Experimental assessment of MRI-induced temperature change and SAR distributions in phantoms

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Background: During an MR procedure, most of the transmitted RF power is transformed into heat within the patients' tissue resulting from resistive losses, referred to as the specific energy absorption rate(SAR) (2). The EU standardisation has mandated that all scanners must measure SAR in patients and develop system safeguards to ensure that the limits(IEC60602-3-33) are not exceeded. Accurate estimation of SAR is critical in safeguarding patients who may be unconscious/sedated, have implants or are pregnant. Modern MRI systems can easily exceed safe SAR levels (1) requiring the independent verification of manufacturers SAR estimations.

The purpose of this research was to develop a protocol to verify the patient specific SAR. To determine RF power deposition experimentally, a T1 doped MR phantom in a birdcage head coil was used, heated solely by the RF fields produced by the imaging coil.

Methods: As there is a negligible contribution from thermal conduction in our SAR assessment and our phantom is a nonperfused material, physiological changes can be ignored. The SAR at discreet points in the observation plane the can be determined by the following equation (2)

$$SAR \approx C_{agar} \frac{\Delta T}{\Delta t} [W \backslash kg]$$

Where C_{agar} is 4200 J/Kg.K, ΔT is the change in temperature and Δt is the change in time.

Proton Resonance Frequency Shift (PRF) thermometry was utilised to find the change in temperature.

$$\Delta T = \frac{\varphi - \varphi_0}{\alpha \gamma B_0 TE}$$

Where α is the temperature co-efficient 0.01ppm/C, γ is the gyromagnetic ratio (MHz/T), B_0 is the field strength (T), TE is the echo time (ms) and $\varphi - \varphi_0$ is the phase shift (degrees).

A 3L volume, T1 doped MR phantom was created by dissolving 60g/L agar, 10g/L NaCl, 1g/L NaCl in distilled water. The solution was autoclaved at 121C for 15min to ensure the solution was homogeneous and to remove air bubbles.

Phase maps were created pre and post heating. These were then used to create a phase difference map and a heat map could then be created using PRF. A FLAIR sequence was used over the whole volume to heat the phantom. The calculated SAR was compared to the scanner readout.

Results.

	Scanner	Calculation
GE 1.5T Signa Explorer	0.42 W/Kg	0.41 W/Kg
Siemens 1.5T Symphony	1.88 W/Kg	1.90 W/Kg
Philips 3T Achieva	1.52 W/Kg	1.52 W/Kg

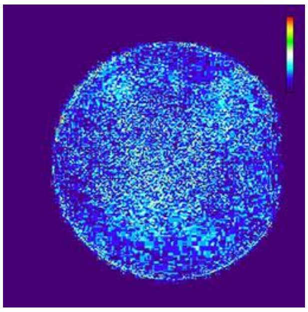

Figure 1:Heat Map of Phantom

Discussion. Our results agreed with the manufacturer's settings.

Conclusion. We have developed an open source phantom that can independently verify the temperature rise associated with SAR.

Key references.
1. Crook N et al., Radiography. 2009;15(4):351-
2. Shellock FG. J Magn Reson Imaging. 2000;12(1):30-6.