

Pulmonary Function Tests

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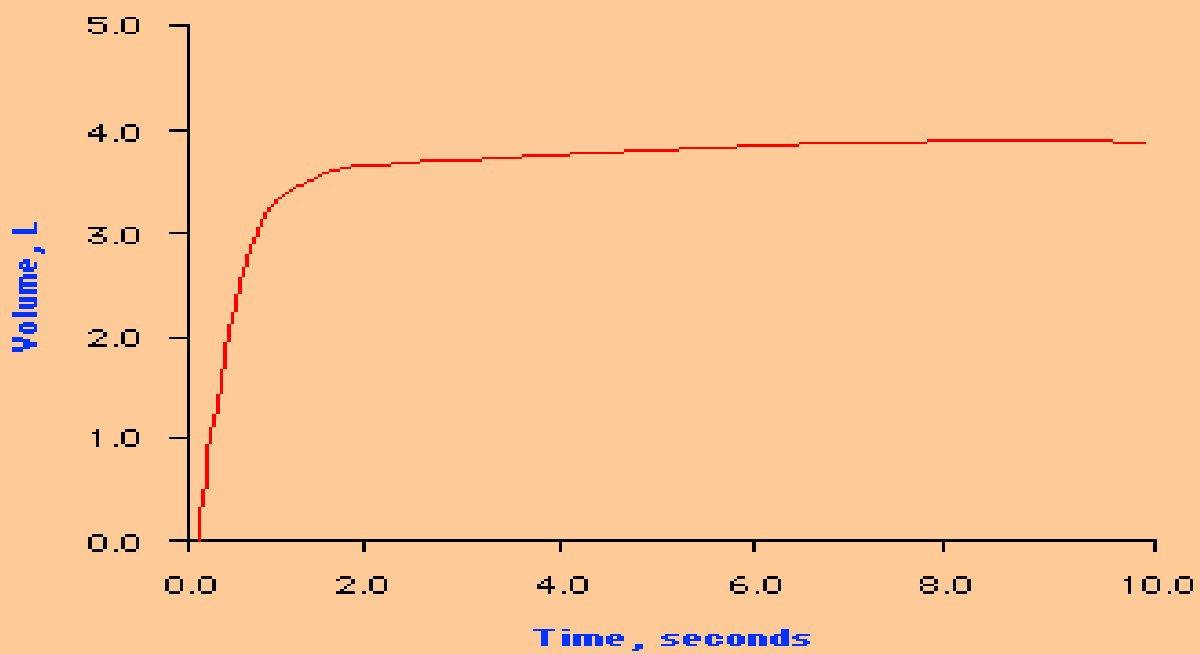
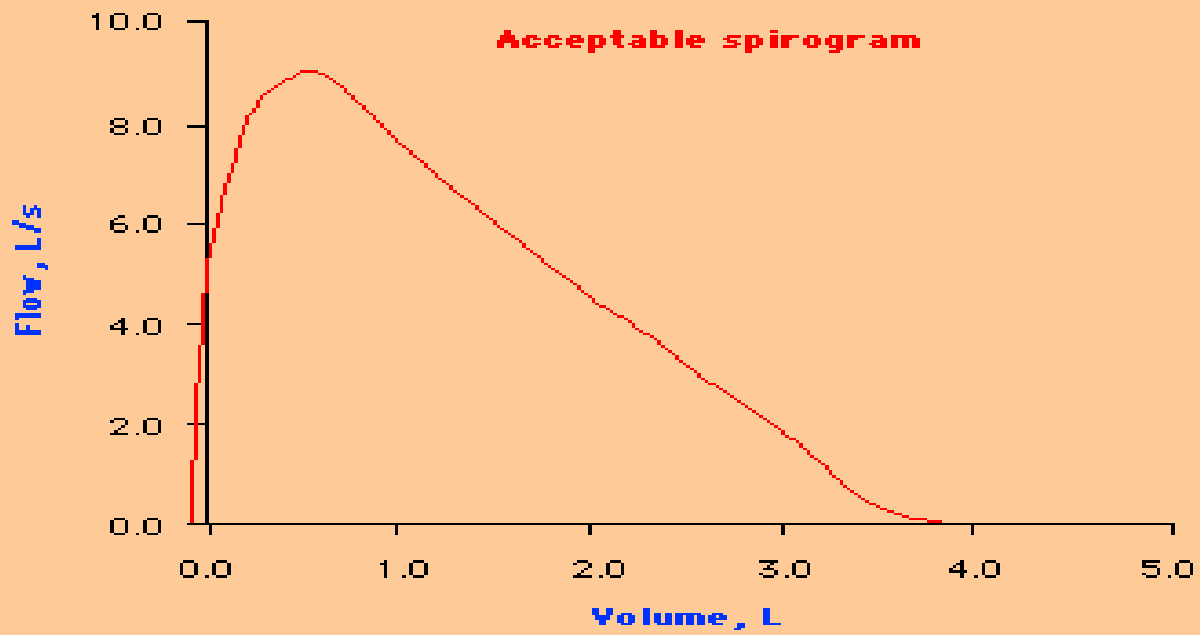
School of medicine

Indications for PFT's

- Evaluation of patient with known or suspected lung disease.
- Objective assessment and monitoring of therapeutic interventions.
- Preoperative evaluation.
- Prognosis assessment.
- Disability evaluation.
- Control of occupationally exposed workers.

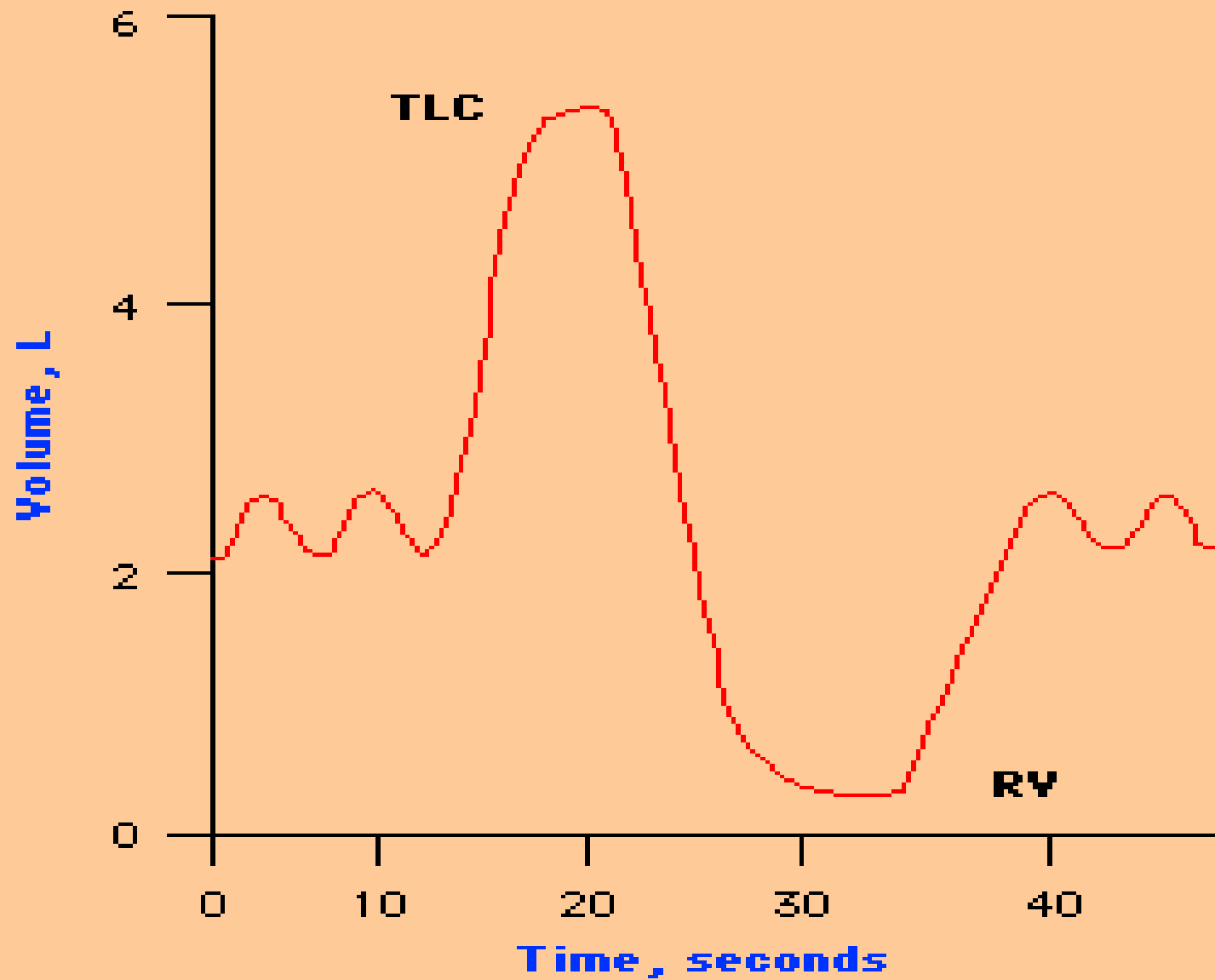
Spirometry

- Measurement the volume of air that individual inhales or exhales, and the respiratory flow (volume as a function of time).

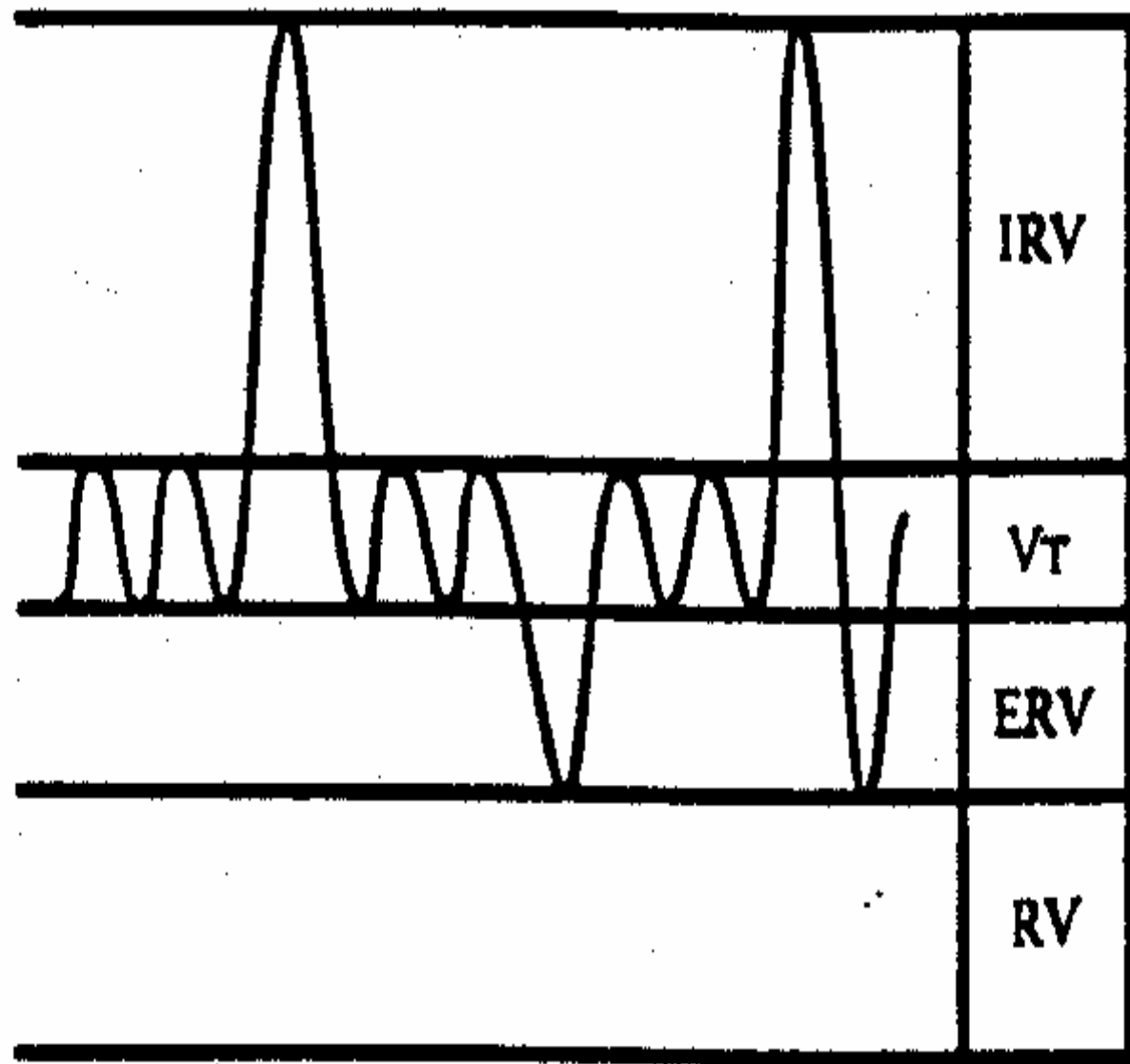


Lung volumes

- Tidal volume (V_T) air inhaled or exhaled each breath during quiet breathing.
- Vital capacity (VC) maximum volume of air exhaled from maximum inspiration.
- Residual volume (RV) air remaining in lungs after maximal exhalation.
- Total lung capacity (TLC) is the total volume of air in lungs after maximal inspiration or $VC + RV$.



