THE INFLUENCE OF SPHEROID CELL DEFORMATIONS ON ELECTRIC FIELD INDUCED TRANSMEMBRANE POTENTIAL AND ELECTROPORATION EFFICIENCY

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Electroporation is a method in which short duration, high amplitude electric pulses are employed to transiently permeabilize the cell membrane, which allows the unhindered delivery of small molecules (e.g., chemotherapeutic drugs) or nucleic acids into the cell. The efficiency of the electroporation depends on many parameters, including the parameters of electric pulses applied and the parameters of cell and the surrounding medium. One of these parameters is the conductivity of electroporation medium.

As shown in [1], under electric field, lipid vesicles deform according to the conductivity ratio of the solution inside and outside of the vesicle. Therefore, it is reasonable to assume that eukaryotic cells would also deform in the electric field, assuming the form of a prolate (elongated) spheroid when the external conductivity is lower than the internal conductivity, and the form of an oblate (squashed) spheroid when the external conductivity is higher than the internal conductivity.

We modelled the effect prolate and oblate deformations would have on the transmembrane potential induced by external electric field. For this model, we assumed that the cell at rest (without external electric field) is a sphere with 9.7 µm radius, which is true for the Chinese Hamster Ovary cells in suspension. Constant cell volume during the electrodeformations was assumed. The cross section of the resulting spheroid on a plane parallel to the electrodes (perpendicular to the electric field) is a circle, and the cross section parallel to the electric field is an ellipsis. Using the formulas derived in [2] and [3], we calculated the changes in cell transmembrane potential for cell deformations when the ratio of cell radius parallel to the electric field and perpendicular to the electric field ranged from 1.5/1 to 5/1 for prolate deformations, and 1/1.5 to 1/5 for oblate deformations. Electric field voltage of 1400 V/cm was used for the model.

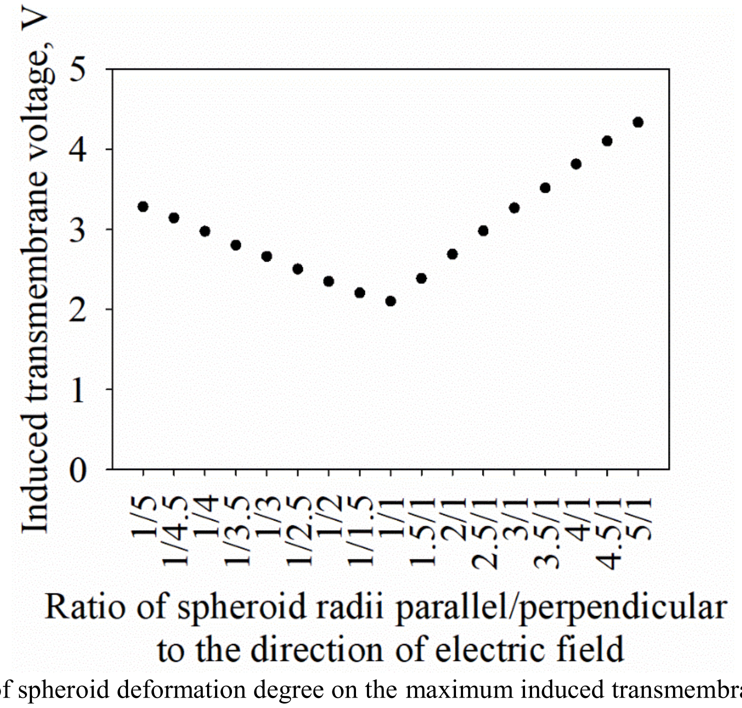

Fig. 1. The influence of spheroid deformation degree on the maximum induced transmembrane potential at the cell poles.

Fig. 1 shows the maximum induced transmembrane potential at the deformed cell poles. It can be seen that, while both oblate and prolate deformations increase the maximum induced transmembrane potential, the rise is steeper in the case of prolate deformation. Therefore, a higher increase in electroporation efficiency is expected when electroporation is performed in solutions with conductivity that is lower than intracellular conductivity.

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