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Abstracts

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Secondly, as the number of cells in a hypothetical multicellular organism increases, the area of its outer surface increases more slowly than its volume. The number of cells in a multicellular organism objectively characterizes its need for substances (plastic supply) and energy. The surface area determines the maximum possible diffusion delivery of substances. And since the requirements grow faster than the possibilities, an incompatible with life deficit inevitably arises.

Most multicellular animals became viable by switching to a different type of nutrition. Not being autotrophs, they became consumers, consuming comparable in size fragments of other multicellular organisms – plants and animals, to the point of consuming prey whole. This adaptation occurred due to the synchronous formation in the body of the first multicellular animals of a system for the destruction of ingested food to the molecular level (digestion), as well as structures with developed surfaces that occupy a small physical volume but provide sufficient contact area for:

- gas exchange between the organism and the environment,
- absorption of food broken down to the molecular level,
- transportation to each cell of the body of oxidant and food molecules.

For humans, these are easily recognizable light organs with alveoli, a delicate intestine with numerous absorbing villi and a circulatory system with a network of active arteries and veins connected by capillaries. All three systems have a fractal character. The lungs and the vascular network have a branching tree-like structure with merging "crowns", where oxygen exchange occurs. The inner surface of the thin intestine has a brush-like structure. Through the villi, proteins and carbohydrates enter the venous network, and fats into the lymphatic.

It seems that speaking further is like to knock at an open door. Nevertheless, the question about the structure and transport function of the circulatory system remains unanswered. Following an old tradition, in textbooks and anatomical atlases, the circulatory system is considered as two loops (circles) providing oxygen exchange. Meanwhile, the transport of food molecules is almost not discussed or discussed briefly. Accordingly, blood is marked as arterial and venous, i.e. oxygen-rich and oxygen-deprived.

If we index the blood and the molecule saturation of food, then the blood circulation looks significantly different. The consumer of transportable molecular nutrition remains the same - the cells of the organism, and the source becomes the small intestine.

Meanwhile, if the oxygen input and carbon dioxide emission are concentrated in the lungs, then the transition from chyme of carbohydrates and proteins to blood, and fats to lymph, occurs in the small intestine. This can be a starting point for the circulation of carbohydrates, proteins, and fats in the organism. And this circulation begins not through the arterial vessel, but through the portal vein. In the discharge of processed products, several systems are always involved. First of all, this is the liver, kidneys, and large intestine. In the case of heavy physical exertion, the skin is involved in the discharge, and in pathological cases, the lungs.

The geometric structure of the capillary network in the lungs and small intestine is well understood, with merged "tree crowns". However, the embedding of the capillary network in the continuum of tissues such as muscle, liver, and kidney is not as clear.

Molecule absorption in capillaries occurs quite quickly, causing the concentration of molecules to drop rapidly from the entrance to the exit of the capillary, limiting the effective length of transport. The author was unable to find any information on how this embedding is structured geometrically. However, the constraints on the effective length of capillaries suggest that it represents an embedding of layers with a thickness equal to the length of a Krogh's cylinder.

With the proposed view, there arises not only a problem of the geometric embedding of a branching vascular network into the continuum of tissues, but also a problem of the stoichiometric balances of oxygen, protein, and fat flows, as well as the removal of heat flows generated by physical work and chemical reactions that sustain the functioning of the organism, into the surrounding space.

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S4.232. Analysis of the postural balance of badminton athletes in the realisation of the positonic reflex on head turns

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Positonic reflexes ensure the preservation of balance when changing the position of the body. In an adult, these reflexes are under inhibitory control from the supra-stem structures. The study of the reaction of the postural system in the implementation of position reflexes in professional athletes is relevant. The aim of the work is to determine the change in plantar pressure during the realization of the reflex to head turns in badminton athletes.

The study involved 12 athletes and 12 subjects not involved in any sport (control group), aged 19 to 23 years. A plantographic study was carried out with a duration of 20 seconds in a standard rack, as well as when turning the head to the right and left. The coefficient of lateral asymmetry (Cl) was calculated by the ratio of the average plantar pressure of the right foot to the left; a test was also conducted to determine functional motor asymmetry.