Acceptable VC maneuver Relaxed VC maneuver in a subject in a normal subject.



IRV

Vt

ERV

RV



IC

FRC



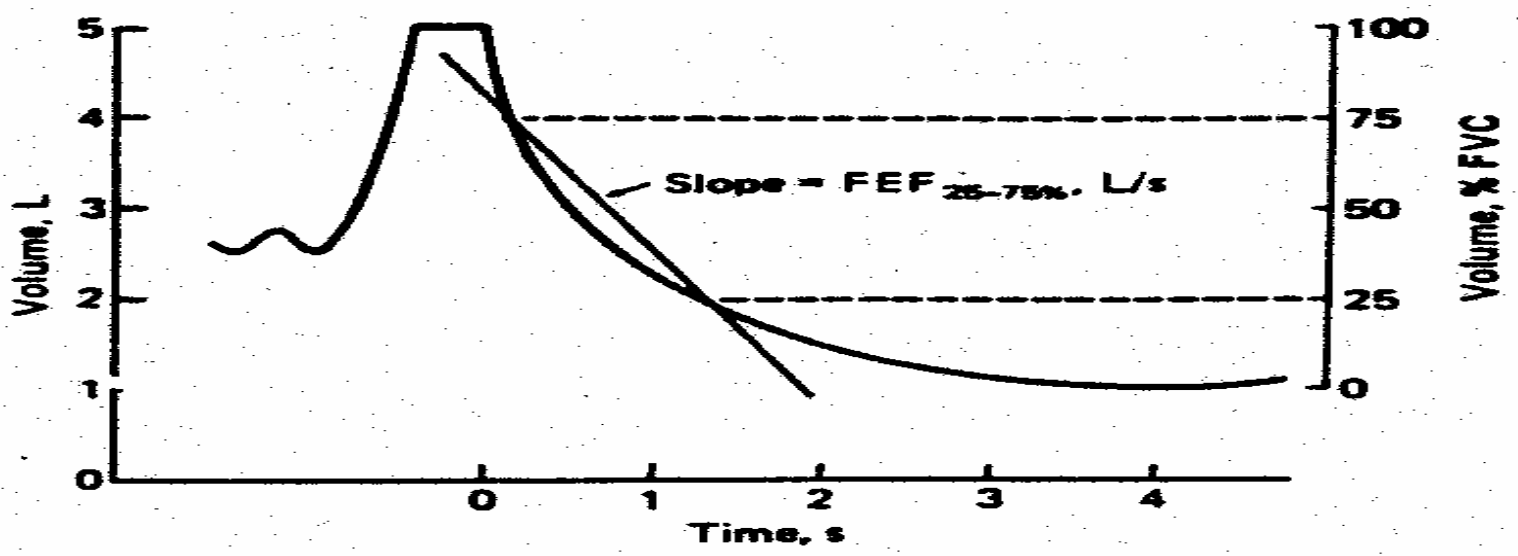
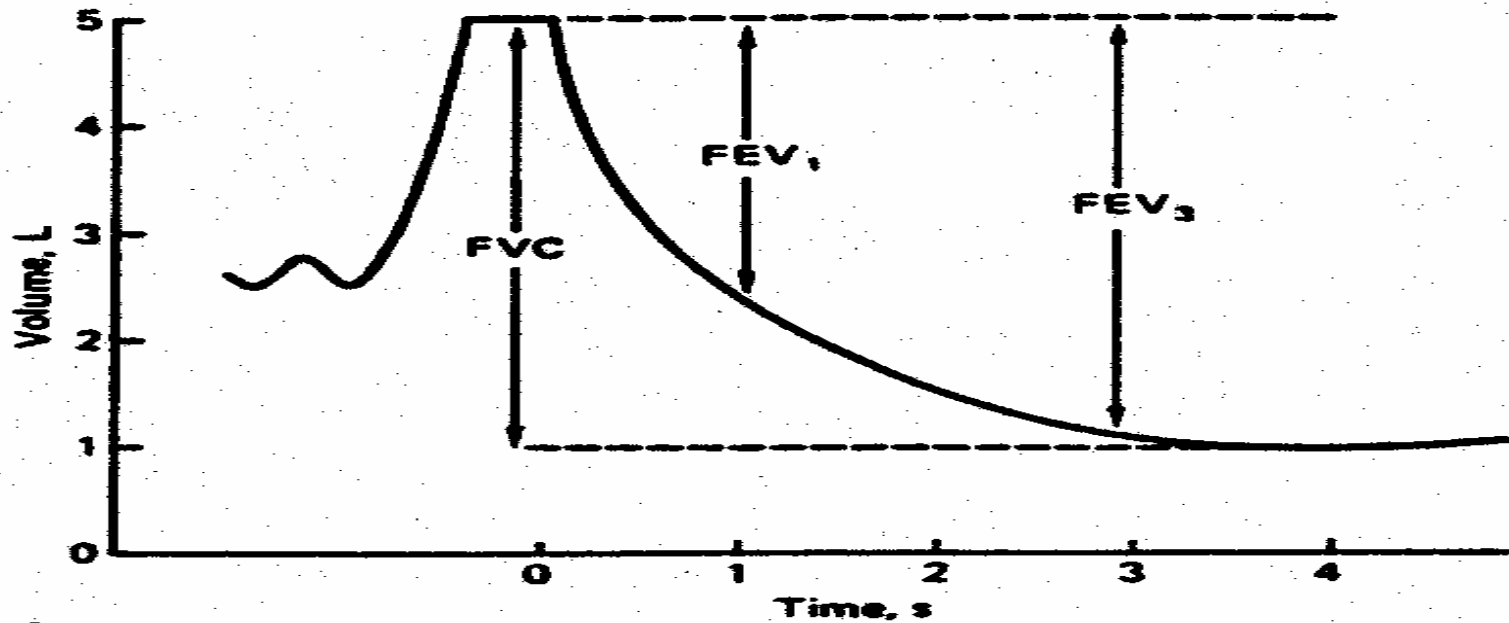
VC

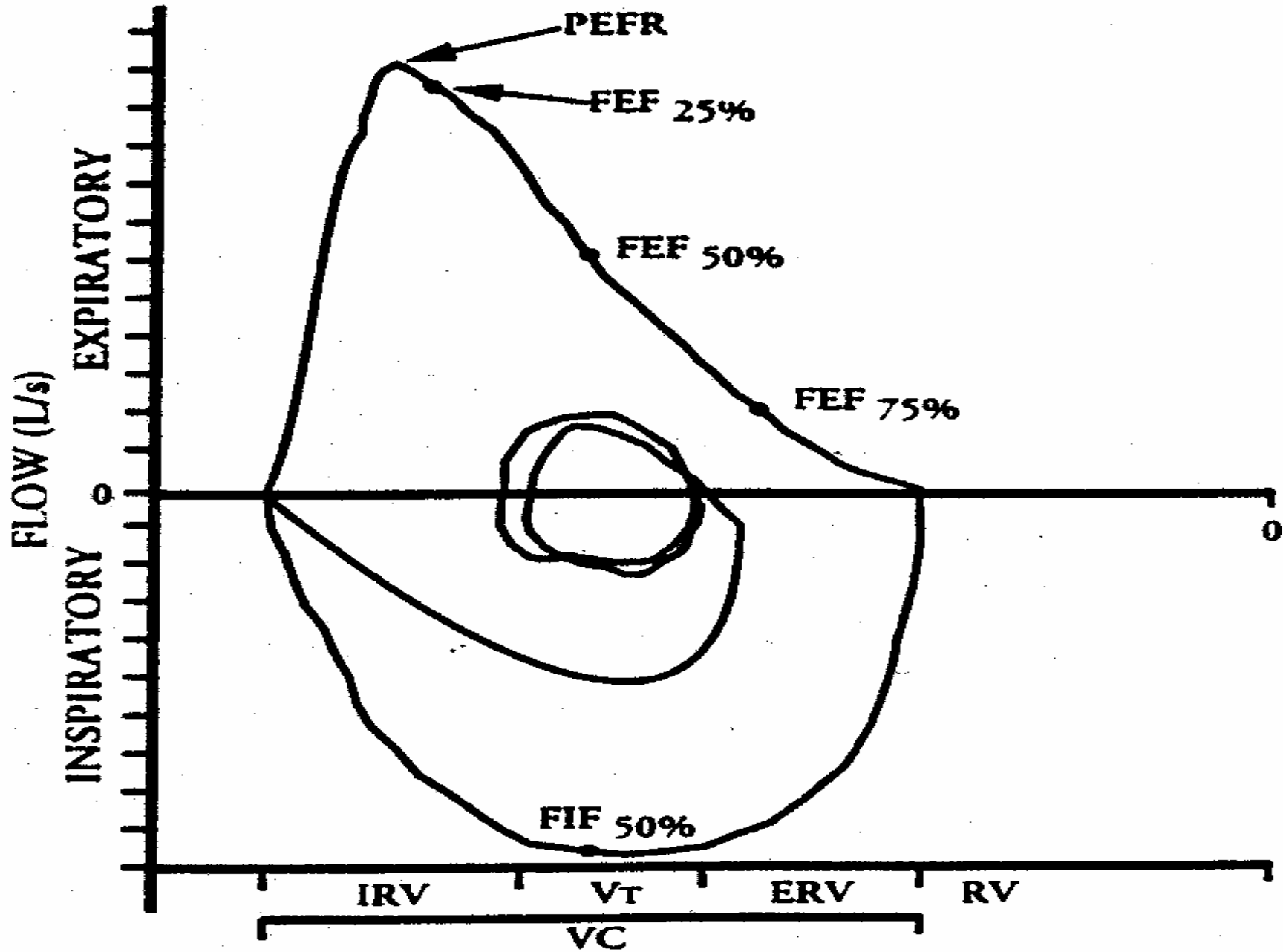


TLC

Expiratory flows

- FEV1 is the volume of air exhaled during the first second of the FVC.
- FEF 25%-75% or mean expiratory flow during the middle half of the FVC.
- PEF is maximal forced expiratory flow.





