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Validation of in situ electroporation performed within a single cell microwave biosensor

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☰ ABSTRACT SUMMARY

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Title, content, keywords, and sessions

Title: Validation of in situ electroporation performed within a single cell microwave biosensor

Body: Context: ElectroPoration (EP) is widely used in clinical practice within ElectroChemoTherapy (ECT) treatments, that consist in the combination of pulsed electric fields' application and anti-cancer agents' administration. The entry of the anti-cancer agents into cells is facilitated as the membranes are transiently permeabilized, thereby increasing drugs' cytotoxicity. If the efficacy of ECT has been demonstrated in the treatment of solid tumors, in ~20% of cases, relapse occurs. Being able to predict treatment efficacy as early as possible constitutes a main challenge. Conducting studies at the single-cell level is essential for a better understanding of the dynamics of the EP phenomenon and enables the study of inter-cellular differences. Among the different existing techniques for electrical characterization of cells, Microwave Dielectric Spectroscopy (MDS) is a promising approach to obtain the dielectric properties of cells directly in their culture medium, in a non-invasive way. MDS can be performed at the single-cell level [1], and it has been effective in detecting cellular states following the application of EP and ECT treatments [2]. In the current study, we aim to perform in-situ EP with conventional microwave probes, in a biosensor initially designed for performing MDS analysis. Such probes are used here to apply DC voltages. Methods: We conduct this study on human cancer cells (THP-1), which we pre-label with Calcein AM. After trapping a single-cell in the biosensor, we deliver electric pulses through microwave probes, placed on either side of the central strip of a coplanar waveguide, which has a 5 μm -capacitive gap at its center. The applied electric pulses are similar to those commonly used for ECT treatments (8 pulses of 100 μs width, at a frequency of 1 Hz). We calibrate the electric field by studying the impact on permeabilization at different voltages, ranging from 0 to 15 V. Electropulsation buffer containing propidium iodide is used while applying the electric pulses. We assess the state of cellular permeabilization by studying the entry of propidium iodide and leakage of Calcein AM. Results: We validate in-situ EP using an existing biosensor originally designed for single-cell MDS analysis. This study allows us to 1) define the permeabilization threshold for the studied cell line; 2) validate the use of microwave probes to apply DC voltages and perform EP; 3) pave the way for further MDS analysis of the EP phenomenon performed in-situ. References: [1] T. Chen et al., "Microwave biosensor dedicated to the dielectric spectroscopy of a single alive biological cell in its culture medium," IEEE MTT-S Int. Microw. Symp. Dig., 2013. [2] A. Tamra et al., "Single Cell Microwave Biosensor for Monitoring Cellular Response to Electrochemotherapy.," IEEE Trans. Biomed. Eng., 2022.

Keywords: EP on chip; biosensor; single cell; microfluidic; microwave dielectric spectroscopy.

Session(s):

S20 - PhD Students as important bricks in the wall of funded projects and basic research [special]

P10 - Electrofluidic, microfluidic and lab on a chip [main track]

Classification

Subject area	Topic	
Basic biology of electroporation	Cell responses (including intracellular trafficking and pathways)	✓
Medical applications	Cancer therapy	✓
Pulsed-power devices, facilities and apparatus for Plasma and PEF treatment	Instrumentation diagnostics (pulsed power, optical, impedance, etc.)	✓
Technology	Micro and nano devices	✓
	Microfluidics	✓

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