REGULATION OF CARDIAC OUTPUT

I. Cardiac Output (CO)

A. Amount of blood pumped by the heart per minute \( CO = HR \times SV \)

B. Cardiac output in various conditions

1. Average CO: \( 5 \text{L/min} = 70\text{ml} \times 72\text{bpm} \)

2. Effect of various conditions on CO

II. Factors controlling CO -- HR or SV

A. Regulation of HR (chronotropic effect)

B. Regulation of SV (SV = EDV-ESV)

-EDV determined by venous pressure (thus VR) and length of ventricular diastole (135 ml)

-ESV determined by arterial blood pressure and force of ventricular contraction (65 ml)

-ejection fraction is the percent of the EDV that is ejected with each stroke

1. Effects of preload change (intrinsic control)

- greater the stretch placed on cardiac muscle, more vigorous the contraction (Starling's law of the heart)

-change preload by changing EDV

-factors influencing EDV:

- increased venous tone
- skeletal muscle pump
- thoracic pump
- stronger atrial contractions
- increased blood volume
2. Effects of contractility changes (extrinsic control)

-if increase strength of contraction without increasing in fiber length (preload), then ESV decreases and ejection fraction increases

a. positive ionotropic effects

i. sympathetic stimulation: increase cAMP, increase Ca^{++} channel opening, increase intracellular Ca^{++} concentration

ii. caffeine: decrease cAMP breakdown, increase Ca^{++} concentration

iii. glucagon: increase cAMP

b. negative ionotropic effects

-hypoxia, acidosis, barbiturates: depress myocardial contractility

3. Effect of afterload- resistance against which blood is expelled

-in normal individuals afterload does not limit SV, in individuals with high BP it does

-chronically elevated afterload -- heart failure

-afterload without heart compensation can cause increase in ESV, decrease in ejection fraction

4. Effect of HR changes only- increase intracellular Ca^{++}

C. Examples of regulation of CO

1. Heart-lung preparation -- the Starling experiments

-heart and lungs of anesthetized animals canulated in following way: aorta-tubes-reservoir-right atrium-heart-lungs-left atrium-left ventricle

a. effect of decreasing caliber of outflow (increase afterload)

-heart pumps out less blood then it receives for several beats, as blood accumulates size of ventricles increases, ventricle beats more forcefully, CO to normal.

b. effect of changing height of reservoir above prep

-change in venous return
2. Integrated control of CO

III. Oxygen consumption by heart

-basal O$_2$ consumption: 2ml/100g/min

-beating heart O$_2$ consumption: 9ml/100g/min

-increase O$_2$ consumption during exercise, since cardiac venous O$_2$ is low, increase in O2 consumption requires increase in coronary blood flow.

-cardiac O$_2$ consumption correlates with intramyocardial tension

-left ventricular work depends on SV and mean aortic pressure

-right ventricular work depends on SV and mean pulmonary artery pressure

- what increases O$_2$ consumption more, an increase in afterload or a corresponding increase in preload?