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Poster presentation

Non-conductive vs. conductive cell membranes – a reassessment of this assumption when modeling cells under magnetic field stimulation

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Background

Experimental and modeling studies have shown that the amount of neuronal cell polarization by electric and magnetic stimulation is dependent on the stimulation parameters and the properties of the target neuronal tissue. This cell-field (i.e. directly applied or magnetically-induced electric field) interdependency determines the efficacy of a cellular response to electric and magnetic stimulation, such as during deep brain stimulation (DBS) or transcranial magnetic stimulation (TMS).

To study this cell-field interaction, particularly when computing the amount of tissue polarization induced by an applied field, several modeling works assume a non-conductive cell membrane. This assumption is based on the fact that the membrane conductivity is several orders lower compared to that of the extracellular medium or cytoplasm. Although this assumption greatly simplifies the computation of the field-induced transmembrane potential, its impact on the dependency of the transmembrane potential to the stimulus parameters (i.e., field intensity and frequency, and its orientation to the target tissue), as well as to the tissue properties (electric and geometric), have not been addressed.

Methods

We have previously computed the transmembrane potential induced by a low frequency magnetic field in a single cell model with a conductive membrane [1]. Here, we have extended this analysis to a cell model with a non-conductive membrane, and investigated the relationship between the transmembrane potential with that of the stimulus parameters and tissue properties under this assumption.

Results

1. The assumption of a non-conductive membrane did not cause a noticeable difference in the transmembrane potential (both pattern and amplitude) as compared with a conductive membrane. 2. Similarly, this assumption did not compromise the linear relationship between the transmembrane potential and the intensity, frequency and cell-coil distance. 3. However, a non-conductive membrane changed the dependency of the transmembrane potential to geometrical tissue properties (i.e. cell radius and membrane thickness) from a nonlinear to linear relationship. 4. Furthermore, assuming the membrane to be non-conductive completely compromised the dependency of the transmembrane potential to electrical tissue properties. The transmembrane potential became insensitive to the conductivities in the extracellular medium and the cytoplasm, which is in disagreement with several experimental studies.

Discussion

The assumption of a non-conductive membrane compromised intrinsic cell-field interactions during electric or magnetic stimulation, specifically, the impact of electrical and geometrical tissue properties on the transmembrane potential. This assumption, made to simplify computations, appears to violate the law of continuous current flow on the boundary of two biological media. Care must be taken in future modeling works that may assume zero conductive membranes.

References

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