«INFLUENCE OF RHEOLOLOGICAL PROPERTIES ON THE HYDRODYNAMICS OF BLOOD FLOW IN THE INTRAORGANIC CIRCULATORY SYSTEM OF THE HEART AND IN THE HUMAN LEFT VENTRICLE.».

Vitalii Overko, minor researcher, Institute of Applied Mathematics and Mechanics, Cherkassy, Ukraine

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MATERIALS AND METHODS

- Morphometry data of the intraorgan arterial canal of the human spleen
- Direct numerical modelling of blood hydrodynamics

MODELLING OPTIONS

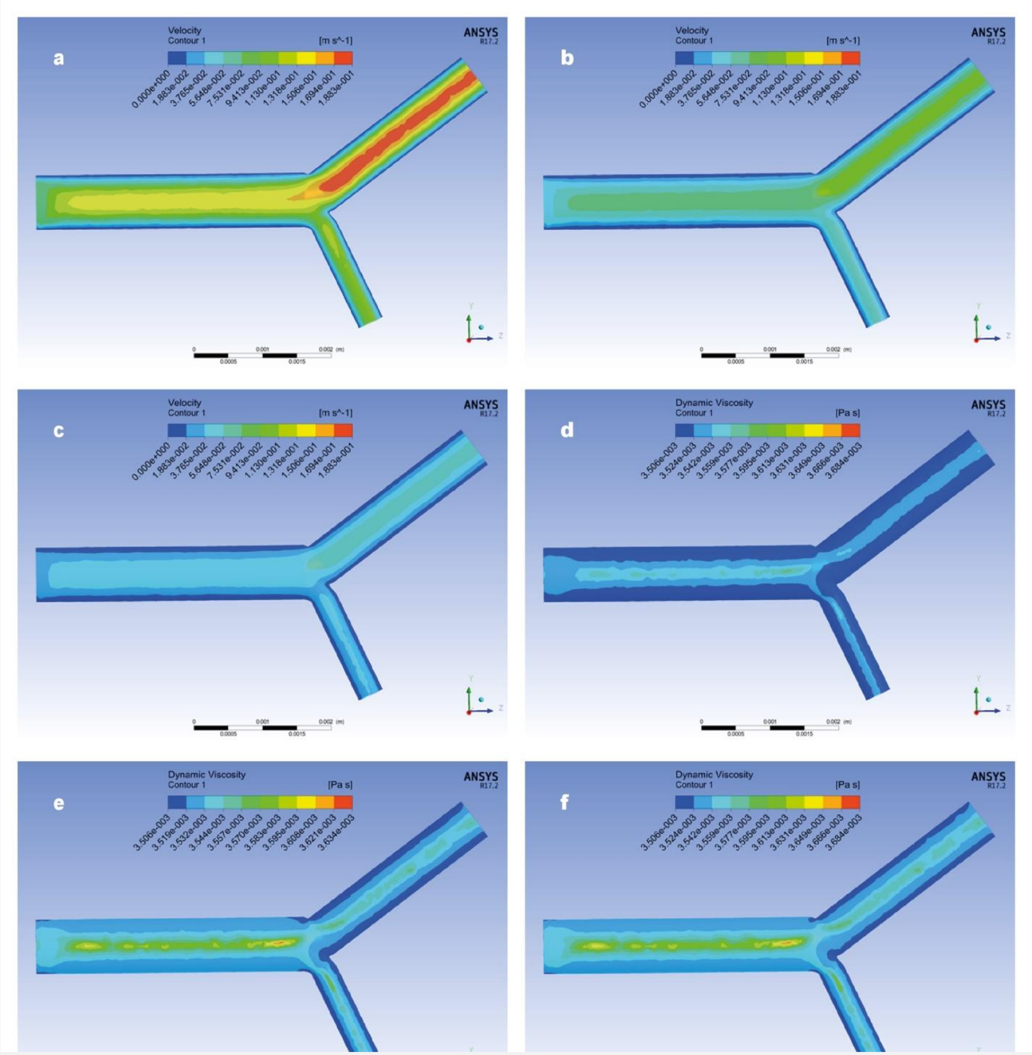
- Non-Newtonian liquid
- Single Phase Approximation
- Three-dimensional problem setting
- Flow is non-stationary
- Density is 1060 kg/m. cube
- Viscosity is changed according to the Carreau Yasuda Law

