3. THE PULMONARY FUNCTION SYSTEM

PULMONARY FUNCTION MEASUREMENT:

Three basic types of measurements are made in pulmonary clinic: ventilation, distribution and diffusion.

VENTILATION: This is performed using device called a spirometer that measure volume displacement and amount of gas moved in a specific time. Usually this requires the patient to take a deep breath and then exhale as a rapidly and completely as possible. Called the forced vital capacity, this gives an indication of how much air can be moved by the lungs and how freely this air flows.

DISTRIBUTION: measurement quantity degrees of lung obstruction and also determine the residual volume, which is the amount of air that cannot be removed from the lungs by the patients effort.

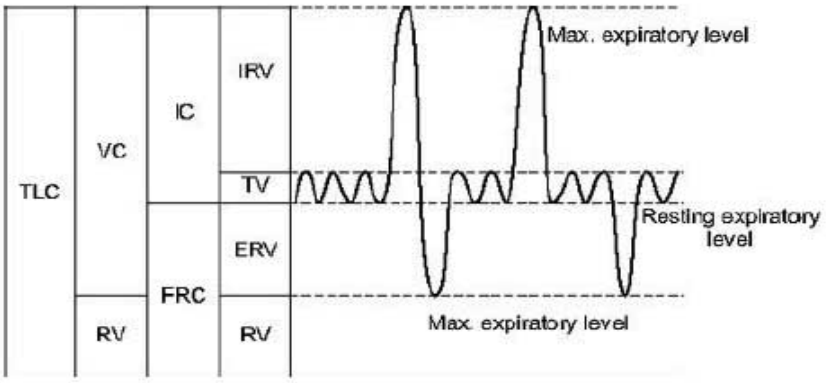
DIFFUSION: Measurements identify the rate at which gas is exchanged with the blood stream.

The pulmonary function can be assessed by means of two major classes of tests. These are:

(i) Evaluation of the mechanical aspects of pulmonary function, which affects the bulk gas transport into and out of the lungs.

(ii) Evaluation of gas exchange or diffusion at the alveoli.

The ability of the pulmonary system to move air and exchange oxygen and carbon dioxide is affected by the various components of the air passages, the diaphragm, the rib cage and its associated muscles and by the characteristics of the lung tissue itself. Among the basic tests performed are those to determine the volumes and capacities of the respiratory system. These are defined as follows in Figure below:



➤ **Fig. 13.1** ***Volume and capacities of the lungs — standardisation of definiti respiratory physiology***

THE RESPIRATORY SYSTEM

The primary functions of the respiratory system are to oxygenate the blood; that is to dissolve oxygen into the blood; also to remove carbon dioxide from the blood. If the blood is not oxygenated sufficiently due to failure of the circulatory system, then the oxygen content of the blood decreases rapidly. After 60 to 90 minutes, the subject will become unconscious, death occurring in 4 to 5 minutes.

- **Inspiratory reserve volume** (IRV) is the maximum additional volume that can be accommodated by the lung at the end of inspiration.
- **Expiratory reserve volume** (ERV). Maximum additional expiration, as measured from lung volume at the end of expiration.
- **Residual volume** (RV) is the amount of gas remaining in the lungs at the end of maximal expiration.
- **Total lung capacity** (TLC): The amount of gas contained in the lung at the end of maximal inspiration.
- **Vital capacity** (VC): The maximal volume of gas that can be forcefully expelled after maximal inspiration.
- **Inspiratory capacity** (IC): The maximal volume of gas that can be inspired from the resting expiratory level
- **Tidal volume** (TV) is normally considered to be the volume of air entering the nose and mouth with each breath.

- **Alveolar ventilation volume**, the volume of fresh air that enters the alveoli during each breath, is always less than tidal volume
- **Functional residual capacity** (FRC): The volume of gas remaining after normal expiration. It will be noted that functional residual capacity (FRC) is the same as the resting volume.
- **Dead space** is the functional volume of the lung that does not participate in gas exchange.

SPIROMETRY

- The instrument used to measure lung capacity and volume is called a *spirometer.* Basically, the record obtained from this device is called a *spirogram.*
- Spirometers are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired.
- By adding a time base, flow-dependent quantities can be measured. The addition of gas analyzers makes the spirometer a complete pulmonary function testing laboratory.
- There are two basic classes of spirometers: *laboratory units*, which are either desktop consoles or cabinet-size machines operated by trained technicians; and *portable spirometers*, which are either compact desktop units or handheld devices intended for general-practice and home use.

