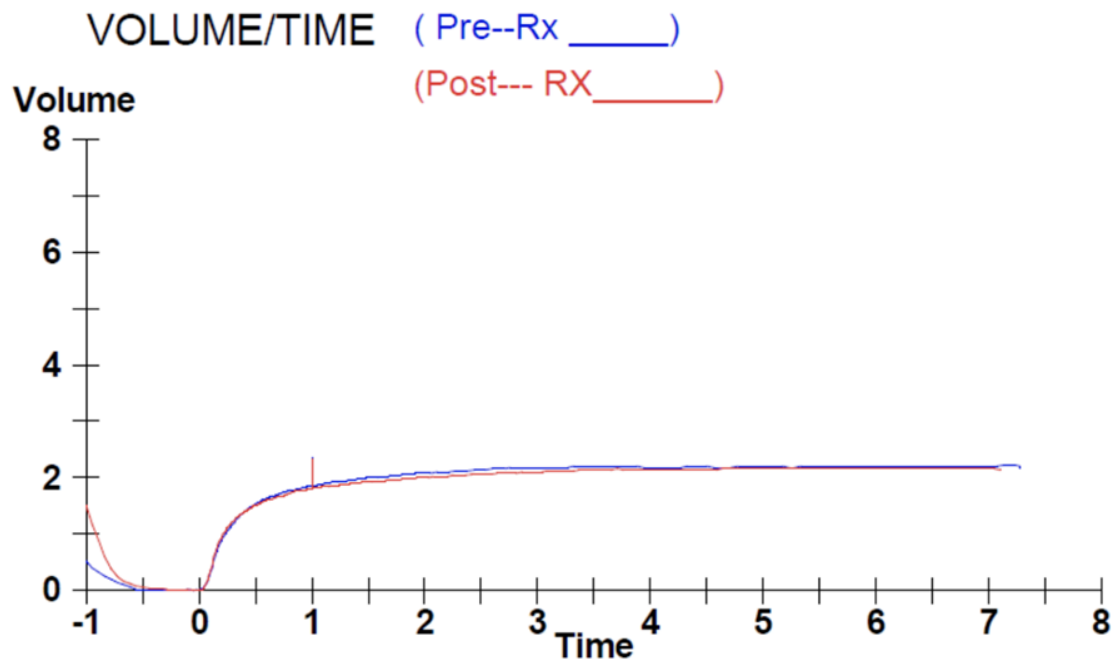
Values in Parentheses or Asterisks are outside the normal range

		PRED	BEST	%PRED	BEST	%PRED	% Chg
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			





CASE 2:

You interpret his PFTs as:

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

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(BTPS)

PRE-RX

POST-RX

PRED

BEST

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% Chg

Spirometry

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FRC N2	Liters	3.19		
ERV	Liters	1.42	1.20	85



You interpret his PFTs as:

Normal spirometry
and lung volumes

obstructive pattern

restrictive pattern

mixed obstructive
restrictive pattern

Is the FEV₁/FVC ratio* less than the lower limit of normal?

No

Restrictive or normal pattern

Is the FVC less than the lower limit of normal?

No

Normal spirometry study

Yes

Restrictive pattern

Is the total lung capacity known?

Yes

Is the total lung capacity less than the lower limit of normal?

Yes

Quantitate the restriction using the total lung capacity as a percentage of predicted value

No

Normal test

Quantitate the restriction using the FVC as a percentage of predicted value

(BTPS)

Spirometry

FVC	Liters
FEV1	Liters
FEV1/FVC	%
FEF25-75%	L/sec
FEF25%	L/sec
FEF50%	L/sec
FEF75%	L/sec
PEF	L/sec
FEF/FIF50	

PRE-RX
PRED BEST %PRED
POST-RX
BEST %PRED

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	7.11		7.09	
	3.11		3.65	
	0.82		0.72	
8.73	7.75	89	8.60	98
	0.68		0.69	

No,

Pure obstruction

No

Possible mixed obstruction and restriction or pure obstruction with pseudo-restriction

No

Pure obstruction with pseudo-restriction

Yes

Is the total lung capacity known?