FEATURES OF HEMODYNAMICS IN STRUCTURALLY DIFFERENT ARTERIAL DICHOTOMIES

Corrosive preparation of intraoral arterial bed of spleen

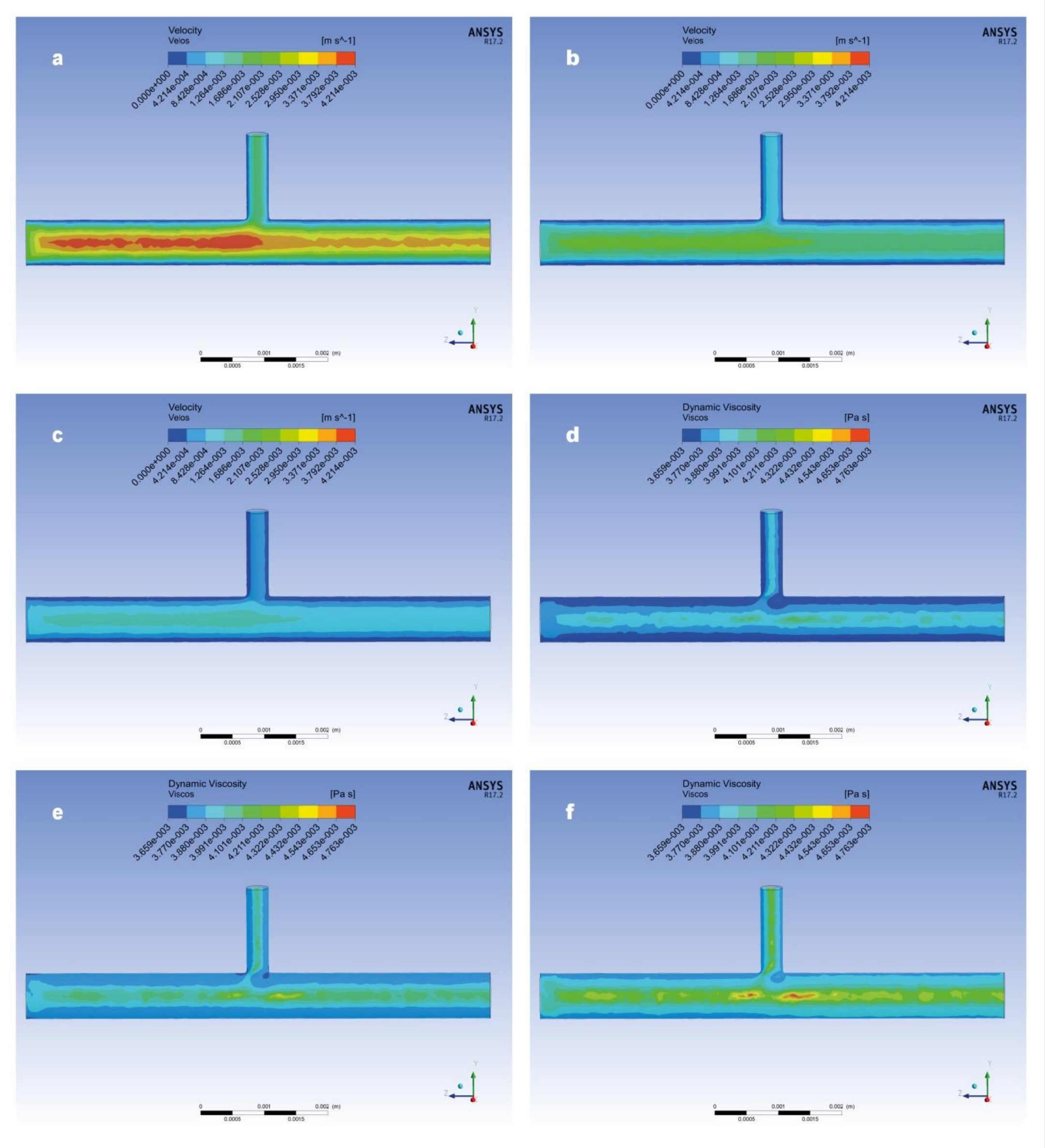
DICHOTOMY I TYPE

Simulation of flow in type 1 dichotomies (total asymmetry): a - velocity field, systolic maximum; b - velocity field, diastolic maximum; c - velocity field, diastolic minimum; d - dynamic viscosity, systolic maximum; e - dynamic viscosity, diastolic maximum; f - dynamic viscosity, diastolic minimum.



