بسم الله الرحمن الرحيم

In this lecture we are going to talk about cardiac output and the next lecture will be about venous return .

Cardiac output is the amount of blood ejected from either right or left per minute (ml/min or L/min)

Venous return is the amount of blood that returns back to the heart either from the superior and inferior vena cava to the right side or from the pulmonary veins to the left side per minute .

They should be equal , we said last lecture that stroke volume should not be different between left and right sides and we said that if there is a difference in 1 ml per beat , it is considered a problem . But actually , the cardiac output of the left side is a little bit higher than the right side ; the reason for this is related to anatomy . the lung is supplied from aortic blood supply (not only from pulmonary trunk) , the drainage is by bronchial veins . they drain directly to the pulmonary veins (the left side) not to the right side . Left side receives blood from pulmonary veins and also from bronchial veins . so , venous blood from the lungs adds to the amount of blood coming from the right side . As a result , cardiac output from the left is a little bit higher than the right . the difference comes from the bronchial veins .

You have to know according to frank-starling law that what comes goes ; what comes the left side is more than what comes to the right side , that's why left ventricle pumps more blood than right ventricle

-we will describe methods of measurement of CO next lecture , direct method usually on animals and indirect methods using dyes or oxygen
-outline the factors that regulates CO , we talked about the factors that regulates CO,what ever regulates stroke volume regulates CO but we must add the factors that regulate heart rate because
Cardiac output = stroke volume x heart rate

** Cardiac index :
When comparing cardiac functions of different individuals it differs according to gender, size ,length and weight . To exclude the effects of these on CO we measure cardiac index:

Cardiac index = CO / surface area (**in meter square**)

The surface area differs according the size , weight , etc . so by dividing CO on surface area , the result will almost be the same .
Cardiac output that comes out from the aorta will be distributed to the tissues
so the CO is the sum of all tissue flows . if there is any increase in blood flow to a tissue , this will lead to an increase in CO to meet the tissue demand . in other words , the need of more or less blood flow to tissue is a factor that regulate CO .
Tissue's need of more or less blood flow depends on oxygen consumption .

***** Cardiac output is proportional to oxygen consumption**

According to Owm's law flow = $\Delta P / R$ ** CO is the same as flow **

ΔP = mean arterial pressure – right atrial pressure

R : resistance between aorta and right atrium (total peripheral resistance TPR)

So, CO output is proportional to the inverse of TPR
CO = (MAP – RAP) / TPR , RAP = 0
CO= MAP / TPR
MAP = CO x TPR

MAP : mean arterial pressure
RAP : right atrial pressure

Slide 4

This figure shows the result of an experiment on different levels of exercise (refer to slide 4)

-You can see that oxygen consumption line and CO line go parallel ; the more oxygen consumption the more CO .

- you can see the difference in CO between very high level of exercise , e.g. athlete and couch potato (lazy person)

Slide 5

Distribution of CO :

Kidney : 20% - 25% , (the highest amount) . that is due to the kidney function : filtration , not because it needs more blood flow

Heart : 3% or 5% (not that much)

Skeletal muscles at rest : 15% , although it constitutes 40% of body weight .But it increases during exercise , the maximum : 64% . And the CO increases too much .

**But how could the CO increases while the blood volume is constant ?

By increasing the speed of blood movement within the circulation.

Also the body need to do a switch in blood supply from organs thet don't need it much during exercise like the digestive system to the skeletal muscles .

Digestive system at rest : 27% , at exercise : very little

-The body can not give all the tissues their maximum need of blood flow . skeletal muscles maximum need =8 L/min , GIT maximum need = 2 L/min , together they exceeds total blood volume .

Note : during exercise heart and skin also need more blood supply .

Slide 6

Blood flow per 100 gram of organ :

Adrenal gland has the highest blood flow per 100 gm (300 ml/min/gm), the reason is because it is too small ,so the amount of blood that flows to it in comparison to its weight is very high.

Also the thyroid : 160 ml/min/100 gm

After that comes the kidney because of its function (filtration)

The heart is one of the highest tissues in blood flow per 100 gm

Skin : 3 ml/min/100 gm

Muscle : 4 ml/min/100 gm

Bone : 3 ml/min/100gm

Also , the heart have the maximum extraction ratio

extraction ratio =conc. Of O_2 in venous blood / conc. Of O_2 in arterial blood

-when arterial blood is 100% saturated with oxygen , it carries 20 ml oxygen (Hg = 15 gm/100 ml) each gram of Hg carries 1.34 ml of O_2.

Extraction ratio of skeletal muscles = 25%

Extraction ratio of the heart = 75% , that's the maximum because the blood is flowing , it does not wait the tissue to take all the oxygen it needs . So if it needs more oxygen it receives more blood supply and this is very essential for the heart , but for the muscle it can increase the extraction ratio.

Slide 7
Refer to slide 7
-Heart rate is regulated intrinsically by sympathetic and parasympathetic stimulation ; sympathetic increases heart rate (+ chronotropic) , para. decreases HR (- chronotropic) .
-How stroke volume is regulated ?
extrinsically : by sympathetic stimulation (+ inotropic) , * not regulated by parasympathetic.
sympathetic stimulation → + inotropic → ↑ stroke volume → ↑ CO
intrinsically : according to frank-starling law : ↑ venous return → ↑ end-diastolic volume → ↑ stroke volume → ↑ CO .