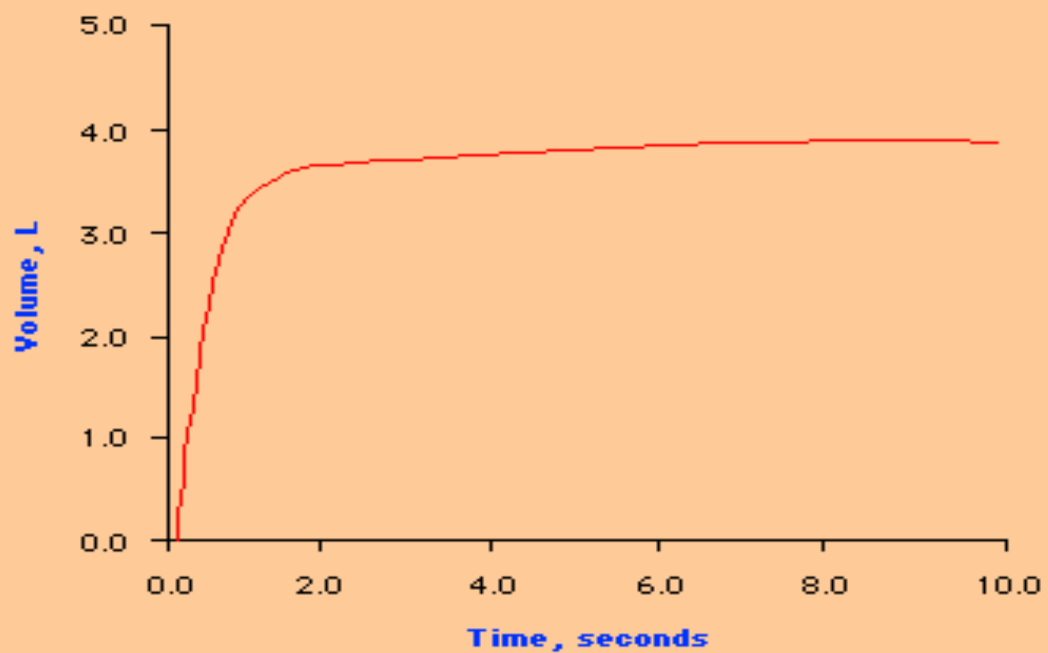
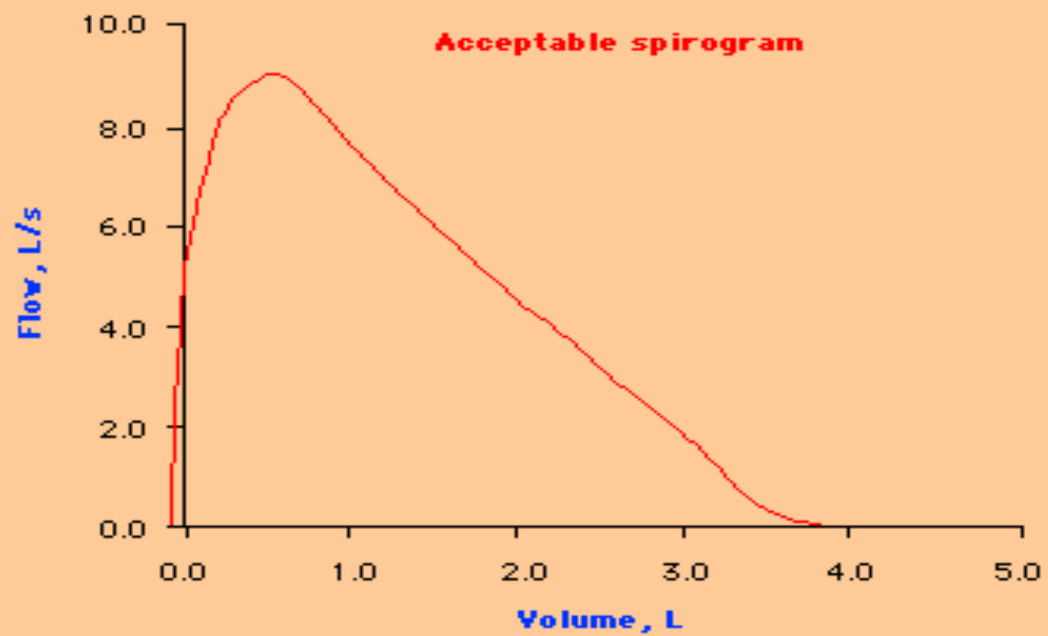
Spirometry

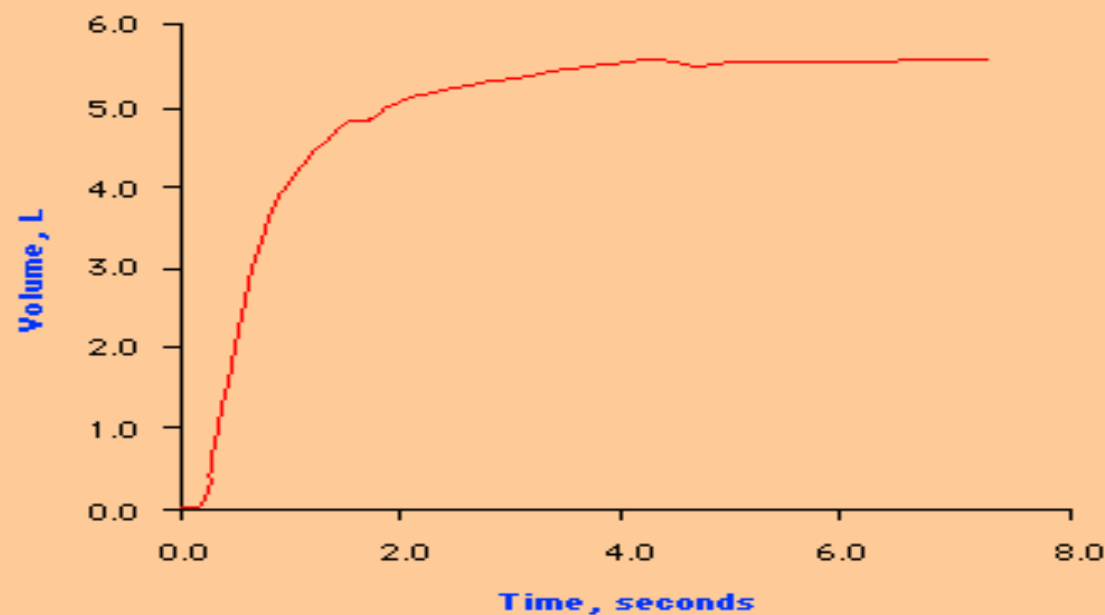
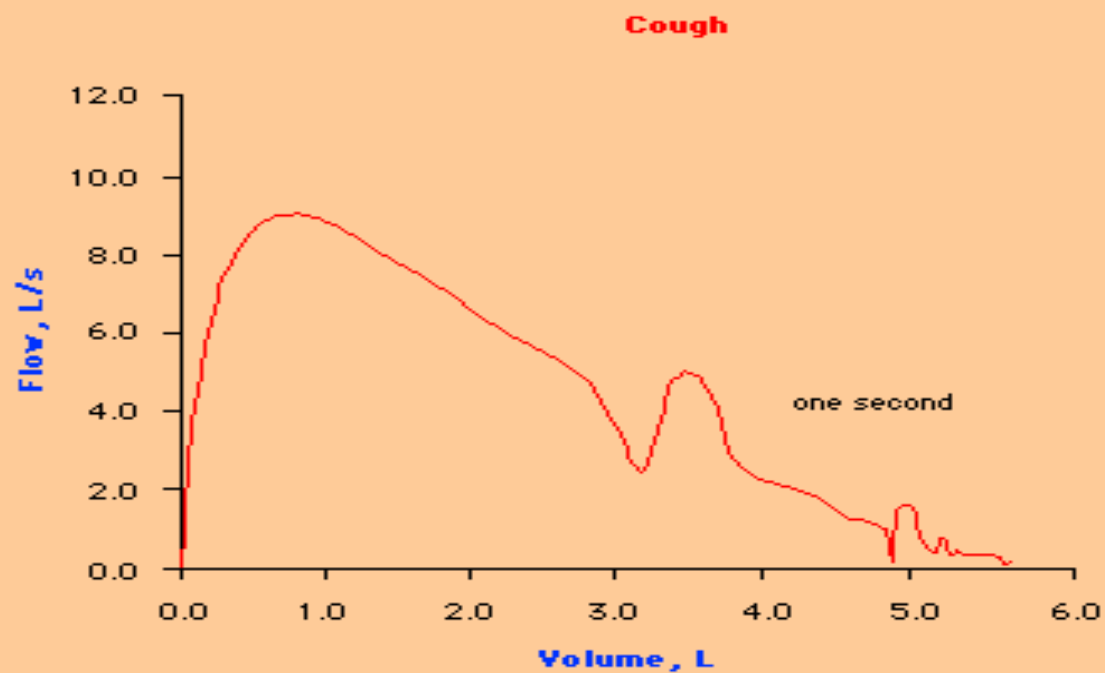
Equipment Quality Control Summary

Test	Minimum interval	Action
Volume	Daily	3-L syringe check
Leak	Daily	3 cm H ₂ O constant pressure for 1 minute
Linearity	Quarterly Weekly (flow spirometers)	1-L increments with a calibrating syringe measured over entire volume range (flow spirometers simulate several different flow ranges)
Time	Quarterly	Mechanical recorder check with stopwatch
Software	New versions	Log installation date and perform test using "known" subject

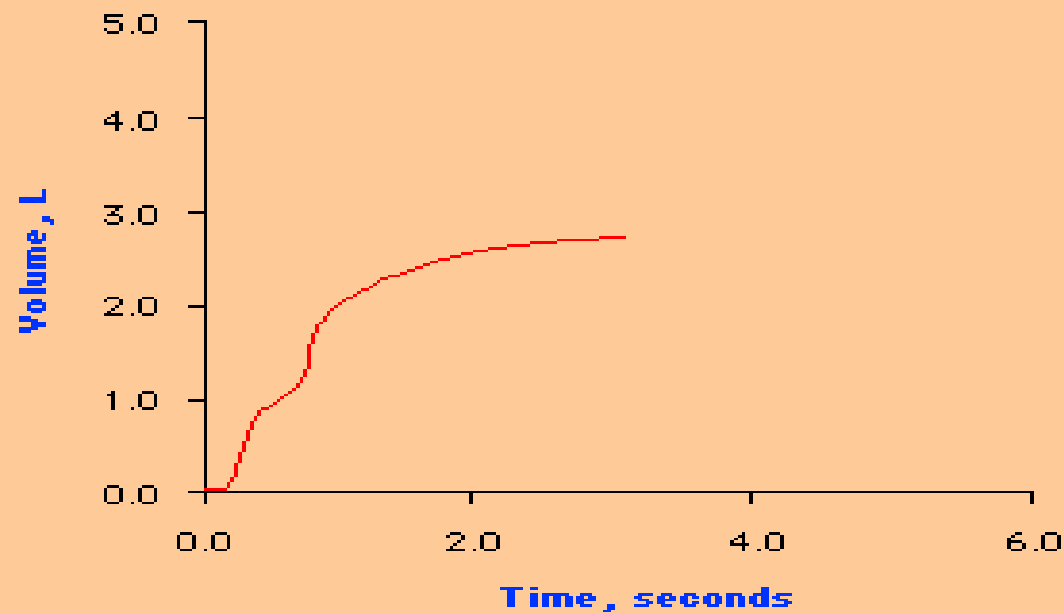
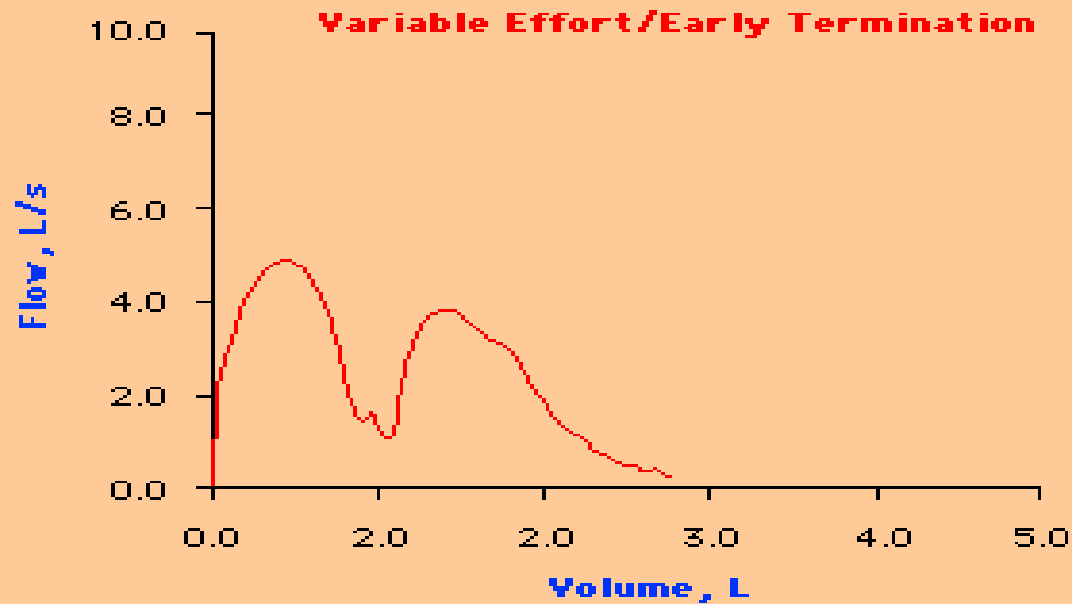
Acceptable spirometry

- Free of artifacts: cough, variable effort, leak, ...
- Good start.
- Satisfactory exhalation, six seconds of exhalation or plateau in the volume-time curve.