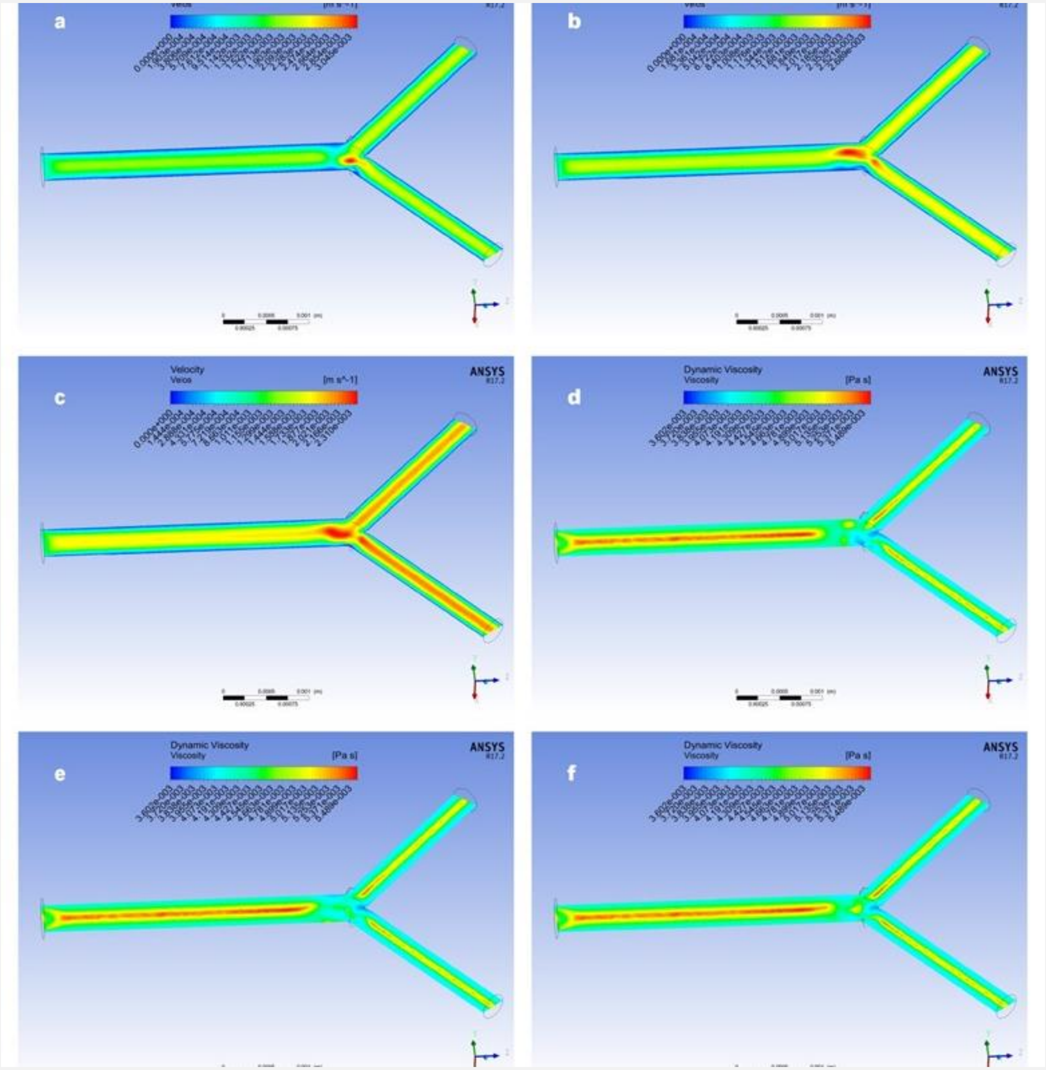
DICHOTOMY 2 TYPE

Simulation of flow in type 2 dichotomies (lateral asymmetry): a - velocity field, systolic maximum; b - velocity field, diastolic maximum; c - velocity field, diastolic minimum; d - dynamic viscosity, systolic maximum; e - dynamic viscosity, diastolic maximum; f - dynamic viscosity, diastolic minimum



