Pulmonary function tests

Pulmonary Function Tests (PFTs)

We will discuss:

1. Spirometry – FEV1 Curve
   i. FEV_1 - Forced expiratory volume in 1 second
   ii. FVC - Forced vital capacity
   iii. FEV_1/FVC ratio of two volumes
2. Spirometry – Flow volume curve or loop
3. Lung volumes
4. Peak Expiratory flow meter (PEFR)
5. Gas transfer
6. Blood gases
7. Pulse oxymetery

Pulmonary Function Tests (PFTs)

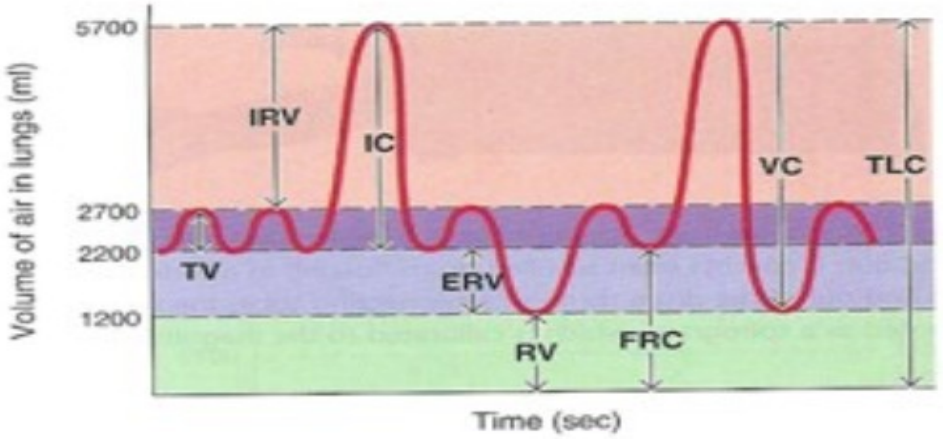
Why we do PFTs?

- PFTs are valuable
  a). In the management of patients with respiratory disease
  b). They aid diagnosis, help monitor response to treatment e.g. in obstructive and restrictive lung disease
  c). They provide important information relating to
    - large and small air ways
    - pulmonary parenchyma and
    - pulmonary capillary bed

- **Important** – The interpretation of PFTs requires knowledge of respiratory physiology

Pulmonary Function Tests (PFTs)

Graph lung volume and capacities (Basic knowledge)



KEY

TV	= Tidal volume (500 ml)
IRV	= Inspiratory reserve volume (3000 ml)
IC	= Inspiratory capacity (3500 ml)
ERV	= Expiratory reserve volume (1000 ml)
RV	= Residual volume (1200 ml)
FRC	= Functional residual capacity (2200 ml)
VC	= Vital capacity (4500 ml)
TLC	= Total lung capacity (5700 ml)

(b) Normal spirogram of a healthy young adult male

FIGURE 13-18 Variations in lung volume in a healthy young adult male. Values for females are somewhat lower. (Note that residual volume cannot be measured with a spirometer but must be determined by another means.)

Pulmonary Function Tests (PFTs)

- We will define lung volumes and capacities, so that we can understand these terms, which are measured during lung function testing:

1. Tidal Volume (VT) : It is the volume of air we breathe in or breathe out with single breath at rest.
2. Inspiratory reserve volume (IRV) : It is the amount of air that we breathe in forcefully after normal inspiration.
3. Expiratory reserve volume (ERV) : It is the amount of air that can be exhaled forcefully after normal tidal expiration.
4. Residual Volume (RV) : It is the air remaining in the lungs after forceful expiration.

Pulmonary Function Tests (PFTs)

5. Vital capacity (VC) : It is the maximum amount of air that can be exhaled forcefully after maximum inspiration
6. Inspiratory capacity (IC) : It is maximum amount of air inhaled after normal expiration. It includes tidal volume and inspiratory reserve volume.
7. Functional residual capacity (FRC) : It is the amount of air left in the lungs after normal expiration.
8. Total Lung capacity (TLC) : It is maximum amount of air that lungs can hold.

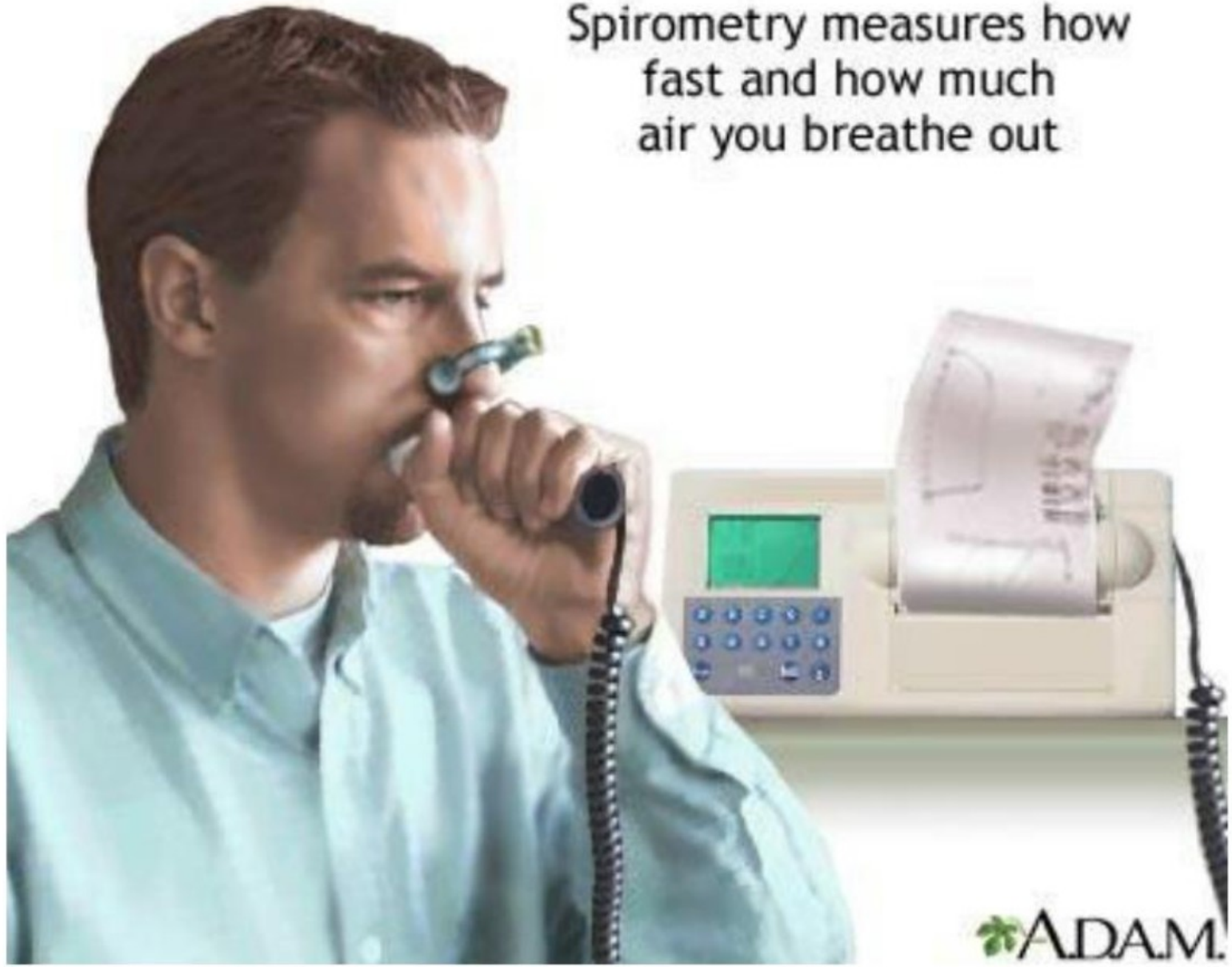
Pulmonary Function Tests (PFTs)

1. Spirometry

- These test mainly assess the degree of air flow limitation during expiration

FEV_1 curve

- The patient takes the maximum inspiration, followed by forced expiration and continues expiration as long as possible in the spirometer.
- The spirometer measures the 1 second expiratory volume (FEV_1) and forced vital capacity (FVC)
- **In normal healthy person, FEV_1 is about 4 liters, FVC is 5 liters and FEV_1/FVC ratio 75% to 80%**


Spirometry measures how
fast and how much
air you breathe out
A.D.A.M.

