Let's start with the last part, which is the circulation in the capillaries of the lungs.

Now the idea is that the blood flow inside the capillaries depends on the pressure inside the alveoli and the pressure inside capillaries. Which means we will find three zones in the lungs:

**Pulmonary zones**

1) **Zone #1**: The blood flow in that area in the capillaries (the pressure of that blood flow) is less than the alveolar pressure, so the blood flow will not continue.

   Remember that the pressure inside the vascular system alternates; there is systolic and diastolic pressure, systolic is the higher and diastolic is the lower.

   So in zone #1, when the pressure inside the capillaries during systole and diastole is less than alveolar pressure, there is zero blood flow, because of the obstruction of blood flow between the two alveoli.

2) **Zone #2**: Intermittent blood flow
In this zone there are two cases:

During systole, blood flow and the blood pressure inside the capillaries is more than alveolar pressure, so blood flow will occur.

During diastole, the blood pressure is lower than the alveolar pressure, so there is aconstriction of the capillaries and no blood flow will occur.

3) Zone #3: In this phase there's continuous blood flow, so during systole and diastole, the capillary pressure is always higher than alveolar pressure.

First you should remember, this type of classification which is related to blood flow in the capillaries of the pulmonary circulation, it is applied only in the upright position.

![Diagram showing blood flow in different zones](image)

When we are standing, we will have this classification, and pay attention there are multiple alveoli surrounding this capillary, but for illustration they draw it as one alveoli.

Let's take the fact that zone #1 under normal conditions doesn't exist, it exists only in diseases such as heart failure, bleeding, and also in individuals who have low blood pressure, especially in females.

But as mentioned above, normally we don't have zone #1, we only have zones #2 and #3.
The length of the lungs from the apex to the base is 23cm, and according to the heart as a reference point these 23cm are divided into 15cm above the heart and 8cm below the heart.

Zone #2: The areas of the lungs which are located above the heart

Zone #3: The areas of the lungs which are located below the heart

If you agree with me, that the blood flow without any other factors when it goes up it will have less pressure, and when it goes down it will have more pressure because of the gravity.

So the vessels going from the heart up and down, the more the vessels goes down, the more the pressure in it (in systole and diastole), and because of that, the area in the basement of the lung, it will reach blood flow, which increase blood pressure during systole and diastole.

The blood pressure in the pulmonary artery is 25mmHg during systole and 8mmHg during diastole.

When the vessel goes up, the more it goes up the lower the pressure, so we have 25mmHg above the heart and this pressure will decrease and become lower and lower until we reach the apex and vice versa.

**SO YOU HAVE TWO CASES:**

1) Areas above the heart until reaching the apex

During systole, the vessel that's going up to the apex (15cm above the heart), so I'll subtract 15mmHg which is the gradient of lowering the blood pressure because of the gravity

\[ 25 - 15 = 10\text{mmHg} \]

during diastole we have 8mmHg in the pulmonary artery

\[ 8 - 15 = -7\text{mmHg} \] (so it will block the blood flow)
2) Areas below the heart until you reach the base
during systole, the vessel that's going down to the base (8cm below the heart), so here I'll add 8mmHg

\[ 25 + 8 = 33 \text{ mmHg} \]
during diastole
\[ 8 + 8 = 16 \text{ mmHg} \]
So the blood flow in the lower region will continue, while in the upper region will be intermittent.

![Diagram]

the apex of the lung is 15cm above the heart level. so
during systole: \( 25 - 15 = 10 \text{ mmHg} \)
during diastole: \( 8 - 15 = -7 \text{ mmHg} \)

the base of the lung is 8cm below the heart level. so
during systole: \( 25 + 8 = 33 \text{ mmHg} \)
during diastole: \( 8 + 8 = 16 \text{ mmHg} \)

NOW, in supine position the upper and lower regions of the lungs are not that significant in comparison to heart level, therefore you'll transfer all of the capillaries inside your lungs with the zone #3.

It's not easy to accommodate an amount of blood in the pulmonary circulation because it's a heavy load on it, and there is a reason for not being in danger under normal physiological conditions.
The effect of increasing Cardiac Output

When oxygen demand increases (during exercise), the human body handles it by increasing the amount of oxygen utilization by hemoglobin as well as by doubling the cardiac output 3, 4 or even 5 times the normal, for instance from 5 L/min to 40 L/min.

That will be dangerous to the pulmonary circulation, because I need to make this 40L load flow in one minute in the small pulmonary circulation, but that doesn't cause a heavy load in this small circulation because of the following:

1) Increasing the number of open capillaries (a person at rest with normal cardiac output will not have all his pulmonary arterioles open, but they will open when Cardiac output increases.)

