Analyzing the Influence of Chest Size on Heart and Body Surface Potentials in Forward Modeling of ECG

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Abstract*– Heart problems are the most common problems causing large number of deaths worldwide. Heart failure or heart tissues' functions imbalance is the major reason seen almost in 90% cases of deaths due to heart disease which causes the emerging heart transplantation exercises. Heart transplantation exercises are practiced either using same species (donor and acceptor) or on different species. When species are same, chances of successful transplantation increased but transplantation between different species encounters a number of factors to be taken care of. Torso (donor and acceptor) size compatibility is very common factor in both (same species and different species) types of transplantation. Therefore, through this paper we would like to reflect the effect of torso size on epicardial (heart surface) and body surface potentials. A 2 layers concentric spheres model is used to model the electrical activity of a human body with inner sphere representing the heart and outer sphere representing the torso. Analytically, the effect of torso size variability is investigated by performing simulation of the model (concentric spheres) keeping origin at heart center with various diameters and comparing the results to those calculated numerically. The simulation results reveal a linear relationship between torso size and body surface potentials, which is consistent with previous research. In the absence of other inhomogeneous regions between the heart and the thorax, numerical calculations show that a 10% increase in torso size results in 0.06 percent - 0.1 percent and 0.01 percent - 0.03 percent increases in body surface and epicardial potentials, respectively.

***Index Terms*–** Torso size, Forward Model of ECG, Body surface potentials, epicardial potentials and concentric spheres model.

I. INTRODUCTION

This study is developed as an initial step towards analyzing the factors affecting heart transplantation. Heart transplantation is the issue covered under both allotransplantation and xenotransplantation. Allotransplantation is defined for same kind of species where transplantation of living cells, tissues or organs is done among one species to another whereas xenotransplantation involves two different species for transplantation of organs. Human donors for heart transplantation are very few (almost negligible), therefore, There is a global shortage of human heart organs for clinical implantation, and approximately 60% of people on the waiting list for replacement organs die while waiting. Thousands of patients who are waiting for donated organs could benefit from xenotransplants. The animal organ, which would most likely come from a pig or a baboon (due to their near proximity to humans), may be genetically modified with human genes to fool a patient's immune system to accept it as it's own part. But there are certain factors like subject and organ size, longevity, hormone and protein differences, environment and temperature bearable capability etc. that limit the possibility of a successful xenotransplantation. To decide whether animal organs can replace the physiological functions of human organs, further research is needed [1].

Torso size compatibility is therefore, very important factor and needs utmost care when allotransplantation or xenotransplantation exercises are to be carried out. Many research groups [2-8] have studied a number of factors including heart and torso inhomogeneties that affect epicardial and body surface potentials but a direct connection between torso volume as well as potentials recorded from epicardial and chest surface for the first time is established in this paper only using boundary element methods and MATLAB.

II. ECG FORWARD MODEL

1.1 Introduction

ECG forward model relates the epicardial and body surface potentials according to the relationship given below:

$$V_B = A_{BH} V_H, \qquad (1)$$

With A_{BH} defined as

$$A_{BH} = (D_{BB} - A_{BH} A_{HH}^{-1} D_{HB})^{-1} (A_{BH} A_{HH}^{-1} D_{HH} - D_{BH}). \qquad (2)$$

V_B and V_H are the body surface and heart surface (epicardial) potential vectors respectively. A_{BH} is the transfer coefficient matrix containing all geometric and conductivity information of the subject under consideration and directly the epicardial potentials are linked to the body surface potentials. Here, the surface containing the observation points is represented by the first subscript, while the surface of integration is represented by the second subscript. D_{HH} and A_{HH} are size N_H x N_H square matrices, D_{BH} and A_{BH} are N_B x N_H square matrices, D_{BB} is another square matrix of size N_B x N_B, and D_{HB} is sized N_H x N_B.

Equations (1) and (2) define the forward problem's solution in the desired format [9-11].

1.2 Solution Method

Based on the Helsinki BEM library [12], a forward model has been created. It is made up of two spheres, one for the heart and the other for the torso, as shown in Figure 1. The following are the different conductivity values assigned to two regions:

$$C^1_H = 12$$
$$C^2_H = 6$$
$$C^1_T = 6$$
$$C^2_T = 0 \quad (3)$$

where terms C^1_H, C^2_H, C^1_T and C^2_T refers to endocardium, epicardium, internal chest and outer surface of the chest conductivities. Since the external environment of the chest is made up of air, therefore, the conductivity is assumed to be zero. This model considers a dipole source with a dipole moment of [100 0 0] in the middle.

III. RESULTS AND DISCUSSION

Epicardial and body surface potentials as a function of torso size is visualised in Table 1 using the two concentric spheres model shown in Figure 1. The inner sphere's radius, r1, is held constant at 2 units, while the outer sphere's radius, r2, is varied in 11 measures from 5.0 to 6.0 units. Terms listed in the table refers to

EP= numerically computed potential at epicardiam
BSP= numerically computed potential at chest surface
EPANA= analytically computed potential at epicardiam

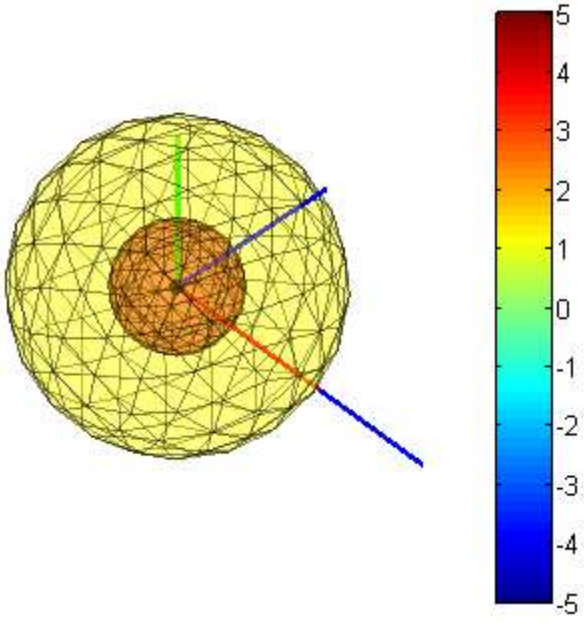

Figure 1: Two spheres (concentric) model with dipole moment [100 0 0] and position [0 0 0].

