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Performance Analysis in Pacemaker Electrode and Study Effect Electric Resistance

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Abstract— In recent years, there has been an increasing use pacemaker electrode that is placed inside the heart and helps the patient's heart to keep a normal rhythm. In this paper, performance of pacemaker electrode and electric resistance are investigated. These structures are modelled and numerically tested by using Finite Element Method (FEM) by using Comsol Multiphysics. The created virtual models using 3D simulation and computation software proved that used shield around the heart body for reduce the effects of EM fields. In this model deals with the current and potential distribution around one pair of electrodes and study the position of the counter electrode affects the electric resistance of the pacemaker electrode.

Keywords— Pacemaker electrode, Finite Element Method (FEM), Comsol Multiphysics, EM fields.

I. Introduction

A pacemaker (or artificial pacemaker, so as not to be confused with the heart's natural pacemaker) is a medical device that uses electrical impulses, delivered by electrodes contracting the heart muscles, to regulate the beating of the heart. The primary purpose of a pacemaker is to maintain an adequate heart rate, either because the heart's natural pacemaker is not fast enough, or there is a block in the heart's electrical conduction system. This can mean tachycardia (rate too fast), bradycardia (rate too slow), or some defect that disrupts the normal rhythm of the heart. The artificial pacemaker works by delivering electrical impulses to specific areas of heart muscle via electrodes. Pacemakers typically have 1-3 electrodes (also referred to as leads), depending on what type of arrhythmia is trying to be corrected. The body of the pacemaker is most often implanted under the skin of the patient's left chest.

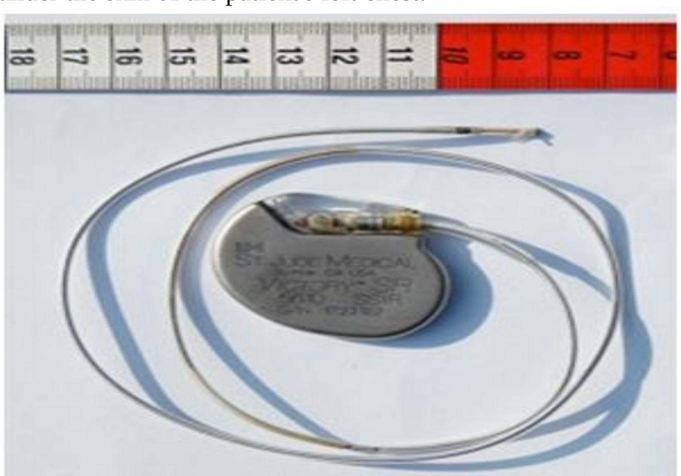

Figure 1. A puls generator of a pacemaker with electrode.

Overall efficiency and efficacy of a pacemaker system depend upon an electrode's ability to interface between the two realms of physiology and electronics. The utility of pacing technology is diminished or lost entirely if an effective interface cannot be established between these two systems. This paper investigates performance analysis in pacemaker electrode and study effect electric resistance.

II. Materials and Methods

Pacemaker is referred to as an electrode, but it actually consists of two electrodes: a cathode and an anode. Figure 1 shows a schematic drawing of two pair of electrodes placed inside the heart. The electrodes are supplied with current from the pulse generator unit, which is also implanted in the patient.

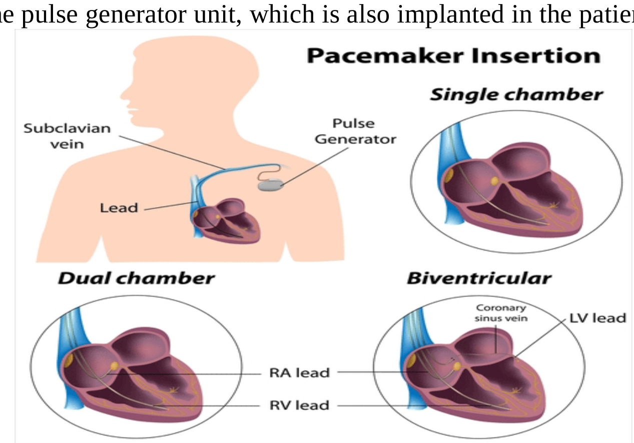

Figure 2. Schematic drawing of the heart with two pairs of pacemaker electrodes.

The model domain consists of the blood and tissue surrounding the electrode pair. The actual electrodes and the electrode support are boundaries to the modeled domain. Figure 2 shows the electrode in a darker shade, while the surrounding modeling domain is shown in a lighter shade.

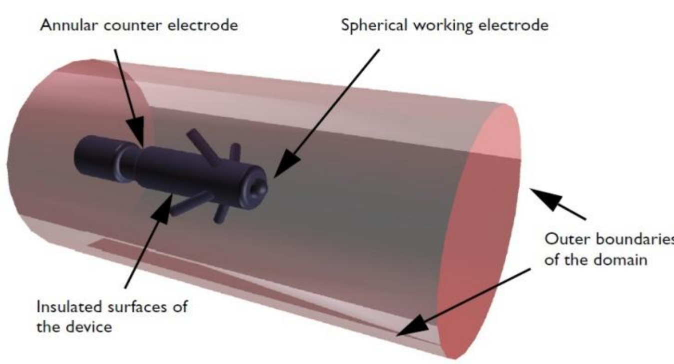

Figure 3. Modeling domain and boundaries.

