Are MR Manufacturer-Reported Specific Absorption Rate Values on Clinical MRI systems correct?

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Target Audience: This study is relevant to MR engineers, investigators, or radiologists who are interested in the specific absorption rate (SAR) during MRI scan in terms of MRI safety.

Purpose: Heating of patients or burning of biological tissues by RF power during MRI scan is a significant patient safety concern. The poor reliability and repeatability of the manufacturer-reported SAR values on clinical MRI systems have been acknowledged[1]. The purpose of this study is to not only measure SAR values, but also RF-induced temperature elevation at 1.5 and 3T MRI systems.

Methods: SAR measurement experiment was performed on three discrete manufacturers at 1.5 and 3T (one 1.5T and two 3T MRI scanners) using a 2-channel volume transmit coil and a 4-or 8-channel torso receive coil. Three MRI RF sequences (T1w TSE, T1w inversion recovery, and T2w TSE) with imaging parameters were selected. According to American Society for Testing and Materials (ASTM) F2182-11a, a hydroxyl-ethylcelluose (HEC) gelled saline phantom (40 L) mimicking human body tissue was made. Human torso phantom were constructed, based on Korean adult standard anthropometric reference data (Fig.1). The finite difference time domain (FDTD) method was utilized to calculate the SAR distribution using CST studio suite 2013 (CST Computer Simulation Technology Co.). The number of simulation mesh cells were 571,736 and the mesh cell ratio is 0.8~2.2. Based on the results of the simulation, 4 electrical field (E-field) sensors were located inside the phantom. 55 Fiber Bragg Grating (FBG) temperature sensors (27 sensors in upper and lower cover lids, and one sensor located in the center as a reference) were located inside the phantom to measure temperature change during MRI scan (Fig.2). Both E-field and FBG temperature sensors were calibrated with traceability at Korea Research Institute of Standards and Science (KRISS). The measured temperature values were converted to an image using custom software written in MATLAB (The MathWorks, Natick, R2012b, MA, USA).

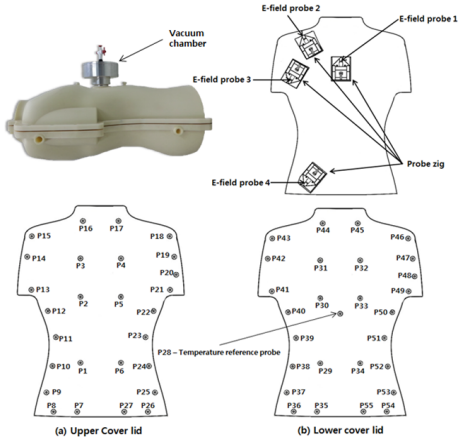

Fig.1 Phantom morphology and location of 4 electrical field sensors and 55 FBG optic temperature sensors

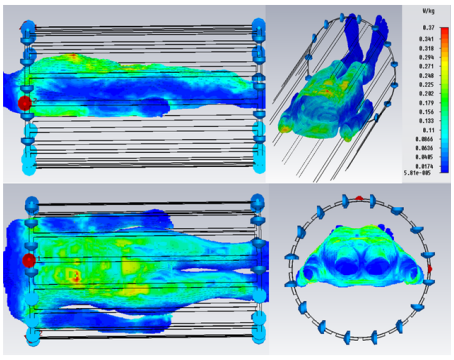

Fig.2 SAR simulation inside HEC gel phantom

Table 1 Comparison of SAR values calculated by 3 T MRI system and measured values via optic E-field probes inside the phantom

	T1w_TSE	T2w_SPIR	T2w_TSE
SAR [W/kg] reported by 3 T MRI system	<1.5	<1.5	<1.5
SAR [W/kg] measured by an E-field probe 1	0.63±0.7 (0.01-1.29)	0.94±0.11 (0.02-1.87)	1.43±1.1 (0.02-3.89)
SAR [W/kg] measured by an E-field probe 2	1.38±1.24 (0.05-3.25)	2.98±1.86 (0.08-5.95)	6.83±2.56 (0.0-14.79)
SAR [W/kg] measured by an E-field probe 3	1.46±1.29 (0.06-3.91)	3.46±2.13 (0.09-6.33)	7.59±2.72 (0.0-15.75)
SAR [W/kg] measured by an E-field probe 4	1.17±1.1 (0.05-2.89)	2.31±0.98 (0.08-4.22)	6.01±2.13 (0.0-12.73)

Results: Simulation shows that SAR value is 0.4 W/kg in the periphery and 0.001 W/kg in the center (Fig.2). One 1.5T and one of two 3T MRI systems represent that the measured SAR values were lower than MRI scanner-reported SAR values. However, the other 3T MRI scanner shows that the averaged SAR values measured by probe 2, 3, and 4 are 6.83, 7.59, and 6.01 W/kg, compared to MRI scanner-reported whole body SAR value (<1.5 W/kg) for T2w TSE (Table 1). The temperature elevation measured by FBG sensors is 5.2°C in the lateral shoulder, 5.1°C in the underarm, 4.7°C in the anterior axilla, 4.8°C in the posterior axilla, and 4.8°C in the lateral waist for T2w TSE (Fig.3).

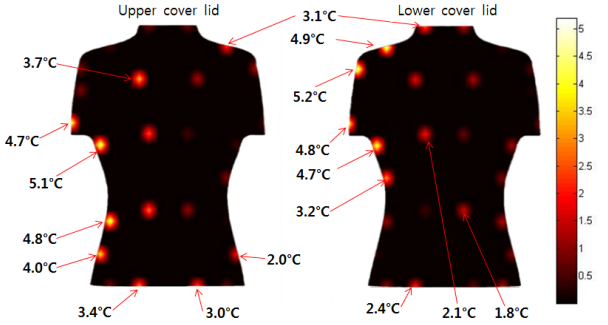

Fig.3 Temperature elevation distribution in upper and lower cover lids for T2w TSE

Discussion: High SAR and temperature change occur in the periphery, and low SAR and temperature change in the center. The averaged SAR values measured in probe 2, 3, and 4 at 3 T are higher than MRI scanner-reported whole body SAR value and lower than SAR limit(=4W/kg) required by IEC(International Electrotechnical Commission) 60601-2-33 for T2w SPIR. However, the averaged SAR values measured in probe 2, 3, and 4 for T2w TSE at 3 T are higher than not only MRI scanner-reported whole body SAR value but also SAR limit required by IEC.

Conclusion: We have demonstrated that the whole body averaged SAR values reported by 3T MRI system is uncertain. Thus, it is essential to assess the safety of MRI system for patient by measuring accurate SAR deposited in the body during clinical MRI.

References: [1] Seo et al. RF dosimeter for the measurement of specific absorption rate (SAR) in MRI, RSNA 98th scientific assembly and annual meeting, Chicago, Illinois, Nov.25-30, 2012;