

Introduction to Medical Science

Laboratory Exercise 4b

Heart Rate and Blood Pressure - Part 2

Blood flow and Perfusion

Blood flow

Flow is a fundamental concept in the field of kinematics of fluids. It is referred to as the volume of fluid flow per unit time:

$$Q = \frac{V}{t}$$

The basic types of flow are:

- steady flow
- laminar flow
- turbulent flow

Steady flow is characterized by uniform speed of flow in each point of the volume occupied by the liquid. Laminar flow occurs when a fluid flows in parallel layers, with no disruption between the layers. Each layer may have different velocity. Finally, the turbulent flow is a flow regime characterized by chaotic property changes. This includes low momentum diffusion, high momentum convection, and rapid variation of pressure and flow velocity in space and time. The laminar and turbulent flow was mentioned in the discussion of Riva-Rocci method.

Blood is a liquid with viscosity approx. 3.5 mPa (at 37 deg. C). Viscosity is the property of the fluid, which defines the internal friction occurring during the flow. In the circulatory system, laminar flow dominates. Turbulent flow appears when the blood encounters the obstacles.

Perfusion

Another phenomenon related to blood flow is the perfusion. It is defined as a body fluid flow through the tissue. Blood perfusion is often referred to as the percentage of the blood volume which the heart pumps within one minute. Quantity of blood perfusion depends, among others, on pressure, the condition of blood vessels and tissue demand for nutrients and oxygen. Perfusion can be calculated as the ratio of flow and mass, that is:

$$Perf = \frac{Q}{m}$$

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The resistance of blood flow

Imagine that we put a tube to our mouth and try to breathe through it. If the tube is wide, we breathe air without major problems. But when we take more and more narrow tubes (of the same length), we feel greater resistance when breathing in the air. What is the reason? Leonard Jean Marie Poiseuille, French physicist and doctor tried to find an answer to this question (Figure 1).



Figure 1

In 1840 Poiseuille formulated the law of stationary laminar flow of incompressible and viscous fluids (Newtonian fluids) for a tube with circular cross-section. Due to the assumptions this law can describe the flow of blood in blood vessels. Knowing the length and radius of a vessel (tube), and viscosity of the fluid, we can calculate the resistance as:

$$R = \frac{4 \cdot L \cdot \eta}{\pi \cdot r^4}$$

where L is the tube length, r is the radius of the tube cross-section, and η is the fluid viscosity. Observe that for the fixed length of the vessel and parameters of the liquid, the resistance R depends only on the radius of the vessel, more specifically is inversely proportional to its 4th power:

$$R \propto \frac{1}{r^4}$$

If we reduce the radius of the tube through which we blow 2-fold, the resistance will increase 16 times.

OBJECTIVES

In this experiment, you will:

- Learn about blood flow and perfusion.

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MATERIALS

- Calculator
- Computer and programming environment for Python

PROCEDURE, DATA ANALYSIS AND CONTROL QUESTIONS

1. Figure 2 shows a simplified model of the heart and lungs. The heart consists of 2 pairs of atria and ventricles, the lungs are connected to them by the pulmonary artery leading off the right atrium. In our model, from the right lobe of the lung go three branches of pulmonary artery, from the left lobe – two. Calculate perfusion and blood flow knowing that:
 - the mass of the left lung = the mass of the right lung = 1kg
 - $CO = 5000\text{ml}$
 - Resistance in each branch of the pulmonary artery is equal to R .
 - the blood flow (Q_L) in left lung = 2500ml/s

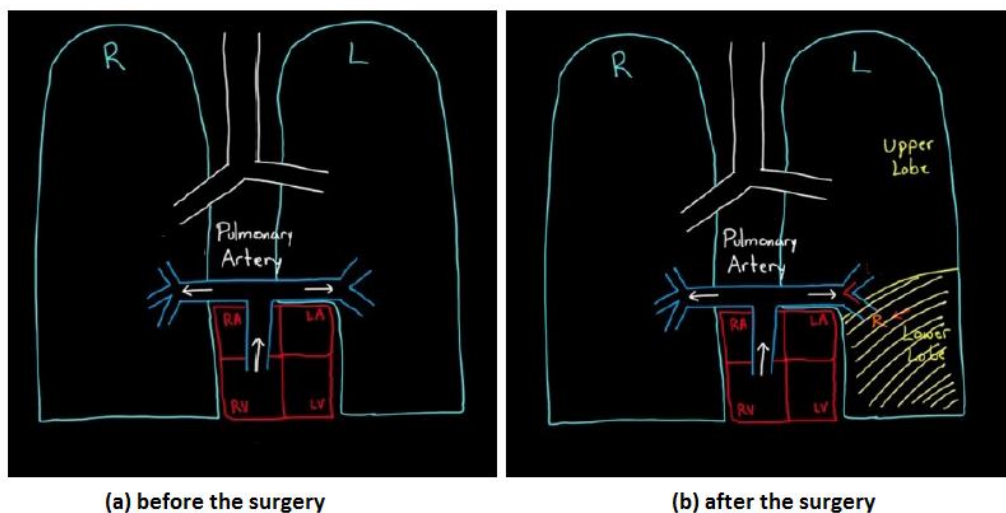


Figure 2

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2. Imagine a patient who had the resection of the lower lobe in the left lung including one of the branches of the pulmonary artery. Calculate the flow resistance in the left lung after the surgery. The resistance in the lung is calculated as the parallel connection of branches in the given lung. How did the values change? Think how will the flow in the left and right lung change knowing that change in pressure $\Delta P = Q \cdot R$. Based on your conclusions give exemplary values of estimated flow and calculate perfusion assuming that the blood flow in the right lung is equal to $Q_R = 3000 \text{ ml/s}$.
- after the surgery mass of the left lung is reduced to 0.5 kg
 - the resistance of blood flow in each branch is R

3. Calculate the total resistance of peripheral blood flow given:
- pressure in the aorta = MAP in the brachial artery + 5 mmHg
 - $\text{MAP} = \frac{2}{3} \text{ Diastole Pressure} + \frac{1}{3} \text{ Systole Pressure}$
 - $\text{CVP} = 5 \text{ mm Hg}$
 - $\text{SV} = \text{Your weight} \cdot [\text{ml/kg}]$
 - $\Delta P = Q \cdot R = \text{MAP} - \text{CVP}$
 - $Q = \text{SV} \cdot \text{HR}$

Other necessary data must be obtained by measurement.

4. Fill the table below given parameters associated with the blood flow for three patients at different age.

Age	BP [mmHg]	MAP [mmHg]	CVP [mmHg]	ΔP [mmHg]	Q [l/min]	R
25	120/80		5		5	
70	150/90		5		5	
100	180/105		5		5	

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5. In Python environment write a program that would help your doctor calculate blood pressure parameters. The function parameters should be measurable quantities: BP, SV, HR, CVP, BSA, and the values to be calculated: MAP, Q, R, PP, CO, CI, TPR. The program should produce as the output a text report with a description of the calculated values. Send the script of the program to the instructor.
6. What is the difference between blood flow and perfusion?
7. Describe the most common type of blood flow.
8. What is the dependence between the resistance of blood flow and the length of the vessel?