The Cardio-VASCULAR System

- ○ Anatomy
- ○ Histology
- ○ Pathology
- ○ Pharmacology
- ● Physiology
- ○ Microbiology

Lec #: **13**

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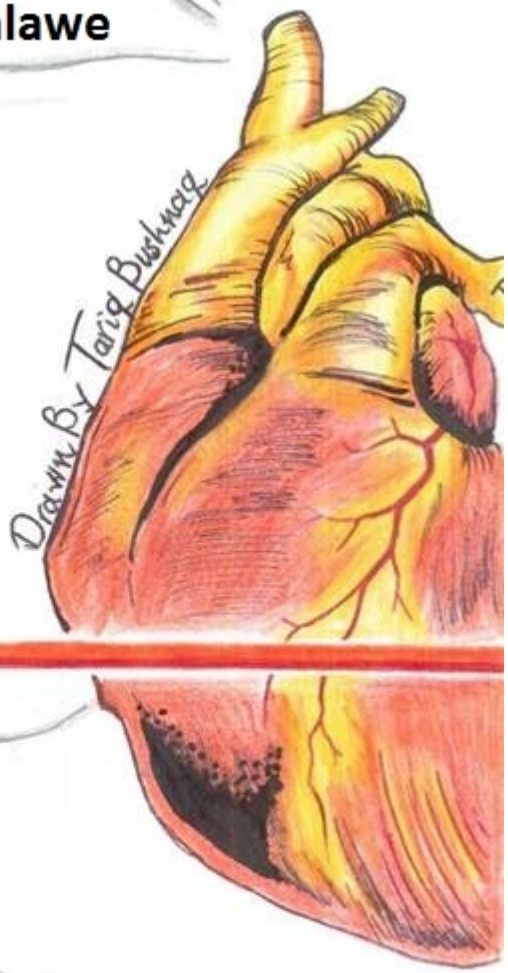
- ○ Handout
- ● Sheet
- ○ Slide



Recap for the last topic from the previous lecture

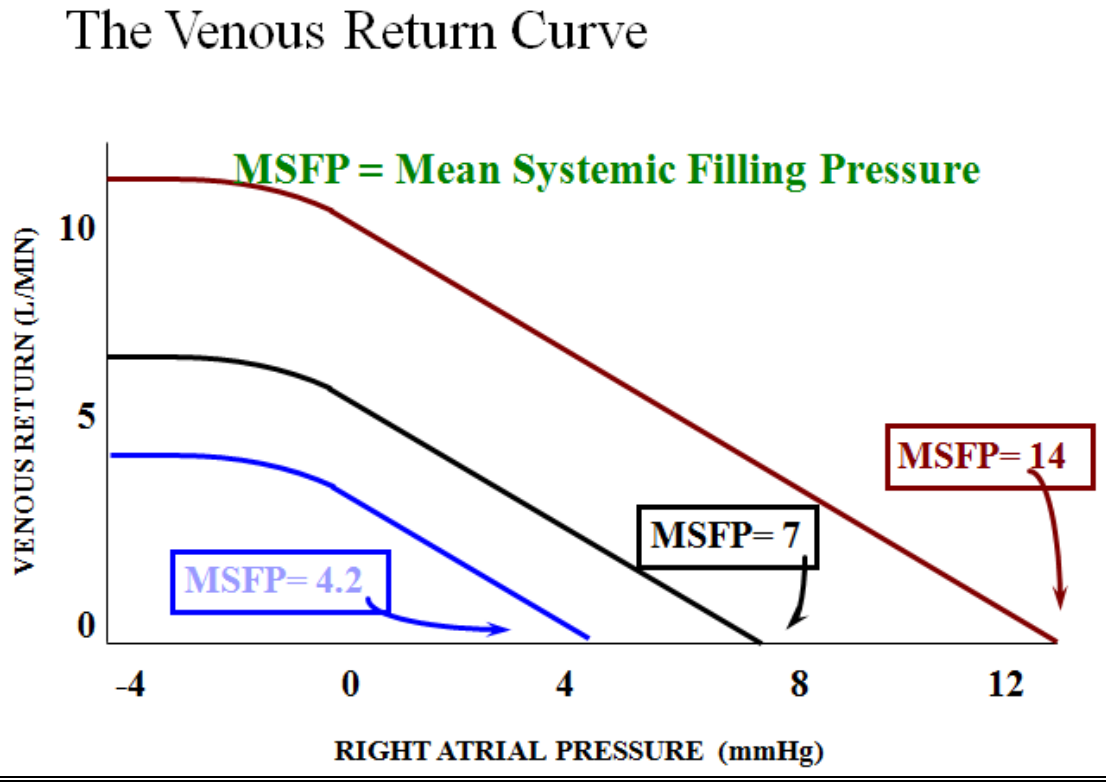
In the second half of the previous lecture we started talking about the venous return (**VR**) , and we said that : **VR** have to be **equal** to the cardiac output (**CO**) , because the VR is the amount of blood coming to the heart per minute , and the **CO** is the amount of blood that is ejected from each ventricle per minute, and this what we mean by ***what comes goes *.**

