Three-dimensional Finite Element Modeling of Current Density in Maternal Transthoracic Defibrillation

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Abstract

Although it has been acknowledged that the cardiac arrest in pregnancy is a rare event it can have significant impact in terms of age of mother, mortality of unborn children (especially with potential loss of two lives) and consequently long-term effect on a family. One of the commonly used procedures in resuscitation is defibrillation which is routinely used for treating ventricular arrhythmias. With recent advances in understanding pathophysiologies behind electrical shock in pregnant women it became more obvious that previous studies of current conduction in human body should be extended to account adequately for changes in maternal body that affect conduction pathways. Namely it has been shown that physiological changes in pregnancy affect transthoracic impedance and thus affect trans- myocardial current which depolarizes heart (myocardium) as a part of resuscitation. However due to the physiological changes (e.g. size of uterus, increased intra- and extra-cellular fluid, increased blood volume, increased thoracic volume, and presence of amniotic liquid) the transthoracic impedance changes may affect current pathways in an unpredictable way. In this paper we present a three-dimensional simplified model for finite-element analysis of maternal transthoracic defibrillation by means of COMSOL Multiphysics. In this procedure an electrical pulse is applied to the torso through electrodes commonly called paddles. One of the most important aspects is the energy or current density generated on the surface (aforementioned transthoracic current) and corresponding current density in the heart (trans-myocardial current) which needs to be above certain threshold, sufficient for stimulation of myocytes that are inexcitable. Three-dimensional models of human defibrillation have been previously studied. However to the best of our knowledge this is a first attempt to model defibrillation in pregnancy. In this preliminary work we propose the simplified model in which the uterus and stomach are modeled as a single area with larger conductivity. In order to account for frequency dependent properties of biological tissues we decompose the biphasic pulse into frequency component and perform frequency-domain analysis resulting in corresponding current harmonics. We then calculate the amplitude of the current density harmonics in the lower abdomen using AC/DC module of COMSOL and analyze these values with respect to position of electrodes and/or energy delivered by defibrillator.

Reference

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Figures used in the abstract

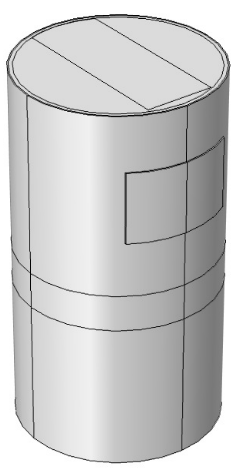

Figure 1: Geometry of the model.

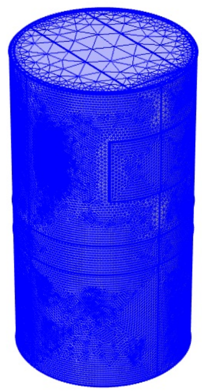

Figure 2: Mesh.

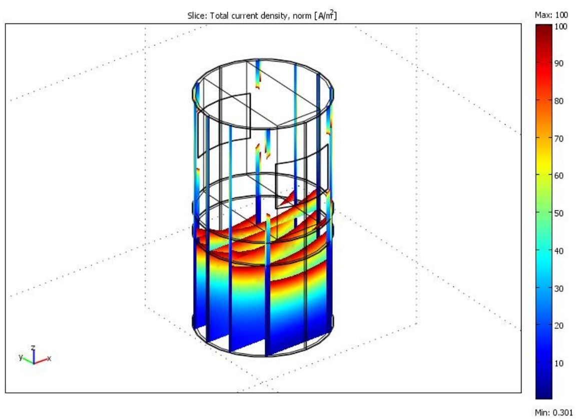

Figure 3: Current density at 1KHz.

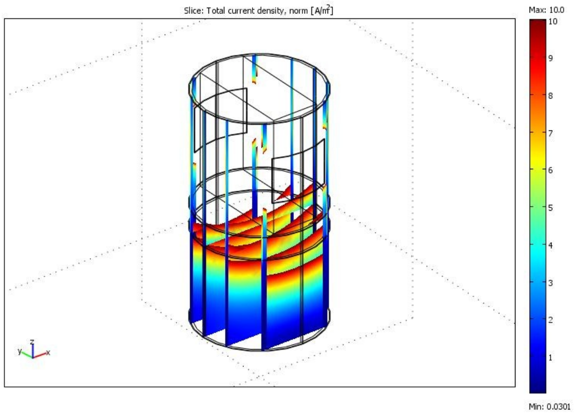

Figure 4: Current density at 1 MHz.