Pulmonary Function tests - Interpretation and application in clinical practice

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Week 3
Lecture 1

Static and Dynamic lung function tests

In this module, we are going to see about Static and Dynamic Lung Function Tests. If you can recollect, this is the slide from module 1, which shows the types of lung function tests, the classification of lung function tests based on the aspects of lung functions measured. We saw about the different tests and the physiological principles behind each of these tests and the tests of air way function, which includes spirometry. And this is all again from module 1, which shows the parameters measured by spirometry technique. So, simple spirometry, which measures static lung volumes, static lung volumes like tidal volume, vital capacity, expiratory reserve volume, inspiratory capacity.

And using forced vital capacity maneuver, dynamic lung volumes can be obtained. Dynamic lung volumes like forced vital capacity, forced expiratory volume in 1 second and forced expiratory flow, maximal expiratory flow volume curves and maximum voluntary ventilation. So, all these are the parameters which can be measured using spirometry technique. I told you, I will explain in detail in module 5 regarding these spirometry techniques.

So, let us see about these parameters measured using spirometry technique in this module. What are static lung function tests and what are dynamic lung function tests? So, these are pulmonary function tests to assess the air way. So, static means what? What does this measure? This measures air movement. Air movement into and out of the lungs in a single breath is measured using static lung function tests and static lung volumes are measured using these tests. What are static lung volumes? Volumes which do not change with time.

What about dynamic lung function tests? What do they measure? They do not measure air movement, but they measure air flow. What is air flow? Volume per unit time. And these are dependent on, the air flow velocity here is dependent on the resistance of the air passages and the compliance which are the mechanical properties of the lung and the chest wall. Hence, this serves as a better indicator of adequacy of pulmonary ventilation. So, let us see about these different static and dynamic lung function tests in this module.

And these lung volumes are all measured using what technique? Using spirometry. You have studied already about the different types of spirometer in module 1. So, this is the

simple water-seal spirometer what you see. So, here the person breathes through the mouthpiece with a nose clip on and this is not used nowadays for clinical purposes. This is mainly used for teaching purposes, not even for research purpose it is used.

And what is the one which is used nowadays? This is a computerized spirometer. So, here it is a handheld device, a mouthpiece, a person is asked to breathe through this mouthpiece and the recordings are all done using the computer. So, using this spirometer we do the recordings. And the recordings what we obtain, we can obtain the static lung volumes and capacities, dynamic lung volumes and capacities, all these can be obtained using this spirometer, computerized spirometer. Let us see about the static lung volumes and capacities first.

So, using this spirometer what we obtain, the graph what you call is the spirogram. So, in this spirogram you can see all the lung volumes and capacities which have been plotted here in this graph. And all these lung volumes are all subdivisions of total lung capacity. Total lung capacity is around 6000 ml or 6 liters and these are all interpreted as volumes and as capacities. So, there are four lung volumes and four capacities.

What are capacities? Capacities are combinations of two or more lung volumes. The static lung volumes, let us see about the four important volumes first. Tidal volume, what is tidal volume? So, the person when he expires through the mouthpiece, inspires and expires through the mouthpiece with the nose clip on during a normal quiet breathing. So, tidal inspiration followed by a normal expiration, the graph what you obtain is the tidal volume. So, tidal volume refers to the amount of air which moves in and out of the lungs in quiet breathing.

The inspiratory reserve volume, what is inspiratory reserve volume? That is the amount of air that can be inspired maximally over and above the normal tidal inspiration, that is inspiratory reserve volume. What about expiratory reserve volume? So, that is the amount of air that can be expired maximally following a normal tidal expiration. What about residual volume? What is residual volume? Even after a maximum expiration, some amount of air remains in the lungs and that constitutes residual volume, that is amount of air which remains in the lungs following a maximal expiration. So, these are the four lung volumes. And what are the respiratory capacities? It is combinations of lung volumes.

So, let us see about four important capacities. Inspiratory capacity, what is inspiratory capacity? So, that is the maximum amount of air that can be inspired following a normal tidal expiration. This is IRV that is inspiratory reserve volume plus tidal volume. Functional residual capacity, what is functional residual capacity? So, that is the amount of air which remains in the lungs following a normal tidal expiration. That constitutes ERV plus residual volume.

And what about vital capacity? Vital capacity, what does this mean? So, that is a maximum amount of air that can be expired maximally following a maximum inspiration. So, that is inspiratory capacity plus expiratory reserve volume. That constitutes vital capacity. What about total lung capacity? Total lung capacity is the total amount of air which the lungs can hold, which is vital capacity plus residual volume. What are the lung volumes and capacities? What are their normal values? So, these are the normal values of these lung volumes and capacities.

