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INDIVIDUALIZATION OF HUMAN BLOOD CIRCULATION

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Various fluid-structure interaction studies of the aortic and implanted aneurysm have been conducted. But at this moment, the interactions between a pulsatile flow and blood vessel walls in an aortic arch models has not enough studied.

According to statistics - 75% disease of aortic aneurysm occurs in the abdominal cavity in the region of the renal arteries. The main cause is - arteriosclerosis. Multiple aneurysms occur for more than 10% of patients. The cases of genetic predisposition are also considered. The category of high risk of human infection - men after 60 years. Course of the disease is accompanied by arterial hypertension more than for 50% of patients [1].

Initial parameters of blood and CT scans can be used for a computer simulation of abdominal aortic aneurysm. Furthermore, the model at COMSOL software was created with prescribed conditions of real aorta. In this case output data can be used for further experiments of prostheses.

There are many types of blood flow simulation in human cardiovascular system. CT scans shows the patient-specific geometry parameters of abdominal aortic aneurysm. But every method have own differences. For example, one method is based on an inverse analysis of shape to calculate a stress-free reference parameter. Other - to update and modify Lagrangian formulation. [2] The main objective of this study is to create a model of blood flow in COMSOL Multiphysics software for future use at its individualization of endovascular prostheses.

A substitute model, made from the transparent silicone with blood flow parameters was used. A liquid composed of water, glycerin, xanthan gum and sodium chloride has been specifically adapted for the this experiment. Simulations of 1:1 model based on CFD have been compared with in situ, laser-Doppler velocimetry measurements in the aortic aneurysm. [3]

It was found that LDA measurements and CFD results were used to get most accurate patient-specific geometry parameters of aorta in common condition. [4]

The main objective of this study is to create a model of blood flow in COMSOL Multiphysics software for future use at its individualization of endovascular prostheses.

Result of the patient diagnosis is the parameter Δp (pressure differential), and Δp plotted versus Reynolds number. Therefore, in the analysis of fluid flow simulation results in the COMSOL graphical extent on the entire plot the pressure distribution has been selected.

The model should be adequate to the real conditions of fluid flow, and comply with all the laws of hydrodynamics. Therefore, to achieve this, the initial parameters were taken from the patient diagnosis results.

Pressure means depends on channel roughness, resistance coefficient and flow type, which is turbulent.

Pressure calculations [5] for the round channel:

$$\Delta p = \xi \, \frac{l}{d} \cdot \frac{\rho \bar{v}^2}{2},$$

where ξ - resistance coefficient, l – specific length, m; d – channel diameter, m; ρ - density kg/m^3, and v – stream velocity, m/s.

Velocity is calculated [5] from debit Q:

$$Q = v \cdot A = v\pi r^2,$$

where r – channel radius, m.

Resistance coefficient [5] calculated:

$$\xi = 0{,}3164 \cdot (Re)^{-1/4},$$

Where flow type defining Reynolds number is calculated [6] from $Re = \frac{\rho v d}{\mu}$, μ - dynamic viscosity, kg/(m·s).

Comparing the pressure distribution graphs in the cases of fluid passing through the direct channel and the endovascular prosthesis the characteristic curves of the pressure at the different Δp could be presented by Figure 1.

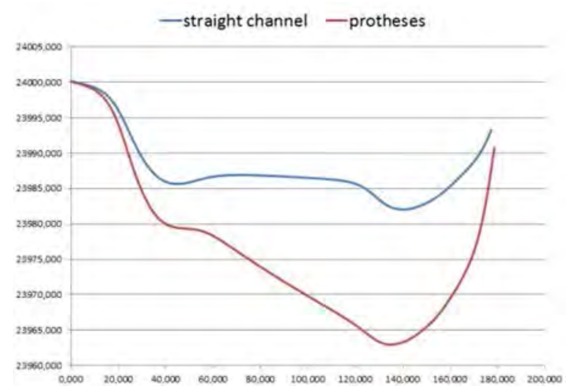

Figure 1: Graphical pressure distribution analysis

Thus simulation by this method, and the model can be used in the future to create individual forms of endovascular prosthesis for each individual case. The initial parameters will serve as tests and the results of medical research. Modeling is performed in step immediately before production and then individualized endovascular prosthesis is created with high precision on specialized equipment.

The main objective of the operation - to prevent pressure effect on the resulting bag to avoid bursting [7]. This form of treatment has proven itself due to the relative ease of fabrication and good properties for introduction into the human body. Over time, the technical production capabilities have grown and it is allowed to create a stent-grafts with branches [8].

Delivery of the stent-graft through the femoral artery is much safer than in the case of open surgery.

In this case, such factors as the symptoms, age, disease, life style, size and morphology of the aneurysm and the implantation site are considered. It's worth noting that according to the International Standardization Organization the mechanical properties of the stent graft should be retained not less than 10-year period [9].

Based on the fact that each person is unique since birth, and even more so according to its style of life, the blood flow in the cardiovascular system, also has its own peculiarities which avoid turbulent flow and unpleasant consequences for the human body. The situation is complicated in the case of the formation of abdominal aortic aneurysm due to trauma. Therefore, to ensure the full protection of all internal organs without prior thorough diagnosis carried out open surgery outside specially designated clinics is extremely dangerous and the risk is very high [10].

Improving the endovascular prosthesis inevitably leads to a reduction in the mortality of patients, the number of which at the moment is still quite high. After the operation in the course of life requires constant monitoring of the health condition. It is necessary for urgent surgical intervention in case of complications detection. [11].

Currently, important aspects are the presence of the transverse corrugation which enables the prosthesis blood vessel to restore its original shape after stretching .: inner and outer gelatin coating which, after implantation into the body provides neointima formation on the inner surface and germination of the connective tissue. The stent graft after deployment should be fixed at the neck of the aneurysm of the abdominal aorta. The force with which the prosthesis is retained in the aorta, should be sufficient to prevent its unintended migration. Therefore, the diameter of the implant should be equal to the diameter of the aorta at the site of its contact solid surface, and the range equilibrium at the junction should be observed [12].

Over time, the shape and design of endovascular prostheses, in particular the methods of delivery, deployment and fixation, matching the real human cardiovascular system should be maintained.

Full individualization stent graft for each patient - this increase in life expectancy and quality.

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