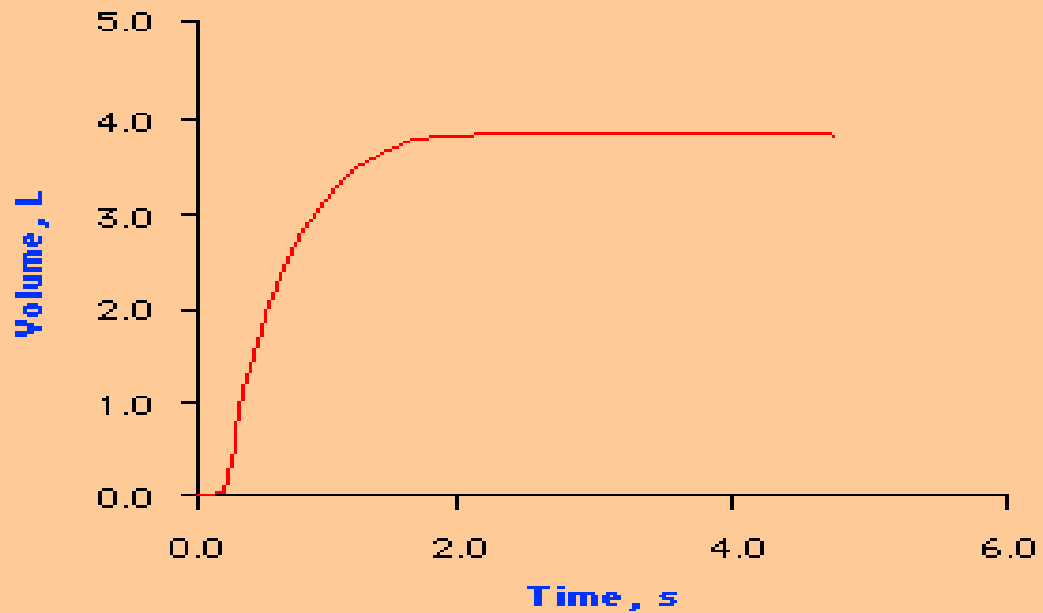
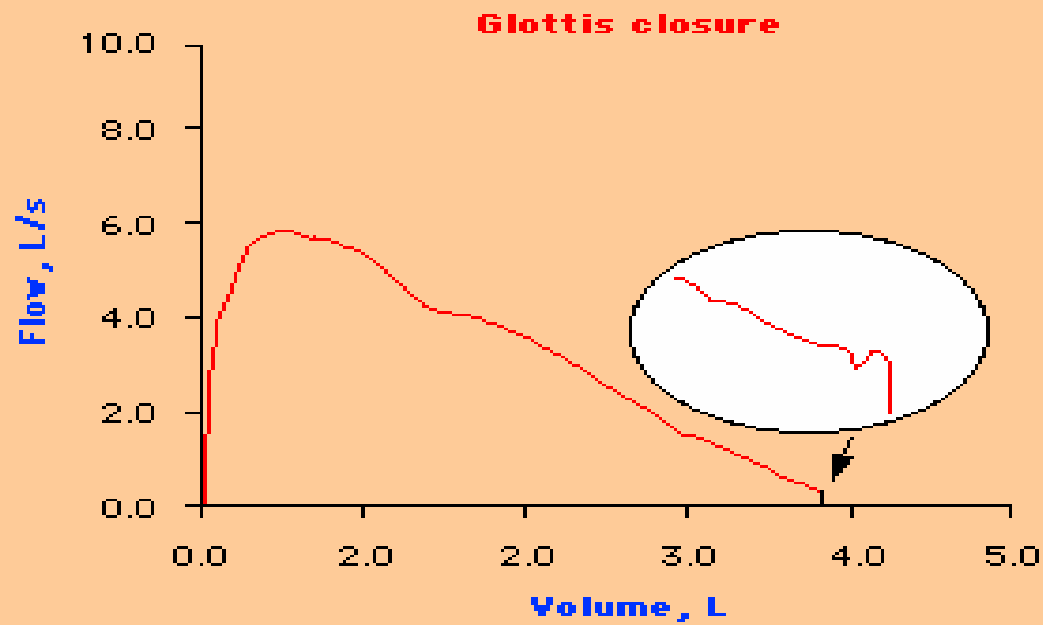




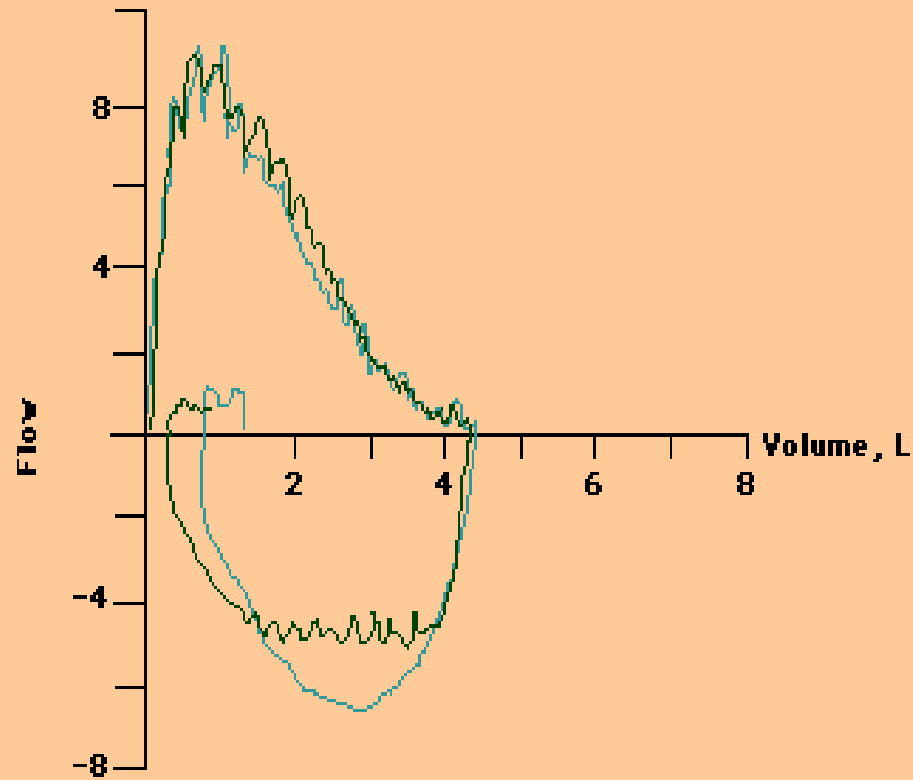
Cough Unacceptable spirometry due to the presence of cough.



Variable effort Unacceptable spirogram due to variable effort and early termination.



Glottis closure Unacceptable spirogram due to possible glottis closure.

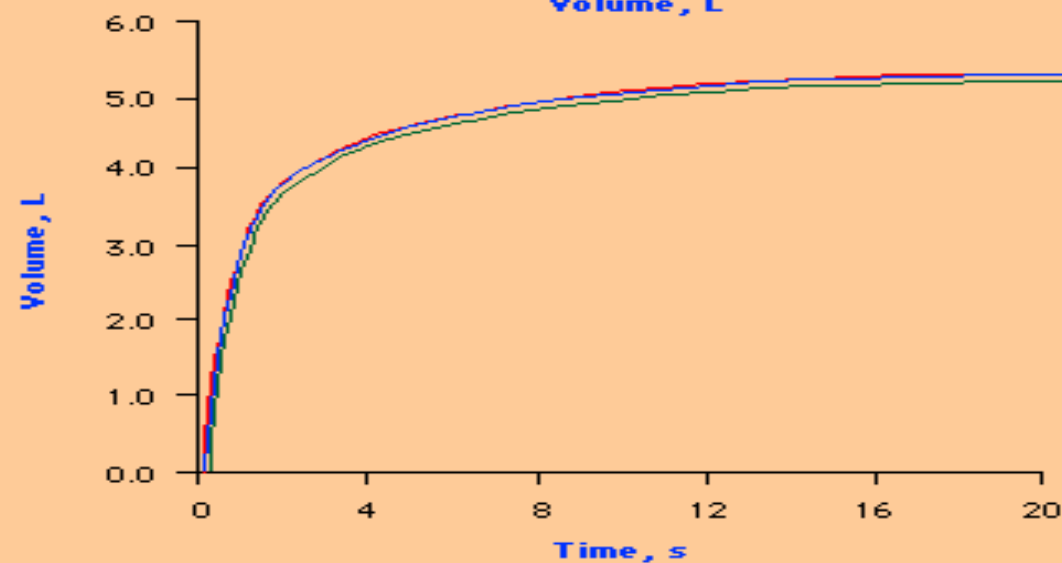
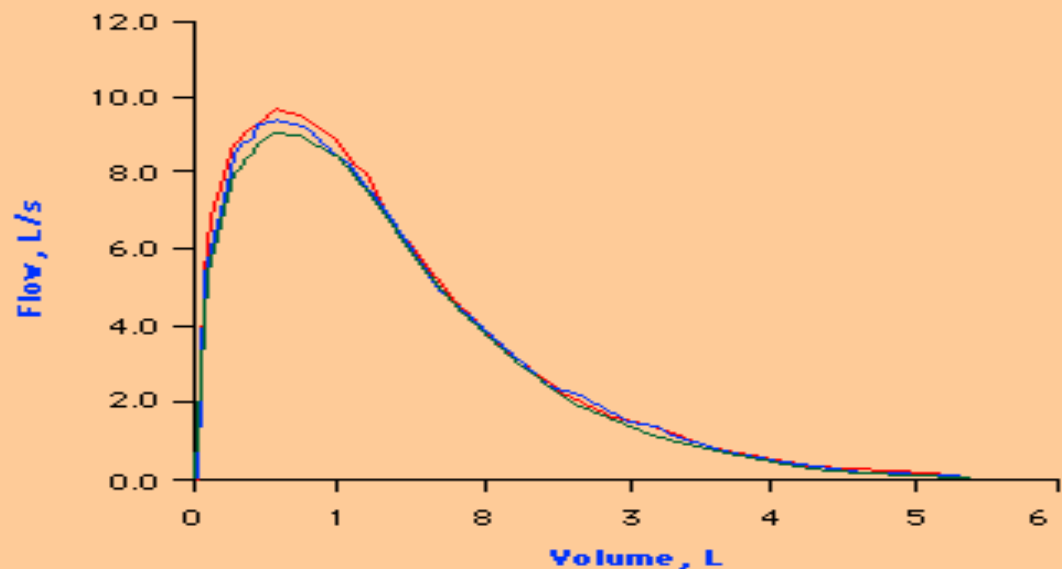


Obstructive sleep apnea Flow-volume loop in obstructive sleep apnea showing a saw-tooth pattern.

Reproducible spirometry

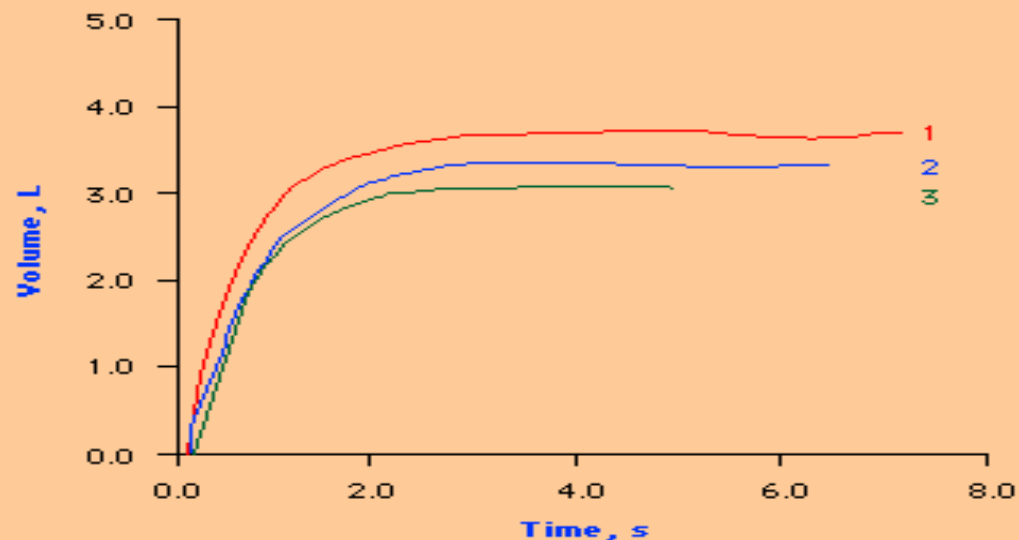
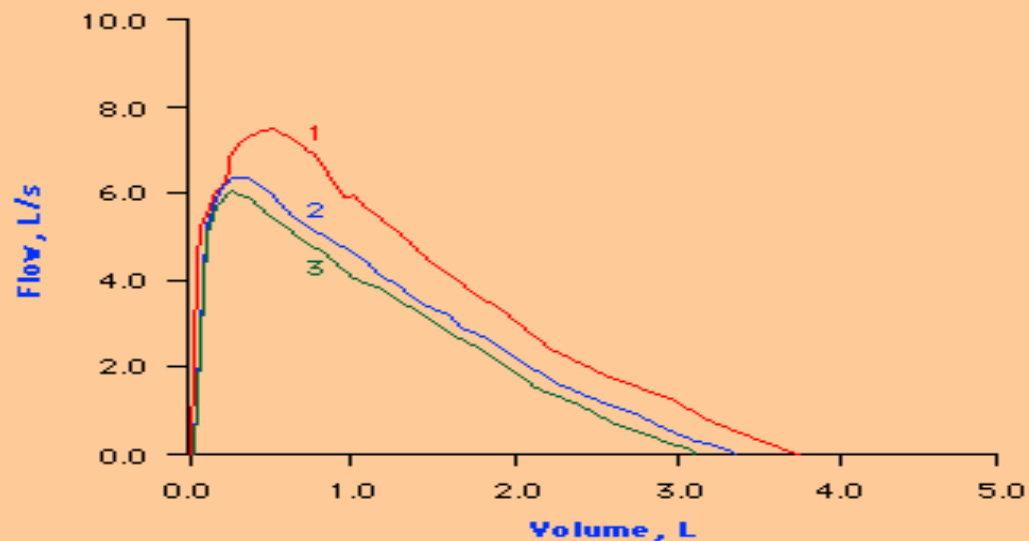
- Three accepted tests should be obtained.
- The two largest FVC should be within 200 ML. difference.
- The two largest FEV1 should be within 200 ML. difference.
- If above not possible, continue to repeat effort until 8 attempts performed or patient cannot continue, then save the best three maneuvers.

