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# THE EFFECT OF GRAVITY ON PRESSURE DURING BLOOD FLOW WITH ROTATION THROUGH ARTERIAL VESSELS

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Despite significant progress in the study of the phenomenon of blood flow in the human circulatory system, many unanswered questions remain, in particular, about the influence of cardiac activity and gravity on blood flow processes. Such questions are important both from a fundamental point of view and for practical biomedical applications. The Bernoulli equation is a reflection of the law of conservation of energy, and therefore it does not allow us to describe in a traditional form the main features of the blood flow process, which is accompanied by the supply of mechanical energy from the heart, as well as the processes of viscous flow dissipation.

Gravity creates a hydrostatic column of blood that is linearly added to the dynamic pressure generated by the heart. In an upright position, the pressure in the vessels located below the level of the heart (for example, in the lower extremities) increases significantly, while the pressure in the vessels located above (for example, in the vessels of the brain) decreases accordingly. This difference, which can reach tens of millimeters of mercury, is a direct consequence of the gravitational effect.

The purpose is to construct a model of blood flow through arterial vessels taking into account cardiac activity and changes in vessel height in a gravitational field based on the proposed modified Bernoulli equation.

From the classical Bernoulli equation [1,2] we move to a modified form that takes into account heart activity, dissipation, and the change in vessel height in the gravitational field.

The classical Bernoulli equation can be written as:

$$const = K + P \pm G \quad (1)$$

• $P$ (Pressure): Corresponds to the pressure energy (Pa), which is the potential energy stored in the fluid due to compression.

• $K$ (Translational Flow Energy): Corresponds to the kinetic energy of the translational motion of the fluid.

• $G$ (Gravitational Contribution): Corresponds to the potential energy of the fluid in the gravitational field.

We propose to write a modified equation based on this traditional equation, namely:

$$\Delta E_{card} - D = K + W + P \pm G$$

• $\Delta E_{card}$ (Cardiac Impulse Supply): This is the external energy source that provides the translational motion of the blood.

• $D$ (Translational Motion Dissipation): This is the active resistance element that reflects the viscous energy losses that inevitably occur when real (viscous) blood moves.

• $W$ (Rotational Flow Energy): Corresponds to the kinetic energy of the rotational component of the blood moving [3-7].

Using this fundamental equation, taking into account the effect of gravity on the pressure at different heights in the system, we obtained a series of temporal dependences of the pressure at different heights of the aorta relative to the initial level.

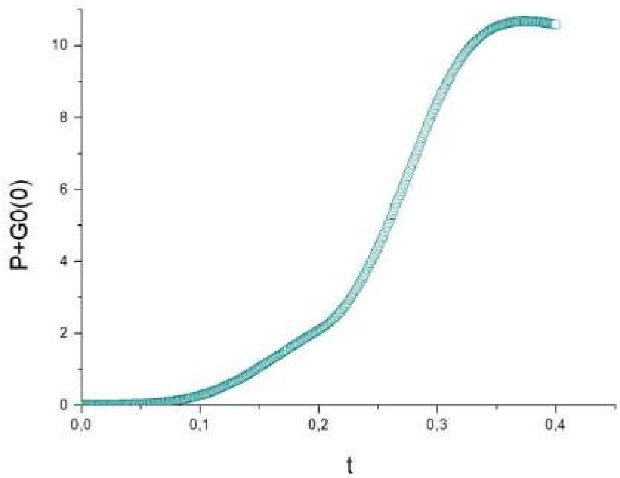


Figure 1 - Time dependence of pressure at relative altitude 0

When raised 20 cm above the heart, the low initial pressure becomes more pronounced, demonstrating a significant decrease in perfusion pressure in the upper body (Figure 2).

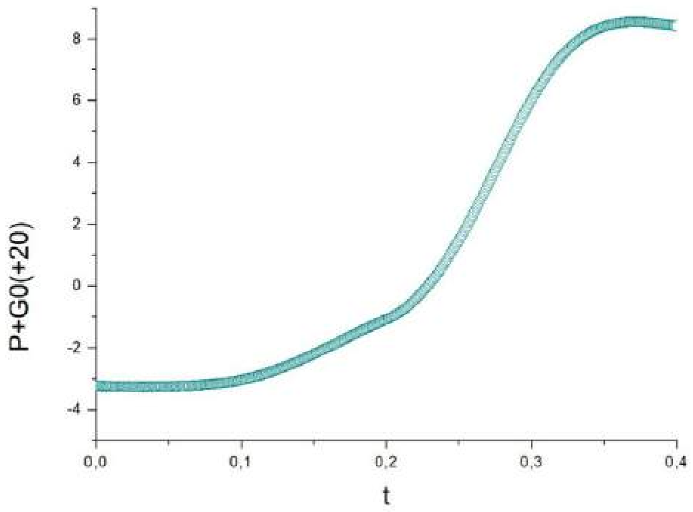


Figure 2 - Time dependence of pressure at a relative altitude of +20

For points located above the heart, the gravitational contribution becomes negative. This causes a decrease in the initial pressure. The systolic rise is maintained, but the absolute values are reduced. The initial pressure passes into the zone of negative values (Fig. 2-4).

