Modeling of Nerve Stimulation Thresholds and Their Dependence on Electrical Impedance with COMSOL

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Introduction

Nerve localization is important for applications in regional anesthesia. Localization is achieved by stimulating the nerve with an electric field produced by a current from a needle inserted into the body of the patient, close to the target nerve. The proximity of the needle to the nerve is judged by the strength of a muscle twitch induced by injected current of pre-determined magnitude. Modeling of the electric field in close proximity to the nerve may help to explain observed variations in threshold currents and can help to devise automated procedures that speed up the process. Of particular importance is the effect of electrical impedance on the nerve stimulation thresholds. We present a realistic model of an arm with frequency dependent dielectric properties of tissues that allows us to study this effect.

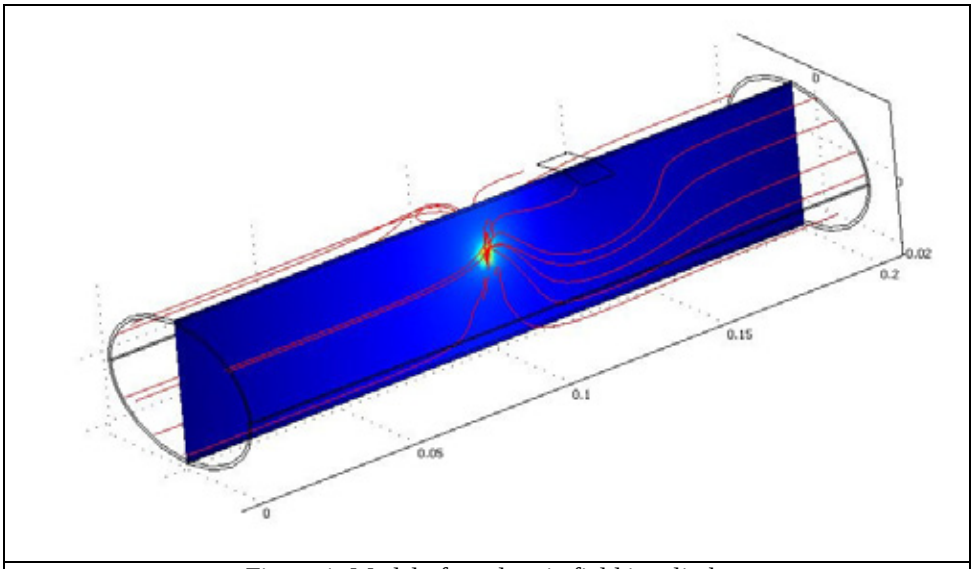

Figure 1: Model of an electric field in a limb.

Use of COMSOL Multiphysics

The electric field inside the body is described by a particular solution of the Helmholtz equation. This equation can be solved by using the PDE solver in COMSOL. Tissues, muscles and bones in general have frequency-dependent and anisotropic conductive properties that need to be properly taken into account. The complicated geometry does not allow for an analytic solution whereas COMSOL offers a very convenient computational environment that allows a precise numerical treatment of this problem. We use COMSOL's parameter sweep option to solve the Helmholtz equation for a number of frequencies and obtain, via inverse FFT, the time dependence of the electric field along the nerve following a short (100 us) pulse. The numerical solution for the electric field found in COMSOL is then used as an input for a Frankenhaeuser-Huxley nerve excitation model allowing calculation of the nerve stimulation thresholds. The functional relationship between the nerve excitation thresholds and the tissue impedance is compared with the one found empirically and presented in a recent publication [1].

Expected Results

The results show that impedance affects nerve stimulation thresholds in a non-trivial way. A comparison with the empirically found inverse relationship between impedance and current thresholds [1] is made.

Reference

1. A. Sauter, *et al*.**,** Current Threshold for Nerve Stimulation Depends on Electrical Impedance of the Tissue: A study of Ultrasound-Guided Electrical Nerve Stimulation of the Median Nerve, *Anesthesia and Analgesia,* vol. 108, No. 4, p.1338, April 2009