

## Physio CVS lec4

### ❖ Cardiac output

it means the volume of blood pumped by each ventricle per minute

كمية الدم الي بيضخها البطين الواحد في الدقيقة

it is about **5 liters** per minute

**Cardiac output (CO)** = stroke volume (EDV – ESV) x heart rate.

Stroke volume: it is the volume of blood pumped by each ventricle per beat. Normally it is 70 ml. (كمية الدم الي بيضخها البطين في الدقة)

Heart rate: is the number of heart contractions per minutes. Normally it's about 72 beat/minute.

So:  $CO = 70 \times 72 \approx 5$  liters/minute.

- Cardiac output is determined by **Stroke volume** and **heart rate**.
- Conditions associated with increased CO:

الحاجات الي بتزود ال cardiac output

- Anxiety and excitement (50-100%)
- eating (30%)
- exercise (up to 700%)
- High environmental temperature
- end of pregnancy.

- Conditions associated with decreased CO:

الحاجات الي بتقل ال cardiac output

- Heart diseases
- Sitting or standing from lying position

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لما بنقوم فجأة الدم بيمشي عكس الجاذبية فيقل ال Venous return و معاه بيقل ال cardiac output. و ال cardiac output لما يقل بيقل ال blood pressure و ممكن يسبب fainting يعني اغماء.

- في الناس الطبيعية ال sympathetic بيقاوم التأثير ده و مبيحصلش اغماء (compensatory mechanism)
- الناس ال diabetic بيبقى عندهم مشاكل في الجهاز العصبي (polyneuropathy) فيحصل

#### ❖ Stroke volume:

- The volume of blood in each ventricle at the end of diastole is about 130 ml and is called diastolic volume (EDV). (كمية الدم في نهاية الراحة)
- The volume of blood in each ventricle at the end of systole is about 60 ml. It's called the end-systolic volume (ESV) (كميته في نهاية الانقباض)

**Stroke volume (SV) = EDV – ESV = 130 - 60 = 70 ml**

#### Control of Cardiac Output:

##### **1- Venous filling pressure (Right atrial pressure RAP) (Central venous pressure CVP) (Preload): (طردى)**

- Increased venous filling pressure will increase the EDV (preload).

بيزيد الضغط جوا الاذنين فيزيد الدم الي بينزل للبطين

- According to Starling's law, increased EDV will lead to increased force of contraction of the ventricle.
- This will increase the stroke volume (**SV**)

##### **2- Aortic pressure (Afterload): (عكسى)**

- Afterload is approximately represented by the aortic pressure. Increased aortic pressure (with constant EDV) leads to increased ESV and thus decreased SV. (لما الضغط يزيد في الشريان هيقفل الدم الخارج من القلب)

##### **3- Contractility of the heart (inotropic state): (طردى)**

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- Contractility of the heart is determined by amount of  $\text{Ca}^{2+}$  entering the myocytes (muscle cells) during activation
- **Increased** contractility leads to **increased** SV and reduction of ESV (positive inotropic state)
- **Decreased** contractility leads to **decreased** SV and increased ESV (negative inotropic state)

#### 4- Heart Rate: (طردي)

- Sympathetic stimulation and catecholamines (**adrenaline**) **increase** heart rate leading to **increased** cardiac output.
- Parasympathetic stimulation **decreases** heart rate and leads to **decreased** cardiac output.

#### 5- Heart Size: (طردي)

Hypertrophy of the heart can occur in athletes. This leads to enlargement of the heart, **increased** EDV and stroke volume

حجم القلب بيزيد في الناس الي بتلعب رياضة عشان عضلة القلب بتشتغل اكثر و ده بيزود ال stroke volume

Cardiac output can increase up to 700% during exercise

### Venous Return

Venous return (VR) is the volume of blood returning to the heart per minute. cardiac output must equal venous return in healthy state.

$$\text{CO} = \text{VR} = 5 \text{ litre}$$

- **Control of Venous Return:**

**Venous return is affected by:**

#### 1- Mean (متوسط) Systemic Filling Pressure (MSFP): (طردي)

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This pressure depends on the blood volume and capacity of the circulation  
الضغط الدم الي راجل للقلب من الجسم

### MSFP is increased when:

- Blood volume increases (serum زي في حالة تركيب المحاليل)
- Capacity of the circulation decrease (vasoconstriction of veins e.g. sympathetic stimulation) يعني لما المساحة تقل الضغط بيزيد زي لما الاوعية تضيق

### MSFP is decreased when:

- Blood volume decreases (e.g. hemorrhage النزيف).
- Capacity of the circulation is increased (vasodilatation of veins).

Normal MSFP is 6-8 mmHg. The difference between MSFP and right atrial pressure is the force that moves blood from vein back to the heart  
الفرق بينهم كل ما زاد بيدفع الدم اكثر ناحية القلب

## 2- Right Atrial Pressure (RAP): (عكسي)

- **Increasing** right atrial pressure will **decrease** the gradient for venous return. This will decrease VR.
- **Normal RAP** = zero
- High RAP decreases VR and can lead to ascites (ترشيع الميا في الجسم)
- If right atrial pressure reaches 8 mmHg (i.e. equal to MSFP) the difference is zero(8-8) and venous return stops. (circulation stops)

لو مفيش فرق في الضغط الدورة الدموية هتقف و ده هيسبب الوفاة و ده بيحصل في حالة ان القلب ضعيف

- **decreasing** right atrial pressure **increases** the gradient (الفرق) and this to increased VR.

## 3- Resistance (مقاومة) to Venous Return (RVR): (عكسي)

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This is the resistance to venous return between the peripheral vessels and the right atrium. When this resistance **increases**, the venous return **decreases** and vice versa.

$$VR = \frac{MSFP - RAP}{RVR} \text{ : لو حطيناهم في قانون}$$

❖ **Mechanisms of venous return in the standing position against the effect gravity:** العوامل الي بترجع الدم للقلب عكس الجاذبية

### 1- Sympathetic venoconstrictor tone:

It increases during standing pushing the blood upwards in the veins.

### 2- Muscular activity and venous valves (muscle pump mechanism):

-During muscle contraction: veins are **compressed** and blood moves upwards towards the heart.

-During muscle relaxation: **valves** prevent return of blood downwards (one way valves) بتفتح في اتجاه واحد

- if valves open in both directions → varicose veins (دوالي)

### 3- Cardiac suction: القلب بيشفط الدم ناحيته

**Atrial suction:** atrial pressure decreases sharply during first part of rapid ejection phase. (بيقل بسبب ان البطين بطل يضغط عليه) This creates a suction force (قوة شفط) that moves the blood upwards to the heart

**Ventricular suction:** ventricular pressure decreases sharply during rapid filling phase. (بسبب ال relaxation) This produces a suction of blood from atria.

### 4- Respiratory movement (Thoracic Pump mechanism):

Intra-thoracic pressure becomes more negative during inspiration (بيحصل في الشهيق اكثر من الزفير) This leads to suction of blood from abdominal veins to thoracic veins (الضغط سالب في منطقة الصدر فيشفط الدم)