Lung Volumes

VC	Liters
TLC	Liters
RV	Liters
RV/TLC	%
FRC PL	Liters
FRC N2	Liters
ERV	Liters

4.29	(2.26)	(53)
6.28	(3.71)	(59)
1.97	1.45	74
31	39	
3.19	2.76	86
3.19		
1.42	1.20	85

Yes

Mixed obstruction and restriction

*FEV₁ = forced expiratory volume in 1 second, FVC = forced vital capacity

CASE 2:

You interpret his PFTs as:

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

CASE 2 CONTINUED:

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

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(BTPS)

PRE-RX

POST-RX

PRED

BEST

%PRED

BEST %PRED

% Chg

Spirometry

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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

Interstitial lung disease

pleural effusions

Kyphoscoliosis

neuromuscular weakness

Obesity

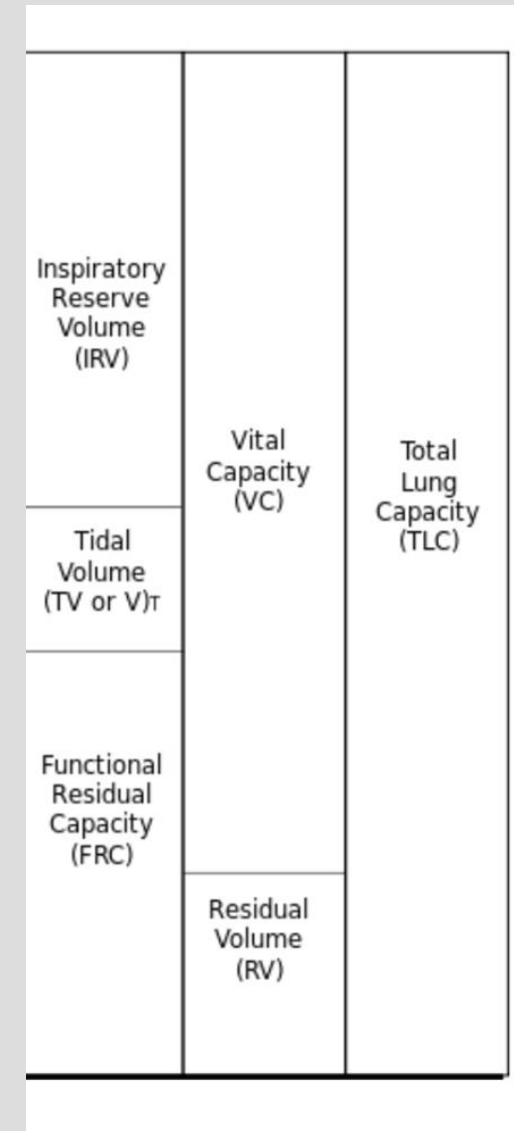
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- e. **Obesity**

