الفسلجة
مرحلة ثانية

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Cardoivascular System
CARDIAC OUTPUT

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The pumping ability of the heart is a function of the beats per minute (cardiac rate) and the volume of blood ejected per beat (stroke volume). The cardiac rate and stroke volume are regulated by autonomic nerves and by mechanisms intrinsic to the cardiovascular system.

Cardiac Output: is the volume of blood pumped per minute by each ventricle.

The average resting cardiac rate in an adult is 70 beats per minute; the average stroke volume (volume of blood pumped per beat by each ventricle) is 70 to 80 ml per beat. The product of these two variables gives an average cardiac output of 5,500 ml (5.5 L) per minute:

Cardiac output = Stroke volume × cardiac rate
(ml⁄min) (ml⁄beat) (beats⁄min)

The **total blood volume** also averages about 5.5 L. This means that each ventricle pumps the equivalent of the total blood volume each minute under resting conditions. Put another way, it takes about a minute for a drop of blood to complete the systemic and pulmonary circuits.

The cardiac index

There is a correlation between resting cardiac output and body surface area. The output per square meter of body surface (*the cardiac index*) averages

Methods of Measurement of Cardiac Output

In experimental animals, cardiac output can be measured with an electromagnetic flow meter placed on the ascending aorta.

Two methods of measuring output that are applicable to humans.

1. Doppler combined with echocardiography.

In combined with Doppler techniques, echocardiography can be used to measure velocity and volume of flow through valves. It has considerable clinical usefulness, particularly in evaluating and planning therapy in patients with valvular lesions.

2. The direct Fick method

states that the amount of a substance taken up by an organ (or by the whole body) per unit of time is equal to the arterial level of the substance minus the venous level **(A-V difference)** times the blood flow. This principle can be applied, of course, only in situations in which the arterial blood is the sole source of the substance taken up. The principle can be used to determine cardiac output by measuring the amount of O_2 consumed by the body in a given period and dividing this value by the A-V difference across the lungs. Because systemic arterial blood has the same O_2 content in all parts of the body, the arterial O_2 content can be measured in a sample obtained from any convenient artery.

A sample of venous blood in the pulmonary artery is obtained by means of a cardiac catheter. It has now become commonplace to insert a long catheter through a forearm vein and to guide its tip into the heart with the aid of a fluoroscope. The procedure is generally benign. Catheters can be inserted through the right atrium and ventricle into the small branches of the pulmonary artery. An example of the calculation of cardiac output using a typical set of values is as follows:

$$\text{Output of left ventricle} = \frac{O_2 \text{ consumption (mL/min)}}{[A_{O_2}] - [V_{O_2}]}$$

$$= \frac{250 \text{ mL/min}}{\begin{array}{c}190 \text{ mL/L arterial blood} - \\ 140 \text{ mL/L venous blood in} \\ \text{pulmonary artery}\end{array}}$$

$$= \frac{250 \text{ mL/min}}{50 \text{ mL/L}}$$

$$= 5 \text{ L/min}$$

The indicator dilution method.

a known amount of a substance such as a dye or, more commonly, a radioactive isotope is injected into an arm vein and the concentration of the indicator in serial samples of arterial blood is determined. The output of the heart is equal to the amount of indicator injected divided by its average concentration in arterial blood after a single circulation through the heart.

In the **rest** example above,

$$\underset{\text{(time of first passage)}}{\text{Flow in 39 s}} = \frac{\text{5 mg injection}}{\underset{\text{(avg concentration)}}{\text{1.6 mg/L}}}$$

$$\text{Flow} = 3.1 \text{ L in 39 s}$$

$$\text{Flow (cardiac output)/min} = 3.1 \times \frac{60}{39} = 4.7 \text{ L}$$

For the **exercise** example,

$$\text{Flow in 9 s} = \frac{5 \text{ mg}}{1.51 \text{ mg/L}} = 3.3 \text{ L}$$

$$\text{Flow/min} = 3.3 \times \frac{60}{9} = 22.0 \text{ L}$$

Thermodilution, a popular indicator dilution technique in which the indicator used is *cold saline*, injected into the right atrium and the temperature change in the blood is recorded in the pulmonary artery.

Table –	Effect of Various Conditions on Cardiac Output
	Condition or Factor[a]
No change	Sleep
	Moderate changes in environmental temperature
Increase	Anxiety and excitement (50–100%)
	Eating (30%)
	Exercise (up to 700%)
	High environmental temperature
	Pregnancy
	Epinephrine
Decrease	Sitting or standing from lying position (20–30%)
	Rapid arrhythmias
	Heart disease

Factors Controlling Cardiac Output