Human Physiology
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Week - 04
Lecture - 04

Hello everyone, welcome to another new class on Human Physiology. In this class, we will learn about different types of lung-related diseases. For example, we will see how carbon monoxide poisoning happens and what the different types of therapies for carbon monoxide poisoning are. We will also look into the use of oximeters and pulse oximeters, their overall theories, and we will also explore other lung diseases and their solutions. So, this class will be very interesting; let us stay with it. So, what different content will be covered for these classes? We will discuss carbon monoxide poisoning, including how it happens and what the management and treatment strategies are.

We will discuss pulse oximeters, their theory and how they function, and we will discuss different types of lung diseases and their treatment options. So, first we have to understand that although we are discussing carbon monoxide poisoning, carbon monoxide is not something that is foreign to our body, right? Because, as you see, our hemoglobin has the heme protein in it. The heme basically undergoes enzymatic degradation. So, in the presence of heme oxygenase, heme converts to bilirubin and eventually to bilirubin.

And during this process, or during this step, a molecule of carbon monoxide is generated. So, this shows that carbon monoxide is not foreign to our body; in cases of regular enzymatic metabolic degradation or metabolism from heme proteins, it kind of creates carbon monoxide, but we have to remember that these carbon monoxide levels are very low, right? So, this carbon monoxide, even if it is formed in the body, is highly likely to be low in amount that is present in the blood at a given time. A low amount of carbon monoxide does not cause any type of significant toxicity to our body. Now, what is carbon monoxide poisoning, basically? So, carbon monoxide poisoning occurs whenever carbon monoxide builds up in the blood, and that can happen due to many reasons. For example, there might be a situation in which too much carbon monoxide is present in the air.

And the carbon monoxide, how it forms, it basically forms from the combustion of the air. So, in cases of combustion with the air or fuel burning, a lot of carbon monoxide can quickly form and accumulate in the local air. Very interestingly, carbon monoxide is an invisible gas; it is a colorless gas, and there is no smell of carbon monoxide. So, more often what happens is that patients who are at risk of carbon monoxide poisoning may not even understand there is a carbon monoxide buildup in the area before the situation becomes too late. And why it is poisonous is that carbon monoxide has a very high affinity for our RBC cells and our hemoglobin.

And basically, carbon monoxide can replace the already attached oxygen from hemoglobin because the binding affinity of carbon monoxide is much higher than the binding affinity of oxygen for hemoglobin. There can be some early signs of carbon monoxide poisoning; for example, it may cause a mild headache, there might be nausea, shortness of breath, or vomiting as well. So, basically, what happens to our body during carbon monoxide poisoning? Generally, we know about red blood cells and hemoglobin, which is present in the red blood cells and carries oxygen throughout our body. And why is it important? All we know is that oxygen needs to be supplied to different cells and organs in our body to perform different types of cellular respiration processes and different types of metabolic processes. But what happens when there is carbon monoxide poisoning in the body is that the carbon monoxide will replace the initial oxygen.

So, basically, the initial attachment of oxygen to the hemoglobin will be replaced by carbon monoxide. And as it replaces the already attached oxygen from the hemoglobin, the hemoglobin will become like deoxyhemoglobin, and that means it will lose the capacity to transport oxygen in the various body parts. And in this way, our different tissues, our cells, and our organs will not be able to get the oxygen. A prolonged hypoxic condition will generate, and the long-term hypoxic condition can damage different components of our organs and cells. And if the situation goes on too long, we can go into a brain coma or even die.

So, why do we basically have to understand why this is so dangerous? Because carbon monoxide, as we are saying, has a higher affinity to hemoglobin compared to oxygen. And it is not just a few folds; you can see that carbon monoxide has almost 200 to 300 times a higher affinity to bind with hemoglobin. And you can see that this is like the oxygen or carbon monoxide dissociation curve with the hemoglobin that we discussed in the last class. You can see in cases of hemoglobin, we said it was a sigmoid type of curve because it binds oxygen in a cooperative manner. We discussed all this in our last class: there are 2 alpha and 2 beta proteins, and initially, hemoglobin is in a tense state; now, when 1 oxygen binds to 1 alpha chamber or alpha protein, the iron or the molecule slowly gets converted from the tense state to the relaxed state.