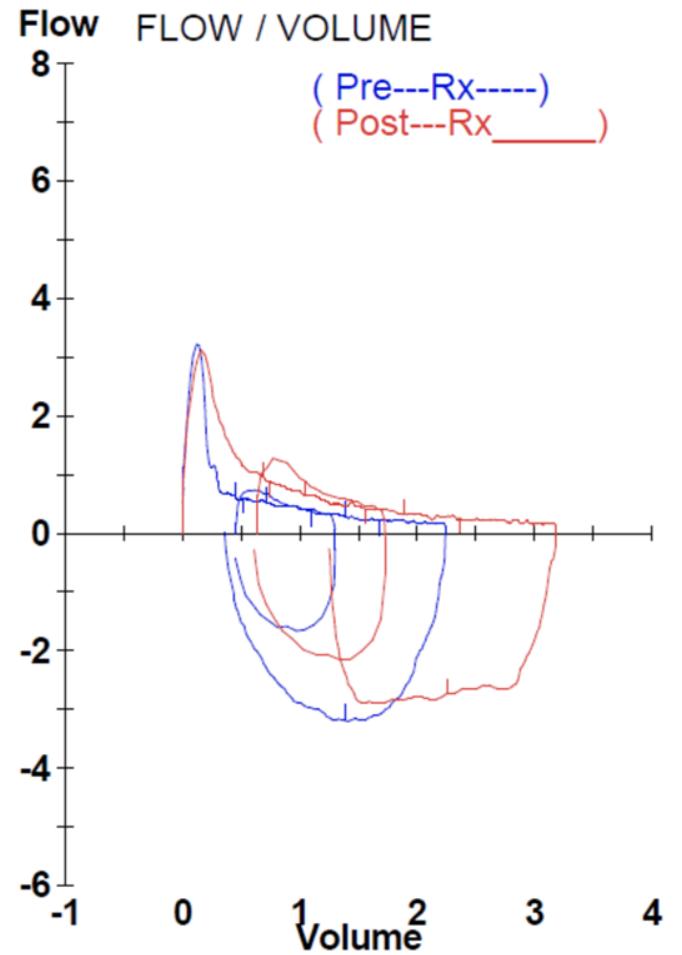
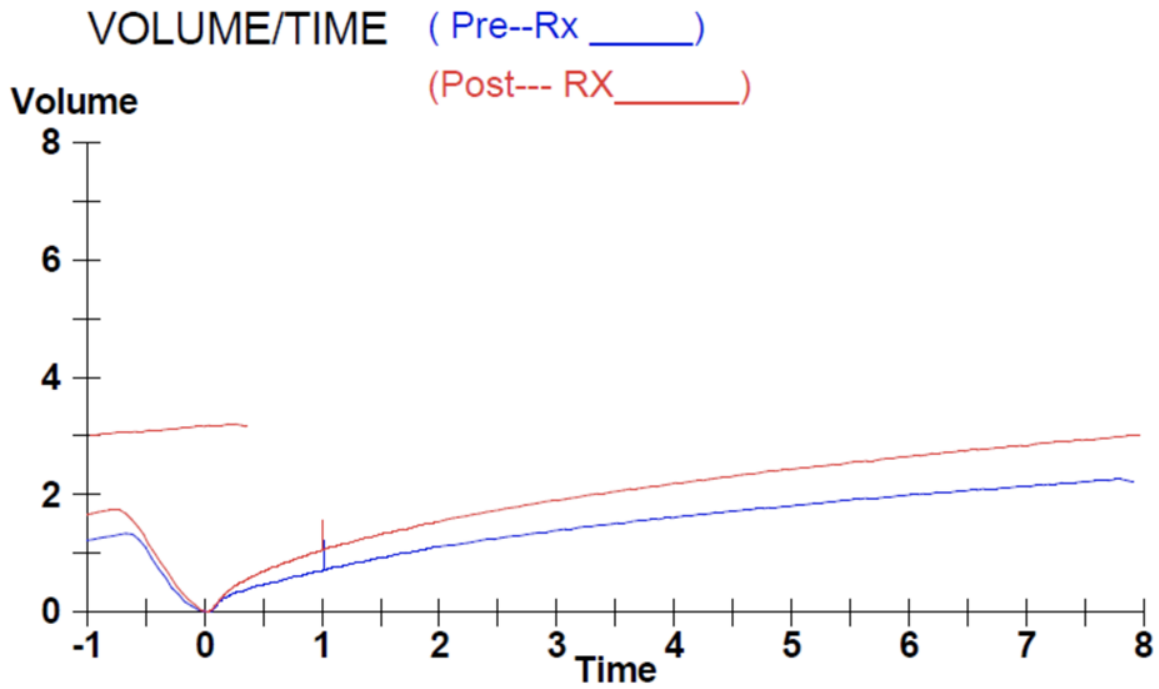
LUNG VOLUMES- PATTERNS TO DIFFERENTIATE RESTRICTIVE DISEASE

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		<i>Values in Parentheses or Asterisks are outside the normal range</i>					
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				



CASE 3

- You interpret these PFTs as:
 - a. Normal spirometry and lung volumes
 - b. Obstructive pattern
 - c. Restrictive pattern
 - d. Mixed obstructive restrictive pattern

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

		PRED	BEST	%PRED	BEST	%PRED	% Chg
Spirometry		<i>Values in Parentheses or Asterisks are outside the normal range</i>					
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				

You interpret these PFTs as

Normal spirometry
and lung volumes

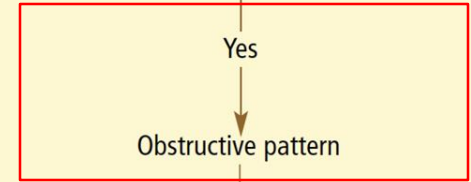
obstructive pattern

restrictive pattern

mixed obstructive and
restrictive pattern

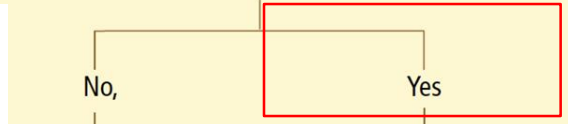
Is the FEV₁/FVC ratio* less than the lower limit of normal?

