

# Using a combination of mathematical multiphase poroelasticity model of parenchyma and experimental approaches to study hydrocephalus

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**Key words:** cerebrospinal fluid, hydrocephalus, mathematical models

*Motivation and Aim:* There are a large number of pathological conditions of the central nervous system characterized by impaired movement of intracerebral fluids [1]. An important example is hydrocephalus, a pathology in which the brain ventricles increase, which leads to displacement and compression of brain tissue. This condition is well described in terms of clinical manifestations, but its causes and development are poorly understood.

*Methods and Algorithms:* The report considers a complex mathematical model of cerebral cerebrospinal fluid and hemodynamics of a person based on a model of multiphase poroelasticity for brain matter. The interaction of cerebral fluids is given by a set of four numerical coefficients. The displacement of the ventricular wall of the brain and the magnitude of pressure on it are studied [2, 4]. A multiple linear regression with interaction is constructed that allows us to quantify the effect of these coefficients on the average ventricular wall displacement. This mathematical model was tested on laboratory animals. This is necessary in order to further use experimental approaches and increase the number of real parameters involved in modeling.

*Results:* It is shown that the considered model allows to describe both the healthy state of organism and the state of organism with hydrocephaly and the transition between them that takes place when the model parameters change [3]. Based on the MRI data of real patients, the patterns of behavior of these values are determined depending on the parameters of the model in hydrocephalus. The prevailing influence of an arterial-liquor component was observed [4]. Using MRI data and a mathematical model in laboratory mice, intertrain differences in the tendency to hydrocephalus were found.

*Conclusion:* The effect of interaction parameters on mean ventricular wall displacement and periventricular pressure is described qualitatively. Based on the regression model analysis the prevailing influence of the capillary-CSF component was found. The analysis reveals the relationship between the interaction coefficients and the pathological conditions. The data used, obtained on laboratory animals, made it possible to construct an animal version of the described mathematical model.

*Acknowledgements:* The study was carried out at the expense of the grant of the Russian Science Foundation No. 22-11-00264, <https://rscf.ru/project/22-11-00264/>.

## References

1. Yankova G., Bogomyakova O., Tulupov A. The glymphatic system and meningeal lymphatics of the brain: new understanding of brain clearance. *Rev Neurosci.* 2021;32(7):693-705.
2. Yankova G.S., Cherevko A.A., Khe A.K., Bogomyakova O.B., Tulupov A.A. Study of hydrocephalus development using poroelastic models. *Appl Mech Tech Phys.* 2020;61(1):17-29.
3. Yankova G.S., Cherevko A.A., Khe A.K., Bogomyakova O.B., Tulupov A.A. Mathematical modeling of normotensive hydrocephalus at different levels of detailed brain geometry. *Appl Mech Tech Phys.* 2021;62(4):148-157.
4. Valova G., Bogomyakova O., Tulupov A., Cherevko A. Influence of interaction of cerebral fluids on ventricular deformation: A mathematical approach. *PLoS One.* 2022;17(2):e0264395.