So, tidal volume, so all these are as per western standards. So, tidal volume which is around 500 ml, inspiratory reserve volume is around 3000 ml, expiratory reserve volume and residual volume are around 1200 ml, inspiratory capacity is around 3500 ml, functional residual capacity 2400 ml, vital capacity 4700 ml and lung capacity, total lung capacity we have already seen this, this is around 6000 ml or 5900 ml. And how is this recorded using a spirometer? What are the different maneuvers? If tidal volume has to be obtained, the maneuver has to be different. If vital capacity has to be obtained, the maneuver has to be different. How should the inspiration be and how should the expiration be through the mouthpiece? So, if tidal volume has to be measured, the inspiration has to be normal and the expiration has to be normal.

If inspiratory capacity has to be obtained, then the inspiration has to be maximal and expiration has to be normal. An inspiratory reserve volume can be obtained, can be calculated from inspiratory capacity by subtracting the tidal volume. What about expiratory reserve volume? How do we obtain expiratory reserve volume? Expiratory reserve volume plus tidal volume is the one which is obtained. So, here the person is asked to breathe normally, that is do a normal inspiration and do a maximum expiration through the mouthpiece. What about vital capacity? So, here the subject is asked to take a maximum inspiration and a maximum expiration.

Of all these volumes and capacities, which do you think is the most reliable? Vital capacity is the most reliable of all these parameters because here the endpoints are well defined. So, for vital capacity, inspiration has to be maximum and expiration has to be maximum. So, this is easy for the patient rather than holding the breath at the end of a normal tidal expiration or inspiration. So, here the endpoints are well defined, subjective variations will be less. So, vital capacity becomes a very reliable maneuver.

And what are the factors which influence these lung volumes? A lot of factors influence these lung volumes like age, gender, body size and composition, posture. And the index, vital index is calculated based on body surface area. So, vital capacity divided by body surface area gives vital index. These lung volumes and capacities, certain lung volumes and capacities cannot be measured using the spirometer. What are those lung volumes and capacities? You cannot measure residual volume, that is the amount of air which remains in the lungs at the end of forced expiration.

Hence, functional residual capacity cannot be measured and also total lung capacity cannot be measured. But how do we measure these lung volumes and capacities? Yes, there are techniques available to measure these lung volumes and capacities using helium dilution technique and body plethysmography, which we have already seen in module 1, the principle of these two techniques, it was discussed in module 1. So, using this spirometer, we cannot measure these lung volumes, but using these techniques, these lung volumes, residual volume, functional residual capacity can be measured. Now, what is the clinical significance of these static lung volume? Why do we have to do these tests? They have a clinical significance. So, what is the clinical significance and which are the parameters which are used for clinical interpretations, especially vital capacity and total lung capacity.

These are very important parameters which are used in clinical interpretations. So, there are conditions in which vital capacity can decrease. Vital capacity decreases if the lung tissue is destroyed, the distensible lung tissue is destroyed in case of pneumonia, lung cancer, atelectasis or collapse. If the lung tissue itself is destroyed, vital capacity is decreased and in obstructive lung diseases due to gas trapping, there can be an elevated residual volume, decreased vital capacity, but the total lung capacity will be normal and reduced chest wall excursions which occurs in case of neuromuscular weakness, chest wall deformity to vital capacity can decrease. So, these are the causes for a decreased vital capacity.

So, this is the clinical significance of knowing these static lung volumes. Now, having seen about these static lung volumes and the static lung function tests, now let us see about the dynamic lung function tests. What is dynamic lung function test, we have already seen. Dynamic lung function tests, they measure air flow rather than air movement, that is volume against time that is measured using these dynamic lung function tests. And these dynamic lung function tests are also measured using spirometry.

Using what maneuver? A forced breathing maneuver which is called the forced vital capacity maneuver. So, how should the subject be instructed? The subject should be instructed to take a maximum inspiration and then following a maximum inspiration, subject's expiration has to be rapid, forceful and complete. So, to make the subject do this, the subject has to be encouraged. Whoever is doing the maneuver, whoever is conducting the test has to encourage the subject to do this maneuver completely. So, because lot of subjective variations can also happen.