		PRED	BEST	%PRED	BEST	%PRED	% Chg
<i>Values in Parentheses or Asterisks are outside the normal range</i>							
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)	(34)	(37)	
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FEF75%	L/sec		0.19		0.24		28
PEF	L/sec		3.22		3.10		-4
FEF/FIF50			0.10		0.14		43



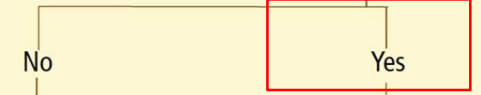
Quantitate the obstruction using the FEV₁ as a percentage of predicted value

Is the FVC less than the lower limit of normal?



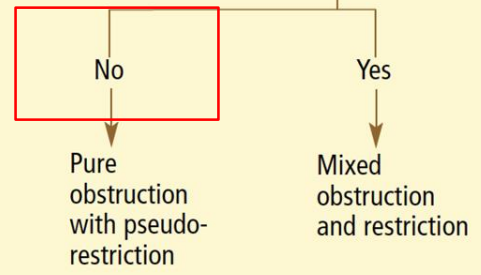
Pure obstruction

Is the total lung capacity known?



Possible mixed obstruction and restriction or pure obstruction with pseudo-restriction

Is the total lung capacity less than the lower limit of normal?



Normal spirometry

Severity of Airflow Obstruction:

FEV1 >80%- mild

FEV1 50-80%- moderate

FEV1 30- 50% severe

FEV1 <30% very severe

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

predicted value

CASE 3

- You interpret these PFTs as:
 - a. Normal spirometry and lung volumes
 - b. Obstructive pattern**
 - c. Restrictive pattern
 - d. Mixed obstructive restrictive pattern

