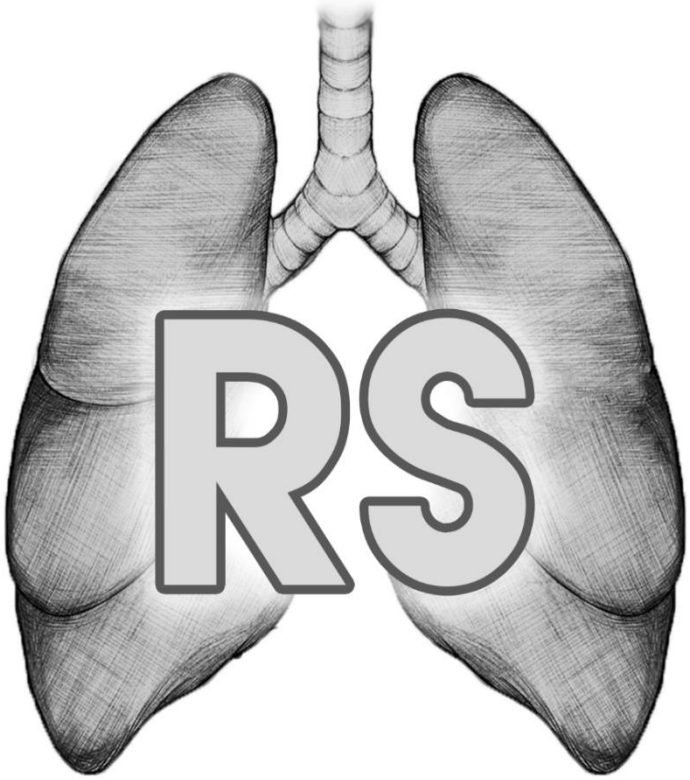

☑ Sheet ○ Slide ○ Handout

Number

5

Subject

Lung Compliance and Functions of Surfactant

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Date: 1/12/2016

Price:

**** This sheet was written according to the recording that belongs to section 2. Please pay attention that the order of ideas in this sheet is a little bit different from that in the recording.**

❖ Topics of this lecture:

*Lung Compliance.

*Functions of surfactant.

*RDS (Respiratory Distress Syndrome).

❖ Lung Compliance

I. Compliance curve of the lung

Figure (1), a quick reminder

- In the previous lecture, we studied the inflation and deflation curves.
- The difference between the inflation curve and deflation curve is referred to as "Hysteresis".
- The involved **elastic forces** are of two types:
  1) The **Surface Tension**
     → responsible for two thirds of the elastic forces.
  2) The **Elastic Fibers** → responsible for one third of the elastic forces.

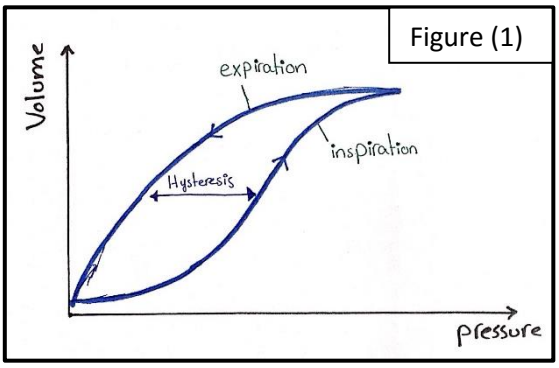


Figure (1)

- How was it possible to find out that the surface tension contributes to 2/3 of the elastic forces, while elastic fibers contribute to 1/3 ?
  An experiment was carried out to separate the effects of these two forces. The main principle was to compare between the inflation-deflation curves for air-filled lung and saline-filled lung. *Figure (2)*

A. The curve of the normal (air-filled) lung appears as (A) due to the presence of surfactant as mentioned in the previous lecture. (the orientation of surfactant is proper during expiration, but not during inspiration).

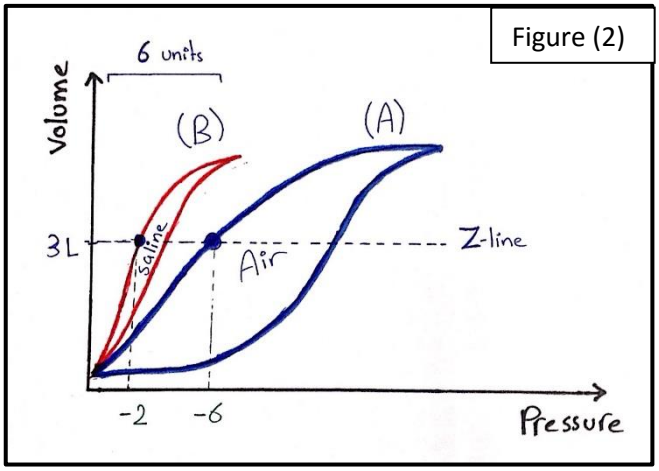
B. If we start filling the lung with normal saline (isotonic solution of 0.9% NaCl), the surface tension will be cancelled.
***Note**: Surface tension needs water-air interface "سطح هوائي مائي" (in this context, it is the alveolar-air interface). If we start filling the lungs with water, air will not stay in the lungs → there will be no more water-air interface and thus, no more water tension. We will be dealing with only one elastic force, which is the elastic fibers.*

We want to measure the amount of force needed to fill the lungs with saline to overcome only one elastic force which is the force of elastic fibers.