- Choose the highest values of FEV1 and FVC, not necessary from the same trial.
- The difference between the three accepted trials should be less than 5 %.



Curve	FVC, percent	FEV1, percent
1	5.34, 0	3.30, 0
2	5.33, 0	3.28, 0
3	5.30, 0	3.29, 0

Reproducible test results Reproducible test with three acceptable flow-volume and volume-time curves. Percents are difference from largest value.

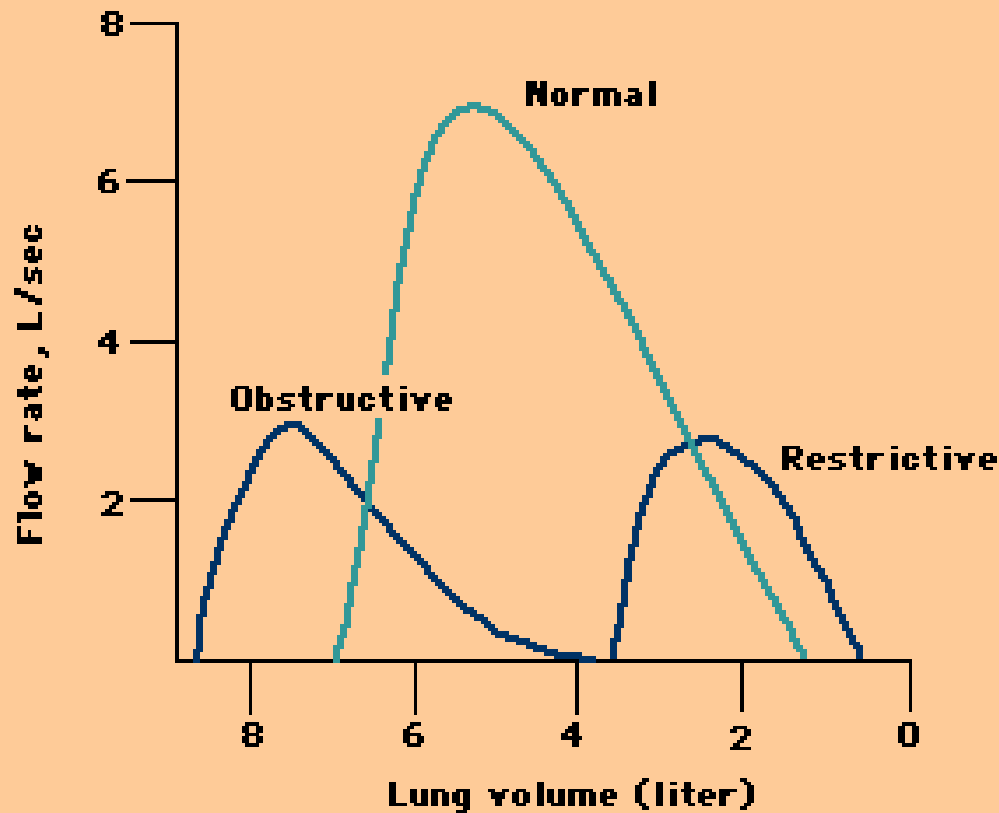


Curve	FVC, percent	FEV1, percent
1	3.70, 0	3.05 0
2	3.33 10.0	2.68 12.1
3	3.07 17.0	2.54 16.7

Nonreproducible spirometry Nonreproducible test with three acceptable attempts. Percents are difference from largest value.

Interpretation of spirometry

- 1- Acceptable spirogram.
- 2- Reproducible FVC, FEV1.
- 3- obtain reference values based on age, sex, height, and race.
- 4- FEV1 and FEF 25-75% are $> 80\%$ of predicted, spirometry is normal.
- 5- FEV1 $< 80\%$ could be obstructive or restrictive defect.



Flow-volume curves in obstructive and restrictive lung disease Sample flow-volume curves during a maximal forced expiration in normals and in obstructive and restrictive lung disease. The normal expiratory portion of the flow volume curve is characterized by a rapid rise to the peak flow rate, followed by a nearly linear fall in flow as the patient exhales toward residual volume. With obstructive disease, maximal expiration begins and ends at higher lung volumes and lower flow rates than normal. With restrictive disease, the lung volumes and flow rates are reduced but the flow in relation to lung volume is actually higher than normal.

- 6- look at the ratio FEV_1/FVC if $< 70\%$ the defect is obstructive.
- 7- If FEV_1/FVC is normal the defect is restrictive, and lung volumes may be indicated to better diagnose the restrictive disease.
- 8- If defect is obstructive, bronchodilator inhalation is indicated to check for reversible airway obstruction.
- 9- If $FEF_{25-75\%}$ is reduced but FEV_1 and FEV_1/FVC are borderline normal indicates early obstruction or small airway disease.

Obstructive lung disease

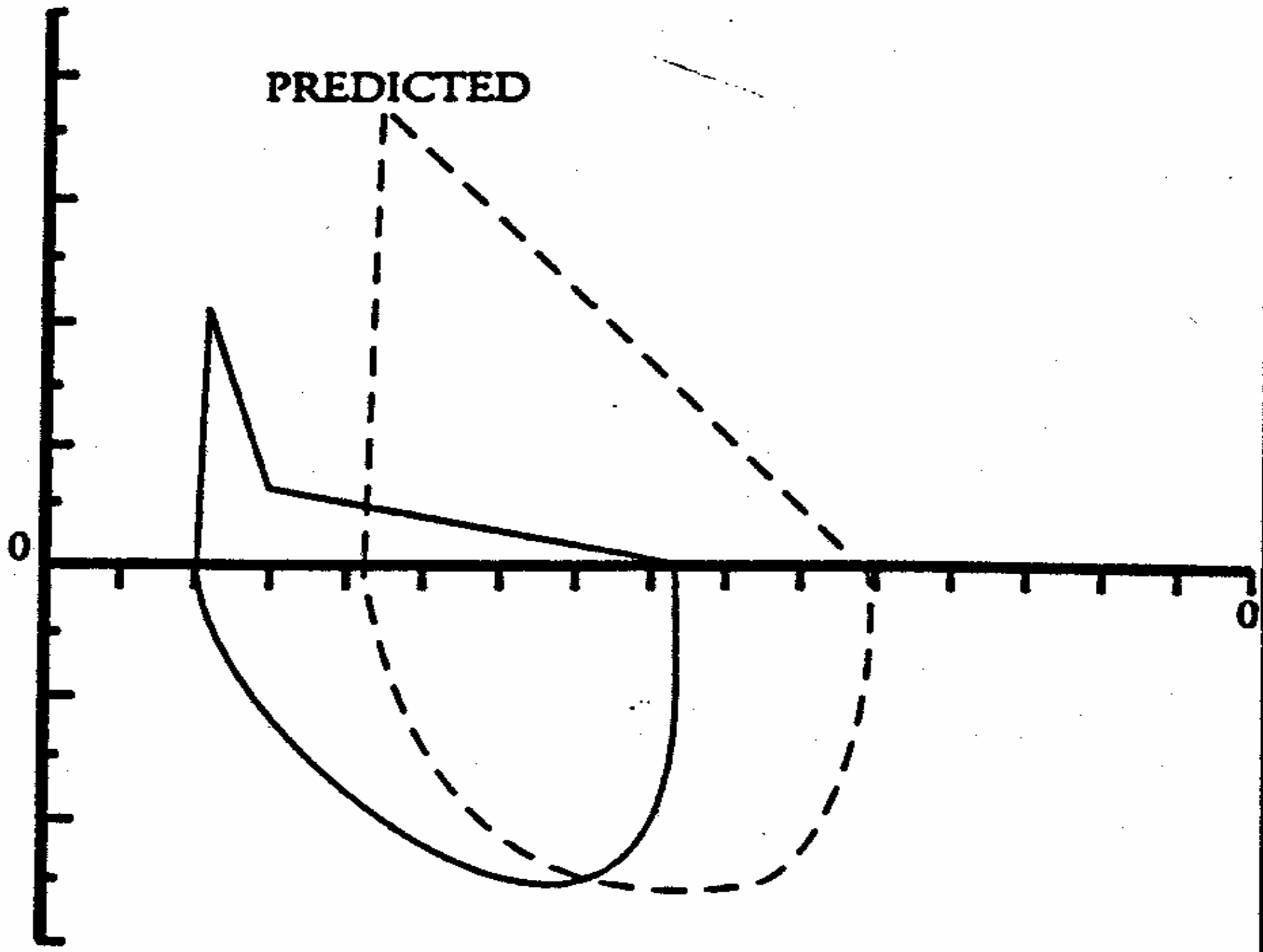
- FEV1/FVC : reduced.
- FEV1 is reduced, and used to determine the severity of OLD:

65-80% mild.