In the group of athletes, 83% (n=10) revealed a cross motor asymmetry: the leading leg is the left, the leading arm is the right. In the control group, only 25% of the subjects (n=3) had cross-motor asymmetry; 58% (n=7) had right-sided motor lateralization, and 17% (n=2) had left-sided lateralization.

According to the Cl in the standard rack (head straight), each group was divided into 3 categories according to the severity of the support lateralization: 1) right support lateralization (RSL), Cl > 1.15; 2) left support lateralization (LSL), Cl <0.85; 3) ambidextrous support asymmetry, Cl = 0.85 - 1.15. In the group of athletes, RSL was registered in 3 subjects, their leading motor limb was the left; 2 out of 3 athletes with LSL leading leg had the left and 1 had the right. 6 athletes were ambidextrous in reference lateralization, while 5 of them had left-sided motor asymmetry, and only 1 had right-sided.

In the control group, 3 subjects had RSL, the leading motor limb in 2 of 3 was the right, 1 was the left; a similar distribution was in subjects with LSL (n=3, 2 with right-sided motor asymmetry, 1 – left-sided). 6 people in the control group were ambidextrous in reference lateralization, while 4 of them had right–sided motor asymmetry, 1 - left-sided, 1 subject was ambidextrous in motor asymmetry.

In the group of athletes with RSL, when turning towards the supporting limb (to the right), there was a tendency to increase the pressure of the contralateral limb (Cl decreased by an average of 2%). In athletes with LSL, a left turn caused an increase in the pressure of the ipsilateral limb by an average of 6%. Turning in the opposite direction from the supporting limb in athletes with RSL did not lead to a change in Cl, and in subjects with LSL, turning the head to the right side led to a slight decrease in the pressure of the supporting limb, Cl increased by an average of 11% and amounted to 0.78 ± 0.07. In athletes with ambidextrous lateralization, turning the head both to the right and to the left caused an increase in pressure of the left limb by an average of 9 and 6%, respectively.

In the control group, who have RSL, head turns also led to a redistribution of plantar pressure in the subjects from the floor: however, when turning towards the support, the CI increased by an average of 4%, which indicates an increase in the pressure of the ipsilateral limb; and when turning the head to the left, the pressure of the right foot also increased in these subjects (CI increased by an average of 8%) whereas in athletes, we did not observe a change in plantar pressure when turning the head in the opposite direction from the supporting limb. In the subjects of the control group with a predominance of LSL, head turns also led to increased pressure of the right limb: when turning towards the supporting foot, CI increased by an average of 16%, when turning to the right – by 14%. In this group, a similar pattern was observed in ambidextrous: the increase in pressure of the right leg when turning right and left averaged 6 and 5%, respectively.

Thus, in the group of athletes, cross-motor and support asymmetry prevailed (10 out of 12 subjects), whereas in the control group, subjects with cross-asymmetry accounted for only 25%. In athletes with LSL, when turning towards the support, there was a tendency to increase pressure on the ipsilateral limb, and in non-sports subjects, when turning to the left, a transfer of support pressure to the contralateral limb was observed, which indicates that athletes with LSL retain support lateralization when turning towards the support. The subjects with RSL (both athletes and the control group) retained right-sided support lateralization when turning towards the support.

Turning in the opposite direction from the supporting limb in athletes with RSL did not cause any changes, whereas in control subjects, turning to the left led to an increase in the pressure of the ipsilateral limb. Both in athletes and in the control group, in subjects with LSL, turning the head in the opposite direction from the support caused an increase in the pressure of the contralateral limb.

Thus, the predominance of cross-motor/support asymmetry in athletes may allow them to improve their capabilities when initiating a motor act of the lower extremities. In athletes, a more pronounced preservation of the supporting lateralization is revealed when turning the head, whereas in the control group, destabilization of the supporting lateralization is more common in similar conditions. These results may indicate the restructuring of the motor system in professional athletes, including those manifested in the preservation of postural balance during the implementation of cervical-tonic reflexes.