The resulting curve in this case will look like curve (B):

- This curve has very little Hysteresis (because there's no surface tension, nor surfactant function).

Figure (2)



Now, look at line Z in the figure and answer the following question: when the volume is 3L, how much pressure do we need to hold the lungs inflated in curve (A), and in curve (B)?

- In curve A (air-filled lung) → the required surrounding negative pressure is -6 mmHg.
  This -6 is needed to overcome two forces; surface tension, and elastic fibers.
- In curve B (saline-filled lung) → the required surrounding negative pressure is -2 mmHg.
  This -2 is needed to overcome only one force which is the elastic fibers.

- From the previous two points, we can conclude that 4 units of negative pressure are needed to overcome the force of surface tension. Whereas only 2 units are needed to overcome the force of elastic fibers *(these numbers are according to our figure and to the example we put (when the volume is 3L). The ratio however will be the same even if we look at a different volume).*
- This explains the fact that surface tension contributes to two thirds of elastic forces (4 units were needed out of 6 in our example) while elastic fibers contribute to one third (2 units out of 6 in our example).

II. الفضيلة تقع بين الرّذيلتَيْن

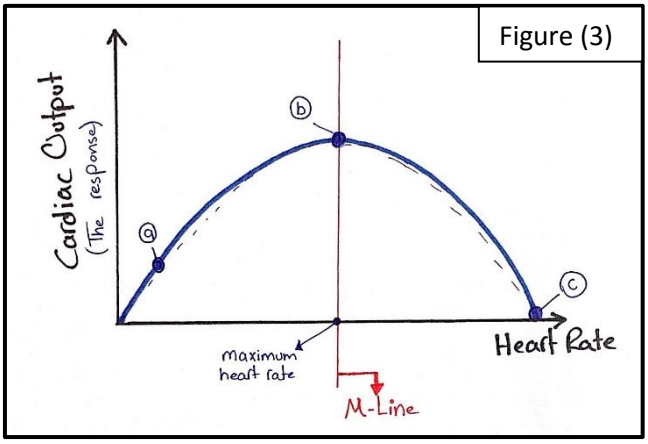
The two extremes of anything are not good.

This rule also applies in physiology.

<u>An example from the Cardiovascular System</u>:

- Figure (3) shows the relationship between the heart rate and the cardiac output.
  Point (a): low HR → low CO
  Point (b): high HR → high CO
  Point (c): very high HR (for example: ventricular fibrillation) → CO is zero.
  - An increase in HR results in increased CO, but this applies only up to a certain limit (this limit is represented by line M in the figure).

Figure (3)



- The maximum heart rate:
  - The heart rate of an individual should not exceed the magnitude of the Maximum Heart Rate for that individual.
  - Max. Heart Rate is calculated by the following equation: HR_{max} = (220 – Age)*75%
  - Let's suppose that a person is exercising – running on a treadmill for example – and his heart rate is being measured during the exercise. If the maximum HR is reached, this individual should slow down and not exceed it.
  - **If the maximum HR is exceeded, the cardiac output starts decreasing.**
    The most important consequence of decreased cardiac output is: less coronary blood flow → less oxygen available to the heart → ischemia → ischemic patches might act as an ectopic pacemaker → ectopic pacemaker might start giving impulses and may result in ventricular fibrillation.
    (in other words, ischemia breeds ectopic pacemaker, and ectopic pacemaker breeds higher heart rate → ventricular fibrillation and death might occur).

<u>Another example from the CVS:</u>

Frank-Starling law of the heart states that "the longer the sarcomere, the stronger the contraction. *(length represents the resting tension before contraction)*, but this rule applies only up to a certain physiologic limit (certain length).

<u>Note:</u> the parts of the normal conducting pathway (SA node, AV node, AV bundle,…) are known as "latent pacemakers".

Anything outside this path is referred to as "ectopic".

An example from the Respiratory System:

- Too much compliance is bad.
  In COPDs -like emphysema-, the compliance is very high → not beneficial because it's difficult for the lungs to deflate.
  Note: in COPDs, the Total Lung Capacity might reach 7- 7.5L (instead of the normal 6L)
- Too little compliance is bad.
  In restrictive lung diseases -like pulmonary fibrosis and RDS-, the compliance is low → not beneficial because it is difficult for the patient to inflate his lungs.
  Note: in restrictive lung diseases, TLC might only reach 4- 4.5L.

