Radio-Frequency Heating at Deep Brain Stimulation Lead Electrodes due to Imaging with Head Coils in 3 T and 7T

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Introduction Radiofrequency (RF) heating due to a deep brain stimulation (DBS) device and its thermo-physiologic consequences are unknown at ultra-high fields (UHFs) (≥3T). Studying the RF heating and associated thermo-physiologic responses are important for safe UHF magnetic resonance (MR) imaging and spectroscopy applications in DBS patients. Clinically harmful RF heating at DBS lead electrodes has been reported for 1.5 tesla (T) (1-4) and 3 T (2) MR systems in gel phantoms.

This preliminary study presents RF heating at the DBS lead electrodes due to head imaging in 3 T and 7 T using a gel phantom. The effect of the placement of the extra-cranial portion of the DBS lead on the RF heating is investigated. RF heating in a uniform, un-perfused, tissue mimicking gel phantom was measured as an upper limit to in vivo RF heating. Future studies employing swine are underway in our laboratory to determine RF heating and its thermo-physiologic consequences during imaging in ultra high fields (5,6). Swine will be used since the World Health Organization recommended swine as appropriate and conservative thermo-physiologic models of humans.(7) Swine and humans have comparable mass, surface area, perfusion, thermal properties, and thermo-regulatory reflexes.

Experiment design and Methods A deep brain stimulation (DBS) lead (3389, Medtronic Inc., Minneapolis, MN, USA) with four electrodes at the distal end was implanted in a uniform, cylindrical tissue mimicking gel phantom. The distal end of the lead was placed vertically, 10 cm deep in the gel phantom. One fluoroptic probe each was taped to the two distal electrodes (i.e., electrodes three and four). Another fluoroptic probe was placed 5 mm away from the distal lead tip in the gel. The instrumented cylindrical phantom was placed in a 3 T or 7 T transmit and receive head coil. The extra-cranial portion of the DBS lead was looped on the surface of cylindrical phantom in three perpendicular orientations to study the effect of the loop orientation on the RF heating. The RF heating was produced with an spin echo sequence running at the whole head average SAR of 3 W/kg.

Results and Discussion Figures 1-2 present RF heating at the DBS lead electrodes and 5 mm away from the distal DBS lead tip due to the top, side, and front loop placement of the extracranial portion of the DBS lead in 3T and 7T, respectively. The significant effect of the lead placement with respect to a coil on the RF heating is clearly demonstrated. Maximum RF heating was produced when the extracranial portion of the DBS lead was looped on the side and closest to the head coils. The data shows that it may be feasible to perform safe imaging in 3T and 7T using head coils by placing the extracranial portion of the lead away from the head coils. Additionally, the data shows that strong temperature gradients and thus electric field gradients may exist near the DBS lead electrodes. The presence of the strong gradients suggest that higher order numerical techniques may need to be employed to obtain reliable numerical predictions of the electromagnetic and temperature fields around the DBS electrodes.

Figure 1 RF heating in 3T

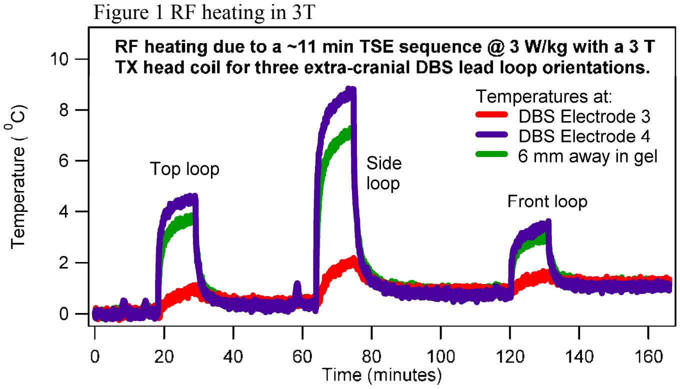
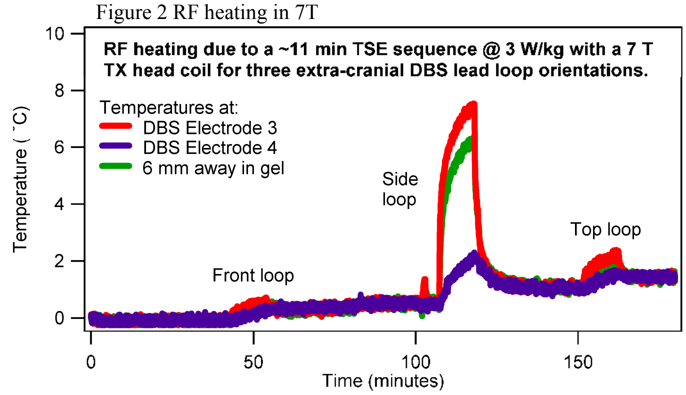


Figure 2 RF heating in 7T



Summary RF safe patient imaging in 3T and 7T with transcieve head coils may be feasible by placing the extracranial portion of the DBS lead 'away' from the head coils. Clinically harmful RF heating may be produced when the extra-cranial portion of the DBS lead is placed 'near' the head coils. RF heating is a function of the DBS lead placement and head coil.

Acknowledgments R01 EB007327, R01 EB000895, BTRR - P41 RR08079, R01 EB006835, R01 EB 00454, CA94200, CA94318, C06 RR17557-01, C06 RR12147-01, and the Keck foundation.

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