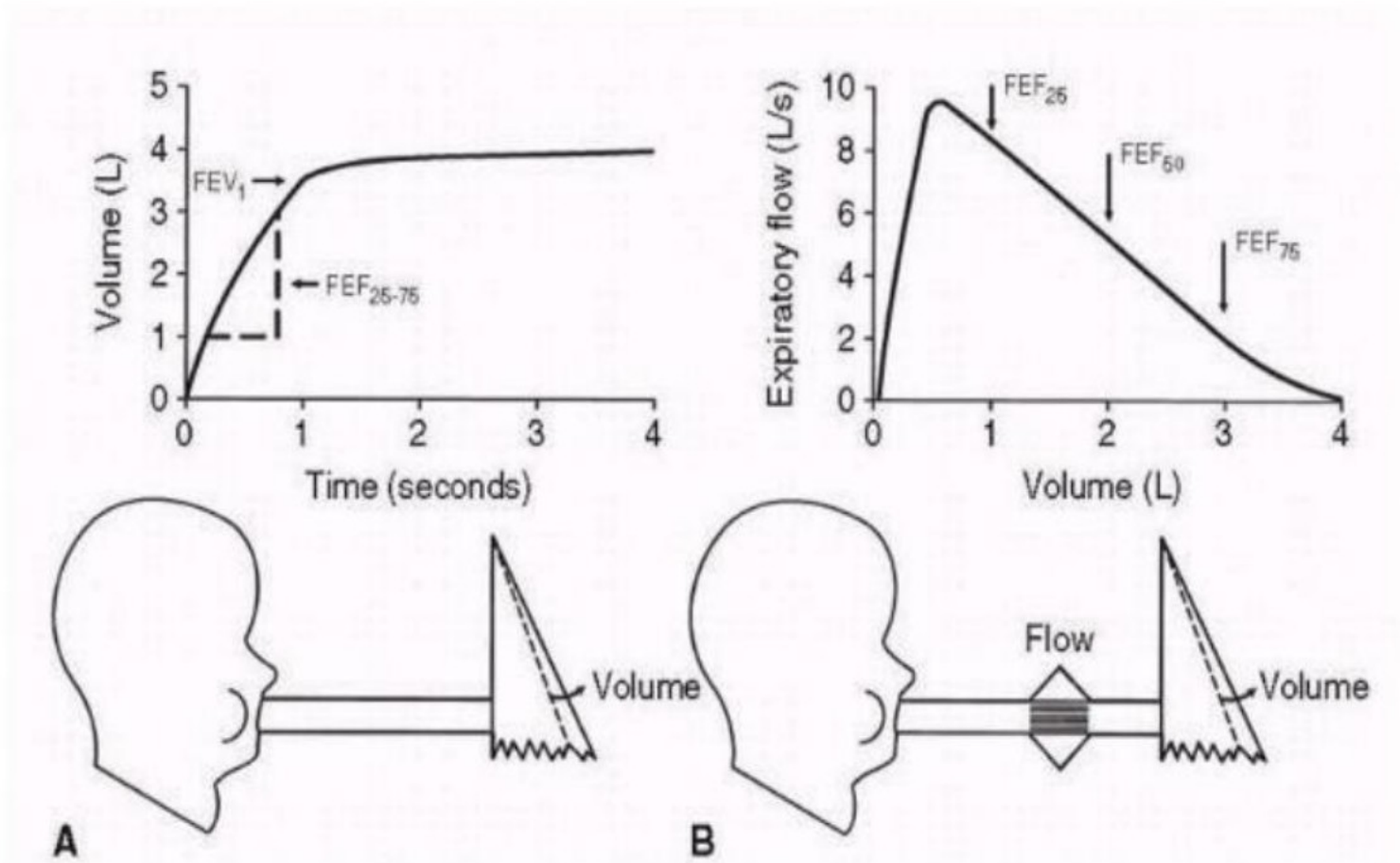


FIG. 2-1. The two ways to record the forced vital capacity (FVC) maneuver. **A.** Volume recorded as a function of time, the spirogram. FEV_1, forced expiratory volume in 1 second; FEF_{25-75}, average forced expiratory flow rate over the middle 50% of the FVC. **B.** Flow recorded as a function of volume exhaled, the flow-volume curve. $FEF_{25(50,75)}$, forced expiratory flow after 25% (50%, 75%) of the FVC has been exhaled.

Pulmonary Function Tests (PFTs)

FEV_1 curve – normal

FEV_1 = 4 liter
FVC = 5 liter
FEV_1/FVC % = 80%

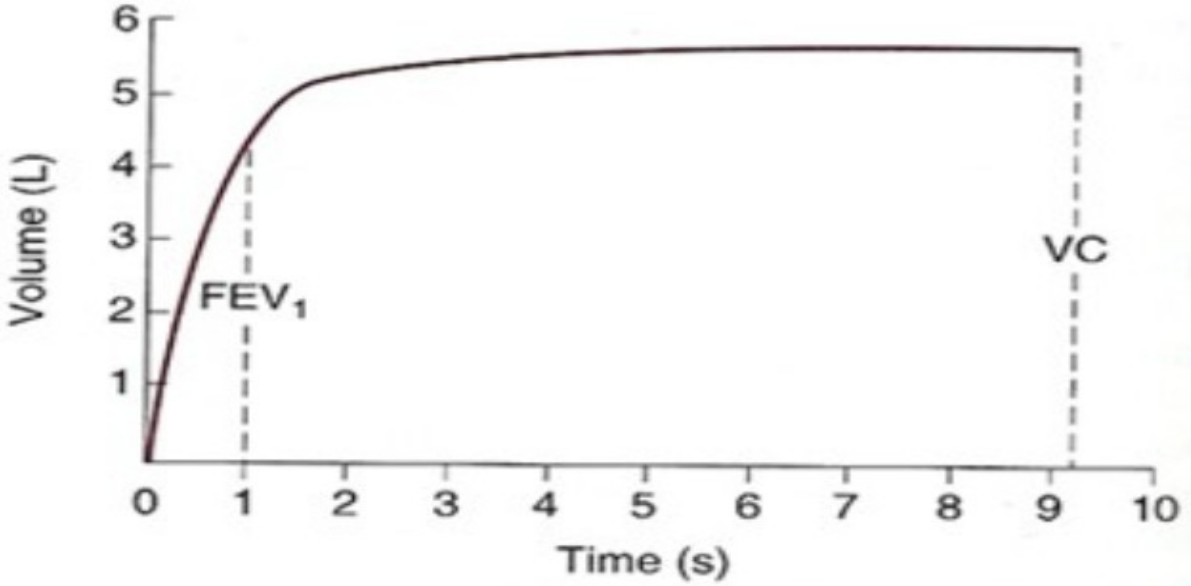
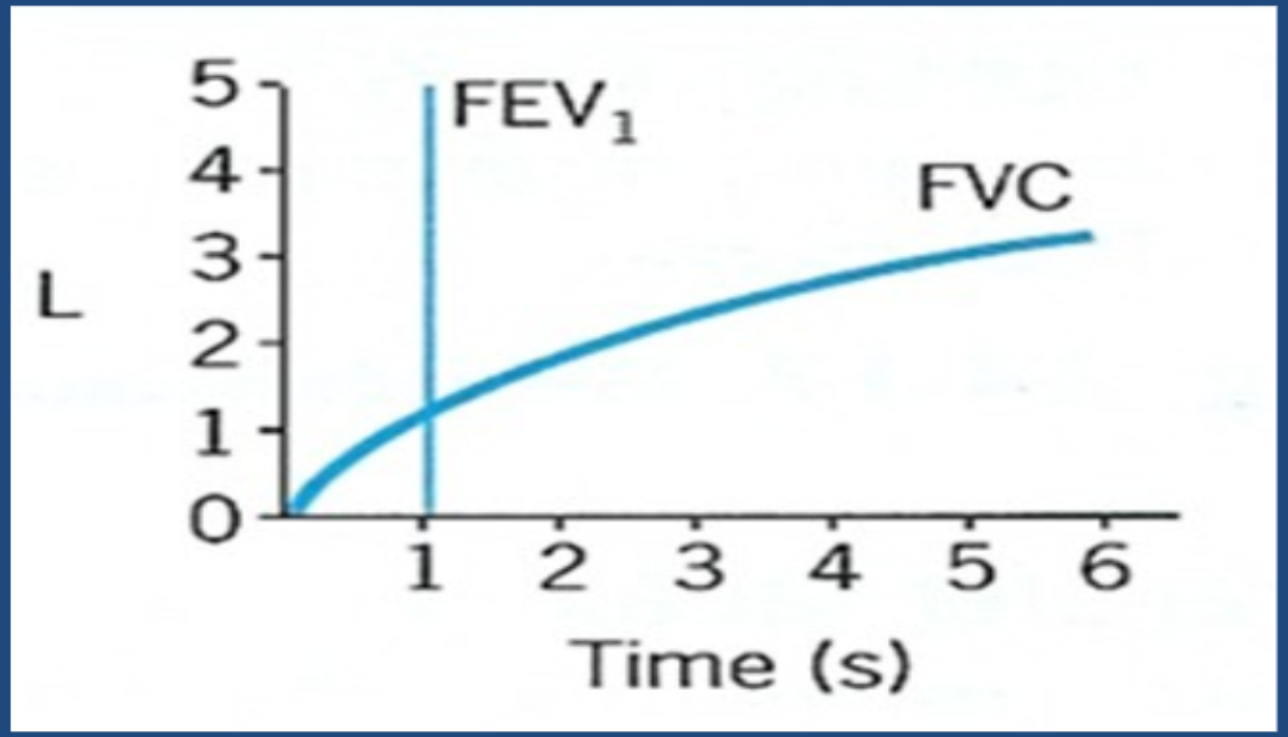


Figure 34–8. Volume of gas expired by a normal adult man during a forced expiration, demonstrating the FEV_1 and the total vital capacity (VC).

