Neurostimulation Systems Used for Deep Brain Stimulation: Factors Impacting MRI-Related Heating at 1.5- and 3-Tesla

K. B. Baker[1], J. Tkach[2], F. G. Shellock[3], J. Nyenhuis[4], A. R. Rezai[5]

[1]Neurology, The Cleveland Clinic Foundation, Cleveland, OH, United States, [2]Radiology, The Cleveland Clinic Foundation, Cleveland, OH, United States, [3]University of Southern California, Los Angeles, CA, United States, [4]Computer and Electrical Engineering, Purdue University, West Lafayette, IN, United States, [5]Neurosurgery, The Cleveland Clinic Foundation, Cleveland, OH, United States

BACKGROUND: Magnetic resonance (MR) safety issues related to exposing patients with neurostimulation systems to MR procedures have been described previously (**1**). Notably, MRI-related heating of up to 25°C above baseline has been reported for a neurostimulation system used for deep brain stimulation (DBS) in association with MRI performed at 1.5-Tesla using a transmit/receive body RF coil (**2**).

PURPOSE: To characterize factors that impact MRI-related heating for neurostimulation systems used for DBS. Specifically, the effects of varying DBS extension and lead configurations, as well as the effect of landmark location in relation to using transmit/receive body coil, were evaluated in 1.5-Tesla and 3-Tesla MR systems.

METHODS: All experiments were performed using the Activa (Medtronic, Minneapolis, MN) series DBS systems in an *in vitro* model consisting of a gel-filled, human head and torso phantom. Temperature changes were recorded during exposure to using head and body, transmit/receive RF coils at 1.5-Tesla and a transmit/receive head-only RF coil at 3-Tesla. DBS electrode heating was measured using a fluoroptic thermometry system (Luxtron, Santa Clara, CA). A skull model placed in the phantom was used to test custom-designed burrhole rings that permitted control of the geometry of the lead as it exited the skull. The influence of the land-marking location on heating was evaluated by varying the site across the phantom's head and torso in 5- to 10-cm increments.

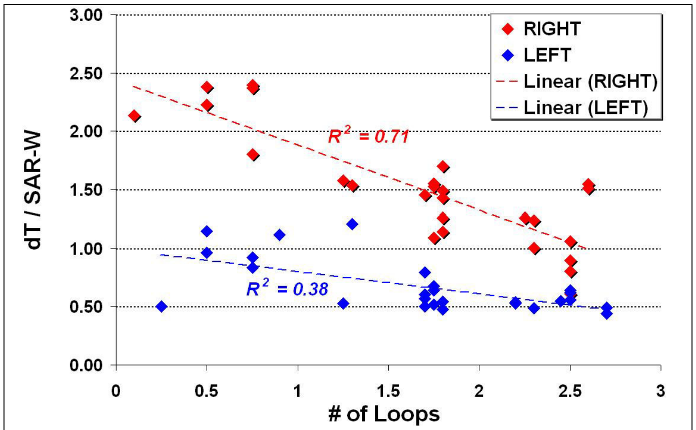

Figure 1. Temperature change, normalized to whole body SAR, at contact 0 of the right and left DBS lead as a function of the number of concentric loops placed around the burrhole where the lead entered the skull.

RESULTS:

I. ***Small, concentric loops around the burr-hole reduced RF-induced heating at the electrode contacts bilaterally.***

In both the transmit/receive body (**Figure 1**) and head (data not shown) coil, heating was reduced by 50% to 70% through the placement of small-diameter (~2.5 cm) loops at the burrhole. The effect was linearly related to the number of loops ($p < 0.01$).

II. ***The amount of RF-induced heating at the electrode contact varies as a function of MR landmark.***

Substantial heating, as high as 38°C above baseline was observed in association with MR imaging performed using the transmit/receive body coil on the 1.5-T MR system (Symphony). As shown in **Figures 2**, the magnitude of the induced temperature increase varied substantially in relation to the location of the MR landmark, with the greatest increase recorded when the landmark was set on or around the lead contacts (i.e., 76.5 cm). The magnitude of the heating decreased as the landmark was moved caudally (lower numbers) or rostrally (higher numbers).

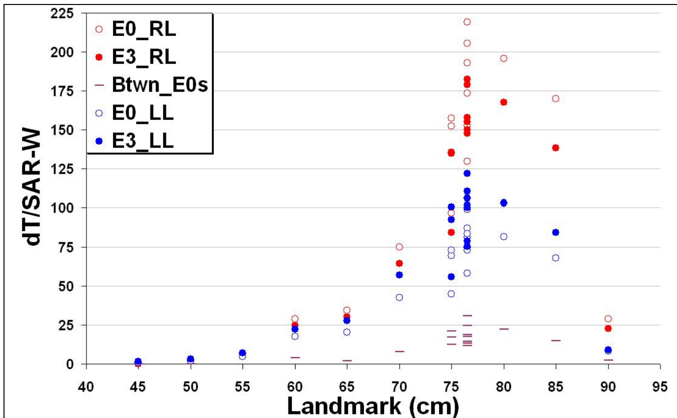

Figure 2. Temperature change, normalized to whole body SAR, as a function of MR landmark location. Note that a landmark location of 50 cm corresponds to the level of the phantom chest and 76.5 cm to the DBS leads placed in the skull.

CONCLUSIONS: The configuration of the DBS lead, as well as the land-marking position used for MRI, has a profound impact on the heating profile of implanted neurostimulation systems used for DBS. Importantly, it may be possible to use lead configurations involving loops to greatly reduce heating. In addition to increasing the safety margin, these findings may permit a wider range of clinical scanning sequences to be used at 1.5- and 3-T in patients with implanted neurostimulation systems.

REFERENCES

(1) Shellock FG. J Magn Reson Imaging 2002;16:485-496.
(2) Rezai AR et al. J Magn Reson Imaging 2002;15:241-250.