And in the relaxed state, the second, third, and fourth oxygens bind rapidly. So, overall, you remember that there is a slow increase and then eventually there is a saturation that looks like a sigmoid curve of oxygen for hemoglobin binding. And also, you remember the P50 or the half saturation of the oxygen was about 30 to 35 torque. We were told that at least 50 percent of the oxygen needs to bind with the hemoglobin, and it takes about 30 to 35 like torque pressure. But in cases of carbon monoxide you see like it is so, rapid right within like 1 to 2 torque pressure within like 1 to 2 torque pressure itself.

You can see that eventually, almost 100 percent of the carbon monoxide saturation occurred. So, within like the 1 to 2 like atmospheric pressure eventually full saturation of the carbon monoxide can happen. So, what are the different types of effects of carbon monoxide in relation to the concentration of ppm in the air? So, depending on the concentration of carbon monoxide, our body can experience different types of toxic symptoms or different types of conditions. So, for example, if the carbon monoxide level is very low, around 35 ppm, then a person can experience headaches and dizziness within 6 to 8 hours of constant exposure. In cases of 100 ppm, there can be a slight headache, especially if the exposure is about 2 to 3 hours.

In cases of 2 to 3 hours of exposure to 200 ppm of carbon monoxide, there can be a loss of judgment along with a headache. In cases of 800 ppm exposure within 45 minutes to 1 hour, a person can experience dizziness, nausea, and convulsions. In cases of 1600 ppm of carbon monoxide within 20 minutes, significant headaches, increased heart rate, dizziness, and nausea can be experienced. If it goes more than that in cases of 3200 ppm within 10 minutes, there can be significant headache, nausea, and dizziness, and within 30 minutes, the person can die. If it goes further in cases of 6400 ppm and 12800 ppm of carbon monoxide, these are highly acute exposures to carbon monoxide; within about 20 minutes, and in cases of 12800 ppm, a person can die within 2 to 3 breaths.

So, you can see that as the concentration of carbon monoxide increases, the physiological condition also changes in a way, and anything beyond 3200 ppm, the chances of survival are very low. So, how can carbon monoxide poisoning be managed or treated? Basically, as we know, carbon monoxide replaces oxygen, so we should immediately remove the patient from the carbon monoxide area and try to bring them to fresh air. So, if we bring in fresh air, for example, in cases of normal atmospheric pressure, what has been seen is that about 21 percent oxygen is generally present, and it takes about 5 hours and 20 minutes in order to fully remove carbon monoxide poisoning. But if we give the patient 100 percent oxygen, or pure oxygen, it has been observed that it takes about 1 hour, or roughly 1 hour and 20 minutes, to replace the carbon monoxide. But the most important thing, as you see, is that this therapy takes a lot of time, and that might be enough to prevent significant brain and other organ damage.

Because if our body stays in a prolonged hypoxic condition even for a few minutes, it can go on for more than 1 hour, 2 hours, or 5 hours. Like the brain, other organs are also very delicate and can experience significant damage, which can lead to a loss of function in those organs. So, the most prominent and crucial therapy is using 100 percent hyperbaric oxygen, which is hyperbaric oxygen therapy. So, basically, hyperbaric oxygen therapy at 3 atmospheric pressures is at a higher atmospheric pressure. So, under higher atmospheric pressure, 100 percent oxygen can be administered, and it takes only about 20 to 23 minutes to replace all the carbon monoxide.

So, basically, a hyperbaric chamber looks like this, where patients can lie down inside a controlled atmospheric pressure chamber, and how much we said the atmospheric pressure would be is 3 atmospheric pressures, right? So, in these cases, the oxygen will be able to replace the carbon monoxide very quickly. And this type of hyperbaric oxygen therapy can also be used for carbon monoxide poisoning. So, the main use is for carbon monoxide poisoning, but apart from that, hyperbaric oxygen therapy can be used for various other purposes. For example, cyanide poisoning, crush injuries, gas gangrene, acute or traumatic reduced blood flow, air or gas bubbles in case they get trapped in blood vessels, chronic infection, and diabetic wounds. Oxygen therapy is crucial in cases of various diseases where inflammation is challenging, and there is a situation of hypoxia.

