A hybrid FEM-Neuron model of the human median nerve for a better understanding of intraneural sensory feedback in amputees

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Abstract— Hybrid computational models can help to better understand, and consequently optimally design innovative neuroprosthetic systems.

I. INTRODUCTION AND METHODS

Studies with amputees have shown that different feedback (afferent) sensations can be delivered by stimulating the peripheral nervous system through intrafascicular electrodes. Several benefits have been observed during clinical trials, indicating that this could be the viable solution to induce sensory function in impaired individuals. In order to gather a better understanding of the phenomena, and to overcome some encountered problems, resulting in optimal neuroprosthetic design, a hybrid [1] (finite element method (FEM) for electromagnetic problem solving, and biophysical for axonal response estimation) model of human median nerve have been developed.

II. RESULTS AND CONCLUSIONS

The model showed to be able to replicate the findings from two different experiments with human amputees, performed in [2], using single wire Longitudinal Intrafascicular electrodes (LIFEs), and in [3], who used a multipolar thin-film version of the LIFEs. In particular, the model was able to predict the modulation of sensation induced by charge variation, during the stimulation. Then, the model was used to understand which was the most likely cause of electrode performance degradation in [3], among the many possible mechanisms. Different hypotheses have been tested in simulations, and the change in conductivity induced by fibrotic tissue, together with the dysfunction of axonal population pushed away from the electrode arise to be the most important ones. The results indicate that failure could be due mainly to acute violent fibrotic reaction provoking these two effects (See Fig.1). However, it is important to point out that the model has two important limitations. First, since the effective relationship between the psychophysical sensation and the neural code is still unknown, simulations were carried out separating population coding (charge variation) and frequency coding, while real sensation could be probably due to the nonlinear combination of these two codes. However, it is certainly true that they can singularly modulate sensation (as it has been shown in both the previously mentioned human studies). Second, it is highly possible that the fibrotic tissue has not a uniform composition (therefore not a conductivity), but, since no specific information are available on this topic this was a reasonable assumption. Regarding the optimization of the design of intrafascicular electrodes, the model predicted that transversal electrodes should be more appropriate for selective stimulation purposes then longitudinal ones, and active sites should be carefully dimensioned in order to support the necessary current. Different electrode designs should be used for different nerves, and models, designed starting from medical imaging information for each patient, could be extremely useful to improve the efficacy of future sensory neuroprosthesis.

REFERENCES

