MODELING THE ELECTRIC PROFILE OF THE NEURON MEMBRANE

T.M. Pinto[1,2], D. Silva[1], C.M. Cortez[1], R. S. Wedemann[3]

[1] Laboratory of Biomembrane and Neuronal Circuits, Dept of Physiological Sciences, Rio de Janeiro State University, Brazil;
[2] Computational Sciences Post Graduation Program, Institute of Mathematics and Statistics, Rio de Janeiro State University, Brazil;
[3] Institute of Mathematics and Statistics, Rio de Janeiro State University, Brazil.

thiagomatos@ime.uerj.br

OBJECTIVE

To determine the electric potential profile for a model of neuron membrane by the numerical solutions of the non-linear Poisson-Boltzmann equation.

METHODS

The space-dependent electric potential equations were determined by solution of non-linear Poisson-Boltzmann equation. It considered a neuron membrane model that takes into account the charge densities due to charges dissolved in an electrolytic solution and fixed on both glycocalyx and cytoplasmic proteins, as showed in Fig. 1.

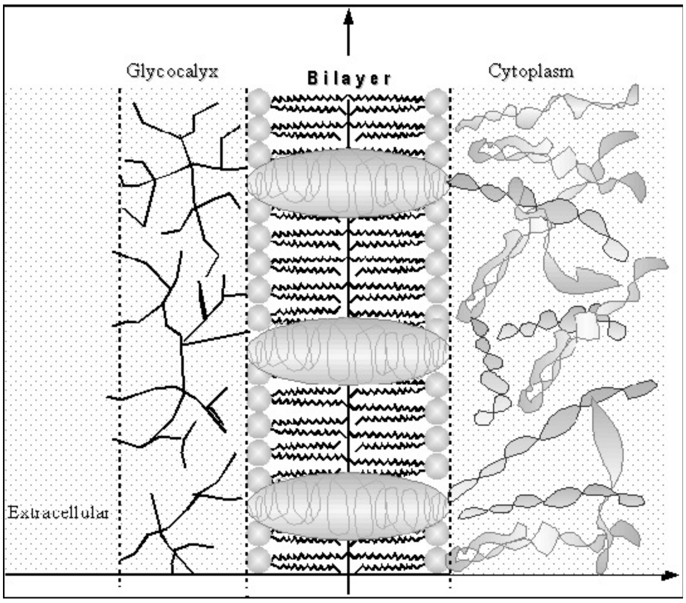

Fig. 1. Membrane model.

It was assumed that on both sides of the membrane the charges are homogeneously distributed. Therefore, the potential was dependent only z-coordinate. The second order solution of equations into the glycocalyx and cytoplasmic regions was performed by means of the Runge-Kutta method. Numerical values from literature were applied in the problem to simulate resting and action conditions of the neuron. The glycocalix surface density has been calculated from the data obtained in electrophoretic experiments, using the Helmholts-Smoluchowski equation. The inner surface charge density of lipidic bilayer was derived from a known lipid composition of neuron membrane. The spatial charge density of the glycocalyx was estimated from the surface charge density, since it can be considered to be almost constant in the z direction.

RESULTS

Results showing the features of the potential profile along the outer electrolytic region are similar for both resting and action states. However, the potential fall along glycocalyx at action state is lower than at resting.

CONCLUSIONS

We conclude that the effects on the potential profile due to surface lipidic bilayer charge and contiguous electric double layers are more relevant than those provoked by fixed charges distributed along the cell cytoplasm.

REFERENCES

[1] Cortez, C.M., Silva D. *Fisiologia aplicada à Psicologia*, vol. 1, Rio de Janeiro: Editora Guanabara Koogan, 2007.

[2] Chang, D. *Dependence of Cellular Potential on Ionic Concentration: Data Supporting a Modification of the Constant Field Equation*, Biophys. J., 43:149-156, 1983.

[3] Cevc, G. *Membrane electrostatics*. Biochim. Biophys. Acta, 1031:311-382, 1990.

[4] Baker, J.; Coakley, W.T.; Gallez, D. *Influence of polymer concentration and molecular weight and of enzymic glycocalyx modification on erythrocyte interaction in dextran solutions.* Eur. Biophys., 22:53-62, 1993.

[5] Schnebli, H.P.; Roeder, C.; Tarcsay, L. *Reaction of lectins with human erythrocytes*. Exper. Cell Res., 98:273-276, 1976.

[6] Cruz, F.A.O.; Vilhena, F..S.D.S.; Cortez, C.M. *Solution of Non-Linear Poisson-Boltzmann Equation for Erythrocyte Membrane*. Braz. J. Phys., 30:403-409, 2000.

[7] Donath, E.; Pastushenko.V. *Electrophoretical study of cell surface properties. The influence of the surface coat on the electric potential distribution and on general electrokinetic properties of animal cells*. J. Electroanal. Chem., 104:543-554, 1979.

[8] Cortez, C.M.; Bisch, P.M. *The Effect of Ionic Strength and Outer Surface Charges on the Mechanical Stability of the Erytrocyte Membranes: A Linear Hydrodynamics Analysis.* J. Theor. Biology, 176:325-339, 1995.

probes. Biochim. Biophys. Acta, 815:455-460, 1985.

[9] Lehninger, A.L. *The Neuronal Membrane*. PNAS, 60:1069-1080, 1968.

[10] Soares, T.A., Ferreira, R. *Aplicação da equação de Poisson-Boltzmann ao cálculo de propriedades dependentes do pH em proteínas*. Química Nova, 27(4):640-647, 2004.

[11] Cortez, C.M., Bish, P.M. *The effect of ionic strength and outer surface charge on the membrane electric potential profile: a simple model for the erythrocyte membrane*. Bioelectrochemistry and Bioenergetics, 32:305-315, 1993.

[12] Quillfeldt, J.A. *Origem dos potenciais elétricos das células nervosas*. Porto Alegre: Departamento de Biofísica - Universidade Federal do Rio Grande do Sul, 2005.