Also , we agreed that VR is equal to the pressure difference between the venous system and the right atrium over the venous return resistance - **VR =(venous pressure –RAP) /VRR** – and from this equation we conclude that what increase the venous pressure or decrease the right atrial pressure will increase the pressure gradient and accordingly increase VR – later on in this lecture we will talk about the third factor which is the venous return resistance – remember that the central venous pressure is the pressure in the right atrium and the surrounding major venous trunks .

Beginning of today's lecture :

Suppose that we stopped the heart pumping action in the body , all the body organs will have the same pressure , then there will be no blood flow since there is no pressure gradient to create this flow of blood , nothing comes in or goes out from the heart .**Guyton** measured this **equal pressure** and he found it equal to **7mmhg** , and because this blood is the same in all of the systemic circulation we called it the **mean systemic pressure** ,and since the right atrium filling is dependent on the difference between this pressure and the right atrial pressure (RAP) we called it the **mean systemic filling pressure** (**MSFP**) .

Now , let's move to the VR curve , notice that the **X axis** is the **RAP** (same as the **CO** curve) and the **Y axis** is the **VR** , look at the curve :



1) The NORMAL MSFP (black curve) - : **MSFP** = **7**mmhg , and if the **RAP=MSFP** ,the pressure gradient will equal to zero and consequently **VR = zero** (since the ohm's equation becomes **VR=(MSFP-RAP)/VRR** , then as we decrease the **RAP** the **VR** will increase in a linear manner , how much the **RAP** decrease is **how much the VR increase until RAP reach zero here VR become mostly constant and then plateau will be reached (max of VR)** , because when the **RAP** become **negative** the large veins (SVC / IVC) will be collapsed (because there intra luminal pressure will decrease) and no more **VR** to the heart will occur (can be considered as **a regulatory method** to limit the venous return) , and they will remain collapsed until the intra luminal pressure inside them increase , so they open then close<< open then close … and so on .

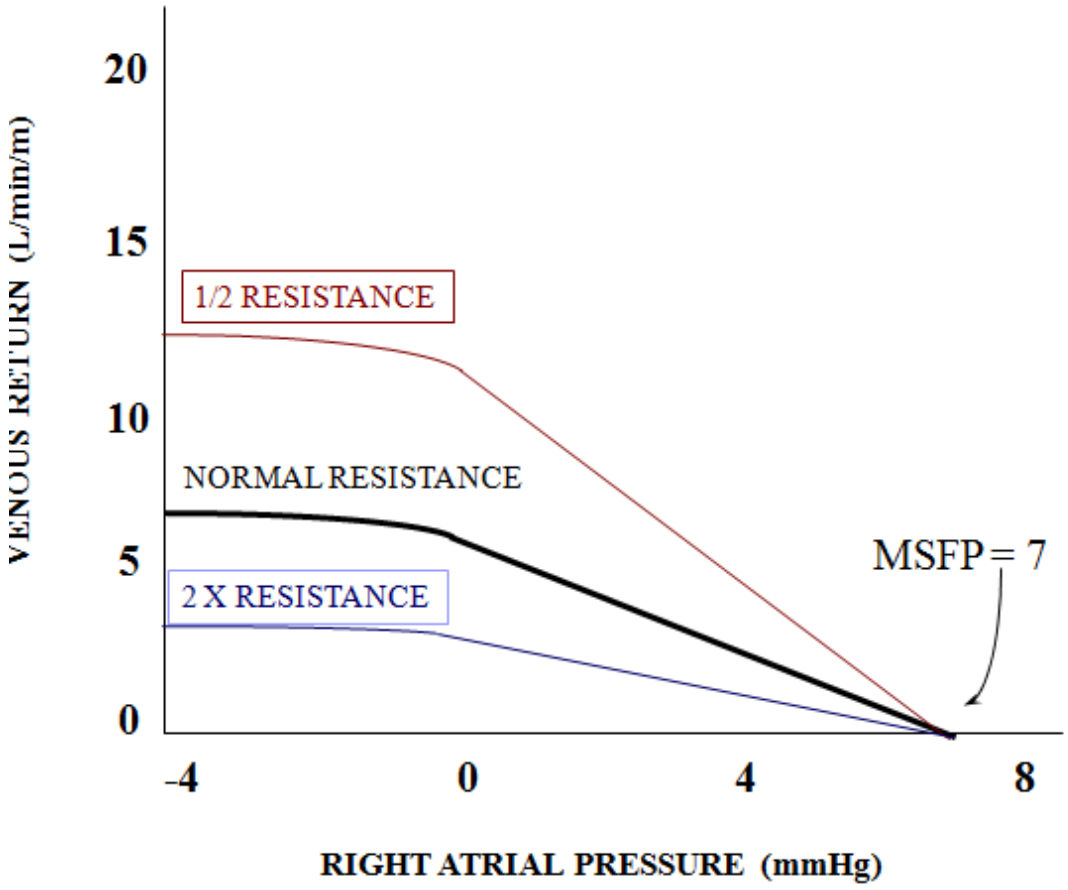
2) The HIGH MSFP-red curve- : we can increase the **MSFP** by increasing the blood volume as in blood transfusions for example , or by sympathetic stimulation (beside that sympathetic stimulation causes arterial constriction and it also cause venous constriction) , here as the **MSFP** increases the pressure gradient will increase and the VR will be increase , here also follow the curve and you will find that as the RAP decrease the VR will be increase until we reach the plateau (negative RAP) „ here **the VR curve is shifted to the right**.