❖ Functions of Surfactant

Five main functions:

I. **Surfactant reduces the surface tension.**

II. **It increases compliance** ("compliance" is opposite to "recoil tendency").

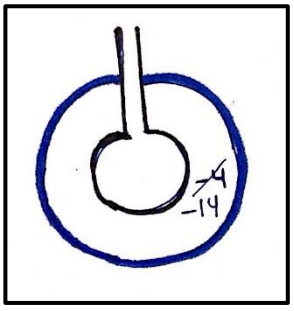
III. **It reduces the work of breathing.**

$$W_{\text{of breathing}} = \Delta P * \Delta V$$

ΔV : Tidal volume

ΔP : amount of pressure needed

If surfactant is absent, the collapsing forces would be huge, and thus, the negativity needed in the pleural cavity will be higher (for example; -14 instead of -4 in a specific region). Since more pressure is needed, more muscle contraction will be needed (to provide a higher force) → higher work of breathing. The opposite applies when surfactant is present.



IV. Surfactant makes surface tension VOLUME-dependent.

To explain this point, we need to revise LaPlace's law:

$$P = 2T/r$$

Additional piece of information:

LaPlace's law states that "the larger the vessel radius, the larger the wall tension required to withstand a given fluid pressure"

Suppose that we normally need a pressure of -4mmHg in the pleural cavity for a normal alveoli to stay inflated. If another alveoli in the same region has a smaller radius, the -4 will not be enough, we might need -6 for example.
(why? Because according to LaPlace's law, the pressure is inversely related to the radius (($P \propto 1/r$)). → the smaller the radius, the higher the pressure needed).

HOWEVER, in reality, if the radius of the alveolus becomes smaller, the **concentration** of the surfactant increases. (the amount of surfactant is the same, but because the volume has decreased, the concentration of surfactant increases and thus becomes more effective in reducing surface tension).

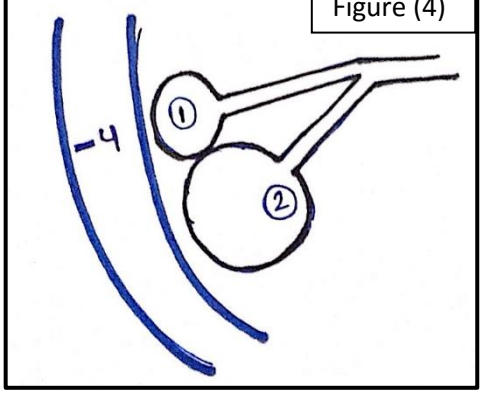
Extremely important conclusions:

- When the radius **decreases**, the surface tension simultaneously **decreases,** to maintain the same needed inflation pressure (here, it's -4 in our example).
- Surfactant makes surface tension **volume-dependent**.
  - Smaller volume → less surface tension (because the surfactant would be more concentrated and thus more effective).
  - Larger volume → higher surface tension.

To understand the importance of this function of surfactant, let's imagine that the surfactant does not make the surface tesnsion volume dependent. What will happen??

- Figure (4) shows a region of the pleural cavity that has a pressure of -4 mmHg surrounding two alveoli. Alveolus (1) is smaller than (2).
- According to LaPlace's law, the pressure needed to hold the smaller alveolus open (to keep it inflated) will be higher (more negative). Let's say that the needed pressure is -6. However, since both alveoli are in the same region, they are surrounded by the same negative pressure (-4). As a result, the smaller alveolus will automatically collapse and empty its content into the larger alveolus. *Figure (5)*
  - This means that small alveoli and large alveoli cannot coexist in the same region in the lung.

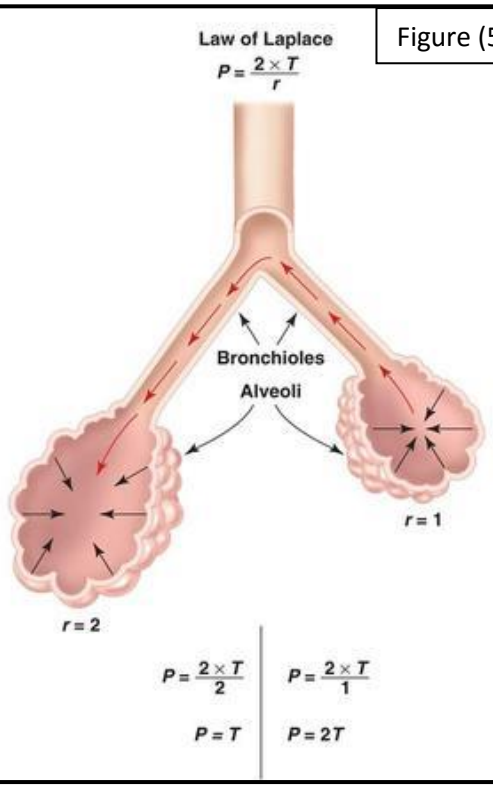
Figure (4)



For better visualization of what actually happens in figure (5), kindly watch the experiment carried out in the 3-minute video provided in the following link:

https://m.youtube.com/watch?v=_btWTwDVRj8

Figure (5)



It's not logical to have the previous scenario present in the human body. What actually happens is the following:

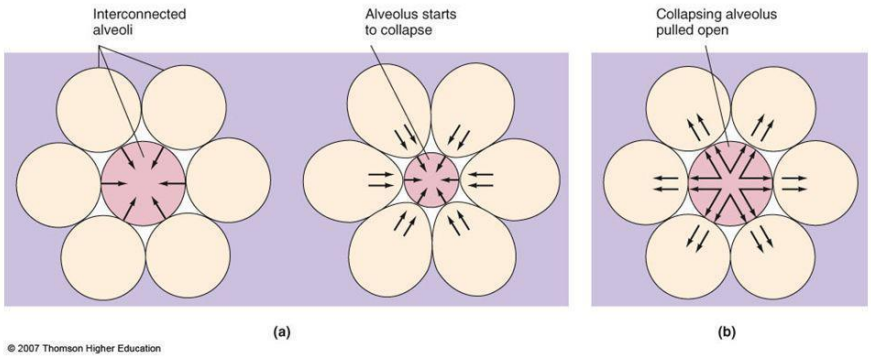
- When the radius is smaller, the surface tenstion is smaller (because the concentration of surfactant would be higher)
  - ➔ The same pressure (-4 mmHg) is enough to keep both, small and large alveoli open.
  - ➔ **Small and large alveoli can coexist in the same area in the lung.** This is referred to as "Alveolar Stability".

Alveolar stability: small alveoli can coexist with large alveoli in the same region in the lung (same surrounding intrapleural pressure) due to two reasons:

1) Surfactant makes surface tension volume dependent.
2) Alveolar traction (also called "alveolar interdependence"). *Figure (6)*
   - Alveoli are surrounded by other alveoli and interconnected by connective tissue.
   - If an alveolus starts to collapse, surrounding alveoli are stretched and they apply expanding forces on the collapsing alveolus (bacuse the surrounding alveoli are trying to resist the extra stretching) thereby help to keep the collapsing alveolus open. This is called alveolar interdependence. *Alveoli depend on each other*.

Note: we keep saying "in the same region" because different parts (regions) of the pleural cavity have different intrapleural negative pressures. This will be discussed in the following sheet.

Another factor which helps keep the alveoli open is:
The Alveolar Interdependence



If an **alveolus start to collapse** the **surrounding alveoli** are **stretched** and **then recoil** exerting **expanding forces** in **the collapsing alveolus** to **open** it

Figure (6)

<u>Additional note:</u> loss of interdependence as a result of the loss of alveolar walls will cause a greater tendency to collapse.

V. Surfactant prevents the occurrence of pulmonary edema.

Before explaining this point, few basic principles related to physiology of fluids were mentioned by Dr.Yanal.

A. <u>Contribution of Albumin in the colloid osmotic pressure</u>

When we talk about colloid osmotic pressure (will be mentioned later in this sheet), we are more concerned with albumin, not globulin. Why?

Because **<u>albumin contribution to the colloid osmotic pressure is higher compared to globulin</u>**. Two reasons stand behind this fact:

1. Albumin has a smaller molecular weight → higher number of particles.
2. Concentration of albumin in plasma is higher.

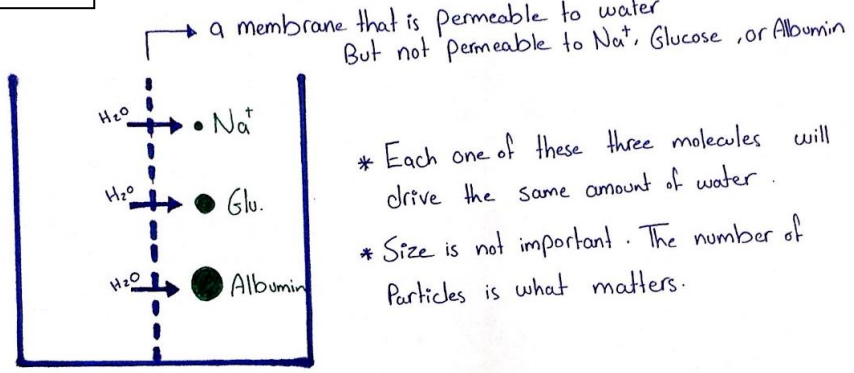
Justification is in the following 2 pages.

- Total plasma protein = 6 – 8 g/dL of blood
  (Albumin → 3.5-5.5 g/ dL of blood, Globulin → 2-4 g/dL of blood)
  → The concentration of albumin is almost double the concentration of globulin.
- To express "amounts" of substances in the body, we use units like **mg** (or g, ng, µg,..), **mole** (or mmol), **osmole** (or mOsmole), or **equivalent**. However, the use of each unit of the previous is not random. For example:
  - <u>Equivalent</u> is used when we are concerned with electricity.
    e.g. when we talk about Na^+ or K^+ in the context of electricity, we use the equivalent unit because we're concerned with charges.

- Osmol is used when we are concerned with the movement of water between the body compartments.