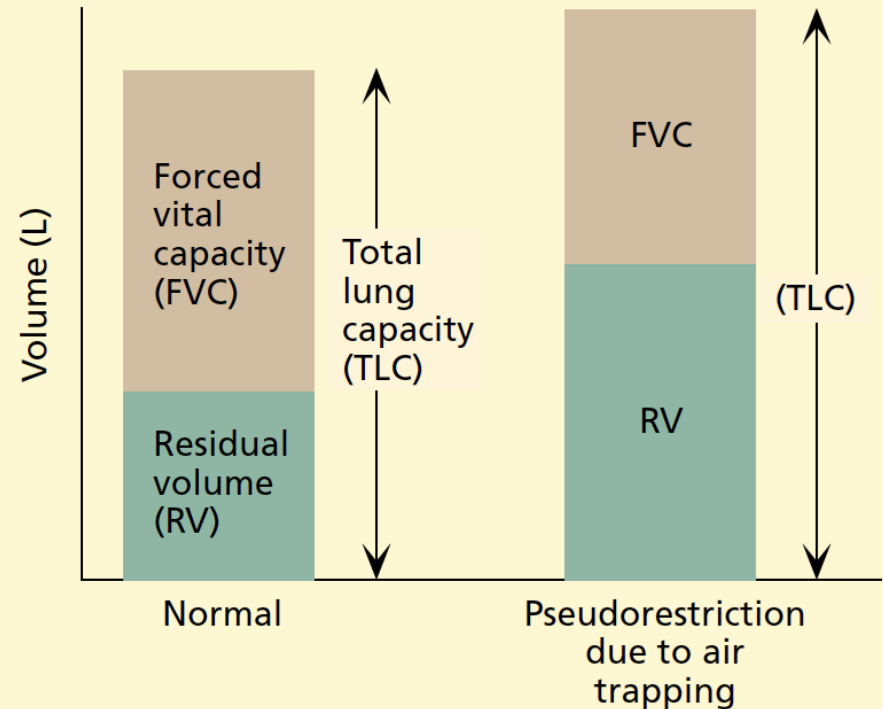
LUNG VOLUMES: HYPERINFLATION AND AIR TRAPPING



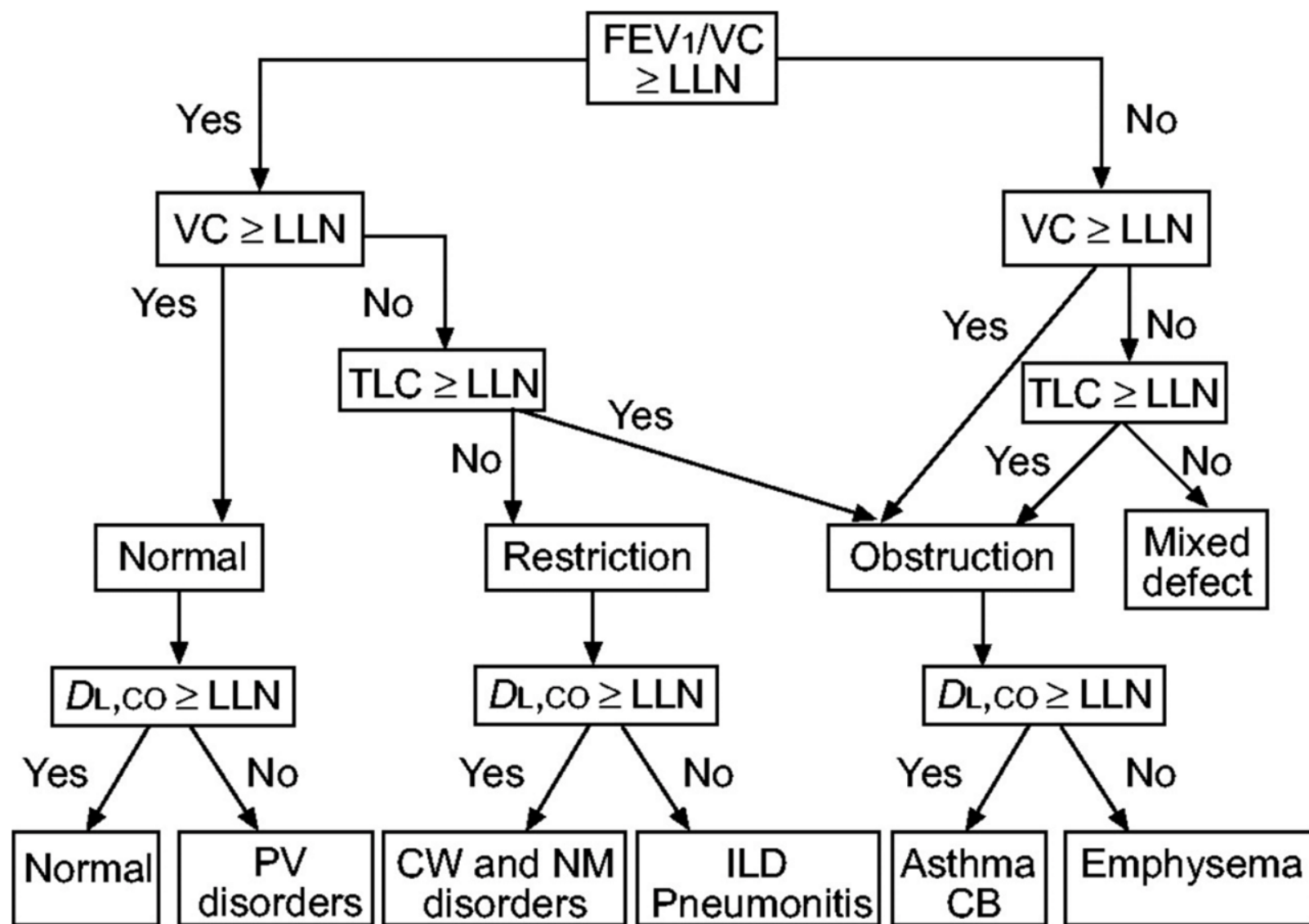
Hyperinflation= $TLC > 120\%$

Air trapping with $RV > 140\%$

Normal spirometry vs pseudorestriction



ATS Interpretation Schema



CASE 4

- A 76 y/o man presents with hypoxemia, you order PFTs which show:

