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Bioimpedance and Electrochemistry for Neural Stem Cell Characterization and Detection of Dopamine Release

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Abstract—Biophysical measurement methods like electrical impedance spectroscopy and amperometry provide an excellent tool for investigation of various cellular phenomena. In this work, bioimpedance measurements have been performed to assess the proliferation of neural stem cells or PC12 cells. Subsequently, amperometry was used to detect neurotransmitter release from PC12 cells or neurons differentiated from neural stem cells.

I. INTRODUCTION

Electrical impedance spectroscopy (EIS) can be used to monitor different cellular changes like proliferation, apoptosis, migration, changes in morphology and also (neuronal) differentiation. Compared to most molecular biological methods, bioimpedance measurements are non-invasive and allow for repeated analysis of the same cell population [1].

II. METHODS

Experiments were performed using two different cell lines: the human ventral mesencephalic neural stem cell line hVM1 [2] and PC12 cells (ATCC® CRL-1721™ [3]). The cells were cultured on pyrolytic carbon electrode chips provided by Technical University of Denmark [4], see Fig. 1. The electrode chips were treated with oxygen plasma and then assembled in a chip holder with magnetic clamping. After sterilization with 0.5 M NaOH and coating of the electrode surface with Geltrex™, hVM1 or PC12 cells were seeded at a density of 0.4 Mio cells/cm² and cultivated at 37 °C and 5 % CO₂.

III. RESULTS

Electrical Impedance Spectroscopy (EIS). Bioimpedance measurements were performed every second day to follow the proliferation of cells using the Zurich Instruments MFIA Impedance Analyzer. A two-electrode configuration was used by connecting only working and counter electrode. Spectra from 1 kHz to 1 MHz (100 points, log) were recorded at a voltage of 45.78 µV. Cells impede the flow of current between the electrodes. Therefore, an increasing number of cells results in an increased impedance.

Electrochemical detection of neurotransmitter release. Amperometry was used to detect the release of neurotransmitters, especially dopamine after triggered depolarization by stimulation with a high K⁺ buffer. Release of oxidizable molecules leads to increased current intensity visible as oxidation peak in the I-t curve.

IV. DISCUSSION & CONCLUSION

This work demonstrates the principle of bioimpedance measurements and electrochemical detection of neurotransmitter release from two different cell lines (PC12 and hVM1). With EIS, cell proliferation can be monitored non-invasively over time. With amperometry, it has been shown that a repeated depolarization of the cells is possible and that cells remain active and viable over several days.

REFERENCES


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Fig 1. Schematic drawing (left) of 2D carbon electrodes: pyrolytic carbon (A), platinum electrodes, contact leads and pads (B), SU-8 passivation layer (C), modified after [4]. CE, WE, RE = counter, working and reference electrode. Chips assembled in chip holder with magnetic clamping (right).