Abstract

Irreversible electroporation (IRE) is a technique in which a series of high-voltage short pulses are used to ablate localized cancer cells or tumors in a non-thermal process. It is well reported that the IRE induces lateral tension in the membranes of giant unilamellar vesicles (GUVs), which is considered as a model of cells. The GUVs were synthesized by a mixture of anionic lipid dioleoylphosphatidylglycerol (DOPG) and neutral lipid dioleoylphosphatidylcholine (DOPC) in a buffer (10mM PIPES, pH 7.0, 150 mM NaCl and 1mM EGTA) using the natural swelling method. We investigated the effects of surface charge density on the constant electric tension-induced rate constant of irreversible pore formation in the membranes of GUVs. The IRE signal of frequency 1.1 kHz was applied through the gold coated electrode system for those investigations. For DOPG mole fraction, X = 0.20, the rate constants were obtained $(1.1 \pm 0.2)\times10^{-2}$, $(2.7 \pm 0.3)\times10^{-2}$ and $(1.0 \pm 0.01)\times10^{-1}s^{-1}$ at tension 5.75, 6.5 and 7.25 mN/m, respectively. Again for X = 0.40, the obtained rate constants were $(0.9 \pm 0.02)\times10^{-2}$, $(4.0 \pm 0.5)\times10^{-2}$ and $(1.4 \pm 0.1)\times10^{-1}s^{-1}$ at 5.0, 6.0 and 7.0 mN/m, respectively. For other values of X, the similar tendency of increasing the rate constant with electric tension was also observed. Therefore, the rate constant of pore formation increased with the increase of external membrane tension. The rate constant became higher at lower tension with the increase of surface charge density in membranes. The tension dependent rate constant of pore formation was fitted to the theoretical equation and obtained the line tension of membranes at various conditions. We also investigated the influence of X on the critical tension of electroporation in GUVs. The critical tension decreased from 9.0 ± 0.3 to 6.0 ± 0.2 mN/m with the increase of X from 0 to 0.60 in GUVs. The theoretical equation was fitted to the X dependent normalized critical tension and the binding constant of lipid-ion interaction was obtained 0.75 M^{-1}. The decreased in energy barrier for the formation of a prepore, due to the increased of X, was the main factor explaining the decreased of critical tension and increased of rate constant of pore formation in GUVs.

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1. Electrostatic effects on the electrical tension-induced irreversible pore formation in giant unilamellar vesicles

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Conference Presentations:

1. Urbi Shyamolima Orchi, Md. Towhiduzzaman, Marzuk Ahmed, Md. Kabir Ahamed, Shareef Ahammed and Mohammad Abu Sayem Karal: Intramembrane Electrostatic Effects on the Irreversible Electroporation induced Rate Constant of Pore Formation in the Membranes of Vesicles (***Abstract-PP-131)International Conference on Physics, Organised by BPS,*** Dhaka, Bangladesh, 05-07 March, 2020.

2. Urbi Shyamolima Orchi, Md. Kabir Ahamed, Md. Towhiduzzaman, Shareef Ahammed, Mohammad Abu Sayem Karal: Pore Formation and Membrane Fusion of Giant Unilamellar Vesicles Using Electrically Induced Constant Tension in the Membrane ***(Abstract-pp-48) National Conference on Electronics and Informatics, Organized by BES and BAEC***, Dhaka, Bangladesh, December, 2019.

3. Md. Towhiduzzaman, Urbi Shyamolima Orchi, Md. Kabir Ahamed, Marzuk Ahmed, Shareef Ahammed and Mohammad Abu Sayem Karal: Effects of Salt Concentration on the Irreversible Electroporation Induced Pore Formation in the Lipid Membranes of Cell Like Vesicles ***(Abstract-pp-111) International Conference on Physics, Organised by BPS,*** Dhaka, Bangladesh, 05-07 March, 2020.