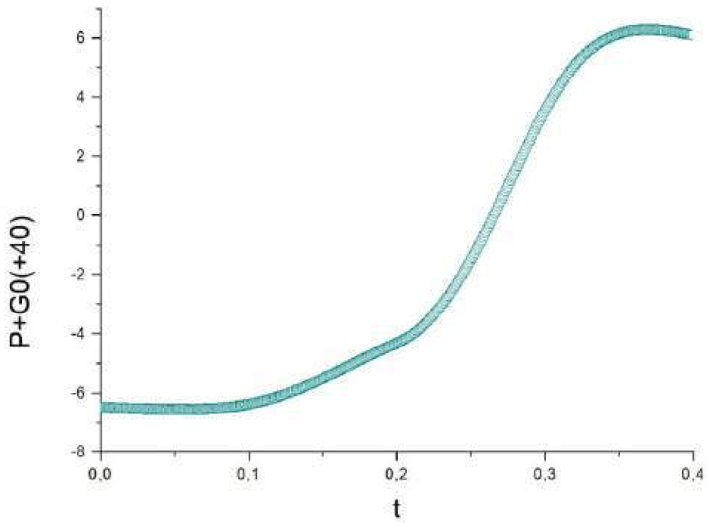


Figure 3 - Time dependence of pressure at relative altitude +40

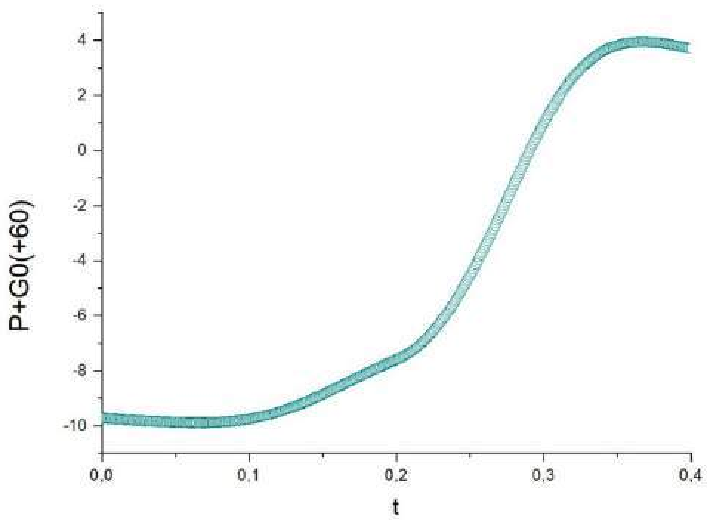


Figure 4 - Time dependence of pressure at relative altitude +60

It can be plot the change in pressure over time as a function of altitude (Fig. 5, 6.)

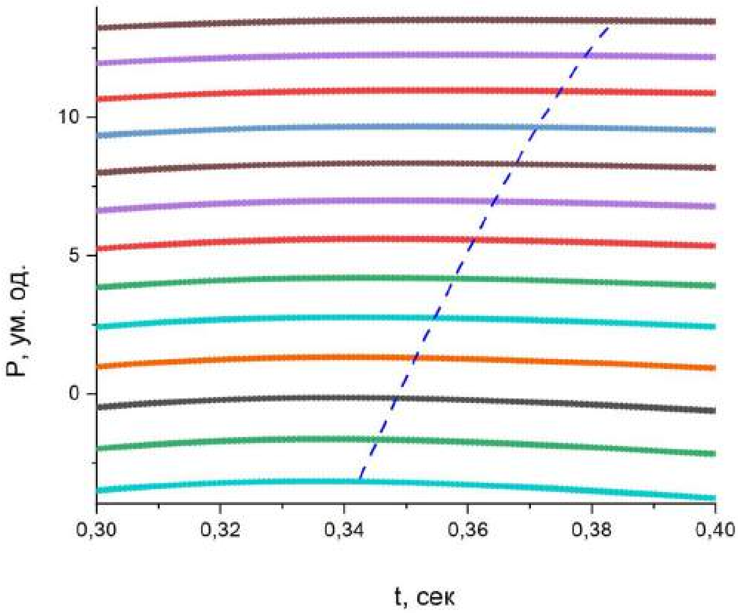


Figure 5. - Time dependences of the pressure of the progressive blood flow through the aorta for different distances in the field from the heart from 0 (upper curve) to 50 cm (lower curve) in the gravitational field.