Pulmonary Function Tests (PFTs)

- FEV_1 curve in Obstructive lung disease e.g. bronchial asthma, COPD



FEV_1 = 1.3
FVC = 3.2
FEV_1 % = (FEV_1/FVC) × 100
= (1.3/3.2) × 100
= 41 %

Pulmonary Function Tests (PFTs)

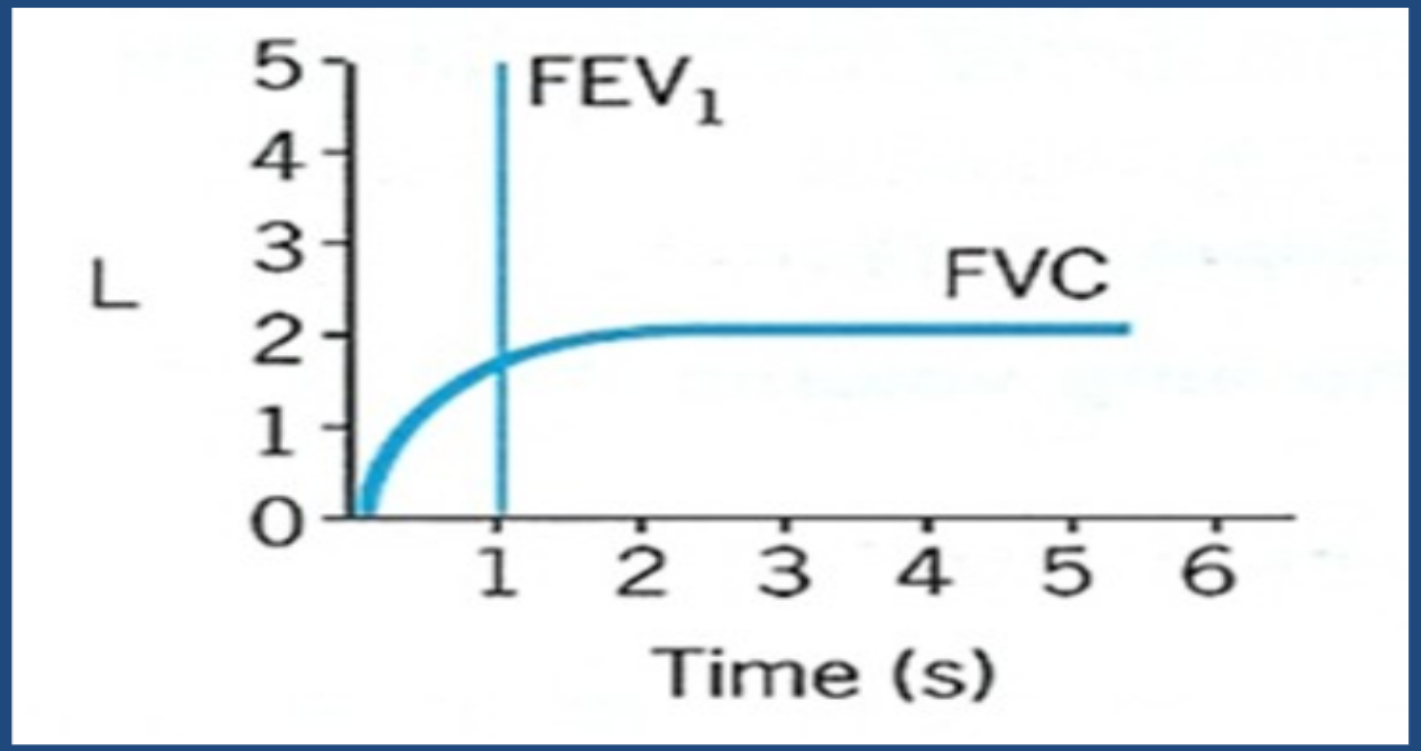
- In Chronic air flow limitation e.g. COPD, Bronchial asthma
  - FVC is slightly reduced
  - FEV_1 is markedly reduced
  - FEV_1/FVC ratio is decreased

  - TLC is usually increased

  - FEV_1/FVC ratio when
    - > 75% Normal
    - 60-75% mild obstruction
    - 50-60% moderate obstruction
    - 30- 50% sever obstruction
    - below 30% very severe obstruction

Pulmonary Function Tests (PFTs)

- FEV_1 curve in Restrictive Lung Disease e.g. Pulmonary fibrosis



FEV_1 = 1.7
FVC = 2
FEV_1 % = (FEV_1/FVC) × 100
= (1.7/2) × 100
= 85 %

Pulmonary Function Tests (PFTs)

- In Restrictive lung disease, e.g. Pulmonary fibrosis
  - FVC is decreased
  - FEV_1 is decreased
  - FEV_1/FVC ratio is normal or increased

  - TLC is decreased

Please Note - We get Restrictive type of FEV_1 curve also in pleural, chest wall and Neuromuscular disease.

Pulmonary Function Tests (PFTs)

2. Spirometry - Flow volume curve or loop

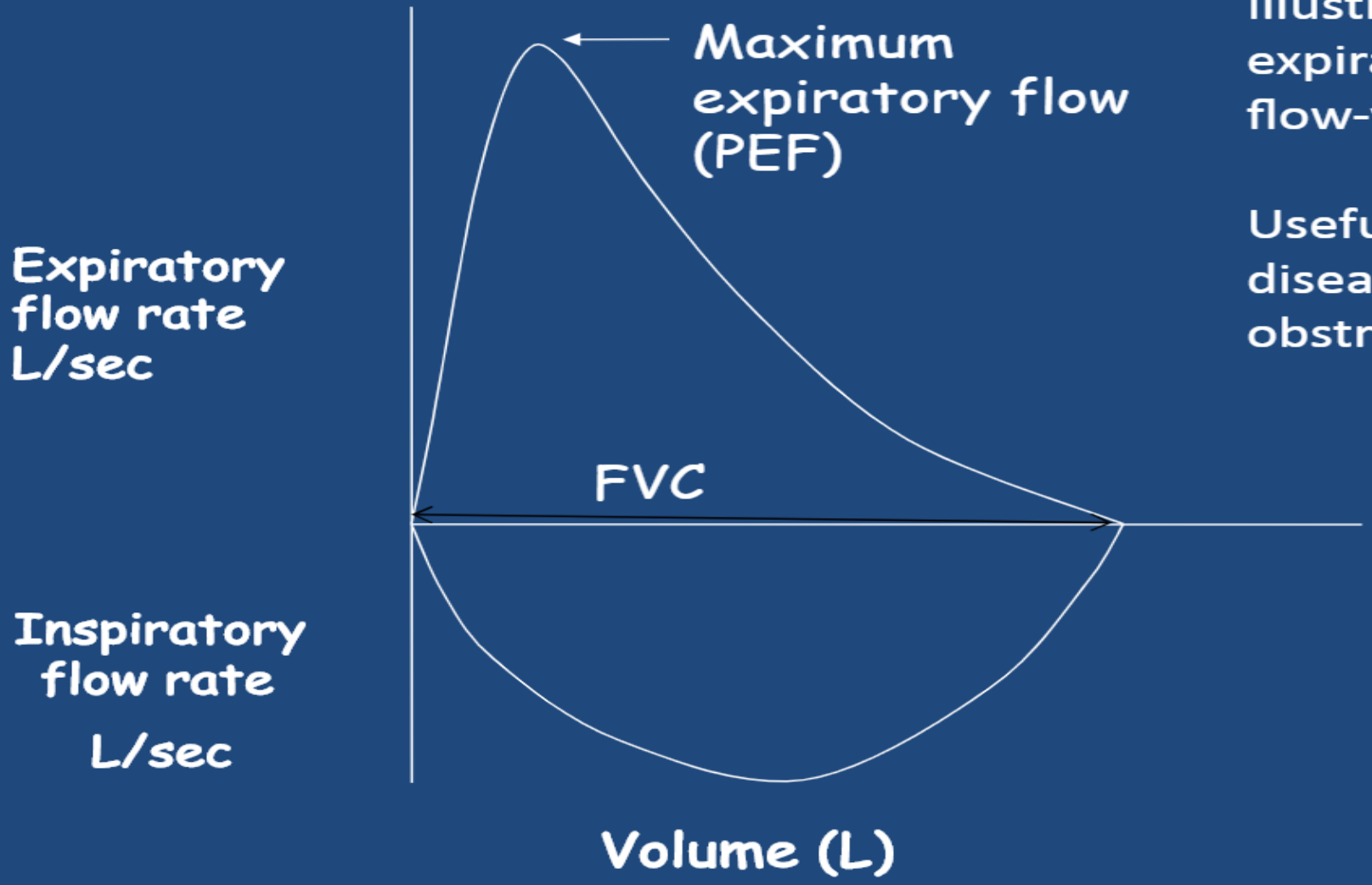
- We plot flow rates against expired volumes
- On x-axis – Volume
- On y-axis – Flow rate
- Method : Subject takes maximum inspiration first then he expires forcefully in the spirometer
- **When subject expires ,maximum resistance is from large air ways initially, then flow rate is dependent on small air way resistance**

Pulmonary Function Tests (PFTs)

2. Flow volume curve or loop

- In COPD, smaller air ways are mainly affected.
- Flow volume changes can be seen when large air way obstruction is there e.g. Large Bronchi, tracheal narrowing due to stenosis or tumors.