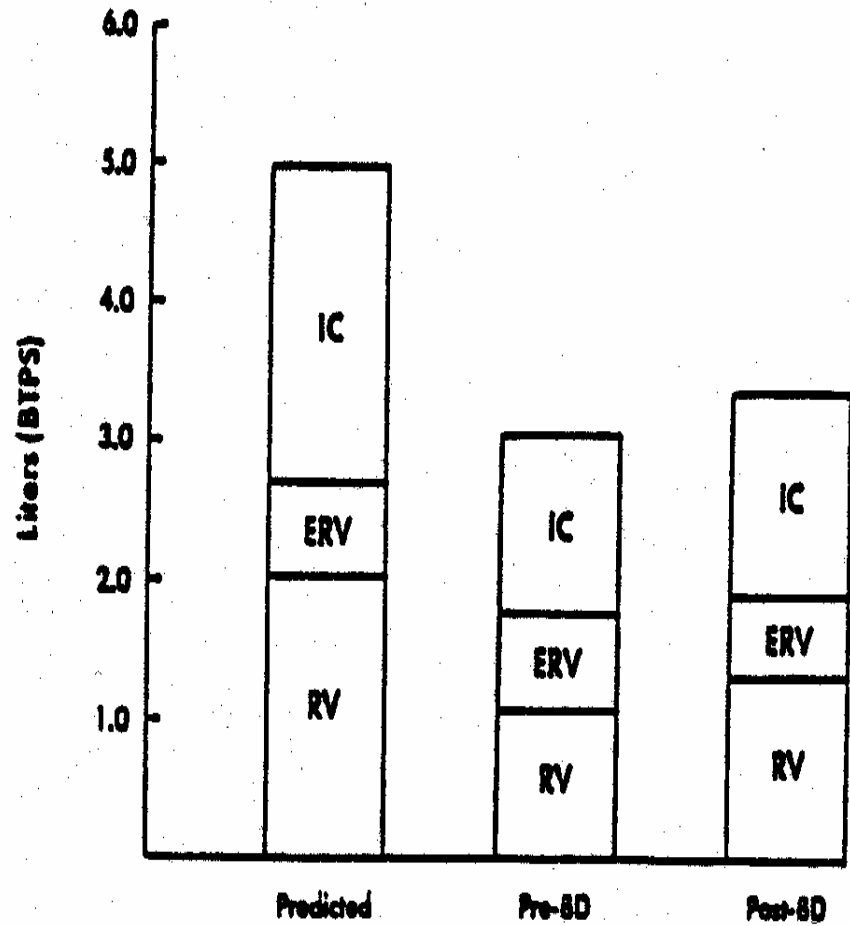
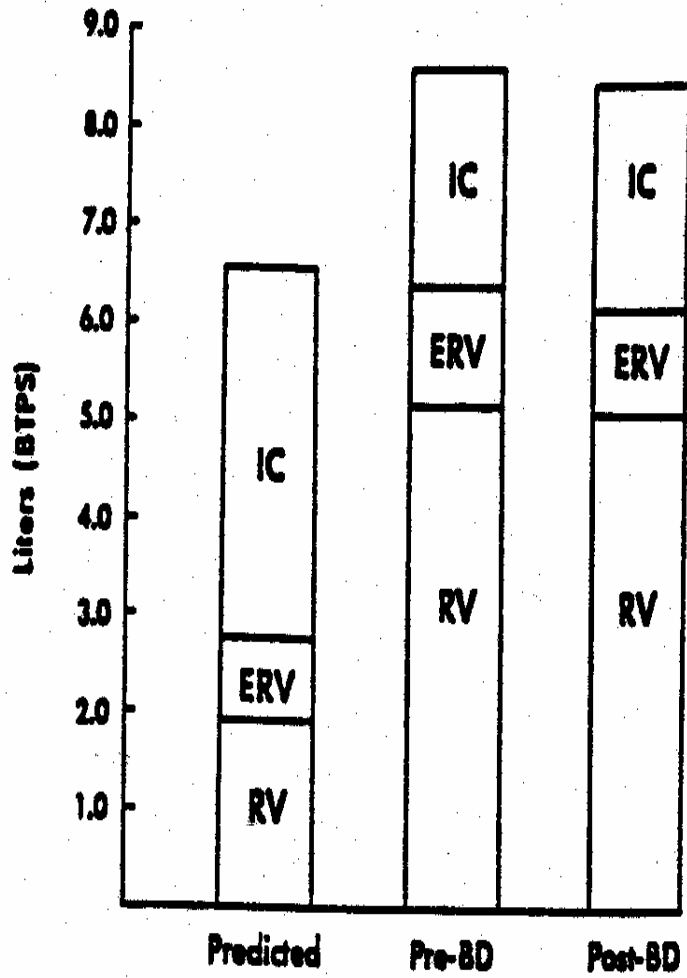
50-64% moderate.

<49 % severe.

PREDICTED



- FEV_{25-75%} is reduced.
- TLC is elevated (hyperinflation).
- RV and RV/TLC are elevated (air trapping)
- DLCO is variable:
 - Reduced in Emphysema.
 - Near normal or slightly reduced in Chronic bronchitis.
 - Elevated in Asthma.
- Pi max. could be reduced with severe air trapping.



OBSTRUCTIVE VENTILATORY IMPAIRMENT (COPD)

RESTRICTIVE VENTILATORY IMPAIRMENT (ILD)

Restrictive lung disease

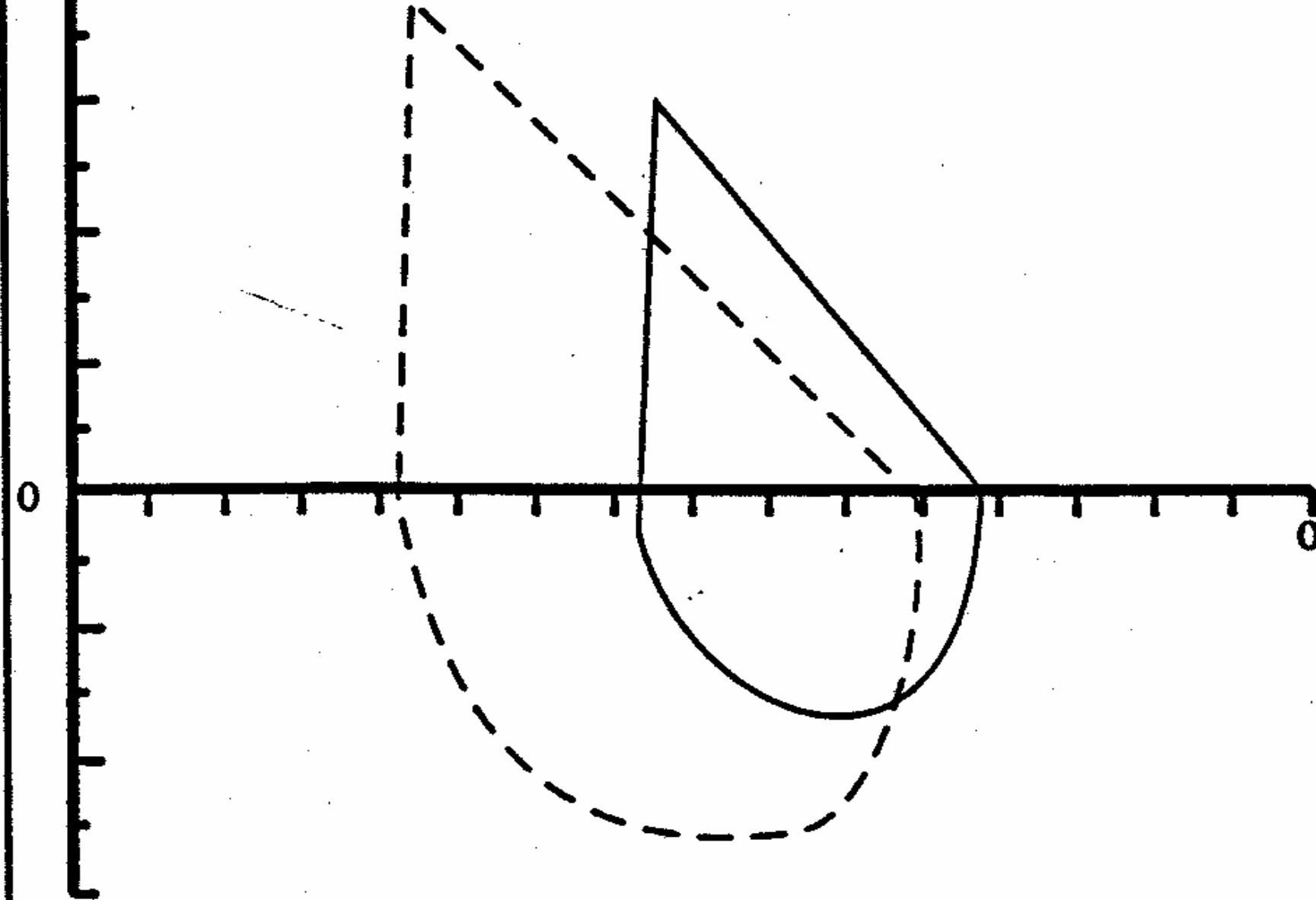
- FEV1 and FVC are proportionally reduced.
- FEV1/FVC is normal, unless if there is associated obstruction.
- TLC is reduced, and used to determine the severity of RLD:

65-80 % mild.

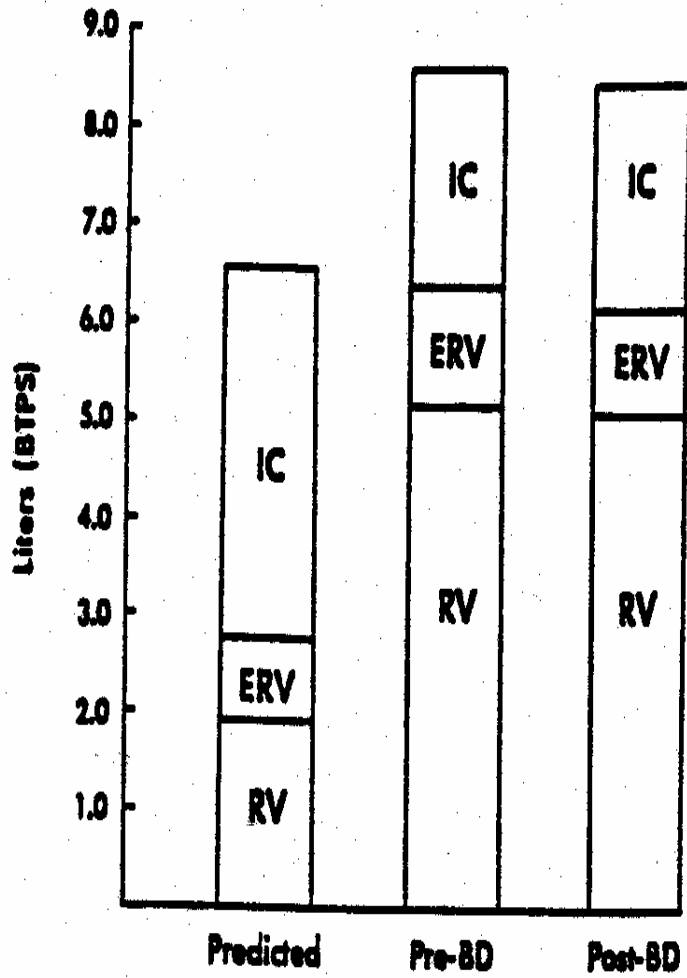
50-64 % moderate.

< 49 % severe.

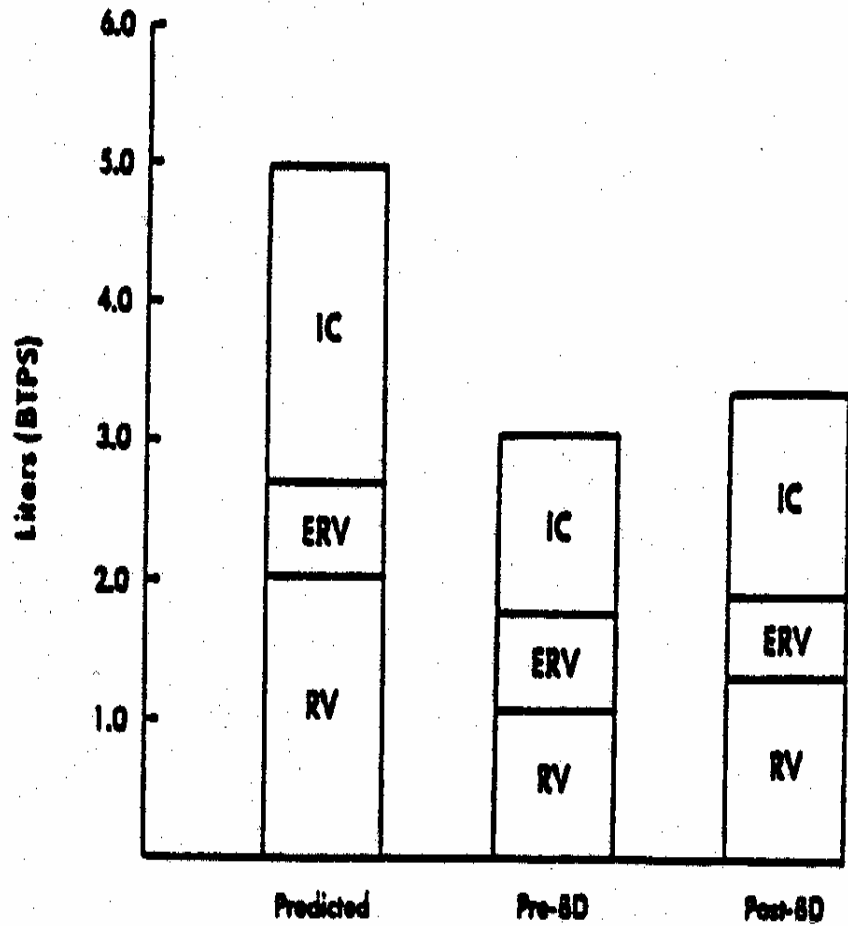
PREDICTED



- RV, FRC are reduced.
- DLCO is reduced in fibrotic lung disease, reduced in RLD secondary to chest wall deformity but normal when corrected to lung volume ($DLCO/VA$).
- Pi max. is reduced in associated respiratory muscle disease.