From Fig. 5. it follows that the line of maximum pressure during systole shifts to the left with distance from the heart

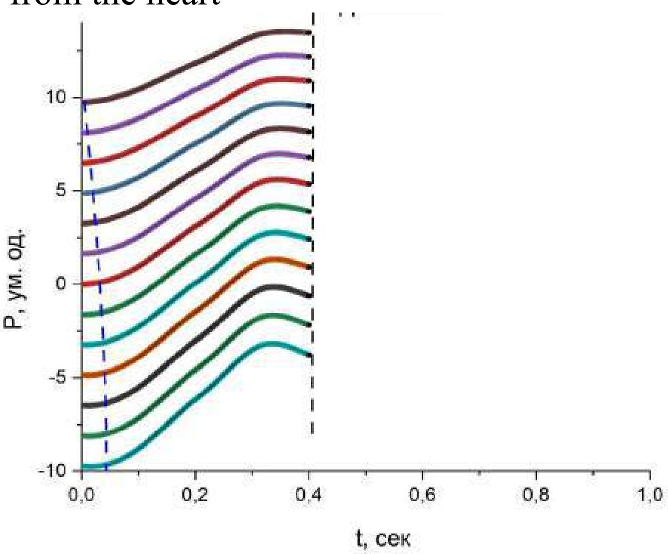


Figure 6. - Time dependences of the pressure of the progressive blood flow through the aorta for different distances in the field from the heart from 0 (upper curve) to 50 cm (lower curve) in the gravity field.

From Fig. 6. it can be seen that the line of minimum pressure before the opening of the aortic valve shifts to the right with distance from the heart

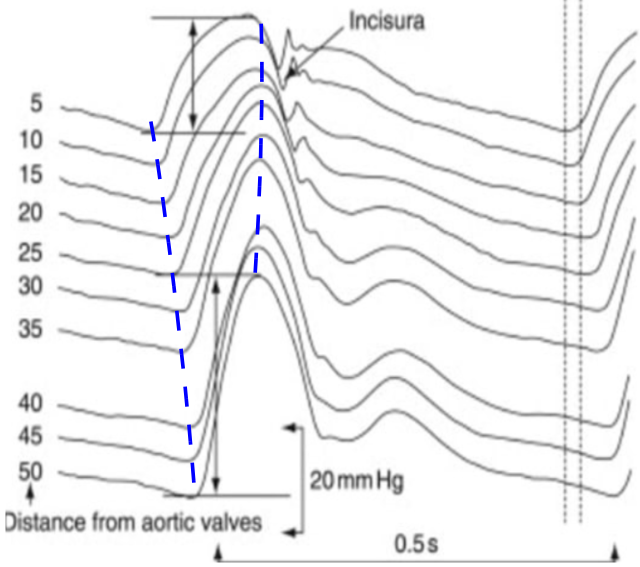


Fig. 7. Typical experimental pressure-time dependences during the cardiac cycle at different heights of the aortic vessel

The Fig. 7. shows the nature of the temporal dependences of pressure at different heights of the aortic section qualitatively corresponds to the simulation (Fig. 1-6), the pressure before the opening of the aortic valve shifts to the right with distance from the heart. In particular, the line of maximum pressure during systole shifts to the left with distance from the heart, and the line of minimum pressure before the opening of the aortic valve shifts to the right with distance from the heart.

Bernoulli's equation has been refined to model blood flow through arterial vessels of the human circulatory system under gravity. The calculations conducted are qualitatively consistent with the lines of maxima and minima of the time dependences of pressure at different heights of the circulatory system.

The proposed model can form the basis for modeling changes in the diameter of the arterial vessel of the human arterial circulatory system in the field of gravity using the modified Bernoulli equation.

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# АНАТОМО-ТОПОГРАФІЧНІ ОСОБЛИВОСТІ ДІЛЯНКИ НОСА ЩОДО РИЗИКІВ ОПЕРАТИВНИХ ВТРУЧАНЬ

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Актуальність. Операції на ділянці носа актуальні у сучасній відновлювальній та естетичній лицьовій хірургії [1; 4]. Збільшення кількості ринопластик, реконструкцій після травм, вроджених вад та пухлинних уражень тягне за собою зростання вимог до надійності та точності хірургічних маніпуляцій у цій анатомічно насиченій ділянці [2; 4]. Перенісся вирізняється тісним переплетенням кісткових, хрящових і м'яких тканин, інтенсивним кровонаповненням та багатою іннервацією, що створює умови підвищеного ризику виникнення ускладнень під час операції та після неї [3; 4].

Розуміння анатомічних орієнтирів та ділянок потенційної небезпеки є життєво важливим чинником у запобіганні кровотечам, ішемічним змінам тканин, розладам чутливості та небажаним зовнішнім дефектам [3; 4]. Хочемо підкреслити, що саме клінічна анатомія, поєднує морфологічні та хірургічні