3) The LOW MSFP –blue curve-: we can decrease the **MSFP** by decreasing the blood volume as in **hemorrhage** (bleeding) for example . and here the **VR** will decrease since we decreased the pressure gradient , also follow the curve and you will find that as the **RAP** decrease the **VR** will increase until we reach the plateau (negative **RAP**) „ **here VR curve shifted to the left** .

Now , we will come to the third factor that affect the **VR** which is the **resistance to VR** , we said that **MSFP** is mainly affected by blood volume and the venous pressure , and here in resistance the veins have no role since the major resistance is found at the level of arterioles , so no change will occur on the **MSFP** value because there is no change in venous pressure and blood volume will not be affected that much since arteries contain only about 15 percent of blood volume , so :

1)increasing the resistance will decrease the VR without change in MSFP (blue curve)

2)decreasing the resistance will increase the VR without change in MSFP (red curve)



***** certain cases that will increase VR by decreasing VRR :***

1) **Thiamine deficiency** as seen in **Beriberi disease** , this disease will cause arteriolar dilation **->** decreasing the resistance **–>** increasing the VR.

2) **Arteriovenous shunt or Anastomosis (AV fistula)** , it is a connection between arteries and veins bypassing the capillaries and it is seen physiologically (normally) in our bodies and it is done in hemo dialysis for patients with renal failure , in hemodialysis we transfuse fluid in the arteries and remove them from the veins , and since sometimes the patient need to do this procedure three times a week ,if each time we put a cannula in arteries and in veins it is not good for patient (maybe painful) so we put a permanent connection between arteries and veins and we created a short cut in the circulation(reduce the distance that have to be traveled by the blood) so eventually this will **reduce** the resistance and increase the **VR** .

3) **Hyperthyroidism** : here patients have a high metabolic rate and as a result oxygen consumption in their tissues will be high so **CO** will be increased and since **VR=CO** , **VR** will be increased. Also, vasodilatation will occur due to release of certain vasodilators (we will come to the blood flow in the tissues

later on) and due to this vasodilatation ,resistance will be decreased and VR will further increase.

4) **Anemia** : here patients have **decreased** number of RBC's and as a result the **viscosity** of the blood decrease, which cause an increase in the **VR** (not mention by the doctor :anemic patient's have tachycardia to compensate the low oxygen in there tissue's).

5) **Sympathetic stimulation** : causes venous constriction which increase **MSFP** , increasing pressure gradient and as a result **VR** will be increased .

6) **Increase in blood volume** : increase **MSFP** , **VR** will increase.

7) **DECREASE in venous compliance** : venous compliance is the change in pressure per change in volume(we know that veins are a low pressure collecting system in our bodies which means that they can accommodate a large volume of blood with a small change in pressure , so veins have high compliance) , now any decrease in the venous compliance (as a result of muscular contraction or venous constriction)means if we add a small amount of blood to the veins the pressure will increase too much , increasing venous pressure then VR will be increased .

