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Electrochemical Analysis of In Vitro Electrical Stimulation

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INTRODUCTION: Electrical stimulations (ES) with various intensity, frequency, duration, signal shape, etc. are used to enhance tissue regeneration. However, it is not yet clear which combination of parameters is efficient in each application. A relevant approach to refine these sets of parameters is to reveal the significant electrochemical features linked to the biophysical responses [1,2].
Here, we characterized the electrochemical features of different in vitro ES systems and regimes in biologically relevant conditions.
METHODS: We characterized three different systems: miniaturized devices with electrode plates, coated with either Pt thin film (TF) or Pt nanocolumns (NC) [3]; and an 8-well plate with L-shaped Pt wires (W). Electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) were measured using a potentiostat. Chronoamperometry was carried out for different ES regimes.
RESULTS: Impedance is significantly reduced when NC are used. The NC effective capacitance is larger than that of TF due to its increased electrochemically active area. The safe limits are between -0.7 V and 1.0 V for both NC and TF. Redox peaks were observed in the same potential ranges for both morphologies. Accumulated charge was considerably larger for both morphologies in the potential regions were oxidation of Pt and adsorption-desorption of H_2 occur, showing its dependency on the applied potential ranges. Moreover, charge per pulse was around two orders of magnitude larger for NC than for TF in every region.
DISCUSSION & CONCLUSIONS: The applied electrical signals are not equal to what cells sense due to the electric double layer at the interface and its characteristics are extractable from EIS. Chronoamperometry provides the accumulated charge in the system. The sum of charges passed to the extracellular fluid highly depends on electrode material, operation voltage range, and signal shape. Finally, even being in the safe operating voltage range, faradaic reactions [4], responsible for production of reactive oxygen species, change with the amount of energy injected to the system. This energy correlates with specific reaction peaks in the CV curve.
Electrochemical characterization will make possible to compare the energy and charge introduced to the system for different ES protocols.
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