- Fluid compartments in the body are three: intracelluar space, interstitium, and intravascular space.
  - The three compartments have different composition in terms of ions (like Na^+, K^+, others), and proteins. However, the three copmartments are all electroneutral and more importantly, the **osmolarity in all of them is the same** (since water moves freely between the compartments).
    → that's why when we are concerned with the movement of water between body comparments, we use the osmol unit.
- Osmole: refers to the number of particles regardless of the size of the particle. One big particle has the same effect as one small particle when we are talking about driving water each to its comparment. *Figure (7)*

Figure (7)



Few basic points: *(added only to make the next part easier to understand, read them quickly just to remember the basics)*

- The number of particles in one mole of un-dissociated solute is called one osmole.
- 1 osmole = 6.02 *10^{23} particles.
- Osmolarity: number of osmoles of solute per liter of solution.
- Don't forget that when we talk about ionic compounds, the number of "types" of particles that result from the dissociation of the ionic compound in water should be taken into consideration when we're talking about the number of osmoles. For example, a solution of 1 mol/L NaCl corresponds to an osmolarity of 2 osmol/L. The NaCl salt particle dissociates fully in water to become two separate particles: an Na^+ ion and a Cl^- ion. Therefore, each mole of NaCl becomes two osmoles in solution, one mole of Na^+ and one mole of Cl^-. Similarly, a solution of 1 mol/L $CaCl_2$, gives a solution of 3 osmol/L (Ca^{2+} and 2 Cl^-).
- Number of moles = mass(g)/ molar mass
- The molar mass of a substance equals the molecular weight of that substance reported in grams.

- One mole of any substance contains a constant number of particles which equals $6.02 * 10^{23}$ (Avogadro's number).

One mole of Na^+	23g (molar mass is 23g/mol)	**$6.02 * 10^{23}$ particles**
One mole of glucose	180g	**$6.02 * 10^{23}$ particles**
One mole of albumin	70,000g	**$6.02 * 10^{23}$ particles**

- If you have three samples: 2g of Na^+, 2g of glucose, and 2g of albumin. Which sample has the highest number of particles?
  The Na^+ sample (because it has the smallest molecular weight), then glucose, then albumin.

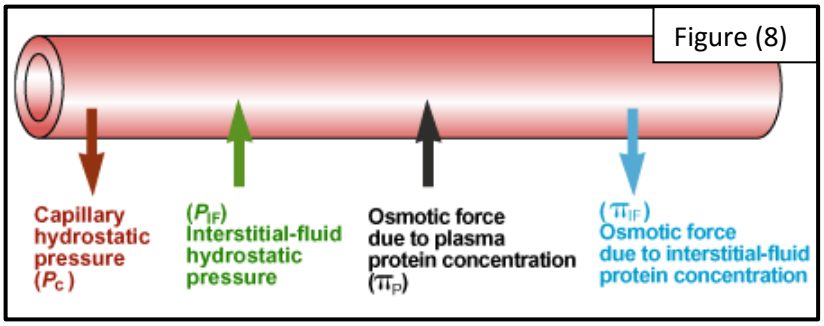
- Applying the same principles, if you have two samples: 2g of albumin, and 2g of globulin, which sample has a higher number of particles and thus contributes more to osmotic pressure?
  Molecular weight of albumin: 70k, Molecular weight of globulin: 200-300k
  →even if the masses of the samples are equal, the albumin sample contains a number of particles that is about 3 times the number of particles in the globulin sample.
  The previous was to explain the statement "**albumin contribution to colloid osmotic pressure is higher…**".

B. Starling forces

- Starling forces are 4 forces that work across the capillary wall. Two of them originate from the interior of the capillary, while the other two originate from the surrounding interstitium.
- Starling forces collectively determine whether net filtration or net reabsorption will occur.
- According to the processes which occcur across the capillary wall, capillaries of the body are classified into three categories:
  1. In some capillaries in the body, only filtration takes place, across the entire length of the capillary. Example: glumerular capillaries in the kidney.
  2. In some other capillaries, only reabsorption takes place (no filtration). Example: intestinal capillaries in the GI tract.
  3. In the remaining capillaries (vast majority of capillaries in the body), filtration occurs at the arterial end of the capillary, while reabsorption takes place at the venous end.
     ***Note**: in these capillaries, filtration does not necessarily equal the reabsorption. Filtration could be a little bit higher, and the extra filtered fluid will be returned back via lymphatics that will eventually deliver it to the right and left subclavian veins (back to the circulation).*

- What are the four starling forces:
  Figure (8)
  - **(1) Pc** → Capillary Hydrostatic pressure - a flitration force (pushes fluid outside the capillary)
    - In muscle capillaries→ Pc is 30 mmHg (at the arterial end: 40, at the venous end: 20, avarage=30)
    - In glumerular capillaries → 60 (very high)
    - In pulmonary capillaries→ 10 (very low)
  - **(1) πc** → osmotic force due to plasma protein concentration – a reabsorption force
    πc is also called "colloid osmotic pressure" and it results from the presence of proteins like albumin and globulins. Contribution of albumin is higher.
    - πc equals 28 in all capillaries of the body because the protein composition in blood is the same everywhere.
    - πc in pulmonary capillaries = 28 mmHg
  - **(1) Pi** →interstitial fluid Hydrostatic pressure - if negative, It's a filtration force, and if positive, it's a reabsorption force.
  - **(2) πi** → osmotic force due to interstitial fluid protein concentration - a filtration force.

