The XXVII International Scientific Conference of Young Scientists and Specialists (AYSS-2023)

Contribution ID: **1362** Type: **Poster**

A MATHEMATICAL MODEL OF CALCIUM CONCENTRACTION WAVES IN HUMAN PLATELETS

Monday, 30 October 2023 21:45 (15 minutes)

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Any living system must continuously exchange energy, matter, and information with the environment, for which a system for interpreting information within the cell is necessary. One of the important mechanisms for the transmission of information from external stimuli into the cell is the system controlling the intracellular calcium ($[Ca^{2+}]$) level as this ion easily binds to proteins and alters their functions. Platelets are anucleate cellular fragments whose functions are mostly controlled by $[Ca^{2+}]$ [1]. Therefore, studying the mechanisms of how cells interpret information about their surrounding environment is conveniently done in platelets.
In the present study, we investigated the issue of spatial heterogeneity of $[Ca^{2+}]$ in platelets. For experimental observation of $[Ca^{2+}]$, platelets were incubated with fluorescent probe CalBryte 590 AM (AAT Bioquest, California, US). Fluorescent probes were excited by a laser at 561 nm wavelength. Nikon Eclipse Ti-E microscope with a CFI Apochromat TIRF 100XC Oil objective with 100-fold magnification and numerical aperture of 1.49 was used in this study. The soft ImageJ with Fiji package and Python 3.10 was used for interpretation of the experimental data. To describe the obtained data, a computer model of calcium signaling was developed which is a reduced model of De Young-Keizer which is augmented by the diffusion equation [2]. The Neumann closed boundary conditions were imposed at the boundaries of the cytoplasm. The model integration was performed using finite-volume method in Python 3.10 environment.
Experimentally, a wave of $[Ca^{2+}]$ is observed in single immobilized platelets of healthy donors, and the wave front propagates with speed
$31.6 \pm 5.7\ nm/s$. The computer model produces conditions in which a wave of $[Ca^{2+}]$ is also observed, but its rate decreases with time from 147 to 30 nm/s. The corresponding diffusion coefficient of calcium ions was set at $5.3\ m^2/s$, which is less than $20 - 100\ m^2/s$ found in the literature [3]. Thus we can conclude that the driving mechanism for spatial heterogeneity of $[Ca^{2+}]$ in the platelet is the slow diffusion of ions in the cytoplasm.

The work was supported by SES «Photonics and digital medicine» 23-III06-03.

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Session Classification: In-person poster session & welcome drinks

Track Classification: Life Science