So, in these cases, oxygen therapy and hyperbaric oxygen therapy can be used. So, one thing to remind again is that this is a crucial therapy in cases of carbon monoxide poisoning at about 3 atmospheric pressures. So, around 3 atmospheric pressures. Atmospheric pressure, the oxygen can be completely replaced within 23 minutes. So, if you remember in these cases, these are all milliliters.

So, basically in cases of normal saturation, you see that carbon monoxide can saturate within 1 to 2 milliliters in our body. So, you can see how it is highly risky. So, next we will discuss the pulse oximeter. So, what is a pulse oximeter? So, the pulse oximeter looks like this, and we mostly use it at our home; it basically observes a rapid measurement of the oxygen saturation level. And this is a non-invasive technique.

So, basically, there is no prick, and we can simply put our fingertip inside the pulse oximeter, and it can give a measurement of the oxygen saturation in our body. And how this basically works like a pulse oximeter is the principle that oxygenated hemoglobin and deoxyhemoglobin absorb red light and near-infrared light differently. So, basically in the oximeter, there are two lights: one is a red light and one is a near IR light, and as you can see, in cases of oxygenated blood, it basically absorbs infrared light and transmits all the red light. So, oxygenated hemoglobin or oxygenated blood basically transmits all the red light, and that is why oxygenated hemoglobin blood mostly looks red in color. In cases of deoxygenated blood, it is exactly the opposite.

It mostly absorbs most of the red light and transmits the majority of the infrared light. So, in this case, in instances of deoxygenated blood, that is why it looks less red in color or a little bit darker in color. So, as you can see, both oxygenated blood and deoxygenated blood have a different pattern for absorbing red light and near IR light. So, one more time to recapitulate: in cases of oxygenated blood, red light mostly gets transmitted, while infrared light mostly gets absorbed; in cases of deoxygenated blood, the opposite is true: red light gets absorbed and infrared light gets transmitted. And basically, SpO2, which is the arterial oxygen pressure, can be calculated using this equation: SpO2 is 130 minus r times 30.

These are constant values, and r can be calculated from the change in the IR light and the red light. So, r is basically equal to Ac red divided by dc red divided by Ac infrared divided by seen for it. So, by calculating this equation, the SpO2 or oxygen saturation level can be immediately measured through the pulse oximeter, and in the case of a normal healthy person, it has been seen that the SpO2 values are around 95 to 100 percent. And whenever there is low oxygen, it can be observed that it may be less than 95 percent of SpO2. So, during the time of COVID, you remember how we used to measure or monitor the SpO2 level, and in cases where the SpO2 level was well below 90, it was a kind of alarming situation where either oxygen therapies could be given or the patients needed to be taken to the hospital to receive oxygen through the nose or via other ventilator conditions.

Now, lastly, we will discuss different lung diseases. For example, there are certain conditions where airway disease can affect the tubes or the airways. Conditions can be like asthma, where inflammation and narrowing of the airways can occur, leading to wheezing and breathlessness. So, you can see that due to the inflammation, it can be caused either by dust allergy or by pollen allergy, or it can be due to a bacterial or viral infection. So, basically, narrowing down the lung airways can cause inflammation, which can lead to wheezing and difficulties in breathing; this type of situation can happen.

So, this is basically called asthma. And then bronchitis can also happen, which can be caused by different types of viral infections, where you can see mucus build-up, and it can basically cause difficulties in breathing, such as damaged cilia cells, chest pain, etc. Then the next condition, which is similar to chronic obstructive pulmonary disease, is considered. So, basically, it is called COPD, and this can happen due to different conditions, for example, bacterial infections, different types of dust, and other macro or micro particles; it can also be caused by viral infections. So, all these presences of different materials and cellular organisms, for example, bacteria, particles, and viruses, can cause overactivation of the immune cells.

