Course Name: Pulmonary Function Test - Interpretation and Application in clinical practice
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W4_L5_Radiological assessment of obstructive and restrictive lung disorders

Today, we shall see Radiological Assessment of Obstructive and Restrictive Lung Disorders. In this topic, we shall be covering the basic terminologies we use in chest X-ray and CT scan. We will discuss in this lecture, how to differentiate a normal lung from an abnormal lung with respect to obstructive and restrictive lung disorders and we shall see the characteristic imaging features we come across in obstructive and restrictive lung diseases. First is we shall see the modalities we commonly used for imaging lung diseases. First is chest X-ray, next is MDCT or high-resolution CT or HRCT. This is a normal chest X-ray PA view.

The commonly used views in chest X-ray are PA view also called as postero anterior view, AP view also called as antero posterior view and lateral view. In this PA view is the most commonly used one in chest X-ray. The L marker here shows that this is the left side of the patient. In PA view, the X-rays come from behind the patient, pass through the patient in a postero-anterior direction and hit the cassette just in front of the patient.

This is the left lung; this is the right lung. Lung contains air, so they are radio loosened or dark in color. This is the left costophrenic angle, this is the right costophrenic angle, this is the right cardio phrenic angle, this is the left cardio phrenic angle. The structure connecting the costophrenic angle and the cardiophrenic angle is the diaphragm. Diaphragm is convex, right hemidiaphragm is at a higher level compared to the left hemidiaphragm.

This central air-filled lucency is the trachea occupying the superior mediastinum. This structure occupying the center of the mediastinum is the heart. Through the heart, we are able to find linear loosened or dark spaces which are nothing but the intervertebral disc spaces and also through the heart, we are not able to find the details of the vertebra. If through the heart, we are able to find the intervertebral disc spaces and not access the details of the vertebra, then that X-ray is called as adequately penetrated chest X-ray. This is the left hilum; this is the right hilum.

Hilum is the structure through which the pulmonary vessels and bronchi enter the lungs. From the hilum, they grow they go towards the periphery of the lung. As they go

towards the periphery, the size of the vessels decreases and we do not find any vessels or bronchi in this outer one third of the lung. You see we are not able to find any vessels in this outer one third of the lung. Then this is the left clavicle, this is the right clavicle, this is the left scapula, this is the right scapula.

In chest X-ray PA view, the scapula is usually outside the thoracic cage so that the lung details are not obscured. Then this is these are the ribs. This is the posterior end of the rib starting at the level of the vertebra. We are tracing the rib here; this is the lateral angle of the rib and this is the anterior end of the rib. The connection of the anterior end of the rib to the sternum will not be visible in all patients due to the unossified costal cartilage.

Normally, in a patient with adequate inspiration, we can find at least 6 anterior ribs. This is the first anterior rib, second anterior rib, third, fourth, fifth and sixth. We can see 6 anterior ribs fully on right side or 10 posterior ribs fully on right side. If you are able to find either 6 anterior ribs or 10 posterior ribs on right side, then that chest X-ray is called as adequately inspired chest X-ray. The part of the lung which is above the level of the right second anterior rib is called as upper lung zone.

The part of the lung between the second to fourth anterior rib is the mid lung zone, the part of the lung below the level of the fourth anterior rib is the lower lung zone. This is the HRCT chest lung window; this is HRCT chest mediastinal window. In lung window, we are able to find the details of the lung. In mediastinal window, we are able to find the details of the mediastinal including the pulmonary vessels and nodes. This is the right main bronchus; this is the left main bronchus.

This lung contains multiple dot and linear opacities which are normal structures nothing but the pulmonary vessels. There are certain hidden areas in X-ray chest. Number 1 is apex, number 2 is hilum, number 3 is retrocardiac area that is the area behind this heart, number 4 is the area around the diaphragm. Opacities in these 4 areas will not be well seen in chest X-ray. We shall see the differences between X-ray chest and CT chest.

CT chest is the first line investigation used in symptomatic patients. It is used for surveillance of disease progression once the diagnosis is made. The advantages of chest X-ray are it is cheap, it is easily available, radiation dose is less, disadvantage is hidden areas cannot be seen. CT scan on the other hand has excellent spatial resolution. The anatomical details we find in CT scan are almost similar to what we find in pathological specimens.