Age: 73 Race: African-American
Height(in): 76 192 cm
Weight(lb): 158 71.8 kg

Temp: 19 PBar: 631 FIN: 1030500541
Physician: ROBERTSON MD
Technician: DANELE ADAMS RRT

		(BTPS)	PRE-RX			POST-RX		
			PRED	BEST	%PRED	BEST	%PRED	% Chg
Spirometry								
<i>Values in Parentheses or Asterisks are outside the normal range</i>								
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

CASE 4

- The PFTs show:
 - a. Normal spirometry and lung volumes
 - b. Obstructive pattern
 - c. Restrictive pattern
 - d. Mixed obstructive restrictive pattern

The PFTs show:

Normal spirometry
and lung volumes

Obstructive
pattern

Restrictive pattern

Mixed obstructive
restrictive pattern

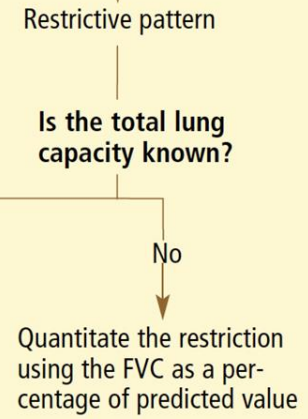
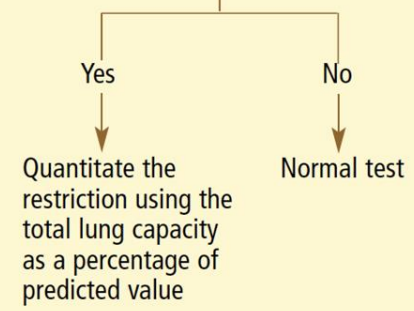
Is the FEV₁/FVC ratio* less than the lower limit of normal?

(BTPS)		PRE-RX			POST-RX		% Chg
		PRED	BEST	%PRED	BEST	%PRED	
Spirometry							
<i>Values in Parentheses or Asterisks are outside the normal range</i>							
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)		
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PEF	L/sec	9.31	(6.59)	(71)	(5.08)	(55)	-23
FEF/FIF50			0.19		0.38		99
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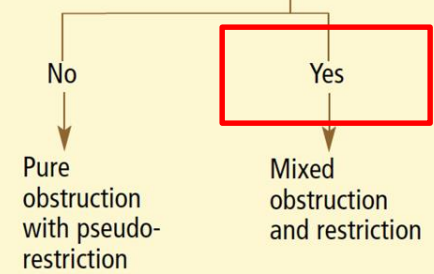
Lung Volumes

VC	Liters	5.30	(3.19)	(60)
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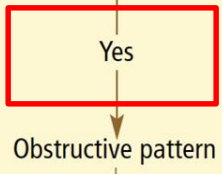
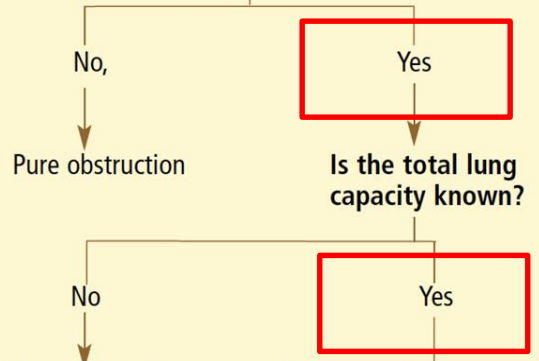
Is the total lung capacity less than the lower limit of normal?



Possible mixed obstruction and restriction or pure obstruction with pseudo-restriction



Is the FVC less than the lower limit of normal?



