Effect of Body Type, Tissue Conductivity and Body Location within the RF Coil on Tangential Electrical Fields in 1.5T MRI

Shiloh Sison[1], Xiaoyi Min[2], Yan Liu[3], Kevin Feng[3], Ji Chen[3], John Nyenhuis[4], Gabriel Mouchawar[2], and Jon Dietrich[2]

[1]*St. Jude Medical, Sunnyvale, CA, United States,* [2]*St. Jude Medical,* [3]*University of Houston,* [4]*Purdue University*

Objective: The temperature rise at the electrodes on the lead of an active implantable medical device is a function of the RF body coil generated electric field. The electric field in turn is a function of lead path, body type and tissue property as well as location within the coil. The objective of this study is to determine which body type, conductivity and location within the coil generates the maximum tangential electric field across many lead paths relevant for implantable cardiac rhythm devices. This can be used to gauge the simulation conditions which will generate the maximum temperature rise at the electrodes of the lead.

Methods: SEMCAD X models of 16 rung copper circularly polarized high-pass RF body coils were created. Five body types were used from the Virtual Population Project: obese male (Fats), adult male (Duke), adult female (Ella), girl (Billie), and boy (Thelonius). Each of the five body types were simulated at multiple landmark positions along the Z-axis where Z = 0mm is defined by the alignment of the eyes with the center of the coil, and 200mm is defined as a 200mm movement of the body further into the coil. A 63cm (diameter) x 71cm (length) high-pass RF body coil was used for all models except 73cm x 71cm for the obese model. All fields were scaled to 2W/kg whole body SAR. Next, simulations were performed using the obese male with the conductivity for each tissue simultaneously shifted to 80% (and subsequently 120%) from its respective nominal value. Finally, the obese male was simulated at multiple X, Y and Z landmarks. For each simulation $E_{rms}^2 = \int_0^L |Etan(l)|^2 dl/L$ was calculated for multiple clinical lead paths in order to determine which body model, landmark and conductivity had the capability of generating larger temperature rises [1].

Results: Figure 1 shows the maximum E_{rms}^2 from all the lead paths in the five human body models for multiple Z-axis locations. The largest values are seen in the obese male model, with a Z-axis position near 0mm. In order of decreasing maximum Erms^2 vs Z-axis are the adult male, adult female, girl and boy. Figure 2 shows the variation in the maximum E_{rms}^2 as the conductivity changes from 120% to nominal to 80% for the obese male. The largest values are seen when the tissue conductivity is shifted to 80% of nominal and the lowest are seen when the conductivity is shifted to 120% of nominal. Figure 3 shows the maximum Erms^2 from all lead paths for variations in the X, Y, and Z axes where X is left to right, Y is back to front and Z is head to foot for a patient supine in bore of the scanner. As expected the E_{rms}^2 decreases with increasing Z-axis with a minimum for X = -20cm for the Z = 200mm and 300mm landmarks and Y = -50cm for the Z = 100mm landmark. Overall the variation in Erms^2 caused by shifts in X and Y for the worst case Z-axis location was negligible.

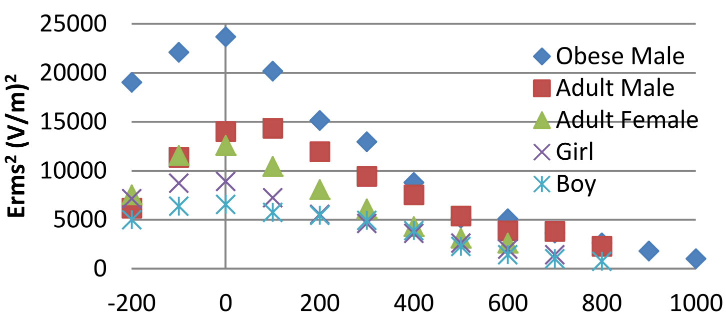

Fig 1. Z-Axis Landmark (mm)

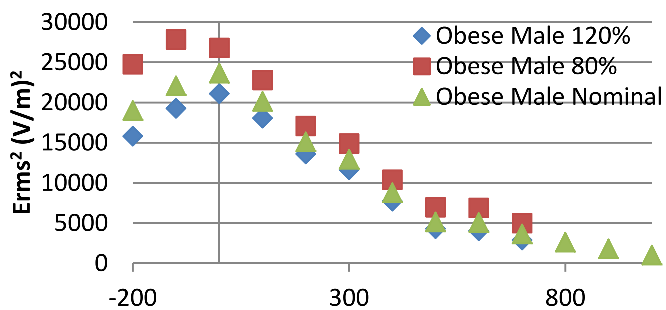

Fig 2. Z-Axis Landmark (mm)

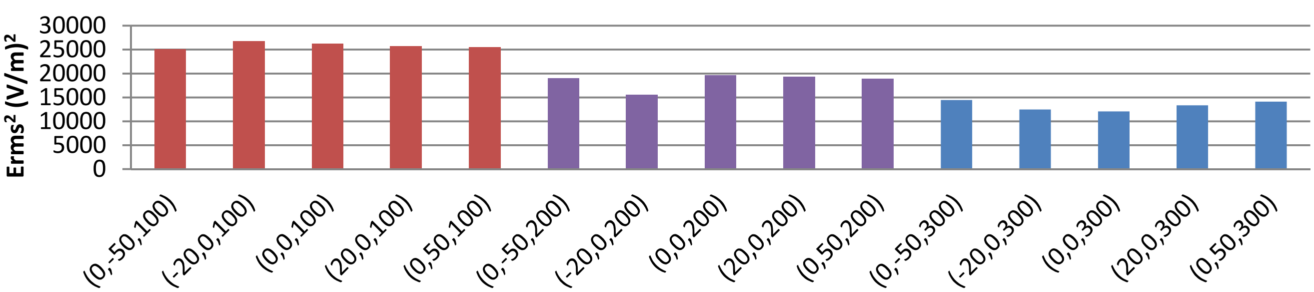

Fig 3. Position (x_mm, y_mm,z_mm)

Conclusion: For the cardiac pacing leads considered here, the simulation conditions which have the possibility of generating the largest temperature rise at the electrodes of a lead are an obese male with tissue conductivity 80% of nominal with landmark Z close to 0mm. Around this Z landmark the effect of 20mm to 50mm shifts in the X and Y direction are negligible although the lowest is for Y = -50mm. The IEC limit of 3.2 W/kg for head SAR may result in a whole body SAR of less than 2 W/kg for some landmarks in Figs. 1 and 2.

1) Park et al. Calculation of MRI Induced Heating of an Implanted Medical Lead Wire With and Electric Field Transfer Function. *JMRI* 26:1278-1285 (2007)