We can reconstruct the images in axial plane, sagittal plane and coronal plane. Disadvantage is the radiation dose is very high compared to chest X-ray and also the image is prone to breathing artifacts. This is the anatomical image of the secondary

pulmonary lobule. This is the periphery of the lobule containing the interlobular septum which contains pulmonary veins and lymphatics. This is the bronchiole and the pulmonary artery entering the center of the lobule.

This is a CT chest axial view image showing a secondary pulmonary lobule along the periphery of the lungs. Let us see few terminologies we come across in CT scan. First three are opacities of increased attenuation, next three are opacities of decreased attenuation. Increased attenuation in the sense they are hyper dense or whiter compared to the normal lung. Increased attenuation in the sense they are hypodense or darker compared to the normal lung.

Linear bar reticular opacities, nodule bar nodular opacities, parenchymal opacification fall under the category of increased attenuation, cyst emphysema bronchiectasis, mosaic attenuation bar perfusion and air trapping fall under the category of decreased attenuation. Let us see few with examples. Interlobular septal thickening. This is nothing but visible linear bar reticular opacities. Interlobular septal thickening almost always indicates some interstitial problem is there.

It can be seen in cases of interstitial fibrosis or whenever the interstitium is thickened because of cells or fluid. Whenever the interlobular septum is thickened, we are seeing multiple polygonal or hexagonal shaped structures which are nothing but the secondary pulmonary lobule walls are thickened seen as interlobular septal thickening. This is a sagittal CT chest seen along the periphery of the lung. We are finding multiple box-box structures which are nothing but thickened interlobular septum.

Next is honeycombing. This is nothing but multiple small cystic lucenses. Here we are finding black lucenses. These are black lucenses having a white wall around it. These lucenses are seen in multiple layers which is honeycombing. Honeycombing is seen in the setting of end stage lung disease.

Traction bronchiectasis. Traction means pulling. Whenever there is fibrosis in the lung there is pulling of the adjacent bronchi leading to dilatation of the bronchi which is traction bronchiectasis. Next is nodular opacities. Any rounded well defined or ill-defined lung opacity less than 3 centimeter is called as a nodular opacity. Depending upon their location within the secondary pulmonary lobule, they are classified as peri lymphatic nodule or centrilobular nodule or random nodule.

This is the margins of the secondary pulmonary lobule. We know along the interlobular septum we will be finding lymphatics. If the nodules seen along the course of the lymphatics, that is if they are seen along the margins of the interlobular septum, then they are following a perilymphatic distribution. Here we are seeing nodules along the septum, along the septum, along the septum. This particular distribution of nodules is called as peri lymphatic distribution of nodules.

Then next is secondary centrilobular nodule. This is the center of the lobule; a nodule is seen here. This is the center of the lobule; a nodule is seen here. Again, within the center we are finding a nodule. This specific pattern is called as centrilobular distribution of nodule.

If a nodule does not follow any of these two patterns, then that is called as random distribution of nodules. Next is parenchymal opacification, which is further divided into ground glass opacity and consolidation. Here we are seeing an area of increased attenuation, that is it is hyper dense or whiter compared to this normal lung. Here also a hyper dense opacity is seen. The difference between these two is through this opacity we are seeing the normal vascular markings here.

Whereas in this case the details of the underlying lung are not visible. If through an opacity the details of the lung are visible, then that is called as ground glass opacity. If through the opacity the details of the lung are not visible, then it is called as consolidation. Next is air filled lucenses. We are finding a black or a hypodense lesion which is darker compared to the underlying lung.

This black structure is having a hyper dense or a white wall. So, this is a lung cyst. Centriloebular emphysema will appear like a lung cyst, that is their hypodense are dark compared to the lung, but they do not have a wall. Because by definition centrilobular emphysema will not have a wall.

Next is cystic bronchitis. Cystic bronchitis will also appear like a lung cyst. They are more hypodense or dark than the underlying lung, but the difference is a pulmonary artery can be seen next to it. A dilated bronchus with a pulmonary artery giving a characteristic signet ring sign. If this is seen, this is highly suggestive of cystic bronchitis. Sometimes in cystic bronchitis we will be finding air fluid level, that is the non-dependent part will contain the dark air and the dependent part will contain white fluid forming air fluid level which is seen in cystic bronchitis not seen in another lung cyst.

Let us go into the pathologies. Under obstructive diseases we will be covering emphysema, bronchitis, asthma and bronchitis. Under restrictive diseases we shall be covering fibrosing, interstitial pneumonias, sarcoidosis, hypersensitivity pneumonitis and asbestos. First is emphysema. This is chest x-ray PAVU, normal chest x-ray. This is x-ray PAVU of an emphysema test patient.