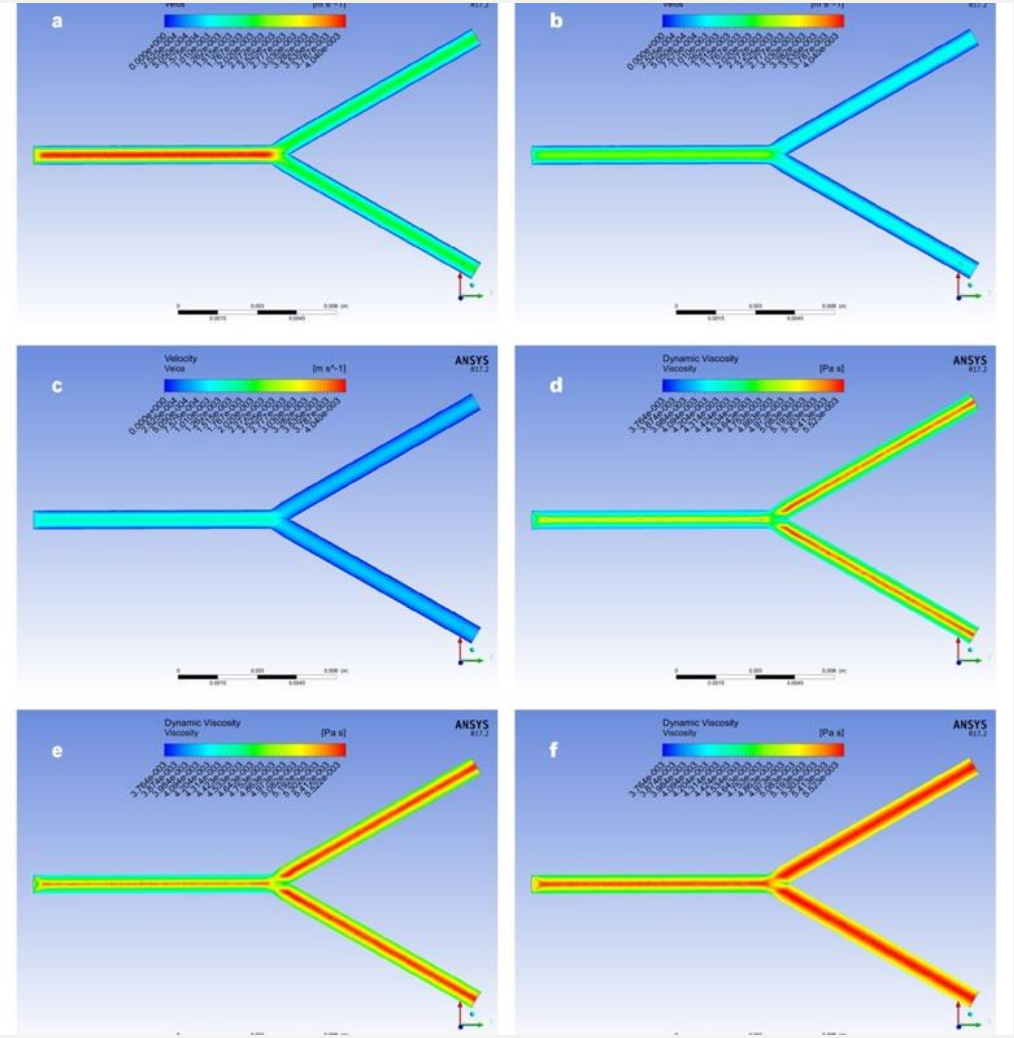
TYPE 3 DICHOTOMY

Results of simulation of flow in type 3 dichotomies (one-way symmetry): a - velocity field, systolic maximum; b - velocity field, diastolic maximum; c - velocity field, diastolic minimum; d -dynamic viscosity, systolic maximum; e - dynamic viscosity, diastolic maximum; f - dynamic viscosity, diastolic minimum.



DICHOTOMY 4 TYPE

Simulation of flow in type 4 dichotomies (full symmetry): a - velocity field, systolic maximum; b - velocity field, diastolic maximum; c - velocity field, diastolic minimum; d -dynamic viscosity, systolic maximum; e - dynamic viscosity, diastolic maximum; f - dynamic viscosity, diastolic minimum.