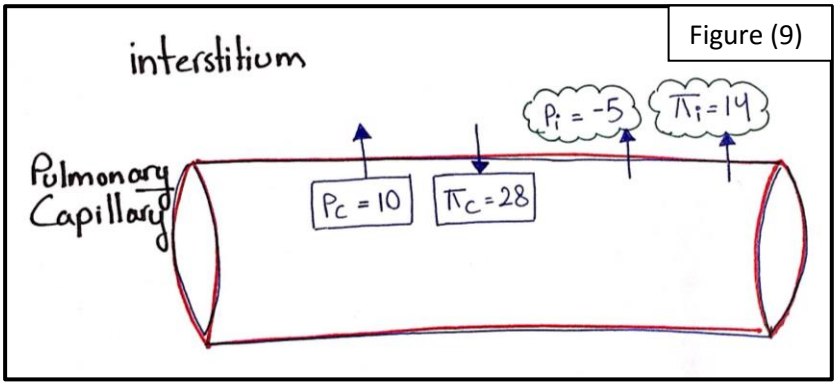
Figure (8)



Revision is now over, let's go back to the topic we started discussing. How does surfactant prevent the occurance of pulmonary edema?

Figure (9) shows a pulmonary capillary. *Pay attention to the following notes.*

Figure (9)



- Pi = -5 → since it's negative, Pi in pulmonary capillaries is a filtration force
- πi = 14 (considered high compared to other locations in the body. This is because the interstitium here is different from any other interstitium and these capillaries are permeable to certain proteins).
  ***note**: proteins, wherever found, will drive water to their compartment.*
- Across the walls of pulmonary capillaries, **πc is the only reabsorption force.**
- Calculations:
  Net filtration force = 5 + 14 + 10 = 29
  Net rabsorption force = 28

  Net result = +1 "Filtration"

➔ More fluid will be filtered than absorbed (but this is a normal physiologic condition).

➔ The lungs are very rich with lymphatics. Any extra filtered fluid will be taken up by lymphatics.

Lymphatics are called "scavengers of the body".

Imagine them as vacuum cleaners that take up anything that didn't get reabsorbed back, and eventually deliver it to the subclavian veins (through the right lymphatic duct on the right side, and the thoracic duct on the left side).

Clinical correlation #1: left heart failure and pulmonary edema.

- Suppose that an obstruction in the LAD caused myocardial infarction followed by left heart failure. What will the consequences be?
  Pumping action will fail → pressure in the left ventricle, left atrium, and pulmonary veins will increase → pressure in pulmonary capillaries (Pc) will increase.
  - If Pc reaches 20 (instead of the normal 10), the net force will be 11mmHg favoring filtration (instead of the normal 1mmHg)
    →More filtration. However, the lymphatics can still take care of the extra filtered fluid and prevent the occurrence of edema.
  - Even if Pc reaches 30, the lymphatics would still be able to fix the problem
  - The previous is called "Pulmonary Edema Safety Factor":
    - In acute cases -like MI: even if Pc increases and reaches up to 30 mmHg, lymphatics can still take care of the extra filtered fluid.
    - In chronic conditions -like chronic left heart failure: even if Pc reaches 40 mmHg, lymphatics can still take care of the extra filtered fluid.

    ➔ Which means that if a person developed pulmonary edema, his situiation must have been really severe (and his body has undergone severe damage).

Clinical correlation #2: Hypoalbuminemia and pulmonary edema.

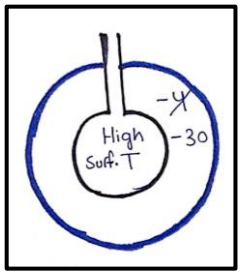
- If the concentration of albumin is less than 3.5 g/dL of blood, this is hypoalbuminemia.
- *Remember: we said that albumin is the main protein contributing to the colloid osmotic pressue, so we expect that hypoalbuminemia will result in decreased colloid osmotic pressure (a reabsorption force).*
  - ➔ Hypoalbuminemia should raise an alarm because we would be afraid of edema.

- Edema in four places is lethal; laryngeal edema, pulmonary edema, pericardial effusion, and brain edema.
- Pulmonary edema is a top medical emergency. The patient might die in two hours if we don't act fast.
- We want the lungs to be DRY all the time. Pulmonary edema interferes with gas exchange since the respiratory membrane becomes thicker.
- Pulmonary edema breeds more pulmonary edema (positive feedback). Why?
  Because pulmonary edema will result in decreased oxygen supply to the heart and thus, weakening of the heart which will result in more pulmonary edema.
- Pulmonary Edema has two stages; Interstitial edema, and alveolar edema.