Compared to this chest x-ray, this x-ray is hyper inflated, that is we are seeing more than 6 anterior ribs fully. First anterior rib, second rib, third rib, fourth, fifth, sixth, seventh, eighth, ninth. We are finding more than 6 anterior ribs or more than 6 more than 10 posterior ribs which is nothing but hyper inflated lung which is one of the features of

emphysema. Next is flattening of the diaphragm. You see this diaphragm is convex whereas, this diaphragm is flattened.

To look for flattening of diaphragm we must draw two parallel lines. One line connecting the right costophrenic angle and cardiophrenic angle and another line along the dome of the diaphragm. If the distance between these two lines is less than 1.5 centimeter, then that is the criteria to say flattening of hemidiaphragm.

And also look at the heart here. Compared to this heart, the heart looks like a tube that is a tubular heart shadow which is one of the features of emphysema. And also look at the vessels here. Compared to the vessels here, there is paucity of vessels that is there is decrease in the attenuation of vessels which is also one of the features of emphysema. Then next is sabersheath trachea which is dilated intrathoracic portion of the trachea in which case the sagittal diameter of the trachea will be greater than the coronal diameter. Next one more finding is increased retrosternal distance which we will be seeing in lateral chest x-ray.

This is a normal lateral chest x-ray. This is chest x-ray of a patient with emphysema. Interiorly seen is the sternum. Behind that is the retrosternal lucency. Then this is the heart, this is trachea, esophagus, these are the vertebra. Compared to this x-ray, you see the retrosternal lucency is widened.

If this distance is more than 2.5 centimeter, this says that it is increased a retrosternal space which is also one of the findings in emphysema. All these findings of emphysema will be seen only in severe cases. It may not be apparent in chest x-ray in mild cases. CT scan helps us to diagnose mild reforms of emphysema and also to characterize the exact type of emphysema. This is a CT picture showing centrilobular emphysema.

Compared to this picture, here we are finding multiple small radiolucency's, black-black structures throughout the lung without any wall. This is characteristic of centrilobular emphysema. Though their centrilobular location may not be apparent in all places, this spotty distribution of radiolucency's that is radiolucencies present here and there in a lung is highly suggestive of centrilobular emphysema. It is usually seen in the upper lobes and it is usually seen in smokers.

Next is para septal emphysema. Compared to the normal lung here, you see the CT chest showing multiple dark cystic lucenses seen arranged along the periphery of the lung. They are seen in a single layer here and these cystic lucenses do not have a wall or either they have a thin wall here. This cystic lucenses lacking a wall seen arranged in a single layer in the periphery of the lung is suggestive of para septal emphysema. The closest differential to this is honeycombing. Honeycombing will be seen in multiple layers whereas, para septal emphysema will be seen in single layer.

Honeycombing will have a thick wall whereas, the wall in case of para septal emphysema will be absent or a thin wall may be seen. If this emphysema at a space is greater than 1 centimeter, then that is called as bulla. Next is panlobular emphysema. Compared to this lung, there is a diffuse simplification of lung architecture that is the lung appears diffusely hypo dense with paucity of vascular markings. Centrilobular emphysema is more commonly seen in upper lobes whereas, pan-lobular emphysema is more commonly seen in lower lobes.

Severe cases of centrilobular emphysema will also have the same picture. Next is bronchiectasis. Bronchiectasis is irreversible abnormal dilatation of bronchus. It is identified by calculating the broncho arterial ratio. Normally, the bronchus and the artery are seen adjacent to each other.

We divide the internal diameter of the bronchus by the diameter of the artery at the same level. The normal broncho arterial ratio is less than 0.7 that is the bronchus is smaller compared to the artery. If the broncho arterial ratio is greater than 1.5 that is the size of the bronchus is greater than that of the pulmonary artery, then that is called as high broncho arterial ratio which is diagnostic of bronchiectasis.

And also, from the high lung as they go towards the periphery of the lung, the bronchi taper gradually. If this tapering is absent that is one of the features of bronchiectasis. In this lung, you see the diameter of the bronchus at this level and the diameter of the bronchus at this level are more or less same. That is, they are not tapering which is suggestive of bronchiectasis. One more type of bronchiectasis is varicose bronchiectasis where there is irregular dilatation of bronchi.