Basic Spirometer

Most of the respiratory measurements can be adequately carried out by the classic water-sealed spirometer (Fig. 2). This consists of an *upright, water filled cylinder containing an inverted counter weighted bell.* Breathing into the bell changes the volume of gases trapped inside, and the change in volume is translated into vertical motion, which is recorded on the moving drum of a Kymograph.

The excursion of the bell will be proportional to the tidal volume. For most purposes, the bell has a capacity of the order of 6-8 litter. Unless a special light weight bell is provided, the normal spirometer is only capable of responding fully to slow respiratory rates and not to rapid breathing, sometimes encountered after anesthesia.

Also, the frequency response of a spirometer must be adequate for the measurement of the forced expiratory volume. The instrument should have no hysteresis, i.e. the same volume should be reached whether the spirometer is being filled or being emptied to that volume.

As the water-sealed spirometer includes moving masses in the form of the bell and counterweights, this leads to the usual problems of inertia and possible oscillation of the bell. This can lead to an over-estimation of the expiratory volume. A suggested compensation is by the use of a spirometer bell having a large diameter and which fits closely over the central core of the spirometer, so that the area of water covered by the bell is small in relation to that of the water tank. If the spirometer is used for time-dependent parameters, then it must also have a fast response time, with a flat frequency response up to 12 Hz. This requirement applies not only to the spirometer, but also to the recorder used in conjunction with the recording device.

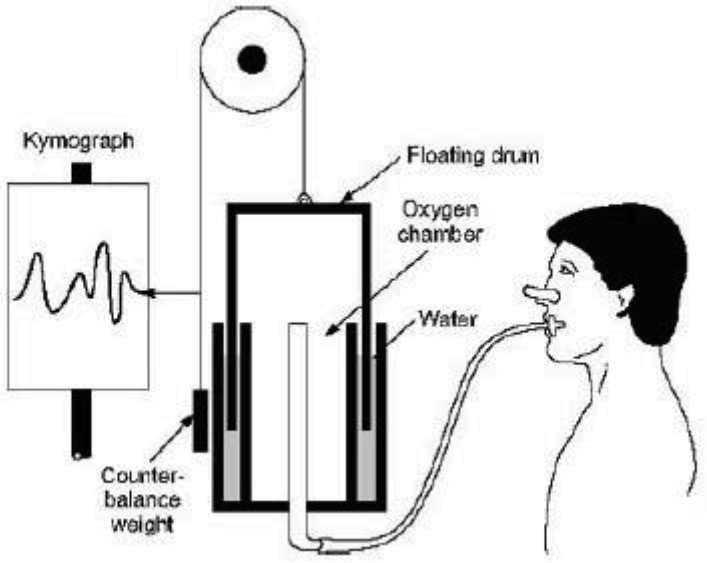


Figure 2: Basic water sealed spirometer

The spirometer is a mechanical integrator, since the input is air flow and the output is volume displacement. An electrical signal proportional to volume displacement can be obtained by using a linear potentiometer connected to the pulley portion of the spirometer. The spirometer is a heavily damped

device so that small changes in inspired and expired air volumes are not recorded. The spirometers can be fitted with a linear motion potentiometer, which directly converts spirometer volume changes into an electrical signal. The signal may be used to feed a flow volume differentiator for the evaluation and recording of data.

Calculating results manually from the graph of the mechanical volume spirometer requires considerable time. Transducers have been designed to transform the movement of the bell, bellows or piston of volume spirometers into electrical signals. These are then used to compute the numerical results electronically. The popularity and low cost of personal computers have made them an attractive method of automating both

volume and flow spirometers. An accurate spirometer connected to a personal computer with a good software program has the potential of allowing untrained personnel to obtain accurate result.

O PNEUMOTACHMETERS

Pneumotachometers are devices that measure the instantaneous rate of volume flow of respired gases. Basically, there are two types of Pneumotachometers, which are:

(i) Differential manometer: Differential pressure sensors are sometimes used in place of turbine transducers. Commonly referred to as pneumotachs, these designs can measure low flow rates with high accuracy.

An added advantage is cost: because they are relatively inexpensive, pressure transducers enable the implementation of disposable pneumotachs.