HUMAN SKIN MODEL SERVING IN ELECTRICAL STIMULATION OF ANTERIOR TIBIAL ARTERY

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ABSTRACT

Cardiac activities are one of the vital signs of life. To monitor these activities there are several methods including electrocardiography (ECG), photo plesysmography, electrical impedance plesysmography. The purpose of the paper is to design external electrodes placed on the uppermost skin layer called stratum corneum which are capable of stimulating human anterior tibial artery without damaging it. This artery is present along the length of human tibia bone. To investigate the transdermal drug deliveries and many other. (Romanian, J. 2008), Electrical impedance plethysmography takes its origin when a normal heart beat is initiated by a small pulse of electric current. This tiny electric "shock" spreads rapidly in the heart and makes the heart muscle contract, helping in way for pumping blood, when this blood reaches the vessels its flow results in changing resistance of arteries, which is the basic principle of this procedure. Electrical impedance plethysmography includes the method of determining changing tissue volume due to change in blood flow. The first publications concerning this method date back to the 1930s and 1940s. Kubicke, W. G 1970. The method reached clinical value about 20 years ago based on the research work by Kinnen, Kubicek. EIP can be useful to study the peripheral circulation of blood. The first publications concerning this method date back to the 1930s and 1940s. Kubicke, W. G 1970. This project shows the model of major human skin layers signifying the depth of anterior tibial artery. Here the two electrodes are used to stimulate the artery thus aiding to examine the volume of blood flow and pulsations and more importantly it can also be useful in the method of electrical impedance plethysmography. As the volume of blood flowing through the artery changes, resistance of the artery will change respectively resulting in varying impedance. If this impedance is measured through the method of EIP the model played a crucial role for diagnosing different diseases related to vessels. The preeminent part of the model is its compact electrode size and inter-distance between them, which is determined by changing inter-distance and area of electrode and considering best dimensions where electric field is endurable by the artery. The model is also least affected by motion artifacts as designed electrodes are small enough to be attached with easily wearable devices which can be fasten on the body.

KEYWORDS

Electrodes, anterior tibial artery, potential, stimulate Electrical impedance plethysmography (EIP), electrode size and distance, consol multiphysics.

INTRODUCTION

The skin is the largest organ of human body and protect organism from various environmental factors. A defective barrier has its origin in a disturbed skin physiology. So, it is very important to assess the skin condition for medical studies. The measurements of the skin electrical impedance are a noninvasive and fast method for assessing the skin. The electrical impedance of the skin can be used to measure skin moisture, to monitor skin irritations and allergic reactions, to detect skin cancer, to investigate the transdermal drug deliveries and many other. (Romanian, J. 2008). Electrical impedance plethysmography takes its origin when a normal heart beat is initiated by a small pulse of electric current. This tiny electric “shock” spreads rapidly in the heart and makes the heart muscle contract, helping in way for pumping blood, when this blood reaches the vessels its flow results in changing resistance of arteries, which is the basic principle of this procedure. Electrical impedance plethysmography includes the method of determining changing tissue volume due to change in blood flow. The first publications concerning this method date back to the 1930s and 1940s. Kubicke, W. G 1970. The method reached clinical value about 20 years ago based on the research work by Kinnen, Kubicek. EIP can be useful to study the peripheral circulation of blood. The first publications concerning this method date back to the 1930s and 1940s. Kubicke, W. G 1970. This project shows the model of major human skin layers signifying the depth of anterior tibial artery. Here the two electrodes are used to stimulate the artery thus aiding to examine the volume of blood flow and pulsations and more importantly it can also be useful in the method of electrical impedance plethysmography. As the volume of blood flowing through the artery changes, resistance of the artery will change respectively resulting in varying impedance. If this impedance is measured through the method of EIP the model played a crucial role for diagnosing different diseases related to vessels. The preeminent part of the model is its compact electrode size and inter-distance between them, which is determined by changing inter-distance and area of electrode and considering best dimensions where electric field is endurable by the artery. The model is also least affected by motion artifacts as designed electrodes are small enough to be attached with easily wearable devices which can be fasten on the body.

MATERIAL AND METHOD

EIP is the technique of determining occlusions in vessels, whenever blood flows through the artery the change in impedance resulted which is the basic principle of this method. Considering the human skin on which EIP electrodes are placed and the artery affecting through the potential provided on electrodes, the model can be drawn to inspect the best position and dimensions of electrodes to stimulate the anterior tibial artery. In initiation of the model, considerable point were to spot the depth and dimensions of anterior tibial artery which was achieved by performing A-scan and B-scan of ultrasound respectively. The images are as follows:
Fig-1: Showing ultrasound scan of anterior tibial artery

After spotting the actual artery position, model was constructed in a software named COMSOL MULTIPHYSICS. Comsol Multiphysics software facilitates all the steps in the modeling process, defining geometry, meshing, specifying physics, solving, and then visualizing results. The model of skin was drawn by considering four (Van De Water, J. 1971) main layers sequentially named as stratum corneum, epidermis, dermis and layers of sub cutaneous fat & muscles.