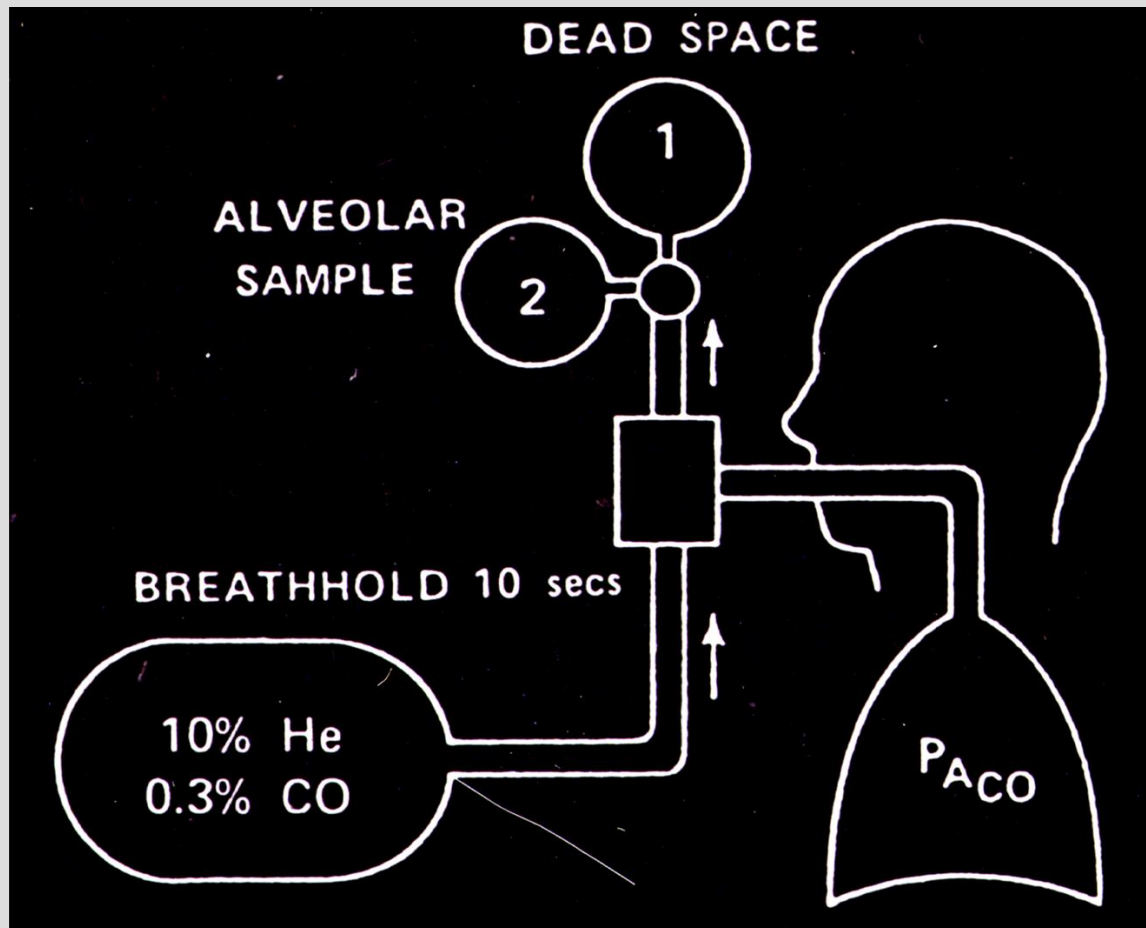
*FEV₁ = forced expiratory volume in 1 second, FVC = forced vital capacity

CASE 4

- The PFTs show:
 - a. Normal spirometry and lung volumes
 - b. Obstructive pattern
 - c. Restrictive pattern
 - d. **Mixed obstructive restrictive pattern**