**OBSTRUCTIVE VENTILATORY
IMPAIRMENT (COPD)**



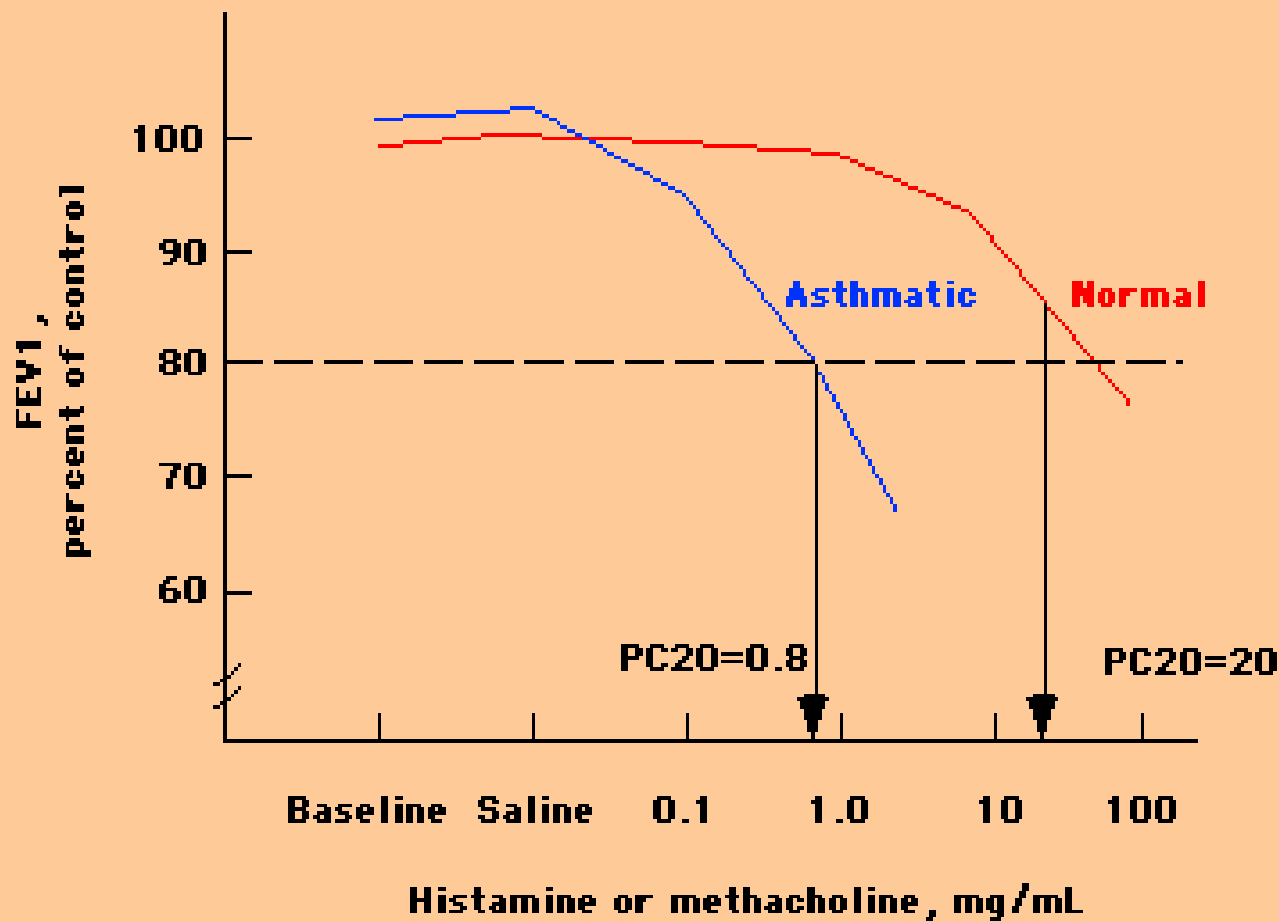
**RESTRICTIVE VENTILATORY
IMPAIRMENT (ILD)**

Response to bronchodilator

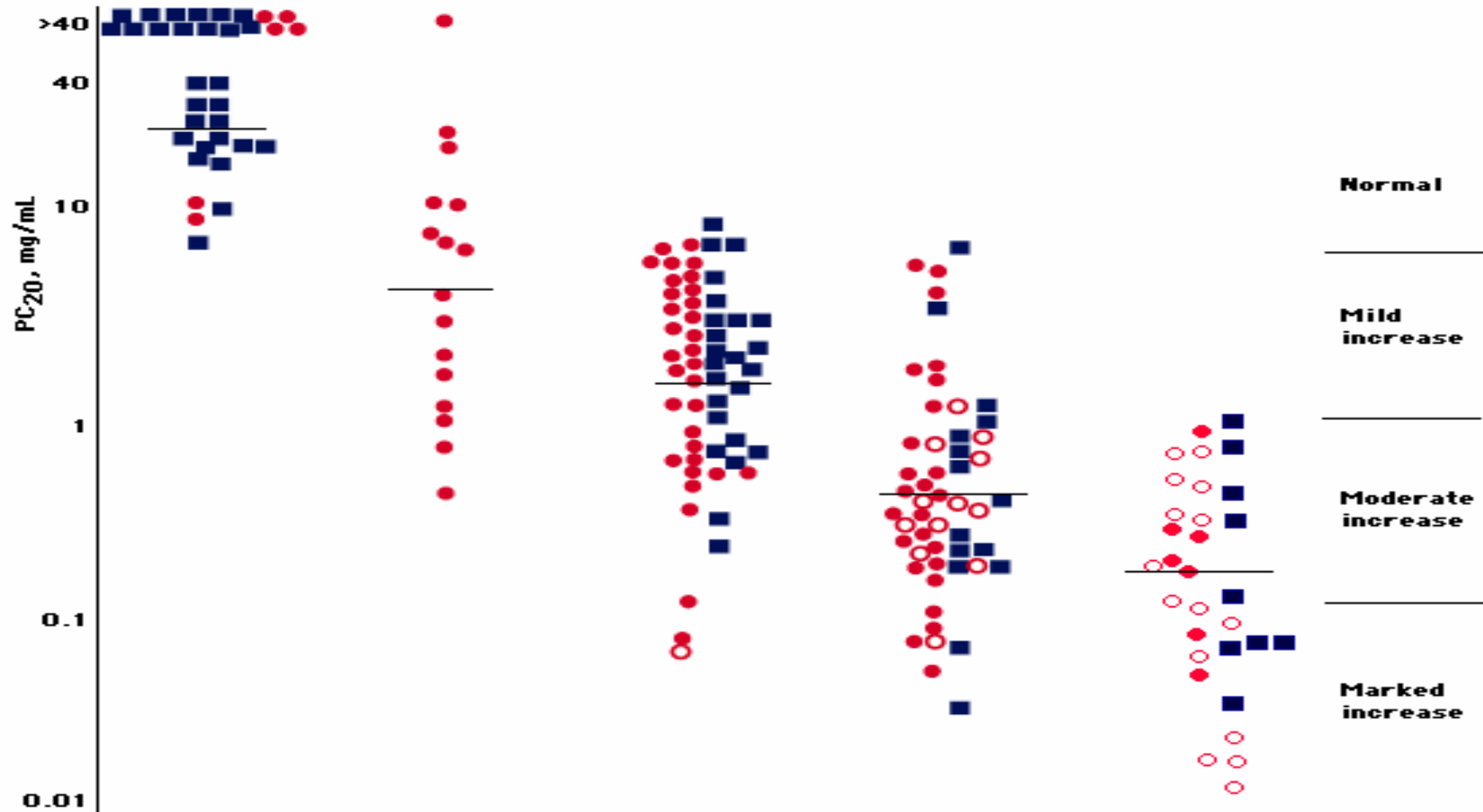
- Positive response according to ATS guidelines is improvement of VC and/ or FEV1 at least 12 % from baseline, with an absolute increase of at least 200 ML, after bronchodilators inhalation.
- % Change: $\frac{\text{postRx} - \text{PreRx}}{\text{PreRx}} \times 100$

Bronchial provocation tests

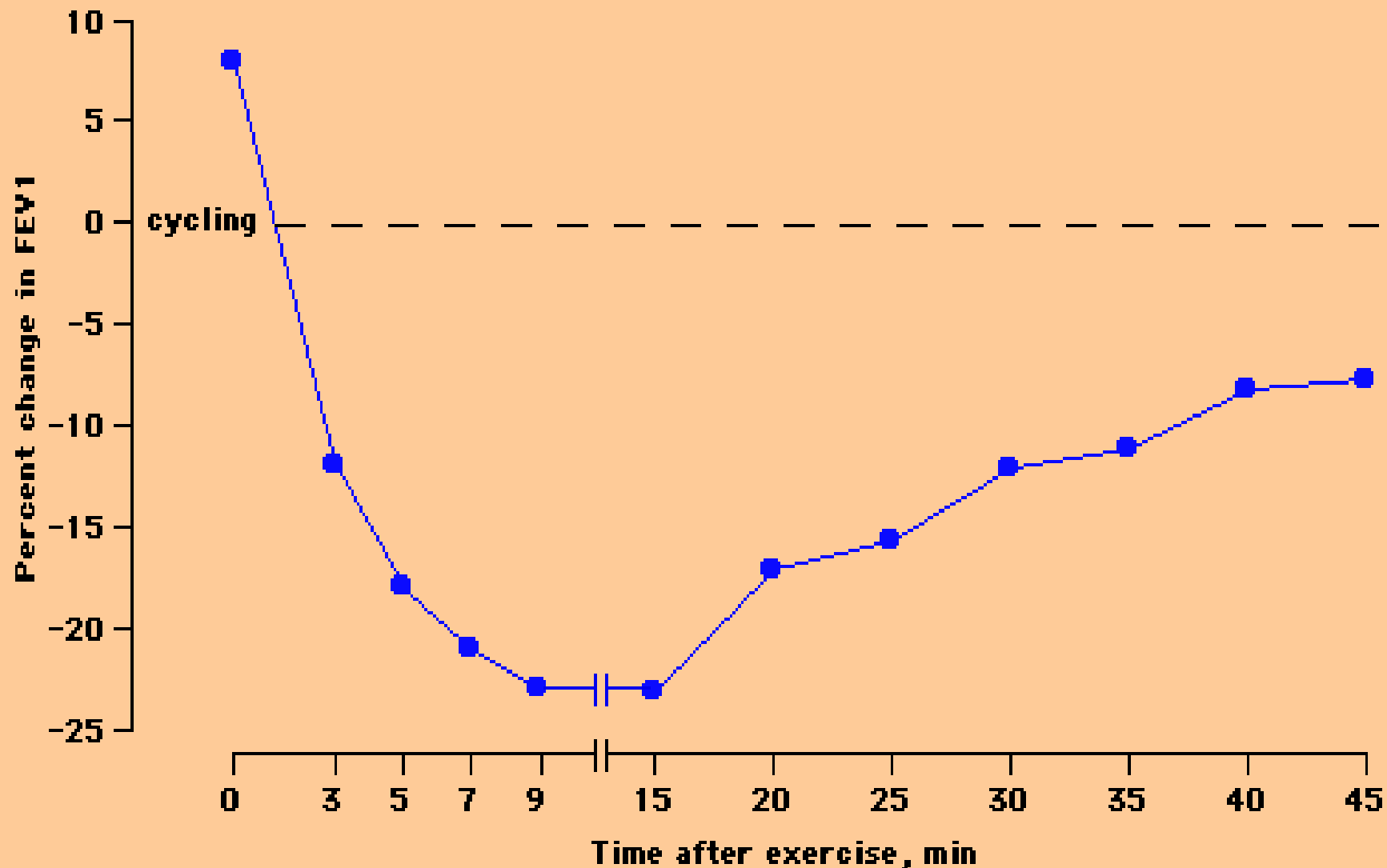
- If spirometry is normal and patient has history suggesting asthma, bronchial provocation test with histamine, methacholine or exercise may be indicated.
- Contraindication if FEV1 severely reduced.
- Positive test by FEV1 reduction of 20% or more.



Bronchoprovocation testing The effect of increasing the inhaled dose of histamine or methacholine in a healthy subject (red) and an asthmatic patient (blue). The provocative concentration is the amount of inhaled agonist required to drop the FEV1 by 20 percent from the baseline (PC20 FEV1), and is much less in the asthmatic than in the normal subject (0.8 versus 20 mg/mL). An increase in responsiveness is characterized by a decrease in the PC20.