Fig-2: Showing layers of human skin

In order to electrically stimulate the skin model, one must be familiar with some important characteristics of human skin which includes electrical conductivity and relative permittivity. Every layer has different value of electrical conductivity but the relative permittivity for all the layers is taken in the model as constant 1.

Table-1: Demonstrating values for electrical conductivity of skin layers and blood.

<table>
<thead>
<tr>
<th>LAYERS OF SKIN</th>
<th>ELECTRICAL CONDUCTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stratum corneum</td>
<td>0.0005 S/m</td>
</tr>
<tr>
<td>2. Epidermis</td>
<td>0.95 S/m</td>
</tr>
<tr>
<td>3. Dermis</td>
<td>0.2 S/m</td>
</tr>
<tr>
<td>4. Fats and muscles</td>
<td>0.66 S/m</td>
</tr>
<tr>
<td>5. Blood</td>
<td>0.8 S/m</td>
</tr>
</tbody>
</table>

The final geometry of model appeared as follows in COMSOL window:

Fig-3: showing basic model in COMSOL MULTIPHYSICS

A. BASIC IDEA OF THE RESEARCH

The basic idea of research is based on the Maxwell’s Equation of Changing Volume of Blood in Artery, the equation is given as:

$$\Delta V = \frac{V^2}{Z_b} (\Delta Z_p + \Delta Z_v)$$

Here,

- $\Delta V =$ change in arterial blood volume.
- $L =$ inter-distance of electrodes
- $\rho =$ blood or artery’s resistivity
- $Z_b =$ basal impedance when there is no blood flow
- $Z_p =$ impedance due to change in blood resistivity
- $Z_v =$ impedance due to change in blood volume

B. SKIN MODEL

In COMSOL skin layers and electrodes are represented through rectangles and the anterior tibial artery is represented through a circle. The electric potential provided at the electrode is 1 volt which remains constant throughout the simulation. The diameter of anterior tibial artery in ultrasound was found to be 2 mm and it is 4.2 mm deep from skin surface.

Table-1: The measurements of skin layers

<table>
<thead>
<tr>
<th>SKIN LAYERS</th>
<th>WIDTH (mm)</th>
<th>HEIGHT (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Stratum corneum</td>
<td>50</td>
<td>0.1</td>
</tr>
<tr>
<td>B. Epidermis</td>
<td>50</td>
<td>0.25</td>
</tr>
<tr>
<td>C. Dermis</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>D. Fats and Muscles</td>
<td>50</td>
<td>6</td>
</tr>
</tbody>
</table>

Figure-4: Final model, rainbow colors representing generated electric field in model

C. SIMULATIONS

In order to design electrodes and find inter-distance that proves to be elegant to stimulate artery without being detrimental for the skin, two types of simulations were performed:
a. Simulation for inter-distance;
b. Simulation for area.
SIMULATION FOR INTER-DISTANCE

By changing inter-distance between electrodes electric field was observed, the best resulting value was found to be 1.3 V/m at a distance of 10mm.

Fig-5: Varying inter-distance of electrodes.

SIMULATION FOR AREA

When the width of electrodes was changed by 1mm to 10mm keeping the inter-distance of electrodes constant as 10mm, the satisfying resulted value of electric field was found to be 1.36 S/m when the area of electrodes was $3 \times 1 \, \text{mm}^2$.

Fig-6: Changing area of electrodes.

RESULT

Acquiring satisfying values for electric field the optimal results of simulation are drawn as:

- The area of electrode = $3 \times 1 \, \text{mm}^2$
- Inter-distance between electrodes = 10mm

Fig-7: final model showing electrodes size and inter-distance.

Due to changing area of electrodes resulting electric field graphically appeared as follows:

By changing inter-distance of electrodes respective electric field graphically appeared as:
At the selected dimensions and inter-distance of electrodes value of electric field was found to be 1.37 S/m. This field was strong enough to stimulate anterior tibial artery without being perilous.

**CONCLUSION**

The designed electrodes are capable of producing sufficient amount of electric field to stimulate anterior tibial artery. There size and placement has been tested by simulation results hence these electrodes can be useful in different procedures, example: to estimate volume of blood flowing through the artery, pulsation rate and more importantly the electrodes are well organized to be used in the method of Electrical impedance plethysmography.

**REFERENCES**

- Guyton, A.C. & Hall, J.E. “Textbook of Medical Physiology