STEP IV: ADDITIONAL TESTS:
DLCO
BRONCHOPROVOCATION
WALK TESTING

MEASURING GAS EXCHANGE: DLCO



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**

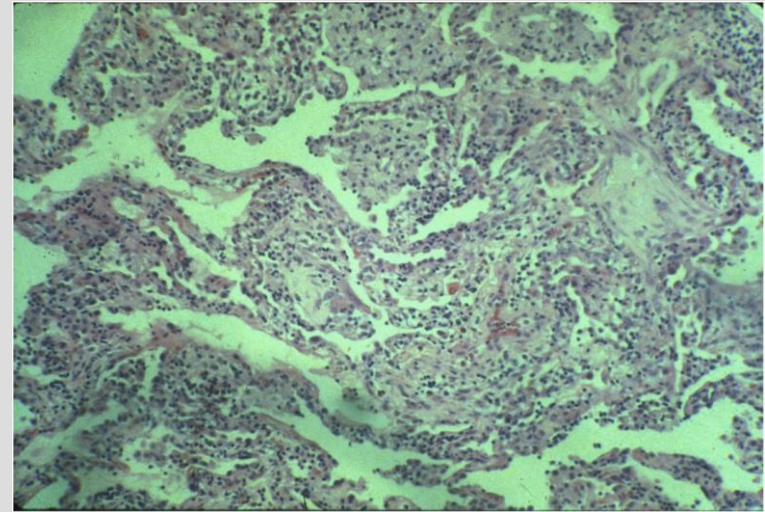
USE OF DLCO

- Restrictive Disease
 - Low- intrinsic disease (parenchymal lung disease)
 - Normal- extraparenchymal causes of restriction (obesity, neuromuscular disease, chest wall limitations)
- Obstructive Disease
 - Low- emphysema
 - Normal- asthma
- Isolated reduction in DLCO--> raises possibility of pulmonary vascular disease

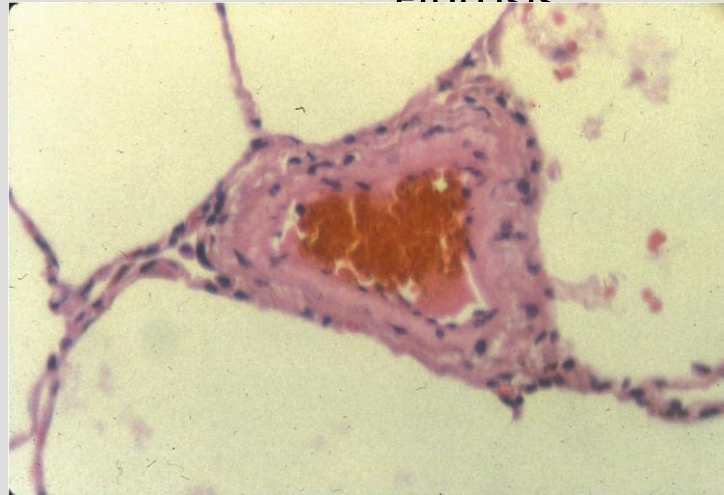
CAUSES OF REDUCED DLCO



Decreased surface area-
Emphysema



Increased membrane thickness-
Fibrosis

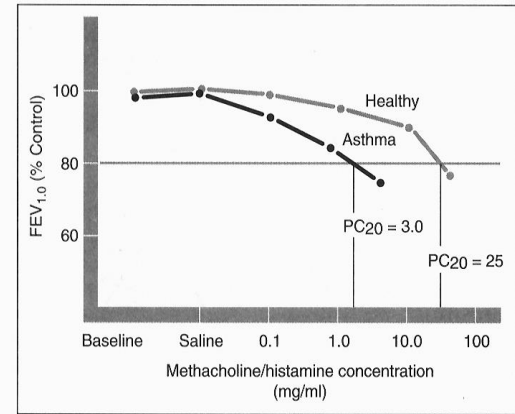


Decreased pulmonary blood volume

AIRWAY RESPONSIVENESS

- Methacholine Challenge

- Obtain baseline FEV₁
- Administer bronchoconstrictive agent, methacholine, at incremental doses until FEV₁ drops by 20% or reach maximal dose (16mg/ml)
- Nebulize methacholine x2 min each dose then measure FEV₁ at 30 and 90 sec after
- PC₂₀ ≤ 4mg/ml consistent with asthma (<1mg/ml is severe)
- PC₂₀ >16mg/ml does not have asthma



EXERCISE CAPACITY TESTING, THE 6MWT

SIX MINUTE WALK TEST

- Measures exercise capacity NOT oxygen titration
- Used for:
 - Pulmonary rehab
 - Pulmonary hypertension response to advanced therapies
 - Prognostication in IPF
 - BODE index
- If you want to determine if your patient needs oxygen with exercise, order an oxygen titration study

SUMMARY

1

PFTs are valuable tests for evaluating symptoms of dyspnea

2

Approach interpretation with a systematic approach

3

PFTs provide a pattern of physiologic impairment but do not make a diagnosis

QUESTIONS/ ADDITIONAL PRACTICE
CASES:

anna.neumeier@dhha.org

<https://depts.washington.edu/uwmedres/Library/eLearning/Pulmonary/>