Is Pacemaker Lead-Tip Heating Greater at 1.5T or 3T?

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INTRODUCTION: MRI exams for patients with pacemakers and implanted cardioverter defibrillators (ICDs) are contraindicated at all clinical field strengths[1-3] due to radiofrequency (RF) lead-tip heating concerns[4]. While research now supports scanning at 1.5T under specific guidelines[5] 3T MRI exams remain contraindicated by the medical community, largely due to concerns that lead-tip heating is likely worse at 3T. The FDA identically regulates the maximum whole-body SAR to <4 W/kg at both 1.5T and 3.0T, but whole-body SAR is not the critical cause of lead-tip heating. In fact, scanner reported SAR has been shown to be a poor predictor of device heating[6]. More important is the B_1-induced electric field (E-field) that couples with the pacemaker's lead and device electronics inducing a current in the pacemaker's lead, which causes lead-tip heating[7]. The conditions that govern E-field coupling with the pacemaker and lead (B_1 homogeneity, E-field wavelength, tissue dielectric and conductivity constants, device impedance and antennae characteristics) are all different at 3T. Therefore, our reluctance to scan patients with pacemakers or ICDs at 3T may be misguided. Lead-tip heating at 3T is not necessarily worse than at 1.5T. Our ***objective*** was to characterize pacemaker lead-tip heating during a range of 3T MRI exams and compare the results to lead-tip heating at 1.5T.

METHODS: A 50cm pacemaker lead connected to pulse generator (St. Jude Medical, Sylmar, CA) was placed in a left pectoral implant configuration inside the ASTM head/torso phantom filled with tissue-mimicking HEC gel solution[8,9]. Pacemaker lead-tip heating (temperature increase relative to background) was measured using a fiber optic temperature probe (Lumasense, Santa Clara, CA) at both 3T (Siemens Trio) and 1.5T (Siemens Avanto). Heating was measured using ***clinically controlled protocols*** for neurological, cardiovascular, and abdominal exams (at corresponding landmark locations) each optimized for clinical imaging at the respective field strength. Given the protocol differences between the 3T and 1.5T, we also evaluated ***SAR controlled protocols*** using a 15-minute balanced steady state free precession (bSSFP) sequence at 2 W/kg and 4 W/kg at each landmark location.

RESULTS: *SAR Results* – In **Figure 1** the clinically controlled protocols, in general, show similar SAR for both neurological and cardiac exams at 3T vs 1.5T. Note, however, that for neurological T1-weighted imaging at 1.5T a Turbo Spin Echo (TSE, 1.2 W/kg) sequence was used, whereas at 3T a Fast Low Angle SHot (FLASH, 0.3 W/kg) sequence was used, which contributed to lower heating at 3T. The clinically controlled abdominal protocols had higher SAR at 3T compared to 1.5T (2.6±0.9 vs 1.0±0.8 W/kg).

Lead Tip Heating Results– In **Figure 2** the pacemaker lead-tip heating for sequences in the clinically controlled neurological protocols was slightly higher (ΔT=0.3±0.5°C) at 3T compared to 1.5T. The pacemaker lead-tip heating for clinically controlled cardiac protocols was lower (ΔT=-1.5±2.2°C) at 3T compared to 1.5T.The pacemaker lead-tip heating for clinically controlled abdominal protocols was higher at 3T than 1.5T (ΔT=1.5±0.3°C). For the SAR controlled 4 W/kg sequence, pacemaker lead-tip heating at 3T was 170% higher (ΔT=1.7°C) at the neurological landmark, 79% lower (ΔT=-4.3°C) at the cardiac landmark, and 400% higher (ΔT=2.8°C) at the abdominal landmark compared to 1.5T and showed similar results at 2 W/kg.

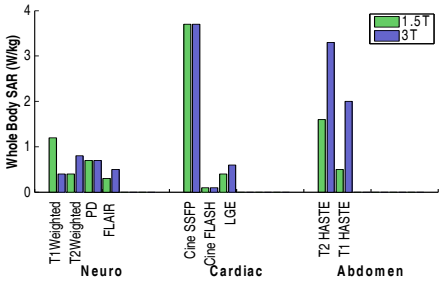

FIGURE 1. The whole body SAR values for each clinically controlled protocol are shown for 1.5T (green) and 3T (blue).

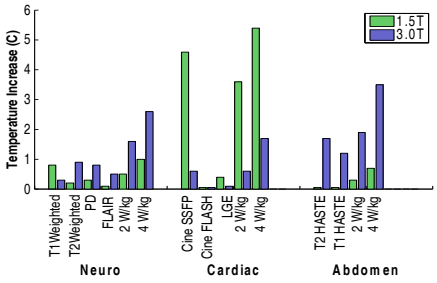

FIGURE 2. Pacemaker lead tip heating at 1.5T and 3T at three landmarks using clinically controlled and SAR controlled protocols.

DISCUSSION: When controlling for consistent clinical image contrast at 1.5T and 3T, the SAR is not necessarily higher at 3T, and depends on the specific sequences that are allowable and/or preferred for diagnosis at each field strength. As seen clearly in the SAR controlled results, the heating is maximum at 1.5T when the device is centered in the B_1-coil (cardiac) and decreases as the device moves to the periphery of the B_1-coil (neuro/abdomen). At 3T, however, lead-tip heating is higher when the device is near the periphery of the B_1-coil (neuro/abdomen) and lower near the center (cardiac), likely due to changes in the E-field coupling with the device and the concomitantly shorter wavelength at 3T. When evaluating the safety of 3T scanning compared to 1.5T careful consideration must be given to the differences in SAR, for comparable clinical sequences, and the impact of device location inside the B_1-coil. Our finding that lead-tip heating at 3T is not always higher than lead-tip heating at 1.5T is a potentially significant finding, but substantial work is still needed to determine how these results translate across manufacturer lead models, implant configurations, and to *in vivo* scenarios.

CONCLUSION: The highest overall pacemaker lead tip heating was measured at the cardiac landmark at 1.5T. Our reluctance to scan patients with pacemakers or ICDs at 3T may be misguided under some conditions and deserves greater consideration.

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