Slide 8 , - refer to slide 8 -
-to increase CO , you either increase heart rate or stroke volume or both.
-what affects the stroke volume are : contractility , preload and afterload
-what affects heart rate are :nervous system, chemicals and extrinsic things like body temperature

Slide 9 :
Refer to slide 9
-This diagram shows the work (energy) done by the heart .
-Work depends on pressure and volume, external energy
-Kinetic energy depends on mass and velocity
-left ventricle stroke work is much more than right ventricle stroke work (the curves look the same , the difference is in the scale of the y axis)
-Left and right ventricles have the same volume , but they differ in **pressure** . The area under the curve of the rt and lt ventricles is totally different . this means that left ventricles spent a lot of energy compared with right ventricle .
-Most of the problems occurs in the left ventricle , aortic valve and mitral valve , why ? because the left ventricle is under too much work , too much oxygen, etc. The work in the left ventricle is 10 times that in the right ventricle .

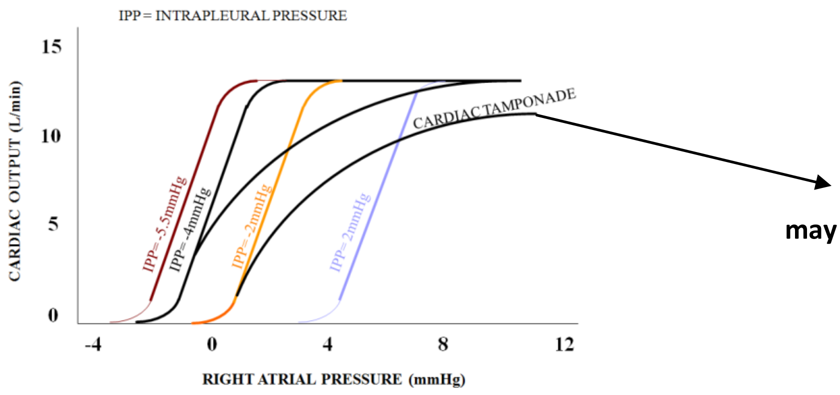
Slide 10
-Cardiac output curve according to frank-starling law
-Right ventricular pressure is proportional to right atrial pressure to keep the blood flowing ; any increase in right ventricular pressure is accompanied by an increase in rt atrial pressure . So you can say rt atrial pressure is proportional to end-diastolic volume and replace it in the x axis
-on the y axis ,you can multiply stroke volume by the heart rate and replace it with CO
-At 0 atrial pressure , CO = 5 L /min
-The curve in the middle is the normal CO curve
-You may shift the curve upward or downward
Upward : hyper effective heart (increase in contractility)
Downward : hypo effective heart (decrease in contractility)
-at any atrial pressure CO will increase in hyper effective heart – draw a vertical line-
-What makes the heart hyper effective ?

1- athletic heart , with the same end-diastolic volume it has more stroke volume. When multiplying it by heart rate it gives large CO , if they don't need that quantity of blood the heart rate will be lower ; lower heart rate x higher stroke volume = normal CO . That's why athletes sometimes have bradycardia . their heart rate may be lower than 60 or may reach 50 .
2- Sympathetic stimulation , one may say parasympathetic inhibition may be but not that much .
3- hypertrophy of heart for any reason . patients with hypertension have heart hypertrophy .

-What makes the heart hypoeffective ?
1-sympathetic inhibition , e.g. spinal block
2- decrease in myocardial mass , e.g. infarction
3-valvular disease (regurgitation -stenosis)

-Other factors that change this curve is the pressure around the heart in pericardium or in pleura . If it was in the pleura it is a little far (not direct pressure on the heart)
Pressure in pleura = -5 mmHg , atmospheric pressure = 0 , that's why lungs are inflated.
Right atrial pressure = pleural pressure plus 5 mmHg ;
When pleural pressure is -5 rt atrial pressure is 0 . If we pleural pressure -7 mmHg , rt. atrial pressure will be -2 mmHg . At -2 pressure ,the curve will be shifted to the left without changing the maximum , as the maximum depends on frank-starling law . So changing the pleural pressure does not change the curve only shifting it to the right or to the left .
In case of pleural effusion (blood or fluid in the pleura) , pleural pressure becomes -3 , rt. atrial pressure will increase to +2 mmHg shifting the curve to the right
***** Cardiac tamponade : pericardial effusion compresses on the heart directly , it's hard to fill the heart with blood even with small effusion**

Result : shifting the curve to right and also lowering the maximum except with very strong contraction it may reach the maximum .* **It changes the shape of the curve**
-When increasing intra pleural pressure IPP , the CO is constant but RAP increases to overcome the increasing pressure around the heart
-We will talk about IPP also when we take the venous return :
For example when IPP = -5 , venous return was 5 L
If IPP becomes -7 mmHg , venous return WILL INCREASE , and that's because the pressure gradient between right atrium and veins increases . So more blood will move from the veins to the right atrium .
-The heart is in the chest . Pleural pressure affects the heart and cardiac tamponade affects it even much more . Whenever cardiac tamponade increases the heart have to increase its pressure and it reaches the maximum (plateau) only with very high pressure .



this cardiac tamponade may not even reach the plateau

The doctor read slide 12 and 13 - refer to the slides -

-All what decrease the plateau decrease the myocardial mass

-slide 13 : tamponade ↓ plateau , ** It may stay the same but with very high pressure **

Note: your HR should not exceed 90% of your maximum HR which is (220-your age)

Eg : if you are 20 ys old >> ur maximum HR should not exceed 180bpm or else there won't be an enough filling time for the ventricles resulting in decreased C.O

DONE BY

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