Pulmonary Function tests - Interpretation and application in clinical practice

Dr A. Ahmed Basha
Department of Physiology
Chettinad Hospital and Research Institute

Week 1
Lecture 5

Essential Principles of Spirometer

I am Dr. A. Ahmed Basha, Professor of Physiology, Chettinad Hospital and Research Institute. Today, I will be speaking about essential principles of spirometer. A spirometer is a simple biomedical device. Spirometry is a common type of pulmonary function test, which measures the volume of air inspired and expired by the lungs.

It is a useful tool in the diagnosis of pulmonary disease. In addition, it is also useful in monitoring patients with pulmonary diseases. If we look back to the history of spirometer, pulmonary function testing equipment has evolved over time. From 1800 to till date, nowadays, we are using a compact spirometer, which is desktop enabled or handheld or even mobile based spirometer.

There are several types of spirometers available on the market. They are broadly classified into volume spirometer and flow spirometers. As I mentioned earlier, commonly used spirometers are desktop or handheld spirometers or else smart phone based spirometers. The principle of various type of spirometry involve understanding how each type measures lung volume and air flow. Here is brief overview of the principles behind some common spirometry.

Volume spirometers. In volume spirometer, as the name indicates, it measures the volume of air directly. They operate based on the principle that the movement of air displaces a physical element in direct proportion to the volume of air moved. Among various volume spirometer, number one is bellows spirometers. The bellows spirometer based on the principle of bellows system that is this spirometer use a bellows system to measure the volume of air displaced during inhalation and exhalation.

The next type of volume spirometer is water seal spirometer. Water seal spirometers uses a water filled chamber to measure the volume of air displaced. To understand the working principle, basic construction must be known. It is mainly used for teaching purposes. This water seal spirometer consists of two chambers.

Number one is outer chamber, next is inner chamber. Let us see one by one. Outer chamber. In the outer chamber, it is filled with water. This is the outer chamber, it is filled with water and an inverted floating drum is immersed in the water.

So, this is the outer chamber where water is filled and an inverted drum is placed immersed in the water. The floating drum is counterbalanced by a weight. This floating drum is counterbalanced by a weight. The weight is attached to the top of the inverted drum by means of a pulley and chain. An ink pen is attached.

You can see the ink pen. An ink pen is attached to counterweight on calibrated paper which is fixed to the recording device. This is about the outer chamber. Next, we move on to the inner chamber. The inner chamber, this is the inner chamber.

An inverted long metal tube with a small hole at the top. It penetrates the outer chamber above the level of water. A rubber tube is connected to the outer end of the metal tube and a mouthpiece is attached. The subject breathes through this mouthpiece by closing the nose with the nose clip. In this picture, nose clip is not seen here.

But while doing spirometry, nose clip has to be applied. Working principle of a water sealed spirometer. When the subject breathes with a spirometer, during expiration, the drum moves up. The drum moves up and the counterweight comes down and the counterweight comes down. The reverse of this occurs at the time of inspiration.

Upward and downward movement of the counterweight are recorded in the form of graph. Upward deflection denotes inspiration and the downward deflection denotes expiration. Next, we move on to the flow spirometers. Flow spirometer measures the air flow. In general, they operate based on the principle that the flow of air is picked up by the transducers.

The example for the flow spirometer is pneumotachometers. Pneumotachometer measures air flow by detecting the pressure drop across the flow resistance. As the air flow through the device, the pressure difference is detected and used to calculate the rate of air flow. So, this is a picture showing the pneumotachometers, where the capillary tubes are placed, the air flow is taking place from this direction to this direction and this pressure air flows through the device. The pressure difference is detected and picked up by the differential pressure transducers and used to calculate the rate of air flow.

Next type of flow spirometer is hot wire anemometer. Here, the hot wire anemometer measures the air flow by passing air over the heated wire. The rate at which the wire cools down due to the air flow is used to calculate the air flow rate. The cooling effect is proportional to the flow velocity. Till now, we saw about the types of spirometer that is volume spirometer and flow spirometer.

Now, we can see what are the commonly used spirometers. Desktop and hand-handled spirometer and smart phone based spirometer are the commonly used spirometers. Both desktop and handheld spirometer measure air flow and lung volumes. They use various sensors and algorithm to measure the rate and volume of air during inhalation and

exhalation. Some devices use digital sensors, while other use traditional flow sensing method.

Next is smart phone based spirometer. Smartphone based spirometer utilizes the sensors present in the smartphones such as accelerometer and pressure sensors to measure the lung function. They often come with an accessories like flow tubes that are connected to the smartphone. Algorithms process the data and from these sensors to calculate air flow and lung volumes. Apart from spirometer, the other devices used to measure the pulmonary function are 1S peak flow meter, next impulse oscillometer.

Peak flow meter works based on the principle of air flow rate. That is peak flow meter measure the maximum speed at which air can be exhaled from the lungs during forced expiration. The patient exhales into the device and the highest air flow value reached during the first expiration is recorded. The next device is impulse oscillometer. Impulse oscillometer based on superimposition of sound waves on normal tidal breathing which leads to the disturbances in flow and pressure across the airways leading to an ultimate output of respiratory resistance, reactance and impedance using FFT technique.

So, till now we saw the working principle of various types of spirometers. From these spirometers, the common parameters measured or derived are volumes and capacities that is lung volumes and capacities like a tidal volume etcetera. Then we can measure the flow volume loop as well as time volume curve. Other tests may be performed in certain situation with the help of spirometers. The clinical application of the spirometers are diagnosis and monitoring of respiratory diseases, both obstructive lung disease and restrictive lung diseases.

In addition to the diagnosis and monitoring of respiratory diseases, it is also useful in the preoperative assessment. Further, it is also useful as occupational health screening tool. Even though there are several types of spirometers are available in the market, each and every spirometers have its own pros and cons. These spirometers are non-invasive and it takes a very minimal time for recording that is minimal time consumption and it is also record dynamic recording. If you see the disadvantages in spirometry, there are some patient cooperation issue, some patient may find difficult and they may not cooperate at the time of recording.

There is a possibility of technical errors and artifacts and additionally it also causes some interpretation challenges. To overcome this, quality assurance and best practices must be adopted, quality control measures must be adopted, calibration has to be done before using the spirometry each and every time, accuracy has to be checked with the predicted value and filter cleaning has to be done regularly, further device has to be operated by professionals to avoid errors. So, finally, to conclude, plenty of spirometer devices are available on the market that can measure either flow or volume ranges from a simple

devices like peak flow meter to advance ultrasonic flow heads. Depending upon the goal appropriate device should be chosen. Further trends in spirometer technology and research have to be studied. Thank you.