This mechanism will accommodate the blood flow, but will not affect the blood pressure in the pulmonary circulation, because these are new tubes through which the blood goes (didn't affect the previous flowing one).

2) These open capillaries and arterioles will become fully distended/dilated due to their large compliance and thus have an effect of keeping the pulmonary blood pressure normal.

NOTE: Reasons 1 and 2 are interrelated and both play a role in keeping the pulmonary blood pressure normal.

3) Increasing pulmonary pressure, this is not significant because it creates load on the right heart and doesn’t conserve energy (point #3 from awn’s lectures).

Increased blood pressure will cause plasma to leak out of the vessels which might be helpful in the systemic circulation for bathing the tissue cells and providing nutrients and oxygen, but has drastic effects in the pulmonary circulation by filling the alveoli with fluid leading to pulmonary edema.
Pulmonary Capillary Dynamics

It is important that our body maintains homeostasis, especially by coordinating plasma filtration and absorption between the pulmonary capillaries and its surrounding interstitial space through different intravascular and interstitial forces in order to prevent pulmonary edema.

*Capillary fluid exchange dynamics:*

Forces causing outward plasma fluid movement

<table>
<thead>
<tr>
<th></th>
<th>lungs</th>
<th>Systemic cir.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary pressure</td>
<td>7 mmHg</td>
<td>17 mmHg</td>
</tr>
<tr>
<td>Interst. Osm. Pr.</td>
<td>14 mmHg</td>
<td>8 mmHg</td>
</tr>
<tr>
<td>Interst. Neg. pr.</td>
<td>-8 mmHg</td>
<td>-3 mmHg</td>
</tr>
</tbody>
</table>

Interstitial Osmotic pressure is generated when small plasma proteins such as albumin escape the capillaries through the large capillary pores (which are larger than the systemic capillary pores) in the lungs, accounting for the larger Interstitial Osmotic pressure in the Lungs compared with the systemic circulation.

*Summing up the total forces causing plasma fluid to move outward*

\[ 7 + 14 + 8 = +29 \]

*The only force causing absorption of fluid into the capillaries is the Plasma colloid osmotic pressure which is equal to 28 mm Hg. (Designated as –28 because it moves fluid into the capillaries)*

*Mean Filtration pressure = +29-28 = +1*
As you know from the previous talk, this +1 pressure is continuous and accumulating; however, it is handled by the lymphatic system which pumps the fluid back to the circulation.

We also have another safety factor which is that small amounts of fluid will enter the alveoli and evaporate accounting to the phenomenon known as insensible water loss, it is not significant but serves as an extra safety factor.

So normally the alveoli should be WET and DRY at the same time.

Wet in a way to have a thin lining layer on the internal surface, and dry in the sense that there shouldn't be any drop of the fluid in the spherical compartment of the alveoli.

And if that happens, that will start what we refer to as pulmonary edema, and that's why there are special Juxtacapillary receptors located between alveoli, and they sense any filling of fluid inside the alveoli.

When they start sensing any filling of fluid inside the alveoli, they will give you a signal of fear, and the patient starts to feel that he's dying.

*Remember that the systemic circulation safety factor handled by the lymph is about 17 mm Hg, but the safety factor in the lungs is much greater than that, reaching around 21-25 mmHg known as the acute safety factor.*
So if the hydrostatic pressure or any other pressure causing outward movement of plasma increases, this creates a mean filtration pressure of more than 17 mm Hg which will cause edema in all body tissues except the lungs, because the lungs can accommodate higher safety factor pressures.

Also chronic conditions (chronic diseases) such as hypertension will lead to an even higher safety factor which will reach up to 35mmHg (40-45mmHg in patients with chronic mitral stenosis) this reflects the capacity of homeostasis to increase its efficiency.

**Pulmonary Edema causes**

1. Increase in pulmonary blood pressure caused by left-sided heart failure and mitral valve disease:
   **Left-sided heart failure =\( \uparrow \)** **venous + capillary Pressure**

2. Damage to the pulmonary capillary membrane caused by:
   a- Infections such as pneumonia.
   b- Breathing chlorine gas or sulfur oxide gas, which are common industrial and agricultural gases, so you might encounter a farmer affected by those gases.

_The doctor mentioned that he encountered such a case during his medical training and theresian administered 80mg of atropine (the antidote) to the patient and you have to act as soon as possible and you have to be brave, because you will give a huge amount of antidote (you don't know how much, it depends on the level of toxication, so you start to give atropine until the pupils are dilated)._  

_Do your best and let God do the rest_

Edited by: Nihad Al-Yousfi

Can't fool the city, man, they know what's up