So, this is a forced vital capacity maneuver. So, using this forced vital capacity maneuver, dynamic lung function tests are done and these interpretations, how is the interpretation after doing the FVC maneuver? They are interpreted in two different ways, either as a spirogram or as a flow volume loop or as both. So, what is a spirogram? So, here volume of the gas exhaled is plotted against time, that gives the spirogram and this gives four major test results, FVC, FEV1, FEV1 by FEC and the average mid maximal expiratory flow. And

another interpretation is using a flow volume loop. So, here recording of instantaneous flow rate versus volume is done and expiratory and inspiratory flow volume loops are obtained.

So, two different ways in which the dynamic lung function tests can be interpreted. So, let us see about the spirogram first. So, the spirogram using the FVC maneuver. So, what you see here is the spirogram. So, what does this give? So, here the person when he starts the FVC maneuver, so he is asked to take a deep inspiration first.

So, in deep inspiration, when he starts the maneuver at zero time, his volume is to his maximum at his total lung capacity. And then when he starts at his total lung capacity, he is encouraged to do an expiration completely. So, completely till all the volume is expired or exhaled. So, that will be the at the end of this maneuver, his volume has to reach the residual volume. And the amount of air which is exhaled during this maneuver, that constitutes forced vital capacity.

So, forced vital capacity, so this is the volume. So, forced vital capacity, that is the amount of air which is expired during this FVC maneuver. And timed vital capacity can be obtained. What is timed vital capacity? So, per unit time, so for 1 second what is the volume expired? In 2 seconds what is the volume expired? That can be calculated. So, the volume of air which is expired over a given time interval from the beginning of the FVC maneuver, that is timed vital capacity.

Of the timed vital capacity values, FEV1 is the most widely used value. FEV1, what is FEV1? That is forced expiratory volume in 1 second. What does this mean? This is the amount of air which is expired during the first 1 second of the FVC maneuver. So, you can see that that is around 4.

2 liters in this case. So, FEV1 is the amount of air which is expired during the first 1 second of FVC maneuver. And what are the other parameters which can be obtained using the spirogram? FEV1 by FVC ratio, ratio between FEV1 by FVC, so that the normal ratio is around 0.8. What does this mean? This means around 80 percent of the volume of the FVC is expired during the first 1 second in normal individuals.

So, normal ratio has to be 0.8. If it is less, what does this indicate? This indicates obstructive lung disorder. And it could be more in normal individuals and also in restrictive lung disorder. This is a very important parameter which is used in clinical interpretations because FVC and FEV1 can be reduced in both obstructive and restrictive lung disorders. But FEV1 by FVC ratio is decreased only in obstructive lung disorders because the extent to which FEV1 is reduced is more in comparison to FVC in obstructive lung disorders. So, this is a very very important clinical interpretation in obstructive lung disorders.

What is the other parameter which can be obtained using this spirogram? Average mid maximal expiratory flow. What does that mean? This is the average flow during the middle half of the vital capacity. This can be obtained by measuring the slope of the curve and this indicates flow from medium and small airways. How is this used in clinical interpretations? This is not used independently to interpret. Only in the case of a borderline reduction in the ratio of FEV1 by FVC, a low value helps to confirm airway obstruction.

So, these are the four parameters which are obtained using the spirogram. What are the four parameters which we have seen? Forced vital capacity, forced expiratory volume in one second, ratio of FEV1 by FVC and average mid maximal expiratory flow. Of these four parameters, the one which is clinically used, widely used for clinical interpretations is FEV1 by FVC which is the most important ratio. Now, having seen about the spirogram, the dynamic lung volumes, how is it interpreted using a spirogram? Now, let us see about how it is interpreted using a flow volume loop.

So, the same FVC maneuver is done and then a flow volume loop is obtained. What is a flow volume loop? Flow is plotted against volume and it is done in both inspiration as well as in expiration and when it is plotted together, it constitutes the flow volume loop. So, the inspiration, the expiratory maneuver, patient exhales from a maximum inspiration from total lung capacity to the residual volume, the subject is asked to do an expiration and an expiratory curve is obtained. So, by convention, expiration is seen in the upward direction and inspiration is obtained in the downward direction. So, similarly in inspiration too, you can get the graph.

So, here the patient inspires maximally after a maximum expiration. So, inspiratory flow volume curve and an expiratory flow volume curve is obtained. What are the parameters which can be interpreted using this flow volume curve? So, let us see about the different parameters. So, the first important one being FVC. So, FVC, what is FVC? We have seen already about FVC that is a maximum amount of air which can be expired or exhaled during this maneuver.