   Note : Venodilation increase the volume of blood in veins **->** increase venous compliance **->** decreasing venous retain . But venoconstriction or muscular contraction decrease the volume of blood in veins **->** decrease venous compliance **->** increase venous return

8) **Obstruction of veins** : this will increase the **VRR**(venous return resistance) DECREASING the **VR** (**this is a NEGATIVE regulator for VR**) . (remember the law VR = MSFP- RAP / VRR)

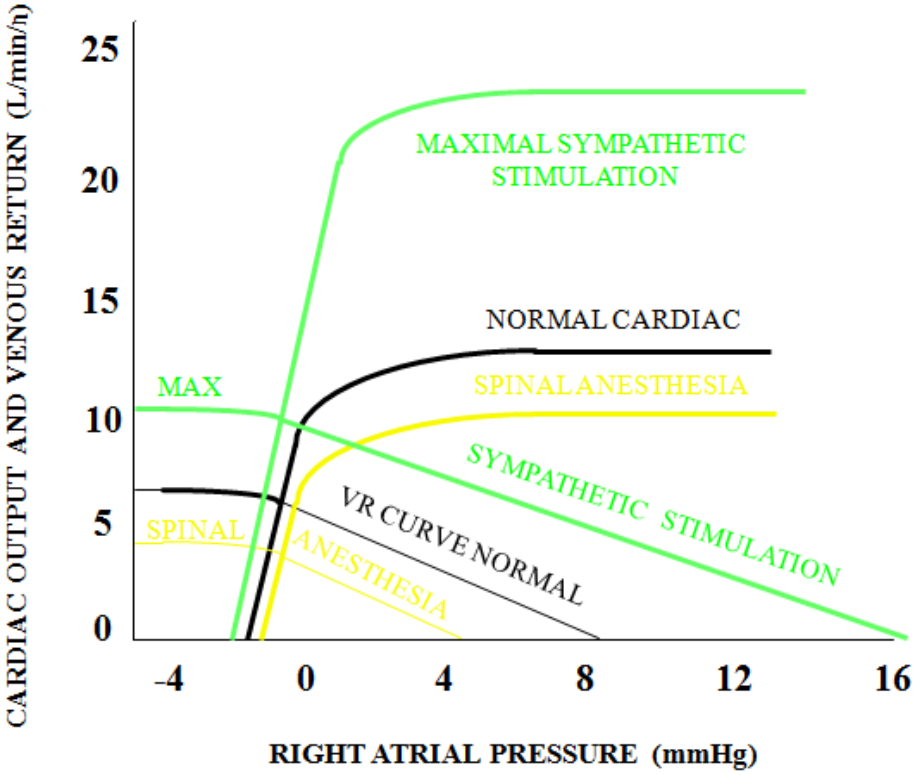
So as a conclusion :

1- **Increasing the MSFP value will increase the VR and the VR curve will be shifted to the right.**

2- **Decreasing the MSFP will decrease the VR and the VR curve will be shifted to the left.**

- So after drawing the **CO** curve and then the **VR** curve , we come to inter relate the two curves in one , as you see in the curve on the **X** axis is the RAP and on the **Y** axis is the **CO** and **VR** , and we will discuss three separate cases

, but in each one the **intersection points** between **CO** and **VR** curve (where they are supposed to be **equal**) is the **WORKING cardiac output** and that is what we want to measure , NOW we will start discussing the three cases :



1) **NORMAL case –black curve**-: the intersection here where the RAP equal to zero is ***5* L/min/m.**

2) **SPINAL ANASTHESIA –yellow curve**-: here the sympathetic nervous system is blocked . decreasing both **CO** and **VR** since as you see the **CO** curve is shifted **downward** and to the **right**, while **VR** curve is shifted **downward** and to the **left** .

3) **MAXIMAL SYMPATHATIC STIMULATION –green curve-:** here both **CO** and **VR** will be increased since as you see the **CO** curve is shifted **upward** and to the **left** , while the **VR** curve is shifted **upward** and to the **right** .

Let's move to a new topic that we left last time .

Measurement of cardiac output

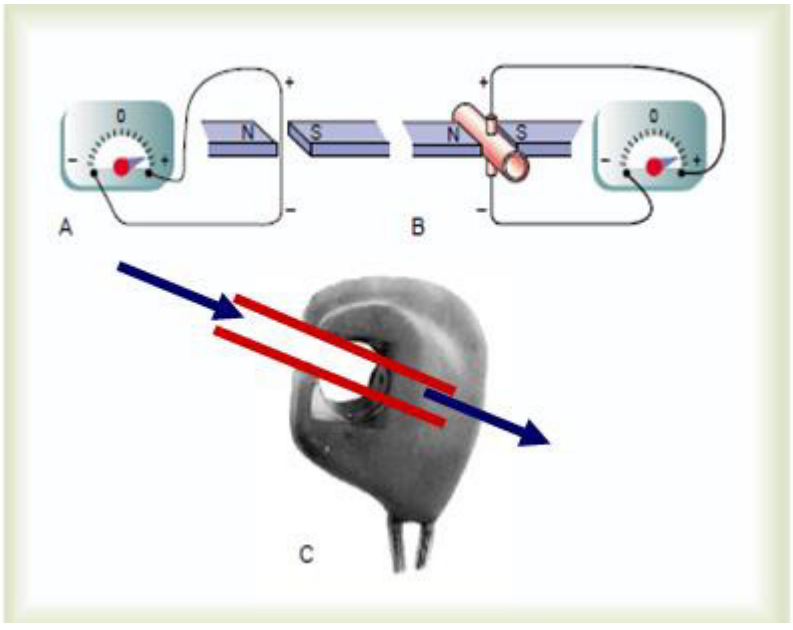
- It can be occur **directly** by collecting the blood that comes out from the aorta or the pulmonary trunk per minute and it is used on experimental animals

mainly and can be used in humans as in the **Electromagnetic flow meter** , or **indirectly** by special methods without the need for exposing the vessels .