Normal Flow Volume Curve



Illustrates maximum expiratory and inspiratory flow-volume curves

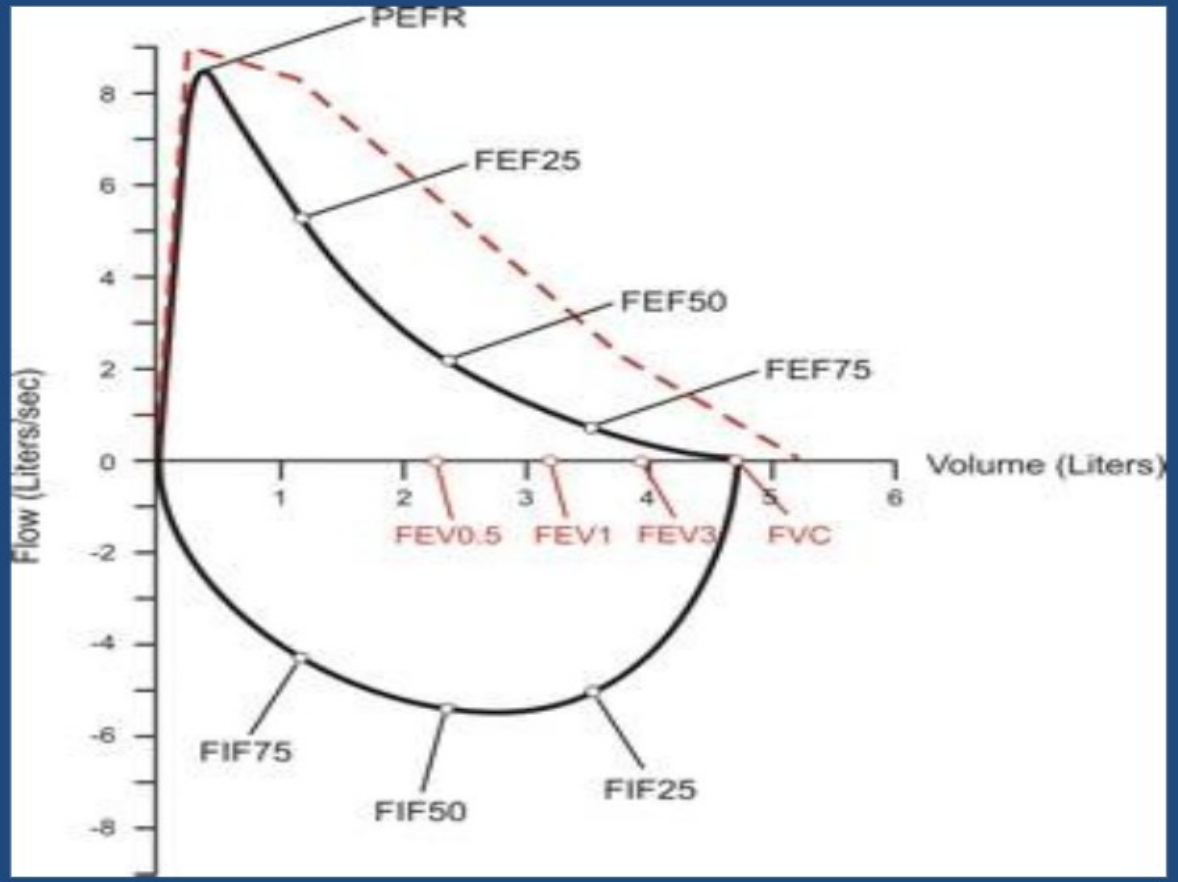
Useful to help characterize disease states (e.g. obstructive vs. restrictive)

Pulmonary Function Tests (PFTs)

- Flow volume curve in Bronchial asthma

Note – Expiratory curve gets concave and FEF50 is Reduced

FEF50 - Forced expiratory flow at 50% of FVC



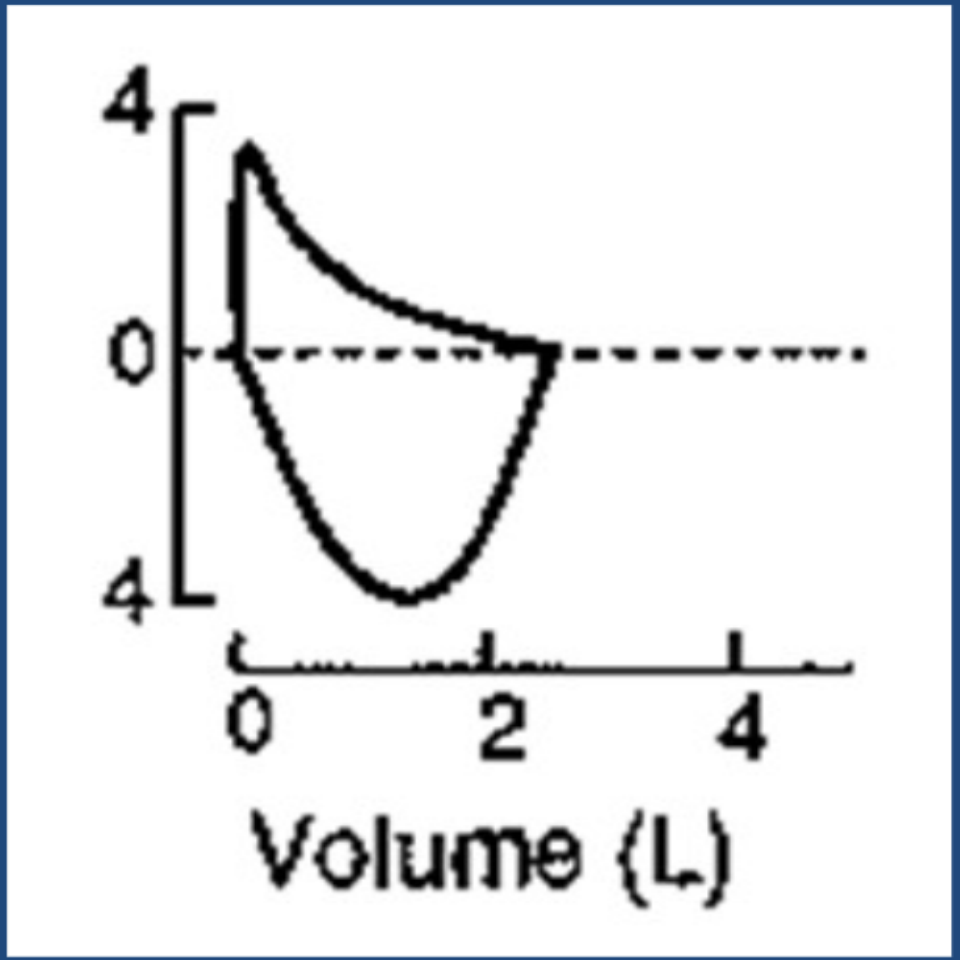
Flow volume curve in obstructive lung disease e.g. Bronchial Asthma

Pulmonary Function Tests (PFTs)

- Flow volume curve in COPD

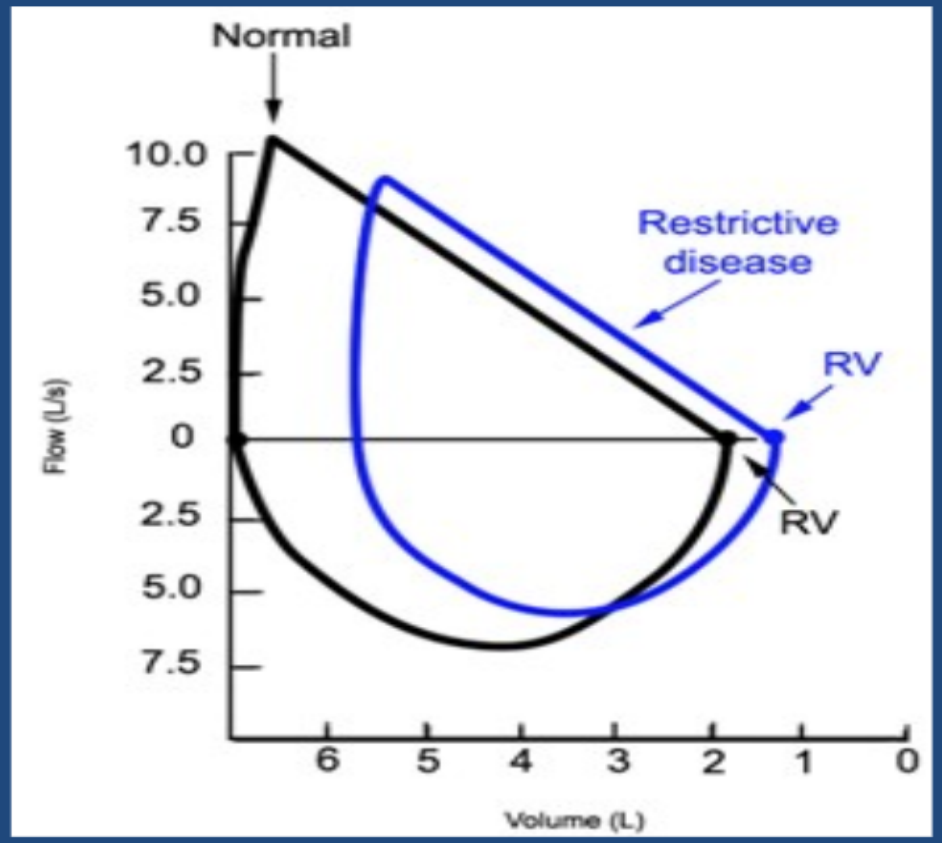
Note – Expiratory curve gets concave and FEF50 is Reduced

FEF50 - Forced expiratory flow at 50% of FVC



Pulmonary Function Tests (PFTs)

