ASYMMETRIC PACEMAKER LEAD TIP HEATING ALONG THE X-AXIS IN 1.5T AND 3T SYSTEMS

D. A. Langman[1], V. S. Desphande[2], F. Thorsten[3], G. A. Laub[2], and P. J. Finn[1]

[1]Radiology, UCLA, Los Angeles, CA, United States, [2]Siemens, Los Angeles, CA, United States, [3]Siemens, Erlangen, Germany

Introduction

Current MR pacemaker safety research is focused on potential thermal damage to myocardial tissue surrounding pacemaker leads due to induced eddy currents from applied RF fields[1]. The heating of the lead tip is due to ohmic losses that arise from the mismatch of resistance at the lead/tissue interface. It is understood that the magnitude of the RF field varies spatially across the diameter of the bore. These variations are expected to directly affect the magnitude of current in the wire and thus the temperature measured at the lead tip. However the current induced in the lead will create a magnetic field that will be superimposed on the main B1 field, the effect of which is still not understood. The goal of this research is to investigate the regional variations of the RF field and MRI-induced pacemaker lead tip heating in 1.5T and 3T systems.

Methods

Measurements were taken in a torso/head phantom (torso: 24inx17in, head: 6.5inx11.5in) filled with 12 liters of 0.45% saline solution. Measurements were performed on 1.5 T Avanto and 3T Trio Siemens systems. An Identity ADxDR (5380) St. Jude Medical pacemaker was examined with a 40cm and 20cm 1688T lead connected to the ventricular port with the atrerial port plugged. Temperature was recorded with Luxtron fiber optic probes positioned in the helix of the active fixation lead. The leads were aligned in six positions in the coronal plane centered along the z axis with the landmark placed at the center of the wire. A TrueFisp sequence with SAR =2.8W/kg at 1.5T and 1.8W/kg at 3T was the source of heating in the pacing wire. The imaging parameters for 1.5T were as follows: TE/TR=1.69/3.37 ms, 256x256 matrix, large FOV 500mm, 5mm coronal slice thickness, 10 slices, 20 averages, scan time 2min 54sec, and flip angle 90 degrees. The imaging parameters for 3T were as follows: TE/TR=1.54/3.07ms, 256x256 matrix, large FOV 500mm, 5mm coronal slice thickness, 10 slices, 20 averages, scan time 2min 39sec, and flip angle 70 degrees.

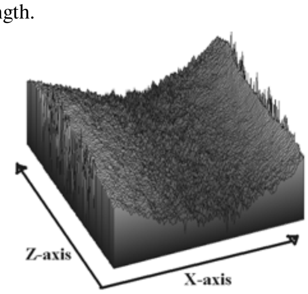
The RF energy deposition in the saline phantom, without leads or pacemakers, was analyzed using a B1 mapping sequence that employs a stimulated echo technique to examine the effect of changing flip angles on signal intensity[2]. The imaging parameters were as follows: TE/TR=14/3000ms, 256x256 matrix, 5mm coronal slice thickness, 1 slice, and a scan time of 12min35sec. The phantom was registered in the head-first supine orientation for all measurements.

Results

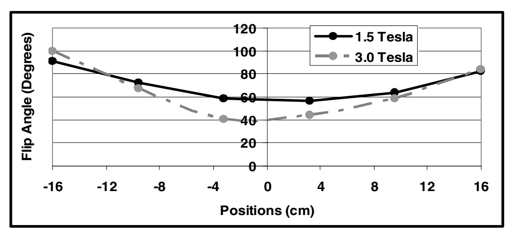
The B1 map depicting flip angle shown in Figure 1a was segmented into six regions representative of the six positions of lead placement. As expected, the B1 field showed considerable variation across the phantom at 1.5T and 3T. The decrease in flip angle seen at the center of the phantom is more pronounced at 3T than at 1.5T but the field is, otherwise, uniform showing little evidence of RF non-uniformity (see Figure 2b). It is also important to note that the B1 map showed reasonable symmetry in the x-direction with the right side of the phantom receiving a slightly higher flip angle near the edge of the phantom.

Despite a fairly uniform B1 field the results of the lead tip heating showed a strong asymmetry at both 1.5T and 3T(see Figure 2a and 2b).The marked asymmetry in the x-direction showed minimum heating occurring 10cm from the center of the phantom. Lead lengths 20cm and 40cm were chosen to examine the effect of lead length on the asymmetric temperature variance. At 1.5T and 3T the same asymmetry of the lead tip heating was evident with both lead lengths. The asymmetry of the heating accounted for 46-66% of the temperature difference between the right and left edge of the phantom depending on lead length and field strength.

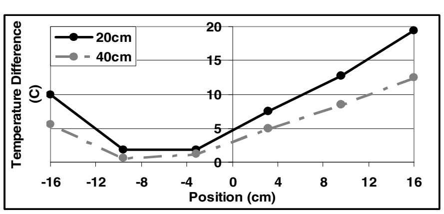
Figure 1. The flip angle image of the B1 map at 1.5T is uniform along the z-axis and showed variation across the x-axis (a). The profile at 1.5T varies approx. 10% from the left edge to the right edge and 38% edge *vs.* center. The profile at 3T varies approx. 16% from the left edge to the right edge and 60% edge *vs.* center (b)



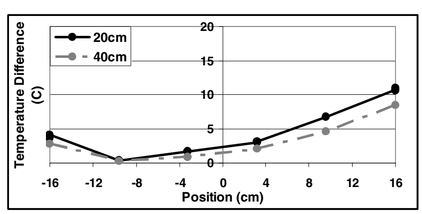
a)



b)



a)



b)

Figure 2. The position dependent temperature increase at the lead tip is shown at 1.5T (a) and 3T (b). The heating was asymmetric along the x-direction and the right edge of the phantom showed 48-66% less heating than the left edge ranging over both field strengths and lead lengths.

Conclusions

The results indicate that patient orientation, head-first *vs*. feet-first supine, could potentially reduce the lead tip heating up to 48-66% depending on the location of the implant. The B1 map indicates that the flip angle drops 38-60% from the edges to the center of the phantom depending on field strength. The lead tip heating showed a large asymmetry across the z-axis, displaying a temperature difference of 48-66% between the right and left edge of the phantom. The mismatched profiles of flip angle and lead tip heating indicate that it does not suffice to just consider the B1 field distribution in order to estimate the local lead tip heating. While the cause of the asymmetry is still undetermined further investigation should involve examining the effect of different phantom sizes, pacemaker manufacturers, and MRI manufacturers.

References

1. Shellock F, et al. American Heart Journal 2006; 151:436-443.
2. Perman, et al. MRM 1989 9:16-24