3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Comparison of in vitro measurements and FEM simulations of guinea pig vestibular system

S. D'Alessandro*(1), M. Pleshkov(2), M. Handler(1), R. Saba(3) and D. Baumgarten(1)
(1) UMIT−Tirol, Hall in Tirol, Austria, e-mail: simone.dalessandro@umit-tirol.at
(2) Faculty of Physics, Tomsk State University, Tomsk, Russia
(3) MED-EL, Innsbruck, Austria

The vestibular system is responsible for our sense of balance and our spatial orientation. It consists of three semi-circular canals where the sensory epithelia in each ampulla is responsible for sensing rotation, and two otolith organs which sense horizontal and vertical acceleration. Recently, it has been shown that vestibular implants can be used as possible treatment to partially restore the function of the vestibular system. Computer modeling is a valuable tool in assisting the development of these implants by investigating stimulation effects. For this purpose, a semi-automatic modular workflow was developed to transform segmented anatomy of vestibular systems using high-resolution µCT scans to corresponding electrical computer models. The existing model has been extended for considering frequency dependent tissue properties. Verification and the accurate determination of tissue properties (e.g. endo- and perilymph, bone and nerves) are required to increase the credibility of the simulations.

In this work, a strategy to verify our simulation environment comparing in vitro measurements and simulations is presented considering guinea pig vestibular anatomy. Moreover, the tissue properties and the contribution of the electrode-tissue interface will be derived. At the first stage, impedance measurements have been performed using 0.9% NaCl saline solution between a pair of electrodes (diameter of 0.5 mm, half exposed) in a frequency range between 100 Hz to 50 kHz. From those measurements the contribution of the electrode-tissue interface and the conductivity of the liquid (assuming the medium being purely resistive) to the overall impedance has been evaluated. In the second stage, impedance measurements have been performed in the guinea pig vestibular system between electrode pairs placed in proximity of the centers of each ampulla at the same frequency range used in the saline solution measurements. Those measurements were compared with the simulation results obtained by considering the electrode-tissue interface derived from the saline solution simulations. Moreover, the dielectric properties of the fluid in the semi-circular canals have been calculated.

Considering 0.9% NaCl saline solution, a quantitative match between measurements and simulations has been obtained. Moreover, the derived conductivity of the fluid and the contribution of the electrode-tissue interface are in agreement with literature values. Regarding the guinea pig vestibular system, the results obtained from the simulations are in accordance with the measurements, and the calculated conductivity and permittivity of the fluid in the semi-circular canals are in agreement with literature values of cerebrospinal fluid (CSF) since the perilymph is a derivative of CSF.

In conclusion, the extended electrical model allowing for considering frequency dependent tissue properties produced a quantitative match between measurements and simulations in both saline solution and guinea pig vestibular system in the considered frequency range. In future work, it is planned to perform impedance measurements on other structures of the vestibular system and extending the measurements also to human inner ears.