Next is cystic bronchiectasis having multiple cystic dilatations of bronchi. This is CT chest axial view showing linear dilatation of bronchus without tapering for a distance of at least 2 centimeters. This is varicose bronchiectasis, there is irregular beading appearance of the bronchus. This is cystic bronchiectasis seen in multiple patchy distribution. We are seeing all three types of bronchiectasis in a single patient.

This is a sagittal CT chest showing varicose bronchiectasis, cystic bronchiectasis and cylindrical bronchiectasis giving a tram track appearance. Next is bronchitis. Usually, imaging has low sensitivity and specificity to diagnose bronchitis. Sometimes we get vascular markings in the outer one third of the lung. In the normal section we saw that no markings will be seen in the outer one third of the lung.

If they are seen in the outer one third of the lung it is one of the features of bronchitis which is nonspecific. In CT we sometimes get nonspecific bronchial wall thickening. Next is asthma. Again, the findings are nonspecific. The imaging is usually done in asthma to rule out any alternative diagnosis and to look for any complications.

Sometimes we may get hyper inflated lungs in asthma. In CT we get bronchial wall thickening which is again nonspecific. Sometimes we get mosaic attenuation pattern which is alternating areas of increased density and decreased density which is due to air trapping. We shall go into restrictive lung diseases now. First, we shall see fibrosing interstitial pneumonias.

Chest X-ray is usually normal in the early stages of disease. In late stages we will find basal zone predominant reticular opacities. You see some abnormality is seen in the basal zone not in the upper lung zone. This is a magnified image showing multiple crisscross linear and reticular opacities with interlobular septal thickening and also the volume of the lung is low compared to the volume seen here. We get certain specific radiological patterns in the setting of interstitial lung disease.

One is usual interstitial pneumonia or the UIP pattern. The hallmark finding seen here is fibrosis that is honey-comb, traction bronchitis and interlobular septal thickening. All these findings are seen in a peripheral and sub pleural distribution. They are seen predominantly in lower lung zones with a posterior predominance sometimes ground glass opacities may be seen. This is the axial CT chest in upper lung zone, axial CT chest in mid lung zone and axial CT chest in lower lung zone. Compared to the upper lung zone the abnormalities are more here in the lower lung zone.

Compared to the anterior part of the lung the abnormalities are more in the posterior part of the lung. And also, we see the sub pleural lung is involved by the disease. The normal pleura will not be visible in a CT scan. The part of the lung immediately next to the pleura is the sub plural lung which also contains the disease here. As we go from the apex to the base of the lung the opacities increase in severity which is called as apico-basal gradient which is one of the features of usual interstitial pneumonia.

Here we are seeing the characteristic honey combing in UIP pattern multiple small cystic looseness having a prominent wall and seen arranged in multiple layers. Here we are seeing the interlobular septal thickening predominantly in the lung bases which are nothing but the thickening of the walls of the secondary pulmonary lobule. This is a coronal reformatted image showing traction bronchiectasis. Normally we do not find any bronchus in the peripheral one third of the lung.

So, this is abnormal. UIP pattern of pneumonia is usually seen in the setting of idiopathic pulmonary fibrosis, connective tissue disease related interstitial lung disorders, asbestosis and in the setting of chronic hypersensitivity pneumonitis. Next is NSIP or non-specific interstitial pneumonia pattern. Here the predominant finding is ground glass opacity. We are finding parenchymal opacification through which the lung markings are visible. It is more or less seen in a symmetrical pattern; it is seen predominantly in the lung bases.

Here the characteristic thing is subpleural sparing. Compared to the UIP, here the subpleural lung is devoid of disease. If subpleural sparing is seen this is characteristic of NSIP. This is axial CT through the lung base showing typical subpleural sparing with multiple ground glass opacities. This is a coronal reformatted CT showing the opacities are mainly concentrated in the lung base in the form of interlobular septal thickening and reticulations.

This is a sagittal image showing traction bronchiectasis. We saw in the normal section that no vessels or bronchi should be seen in the outer one third of the lung. Here we are finding dilated bronchi in the outer one third of the lung which is nothing but bronchiectasis. Next is cryptogenic organizing pneumonia. Here we will be seeing bilateral consolidations. This is a consolidation patch that is increased parenchymal opacification through which lung details are not visible.

It is seen bilaterally, bilaterally it is seen along the periphery more than the central part of the lung, it is following the bronchus. The typical description is bilateral patchy peripheral consolidations and ground glass opacities. Usually, it will resolve spontaneously.