BSPANA= analytically computed potential at chest surface
RE1= Difference error between EP and EPANA
RE2= Difference error between BSP and BSPANA
CC1=correlation coefficient at epicardium and
CC2= correlation coefficient at chest surface.

There is a linear connection between torso size and chest surface potentials, as seen in Figure 2. This linear association is supported by findings in the literature [13-16].

Table1: Simulation results with r2=5.0 to 6.0 units

r1 (fixed)=2 **r2 (variable)**	**EP**	**BSP**	**EPANA**	**BSPANA**	**RE1**	**RE2**	**CC1**	**CC2**
5.0	-0.0678	-0.0285	-0.0670	-0.0282	0.011043	0.012148	1.000000	0.999999
5.1	-0.0675	-0.0275	-0.0667	-0.0271	0.011035	0.012112	1.000000	0.999999
5.2	-0.0672	-0.0265	-0.0664	-0.0261	0.011029	0.012079	1.000000	0.999999
5.3	-0.0669	-0.0255	-0.0662	-0.0252	0.011023	0.012048	1.000000	0.999999
5.4	-0.0667	-0.0246	-0.0659	-0.0243	0.011018	0.012019	1.000000	0.999999
5.5	-0.0664	-0.0238	-0.0657	-0.0235	0.011013	0.011992	1.000000	0.999999
5.6	-0.0662	-0.0230	-0.0655	-0.0227	0.011009	0.011967	1.000000	0.999999

5.7	-0.0660	-0.0222	-0.0653	-0.0219	0.011005	0.011944	1.000000	0.999999
5.8	-0.0658	-0.0214	-0.0651	-0.0212	0.011002	0.011922	1.000000	0.999999
5.9	-0.0656	-0.0207	-0.0649	-0.0205	0.010999	0.011902	1.000000	0.999999
6.0	-0.0655	-0.0201	-0.0647	-0.0198	0.010996	0.011883	1.000000	0.999999

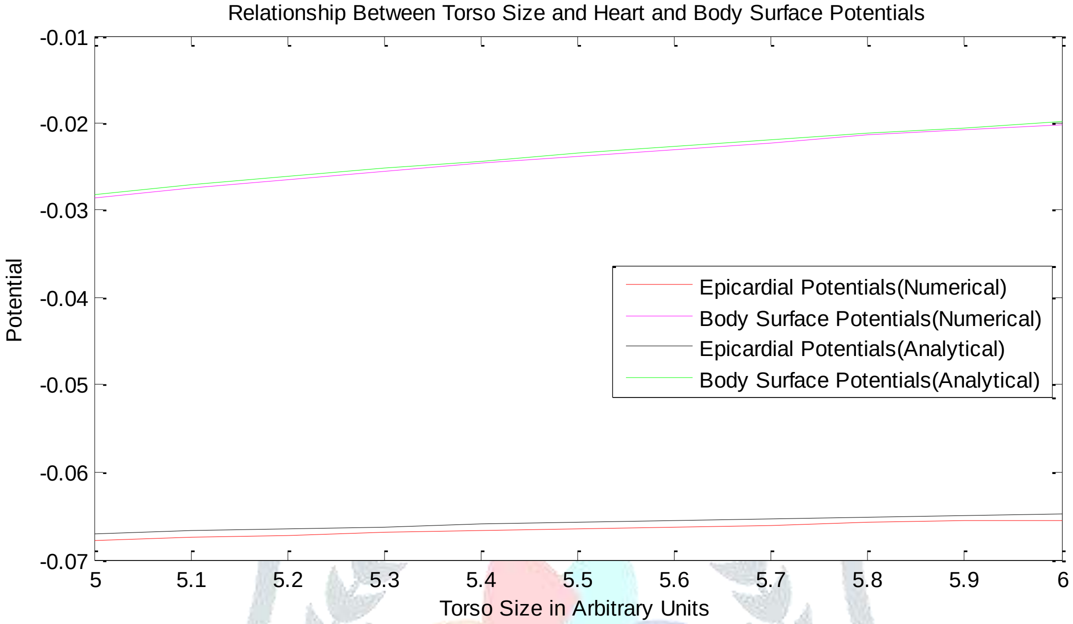

Figure 2: Link between torso size and heart and chest surface potentials

IV. CONCLUSION

Increases in epicardial and body surface potentials have been identified as a result of increased torso size. According to empirical calculations, a 10% increase in torso size results in increases in body surface and epicardial potentials of 0.06 percent to 0.1 percent and 0.01 percent to 0.03 percent, respectively.. This rise in potentials with rise in torso rise is in confirmation with the literature cited values [13-16] which shows that body surface potentials increase with growing age from a new born baby to a younger one for a certain period of time and then settle down to a standard value.

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