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S4.233. Application of computational fluid dynamics to solution of actual cardiovascular tasks

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The development of non-invasive diagnostic methods in modern surgery and mathematical and computer models makes it possible to describe the biomechanical processes occurring in the body with an increasing degree of accuracy. This increases the possibility of their use in the improvement of existing and the development of new personalised methods of diagnosis and treatment prognosis. Computational fluid dynamics is a dynamic tool for engineering and interdisciplinary problems. Medicine is one of the fields where the application of computational methods and technologies is essential. One of the important aspects is the consideration of the application of biomechanics and computational fluid dynamics methods. In the present work the results of computational fluid dynamics methods application in solving cardiovascular surgery problems (blood flow modeling to estimate the efficiency of bypass at aortopulmonary anastomosis in children with congenital heart disease, estimation of hemodynamic parameters in aortic valve in norm and pathology, modeling of blood flow in stenting) are presented.

Blood flow modelling to assess the effectiveness of bypass for aorto-pulmonary anastomosis in children with congenital heart disease

Based on magnetic resonance imaging, an aorta-pulmonary artery-shunt system was constructed to analyse haemodynamics in children with congenital heart disease. Blood was treated as a Newtonian fluid (density, 1060 kg/m3; density, 0.0035 Pa-s). Boundary conditions were obtained from ultrasonic measurements.

In this paper, an aorta-shunt-pulmonary artery blood flow model was considered. A set of geometric images in four patients was obtained for subsequent import into the ANSYS CFX finite element solver to solve the haemodynamics problem. Three variants of modified Blalock-Taussig shunt placement were analyzed using common hemodynamic indices (wall shear stress, time-averaged wall shear stress, oscillatory shear index). It was revealed that the variants of shunt formation should be individual, i.e., take into account anatomical and physiological features of a particular patient. The asymmetry of blood flow in the pulmonary arteries in different locations of the shunt implantation was noted. Hemodynamic performance was also compared to assess the effectiveness of the modified Blalock-Taussig shunt. An objective and personalised approach to the specific treatment of each individual patient will significantly reduce pediatric mortality and improve the quality of rehabilitation.

Assessment of hemodynamic parameters in the aortic valve in normal and abnormal conditions

This paper analyses the use of two approaches to simulate turbulent processes: using the large vortex method and based on turbulent viscosity models. The axisymmetric problem was solved on an idealised three-dimensional geometry constructed on the basis of ultrasonic image data and literature review. The problem was solved within the FSI approach using the COMSOL Multiphysics software package. Blood flow is modelled as an incompressible Newtonian fluid with constant density and viscosity.

The Holzapfel-Hasser-Ogden anisotropic hyperelasticity model is used to simulate the biomechanical behavior of aortic valve leaflets in normal conditions. The pathological state of aortic valve cusps is described by a linear elastic model.

The mathematical formulation includes Navier-Stokes equation with incompressibility condition, equations to describe turbulence patterns. The equation of motion for solids is also written. The system is closed by initial and boundary conditions as well as fluid-solid coupling conditions. A velocity profile is given at the inlet to the computational domain. To determine the pressure at the outlet of the computational domain, a two-element Windexcel model is used, where the velocity profile is taken as an input.

The results obtained describe changes in the main haemodynamic indices: velocity, pressure, near wall tangential stresses and tangential stress fluctuation index. Results are also compared for kinetic and turbulent kinetic energy values between the two turbulence models and the normal and abnormal condition.

Simulation of blood flow during stenting

The purpose of this work is to evaluate the influence of artery, plaque and stent mechanical parameters on the effectiveness of stenting by analyzing both the stress-strain state and haemodynamics parameters. In this study, an idealised model of artery - plaque - stent system is considered. The geometric model consists of several layers: adventitia - outer layer, media - middle layer, plaque and stent. The mechanical parameters of the arterial layers were described using the three-parameter Ogden model. Hemodynamic parameter distributions were found as a result of one-way and two-way fluid-structure interaction algorithms.

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