Some cases may show fibrosis like here. Next is sarcoidosis. It is a granulomatous disorder. It is classified into five stages. This will help us to prognosticate the patient. This does not state the normal course of the disease.

Stage 1 means stage 0 means chest x-ray is normal, stage 1 is hilar lymphadenopathy. Normally, the shape of the hilum is concave that is it will be like this. It is concave outside. If it is rounded or convex outside that means that the hilum is abnormal. In other inwards, it means the hilum is enlarged due to lymph nodes that is seen in stage 1 sarcoidosis without any lung findings.

In stage 2, we will be finding hilar lymphadenopathy with multiple lung infiltrates. In stage 3, hilum will be normal, only lung infiltrates will be seen. In stage 4, there will be upper and mid zone lung fibrosis. This is a CT scan axial section showing the characteristic perilymphatic nodules. This is nodular thickening of the bronchovascular interstitium due to the accumulation of the peri lymphatic nodules. This is a coronal reformatted CT showing findings predominantly in the upper and mid lung zone and no findings in the lower lung zone.

And also, the findings are predominantly seen in the parahilar region that is the central region rather than the periphery of the lungs. This is end-stage sarcoidosis in CT scan. We are finding complete architectural distortion with dilated bronchi. We are finding multiple irregular mass like opacities in both upper lung zones.

The opacities are seen more in the central lung than in the periphery of the lung. Also, we are seeing a high attenuation structure just anterior to the level of the carina which is nothing but a calcified lymph node. The presence of this calcified lymph node and upper lung zone predominant fibrosis shows that this is a fibrosis related to sarcoidosis rather than idiopathic pulmonary fibrosis. Next is hypersensitivity pneumonitis. The characteristic picture we see here is centrilobular nodules.

We are finding multiple small rounded nodules seen throughout the lung. This is centrilobular glass nodules. Next is mosaic attenuation, sharply demarcated areas of increased attenuation and normal attenuation. Then this is air trapping. These black dark areas are air trapping seen in expiratory CT scan. The characteristic feature we see in CT scan is three density pattern that is sharply demarcated lobular areas of increased attenuation, normal attenuation and decreased attenuation.

This is due to both parenchymal infiltration and bronchiolar obstruction. If this three-density pattern is seen, it is more in favor of fibrotic hypersensitivity pneumonitis rather than idiopathic pulmonary fibrosis. This is a follow up case of hypersensitivity pneumonitis where there is extensive lung fibrosis in the form of honeycombing and interlobular septal thickening. Here the fibrosis will be more in mid and upper lung zone rather than the lower zone predominant idiopathic pulmonary fibrosis. Last is asbestos.

This is chest x-ray PAV showing multiple reticular shadows in a lower zone predominance. Also, we are finding sharply demarcated well defined calcified pleural plaques on both sides. If we are finding pleural plaques in a predominant diaphragmatic pleura on both sides, it is highly diagnostic of asbestos. This is a magnified view showing linear and reticular opacities forming honeycombing and interlobular septal thickening in lung bases. This is CT lung window of an asbestos patient.

The characteristic finding is a linear sub pleural line not seen here. This sub pleural line will be paralleling the pleura and will be seen in the lung bases more commonly. In the mediastinal window, we can see pleural thickening along with a high attenuation structure which is nothing but a calcified pleural plaque. This is pleural thickening; this is a calcified pleural plaque. We are seeing calcified pleural thickening on both sides.

This is end-stage asbestos showing lung fibrosis. The fibrosis in asbestos will also be predominant in the lower lung zone. However, the difference is the calcified pleural plaque and occupational exposure to asbestos. If these two features are there, we can give a diagnosis of asbestos related fibrosis rather than idiopathic pulmonary fibrosis. Before reporting any chest X-ray or CT scan, clinical history is more important.

Spirometry findings helps us to diagnose whether it is obstructive or restrictive lung diseases. HRCT will give us the severity of the abnormalities. It help us to identify the

exact disease pattern like interlobular septal thickening, bronchiectasis, emphysema, consolidation, honeycomb being, centriobular nodules etcetera. Disease distribution in CT helps us to helps us to come to a conclusion like posterior zone involvement, upper zone involvement is more in favor of sarcoidosis, lower zone involvement is more in favor of idiopathic pulmonary fibrosis. Peripheral involvement can be seen in NSIP and UIP pattern.

Para-hilar involvement can be seen in sarcoidosis.