Cell Circuits: Using Nyquist Plot to Find Equivalent Circuit Models to Human Keratinocyte Cells

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This study investigates the use of Electrochemical Impedance Spectroscopy (EIS) to create equivalent circuits for human keratinocyte cells in Dulbecco's Modified Eagle Media (DMEM) with and without silver nanoparticles (AgNPs). The human keratinocyte cells (HaCaT) were grown in the lab's incubator at 32ºC and 4% CO2 content. They were detached from flasks with trypsin solution, re-suspended in DMEM media, and later placed into the electrode devices prior to treatment with the AgNPs. Electrochemical Impedance Spectroscopy with a multi-electrode sensing device was used to record impedance measurements to study the changes in the HaCaT cells with and without AgNPs. Numerical analyses were performed to quantify and monitor system parameters such as cell membrane capacitance, solution resistance, cell–cell junction resistance, and cell–substrate contact resistance. The EIS Spectrum Analyzer program used the Powell fitting algorithm to produce values for the resistance, capacitance, and constant-phase-element properties from Nyquist plots of the impedance data. The equivalent circuit model was hypothesized and tested using the Nyquist plots of the DMEM media, cells with DMEM, and cells with DMEM and AgNPs. The fitted values for the individual components of the equivalent circuits were found for each case: capacitance (C1), 3.75E-11F (Cells/DMEM), 2.52E-11F (DMEM/cells/AgNPs); and resistance (R2), 2270.1Ω (Cells/DMEM), 6264.8Ω (DMEM/cells/AgNPs). The lower capacitance of cells with AgNPs could be explained by the drop in their mitochondrial membrane potential since In vitro studies have shown decreased mitochondrial function after exposure to AgNPs in other cells. EIS and the equivalent circuit could be used to create gel models of cells for drug discovery.