So, in this case, this constitutes around 4 litres. So, FVC can be obtained and after FVC, we can also calculate peak expiratory flow rate, we can also interpret peak expiratory flow rate using this flow volume curve. What is peak expiratory flow rate? That is the highest flow or the greatest flow achieved during the expiratory maneuver. This occurs early in the maneuver itself. Around you know, you can see from this graph that only 20 percentage of the FVC is exhaled, whereas peak flow is obtained at that point itself.

So, peak expiratory flow occurs early in the maneuver. Similarly, inspiratory flow can also be obtained, peak inspiratory flow. So, this is peak inspiratory flow, what you see here. So, this is midway between TLC and RV. So, unlike the expiratory flow which occurs during the initial part of the maneuver itself, this occurs midway between TLC and residual

volume. So, here as the lung volume increases, the inspiratory muscle pressures decrease and the lung recoil increases and the airway resistance decreases.

So, that is the reason why peak inspiratory flow occurs midway between TLC and residual volume. What is the other parameter which can be obtained using the flow volume curve? Instantaneous flow at lung volumes can also be obtained, forced expiratory flow, 75 percentage forced expiratory flow, 50 percentage and forced expiratory flow 25 percentage. And what are these instantaneous flows and how is it obtained? So, here the flow volume curve is divided into quarters and then instantaneous flow at any lung volume can be measured. So, instantaneous flow rate at which 25 percentage, 50 percentage and 75 percentage of vital capacity remains to be exhaled.

And how are these used clinically to interpret? These instantaneous flows just like the average flow, they are not used independently to interpret, they are used only along with FEV1 by FVC ratio. Only when there are these ratios are close to normal or when there are borderline reductions, these values are helpful in interpreting obstruction. What about peak expiratory flow rate? What is peak expiratory flow rate? We have already seen how to obtain this peak expiratory flow rate using the flow volume curve. So, this is a maximum flow obtained during the FVC maneuver. So, this can be measured from the flow volume curve and also using devices which sense flow directly it can be measured.

So, this is the device, handheld device to sense flow and using this peak expiratory flow can be directly measured. So, how should the patient do it? The patient should do exhalation maximally through this. After a maximum inspiration, peak expiratory flow rate is obtained. What is the significance of this peak expiratory flow rate? The peak expiratory flow rate can be used for self-monitoring by the asthmatic patients. Asthmatic patients when they are started on bronchodilators, for them to do a self-assessment, they can use this peak expiratory flow rate and they can assess their own response to therapy.

So, that is the significance of peak expiratory flow rate. So, now let us see about the next parameter, maximum voluntary ventilation. What is maximum voluntary ventilation? That is a maximum breathing capacity. So, we have already seen about minute ventilation, this is similar to that, but it is the largest volume of air that can be moved in and out of the lungs in 1 minute by voluntary effort. So, this is the normal maximum voluntary ventilation that is around 125 to 170 liters per minute. And how do we obtain this maximum voluntary ventilation? This is also measured using spirometry.

So, here the patient is asked to breathe rapidly and deeply for around 12 to 15 seconds, almost like hyperventilating maneuver. So, hence the volume breathed should be less than the vital capacity, but it should be more than the tidal volume. So, a patient is asked to do almost like a hyperventilating maneuver, but it should not be longer than 15 seconds because this could be dangerous hyperventilation. So, it should be less than 15 seconds

and usually it is done for 12 seconds and this 12 seconds' value is interpreted for 1 minute to obtain the maximum voluntary ventilation. How is this MVV used to clinically interpret? So, MVV assesses the overall lung functions.

They are influenced by a lot of parameters like airway resistance, compliance, respiratory muscles and the respiratory control systems. And only large reductions in MVV are considered significant. Patients with lung diseases, they achieve only 40 percentage of the MVV. So, that is how MVV is used clinically to interpret. So, we have seen about the different parameters in this module, we have seen about the different parameters measured using spirometry technique.

What is spirometry? Again, let me repeat. So, spirometry is a very important airway function test, very important pulmonary function test which is used for diagnostic purpose, research purpose which is used widely for all these purposes. And there are simple spirometry techniques and spirometry using forced vital capacity techniques. And we saw static lung volumes which are measured using simple spirometry technique and the dynamic lung volumes which are measured using the forced vital capacity technique. And also we saw about the flow volume curves and about the peak expiratory flow rate, how it is measured and about maximum voluntary ventilation and its clinical application.

So, all these are the parameters measured using spirometry. These are my references. Wish you all a very happy learning. Thank you.