RF HEATING DUE TO A DEEP BRAIN STIMULATION ELECTRODE AT 9.4 T (400.2 MHz) IN PORCINE HEADS

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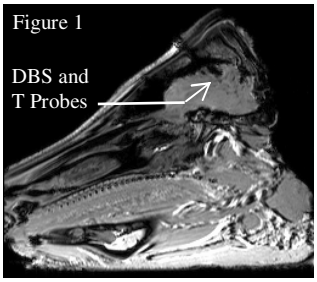
Introduction Radiofrequency (RF) heating due to a deep brain stimulation (DBS) device and its thermo-physiologic consequences are unknown at ultra-high fields (UHFs) (≥3T). Studying the RF heating induced temperature and associated thermo-physiologic responses are important for safe UHF magnetic resonance (MR) imaging and spectroscopy applications in DBS patients. Excessive (~≥ 1 degree C) RF heating at DBS electrode contact points has been reported previously for 1.5 tesla (T) and 3 T MR systems using gel phantoms.(1-5)

This preliminary study presents temperature changes due to RF heating at the DBS electrode contact points in two ex vivo, non-perfused porcine heads at 9.4 T. RF heating in ex vivo, non perfused porcine heads was measured as an upper limit to in vivo RF heating in porcine heads. Porcine heads were studied since the World Health Organization recommended swine as appropriate and conservative thermo-physiologic models of humans.(6) Swine and humans have comparable mass, surface area, perfusion, thermal properties, and thermo-regulatory reflexes. Additionally, swine have critical, hot temperature limit comparable to and lower than that of humans. Swine are being used in our laboratory to determine thermo-physiologic consequences of the RF heating due to implants at ultra high fields.(7,8)

Experiment design and Methods To quantify RF heating due to a DBS electrode (3389, Medtronic Inc., Minneapolis, MN, USA), temperatures were measured in the brain and head skin of two porcine heads (mean animal weight = 76.2 kg, SD = 1.7 kg; mean animal head weight = 5.49 kg, SD = 0.30 kg) with and without the DBS electrode. Brain temperatures were recorded using fluoroptic probes placed at 15 mm and 10 mm depths from the dura inside the brain. Skin temperature was recorded using a separate fluoroptic probe placed in the head cutaneous layer using an 18G catheter. The DBS electrode was placed such that a brain fluoroptic probe was adjacent to the first of the four electrode contact points at the 15 mm depth. The other brain fluoroptic probe was adjacent to the third electrode contact point at the 10 mm depth. (Figure 1) The other end (the percutaneous connector end) of the DBS electrode was left freely hanging outside the RF coil. An ~18G hole was drilled into the porcine cranium perpendicular to the coil plane to place the probes and the DBS electrode. The air temperature next to the head was also recorded using a fluoroptic probe.



A 400.2 MHz (9.4 T) continuous wave (CW) RF energy (mean SAR = 2.93 W/kg, SD = 0.13 W/kg) was deposited to porcine heads for 1.5 hours using a tuned and matched, four loop, transmit and receive volume head coil. The net average coil input power (forward minus reverse) was measured at the coil by a power meter (Gigatronics Universal Power Meter, model #8652A). The net, whole head average SAR was calculated by measuring the head weight and the total RF power.

Results and Discussion Figures 2 and 3 present the typical temperature response in the brain, head skin, and air in the RF coil with and without the DBS electrode, respectively. Figure 4 directly compares the temperature responses with the DBS to those without the DBS for the head skin and brain in a porcine head. Note that no statistically significant RF heating was measured at the DBS contact points due to the DBS alone at 9.4 T when the percutaneous connecter end of the DBS was freely hanging outside the RF coil. This result is consistent with earlier reports obtained for 1.5 T and 3 T systems. No DBS induced RF heating at the contact points have been measured when the DBS electrode was disconnected from the DBS lead.(9)

Figure 2

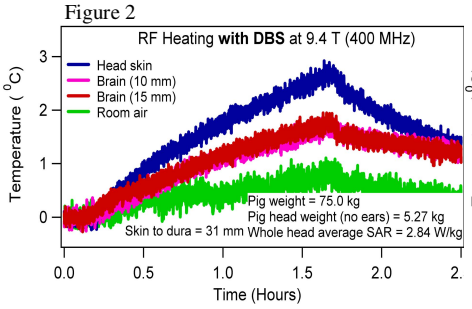


Figure 3

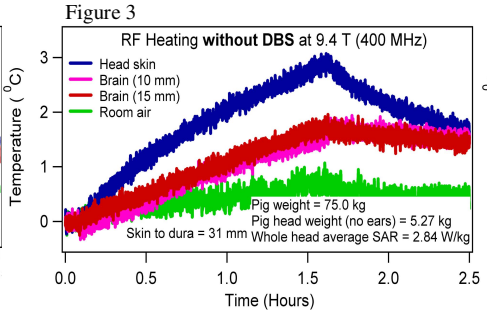
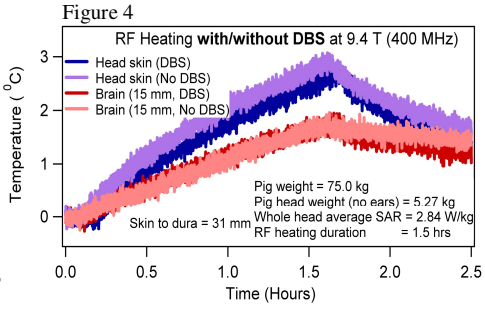


Figure 4



Summary No RF heating was measured at the DBS electrode contact points in porcine heads due to the DBS alone at 400 MHz (9.4T). Future studies into the nature of RF heating and associated thermoregulatory temperature response are underway for different DBS electrode and lead configurations using swine and new bioheat thermal models to better understand RF safety in DBS patients at ultra high fields.

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