- Flow Volume Loop in Restrictive Lung Disease

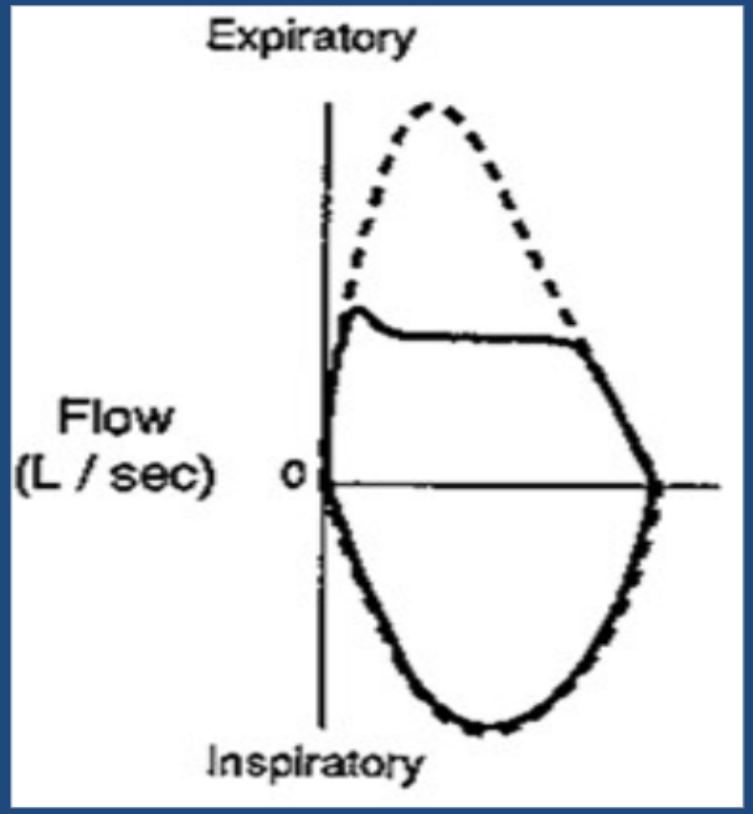


- Characterized by diminished lung volume due to:
  - —change in alteration in lung parenchyma (interstitial lung disease)
  - —disease of pleura, chest wall (e.g. scoliosis), or neuromuscular apparatus (e.g. muscular dystrophy)
- Decreased TLC, FVC
- Shape of the curve is like normal but it is small

Pulmonary Function Tests (PFTs)

Note – Large airway obstruction
e.g. Carcinoma Bronchus

Expiratory loop is truncated



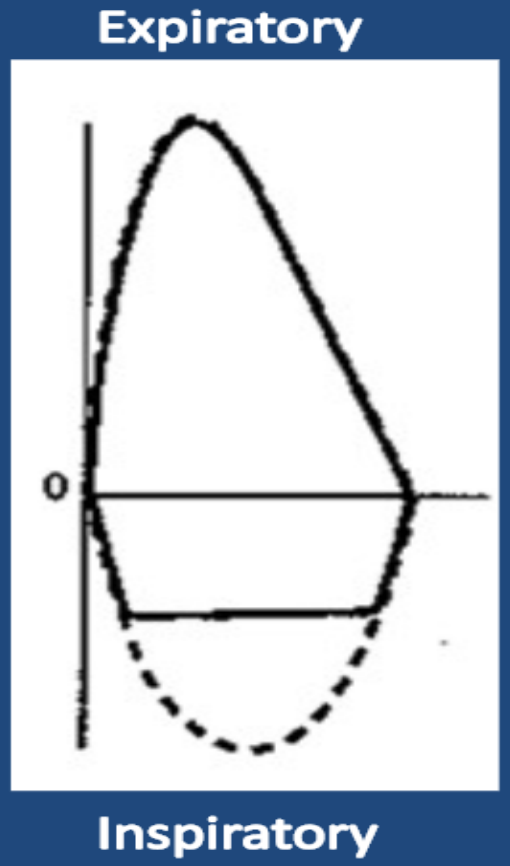
Flow volume curve seen with intra-thoracic large airway obstruction.

Pulmonary Function Tests (PFTs)

- Flow volume loop in extra thoracic obstruction e.g. vocal cord paralysis

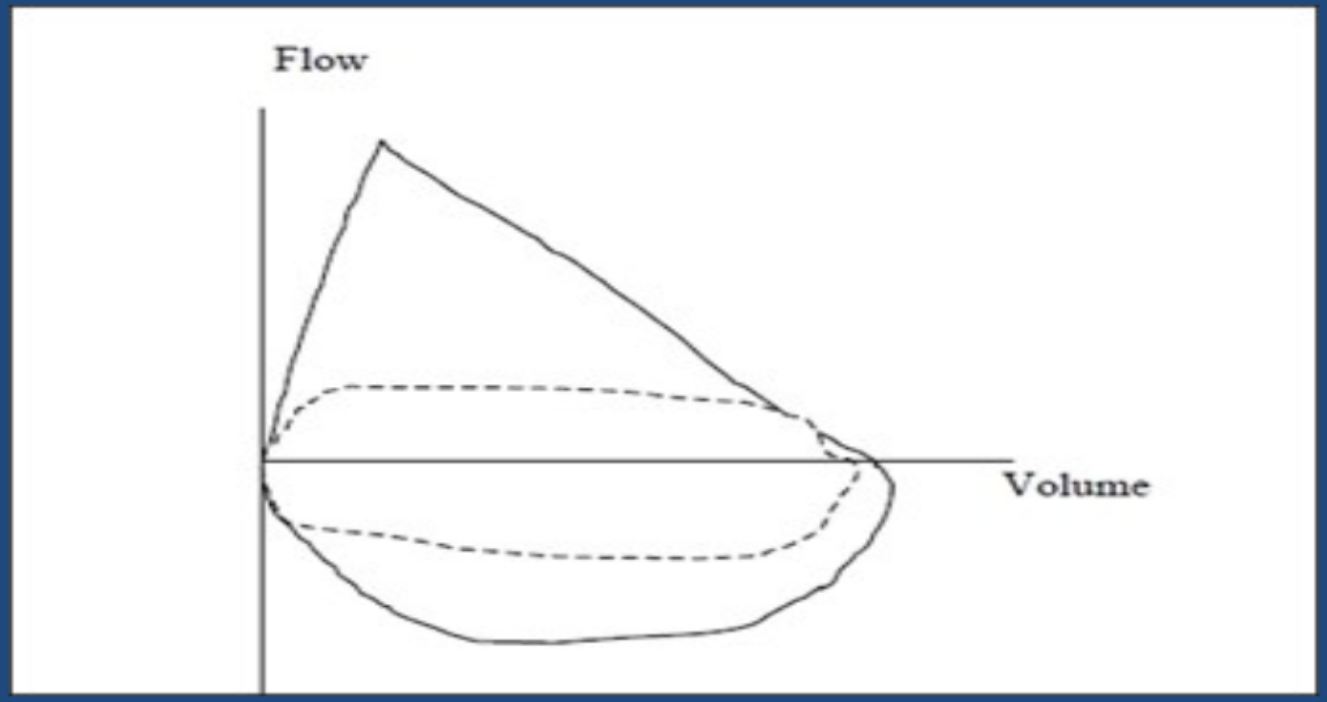
Note – Extra thoracic obstruction
e.g. vocal cord paralysis

Inspiratory loop is truncated



Pulmonary Function Tests (PFTs)

Note – Fixed Extra thoracic obstruction
e.g. tracheal stenosis
Both inspiratory and expiratory loop are truncated