Clinical correlation #3: surfactant and pulmonary edema.

If surfactant is absent:

- Surface tension will be higher → higher collapsing force



→ more negative pressure is needed (in infants, -30 is needed)

→Higher negative pressure surrounding the capillaries means more chance of filtration (because the summation of starling forces will be higher than normal).

→Pulmonary Edema might occur.

- A baby who's born with absence of surfactant could die due to several reasons that include:
  1) **Pulmonary Edema**

  2) **Hypoxemia** (low oxygen in the blood (decreased arterial pO_2)) and muscle fatigue.
     The baby would have a problem in ventilation *(because the alveoli have a high collapsing tendency)* resulting in hypoxemia.

→ Decreased pO2 in the pulmonary circulation has a vasoconstrictor effect.
→ Vasoconstriction in the pulmonary artery will cause an increase in its pressure (pulmonary hypertension).
→ Ductus arteriousus between the aorta and the left pulmonary artery will re-open. Foramen ovale between the two atria will also re-open because the presuure in the right side has increased.
→ Patent ductus arteriosus and foramen ovale will result in mixing of arterial blood with venous blood.
→ More dilution of the arterial blood.
→ More hypoxemia.

Decreased pO_2 in the systemic circulation is a vasodilating factor. Whereas decreased pO_2 in the pulmonary circulation is a vaso-constricting factor.

3) **Acidosis** and hypoglycemia (metabolic disturbances).
Since oxygen is low, glucose will be burned anaerobically.
→ Waste products of anaerobic respiration include lactic acid.
→ Decreased pH
→ Acidosis that might be fatal.

The presence of surfactant prevents the negative interstitial pressure from becoming more negative and driving water outside the capillaries → **surfactant prevents the occurrence of pulmonary edema.**

❖ RDS (Respiratory Distress Syndrome)

I. IRDS (Infant Respiratory Distress Syndrome)

- Normal Gestation period: 40 weeks *(from the last menstrual period)*
  - If the baby is born in the period between 26-28 weeks (premature), the chance of mortality is 50%.
  - If the baby is born in the period between 30-31 weeks (also premature), the chance of mortality is 25%.

  ➔ One extra day makes a difference. That's why if we can delay labor -even by one or few days- we can make a difference (because we would be giving the lungs more time to make surfactant).

Note: it's not true that delivery in the seventh month is better than in the eighth as some people think.

Note.2: surfactant is made by the lungs of the embryo, and not given to him by his mother.

- In certain cases -like eclampsia in the pregnant woman-, induced labor might be necessary for the sake of protection of the health of the mother. In such cases, what can we do to assure that lack of surfactant will not cause the complications mentioned previously in pages 12 and 13 (in other words, to prevent complications of IRDS)?
  - First, we need to predict the maturity of the lungs in the baby (if enough surfactant is present or not).
    We take samples from the amniotic fluid (by amniocentesis) to decide whether the lungs are mature or immature by using **lung markers** that include:
    (1) Lecithin to sphingomyelin ratio
    If > 2 → the lung is mature
    (2) Phosphatidyl-glycerol
    If present → the lung is mature
    (3) Surfactant to albumin ratio
    This is the most important lung marker.
    Surfactant(**mg**) / albumin(**g**)
    - If > 55 → the lung is mature
    - 35 - 55 → borderline
    - If < 35 → the lung is immature

    These markers determine if the doctor should refer the mother to an advanced medical center to take care of IRDS.
  - We have to make sure that the baby will be delivered in a good fully equipped hospital that has an advanced infant care unit.
  - The mother should be given two shots of dexamethasone (a steroid) -in a period of two days. Why?
    Because the production of surfactant by the baby needs four hormones; prolactin, estrogen, thyroxine (T_4) and **glucocorticoids** (cortisone).
    Giving two shots of dexamethasone accelerates the production of surfactant in the embryo.
  - The surgeon will either induce labor by giving oxytocin or carry out a cesarean section.
  - When the baby is born, we should help him because each time he exhales, the alveoli close, and thus, airways close because they are very fragile *(collapsing tendency in alveoli is huge)*.
    a. We provide the baby with CPAP (Continuous Positive Airway Pressure) so that alveoli will remain open.
    b. In certain cases (mild cases), providing **CPAP** will be enough. However, in other -more severe- cases, the baby may need intubation: we insert a tube in the trachea and connect it to a

respirator (ventilator). This method is called **PEEP** "Positive End-Expiratory Pressure".

c. We can also give the baby **surfactant** in the form of inhaled aerosols. But this is a little bit expensive.
d. We give the baby **glucose** and we **treat acidosis** if present (we should maintain the acid-base balance).

- In many cases, the health of the baby improves, but unfortunately, these individuals usually face problems in the future; like recurrent respiratory infections.