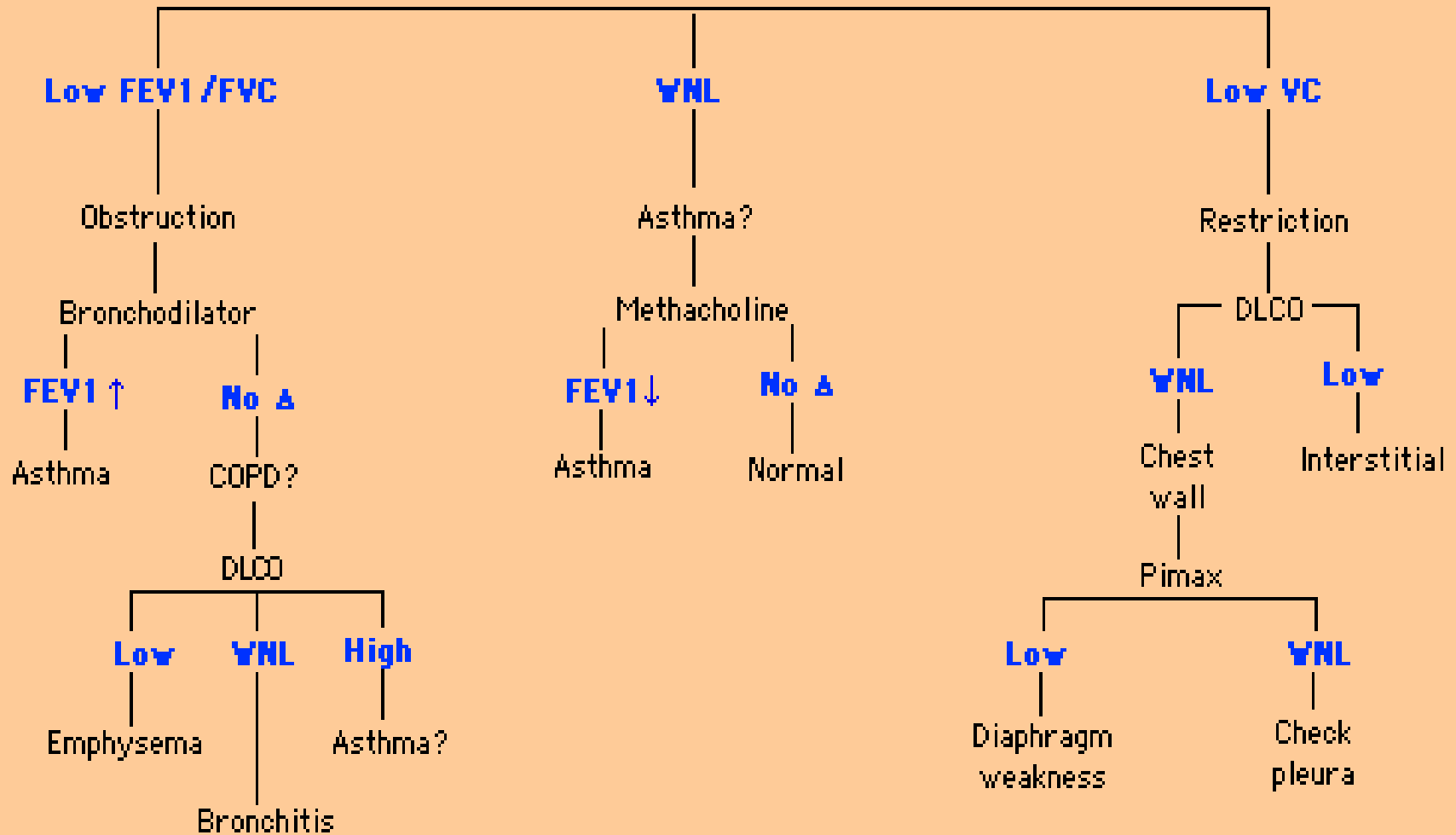
Normal**Asymptomatic
seasonal****Bronchodilator
PRN****Bronchodilator
regular****Steroid
dependent**

Correlation of treatment requirements and airway responsiveness The relationship between PC₂₀ for inhaled histamine and requirement for treatment to control symptoms in patients with asthma. Circles represent atopic individuals, and squares represent non-atopic individuals; closed symbols are used when FEV₁ ≥ 70 percent, and open symbols are used when FEV₁ < 70 percent predicted. While there is considerable overlap between the groups, there is a rough relationship between PC₂₀ and the need for medication. (Redrawn from Cockcroft, DW, Killian, DN, Mellon, JA, Hargreave, FE. Clin Allergy 1977; 7:235.)



Exercise-induced bronchoconstriction The time course of exercise-induced bronchoconstriction in an asthmatic patient in whom the FEV1 fell by more than 20 percent after cycling.

Spirometry



Approach to the patient with dyspnea An efficient stepwise method of determining the cause of chronic dyspnea using pulmonary function tests. WNL = within normal limits; VC = vital capacity; TLC = total lung capacity; DLCO = diffusing capacity.

Methods of measurement of TLC and RV

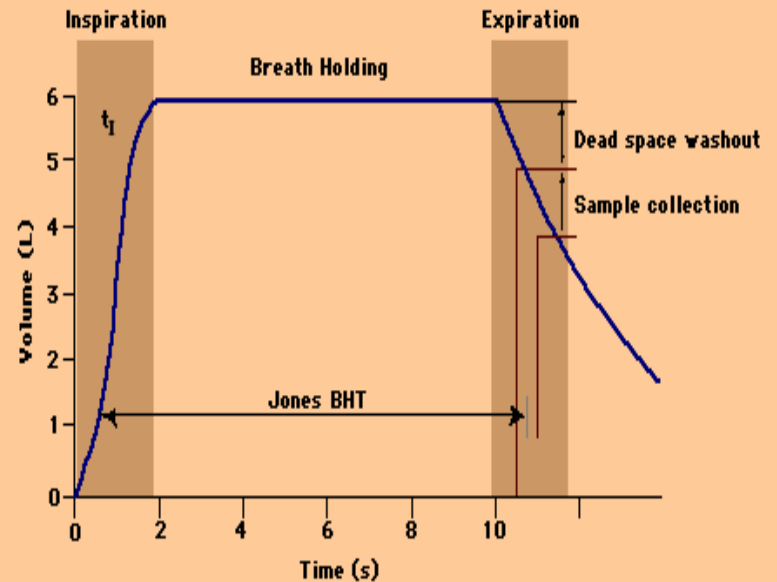
- Plethysmography: accurate but complex.
- Closed-circuit(He dilution), and open-circuit (N₂ washout) measure the communicating alveolar volume, underestimate TLC if there is airway obstruction.
- CXR, not accurate.

Diffusing Capacity

- Dlco is the measurement of the volume of gas transferred across the alveolar-capillary membrane per minute per mmHg of difference between the alveolar and capillary blood, mostly by using single breath technique, by using diffusion limited gas (CO).

Criteria for acceptability of DLCO

- Rapid inspiration less than 2.5 seconds.
- Dead space washout 0.75-1 L.
- Alveolar sample volume < 0.5-1 L.
- Breath hold time 9-11 seconds.



Single breath DLCO maneuver The patient quickly inhales a deep breath of test gas, holds his or her breath for 10 seconds, and then exhales quickly. RV = residual volume; TLC = total lung capacity. The Jones method measures breathhold time (BHT) starting at 30 percent of inspiratory time (t_i) and extending to half of sampling time. (Adapted from Am J Respir Crit Care Med 1995; 152:2185.)

- Average of two or more acceptable tests should be reported.
- Reproducible efforts should be within 10% or 3 ML/Min./mmHg.

Correction of DLCO

- Anemia causes less CO binding to RBC, and Dlco is falsely low.
- High CO in the blood (i.e.. Smoking) causes back pressure , DLCO decreases by 1% for each 1% increase in carboxyhemoglobin.
- The CO and the O2 compete to the hemoglobin, when the FiO2 decreases as in high altitude, the transfer rate of CO increases

DlCO reduction:

- Emphysema.
- Interstitial lung disease such in pulmonary fibrosis, CTD's.
- Pneumonectomy.
- Pulmonary edema.
- Acute and recurrent pulm. Embolism.
- Anemia.
- Smoking.

DLCO elevation:

- Polycythemia.
- Asthma.
- Pulmonary hemorrhage.
- Increase pulmonary blood flow such left to right shunt.

Volunteers wanted

<u>Spirometry</u>	<u>Predicted</u>	<u>Best</u>	<u>%pred.</u>	<u>Post.Rx.</u>	<u>%change</u>
FVC	4.10	4.06	99%	4.10	1%
FEV1	3.50 L.	2.27 L.	80%	2.48	17%
FEV1/FVC	83	69			
FEV 25-75	3.54	1.91	54%	2.37	40%

Lung volume

TLC	5.91	6.36	107%		
RV	1.86	2.27	122%		
RV/TLC	32	36			

Diffusion lung capacity Ml/mmHg/Min.

DlCO	20.8	33.3	160%		
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Maximal respiratory pressure Cm H2O

Pimax	118	54	46%		
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<u>Spirometry</u>	<u>Pred.</u>	<u>Best</u>	<u>%pred.</u>	<u>Post.Rx.</u>	<u>%change</u>
FVC	2.54	2.18	84%	2.40	12
FEV1	1.71	1.04	61%	1.20	15
FEV1/FVC	80	65			
FEV25-75	1.39	0.31	23%	0.45	45

Lung Volumes

TLC	4.12	7.05	171%		
RV	1.79	4.51	252%		
RV/TLC	43	64			

Diffusion ml/mmHg/Min.

Dlco	13.1	7.0	53%		
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Maximal Respiratory Pressure CmH2O

PI max.	63	32	51%		
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<u>Spirometry</u>	<u>Pred.</u>	<u>Best</u>	<u>%pred.</u>	<u>Post.Rx.</u>	<u>%change</u>
FVC	2.64	2.10	80%	2.15	2
FEV1	2.09	1.04	49%	1.10	9
FEV1/FVC	87	49			
FEV25-75	1.39	0.31	23%	0.40	16

Lung Volumes

TLC	3.12	6.10	160%		
RV	1.79	3.51	198%		
RV/TLC	43	64			

Diffusion Ml/mmHg/Min.

Dlco	13.1	6.5	45%		
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Maximal Respiratory Pressure CmH2O

PI max.	67	37	51%		
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<u>Spirometry</u>	<u>Pred.</u>	<u>Best</u>	<u>%pred.</u>	<u>Post.Rx.</u>	<u>%change</u>
FVC	2.75	2.38	84%	2.54	5
FEV1	2.25	2.05	76%	2.40	7
FEV1/FVC	86	82			
FEV25-75	1.79	1.31	73%	1.45	15

Lung Volumes

TLC	5.12	4.05	76%		
RV	3.79	3.51	79%		
RV/TLC	61	64			

Diffusion ml/mmHg/Min.

Dlco	19.1	14.0	63%		
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Maximal Respiratory Pressure CmH2O

PI max.	95	89	91%		
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<u>Spirometry</u>	<u>Pred.</u>	<u>Best</u>	<u>%pred.</u>	<u>Post.Rx.</u>	<u>%change</u>
FVC	4.14	4.00	84%	4.10	12
FEV1	3.91	3.74	61%	3.89	15
FEV1/FVC	87	84			
FEV25-75	2.39	2.31	23%	2.45	45

Lung Volumes

TLC	5.82	4.05	60%		
RV	2.99	1.51	52%		
RV/TLC	36	39			

Diffusion ml/mmHg/Min.

Dlco	20.1	19.0	93%		
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Maximal Respiratory Pressure CmH2O

PI max.	96	32	31%		
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<u>Spirometry</u>	<u>Pred.</u>	<u>Best</u>	<u>%pred.</u>	<u>Post.Rx.</u>	<u>%change</u>
FVC	2.54	2.18	84%	2.34	10
FEV1	1.91	1.74	61%	1.89	11
FEV1/FVC	79	82			
FEV25-75	1.59	1.35	70%	1.45	11

Lung Volumes

TLC	6.12	3.05	49%		
RV	2.79	1.51	51%		
RV/TLC	43	39			

Diffusion ml/mmHg/Min

Dlco	13.9	6.5	48%		
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Maximal Respiratory Pressure

PI max.	63	56	91%		
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<u>Spirometry</u>	<u>Pred.</u>	<u>Best</u>	<u>%pred.</u>	<u>Post.Rx.</u>	<u>%change</u>
FVC	2.54	2.18	84%	2.40	12
FEV1	1.71	1.04	61%	1.10	11
FEV1/FVC	84	69			
FEV25-75	1.39	0.31	23%	0.39	13

Lung Volumes

TLC	4.12	4.05	79%		
RV	1.79	1.51	70%		
RV/TLC	38	36			

Diffusion

Dlco	13.1	7.9	59%		
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Maximal Respiratory Pressure

PI max.	63	32	51%		
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