Scanner specific relationship between displayed SAR and heating adjacent to deep brain stimulation leads: an in vitro study

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Target Audience: MRI physicists, MRI technologists, neurologists, neurosurgeons, and others involved in MRI of patients with implanted deep brain stimulation leads.

Purpose: The published limit for head specific absorption rate (SAR) in patients with implanted deep brain stimulation (DBS) leads is difficult to interpret because not all major MRI vendors use exactly the same method for estimating head SAR.[1] The purpose of this study was to measure the temperature near a DBS lead in a gel phantom during several common pulse sequences in our particular model of MRI scanner, thereby establishing a scanner-specific relation between displayed head SAR and tissue heating.

Methods: We constructed a PVC box approximating the shape of an adult human torso, as described by others.[2] This box was filled with saline to which polyacrylic acid had been added, giving it a gel-like consistency. A unilateral DBS lead (Model 3389, Medtronic, Minneapolis, MN) and extension were placed in the gel phantom in an arrangement mimicking a typical implanted configuration. The phantom was placed in a 1.5-T scanner (MAGNETOM Espree with VB17 software, Siemens Healthcare, Erlangen, Germany) with transmit-receive head coil. A fiber optic probe affixed immediately adjacent to the tip of the DBS lead recorded temperature during the following pulse sequences: MP-RAGE, T_1-weighted spin echo (T_1SE), T_2-weighted turbo spin echo (T_2TSE), and T_2-weighted turbo spin echo with low-SAR RF pulses (T_2TSE_{lowSAR}).

Results: The temperature rise for each sequence was as follows (Fig. 1): T_1SE, 0.76˚ C (1.4˚ F); MP-RAGE, 0.17˚ C (0.3˚ F); T_2TSE_{lowSAR}, 1.3˚ C (2.3˚ F); T_2TSE, 2.2˚ C (4.0˚ F). By plotting the heating for the four sequences against their respective displayed head SAR (graph not shown), an approximately linear relationship was observed between the two quantities, with 4.9° C of heating occurring per 1.0 W/lb. of displayed head SAR (95% confidence interval of slope = 2.1-7.7° C per W/lb., R^2 = 0.97). To maintain consistency among the displayed SAR values, the input patient weight was always 175 lb.

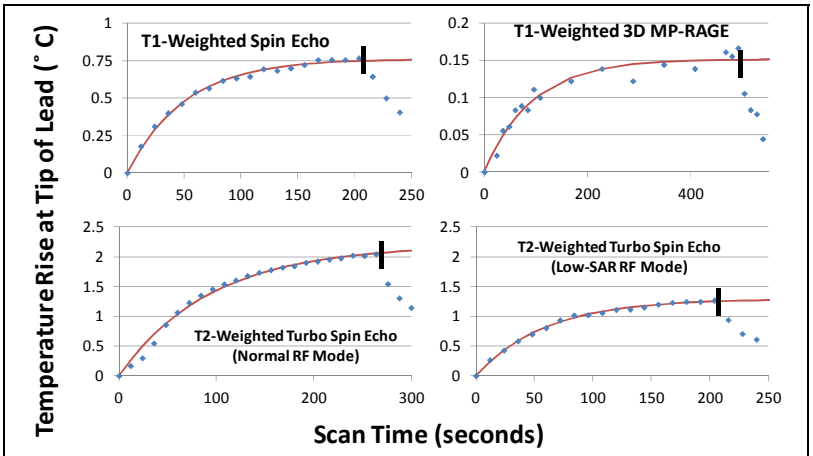

Figure 1. Temperature rise at the tip of the DBS lead during four different pulse sequences. Points represent observed data. Solid curved lines represent an exponential fit to the data. Short vertical bars indicate the end of the scan, after which point cooling of the tissue phantom occurred.

Discussion and Conclusion: In the specific model of 1.5-T scanner that was employed, and neglecting the cooling effect of blood perfusion that is likely to occur in vivo, pulse sequences that approach the maximum head SAR allowable for implant-free patients (1.5 W/lb) could be expected to produce more than 7° C of local tissue heating in patients with implanted DBS leads. This value is close to the threshold thought to cause permanent tissue damage,[1] so it is certainly prudent to limit SAR for MRI of DBS leads. On the other hand, the manufacturer guideline of 0.1 W/kg (0.045 W/lb.)[3] may be overly conservative, since our particular scanner produced only 0.17° C of heating at this SAR value (during the MP-RAGE). This would explain why others have apparently exceeded the 0.1 W/kg limit on a routine basis without incident (provided other key safety measures are met).[1] This study shows that the blanket SAR limitation for patients with implanted DBS leads does not align well with the heating actually produced in at least one late-model 1.5-T MRI scanner. Since this blanket SAR limit can severely restrict the type and quality of MR images that can be acquired, it might be worthwhile to develop scanner-specific DBS protocols that are thoroughly tested and do not rely on displayed SAR estimates as the tissue heating safety net.

References: 1. Larson PS, Richardson RM, Starr PA, Martin AJ. *Stereotact Funct Neurosurg*. 2008;86(2):92-100. 2. Rezai AR, Finelli D, Nyenhuis JA, et al. *Journal of Magnetic Resonance Imaging*. 2002;15(3):241-250. 3. Tremmel J. *Medtronic Inc, Minneapolis (MN)*. 2005.