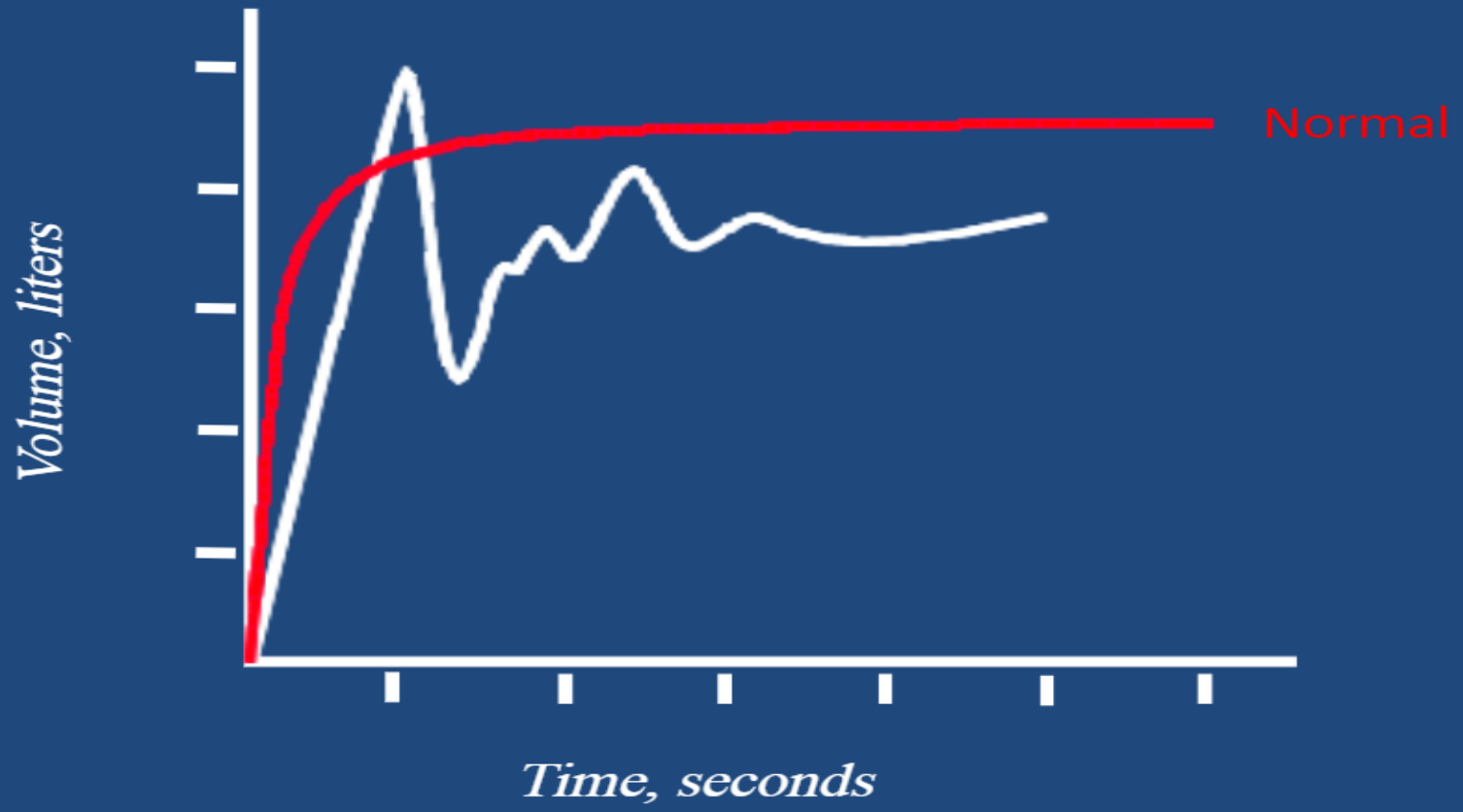


Flow volume curve

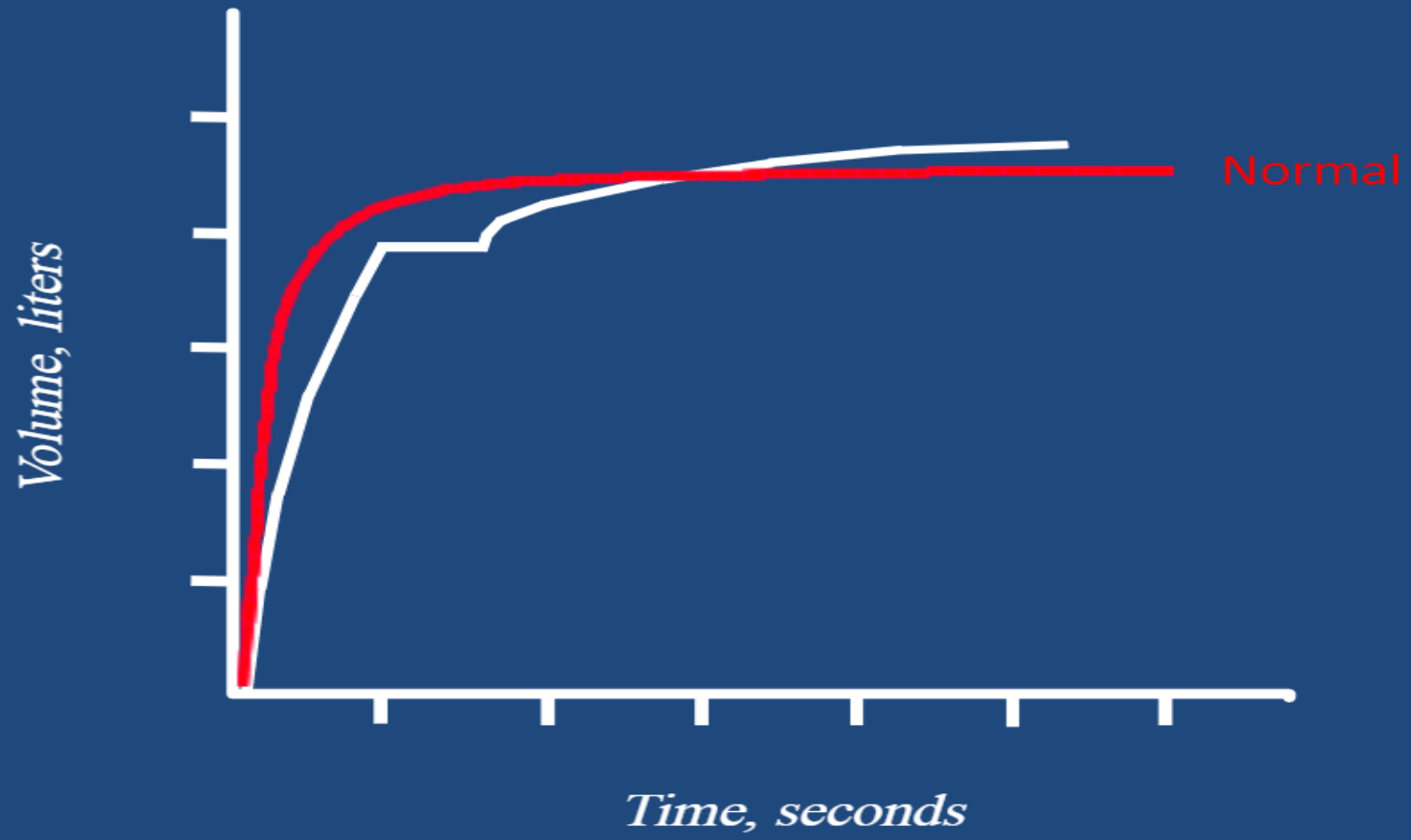
Troubleshooting

Examples - Unacceptable Traces

Unacceptable Trace - Coughing



Unacceptable Trace – Extra Breath



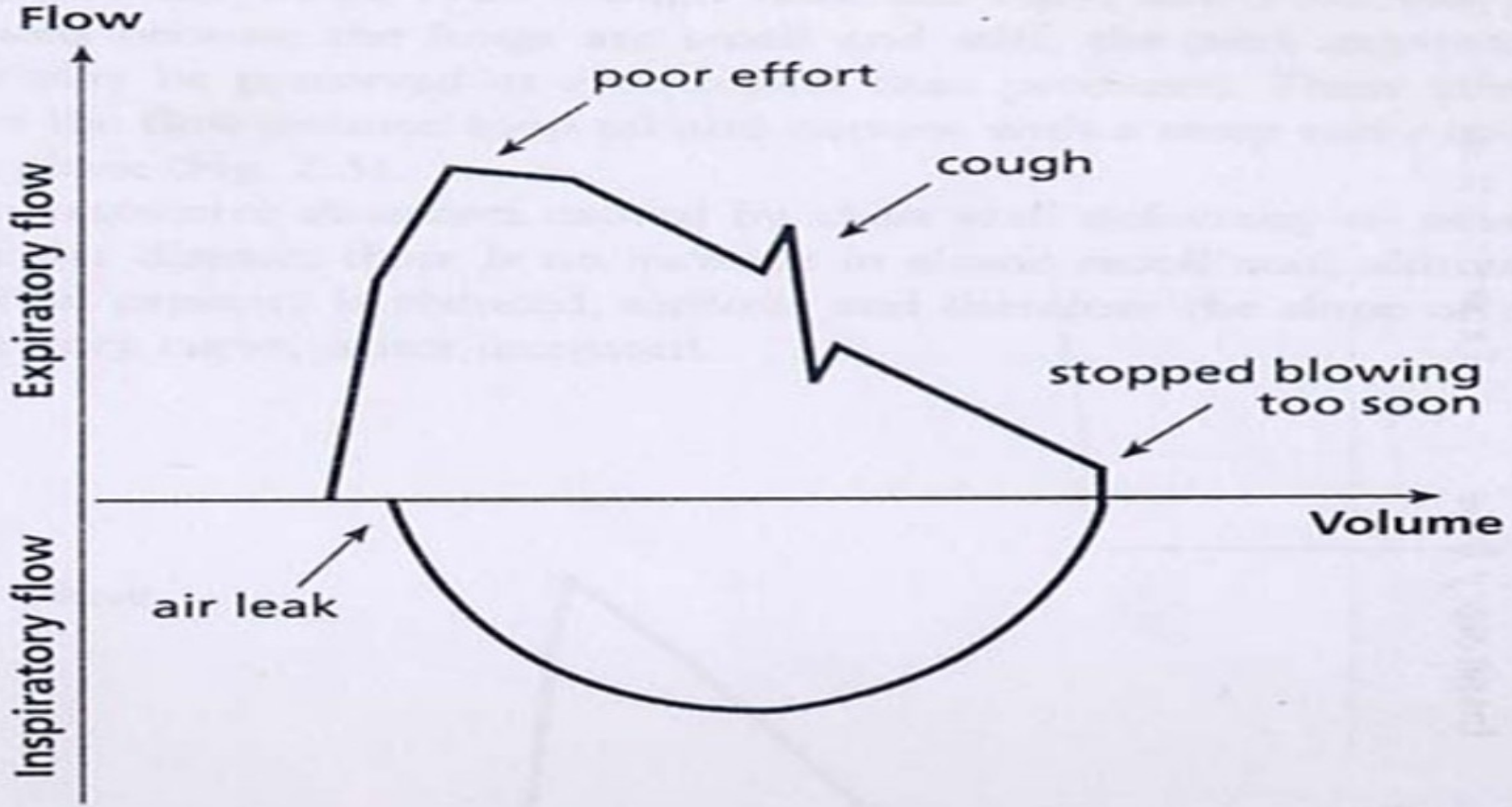


Figure 2.3 Errors identified by flow-volume loops

Pulmonary Function Tests (PFTs)

