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Real-Time Conductivity Measurements of Mammalian Cell Suspension during Nanosecond Electric Pulse Trains

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Electric pulses (EPs) have multiple medical applications that depend upon their impact on plasma membrane integrity and ion and molecular transport [1]; however, the motion of the ions during the EPs, which may impact the resulting phenomena, remain poorly understood. This study reports the net ion motion during the application of multiple nanosecond EPs (NSEPs) to a Jurkat cell suspension by determining the electrical conductivity by measuring the applied voltage and resulting current during the final EP of the train. The cells were suspended in a high conductivity buffer, growth media (GM), and a low conductivity buffer (LCB) [2] and exposed to trains of one, five, and fifteen 60 ns EPs of fixed energy while 300 ns pulses of fixed energy were applied to LCB. For 60 ns EPs, the extracellular conductivity increased for the higher conductivity buffers and decreased for the LCB, indicating ion motion out of and into the cells, respectively. Applying a train of 300 ns EPs to LCB also increased extracellular conductivity. Calculations indicate that the variation in extracellular conductivity observed during the shorter EP and lower conductivity buffer arises due to non-electrical effects, such as shocks waves, membrane temperature gradients, and colloid-osmotic swelling. The potential significance of these multiphysics phenomena on fundamental biophysical phenomena and the implications on biomedical applications will be discussed.

[1] M. L. Yarmush, A. Golberg, G. Serša, T. Kotnik, and D. Miklavčič, "Electroporation-based technologies for medicine: Principles, applications and challenges,"Ann. Rev. Biomed. Eng., vol. 16, pp. 295-320, 2014.
[2] A. L. Garner et al., "Ultrashort electric pulse induced changes in cellular dielectric properties,"Biochem. Biophys. Res. Commun., vol. 362, no. 1, pp. 139–44, 2007.

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