Question: **what is the purpose of the PEEP method?**

The baby would have a very high respiratory rate (near 60) because he would be fighting for air. This will lead to muscle fatigue.

When we connect the baby to a ventilator, the effort spent by the lungs will be lowered and thus they would have enough time and more ability to make surfactant.

(بنريّح الرئتين و العضلات)

The baby will be kept on the PEEP method (maybe for two weeks, three weeks, or even more) until his condition improves and surfactant becomes enough.

Note: IRDS is more seen when the mother is diabetic.

Notes about steroids (mentioned by Dr. Yanal):

What is the difference between dexamethasone and cortisone?

- Dexamethasone is 30 times more potent and it has a longer duration of action.
- Dexamethasone is a C22 steroid, which means that it's not a naturally occurring steroid. It is synthetic.

Naturally occurring steroids in human bodies -synthesized by the adrenals, ovaries and testes- are of three categories:

1. C18 : has 18 carbon atoms (like estrogen)
2. C19 : has 19 carbon atoms (like testosterone)
3. C21 : has 21 carbon atoms (like aldosterone and cortisone)

Steroids and thyroid hormones (T3, T4) can cross the membrane easily, and their receptors are intracellular.

All steroids -whether natural or synthetic- can cross the placenta, because steroids are derivatives of cholesterol which is a lipid molecule that can easily cross the lipid bilayer.

There are three locations in the steroid structure that can be modified to make the steroid more potent. *These include the double bond, the hydroxyl group, and a third location.*

II. ARDS (Acute Respiratory Distress Syndrome)

- Other terms for the same condition include: "wet lung", "toxic lung".
- Previously, ARDS used to refer to "Adult RDS", but when doctors noticed that this condition can affect children, they decided to name it "Acute RDS".
- The mortality rate in ARDS is higher than 70% because it is part of multi-organ failure. (usually, the patient is in the ICU and has heart failure, liver failure, kidney failure, and lung failure).

- Three criteria are used to diagnose ARDS:
  (Dr. Yanal wants us to focus on the first criterion since it is the most important)

  (1) If the Arterial pO_2 divided by the fraction of inspired O_2 (arterial pO_2/FiO_2) is less than 200, the case is ARDS.

  Note: If arterial pO_2/FiO_2 is between 200 and 300, the case is called "Acute Lung Injury" (this condition is a precursor for ARDS).

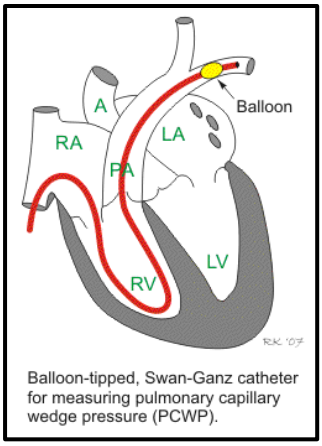
  The normal arterial pO_2 = 100

  The normal fraction of inspired O_2 is 21%

  ➔ The normal pO_2/FiO_2 is around 500.

  (2) Pulmonary Capillary Wedge Pressure

  We insert a catheter in the right atrium, then move to the right ventricle then to the pulmonary artery and continue until we reach a pulmonary capillary. The pressure there is called pulmonary capillary wedge pressure.
  (from Wikipedia: pulmonary capillary wedge pressure is the pressure measured by wedging a catheter with an inflated balloon into a small pulmonary arterial branch).



Balloon-tipped, Swan-Ganz catheter for measuring pulmonary capillary wedge pressure (PCWP).

  - The normal value of PCWP is only 5 or 6 mmHg
    (according to Wikipedia, the physiologic range is between 6-12 mmHg)

  - If the PCWP is higher than normal, but **less than 18 mmHg**, and there's pulmonary edema:
    This means that the pulmonary edema is not due to left heart failure. It's most likely due to ARDS.

  - If the PCWP is higher than 18, this indicates the presence of left heart failure.

  (3) Chest X-ray imaging reveals **lung infiltrates.**

Final note

At the end of the lecture, Dr. Yanal discussed the following problem. He also said that his slides contain such examples, and we should be able to solve such questions.

If an individual inspires pure oxygen, the alveolar pO_2 will be ….?

Alveolar pO_2 = piO_2 – (Alveolar pCO_2 / R)

piO_2 : pressure of inspired Oxygen

R : respiratory exchange ratio

- $R = \frac{\text{CO2 production (volume/min)}}{\text{O2 consumption (volume/min)}}$
- Normal R = 200/250 = 0.8

- If a person inspires pure oxygen, piO_2 will be 760 – 47 = 713 mmHg
  (the 47 is the partial pressure of water vapor)

- The solution of the problem:

  Alveolar pO_2 = piO_2 – (Alveolar pCO_2 / R)

  = 713 – (40 / 0.8)

  = 713 – 50

  = 663 mmHg

  (note: following oxygen diffusion, this will also be the arterial pO_2)

I apologize for any mistake I might have made.

Special thanks goes to the eleven monkeys :')

Wish you all best of luck..