4. Peak Expiratory flow meter (PEFR)

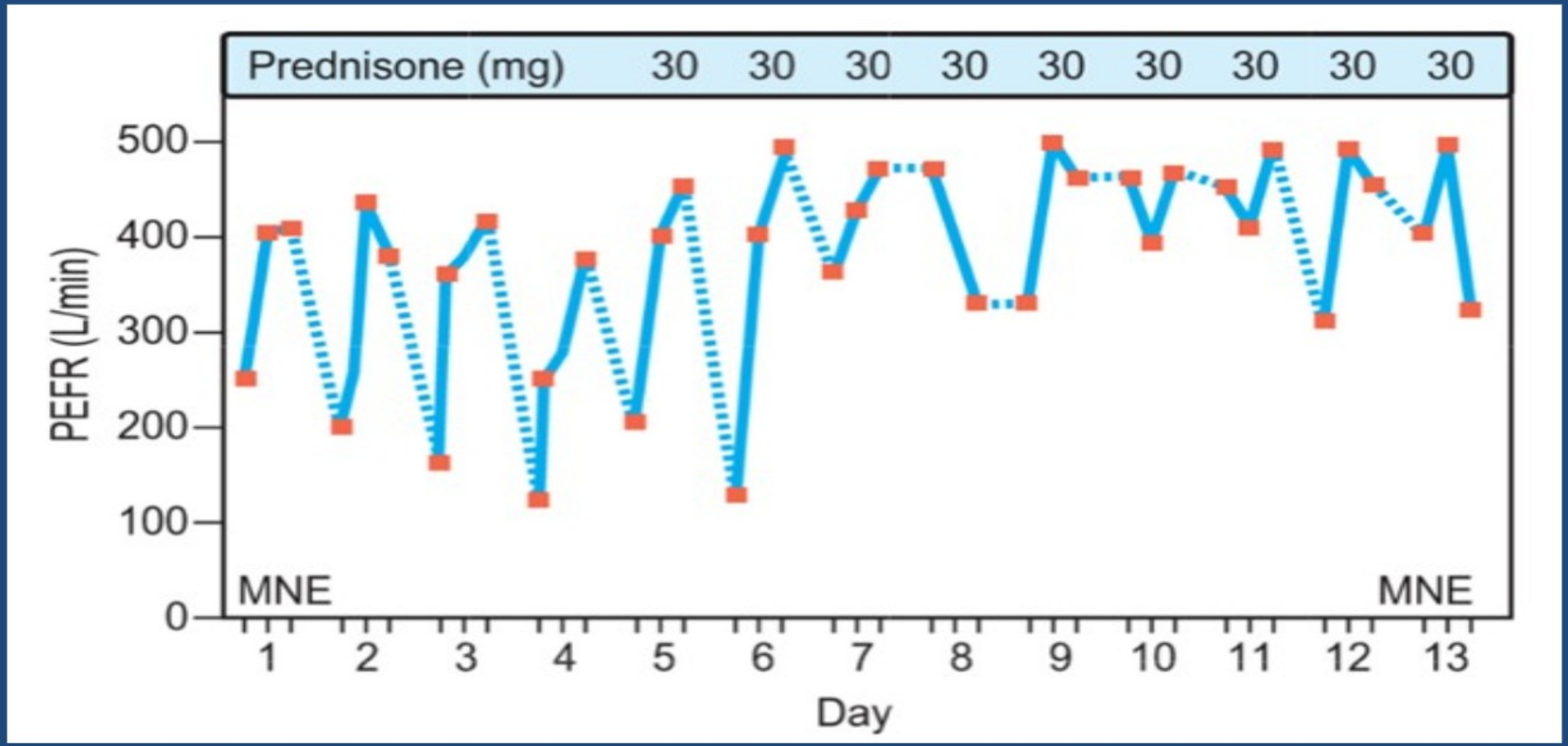
- This is very simple and cheap test, can be used by patient at home to monitor
- Subject takes a deep inspiration and then blows out forcefully into the peak flow meter

Flow meter

Pulmonary Function Tests (PFTs)

- **PEFR is mainly used to diagnose Bronchial Asthma and to monitor exacerbation of Asthma and response to treatment.**
- Measurements of Peak Flow Rates are done on waking, at afternoon and before going to bed and demonstrate diurnal variations in airflow limitations in Asthma and response to treatment.

PFTS


Prednisone (mg) 30 30 30 30 30 30 30 30 30
PEFR (L/min)
500
400
300
200
100
0
MNE
MNE
1 2 3 4 5 6 7 8 9 10 11 12 13
Day

Predicted average peak expiratory flow for normal males (L/min)

Age	Height				
	60 inches/152 cm	65 inches/165 cm	70 inches/178 cm	75 inches/191 cm	80 inches/203 cm
20	554	602	649	693	740
25	543	590	636	679	725
30	532	577	622	664	710
35	521	565	609	651	695
40	509	552	596	636	680
45	498	540	583	622	665
50	486	527	569	607	649
55	475	515	556	593	634
60	463	502	542	578	618
65	452	490	529	564	603
70	440	477	515	550	587

These values represent average normal values within 100 L/min. Predicted values for African American and Hispanic minorities are approximately 10 percent lower.

Redrawn from: Leiner GC, et al, Am Rev Respir Dis 1963; 88:644.

Predicted average peak expiratory flow for normal females (L/min)

Age	Height				
	55 inches/140 cm	60 inches/152 cm	65 inches/165 cm	70 inches/178 cm	75 inches/190 cm
20	390	423	460	496	529
25	385	418	454	490	523
30	380	413	448	483	516
35	375	408	442	476	509
40	370	402	436	470	502
45	365	397	430	464	495
50	360	391	424	457	488
55	355	386	418	451	482
60	350	380	412	445	475
65	345	375	406	439	468
70	340	369	400	432	461

These values represent average normal values within 80 L/min. Predicted values for African American and Hispanic minorities are approximately 10 percent lower.

Redrawn from: Leiner GC, et al, Am Rev Respir Dis 1963; 88:644.

Pulmonary Function Tests (PFTs)

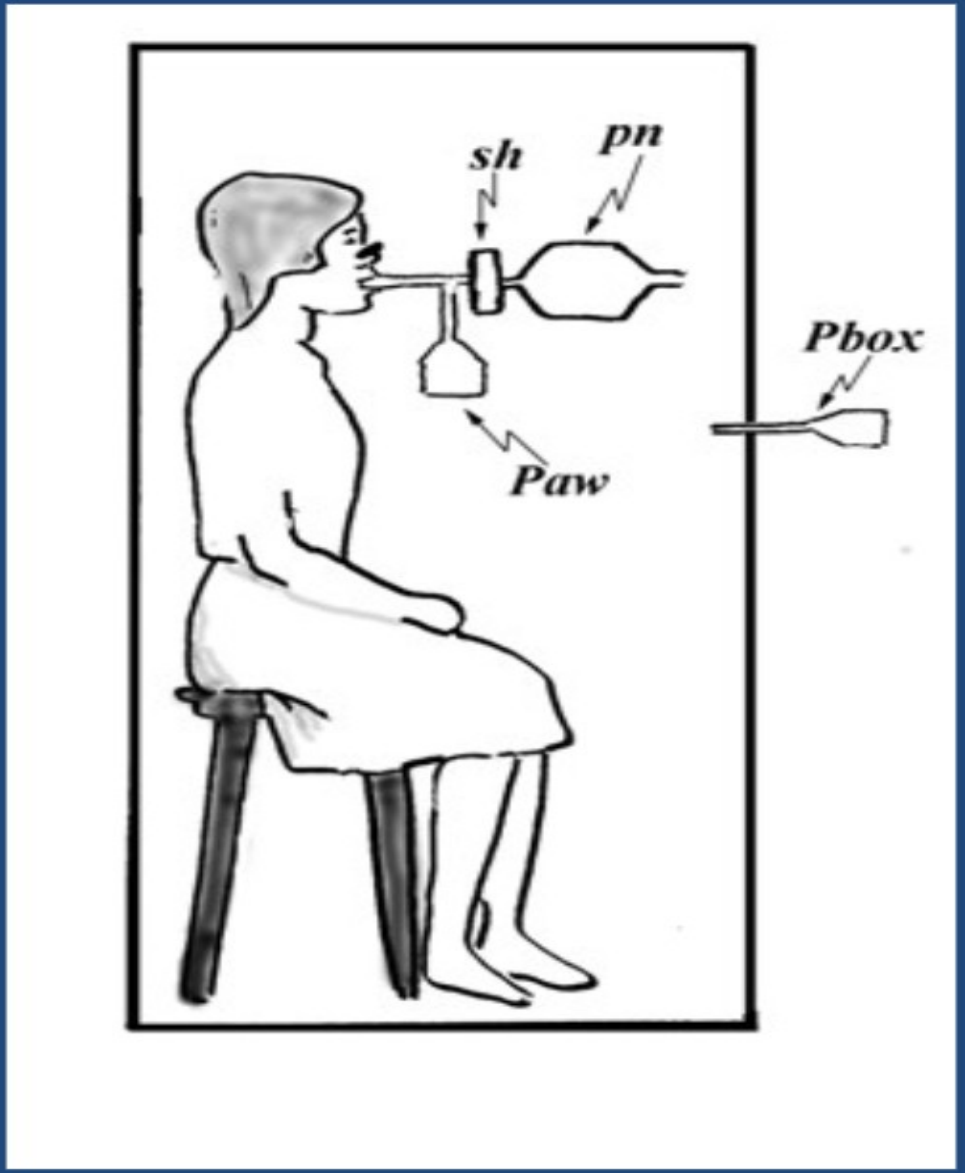
3. Lung Volumes

- Lung Volumes and Capacities can be measured by Simple Spirometry.
- We can measure TV, IRV, ERV but we can not measure Residual volume by Simple Spirometry.

