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Influence of active electrode location and electrode configuration on the electrical excitation fields in cochlear implant stimulation

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Stimulation parameters, such as electrode configuration, affect, through the generated electric field, the electrical neural stimulation in the implanted cochlea. For example, it is well known that currents levels required to elicit threshold (T) listening levels varied with electrode configuration and basal to apical location of the active electrode. Knowledge of the relationship between the stimulation parameters and the electric excitation field in the implanted cochlea is crucial to develop more efficient and spatially focused excitations neural tissues. Aim of this study is the quantitative comparison, through numerical simulations, of the spread of excitation field in cochlear tissues around the electrode array across different stimulation parameters.
Electric excitation field distribution in the cochlea was simulated by 3D modeling a true human cochlea and electrode array. Excitation fields were obtained by varying electrode configuration (monopolar, bipolar, and common ground) and location of the active electrode (i.e., basal, medial, or apical). For each tested configuration, the peak value of the excitation field and spatial spread of suprathreshold field were calculated.
Results showed that the peak of the excitation field varied not only with electrode configuration but also with location of the active electrode. The peak increased from bipolar to monopolar configuration (in monopolar configuration the peak was about two times greater than that in bipolar configuration) and from basal to apical location of the active electrode. The spread of suprathreshold field increased from apex to base and from bipolar to monopolar configuration. Also, simulations revealed the presence of quite high excitation further away from the active electrode, which could create some interferences. Results were in agreement with current clinical and physiological knowledge on the relationship between cochlear electrical stimulation and excitation thresholds. The proposed approach is useful to provide the excitation profiles inside the cochlea and in the design of new electrode arrays.