Finite Element Analysis of Defibrillation Current Density in Pregnant Women

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Abstract

Although it has been acknowledged that cardiac arrest in pregnancy is a rare event, it can have significant impact in terms of the age of the mother, mortality of unborn children (especially with potential loss of two lives) and consequently long-term effects on a family. Due to recent advances in understanding physiologies behind electrical shock in pregnant women, it became more obvious that the existing studies of current conduction in the human body should be extended to account adequately for changes in a maternal body that affect conduction pathways.

It has been shown that physiological changes in pregnancy affect transthoracic impedance, and consequently transmyocardial current, which depolarizes the heart 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 the presence of amniotic liquid) the transthoracic impedance changes may affect current pathways in an unpredictable way.

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 (transmyocardial current) which needs to be above a certain threshold, sufficient for stimulation of myocytes that are inexcitable.

In this paper, we extend our previously reported three-dimensional model for finite-element analysis of maternal transthoracic defibrillation using COMSOL Multiphysics® software. In this procedure, an electrical pulse is applied to the thorso through electrodes commonly called paddles. To account for the time-dependent shape of the waveform, we decompose the pulse into discrete sinusoidal components, and perform AC analysis assuming constant frequency in a particular bandwidth. In order to capture the frequency dependent properties of the tissue, we use previously reported values for the permitivity of biological tissues.

We expand the complexity of the previous models by modeling the uterus and stomach as separate compartments as well as including a spherical model of the amniotic liquid which has significantly larger conductivity compared to other surrounding tissues (see Figure 1). We then calculate the amplitude of the current density harmonics in the lower abdomen using COMSOL's AC/DC Module and we analyze these values with respect to the position of electrodes and/or energy delivered by a defibrillator. Furthermore, we investigate the changes due to the expansion of uterus and fetus development and calculate the corresponding current distributions for various

stages of pregnancy.

Figures used in the abstract

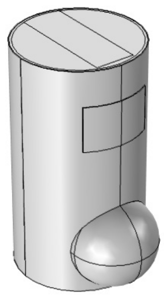

Figure 1: FInite element model of a pregnant woman torso