Abstract for General Public

Age-related macular degeneration, cystoid macular edema, and diabetic retinopathy are currently the main causes of severe visual impairment and even blindness in millions of people worldwide. So far, no effective method has been developed to prevent or completely cure these diseases. It is known that they are associated with pathology of retinal blood vessels. Diseased blood vessels often tend to rupture. Weakened vessel walls can lead to the formation of microaneurysms, which, when they rupture, cause hemorrhages into the vitreous body. This significantly affects the degree of visual impairment by hindering the passage of light.

Bevacizumab is one of the most commonly used drugs that inhibit excessive growth of blood vessels. To prevent potential systemic side effects, it began to be administered intravitreally (a procedure in which the drug is placed directly into the space in the back of the eye called the vitreous cavity, which is filled with a gel-like substance known as the vitreous humor, and at much lower doses than intravenous administration). It should be noted that these injections cause considerable discomfort for patients and carry a risk of complications, which is why efforts are being made to reduce the frequency of injections. In addition, the standard treatment procedure does not include the possibility of therapy individualization.

The use of controlled-release systems for bevacizumab could potentially reduce the frequency and volume of injections.

One approach involves using biodegradable micro- and nanoparticles that release the drug inside the eye. Delivering drugs into the eye using microparticles made of a biodegradable polymer - poly(lactic-co-glycolic acid) (PLGA) - has several advantages, one of which is the ease of injection without the need for large-gauge needles.

The main innovation of the project is the improvement of current drug delivery systems based on biodegradable polymeric particles, which have significant drawbacks such as an initial burst release of the drug and unpredictable material degradation. To address these issues, a process for effective atmospheric pressure plasma (APP) modification of drug-loaded PLGA microparticles will be developed. This will enable better control over drug release and enhance the safety and effectiveness of ophthalmic treatments.

The process of plasma modification of drug-loaded PLGA particles will be optimized using machine learning methods. A neural network trained on experimental data will learn to predict drug release pharmacokinetics and therapeutic effectiveness depending on the applied functionalization parameters, parameters describing the geometry of the eye, and the type of tamponade used (in patients after vitrectomy surgery). The developed AI model will be coupled with a genetic algorithm (GA) - a computer optimization method inspired by evolutionary processes - to automatically select the best plasma treatment parameters for PLGA particles for a given patient. This approach represents an important step toward truly personalized ophthalmic care.

To reduce the need for animal studies and increase research efficiency, the project also includes the creation of a laboratory model of the human eye. The two-chamber system closely replicates the structure and physiology of the eye, allowing the study of the pharmacokinetics and pharmacodynamics of ophthalmic drugs under physiologically relevant conditions.

This interdisciplinary project, with high translational potential, addresses an urgent medical need by bringing together experts from various fields: materials science, plasma engineering, pharmacology, ophthalmology, and artificial intelligence. The ambition of the project is to improve patient safety and comfort, increase the effectiveness of retinopathy treatment, and reduce healthcare costs.