So, the activation of immune cells can involve macrophages, eosinophils, and neutrophils, and this overactivation of immune cells can cause the secretion of a lot of pro-inflammatory cytokines. So, basically, overactivation of those immune cells can cause the secretion of a lot of pro-inflammatory cytokines. This can be like IL-1, IL-6, etc., TNF alpha, and these will create a lot of damage and chronic inflammation to the lung; basically, this is called chronic obstructive pulmonary disease, or COPD. Then there can be diseases related to lung tissue, for example, pulmonary fibrosis, and in response to foreign particles, such as microparticles or dust particles.

In case the particles, viruses, or other bacteria can be eliminated by your immune cells, then it is good; but if they cannot eliminate foreign particles, especially micro- and nano-sized dust particles and other toxins, what our lung cells do is develop a response called fibrosis. And fibrosis is nothing but creating a thick layer of myofibroblasts and collagen cells around those particles. So, what we are saying is that in cases where the immune system is able to eliminate those particles, then it is good, but in cases where it is not able to eliminate them, what will happen is that in these cases, lung cells will develop a coating of myofibroblast cells along with a collagen layer. In this way, the cells will become harder, thicker, and eventually, they will replace those active, functional alveolar cells. So, this is a situation called fibrosis, and this is a deadly condition because once fibrosis occurs, we will basically lose functional cells, and as the fibrosis progresses, it will damage the majority of the lung area, leading to a lack of oxygen saturation, which will be a highly detrimental situation.

Finally, there can be other different conditions; for example, pulmonary hypertension or pulmonary embolism. In cases of pulmonary hypertension, you can see that high blood pressure in the arteries of the lungs can cause the lungs, like the nearer heart, to kind of strain. In normal cases, the pulmonary artery of the heart has a proper shape and observation. But in cases of a narrow pulmonary artery, when there is blood pressure that builds up, you can see that heart strain can happen, or you can observe the enlarged right ventricle. So, there are specific conditions, like an enlarged right ventricle, that can be observed in cases of pulmonary hypertension.

Also, pulmonary embolism is another condition. So, this is basically like a blood clot formation that blocks a lung artery, and this is also a very dangerous situation; it can mostly originate from a leg vein, which is also called deep vein thrombosis. Then there can be different infectious diseases related to the lungs; for example, pneumonia, tuberculosis, and influenza. So, basically, either bacterial infections like pneumonia and tuberculosis can occur in the lungs, and they can damage our lungs. There can be virus-related infections of influenza, and if these infections are persistent and last long-term in the body, they can completely damage and destroy the lung tissues, which can also be detrimental and cause mortality.

Finally, the last condition we will discuss, like any other organ, lung cancer is also a very critical condition in the body. And as you see, lung cancer is one of the primary causes of death. Lung cancer can happen due to many reasons. And mostly two types of lung cancer can be observed: one is non-small cell lung cancer or NSCLC, which is the most common form; about 80 percent of lung cancer cases are associated with NSCLC, but these are a less aggressive form of tumor. But in the case of small cell lung cancer or SCLC, although it happens in only 20 percent of cases, these are the most progressive and aggressive forms of cancer.

Then it has been seen that in these cases of SCLC, the mortality rates are too high and the 5-year survival rate is also too low. So, there are different reasons that can cause lung cancer; the primary reasons include smoking, environmental pollution, exposure to radiation, and other toxins or chemicals, and it can also be associated with genetic mutations. In cases of lung cancer, shortness of breath, coughing up blood, chest pain, asthma, shortness of breath, and fatigue can be observed along with weight loss. And different treatment options, of course, are available, including surgery, radiation therapy, chemotherapy, immunotherapy, hormonal therapy, etc. So, think about why carbon monoxide is called a poison and referred to as a silent killer.

Can a pulse oximeter accurately detect oxygen levels in patients suffering from carbon monoxide poisoning? Why and why not? Why are lung diseases like asthma and chronic obstructive pulmonary disease often described as obstructive? So, why are these asthma and COPD called obstructive diseases? You can also refer to these books. Hopefully, you are enjoying the human physiology class. If you have any further questions, please discuss them during the live sessions. You can also send your questions to the email.

Thank you again for attending today's class. We will meet with you very soon for another new class of human physiology. Thank you.