The working electrode consists of a hemisphere placed on the tip of the supporting cylindrical structure. The counter electrode is placed in the "waist" of this structure. All other surfaces of the supporting structure are insulated. The outer boundaries are placed far enough from the electrode to give a small impact on the current and potential distribution.

In COMSOL Multiphysics, use the Electric Currents interface for the analysis of the electrode. This physics interface is useful for modeling conductive materials where a current flows due to an applied electric field.

II. Domain Equations

The current in the domain is controlled by the continuity equation, which follows from Maxwell's equations:

$$-\nabla.(\sigma \nabla V) = 0$$

Where σ is the conductivity of the human heart. This equation uses the following relations between the electric potential and the fields.

$$E = -\nabla V, J = \sigma E$$

III. Boundary Conditions

Ground potential boundary conditions are applied on the thinner waist of the electrode, and a positive potential is applied to the lower half sphere. All other boundaries are kept electrically insulated. The tip of the electrode has a fixed potential of 1 V. All other boundaries are electrically insulated.

$$n.J = 0$$

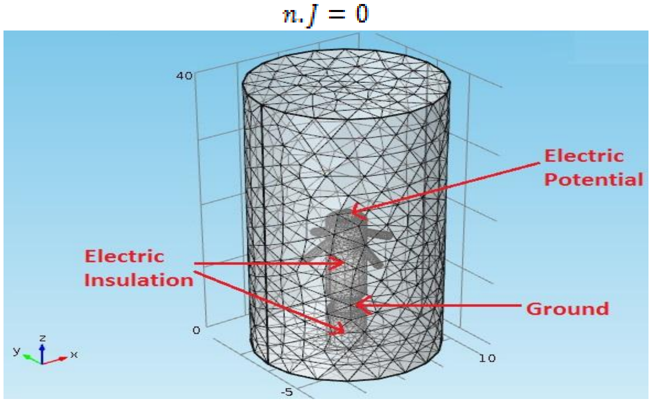

Figure 4. Boundary conditions and mesh

IV. Results and discussion

This model deals with the current and potential distribution around one pair of electrodes. This simulation gives the potential distribution on the electrode surface and streamlines of the current distribution inside the human heart; see Figure 3.

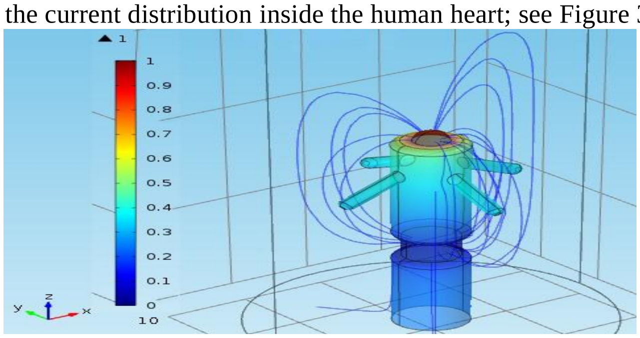

Figure 5. The plot shows the electrostatic potential distributed on the surface of the electrode. The total current density is shown as streamlines.

As expected, the current density is highest at the small hemisphere, which is the one that causes the excitation of the heart. The current density is fairly uniform on the working electrode. The counter electrode is larger and there are also larger variations in current density on its surface. Mainly, the current is lower with the distance from the working electrode. The model shows that the anchoring arms of the device have little influence on the current density distribution.

Moving the location of the counter electrode closer to the anchoring arms on the device has little influence on the current distribution. The position of the counter electrode affects the electric resistance of the pacemaker electrode, which is important when designing the electric circuit, in which the pacemaker electrode is included; see Figure 4, which shows a plot of the electric resistance of the pacemaker electrode for different values of the distance between counter electrode and working electrode.

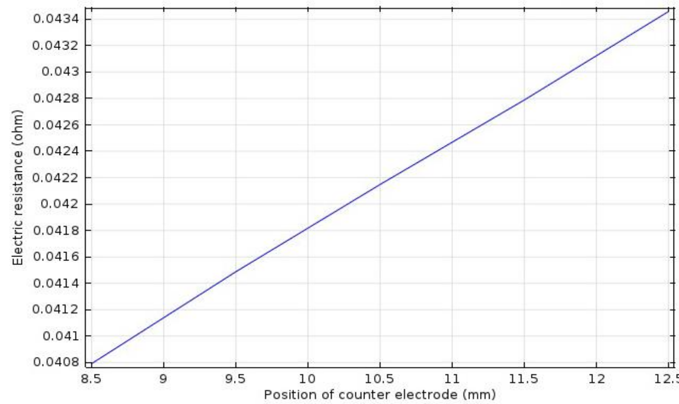

Figure 6. The plot shows the electric resistance of the pacemaker electrode in relation to the distance between the counter electrode and the working electrode.

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