Simulating Current Distribution in Tissue During Electrical Stimulation Using Finite Element Model

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Abstract

Electrical stimulation of nerve/muscle is achieved by passing current between stimulating and return electrode. The electrodes can be placed either on the surface or inserted inside the body for localization of current. The spread of current depends on several factors such as tissue properties, shape and size of electrodes and stimulation parameters. For a desired stimulus response, it is important to understand the current distribution by varying aforementioned factors before trying on the patient.
The hypothetical model comprising of three concentric cylinders representing skin (outermost), soft tissue (middle) and muscle (innermost) layer to mimic the human thigh was developed in COMSOL Multiphysics®. The surface electrical stimulation model was built using circular conductive disc (electrode (top) and gel (bottom) layer stacked together) placed over the skin while the needle stimulation model was built using two concentric cylinders [insulation (outer) and electrode layer (inner)] placed between the skin and muscle. Either end of needle electrodes configuration insulation layer was removed.The distance between stimulating and return electrode was kept at 120 mm. The constructed geometry was assigned user-defined material property from the data available from the literature [1, 2]. Periodic current pulses were assigned between stimulating and return electrode using electrical circuit property of COMSOL's AC-DC module. Parameters for the simulated current were current strength (1mA to 50mA), pulse width (200 us), frequency (1-10Hz). The results were simulated using time dependent multislice, contour and volume plot.
Finite element analysis on real tissue model was also studied using combination of COMSOL Multiphysic ver 5.3a and Simpleware N-2018-03 ver.1. Three dimensional thigh section was extracted from the MRI images of a volunteer using Simpleware software. The needle and surface electrodes were drawn separately in two different models similar to the above hypothetical model. Skin, soft tissue and muscle were assigned placeholder property. Mesh was generated and data was exported to COMSOL® readable file format. After importing the file various tissue were assigned user-defined material property similar to the hypothetical model. Similar analysis using AC/DC module was performed and results were compared.

It was observed that the localization of current was achieved in needle stimulation and wide spread of current across the tissue was seen in surface stimulation model, most of

which, got attenuated at the skin layer. The model is useful in understanding the factors that affect the current distribution during electrical stimulation. The model not only finds its usefulness in pre-determining the parameters of stimulation but also gives pictorial view of spread of current inside the tissue.

Reference

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2. https://www.itis.ethz.ch/virtual-population/tissue-properties/database/dielectric-properties