Four methods will be discussed separately :

1- ***The first one is the Electromagnetic flow meter*** : here we place the aorta between the two poles of the magnet (north and south poles) then the fluid (blood) will pass and as the blood passes it will generate an electrical current –due to the negative and positive ions within the blood- and the amount of the generated electrical current is proportional to the amount of blood that flowed(CO),how much is the generated current-> how much is the flow .The two poles are connected through wires to the flow meter (recording meter) that measures how much is the current , then the reading of the device will be calibrated (by putting a standards to know the unknown flow in reference to these standards) , by this method we can measure the flow of blood in any vessel . This method is not applicable unless in case of cardiac surgery in which the vessels will be exposed to put the electromagnetic device .

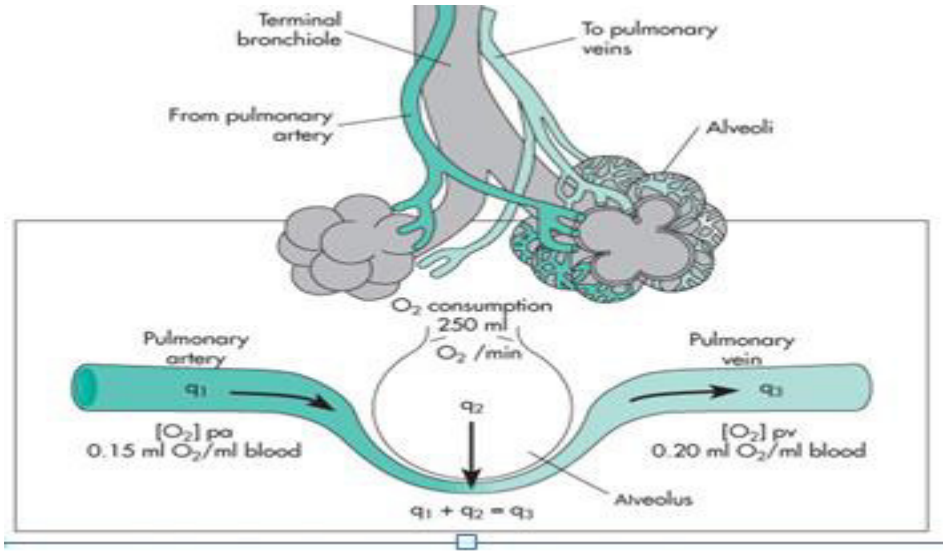
Electromagnetic flow meter



2- ***The second one is Oxygen fick principle or oxygen dilution method***

indirect method , here we measure the CO from the oxygen concentration in both the venous and arterial blood , but note that the amount of blood that is coming through pulmonary artery to the lungs per minute , the amount of blood within pulmonary veins per minute and

the amount of the blood that is ejected from the left ventricle to the aorta per minute are equal to the CO , look to the figure then note the following :



****the amount of the oxygen that passes to the lungs through pulmonary artery per minute(q1) equals the cardiac output MULTIPLIED by oxygen concentration in the mixed systemic venous blood (pulmonary artery blood).** [***q1= CO * CVO2]***

*****the amount of oxygen within pulmonary veins per minute (Q3) EQUALS the cardiac output MULTIPLIED by oxygen concentration in the systemic arterial blood*** ***[q3= CO * CAO2].***

******the amount of oxygen in the pulmonary veins per minute (q3) also equals to the amount of oxygen in the pulmonary artery blood (which is mixed venous blood) PLUS how much oxygen is being up taken from the lung (Q2**). [***q3 = q1 + O2 uptake].***

SO the net is that : **[q1= CO * CVO2] ,, q2 = [oxygen uptake from the lungs] ,, [q3= CO * CAO2] ,, [q3 = q1 + O2 uptake(q2)].**

Now since ,, [q3 = q1 + O2 uptake(q2)] and ,, [q3= CO * CAO2] ,, then [CO * CAO2 = O2 uptake(q2)+ CO * CVO2] and by taken the CO as a common factor [O2 uptake=CO(CAO2 - CVO2)] and as a result the

