BMC Neuroscience

BioMed Central

Poster presentation

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Revealing the biophysical mechanism for configuring electrode contacts in deep brain stimulation

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from Sixteenth Annual Computational Neuroscience Meeting: CNS*2007
Toronto, Canada. 7–12 July 2007

Published: 6 July 2007

BMC Neuroscience 2007, **8**(Suppl 2):P143 doi:10.1186/1471-2202-8-S2-P143

Background

Deep brain stimulation (DBS) is a widely used clinical treatment for various neurological disorders, and particularly movement disorders. The procedure involves implanting a four contact macro-electrode into disorder-specific targets within the brain, thereby creating a depth electrode brain interface (EBI). In order to maximise the therapeutic effect, the current parameters and contact configurations need to be tuned for each patient, a process which is accomplished by systematic trial and error. The difficulty of this process is confounded by the fact that in vivo visualisation of the current spread is impossible.

Methods

We constructed a three-dimensional model of DBS using the finite element method, in order to compensate for the restrictions on the physiological study of the EBI in situ. We focused on the quantitative investigation of the changes in the electric field created during a number of both currently used and hypothetical configurations of the quadripolar electrode.

Results

Our results show that contact configuration has a significant effect on the shape and strength of the electric field created in the neural tissue. For example, monopolar stimulation creates a far-field dipole capable of stimulating relatively larger volumes of neural tissue, whilst bipolar stimulation creates a near-field dipole more suited to stimulating smaller volumes of tissue. Furthermore, by using the normally isolated "spare" electrode contacts, it is possible to further shape the field in order to better focus the electrical current.

Conclusion

In conclusion: (1) monopolar stimulation stimulates a larger volume of tissue than bipolar stimulation; (2) as the active contacts move further apart in bipolar stimulation, the field expands; (3) grounding the spare contacts shrinks the volume of tissue stimulated; (4) and using two contacts with the same polarity generates a stronger field than other settings, including monopolar setting. This provides a quantitative assessment on how to shape the electric field in DBS in order to optimise the therapeutic effects and minimise the undesirable side effects.

Acknowledgements

The project was supported by grants (id 71766 and 78512) from the Medical Research Council, UK