LUNG CAPACITIES

- We can measure VC, IC but we can not measure FRC and TLC by simple Spirometry.
- **IMPORTANT- TLC, RV, FRC can be measured by using Helium dilution method and Body plethysmography.**

Lung Volume and Capacities



Body plethysmography for measurements of absolute lung volume. The subject is sitting in an airtight box ("body box"), breathing through a pneumotachograph

Pulmonary Function Tests (PFTs)

5. Gas Transfer (DLCO – Diffusion lung capacity for carbon monoxide)

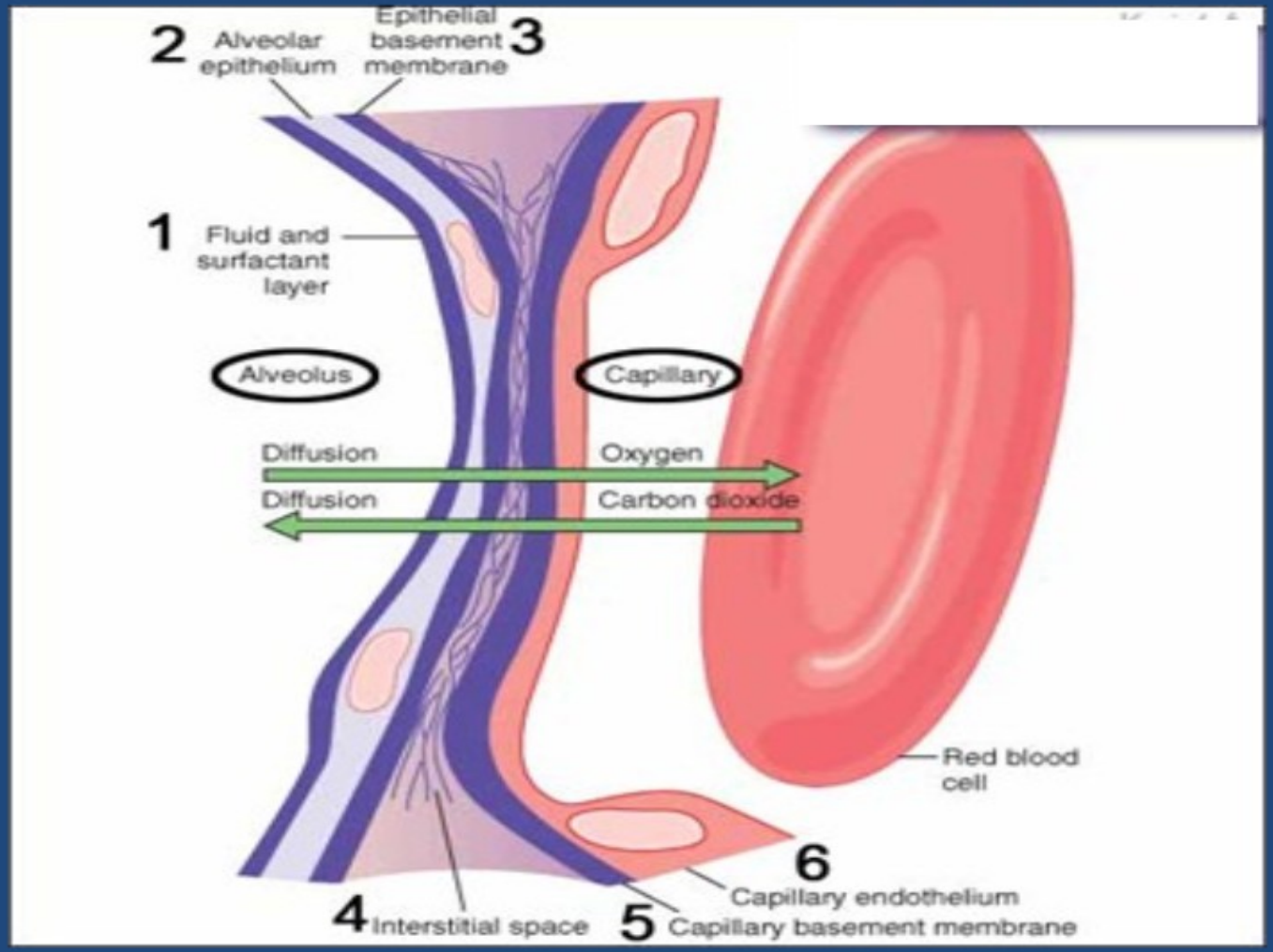
- To measure the gas transfer across the alveolar capillary membrane, carbon monoxide (CO) is used . Why?

➢ Because its diffusion rate is similar to O_2

- Transfer factor, therefore, reflects the diffusion capacity of lungs for O_2 and depends on thickness of Alveolar- Capillary membrane.

Pulmonary Function Tests (PFTs)

- Alveolar capillary membrane consists of



Pulmonary Function Tests (PFTs)

- Gas Transfer (DLCO)is **REDUCED** in following conditions
  - Emphysema , COPD
  - Pulmonary fibrosis
  - Heart failure
  - Anaemia
  - Sarcoidosis
  - Asbestosis

- Gas Transfer (DLCO)is **INCREASED** in
  - Bronchial asthma (may be normal or increased)
  - Pulmonary hemorrhage
  - Polycythemia

Pulmonary Function Tests (PFTs)

6. Measurement of Blood Gases

- Measurement of PO_2 and PCO_2 in the arterial blood is essential in managing Respiratory failure and severe asthma.
- Repeated measurement are required, which are best guide to therapy.

Arterial blood

- Normal PO_2 is 10.6-13.3 kPa (80-100mmHg)
- Normal PCO_2 is 4.8-6.1 kPa (36-46mmHg)

Pulmonary Function Tests (PFTs)

7. Pulse Oxymetery

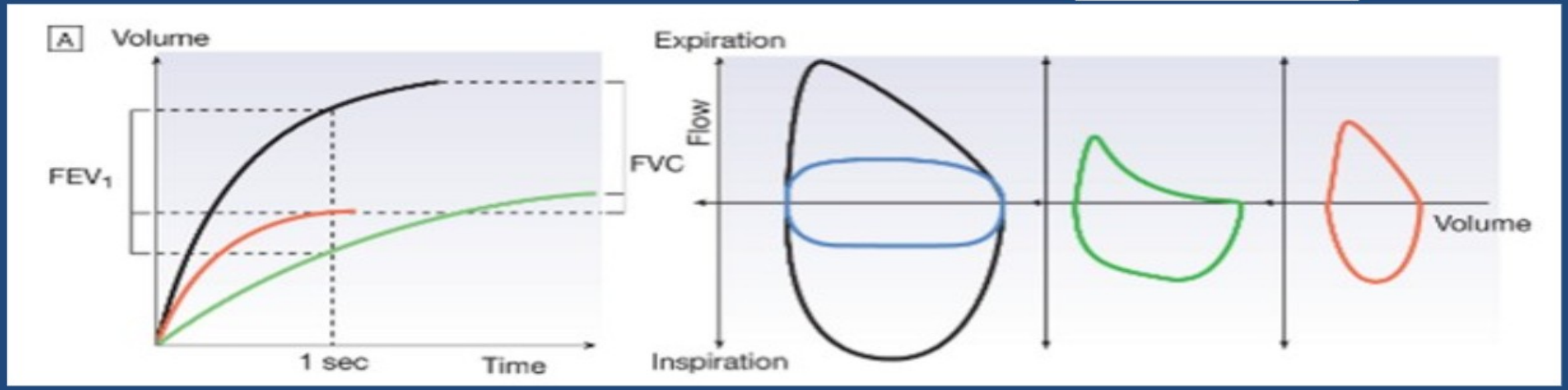
- Peripheral oxygen saturation (SpO_2) can be continuously measured using oximeter with finger probes. Normal SpO2 is 95-100%
- It is now essential part of routine monitoring of patients in hospitals and clinics

Pulmonary Function Tests (PFTs)

Summary

Pulmonary Function Tests (PFTs)

Summary



FEV_1 Curve

Flow Volume Loop

Summary (cont)

19.4 How to interpret respiratory function abnormalities

	Asthma	Chronic bronchitis	Emphysema	Pulmonary fibrosis
FEV_1	↓↓	↓↓	↓↓	↓
VC	↓	↓	↓	↓↓
FEV_1/VC	↓	↓	↓	→/↑
TL_{CO}	→	→	↓↓	↓↓
K_{CO}	→/↑	→	↓	–/↓
TLC	→/↑	↑	↑↑	↓
RV	→/↑	↑	↑↑	↓

(RV = residual volume; see text for other abbreviations)