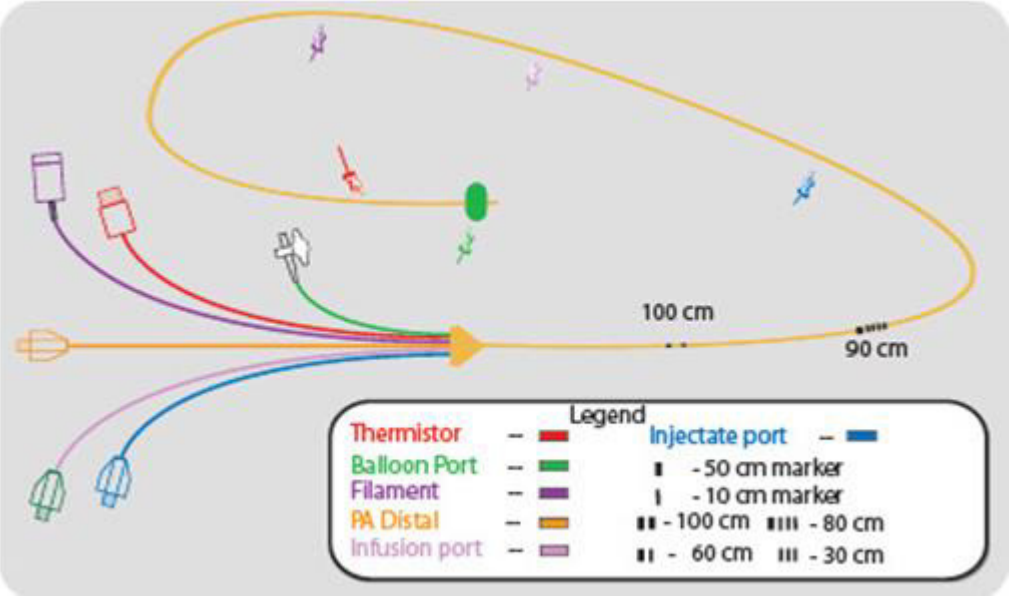
CO = O2 uptake / (CAO2 - CVO2)

pay attention that while you are dealing with this equation you have to be very careful because the units have to be unified . SO , to calculate CO you need three values **(CAO2, CVO2, O2 uptake(q2)).**

1) **Cvo2** : to find the oxygen concentration in the systemic venous blood you have to take a sample from a vein and calculate the oxygen concentration there , BUT the question is from which vein the sample must be taken? since I cannot take it from any vein because different veins have different oxygen concentration according to its anatomical location , for example the veins of the leg have a high oxygen concentration that is different from oxygen concentration in the upper limb or the thyroid …etc. So because of that , we have to take the sample from the **pulmonary trunk** where all venous blood have been collected and mixed „ BUT how the sample will be taken ?

By inserting a catheter in the median cubital vein (in the cubital fossa) to reach axillary vein then subclavian then brachiocephalic then SVC after that the right atrium and right ventricle until reaching the pulmonary trunk (since it contain the systemic venous blood), and take the sample from there (you can take it from right ventricle but as you go deeper it will be better since there will be better mixing for the blood) .The catheter that is used is called **Swan-Ganz catheter** in reference to the name of the two scientists who discovered it . and as we said this catheter will be placed at the median cubital vein and directed toward the pulmonary trunk , this catheter consist of multiple tubes each one with different function as you can see in the figure :

Swan-Ganz catheter



1-**thermistor** : from its name it is a thermometer to measure the temperature

2-**baloon port**: the last part in the catheter as you see in the figure , we can inflate this balloon (blow up the balloon) blocking the artery and measuring the pressure there (pulmonary artery pressure).

3-**infusion port** : to inject an indicator (will be used in the next method not here since we do not use any indicator) . the doctor did not talk about the other tubes .

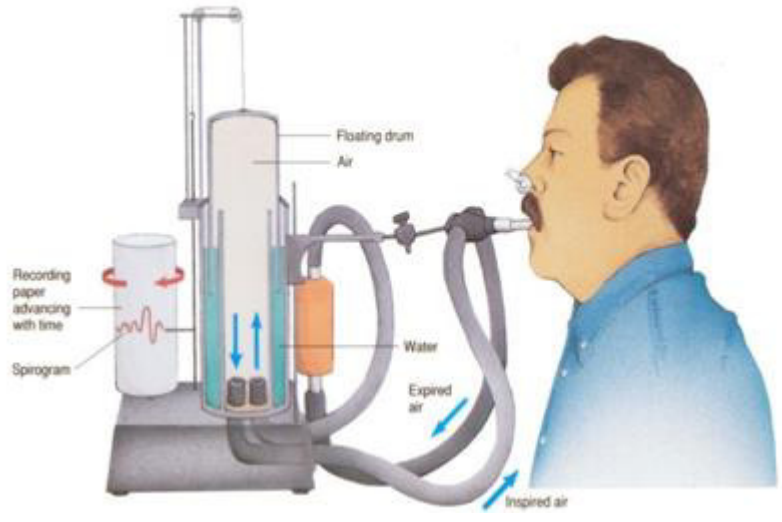
***And by this we measure oxygen concentration in the systemic venous blood (Cvo2**)