DISCUSSION

- •Numerical simulations of blood flow in type 1 dichotomies (total asymmetry) showed that the passage of blood flow through type one dichotomy increases flow fluctuations and increases the maximum speed in a larger branch (dmax) and forms a practically stationary current in a smaller branch (dmin). The viscosity of the blood in the core of the stream, both larger (dmax) and smaller (dmin) branches, decreases due to increased velocity profile deformation and increased shear stresses. Thus, the first type dichotomy (total asymmetry) increases the intensity of flow fluctuations and the maximum flow rate, and also reduces the dynamic viscosity of the blood during the cardiac cycle in a larger branch. A quasi-static current is formed in the smaller branch.

- •The current pattern in type two dichotomies (lateral asymmetry) demonstrates that, despite some structural similarity of type two dichotomies to type one (complete asymmetry), current patterns differ significantly. In particular, the maximum speed in the larger child branch (dmax) is noticeably lower than the maximum speed in the parent branch (D). The velocity field in the smaller branch (dmin) changes significantly during the cardiac cycle, which is not the case in type one dichotomies (total asymmetry). The non-Newtonian properties of blood change insignificantly after the flow of blood dichotomy type II (lateral asymmetry). Dynamic viscosity increases in the larger child branch (dmax) and decreases in the smaller child branch (dmin). Thus, type two dichotomy (lateral asymmetry) reduces the maximum flow rate and dynamic viscosity in all branches.

- •The results of blood flow modelling in the third type of arterial dichotomy (one-way symmetry) strongly suggest an increase in maximum speed in the daughter branches. In the phase of systol, the effect of the emergence of a detached zone is evident. It should also be noted that in the diastolic phase, the speed profile becomes less full, with a more pronounced maximum on the axis, this is the reason for the increase in shear stresses and affects the change of blood viscosity. The presence of areas with low shear stresses on the flow axis results in areas with increased viscosity on the receptacle axis. At the branching point, shear stresses increase significantly due to the turn of the flow, as a consequence of which the dynamic viscosity of the blood decreases. В течение кардиального цикла колебания вязкости в целом незначительны для прямолинейных участков как родительского (D), так и дочерних сегментов (dmax, dmin).

- However, the structure of the viscosity field undergoes significant changes, if in the mother vessel the area with increased viscosity occupies half the diameter, then in the daughter branches not more than a quarter. In addition, in the diastolic minimum phase, an area with a locally increased dynamic viscosity is created in the branching zone, which facilitates flow separation in the subsequent systolic phase of the cardiac cycle. Hence, type three dichotomies (one-way symmetry) increase the flow rate and deform its profile in such a way that shear stresses increase, which in turn leads to a reduction of viscosity not only in the pristine area, but also in the nearest flow core area. The resulting forces are likely to contribute to the concentration of shaped blood cells near the axis of the vessel.

- •Analysis of the results of blood flow modelling in the fourth type of arterial dichotomy (full symmetry) convincingly demonstrates a significant reduction of speed in the daughter branches compared to the parent vessel, as well as a flattening of the velocity profile in the cross section of the vessel. The speed profile is getting more complete. Unlike the blood flow in the third type of dichotomy (one-way symmetry), the detached zone does not occur. Flattening the velocity profile reduces shear stresses in the core of the stream, which in turn increases the dynamic viscosity of the blood flow in the daughter branches of this dichotomy.Thus, the fourth type dichotomy (full symmetry) reduces the maximum flow rate, deforms the velocity profile, and greatly increases blood viscosity. Moreover, the area with increased viscosity extends from the core of the stream to almost the entire flow area.

CONCLUSION

The results of numerical modelling of the blood flow in structurally different types of arterial dichotomies of the intraorgan channel of the human heart allow us to assert their different functional role.

After the successive passage of blood through various types of dichotomies, its flow acquires the unified properties necessary for the flow in the hemomicro channel.

The observed patterns should be taken into account when numerically modeling the structure of the intraorgan arterial channel of the human heart and intraarterial hemodynamics.

PAPERS

1. Influence of rheolological properties on the hydrodynamics of blood flow in the intraorganic circulatory system of the heart and in the human left ventricle. Applied and Computational Mathematics an International Journal», Institute of Applied Mathematics of Baku State University,, Baku, Azerbaijan (submit)
2. Non-Newtonian blood flow in the different types of arteria dichotomy. WSEAS TRANSACTIONS ON FLUID MECHANICS (Special Issue for Tony Maxworthy) (submit)