Implant insertion depth and bone resistivity uncertainty in cochlear implantation computational predictions

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1. Introduction

Computational models of cochlear implantation (CI) help to estimate the outcome procedure and to predict the performance according to a set of surgical parameters and physiological conditions. The outcomes CI surgery vary broadly among patients, being the insertion depth of the implant and the electrical properties of the surrounding bone identified as major source of variability [1,2]. In this context, we developed an automatic framework for the assessment of the functional outcome of the CI, which combined with uncertainty quantification techniques, allows for the evaluation of input uncertain factors that may influence the final neural response of the patient. This computational tool provides the final neural activation evoked by the implant activation in terms of computational global performance, frequency specificity and cross-turn stimulation. In this work, we statistically explore the distribution of the uncertain input variables in a patient-specific case.

2. Methods

The automatic framework encompasses (1) the creation of the cochlear surface by means of a statistical shape model, (2) the simulation of a virtual surgical insertion, (3) the generation of a full head CI model, (4) the computation of the electrical field caused by the implant activation and finally, (5) the simulation of the neural response of the auditory nerve fibers (ANF) (see further implementation details in [3]). Monte Carlo sampling method is employed to create a set of instances with different insertion depth and bone resistivity values considering the same cochlear morphology. The electrode array, based on Med-EL Flex28 design with 12 electrodes (19 contacts). In this work, the electrical finite element simulations are computed setting the stimulation in monopolar strategy and considering biphasic cathodic-first pulse of 100 μs per phase with a stimulation intensity of 350 μA. According to the implant design, a target ANF activation is defined, which is compared with the actual activation computed by the framework.

3. Results

The framework was used to create 250 models with an uncertainty characterization of the insertion depth (*μ= 27mm, σ=0.5mm*) and the bone resistivity (μ=65.0 Ω·m, σ=4.5 Ω·m) defined both as Gaussian distribution. All simulations create an activation map where the global neural response of the evoked auditory nerve fiber is evaluated. Figure 1.A illustrates a detail of the 3D CI model and the computed activation map describing the obtained neural response (vertical axis: frequency along the cochlea; horizontal axis: electrode contact delivering the stimulus). The impact of the bone electrical properties on the proposed global performance measure proposed according to the insertion depth is shown in Figure1.B

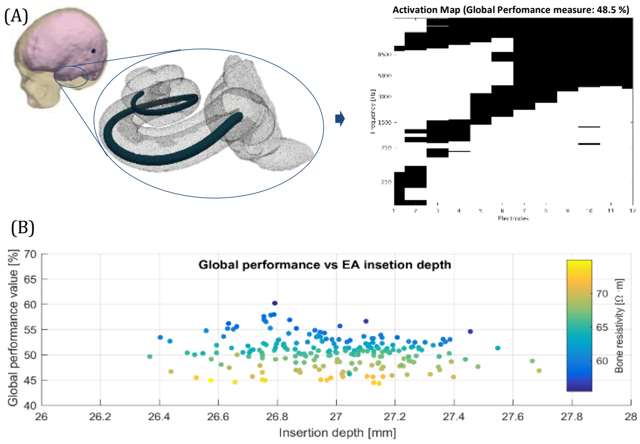

Figura 1.*(A) Example CI computational model and the obtained neural response. (B) Relation between the input uncertain parameters and the CI global performance.*

4. Conclusions

We presented a complete computational framework for the functional assessment of CI outcomes taking into account uncertainty input factors. Results show that bone resistivity provokes a large influence on CI outcomes, which may hinder the impact of the insertion depth. The increase in the electrical resistivity is related to bone demineralization, which is reported to reduce considerable the CI outcomes [2]. Overall, the framework has the potential to support pre and post-surgical decisions thanks to its easy applicability to a range of surgical scenarios and patient-specific parameters.

Referencias

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