2) **Cao2** : What about the oxygen concentration in the systemic arterial blood ? from where we will take the sample ? we take it from any artery in the body because no exchange of oxygen will occur unless we reach the capillaries . so before capillaries , any artery contain the same oxygen concentration (no difference in oxygen concentration between aorta or any other artery) , and this is the **Cao2** .

Now we have to know how much is the ***amount of oxygen that is uptaken by the lung per minute*** (q2)

2) How to measure the **q2** ? by a device called ***Spirometer:***

A spirometer



we connect the device to the patient's mouth and close her/his nose so the patient will not inspire from the nose , then we put a certain concentration of oxygen in this device and allow the patient to inhale the oxygen for one or two or three(minutes) ..as much time as you want . then we measure the

patient's oxygen consumption in one minute by measuring the difference in oxygen concentration in the **spirometer** .

*****Now , we know the three values "Cvo2 , Cao2 , q2" ,, then we apply them in the equation : CO = O2 uptake / (CAO2 - CVO2) ,, and we will end up with the cardiac output .***

***** sheet writer note :**

1) **When we said that X is the oxygen concentration In pulmonary veins that means X is the value of Cao2 , because the vein here contain mostly oxygenated blood (arterial blood) , and it represents the systemic arterial blood .**

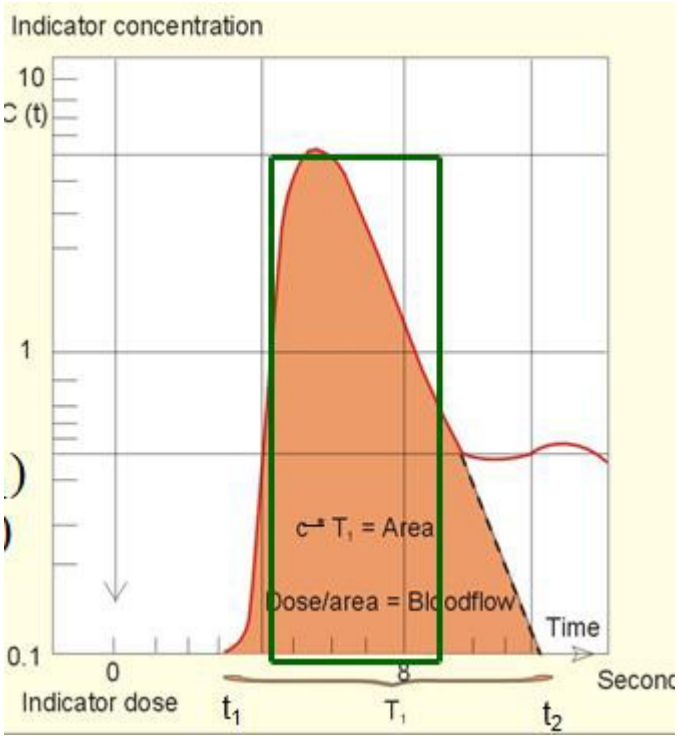
2) **when we said that y is the oxygen concentration In pulmonary artery that means y is the value of Cvo2, because the artery here contain mostly deoxygenated blood(venous blood) , and it represents the systemic venous blood .**

look to the example and try to solve it and pay attention to the units :

- If pulmonary vein O_2 content = 200 ml O_2/L blood
- Pulmonary artery O_2 content = 160 ml O_2 /L blood
- Lungs add 400 ml O_2 /min
- What is cardiac output?
- Answer: 400/(200-160)=10 L/min

3) ***the third one is the indicator dilution method***: also it is indirect method , we use a dye (for example cardiogreen) and by using the same catheter (***Swan-Ganz catheter***)we inject the dye to be directed to the right ventricle , look at the figure ; on the **y** axis we have the dye concentration in mg and on the **X** axis is the time in seconds , where the zero time is the time of dye injection and here the con of dye is the **least ,** since the circulation has not yet started then at t1 the dye start to appear and it's concentration increase **rapidly**

until it reach the **peak** (the maximum) then it start to decrease gradually and because the circulation is continuous in close circle (**follow the circulation is the recirculation)** the concentration of the dye never ever reach zero and another peak will be generated and so on until the dye is eliminated from the **body depending on the rate of renal excretion** , and because it never reach the zero we extrapolate the line (dashed line in the figure) until we reach **t2** and the difference between **t1** and **t2** is the duration of dye collection in seconds , but how we can measure the **CO**? **CO** it is the volume of the dye that flows multiplied by time of collection.

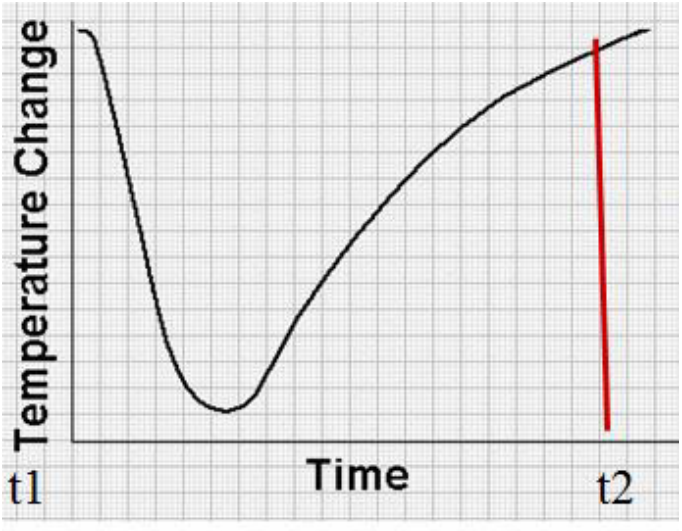


the volume of the dye is equal to the amount of dye over the concentration , v=q/c , (we know the amount of the dye that is injected **(q)** but how to measure the mean concentration ? it is equal to the area under the **triangle** and since this area calculations need **integrations** we draw a **rectangle** (اسهل قياسه لانه منتظم الشكل) in which the area under it mostly equals to the area under the **triangle** that we left it , **Area = C*(t2-t1)** , so now the **CO** =***q/ Area = q/ C*(t2-t1) =q/c*T ,,*** but the cardiac output is per minute not per second so the equation become **CO=(q/c)*(60/T)**.

$$\text{Cardiac output} = \frac{q}{C} X \frac{60}{\text{duration in seconds}}$$

*** the doctor said that the question will be in a direct way , he will give you what you need to apply on the equation but again pay attention to the units.

4)***the fourth one is the Thermo dilution method*** : same principle of the previous method , we use the same catheter (**Swan-Ganz catheter**) , then we inject a **cold saline** (**0.9NACL but cold**) , no values are used as in the previous methods to calculate it manually ; it is a computerized method (all mathematics are computerized) , the computer ask you about the amount of injected saline which is ***10*** ml for **adults** and ***5*** ml for **children** and then it ask you about the saline's temperature (***3-5 c)*** , after that once you inject the saline the computer will do all the calculations and it till you how much is the CO , using the same principle of indicator dilution and the thermistor will measure the temperature, after the injection the temperature will be drop and because new blood will come it will get back to normal value , look to the figure , at **X** axis is the time of collection (**t2-t1)** like the dye method but here the temperature decrease unlike the previous method where the concentration of the dye was increasing , and on **Y** axis it is the temperature and the area under the curve called the **men drop in temperature.**



It is the method that is used nowadays , especially for the women who will get pregnant and they have heart problems ; to know if they will have a normal delivery or not , that is because this method has a number of good properties : it is **a very fast** method that give you the CO within minutes and **we can do it many times let's say** 6 times in 15 minutes and then we will take the **average** for **more accuracy** .

The doctor answers student question that we cannot calculate the CO from the systole and the diastole only since the CO=(MAP-RAP(zero))/TPR)and they will give us the value of MAP(2/3 of diastole +1/3 of systole) ,, we will end up with variable that is unknown which is the total peripheral resistance.

New subject to be continued in the upcoming lectures :

Hemodynamic

Main objectives :

1. Point out the physical characteristics of the circulation: in term of change in : Distribution of blood volume/ Total cross sectional area /Velocity / Blood Pressure
2. List the determinants of blood flow : what determining blood flow to the tissues is the change in pressure over the resistance , and we will talk about the factors that affect each one of them
3. Define and calculate blood flow, resistance, and pressure
4. Define and calculate conductance :conductance is something like permeability
5. Apply Poiseulle's law : he put a low that elate the flow to the resistance, to the radius and to the viscosity of fluid

****Blood flow through body tissues is involved in:*

- Delivery of O2 and removal of CO2 from tissue cells
- Gas exchange in lungs
- Absorption of nutrients from GIT
- Urine formation in the kidneys

Best of luck

Done by : Moath A.Elbalawe

Dedicated to : Nedal alSabatin , shehata jaser ,basim alSababha .

" Snow is coming "